RoboteQ

Advanced Brushed and Brushless Digital Motor Controllers

User Manual

V1.8, August 28, 2017

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Revision History

Date	Version	Changes
August 29, 2017	1.8	Added AC Induction Sections Extended command set
October 15, 2016	1.7	Added Speed Position Mode Major Additions to Brushless Motor Section Added RoboCAN protocol Miscellaneous updates
May 10, 2012	1.2	Added CAN Networking Added Closed Loop Count Position mode, Closed Loop Torque mode Extended command set
January 8, 2011	1.2	Added Brushless Motor Connections and Operation
July 15, 2010	1.2	Extended command set Improved position mode
May 15, 2010	1.1	Added Scripting
January 1, 2010	1.0	Initial release
September 15, 2008	1.9d	Created Brushless DC version
June 1, 2007	1.9b	Added Output C active when Motors On Fixed Encoder Limit Switches Protection in case of Encoder failure in Closed Loop Speed Added Short Circuit Protection (with supporting hardware) Added Analog 3 and 4 Inputs (with supporting hardware) Added Operating Mode Change on-the-fly Changeable PWM frequency Selectable polarity for Dead Man Switch Modified Flashing Pattern Separate PID Gains for Ch1 and C2, changeable on-the-fly Miscellaneous additions and correction Added Amps Calibration option
January 10, 2007	1.9	Changed Amps Limit Algorithm Miscellaneous additions and correction Console Mode in Roborun
March 7, 2005	1.7b	Updated Encoder section.
February 1, 2005	1.7	Added Position mode support with Optical Encoder Miscellaneous additions and corrections
April 17, 2004	1.6	Added Optical Encoder support

Date	Version	Changes
March 15, 2004	1.5	Added finer Amps limit settings Enhanced Roborun utility
August 25, 2003	1.3	Added Closed Loop Speed mode Added Data Logging support Removed RC monitoring
August 15, 2003	1.2	Modified to cover XDC24xx - XBL16xx - XSX18xx controller design Changed Power Connection section
April 15, 2003	1.1	Added analog mode section Added position mode section Added RCRC monitoring feature Updated Roborun utility section Modified RS232 watchdog
March 15, 2003	1.0	Initial Release

The information contained in this manual is believed to be accurate and reliable. However, it may contain errors that were not noticed at time of publication. User's are expected to perform their own product validation and not rely solely on data contained in this manual.

Introduction

Refer to the Datasheet for Hardware-Specific Issues

This manual is the companion to your controller's datasheet. All information that is specific to a particular controller model is found in the datasheet. These include:

- Number and types of I/O
- Connectors pin-out
- Wiring diagrams
- Maximum voltage and operating voltage
- Thermal and environmental specifications
- Mechanical drawings and characteristics
- Available storage for scripting
- Battery or/and Motor Amps sensing
- Storage size of user variables to Flash or Battery-backed RAM

User Manual Structure and Use

The user manual discusses issues that are common to all controllers inside a given product family. Except for a few exceptions, the information contained in the manual does not repeat the data that is provided in the datasheets.

The manual is divided in 18 sections organized as follows:

SECTION 1 Connecting Power and Motors to the Controller

This section describes the power connections to the battery and motors, the mandatory vs. optional connections. Instructions and recommendations are provided for safe operation under all conditions.

SECTION 2 Safety Recommendations

This section lists the possible motor failure causes and provides examples of prevention methods and possible ways to regain control over motor if such failures occur.

SECTION 3 Connecting Sensors and Actuators to Input/Outputs

This section describes all the types of inputs that are available on all controller models and describes how to attach sensors and actuators to them. This section also describes the connection and operation of optical encoders.

SECTION 4 I/O Configuration and Operation

This section details the possible use of each type of Digital, Analog, Pulse or Encoder inputs, and the Digital Outputs available on the controller. It describes in detail the software configurable options available for each I/O type.

SECTION 5 Magentic Sensor

This section discusses how to interface one or more Roboteq's MGS1600 Magnetic Guide Sensors to the motor controller.

SECTION 6 Command Modes

The controller can be operated using serial, analog or pulse commands. This section describes each of these modes and how the controller can switch from one command input to another. Detailed descriptions are provided for the RC pulse and Analog command modes and all their configurable options.

SECTION 7 Motor Operating Features and Options

This section reviews all the configurable options available to the motor driver section. It covers global parameters such as PWM frequency, overvoltage, or temperature-based protection, as well as motor channel-specific configurations. These include amps limiting, acceleration/deceleration settings, or operating modes.

SECTION 8 Brushless Motor Connections and Operation

This section addresses installation and operating issues specific to brushless motors. It is applicable only to brushless motor controller models.

SECTION 9 AC Induction MotorOperation

This section discusses the controller's operating features and options when using three phase AC Induction motors.

SECTION 10 Closed Loop Speed and Speed Position Modes

This section focuses on the closed loop speed mode with feedback using analog speed sensors or encoders. Information is provided on how to setup a closed loop speed control system, tune the PID control loop, and operate the controller.

SECTION 11 Closed Loop Relative and Tracking Position Modes

This section describes how to configure and operate the controller in position mode using analog, pulse, or encoder feedback. In position mode, the motor can be made to smoothly go from one position to the next. Information is provided on how to setup a closed loop position system, tune the PID control loop, and operate the controller.

SECTION 12 Closed Loop Count Position Mode

This section describes how to configure and operate the controller in Closed Loop Count Position mode. Position command chaining is provided to ensure seamless motor motion.

SECTION 13 Closed Loop Torque Mode

This section describes how to select, configure and operate the controller in Closed Loop Torque mode.

SECTION 14 Serial (RS232/USB) Operation

This section describes how to communicate to the controller via the RS232 or USB interface.

SECTION 15 CAN Networking on Roboteq Controllers

This section describes the RawCAN and MiniCAN operating modes available on CAN-enabled Roboteq controllers.

SECTION 16 RoboCAN Networking

This section describes the RoboCAN protocol: a simple and efficient meshed network scheme for Roboteq devices

SECTION 17 CANopen Interface

This section describes the configuration of the CANopen communication protocol and the commands accepted by the controller operating in the CANopen mode.

SECTION 18 MicroBasic Scripting

This section describes the MicroBasic scripting language that is built into the controller. It describes the features and capabilities of the language and how to write custom scripts. A Language Reference is provided.

SECTION 19 Commands Reference

This section lists and describes in detail all configuration parameters, runtime commands, operating queries, and maintenance commands available in the controller.

SECTION 20 Using the Roborun Configuration Utility

This section describes the features and capabilities of the Roborun PC utility. The utility can be used for setting/changing configurations, operate/monitor the motors and I/O, edit, simulate and run Microbasic scripts, and perform various maintenance functions such as firmware updates.

SECTION 1

Connecting Power and Motors to the Controller

This section describes the controller's connections to power sources and motors.

This section does not show connector pin-outs or wiring diagram. Refer to the datasheet for these.

Important Warning

The controller is a high power electronics device. Serious damage, including fire, may occur to the unit, motor, wiring and batteries as a result of its misuse. Please follow the instructions in this section very carefully. Any problem due to wiring errors may have very serious consequences and will not be covered by the product's warranty.

Power Connections

Power connections are described in the controller model's datasheet. Depending on the model type, power connection is done via wires, fast-on tabs, screw terminals or copper bars coming out of the controller.

Controllers with wires as power connections have Ground (black), VMot (red) power cables and a Power Control wire (yellow). The power cables are located at the back end of the controller. The various power cables are identified by their position, wire thickness and color: red is positive (+), black is negative or ground (-).

Controllers with tabs, screw terminals or copper bars have their connector identified in print on the controller.

Controller Power

The controller uses a flexible power supply scheme that is best described in Figure 1-1. In this diagram, it can be seen that the power for the Controller's internal microcomputer is separate from this of the motor drivers. The microcomputer circuit is connected to a DC/DC converter which takes power from either the Power Control input or the VMot input. A diode circuit that is included in most controller models, is designed to automatically select one power source over the other and lets through the source that has the highest voltage.

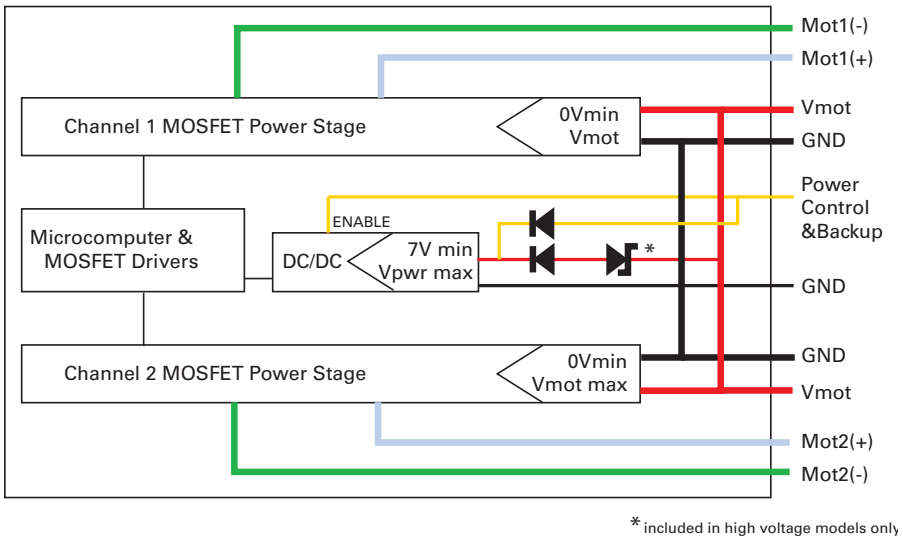


FIGURE 1-1. Representations of the controller's Internal Power Circuits

When powered via the Power Control input only, the controller will turn On, but motors will not be able to turn until power is also present on the VMot wires or Tab.

The Power Control input also serves as the Enable signal for the DC/DC converter. When floating or pulled to above 1V, the DC/DC converter is active and supplies the controller's microcomputer and drivers, thus turning it On. When the Power Control input is pulled to Ground, the DC/DC converter is stopped and the controller is turned Off.

The Power Control input **MUST** be connected to Ground to turn the Controller Off. For turning the controller On, even though the Power Control may be left floating, whenever possible pull it to a 12V or higher voltage to keep the controller logic solidly On. You may use a separate battery to keep the controller alive as the main Motor battery discharges.

On high voltage controller that are rated above 60V, a zener diode is inserted between the VMot supply and the DC/DC converter. This causes a voltage drop that keeps the voltage at the converter's input within its maximum operating range. However, this diode also

increases by around 20V the low voltage threshold at which the controller will start operating when powered from VMot alone.

The table below shows the state of the controller depending on the voltage applied to Power Control and VMot.

TABLE 1-1. Controller Status depending on Power Control and VMot

Power Control input is connected to	**And Main Battery Voltage is**	**Action**
Ground	Any Voltage	Controller is Off. **Required Off Configuration.**
Floating	0V	Controller is Off. **Not Recommended Off Configuration.**
Floating	Above VMotMin (1)	Controller is On. Power Stage is Active (2)
7V to max PwrCtl (3) Volts	Any Voltage	Controller is On. Power Stage is Active (2)
Note 1: VMotMin = 7V on all controller rated up to 60V. VMotMin = 28V on all controllers rated above 60V. See product datasheet Note 2: Power Stage is active but turned off when overvoltage or undervoltage condition. Note 3: 35V max on 30V controllers. 60V max on all products rated above 30V		

Note: All ground terminals (-) are connected to each other inside the controller. On dual channel controllers, the two VMot main battery wires are also connected to each other internally. However, you must never assume that connecting one wire of a given battery potential will eliminate the need to connect the other. When pre-charging the controller's capacitors, the Power Control input must be grounded. See the note on capacitor pre-charging on page 27. "Capacitor precharging"

Controller Powering Schemes

Roboteq controllers operate in an environment where high currents may circulate in unexpected manners under certain condition. Please follow these instructions. Roboteq reserves the right to void product warranty if analysis determines that damage is due to improper controller power connection.

The example diagram on Figure 1-2 on page 26 shows how to wire the controller and how to turn power On and Off. All Roboteq models use a similar power circuit. See the controller datasheet for the exact wiring diagram for your controller model.

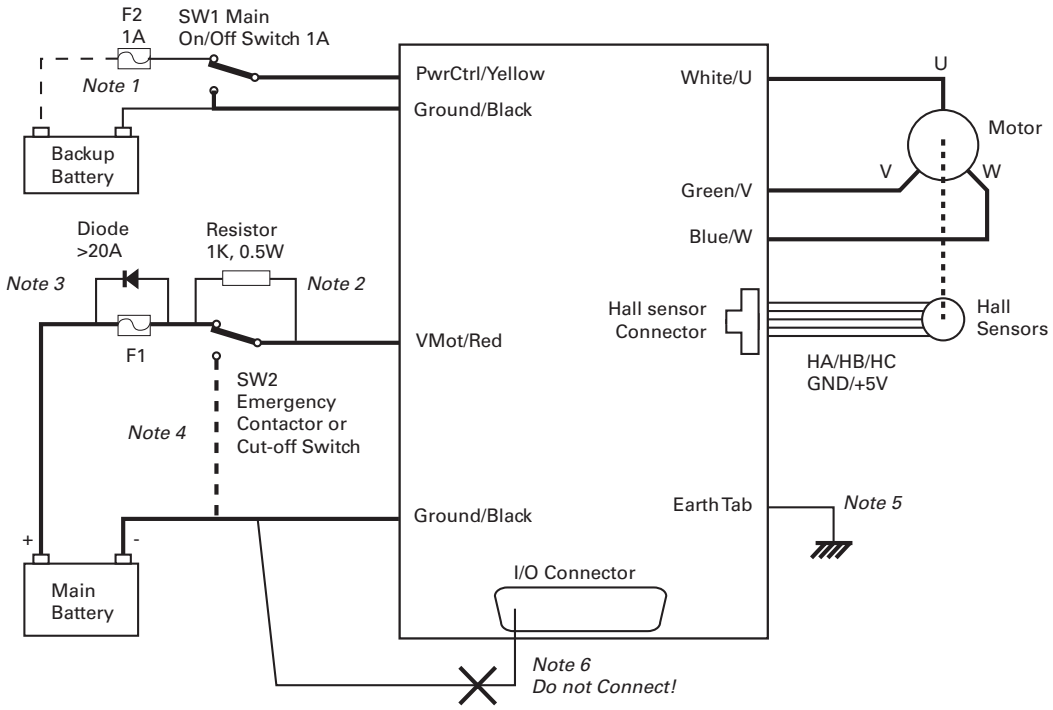


FIGURE 1-2. Brushless DC Controller power wiring diagram

Mandatory Connections

It is imperative that the controller is connected as shown in the wiring diagram provided in the datasheet in order to ensure a safe and trouble-free operation. All connections shown as thick black lines are mandatory.

- Connect the thick black wire(s) or the ground terminal to the minus (-) terminal of the battery that will be used to power the motors. Connect the thick red wire(s) or VMot terminal to the plus (+) terminal of the battery. The motor battery may be of 12V up to the maximum voltage specified in the controller model datasheet.
- The controller must be powered On/Off using switch SW1on the Power Control wire/terminal. Grounding this line powers Off the controller. Floating or pulling this line to a voltage will power On the controller. (SW1 is a common SPDT 1 Amp or more switch).
- Use a suitable high-current fuse F1 as a safety measure to prevent damage to the wiring in case of major controller malfunction. (Littlefuse ATO or MAXI series).
- The battery must be connected in permanence to the controller's Red wire(s) or VMot terminal via a high-power emergency switch SW2 as additional safety measure. Partially discharged batteries may not blow the fuse, while still having enough power left to cause a fire. Leave the switch SW2 closed at all times and open only in case of an emergency. Use the main On/Off switch SW1 for normal operation. This will prolong the life of SW2, which is subject to arcing when opening under high current with consequent danger of contact welding.
- If installing in an electric vehicle equipped with a Key Switch where SW2 is a contactor, and the key switch energizes the SW2 coil, then implement SW1 as a relay. Connect the Key Switch to both coils of SW1 and SW2 so cutting off the power to the vehicle by the key switch and SW2 will set the main switch SW1 in the OFF position as well.

Connection for Safe Operation with Discharged Batteries (note 1)

The controller will stop functioning when the main battery voltage drops below 7V. To ensure motor operation with weak or discharged batteries, connect a second battery to the Power Control wire/terminal via the SW1 switch. This battery will only power the controller's internal logic. The motors will continue to be powered by the main battery while the main battery voltage is higher than the secondary battery voltage.

Use precharge Resistor to prevent switch arcing (note 2)

Insert a 1K, 0.5W resistor across the SW2 Emergency Switch. This will cause the controller's internal capacitors to slowly charge and maintain the full battery voltage by the time the SW2 switch is turned on and thus eliminate damaging arcing to take place inside the switch. Make sure that the controller is turned Off with the Power Control wire grounded while the SW2 switch is off. The controller's capacitors will not charge if the Power Control wire is left floating and arcing will then occur when the Emergency switch is turned on.

Protection against Damage due to Regeneration (notes 3 and 4)

Voltage generated by motors rotating while not powered by the controller can cause serious damage even if the controller is Off or disconnected. This protection is highly recommended in any application where high motion inertia exists or when motors can be made to rotate by towing or pushing.

- Use the main SW1 switch on the Power Control wire/terminal to turn Off and keep Off the controller.
- Insert a high-current diode (Digikey P/N 10A01CT-ND) to ensure a return path to the battery in case the fuse is blown. Smaller diodes are acceptable as long as their single pulse current rating is > 20 Amp.
- Optionally use a Single Pole, Dual Throw switch for SW2 to ground the controller power input when OFF. If a SPDT switch cannot be used, then consider extending the diode across the fuse and the switch SW2.

Connect Case to Earth if connecting AC equipment (note 5)

If building a system which uses rechargeable batteries, it must be assumed that periodically a user will connect an AC battery charger to the system. Being connected to the AC main, the charger may accidentally bring AC high voltage to the system's chassis and to the controller's enclosure. Similar danger exists when the controller is powered via a power supply connected to the mains.

Some controller models in metallic enclosures are supplied with an Earth tab, which permits earthing the metal case. Connect this tab to a wire connected to the Earth while the charger is plugged in the AC main, or if the controller is powered by an AC power supply or is being repaired using any other AC equipment (PC, Voltmeter etc.)

Avoid Ground loops when connecting I/O devices (note 6)

When connecting a PC, encoder, switch or actuators on the I/O connector, be very careful that you do not create a path from the ground pins on the I/O connector and the battery minus terminal. Should the controller's main Ground wires (thick black) or terminals be disconnected while the VMot wires (thick red) or terminals are connected, high current would flow from the ground pins, potentially causing serious damage to the controller and/or your external devices.

- Do not connect a wire between the I/O connector ground pins and the battery minus terminal. Look for hidden connection and eliminate them.
- Have a very firm and secure connection of the controller ground wire and the battery minus terminal.
- Do not use connectors or switches on the power ground cables.

Important Warning

Do not rely on cutting power to the controller for it to turn Off if the Power Control is left floating. If motors are spinning because the robot is pushed or because of inertia, they will act as generators and will turn the controller On, possibly in an unsafe state. ALWAYS ground the Power Control wire terminal to turn the controller Off and keep it Off.

Important Warning

Unless you can ensure a steady voltage that is higher than 7V (28V in controllers rated above 60V) in all conditions, it is recommended that the battery used to power the controller's electronics be separate from the one used to power the motors. This is because it is very likely that the motor batteries will be subject to very large current loads which may cause the voltage to eventually dip below 7V as the batteries' charge drops. The separate backup power supply should be connected to the Power Control input.

Connecting the Motors

Refer to the datasheet for information on how to wire the motor(s) to a particular motor controller model.

After connecting the motors, apply a minimal amount of power using the Roborun PC utility with the controller configured in **Open Loop speed mode**. Verify that the motor spins in the desired direction. Immediately stop and swap the motor wires if not.

In Closed Loop Speed or Position mode, beware that the motor polarity must match this of the feedback. If it does not, the motors will runaway with no possibility to stop other than switching Off the power. The polarity of the Motor or of the feedback device may need to be changed.

Important Warning

Make sure that your motors have their wires isolated from the motor casing. Some motors, particularly automotive parts, use only one wire, with the other connected to the motor's frame. If you are using this type of motor, make sure that it is mounted on isolators and that its casing will not cause a short circuit with other motors and circuits which may also be inadvertently connected to the same metal chassis.

Single Channel Operation

Dual channel Brushed DC controllers may be ordered with the -S (Single Channel) suffix.

The two channel outputs must be paralleled as shown in the datasheet so that they can drive a single load with twice the power. To perform in this manner, the controller's Power Transistors that are switching in each channel must be perfectly synchronized. Without this synchronization, the current will flow from one channel to the other and cause the destruction of the controller.

The single channel version of the controller incorporates a hardware setting inside the controller which ensures that both channels switch in a synchronized manner and respond to commands sent to channel 1.

Important Warning

Before pairing the outputs, attach the motor to one channel and then the other. Verify that the motor responds the same way to command changes.

Power Fuses

For low Amperage applications (below 30A per motor), it is recommended that a fuse be inserted in series with the main battery circuit as shown in Figure 1-2 on page 26.

The fuse will be shared by the two output stages and therefore must be placed before the Y connection to the two power wires. Fuse rating should be the sum of the expected current on both channels. Note that automotive fuses above 40A are generally slow, will be of limited effectiveness in protecting the controller and may be omitted in high current application. The fuse will mostly protect the wiring and battery against after the controller has failed.

Important Warning

Fuses are typically slow to blow and will thus allow temporary excess current to flow through them for a time (the higher the excess current, the faster the fuse will blow). This characteristic is desirable in most cases, as it will allow motors to draw surges during acceleration and braking. However, it also means that the fuse may not be able to protect the controller.

Wire Length Limits

The controller regulates the output power by switching the power to the motors On and Off at high frequencies. At such frequencies, the wires' inductance produces undesirable effects such as parasitic RF emissions, ringing and overvoltage peaks. The controller has built-in capacitors and voltage limiters that will reduce these effects. However, should the wire inductance be increased, for example by extended wire length, these effects will be amplified beyond the controller's capability to correct them. This is particularly the case for the main battery power wires.

Important Warning

Avoid long connection between the controller and power source, as the added inductance may cause damage to the controller when operating at high currents. Try extending the motor wires instead since the added inductance is not harmful on this side of the controller.

If the controller must be located at a long distance from the power source, the effects of the wire inductance may be reduced by using one or more of the following techniques:

- Twisting the power and ground wires over the full length of the wires
- Use the vehicle's metallic chassis for ground and run the positive wire along the surface
- Add a capacitor (10,000uF or higher) near the controller

Electrical Noise Reduction Techniques

As discussed in the above section, the controller uses fast switching technology to control the amount of power applied to the motors. While the controller incorporates several circuits to keep electrical noise to a minimum, additional techniques can be used to keep the noise low when installing the controller in an application. Below is a list of techniques you can try to keep noise emission low:

- Keep wires as short as possible
- Loop wires through ferrite cores
- Add snubber RC circuit at motor terminals
- Keep controller, wires and battery enclosed in metallic body

Battery Current vs. Motor Current

The controller limits the current that flows through the motors and not the battery current. Current that flows through the motor is typically higher than the battery current. This counter-intuitive phenomenon is due to the "flyback" current in the motor's inductance. In some cases, the motor current can be extremely high, causing heat and potentially damage while battery current appears low or reasonable.

The motor's power is controlled by varying the On/Off duty cycle of the battery voltage 16,000 times per second to the motor from 0% (motor off) to 100 (motor on). Because of the inductive flyback effect, during the Off time current continues to flow at nearly the same peak - and not the average - level as during the On time. At low PWM ratios, the peak current - and therefore motor current - can be very high as shown in Figure 1-4, below.

The relation between Battery Current and Motor current is given in the formula below:

Motor Current = Battery Current / PWM ratio

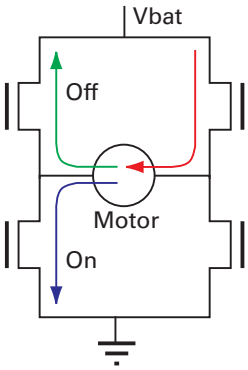


FIGURE 1-3. Current flow during operation

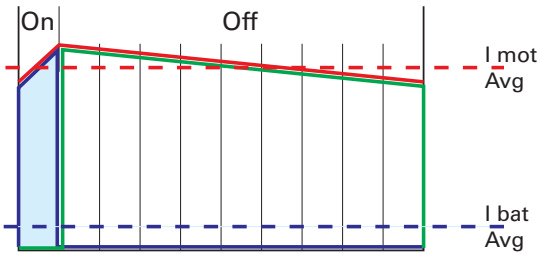


FIGURE 1-4. Instant and average current waveforms

The relation between Battery Current and Motor current is given in the formula below:

Motor Current = Battery Current / PWM Ratio

Example: If the controller reports 10A of battery current while at 10% PWM, the current in the motor is 10 / 0.1 = 100A.

Measured and Calculated Currents

All Roboteq Brushed DC motor controllers, have current sensors for measuring the battery current and estimate the motor current. At 20% PWM and above, the motor current is computed using the formula above. Below 20%, and approaching 0%, this method cause unstable and imprecise readings. At these levels, formula used is

Motor Current = Battery Current / 0.20

This approximation creates a more stable value but one that is increasingly inaccurate as the PWM approaches 0%. This approximation produces usable value nevertheless.

Roboteq's Brushless motor controllers use sensors on the motor outputs or/and on the battery ground terminal. Controllers using sensors on the battery terminal outputs suffer the same limitation at low PWM as discussed above.

Controllers with sensors on the motor terminals provide accurate motor current sensing in all conditions, and provide a good estimate battery current value. Some controller models have sensors on the motor and on the battery terminals, and provide the most accurate current sensing as all are actually measured values.

Whether sensors are on motor or/and battery terminals can be found in the product's datasheet

Important Warning

Do not connect a motor that is rated at a higher current than the controller.

Power Regeneration Considerations

When a motor is spinning faster than it would normally at the applied voltage, such as when moving downhill or decelerating, the motor acts like a generator. In such cases, the current will flow in the opposite direction, back to the power source.

It is therefore essential that the controller be connected to rechargeable batteries. If a power supply is used instead, the current will attempt to flow back in the power supply during regeneration, potentially damaging it and/or the controller.

Regeneration can also cause potential problems if the battery is disconnected while the motors are still spinning. In such a case, the energy generated by the motor will keep the controller On, and depending on the command level applied at that time, the regenerated current will attempt to flow back to the battery. Since none is present, the voltage will rise to potentially unsafe levels. The controller includes an overvoltage protection circuit to prevent damage to the output transistors (see "Using the Controller with a Power Supply" below). However, if there is a possibility that the motor could be made to spin and generate a voltage higher than 40V, a path to the battery must be provided, even after a fuse is blown. This can be accomplished by inserting a diode across the fuse as shown in Figure 1-2 on page 26.

Please download the Application Note "Understanding Regeneration" from the www.roboteq.com for an in-depth discussion of this complex but important topic.

Important Warning

Use the controller only with a rechargeable battery as supply to the Motor Power wires (thick black and red wires). If a transformer or power supply is used, damage to the controller and/or power supply may occur during regeneration. See "Using the Controller with a Power Supply" below for details.

Important Warning

Avoid switching Off or cutting open the main power cables while the motors are spinning. Damage to the controller may occur. Always ground the Power Control wire to turn the controller Off.

Using the Controller with a Power Supply

Using a transformer or a switching power supply is possible but requires special care, as the current will want to flow back from the motors to the power supply during regeneration. As discussed in "Power Regeneration Considerations" above, if the supply is not able to absorb and dissipate regenerated current, the voltage will increase until the over-voltage protection circuit cuts off the motors. While this process should not be harmful to the controller, it may be to the power supply, unless one or more of the protective steps below is taken:

- Use a power supply that will not suffer damage in case a voltage is applied at its output that is higher than its own output voltage. This information is seldom published in commercial power supplies, so it is not always possible to obtain positive reassurance that the supply will survive such a condition.
- Avoid deceleration that is quicker than the natural deceleration due to the friction in the motor assembly (motor, gears, load). Any deceleration that would be quicker than natural friction means that braking energy will need to be taken out of the system, causing a reverse current flow and voltage rise.
- Place a battery in parallel with the power supply output. This will provide a reservoir into which regeneration current can flow. It will also be very helpful for delivering high current surges during motor acceleration, making it possible to use a lower current power supply. Batteries mounted in this way should be connected for the first time only while fully charged and should not be allowed to discharge. The power supply will be required to output unsafe amounts of current if connected directly to a discharged battery. Consider using a decoupling diode on the power supply's output to prevent battery or regeneration current to flow back into the power supply.
- Place a resistive load in parallel with the power supply, with a circuit to enable that load during regeneration. This solution is more complex but will provide a safe path for the braking energy into a load designed to dissipate it. The diagram below shows an example of such a circuit. The controller must be configured so that its digital output is activated when an overvoltage condition is detected. The MOSFET and brake resistor value must be sized according to the expected regeneration current that must be absorbed.

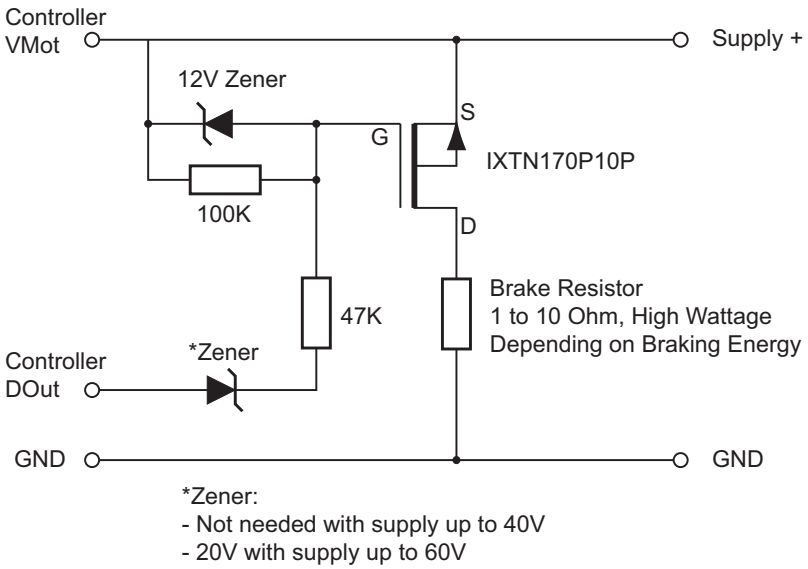


FIGURE 1-5. regen brake resistor

Note: The schematic above is provided for reference only. It may not work in all conditions.

SECTION 2

Safety Recommendations

In many applications, Roboteq controllers drive high power motors that move parts and equipment at high speed and/or with very high force. In case of malfunction, potentially enormous forces can be applied at the wrong time and/or wrong place causing serious damage to property and/or harm to person. While Roboteq controllers operate very reliably, and failures are rare, a failure is possible as with any other electronic equipment. If there is any danger that a loss of motor control can cause damage or injury, you must plan on that possibility and implement methods for stopping the motor **independently of the controller operation**.

Below is a list of failure categories, their effect and possible ways to regain control, or minimize the consequences. The list of possible failures is not exhaustive and the suggested prevention methods are provided as examples for information only.

Important Safety Disclaimer

Dangerous uncontrolled motor runaway condition can occur for a number of reasons, including, but not limited to: command or feedback wiring failure, configuration error, faulty firmware, errors in user MicroBasic script or in user program, or controller hardware failure. The user must assume that such failures can occur and must take all measures necessary to make his/her system safe in all conditions. The information contained in this manual, and in this section in particular, is provided for information only. Roboteq will not be liable in case of damage or injury as a result of product misuse or failure.

Possible Failure Causes

Dangerous unintended motor operation could occur for a number of reasons, including, but not limited to:

- Failure in Command device
- Feedback sensors malfunction
- Wiring errors or failure
- Controller configuration error

- Faulty firmware
- Errors or oversights in user MicroBasic scripts
- Controller hardware failure

Motor Deactivation in Normal Operation

In normal operation, the controller is always able to turn off the motor if it detects faults or if instructed to do so from an external command.

In case of wiring problem, sensor malfunction, firmware failure or error in user Microbasic scripts, the controller may be in a situation where the motors are turned on and kept on as long as the controller is powered. A number of features discussed throughout this manual are available to stop motor operation in case of abnormal situation. These include:

- Watchdog on missing incoming serial/USB commands
- Loss detection of Radio Pulse
- Analog command outside valid range
- Limit switches
- Stall detection
- Close Loop error detection
- Other …

Additional features can easily be added using MicroBasic scripting.

Ultimately, the controller can be simply turned off by grounding the Power Control pin. Assuming there is no hardware damage in the power stage, the controller output will be off (i.e. motor wires floating) when the controller is off.

Important Warning:

While cutting the power to the motors is generally the best thing to do in case of major failure, it may not necessarily result in a safe situation.

Motor Deactivation in Case of Output Stage Hardware Failure

On brushed DC motor controllers, the power stage for each motor is composed of 4 MOSFETs (semiconductor switches). In some cases of MOSFET failures, it is possible that one or both motors will remain permanently powered with no way to stop them either via software or by turning the controller off.

On brushless motor controllers, shorted MOSFETs will not cause the motor to turn on its own. Nevertheless, it is still advised to follow the recommendations included in this section.

The figures below show all the possible combinations of shorted MOSFETs switches in a brushed DC motor controller.

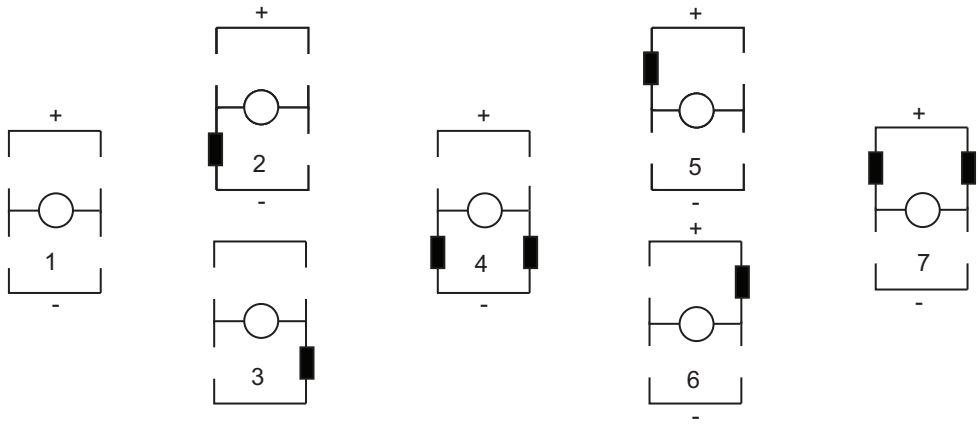


FIGURE 2-1. MOSFET Failures resulting in no motor activation

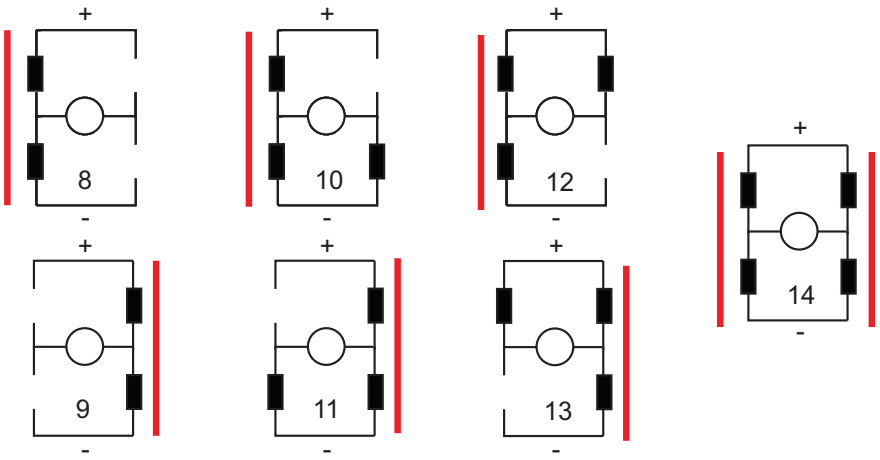


FIGURE 2-2. MOSFET Failures resulting in battery short circuit and no motor activation

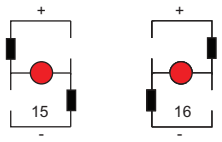


FIGURE 2-3. MOSFET Failure resulting in motor activation

Two failure conditions (15 and 16) will result in the motor spinning out of control regardless whether the controller is on or off. While these failure conditions are rare, users must take them into account and provide means to cut all power to the controller's power stage.

Manual Emergency Power Disconnect

In systems where the operator is within physical reach of the controller, the simplest safety device is the emergency disconnect switch that is shown in the wiring diagram inside all controller datasheets, and in the example diagram below.

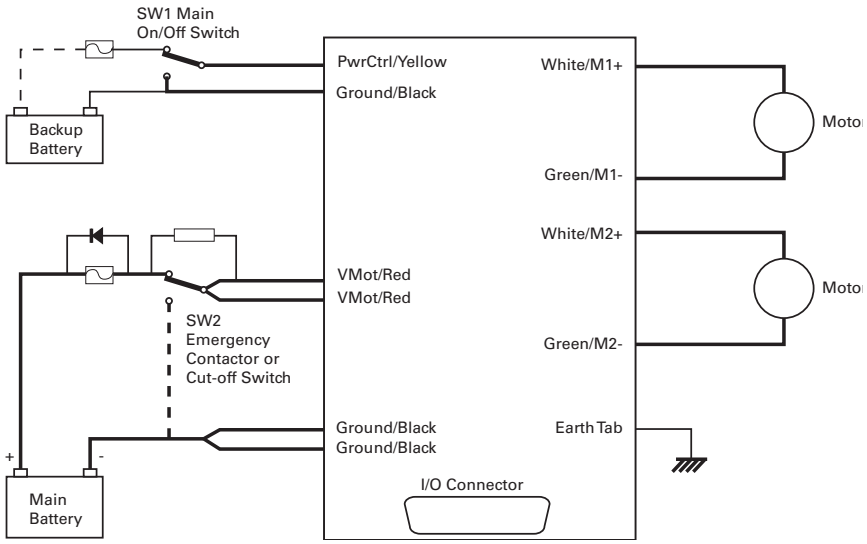


FIGURE 2-4. Example powering diagram (Brushed DC motor Controller)

The switch must be placed visibly and be easy to operate. Prefer "mushroom" emergency stop push buttons. Make sure that the switches are rated at the maximum current that can be expected to flow through all motors at the same time.

FIGURE 2-5. "Mushroom" type Emergency Disconnect Switch

Remote Emergency Power Disconnect

In remote controlled systems, the emergency switch must be replaced by a high power contactor relay as shown in Figure 2-6. The relay must be normally open and be activated using an RC switch on a separate radio channel. The receiver should preferably be powered directly from the system's battery. If powered from the controller's 5V output, keep in mind that in case of a total failure of the controller, the 5V output may or may not be interrupted.

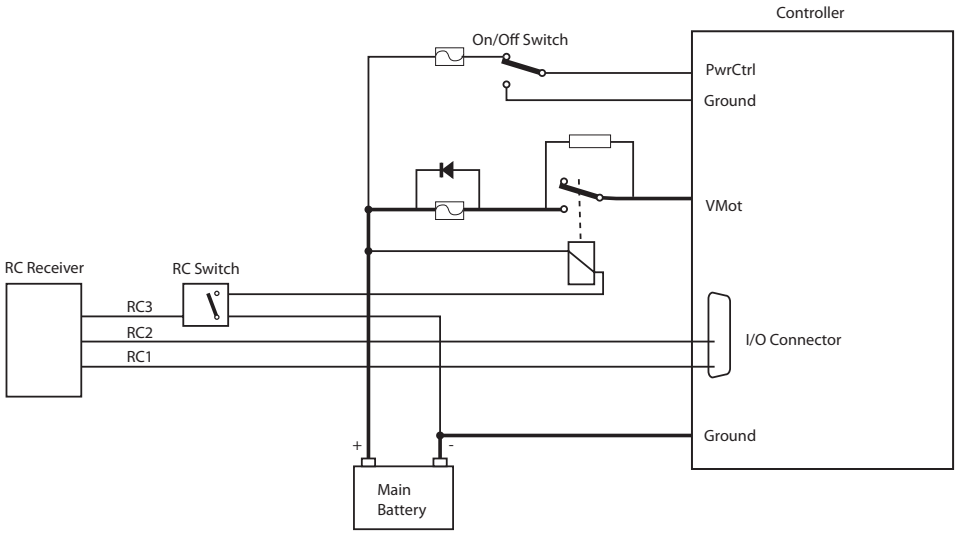


FIGURE 2-6 Example of remotely operated safety disconnect

The receiver must operate in such a way that the contactor relay will be off if the transmitter if off or out of range.

The transmitter should have a visible and easy to reach emergency switch for the operator. That switch will be used to deactivate the relay remotely. It could also be used to shutdown entirely the transmitter, assuming it is determined for certain that this will deactivate the relay at the controller.

Protection using Supervisory Microcomputer

In applications where the controller is commanded by a PC, a microcomputer or a PLC, that supervisory system could be used to verify that the controller is still responding and cut the power to the controller's power stage in case a malfunction is detected. The supervisory system would only require a digital output or other means to activate/deactivate the contactor relay as shown in the figure below.

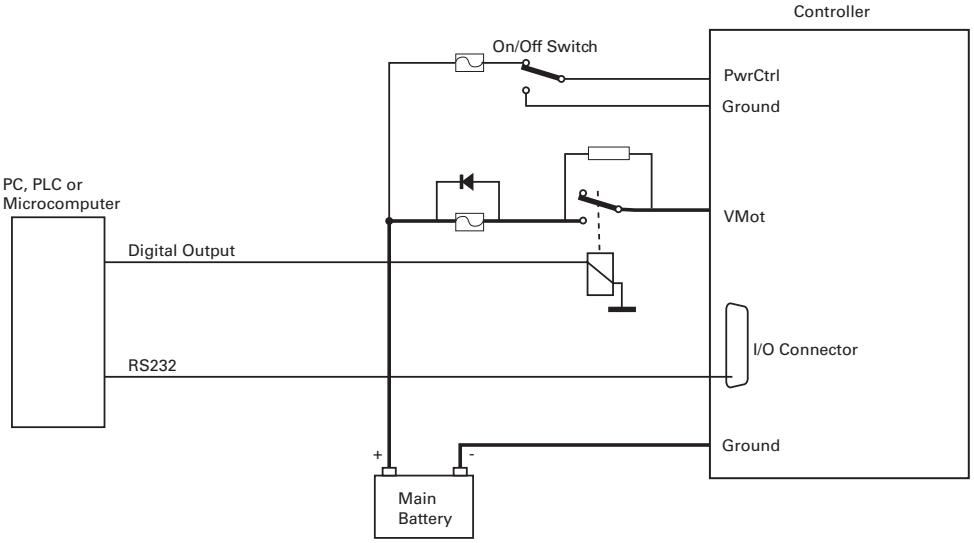


FIGURE 2-7. Example of safety disconnect via supervisory system

Self Protection against Power Stage Failure

If the controller processor is still operational, it can self detect several, although not all, situations where a motor is running while the power stage is off. The figure below shows a protection circuit using an external contactor relay.

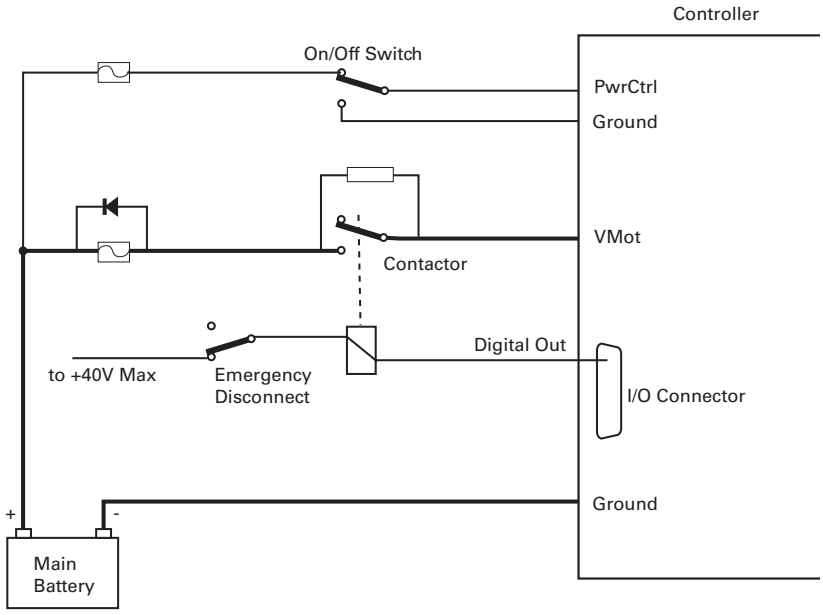


FIGURE 2-8. Self protection circuit using contactor

Note: Digital outputs are rated 40V max. If the battery voltage is higher than 40V, the relay must be connected to the + of an alternate power source of lower voltage.

The controller must have the Power Control input wired to the battery so that it can operate and communicate independently of the power stage. The controller's processor will then activate the contactor coil through a digital output configured to turn on when the "No MOSFET Failure" condition is true. The controller will automatically deactivate the coil if the output is expected to be off and battery current is above 500mA to 2.5A (depending on the controller model) for more than 0.5s.

The contactor must be rated high enough so that it can cut the full load current. For even higher safety, additional precaution should be taken to prevent and to detect fused contactor blades.

This contactor circuit will only detect and protect against damaged output stage conditions. It will not protect against all other types of fault. Notice therefore, the presence of an emergency switch in series with the contactor coil. This switch should be operated manually or remotely, as discussed in the Manual Emergency Power Disconnect the Remote Emergency Power Disconnect and the Protection using Supervisory Microcomputer earlier in this section of the manual.

Using this contactor circuit, turning off the controller will normally deactivate the digital output and this will cut the power to the controller's output stage.

Important Warning

Fully autonomous and unsupervised systems cannot depend on electronics alone to ensure absolute safety. While a number of techniques can be used to improve safety, they will minimize but never totally eliminate risks. Such systems must be mechanically designed so that no moving parts can ever cause harm in any circumstances.

SECTION 3

Connecting Sensors and Actuators to Input/Outputs

This section describes the various inputs and outputs and provides guidance on how to connect sensors, actuators or other accessories to them.

Controller Connections

The controller uses a set of power connections DSub and plastic connectors for all necessary connections.

The power connections are used for connecting to the batteries and motor, and will typically carry large current loads. Details on the controller's power wiring can be found at "Connecting Power and Motors to the Controller" section of this manual.

The DSub and plastic connectors are used for all low-voltage, low-current connections to the Radio, Microcontroller, sensors and accessories. This section covers only the connections to sensors and actuators.

For information on how to connect the RS232 port, see "Serial (RS232/USB) Operation" section.

The remainder of this section describes how to connect sensors and actuators to the controller's low-voltage I/O pins that are located on the DSub connectors.

Controller's Inputs and Outputs

The controller includes several inputs and outputs for various sensors and actuators. Depending on the selected operating mode, some of these I/Os provide command, feedback and/or safety information to the controller.

When the controller operates in modes that do not use these I/Os, these signals are ignored or can become available via the USB/RS232 port for user application. Below is a summary of the available signals and the modes in which they are used by the controller. The actual number of signal of each type, voltage or current specification, and their position on the I/O connector is given in the controller datasheet.

TABLE 3-1. Controller's IO signals and definitions

Signal	I/O type	Use/Activation
DOUT1 to DOUTn	Digital Output	- Activated when motor(s) is powered - Activated when motor(s) is reversed - Activated when overtemperature - Activated when overvoltage - Mirror Status LED - Deactivates when output stage fault - User activated (RS232/USB or via scripting)
DIN1 to DINn	Digital Input	- Safety Stop - Emergency stop - Motor Stop (deadman switch) - Invert motor direction - Forward or reverse limit switch - Run MicroBasic Script - Load Home counter
AIN1 to AINn	Analog Input	- Command for motor(s) - Speed or position feedback - Trigger Action similar to Digital Input if under or over user-selectable threshold
PIN1 to PINn	Pulse Input	- Command for motor(s) - Speed or position feedback - Trigger Action similar to Digital Input if under or over user selectable threshold
ENC1a/b to ENC2a/b	Encoder Inputs	- Speed or position feedback - Trigger action similar to Digital Input if under or over user-selectable count threshold

Connecting devices to Digital Outputs

Depending on the controller model, 2 to 8 Digital Outputs are available for multiple purposes. The Outputs are Open Drain MOSFET outputs capable of driving over 1A at up to 24V. See datasheet for detailed specifications.

Since the outputs are Open Drain, the output will be pulled to ground when activated. The load must therefore be connected to the output at one end and to a positive voltage source (e.g. a 24V battery) at the other.

Connecting Resistive Loads to Outputs

Resistive or other non-inductive loads can be connected simply as shown in the diagram below.

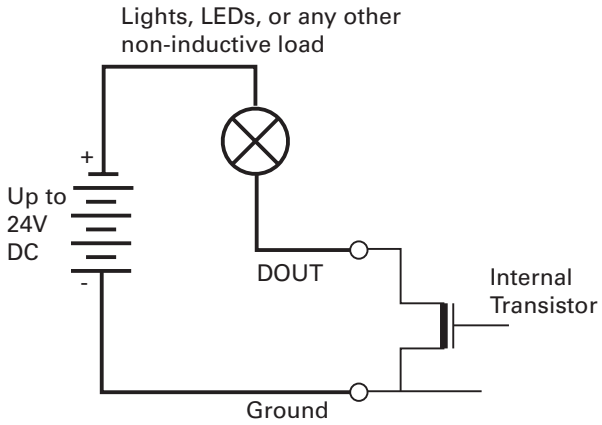


FIGURE 3-1. Connecting resistive loads to Dout pins

Connecting Inductive loads to Outputs

The diagrams on Figure 3-2 show how to connect a relay, solenoid, valve, small motor, or other inductive load to a Digital Output:

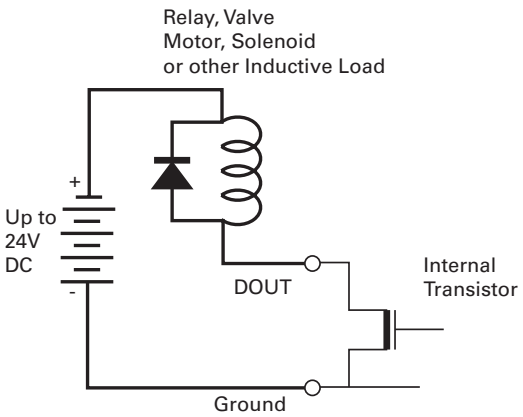


FIGURE 3-2. Connecting inductive loads to Dout pins

Important Warning

Overvoltage spikes induced by switching inductive loads, such as solenoids or relays, will destroy the transistor unless a protection diode is used.

Connecting Switches or Devices to Inputs shared with Outputs

On HDCxxxx and HBLxxxx controllers, Digital inputs DIN12 to DIN19 share the connector pins with digital outputs DOUT1 to DOUT8. When the digital outputs are in the Off state, these outputs can be used as inputs to read the presence or absence of a voltage at these pins.

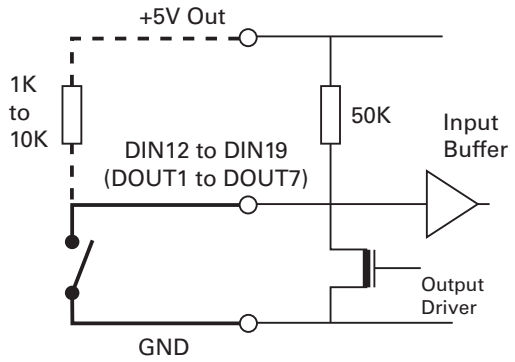


FIGURE 3-3. Switch wiring to inputs shared with outputs

For better noise immunity, an external pull up resistor should be installed even though one is already present inside the controller.

Important Warning

Do not activate an output when it is used as input. If the input is connected directly to a positive voltage when the output is activated, a short circuit will occur. Always pull the input up via a resistor.

Connecting Switches or Devices to direct Digital Inputs

The controller Digital Inputs are high impedance lines with a pull down resistor built into the controller. Therefore it will report an Off state if unconnected, A simple switch as shown on Figure 3-4 can be used to activate it. When a pull up switch is used, for better noise immunity, an external pull down resistor should be installed even though one is already present inside the controller.

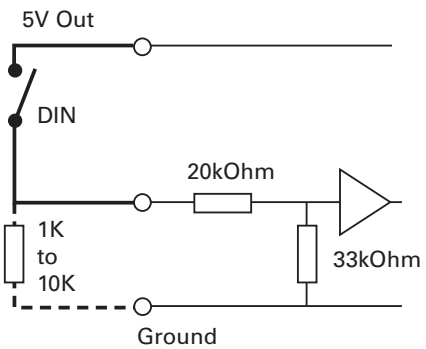


FIGURE 3-4. Pull up (Active High) switch wirings to DIN pins

A pull up resistor must be installed when using a pull down switch.

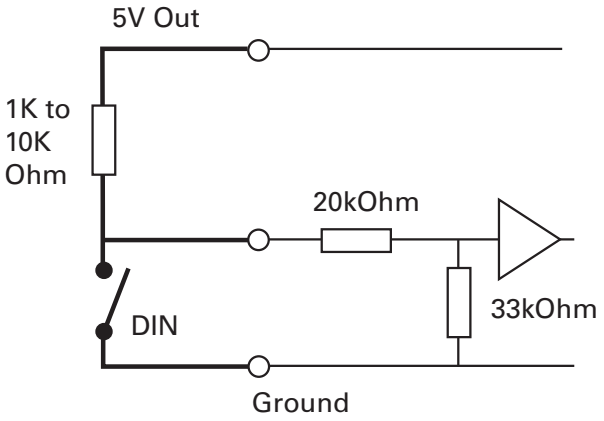


FIGURE 3-5. Pull down (Active Low) switch wirings to DIN pins

Connecting a Voltage Source to Analog Inputs

Connecting sensors with variable voltage output to the controller is simply done by making a direct connection to the controller's analog inputs. When measuring absolute voltages, configure the input in "Absolute Mode" using the PC Utility.

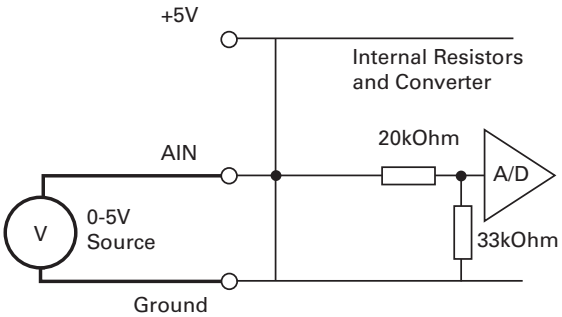


FIGURE 3-6. 0-5V Voltage source connected to Analog inputs

Using external resistors, it is possible to alter the input voltage range to 0V/10V or -10V/+10V.

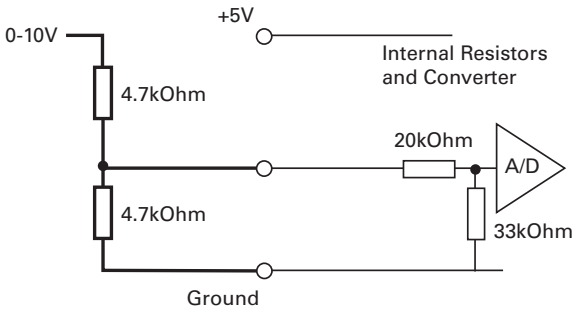


Figure 3-7. External resistor circuit for 0 to 10V capture range

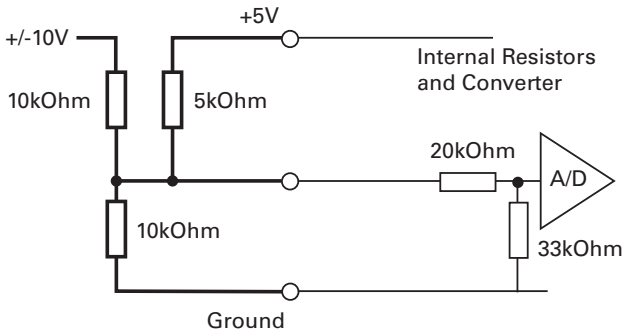


Figure 3-8. External resistors circuit for -10V to 10V capture range

Important Notice

On newer motor controllers models, activating the pulse mode on an input will also enable a pull up resistor on that input. If the input is also used for analog capture, the analog reading will be wrong. Make sure the pulse mode is disabled on that input.

Reducing noise on Analog Inputs

The Analog inputs are very fast and have a high input resistance. They will therefore easily be disturbed by ambient electrical noise and this will cause the analog reading to be fluctuating. Use shielded cables between the input and the analog sensor. Add a 1uF capacitor between the input pin and the GND pin. With good shielding and filtering, a signal stable to withing +/-5V or better can generally be achieved.

Connecting Potentiometers to Analog Inputs

Potentiometers mounted on a foot pedal or inside a joystick are an effective method for giving command to the controller. In closed loop mode, a potentiometer is typically used to provide position feedback information to the controller.

Connecting the potentiometer to the controller is as simple as shown in the diagram on Figure 3-9.

The potentiometer value is limited at the low end by the current that will flow through it and which should ideally not exceed 5 or 10mA. If the potentiometer value is too high, the analog voltage at the pot's middle point will be distorted by the input's resistance to ground of 53K. A high value potentiometer also makes the input sensitive to noise, particularly if wiring is long. Potentiometers of 1K or 5K are recommended values.

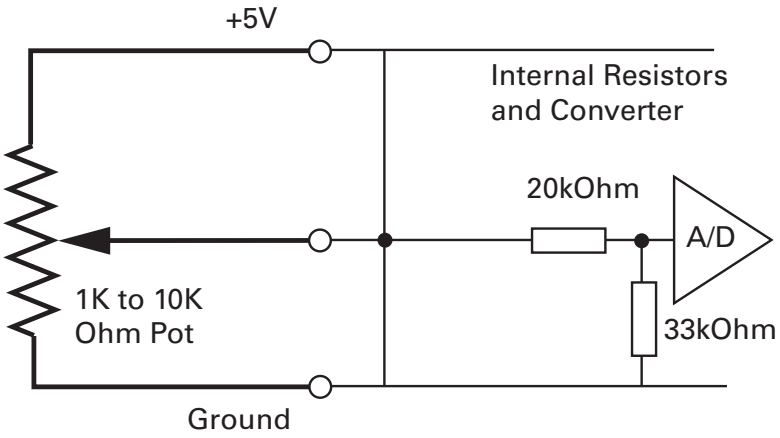


FIGURE 3-9. Potentiometer wiring

Because the voltage at the potentiometer output is related to the actual voltage at the controller's 5V output, configure the analog input in "Relative Mode". This mode measures the actual voltage at the 5V output in order to eliminate any imprecision due to source voltage variations. Configure using the PC Utility.

Connecting Potentiometers for Commands with Safety band guards

When a potentiometer is used for sensing a critical command (Speed or Brake, for example) it is critically important that the controller reverts to a safe condition in case wiring is sectioned. This can be done by adding resistors at each end of the potentiometer so that the full 0V or the full 5V will never be present, during normal operation, when the potentiometer is moved end to end.

Using this circuit shown below, the Analog input will be pulled to 0V if the two top wires of the pot are cut, and pulled to 5V if the bottom wire is cut. In normal operation, using the shown resistor values, the analog voltage at the input will vary from 0.2V to 4.8V.

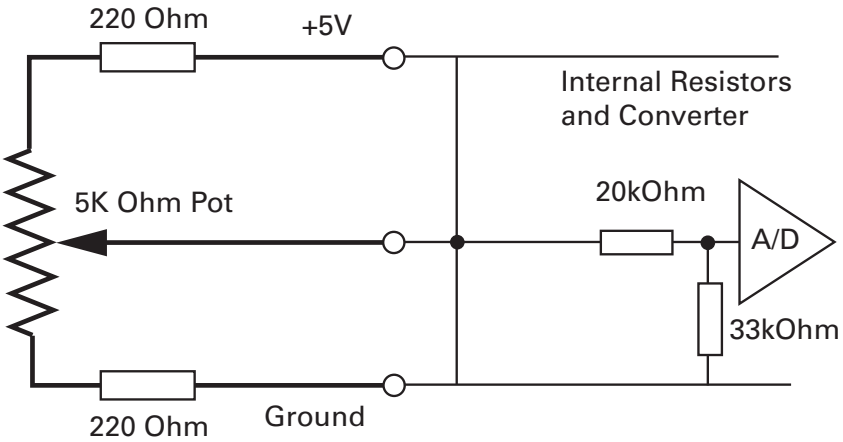


FIGURE 3-10. Potentiometer wiring in Position mode

The controller's analog channels are configured by default so that the min and max command range is from 0.25V to 4.75V. These values can be changed using the PC configuration utility. This ensures that the full travel of the pot is used to generate a command that spans from full min to full max.

If the Min/Max safety is enabled for the selected analog input, the command will be considered invalid if the voltage is lower than 0.1V or higher than 4.9. These values cannot be changed.

Connecting Tachometer to Analog Inputs

When operating in closed loop speed mode, tachometers can be connected to the controller to report the measured motor speed. The tachometer can be a good quality brushed DC motor used as a generator. The tachometer shaft must be directly tied to that of the motor with the least possible slack.

Since the controller only accepts a 0 to 5V positive voltage as its input, the circuit shown in Figure 3-11 must be used between the controller and the tachometer: a 10kOhm potentiometer is used to scale the tachometer output voltage to -2.5V (max reverse speed) and +2.5V (max forward speed). The two 1kOhm resistors form a voltage divider that sets the idle voltage at mid-point (2.5V), which is interpreted as the zero position by the controller.

With this circuitry, the controller will see 2.5V at its input when the tachometer is stopped, 0V when running in full reverse, and +5V in full forward.

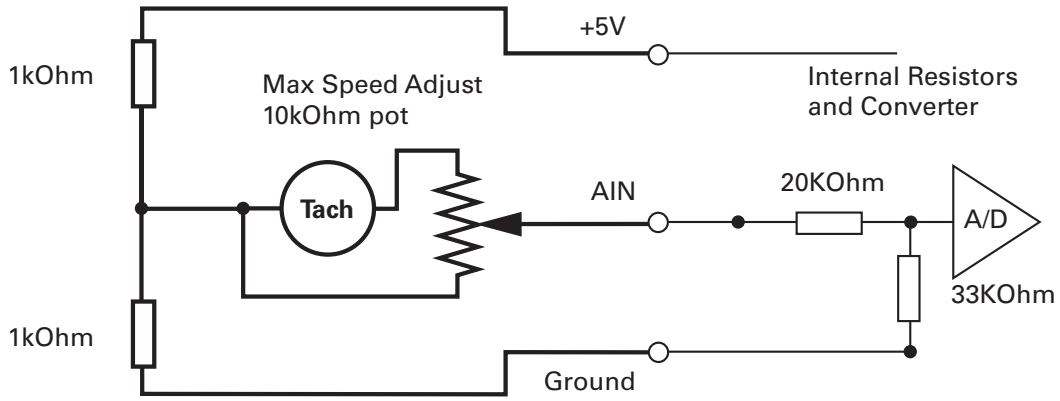


FIGURE 3-11. Tachometer wiring diagram

The tachometers can generate voltages in excess of 2.5 volts at full speed. It is important, therefore, to set the potentiometer to the minimum value (cursor all the way down per this drawing) during the first installation.

Since in closed loop control the measured speed is the basis for the controller's power output (i.e. deliver more power if slower than desired speed, less if higher), an adjustment and calibration phase is necessary. This procedure is described in "Closed Loop Speed Mode" section of this manual.

Important Warning

The tachometer's polarity must be such that a positive voltage is generated to the controller's input when the motor is rotating in the forward direction. If the polarity is inverted, this will cause the motor to run away to the maximum speed as soon as the controller is powered and eventually trigger the closed loop error and stop. If this protection is disabled, there will be no way of stopping it other than pressing the emergency stop button or disconnecting the power.

Connecting External Thermistor to Analog Inputs

Using external thermistors, the controller can be made to supervise the motor's temperature and cut the power output in case of overheating. Connecting thermistors is done according to the diagram shown in Figure 3-12. Use a 10kOhm Negative Coefficient Thermistor (NTC) with the temperature/resistance characteristics shown in the table below. Recommended part is Vishay NTCALUG03A103GC, Digikey item BC2381-ND.

TABLE 3-1. Recommended NTC characteristics

Temp (˚C)	-25	0	25	50	75	100
Resistance (kOhm)	129	32.5	10.00	3.60	1.48	0.67

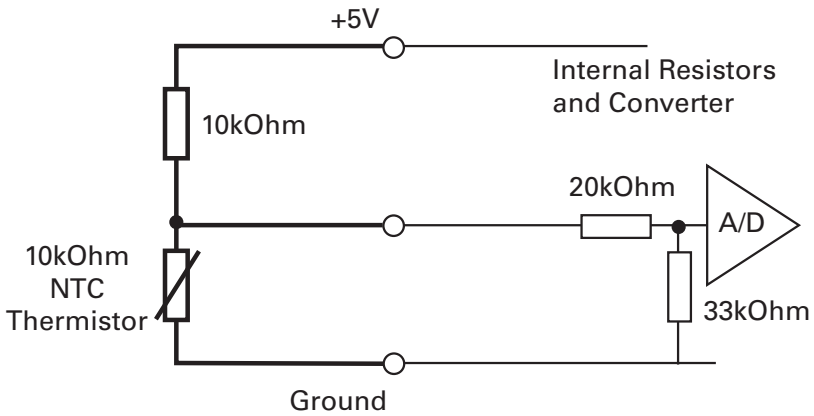


FIGURE 3-12. NTC Thermistor wiring diagram

Thermistors are non-linear devices. Using the circuit described on Figure 12, the controller will read the following values according to the temperature. For best precision, the analog input must be configured to read in Relative Mode.

The analog input must be configured so that the minimum range voltage matches the desired temperature and that an action be triggered when that limit is reached. For example 500mV for 80oC, according to the table. The action can be any of the actions in the list. An emergency or safety stop (i.e. stop power until operator moves command to 0) would be a typical action to trigger.

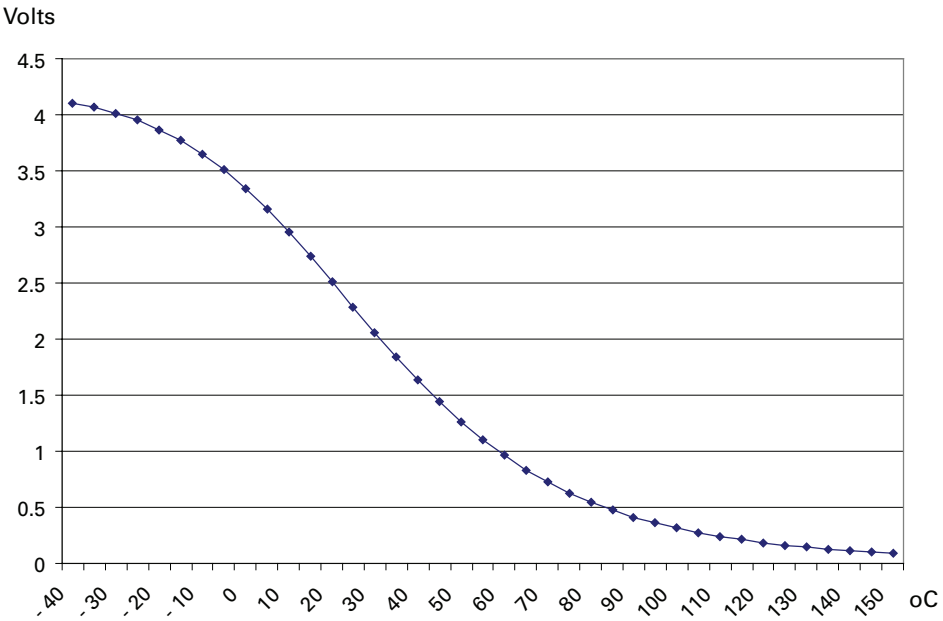


FIGURE 3-13. Voltage reading by Controller vs NTC temperature

Note: The voltage values in this chart are provided for reference only and may vary based on the Thermistor model/brand and the resistor precision. It is recommended that you verify and calibrate your circuit if it is to be used for safety protection.

Using the Analog Inputs to Monitor External Voltages

The analog inputs may also be used to monitor the battery level or any other DC voltage. If the voltage to measure is up to 5V, the voltage can be brought directly to the input pin. To measure higher voltage, insert two resistors wired as voltage divider. The figure shows a 10x divider capable of measuring voltages up to 50V.

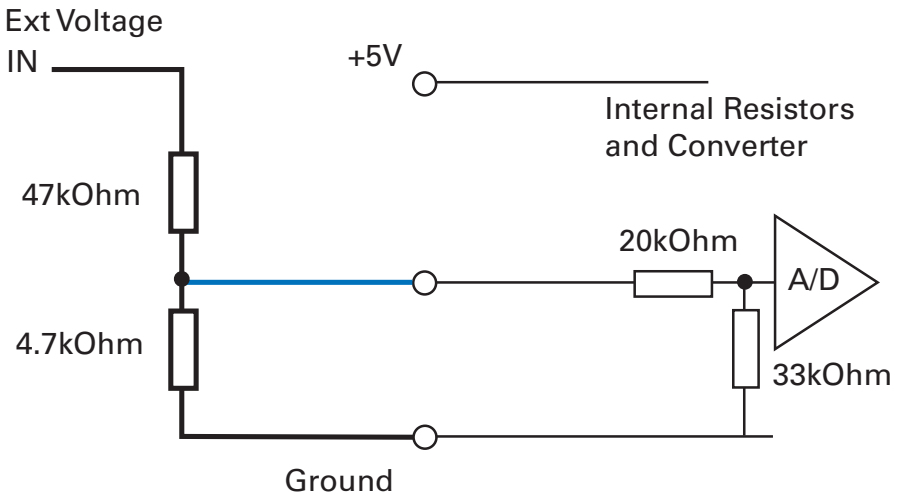


FIGURE 3-14. Battery Voltage monitoring circuit

Connecting Sensors to Pulse Inputs

The controller has several pulse inputs capable of capturing Pulse Length, Duty Cycle or Frequency with excellent precision. Being a digital signal, pulses are also immune to noise compared to analog inputs.

Important Notice

On newer motor controllers models, activating the pulse mode on an input will also enable a pull up resistor on that input. If the input is also used for analog capture, the analog reading will be wrong.

Connecting to RC Radios

The pulse inputs are designed to allow direct connection to an RC radio without additional components.

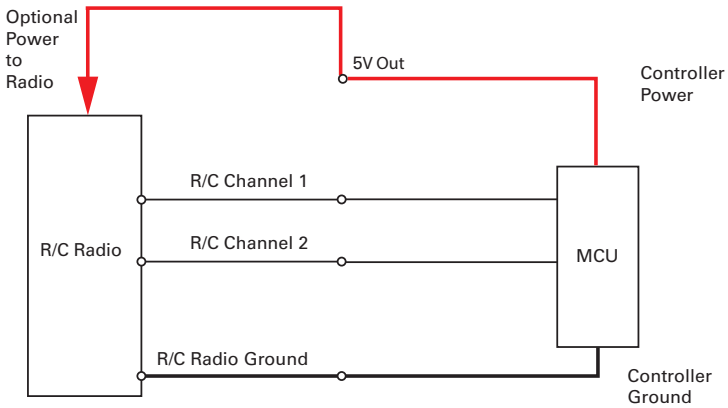


FIGURE 3-15. RC Radio powered by controller electrical diagram

Connecting to PWM Joysticks and Position Sensors

The controller's pulse inputs can also be used to connect to sensors with PWM outputs. These sensors provide excellent noise immunity and precision. When using PWM sensors, configure the pulse input in Duty Cycle mode. Beware that the sensor should always be pulsing and never output a steady DC voltage at its ends. The absence of pulses is considered by the controller as a loss of signal.

Connecting Optical Encoders

Optical Incremental Encoders Overview

Optical incremental encoders are a means for capturing speed and traveled distance on a motor. Unlike absolute encoders which give out a multi-bit number (depending on the resolution), incremental encoders output pulses as they rotate. Counting the pulses tells the application how many revolutions, or fractions of, the motor has turned. Rotation velocity can be determined from the time interval between pulses or by the number of pulses within a given time period. Because they are digital devices, incremental encoders will measure distance and speed with perfect accuracy.

Since motors can move in forward and reverse directions, it is necessary to differentiate the manner that pulses are counted so that they can increment or decrement a position

counter in the application. Quadrature encoders have dual channels, A and B, which are electrically phased 90° apart. Thus, direction of rotation can be determined by monitoring the phase relationship between the two channels. In addition, with a dual-channel encoder, a four-time multiplication of resolution is achieved by counting the rising and falling edges of each channel (A and B). For example, an encoder that produces 250 Pulses per Revolution (PPR) can generate 1,000 Counts per Revolution (CPR) after quadrature.

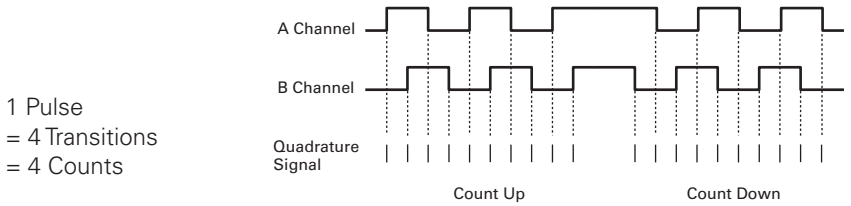


FIGURE 3-16. Quadrature encoder output waveform

The figure below shows the typical construction of a quadrature encoder. As the disk rotates in front of the stationary mask, it shutters light from the LED. The light that passes through the mask is received by the photo detectors. Two photo detectors are placed side by side at so that the light making it through the mask hits one detector after the other to produces the 90o phased pulses.

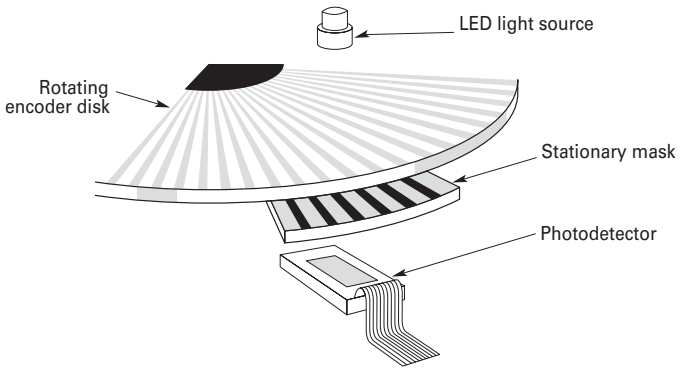


FIGURE 3-17. Typical quadrature encoder construction

Unlike absolute encoders, incremental encoders have no retention of absolute position upon power loss. When used in positioning applications, the controller must move the motor until a limit switch is reached. This position is then used as the zero reference for all subsequent moves.

Recommended Encoder Types

The module may be used with most incremental encoder modules as long as they include the following features:

- Two quadrature outputs (Ch A, Ch B), single ended
- 3.0V minimum swing between 0 Level and 1 Level on quadrature output
- 5VDC operation. 50mA or less current consumption per encoder

More sophisticated incremental encoders with index, and other features may be used, however these additional capabilities will be ignored.

The choice of encoder resolution is very wide and is constrained by the module's maximum pulse count at the high end and measurement resolution for speed at the low end.

Specifically, the controller's encoder interface can process 1 million counts per second, unless otherwise specified in the product datasheet.

Commercial encoders are rated by their numbers of "Pulses per Revolution" (also sometimes referred as "Number of Lines" or "Cycles per Revolution"). Carefully read the manufacturer's datasheet to understand whether this number represents the number of pulses that are output by each channel during the course of a 360 degrees revolution rather than the total number of transitions on both channels during a 360 degrees revolution. The second number is 4 times larger than the first one.

The formula below gives the pulse frequency at a given RPM and encoder resolution in Pulses per Revolution.

Pulse Frequency in counts per second = RPM / 60 * PPR * 4

Example: a motor spinning at 10,000 RPM max, with an encoder with 200 Pulses per Revolution would generate:

10,000 / 60 * 200 * 4 = 133.3 kHz which is well within the 1MHz maximum supported by the encoder input.

An encoder with a 200 Pulses per Revolutions is a good choice for most applications.

A higher resolution will cause the counter to count faster than necessary and possibly reach the controller's maximum frequency limit.

An encoder with a much lower resolution will cause speed to be measured with less precision.

Connecting the Encoder

Encoders connect directly to pins present on the controller's connector. The connector provides 5V power to the encoders and has inputs for the two quadrature signals from each encoder. The figure below shows the connection to the encoder.

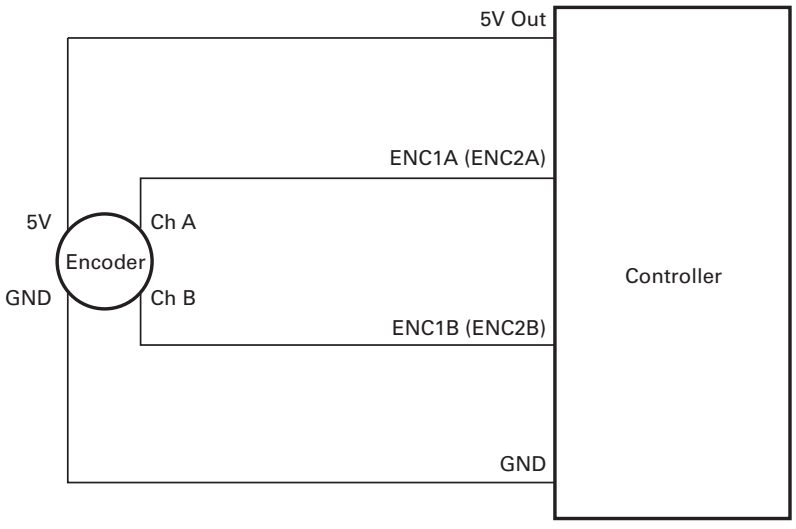


FIGURE 3-18. Controller connection to typical Encoder

Cable Length and Noise Considerations

Cable should not exceed one 3' (one meter) to avoid electrical noise to be captured by the wiring. A ferrite core filter should be inserted near the controller for length beyond 2' (60 cm). For longer cable length use an oscilloscope to verify signal integrity on each of the pulse channels and on the power supply.

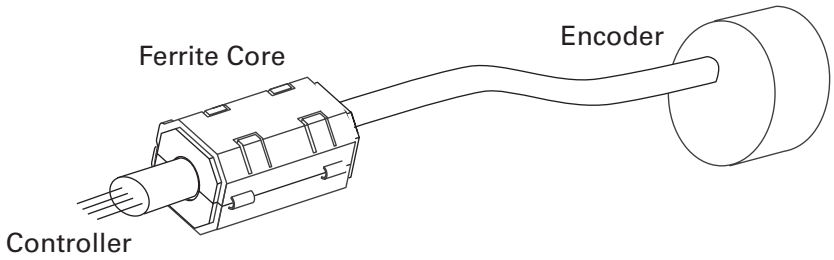


FIGURE 3-19. Use ferrite core on cable length beyond 2' or 60cm

Important Warning

Excessive cable length will cause electrical noise to be captured by the controller and cause erratic functioning that may lead to failure. In such situation, stop operation immediately.

Motor - Encoder Polarity Matching

When using encoders for closed loop speed or position control, it is imperative that when the motor is turning in the forward direction, the counter increments its value and a positive speed value is measured. The counter value can be viewed using the PC utility.

If the Encoder counts backwards when the motor moves forward, correct this by either:

1- Swapping Channel A and Channel B on the encoder connector. This will cause the encoder module to reverse the count direction,

2- Enter a negative number in the PPR configuration will also cause the counter to count in the reverse direction

3- Swapping the leads on the motor. This will cause the motor to rotate in the opposite direction.

SECTION 4

I/O Configuration and Operation

This section discusses the controller's digital and analog inputs and output and how they can be used.

Basic Operation

The controller's operation can be summarized as follows:

- Receive commands from a radio receiver, joystick or a microcomputer
- Activate the motor according to the received command
- Perform continuous check of fault conditions and adjust actions accordingly
- Report real-time operating data

The diagram below shows a simplified representation of the controller's internal operation. The most noticeable feature is that the controller's serial, digital, analog, pulse and encoder inputs may be used for practically any purpose.

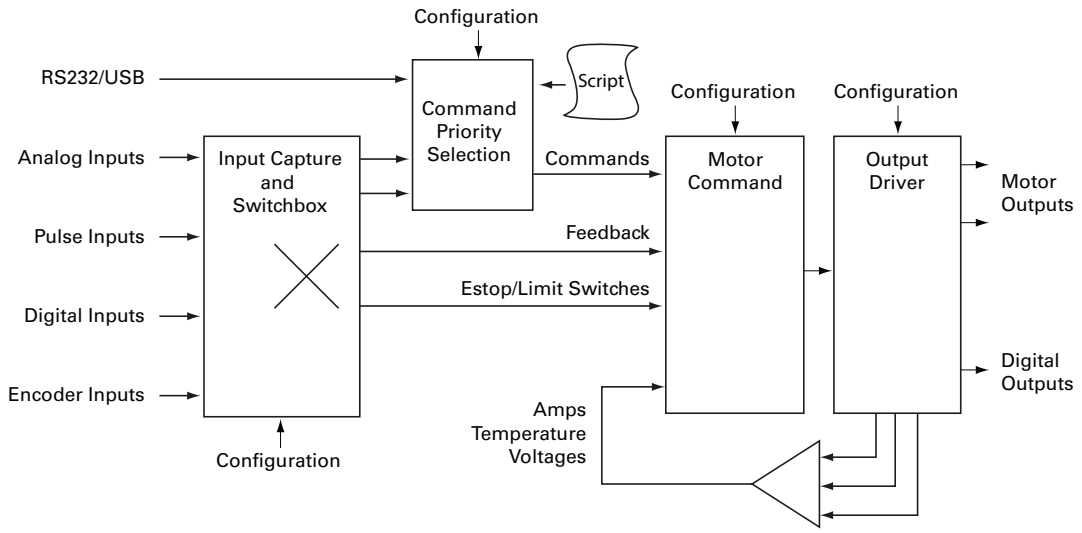


FIGURE 4-1. Simplified representation of the controller's internal operation

Practically all operating configurations and parameters can be changed by the user to meet any specific requirement. This unique architecture leads to a very high number of possibilities. This section of the manual describes all the possible operating options.

Input Selection

As seen earlier in the controller's simplified internal operating diagram on Figure 4-1, any input can be used for practically any purpose. All inputs, even when they are sharing the same pins on the connector, are captured and evaluated by the controller. Whether an input is used, and what it is used for, is set individually using the descriptions that follow.

Important Notice

On shared I/O pins, there is nothing stopping one input to be used as analog or pulse at the same time or for two separate inputs to act identically or in conflict with one another. While such an occurrence is normally harmless, it may cause the controller to behave in unexpected manner and/or cause the motors not to run. Care must be exercised in the configuration process to avoid possible redundant or conflictual use.

Digital Inputs Configurations and Uses

Each of the controller's digital Inputs can be configured so that they are active high or active low. Each output can also be configured to activate one of the actions from the list in the table below. In multi-channel controller models, the action can be set to apply to any or all motor channels.

TABLE 4-1. Digital Input Action List

Action	Applicable Channel	Description
No Action	-	Input causes no action
Safety Stop	Selectable	Stops the selected motor(s) channel until command is moved back to 0 or command direction is reversed
Emergency stop	All	Stops the controller entirely until controller is powered down, or a special command is received via the serial port
Motor Stop (deadman switch)	Selectable	Stops the selected motor(s) while the input is active. Motor resumes when input becomes inactive
Invert motor direction	Selectable	Inverts the motor direction, regardless of the command mode in used
Forward limit switch	Selectable	Stops the motor until command is changed to reversed
Reverse limit switch	Selectable	Stops the motor until the command is changed forward
Run script	NA	Start execution of MicroBasic script
Load Home counter	Selectable	Load counter with Home value

Configuring the Digital Inputs and the Action to use can be done very simply using the PC Utility.

Wiring instructions for the Digital Inputs can be found in "Connecting Switches or Devices to Inputs shared with Outputs" onpage 46

Analog Inputs Configurations and Use

The controller can do extensive conditioning on the analog inputs and assign them to different use.

Each input can be disabled or enabled. When enabled, it is possible to select the whether capture must be as absolute voltage or relative to the controller's 5V Output. Details on how to wire analog inputs and the differences between the Absolute and Relative captures can be found in "Using the Analog Inputs to Monitor External Voltages" page 47.

TABLE 4-2. Analog Capture Modes

Analog Capture Mode	Description
Disabled	Analog capture is ignored (forced to 0)
Absolute	Analog capture measures real volts at the input
Relative	Analog captured is measured relative to the 5V Output which is typically around 4.8V to 5.1V depending on the controller model and the load. Correction is applied so that an input voltage measured to be the same as the 5V Output voltage is reported at 5.0V

The raw Analog capture then goes through a series of processing shown in the diagram below.

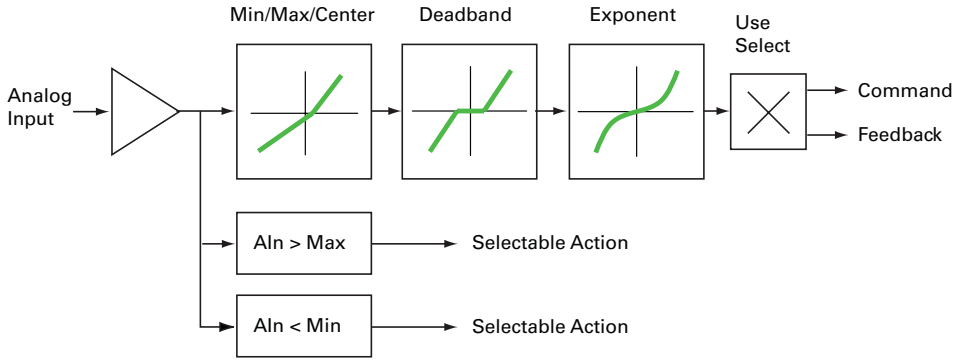


FIGURE 4-2. Analog Input processing chain

Analog Min/Max Detection

An analog input can be configured so that an action is triggered if the captured value is above a user-defined Maximum value and/or under a user-defined Minimum value. The actions that can be selected are the same as these that can be triggered by the Digital Input. See the list and description in Table 4.1, "Digital Input Action List" on page 58.

Min, Max and Center adjustment

The raw analog capture is then scaled into a number ranging from -1000 to +1000 based on user-defined Minimum, Maximum and Center values for the input. For example, setting the minimum to 500mV, the center to 2000mV, and the maximum to 4500mV, will produce the output to change in relation to the input as shown in the graph below

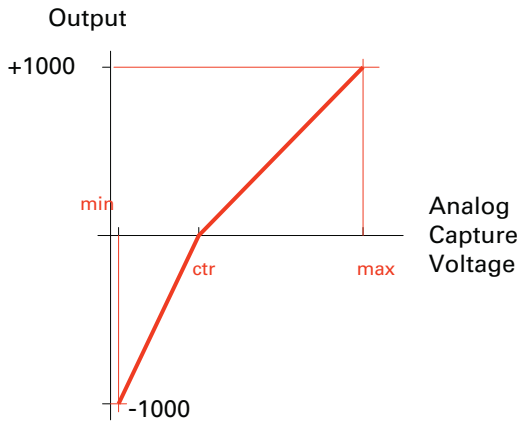


FIGURE 4-3. Analog Input processing chain

This feature allows to capture command or feedback values that match the available range of the input sensor (typically a potentiometer).

For example, this capability is useful for modifying the active joystick travel area. The figure below shows a transmitter whose joystick's center position has been moved back so that the operator has a finer control of the speed in the forward direction than in the reverse position.

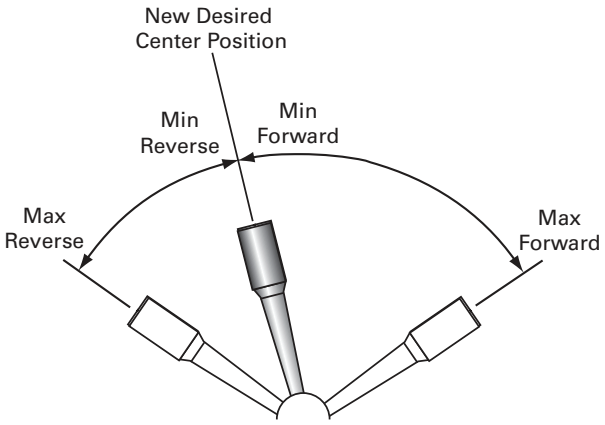


FIGURE 4-4. Calibration example where more travel is dedicated to forward motion

Setting the center value to be the same as the min value makes the input capture only commands in the positive direction. For example if Min = Center = 200 and Max = 4500, the input will convert into 0 when 200 and below, and 1000 above 4500.

The Min, Max and Center values are defined individually for each input. They can be easily entered manually using the Roborun PC Utility. The Utility also features an Auto-calibration function for automatically capturing these values.

Deadband Selection

The adjusted analog value is then adjusted with the addition of a deadband. This parameter selects the range of movement change near the center that should be considered as a 0 command. This value is a percentage from 0 to 50% and is useful, for example, to allow some movement of a joystick around its center position before any power is applied to a motor. The graph below shows output vs input changes with a deadband of approximately 40%.

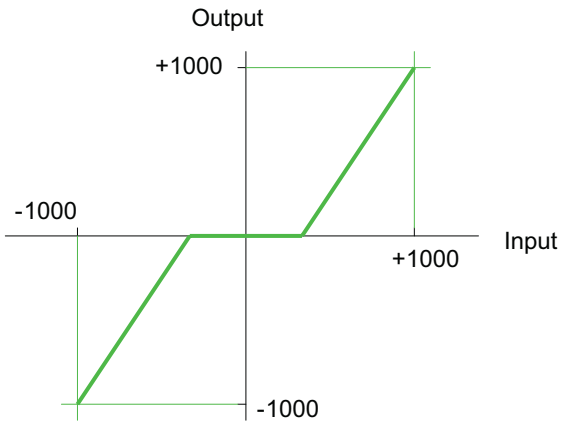


FIGURE 4-5. Effect of deadband on the output

Note that the deadband only affects the start position at which the joystick begins to take effect. The motor will still reach 100% when the joystick is at its full position. An illustration of the effect of the deadband on the joystick action is shown in the Figure 4-6 below.

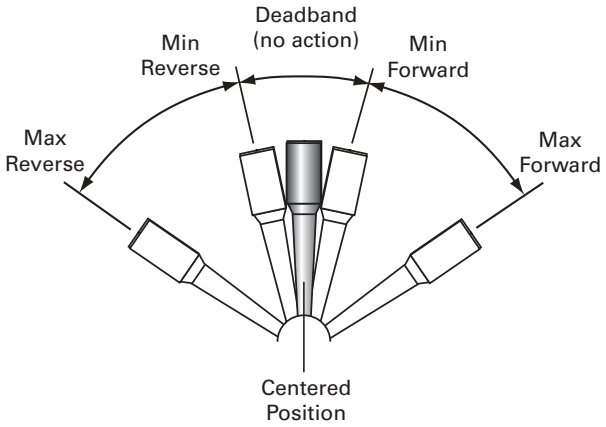


FIGURE 4-6. Effect of deadband on joystick position vs. motor command

The deadband value is set independently for each input using the PC configuration utility.

Command Correction

An optional exponential or a logarithmic adjustment can then be applied to the signal. Exponential correction will make the commands change less at the beginning and become stronger at the end of the joystick movement. The logarithmic correction will have a stronger effect near the start and lesser effect near the end. The linear selection causes no change to the input. There are 3 exponential and 3 logarithmic choices: weak, medium and strong. The graph below shows the output vs input change with exponential, logarithmic and linear corrections.

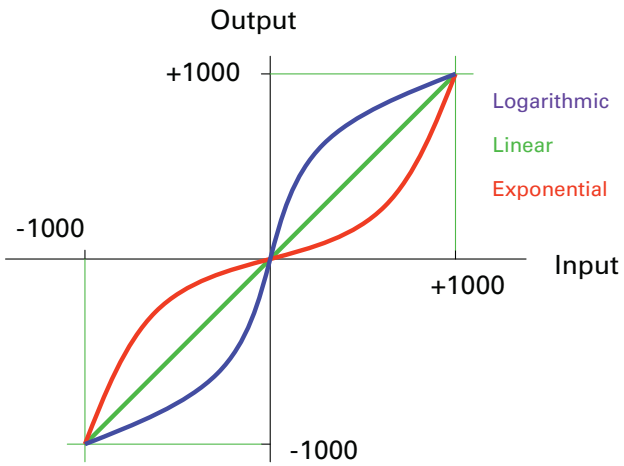


FIGURE 4-7. Effect of exponential / logarithmic correction on the output

The exponential or log correction is selected separately for each input using the PC Configuration Utility.

Use of Analog Input

After the analog input has been fully processed, it can be used as a motor command or, if the controller is configured to operate in closed loop, as a feedback value (typically speed or position).

Each input can therefore be configured to be used as command or feedback for any motor channel(s). The mode and channel(s) to which the analog input applies are selected using the PC Configuration Utility.

Pulse Inputs Configurations and Uses

The controller's Pulse Inputs can be used to capture pulsing signals of different types.

TABLE 4-3. Analog Capture Modes

Catpure Mode	Description	Typical use
Disabled	Pulse capture is ignored (forced to 0)	
Pulse	Measures the On time of the pulse	RC Radio

TABLE 4-3. (*continued*)

Catpure Mode	Description	Typical use
Duty Cycle	Measures the On time relative to the full On/Off period	Hall position sensors and joysticks with pulse output
Frequency	Measures the repeating frequency of pulse	Encoder wheel

The capture mode can be selected using the PC Configuration Utility.

The captured signals are then adjusted and can be used as command or feedback according to the processing chain described in the diagram below.

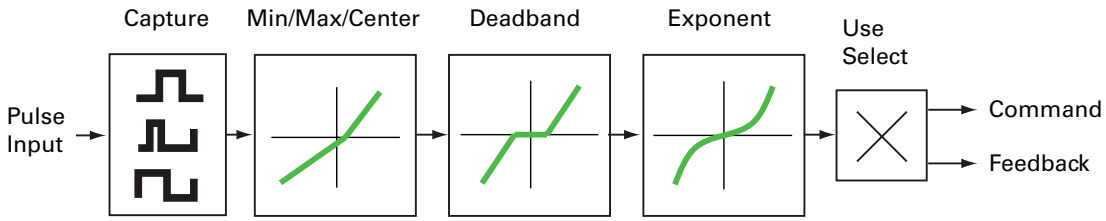


FIGURE 4-8. Pulse Input processing chain

Except for the capture, all other steps are identical to these described for the Analog capture mode.

Use of Pulse Input

After the pulse input has been fully processed, it can be used as a motor command or, if the controller is configured to operate in closed loop, as a feedback value (typically speed or position).

Each input can therefore be configured to be used as command or feedback for any motor channel(s). The mode and channel(s) to which the analog input applies are selected using the PC Configuration Utility.

Digital Outputs Configurations and Triggers

The controller's digital outputs can individually be mapped to turn On or Off based on the status of user-selectable internal status or events. The table below lists the possible assignment for each available Digital Output.

Action	Output activation	Typical Use
No action	Not changed by any internal controller events.	Output may be activated using Serial commands or user scripts
Motor(s) is on	When selected motor channel(s) has power applied to it.	Brake release
Motor(s) is reversed	When selected motor channel(s) has power applied to it in reverse direction.	Back-up warning indicator
Overvoltage	When battery voltage above over-limit	Shunt load activation
Overtemperature	When over-temperature limit exceeded	Fan activation. Warning buzzer
Status LED	When status LED is ON	Place Status indicator in visible location.

Encoder Configurations and Use

On controller models equipped with encoder inputs, external encoders enable a range of precision motion control features. See "Connecting Optical Encoders" page 53 for a detailed discussion on how optical encoders work and how to physically connect them to the controller. The diagram below shows the processing chain for each encoder input

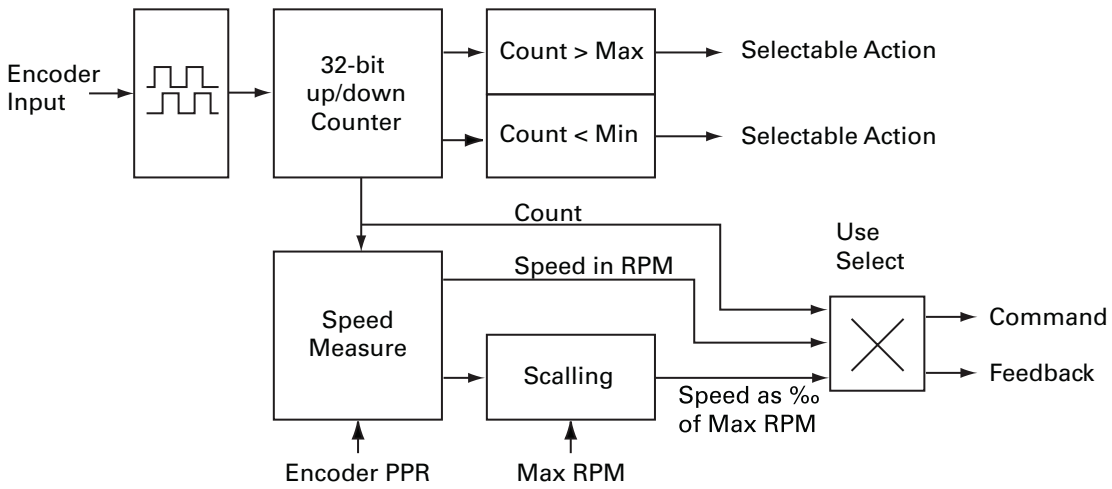


FIGURE 4-9. Encoder input processing

The encoder's two quadrature signals are processed to generate up and down counts depending on the rotation direction. The counts are then summed inside a 32-bit counter. The counter can be read directly using serial commands and/or can be used as a position feedback source for the closed loop position mode.

The counter can be compared to user-defined Min and/or Max values and trigger action if these limits are reached. The type actions are the same as these selectable for Digital Inputs and described in "Digital Inputs Configurations and Uses"page 58.

The count information is also used to measure rotation speed. Using the Encoder Pulse Per Rotation (PPR) configuration parameter, the output is a speed measurement in actual RPM that is useful in closed loop speed modes where the desired speed is set as a numerical value, in RPM, using a serial command.

The speed information is also scaled to produce a number ranging from -1000 to +1000 relative to a user-configured arbitrary Max RPM value. For example, with the Max RPM configured as 3000 and the a motor rotating at 1500 RPM, the measured relative speed will be 500. Relative speed is useful for closed loop speed mode that use Analog or Pulse inputs as speed commands.

Configuring the encoder parameters is done easily using the PC Configuration Utility.

Hall and other Rotor Sensor Inputs

On brushless motor controllers, the Hall or other Rotor position sensor that are used to switch power around the motor windings, are also used to measure speed and distance traveled.

Speed is evaluated by measuring the time between transition of the Hall Sensors. A 32 bit up/down counter is also updated at each Hall Sensor transition.

Speed information picked up from the Hall Sensors can be used for closed loop speed operation without any additional hardware.

SECTION 5

Magnetic Guide Sensor Connection and Operation

This section discusses how to interface one or more Roboteq's MGS1600 Magnetic Guide Sensors to the motor controller. Details of the Sensor's operation can be found in the product's datasheet.

Introduction to MGS1600 Magnetic Guide Sensor

Roboteq's Magnetic Guide Sensor is a sensor capable of detecting and reporting the position of a magnetic field along its horizontal axis. The sensor is intended for applications in Automatic Guided Vehicles using inexpensive adhesive magnetic tape to form a guide on the floor. The tape creates an invisible field that is immune to dirt and unaffected by lighting conditions. The sensor can be interfaced directly to any of Roboteq's motor controllers in order to create an effective AGV solution with just two components.

The sensor generates the following information about the track:

- Tape Detect
- Position of Left Track
- Position of Right Track
- Presence of Left Marker
- Presence of Right Marker

This data can be transmitted to Roboteq controller and other devices using one of the following methods

Method	To Roboteq Controllers	To PLCs	To PC's
MagSensor MultiPWM	Preferred	Unsuitable	Unsuitable
Serial	Not Recommended	Preferred	Suitable
CANbus	Suitable	Preferred	Suitable (1)
USB	N/A	Unsuitable	Suitable

Notes:
1: PC must be fitted with CAN adapter

MagSensor MultiPWM interface

The recommended interfacing method to Roboteq motor controller is the MagSensor MultiPWM mode. As the name implies, this proprietary method uses a succession of variable duty-cycle pulses to carry the Tracks, Tape Detect, Markers and Gyroscope information.

Any of the controller's pulse input can be configured as a MultiPWM input. The diagram below shows how simple this one-wire interfacing is.

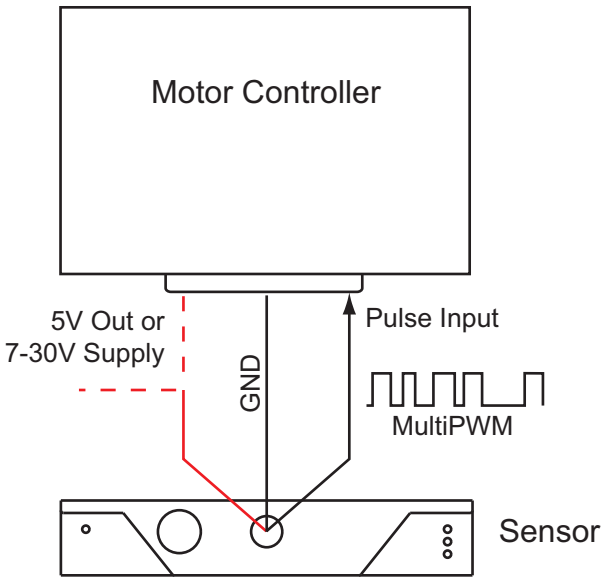


Figure 5-1: One-wire interfacing using MultiPWM

Enabling MagSensor MultiPWM Communication

MGS1600 Sensor is set to MultiPWM mode in its factory default configuration. To enable capture, the selected pulse input on the controller must be configured to "MagSensor" when using the PC utility. When changing via the console use

^PMOD cc 4

To enable pulse input cc in MultiPWM mode.

Accessing Sensor Information

Once enabled, the pulses are sent continuously by the sensor 100 times per second. The pulses are captured and parsed by the motor controller as they arrive. A real time mirror image of sensor data is then present inside the controller. From there the sensor information can be read using serial, USB, CAN or MicroBasic scripts like any other of the controller's operational parameters.

The following Motor Controller queries are available for reading the captured sensor data.

?MGD : Read tape detect

?MGT nn : Read left track when nn= 1 or right track when nn= 2

?MGM nn : Read left marker when nn=1 or right track when nn= 2

Details on these commands can be found in the Commands Reference section of this manual

Connecting Multiple Magnetic Guide Sensor

More than one sensor can be connected to a single motor controller. This can be useful in AGV designs that must be able to move in the forward and reverse direction along the guide. Connecting multiple sensor can be done by connecting each sensor to one of the available pulse input, as shown in the figure below.

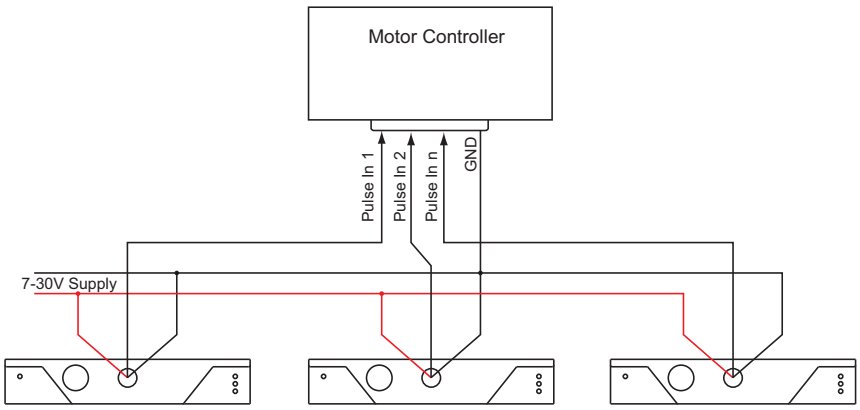


Figure 5-2: Connecting multiple sensors to a motor controller

Accessing Multiple Sensor Information Sequentially

Two methods are available for accessing each sensor's data when multiple sensors are connected.

The first method is to only have one sensor enabled at any one time. This is done by enabling and disabling pulse inputs via serial commands or MicroBasic scripting. Examples:

^PMOD 1 0 : Serial command to Disable Sensor on pulse input 1

Setconfig(_PMOD, 1, 0) : Microbasic instruction to disable sensor on Pulse input 1

^PMOD 2 4 : Enable Sensor on Pulse input 2

Setconfig(_PMOD, 2, 4) : Microbasic instruction to enable sensor on Pulse input 2

The sensor information can then be accessed with the ?MGD, ?MGT and ?MGM function discussed above.

Accessing Multiple Sensor Information Simultaneously

It is possible to have all magnetic sensors enabled at the same time by having their respective pulse input set to MagSensor MultiPWM

When more than one pulse input is configured that way, the sensor data is accessible using the ?MGD, ?MGT, ?MGM and ?MGY queries as follows, where x is the pulse input number (1, 2, 3 etc.).

Reading Tape Detect

?MGD x or GetValue(_MGD, x)

Returns the Tape Detect state of Sensor at Pulse input x

Example:

?MGD 2 : Returns the Tape Detect state of Sensor 2

Reading Marker Detect

?MGM 2*(x-1)+1 or GetValue(_MGM, 2*(x-1)+1)

Returns the state of the Left Marker Detect state of Sensor at Pulse input x

?MGM 2*(x-1)+2 or GetValue(_MGM, 2*(x-1)+2)

Returns the state of the Right Marker Detect state of Sensor at Pulse input x

Examples:

?MGM 1 : Returns the Left Marker Detect state of Sensor at input 1

?MGM 2 : Returns the Right Marker Detect state of Sensor at input 1

?MGM 3 : Returns the Left Marker Detect state of Sensor at input 2

?MGM 4 : Returns the Right Marker Detect state of Sensor at input 2

Reading Track Positions

?MGT 3*(x-1)+1 or GetValue(_MGT, 3*(x-1)+1)

Returns the Left Track Position of Sensor at input x

?MGT 3*(x-1)+2 or GetValue(_MGT, 3*(x-1)+2)

Returns the Right Track Position of Sensor at input x

?MGT 3*(x-1)+3 or GetValue(_MGT, 3*(x-1)+3)

Returns the Active (Left or Right) Track Position of Sensor at input x

Examples:

?MGT 1 : Returns the Left Track Position of Sensor at input 1

?MGT 2 : Returns the Right Track Position of Sensor at input 1

?MGT 4 : Returns the Left Track Position of Sensor at input 2

?MGT 5 : Returns the Right Track Position of Sensor at input 2

?MGT 7 : Returns the Left Track Position of Sensor at input 3

SECTION 6

Command Modes

This section discusses the controller's normal operation in all its supported operating modes.

Input Command Modes and Priorities

The controller will accept commands from one of the following sources

- Serial data (RS232, USB, MicroBasic script)
- Pulse (R/C radio, PWM, Frequency)
- Analog signal (0 to 5V)
- Spektrum Radio (on selected models)
- CAN Interface

One, many or all command modes can be enabled at the same time. When multiple modes are enabled, the controller will select which mode to use based on a user selectable priority scheme. Setting the priorities is done using the PC configuration utility.

This scheme uses a priority table containing three parameters and let you select which mode must be used in each priority order. During operation, the controller reads the first priority parameter and switches to that command mode. If that command mode is found to be active, that command is then used. If no valid command is detected, the controller switches to the mode defined in the next priority parameter. If no valid command is recognized in that mode, the controller then repeats the operation with the third priority parameter. If no valid command is recognized in that last mode, the controller applies a default command value that can be set by the user (typically 0).

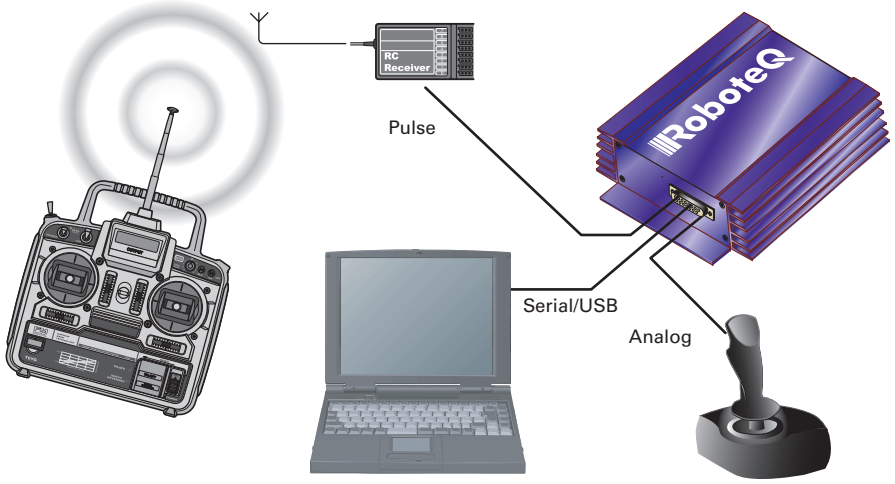


FIGURE 6-1. Controller's possible command modes

In the Serial mode, the mode is considered as active if commands (starting with "!") arrive within the watchdog timeout period via the RS232 or USB ports. The mode will be considered inactive, and the next lower priority level will be selected as soon as the watchdog timer expires. Note that disabling the watchdog will cause the serial mode to be always active after the first command is received, and the controller will never switch to a lower priority mode.

In the pulse mode, the mode is considered active if a valid pulse train is found and remains present.

In analog mode, the mode is considered active at all time, unless the Center at Start safety is enabled. In this case, the Analog mode will activate only after the joystick has been centered. The Keep within Min/Max safety mode will also cause the analog mode to become inactive, and thus enable the next lower priority mode, if the input is outside of a safe range.

The example in Figure 6-1 shows the controller connected to a microcomputer, a RC radio, and an analog joystick. If the priority registers are set as in the configuration below:

1- Serial
2- Pulse
3- Analog

then the active command at any given time is given in the table below.

TABLE 6-1. Priority resolution example

Microcomputer Sending commands	Valid Pulses Received	Analog joystick within safe Min/Max	Command mode selected
Yes	Don't care	Don't care	Serial
No	Yes	Don't care	RC mode
No	No	Yes	Analog mode
No	No	No	User selectable default value

Note that it is possible to set a priority level to "None". For example, the priority table

1 - Serial
2 - RC Pulse
3 - None

will only arbitrate and use Serial or RC Pulse commands.

USB vs Serial Communication Arbitration

On controllers equipped with a USB port, commands may arrive through the RS232 or the USB port at the same time. They are executed as they arrive in a first come first served manner. Commands that are arriving via USB are replied on USB. Commands arriving via the UART are replied on the UART. Redirection symbol for redirecting outputs to the other port exists (e.g. a command can be made to respond on USB even though it arrived on RS232).

CAN Commands Arbitration

On controllers fitted with a CAN interface, commands received via CAN are processed as they arrive regardless if any other mode is active at the same time. Care must be taken to avoid conflicting commands from different sources. Queries of operating parameters will not interfere with queries from serial or USB.

Commands issued from MicroBasic scripts

When sending a Motor or Digital Output command from a MicroBasic script, it will be interpreted by the controller the same way as a serial command (RS232 or USB). If a serial command is received from the serial/USB port at the same time a command is sent from the script, both will be accepted and this can cause conflicts if they are both relating to the same channel. Care must be taken to avoid, for example, cases where the script commands one motor to go to a set level while a serial command is received to set the motor to a different level.

Important Warning

When running a script that sends motor command, make sure you click "Mute" in the PC utility. Otherwise, the PC will be sending motor commands continuously and these will interfere with the script commands.

Script commands are also subject to the serial Watchdog timer and share the same priority level as Serial commands. Use the "Command Priorities" configuration to set the priority of commands issued from the script vs commands received from the Pulse Inputs or Analog Inputs.

Operating the Controller in RC mode

The controller can be directly connected to an R/C receiver. In this mode, the speed or position information is contained in pulses whose width varies proportionally with the joysticks' positions. The controller mode is compatible with all popular brands of RC transmitters.

The RC mode provides the simplest method for remotely controlling a robotic vehicle: little else is required other than connecting the controller to the RC receiver and powering it On.

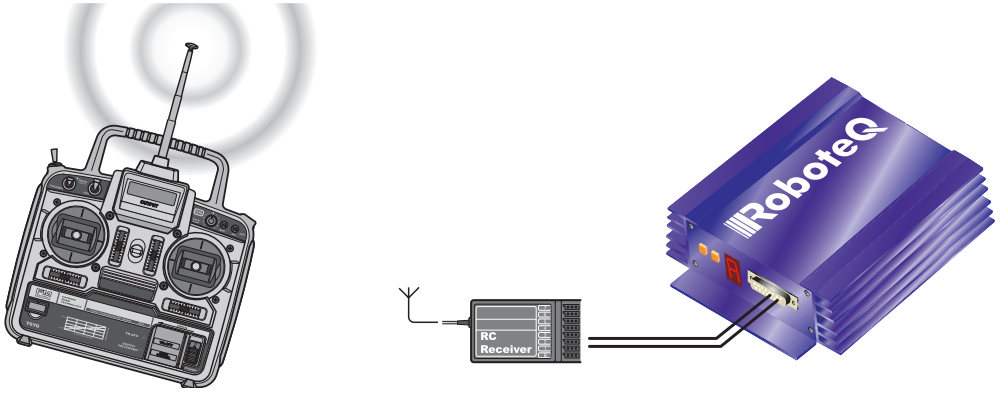


FIGURE 6-2. R/C radio control mode

The speed or position information is communicated to the controller by the width of a pulse from the RC receiver: a pulse width of 1.0 millisecond indicates the minimum joystick position and 2.0 milliseconds indicates the maximum joystick position. When the joystick is in the center position, the pulse should be 1.5ms.

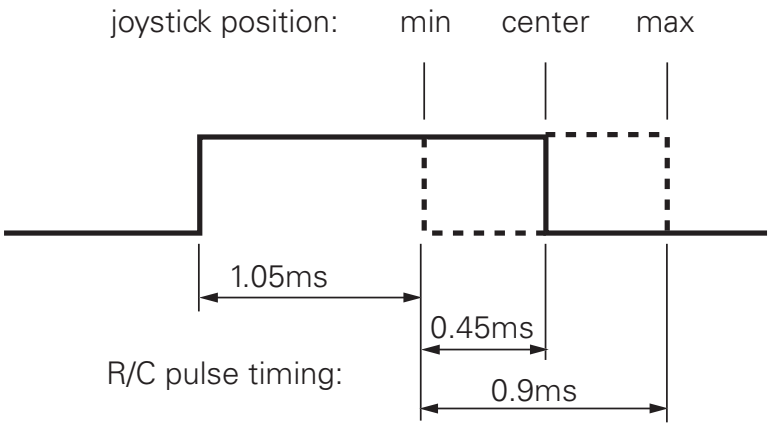


FIGURE 6-3. Joystick position vs. pulse duration default values

The controller has a very accurate pulse capture input and is capable of detecting changes in joystick position (and therefore pulse width) as small as 0.1%. This resolution is superior to the one usually found in most low cost RC transmitters. The controller will therefore be able to take advantage of the better precision and better control available from a higher quality RC radio, although it will work fine with lesser expensive radios as well.

Input RC Channel Selection

The controllers features several inputs that can be used for pulse capture. See product datasheet for actual number of pulse input. Any RC input can be used as command for any motor channels. The controller's factory default defines two channels for RC

capture (one input on single channel products). Which channel and which pin on the input connector depends on the controller model and can be found in the controller's datasheet.

Changing the input assignment is done using the PC Configuration utility.

Input RC Channel Configuration

Internally, the measured pulse width is compared to the reference minimum, center and maximum pulse width values. From this is generated a command number ranging from -1000 (when the joystick is in the min. position), to 0 (when the joystick is in the center position) to +1000 (when the joystick is in the max position). This number is then used to set the motor' desired speed or position that the controller will then attempt to reach.
For best results, reliability and safety, the controller will also perform a series of corrections, adjustments and checks to the R/C commands, as described below.

Joystick Range Calibration

The Joystick min, max and center position are adjustable. For best control accuracy, the controller can be calibrated to capture and use your radio's specific timing characteristics and store them into its internal Flash memory. This is done using a simple calibration procedure described page 60.

Deadband Insertion

The controller allows for a selectable amount of joystick movement to take place around the center position before activating the motors. See the full description of this feature at "Deadband Selection" page 61

Command Correction

The controller can also be set to translate the joystick motor commands so that the motor responds differently depending on whether the joystick is near the center or near the extremes. Five different exponential or logarithmic translation curves may be applied. Since this feature applies to the R/C, Analog and RS232 modes, it is described in detail in "Command Correction" page 62, in the General Operation section of the manual.

Reception Watchdog

Immediately after it is powered on, if in the R/C mode, the controller is ready to receive pulses from the RC radio.

If valid pulses are received on any of the enabled Pulse input channels, the controller will consider the RC Pulse mode as active. If no higher priority command is currently active (See "Input Command Modes and Priorities" page 73), the captured RC pulses will serve to activate the motors.

If no valid RC pulses reach the controller for more than 500ms, the controller no longer considers it is in the RC mode and a lower priority command type will be accepted if present.

Important Warning

Some receivers include their own supervision of the radio signals and will move their servo outputs to a safe position in case of signal loss. Using these types of receiver, the controller will always be receiving pulses even with the transmitter off.

Using Sensors with PWM Outputs for Commands

The controller's Pulse inputs can be used with various types of angular sensors that use contactless Hall technology and that output a PWM signal. These type of sensors are increasingly used inside joysticks and will perform much more reliably, and typically with higher precision than traditional potentiometers.

The pulse shape output from these devices varies widely from one sensor model to another and is typically different than this of RC radios:

- They have a higher repeat rate, up to a couple of kHz.
- The min and max pulse width can reach the full period of the pulse

Care must therefore be exercised when selecting a sensor. The controller will accommodate any pulsing sensor as long as the pulsing frequency does not exceed 250Hz. The sensor should not have pulses that become too narrow - or disappear altogether - at the extremes of their travel. Select sensors with a minimum pulse width of 10us or higher. Alternatively, limit mechanically the travel of the sensor to keep the minimum pulse width within the acceptable range.

A minimum of pulsing must always be present. Without it, the signal will be considered as invalid and lost.

Pulses from PWM sensors can be applied to any Pulse input on the controller's connector. Configure the input capture as Pulse or Duty Cycle.

A Pulse mode capture measures the On time of the pulse, regardless of the pulse period.

A Duty Cycle mode capture measures the On time of the pulse relative to the entire pulse period. This mode is typically more precise as it compensates for the frequency drifts o the PWM oscillator.

PWM signals are then processed exactly the same way as RC pulses. Refer to the RC pulse paragraphs above for reference.

Operating the Controller In Analog Mode

Analog Command is the simplest and most common method when the controller is used in a non-remote, human-operated system, such as Electric Vehicles.

Input Analog Channel Selection

The controller features 4 to 11 inputs, depending on the model type, that can be used for analog capture. Using different configuration parameters, any Analog input can be used as command for any motor channel. The controller's factory default defines two channels as

Analog command inputs. Which channel and which pin on the input connector depends on the controller model and can be found in the controller's datasheet.

Changing the input assignment is done using the PC Configuration utility. See "Analog Inputs Configurations and Use" on page 59.

Input Analog Channel Configuration

An Analog input can be Enabled or Disabled. When enabled, it can be configured to capture absolute voltage or voltage relative to the 5V output that is present on the connector. See "Analog Inputs Configurations and Use" on page 59

Analog Range Calibration

If the joystick movement does not reach full 0V and 5V, and/or if the joystick center point does not exactly output 2.5V, the analog inputs can be calibrated to compensate for this. See "Min, Max and Center adjustment" on page 60 and "Deadband Selection"on page 61.

Using Digital Input for Inverting direction

Any digital input can be configured to change the motor direction when activated. See "Digital Inputs Configurations and Uses" on page 58. Inverting the direction has the same effect as instantly moving the command potentiometer to the same level the opposite direction. The motor will first return to 0 at the configured deceleration rate and go to the inverted speed using the configured acceleration rate.

Safe Start in Analog Mode

By default, the controller is configured so that in Analog command mode, no motor will start until all command joysticks are centered. The center position is the one where the input equals the configured Center voltage plus the deadband.

After that, the controller will respond to changes to the analog input. The safe start check is not performed again until power is turned off.

Protecting against Loss of Command Device

By default, the controller is protected against the accidental loss of connection to the command potentiometer. This is achieved by adding resistors in series with the potentiometer that reduce the range to a bit less than the full 0V to 5V swing. If one or more wires to the potentiometer are cut, the voltage will actually reach 0V and 5V and be considered a fault condition, if that protection is enabled. See "Connecting Potentiometers for Commands with Safety band guards" on page 49.

Safety Switches

Any Digital input can be used to add switch-activated protection features. For example, the motor(s) can be made to activate only if a key switch is turned On, and a passenger is present on the driver's seat. This is done using by configuring the controller's Digital inputs. See "Digital Inputs Configurations and Uses" page 58.

Monitoring and Telemetry in RC or Analog Modes

The controller can be fully monitored while it is operating in RC or Analog modes. If directly connected to a PC via USB or RS232, the controller will respond to operating queries (Amps, Volts, Temperature, Power Out, ...) without this having any effect on its response to Analog or RC commands. The PC Utility can therefore be used to visualize in real time all operating parameters as the controller runs. See "Run Tab" on page 363.

In case the controller is not connected via a bi-directional link, and can only send information one-way, typically to a remote host, the controller can be configured to output a user-selectable set of operating parameters, at a user selectable repeat rate. See "Query History Commands" on page 263.

MicroBasic scripting can also be used to generate a periodic text string containing parameters to monitor.

Using the Controller with a Spektrum Satellite Receiver

Some controller models can be connected directly to a miniature Spektrum SP9545 satellite receiver. Using only 3 wires this interface will carry the information of up to 6 command joysticks with a resolution and precision that is significantly higher than traditional 1.5ms pulse signals.

The PC utility is used to map any of the 6 channels as a command for each motor. Binding the receiver to the transmitter is done using the %BIND maintenance command. See "Maintenance Commands" on page 209 for details on the binding procedure.

Using the Controller in Serial (USB/RS232) Mode

The serial mode allows full control over the controller's entire functionality. The controller will respond a large set of commands. These are described in detail in "Serial (RS232/USB) Operation" on page 141.

SECTION 7

Motor Operating Features and Options

This section discusses the controller's operating features and options relating to its motor outputs.

Power Output Circuit Operation

The controller's power stage is composed of high-current MOSFET transistors that are rapidly pulsed on and off using Pulse Width Modulation (PWM) technique in order to deliver more or less power to the motors. The PWM ratio that is applied is the result of computation that combines the user command and safety related corrections. In closed-loop operation, the command and feedback are processed together to produced a the adjusted motor command. The diagram below gives a simplified representation of the controller's operation.

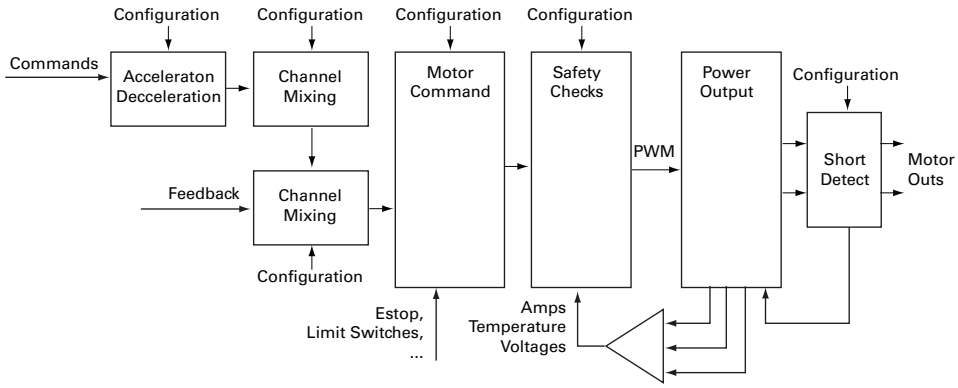


FIGURE 7-1. Simplified diagram of power output operation

Global Power Configuration Parameters

PWM Frequency

The power MOSFETs are switched at 16kHz by default. This frequency can set to another value ranging from 10 kHz to 50 kHz. Increasing the frequency reduces the efficiency due to switching losses. Lowering the frequency eventually creates audible noise and can be inefficient on low inductance motors.

Changing the PWM frequency typically results in no visible change in the motor operation and should be left untouched.

Overvoltage Protection

The controller includes a battery voltage monitoring circuit that will cause the output transistors to be turned Off if the main battery voltage rises above a preset Over Voltage threshold. The value of that threshold is set by default and may be adjusted by the user. The default value and settable range is given in the controller model datasheet.

This protection is designed to prevent the voltage created by the motors during regeneration to be "amplified" to unsafe levels by the switching circuit.

The controller will resume normal operation when the measured voltage drops below the Over Voltage threshold minus an user definable hysteresis voltage.

The controller can also be configured to trigger one of its Digital Outputs when an Over Voltage condition is detected. This Output can then be used to activate a Shunt load across the VMot and Ground wires to absorb the excess energy if it is caused by regeneration. This protection is particularly recommended for situation where the controller is powered from a power supply instead of batteries.

Undervoltage Protection

In order to ensure that the power MOSFET transistors are switched properly, the controller monitors the internal preset power supply that is used by the MOSFET drivers. If the internal voltage drops below a safety level, the controller's output stage is turned Off. The rest of the controller's electronics, including the microcomputer, will remain operational as long as the power supply on VMot is above the minimum voltage specified in the product datasheet or if Power Control is above 7V.

Additionally, the output stage will be turned off when the main battery voltage on VMot drops below a user configurable level that is factory preset at 5V.

Temperature-Based Protection

The controller features active protection which automatically reduces power based on measured operating temperature. This capability ensures that the controller will be able to work safely with practically all motor types and will adjust itself automatically for the various load conditions.

When the measured temperature reaches 70°C, the controller's maximum allowed power output begins to drop by 20% for every degree until the temperature reaches 75°C. Above 75°C, the controller's power stage turns itself off completely.

Note that the measured temperature is measured on the heat sink near the Power Transistors and will rise and fall faster than the outside surface.

The time it takes for the heat sink's temperature to rise depends on the current output, ambient temperature, and available air flow (natural or forced).

Short Circuit Protection

The controller includes a circuit that will detect very high current surges that are consistent with short circuits conditions. When such a condition occurs, the power transistor for the related motor channel are cut off within a few microseconds. Conduction is restored at 1ms intervals. If the short circuit is detected again for up to a quarter of a second, it is considered as a permanent condition and the controller enters a Safety Stop condition, meaning that it will remain off until the command is brought back to 0.

The short circuit detection can be configured with the PC utility to have one of three sensitivity levels: quick, medium, and slow.

The protection is very effective but has a few restrictions:

Only shorts between two motor outputs of the same channel are detected. Shorts between a motor wire and VMot are also detected. Shorts between a motor output and Ground are not detected.

Wire inductance causes current to rise slowly relative to the PWM On/Off times. Short circuit will typically not be detected at low PWM ratios, which can cause significant heat to eventually accumulate in the wires, load and the controller, even though the controller will typically not suffer direct damage. Increasing the short circuit sensitivity will lower the PWM ratio at which a short circuit is detected.

Since the controller can handle very large current during its normal operation, Only direct short circuits between wires will cause sufficiently high current for the detection to work. Short circuits inside motors or over long motor wires may go undetected.

A simplified short circuit protection logic is implemented on some controller models. Check with controller datasheet for details.

Mixed Mode Select

Mixed mode is available as a configuration option in dual channel controllers to create tank-like steering when one motor is used on each side of the robot: Channel 1 is used for moving the robot in the forward or reverse direction. Channel 2 is used for steering and will change the balance of power on each side to cause the robot to turn. Figure 7-2 below illustrates how the mixed mode motor arrangement.

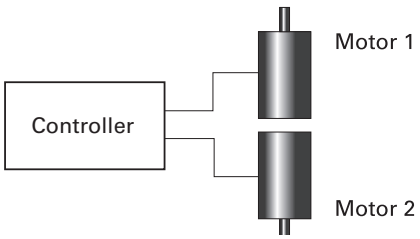


FIGURE 7-2. Effect of commands to motor examples in mixed mode

The controller supports 3 mixing algorithms with different driving characteristics. The table below shows how each motor output responds to the two commands in each of these modes.

TABLE 7-1. Mixing Mode characteristics

Input		Mode 1		Mode 2		Mode 3	
Throttle	**Steering**	**M1**	**M2**	**M1**	**M2**	**M1**	**M2**
0	0	0	0	0	0	0	0
0	300	300	-300	300	-300	300	-300
0	600	600	-600	600	-600	600	-600
0	1000	1000	-1000	1000	-1000	1000	-1000
0	-300	-300	300	-300	300	-300	300
0	-600	-600	600	-300	300	-600	600
0	-1000	-1000	1000	-1000	1000	-1000	1000
300	300	600	0	600	0	522	90
300	600	900	-300	900	-300	762	-120
300	1000	1000	-700	1000	-1000	1000	-400
300	-300	0	600	0	600	90	522
300	-600	-300	900	-300	900	-120	762
300	-1000	-700	1000	-1000	1000	-400	1000
600	300	900	300	900	300	708	480
600	600	1000	0	1000	-200	888	360
600	1000	1000	-400	1000	-1000	1000	200
600	-300	300	900	300	900	480	708
600	-600	0	1000	-200	1000	360	888
600	-1000	-400	1000	-1000	1000	200	1000
1000	300	1000	700	1000	400	900	1000
1000	600	1000	400	1000	-200	1000	1000
1000	1000	1000	0	1000	-1000	1000	1000
1000	-300	700	1000	400	1000	1000	900
1000	-600	400	1000	-200	1000	1000	1000
1000	-1000	0	1000	-1000	1000	1000	1000

Motor Channel Parameters

User Selected Current Limit Settings

The controller has current sensors at each of its output stages. Every 1 ms, this current is measured and a correction to the output power level is applied if higher than the user preset value.

The current limit may be set using the supplied PC utility. The maximum limit is dependent on the controller model and can be found on the product datasheet.

The limitation is performed on the Motor current and not on the Battery current. See "Battery Current vs. Motor Current" on page 30 for a discussion of the differences.

Selectable Amps Threshold Triggering

The controller can be configured to detect when the Amp on a motor channel exceed a user-defined threshold value and trigger an action if this condition persists for more than a preset amount of time.

The list of actions that may be triggered is shown in the table below.

TABLE 7-2. Possible Action List when Amps threshold is exceeded

Action	Applicable Channel	Description
No Action	-	Input causes no action
Safety Stop	Selectable	Stops the selected motor(s) channel until command is moved back to 0 or command direction is reversed
Emergency stop	All	Stops the controller entirely until controller is powered down, or a special command is received via the serial port

This feature is very different than amps limiting. Typical uses for it are for stall detection or "soft limit switches". When, for example, a motor reaches an end and enters stall condition, the current will rise, and that current increase can be detected and the motor be made to stop until the direction is reversed.

Programmable Acceleration & Deceleration

When changing speed command, the controller will go from the present speed to the desired one at a user selectable acceleration. This feature is necessary in order to minimize the surge current and mechanical stress during abrupt speed changes.

This parameter can be changed by using the PC utility. Acceleration can be different for each motor. A different value can also be set for the acceleration and for the deceleration. The acceleration value is entered in RPMs per second. In open loop installation, where speed is not actually measured, the acceleration value is relative to the Max RPM parameter. For example, if the Max RPM is set to 1000 (default value) and acceleration to 2000, this means that the controller will go from 0 to 100% power in 0.5 seconds.

Important Warning

Depending on the load's weight and inertia, a quick acceleration can cause considerable current surges from the batteries into the motor. A quick deceleration will cause an equally large, or possibly larger, regeneration current surge. Always experiment with the lowest acceleration value first and settle for the slowest acceptable value.

Forward and Reverse Power Adjustment Gain

This parameter lets you select the scaling factor for the power output as a percentage value. This feature is used to connect motors with voltage rating that is less than the battery voltage. For example, using a factor of 50% it is possible to connect a 12V motor onto a 24V system, in which case the motor will never see more than 12V at its input even when the maximum power is applied.

Selecting the Motor Control Modes

For each motor, the controller supports multiple motion control modes. The controller's factory default mode is Open Loop Speed control for each motor. The mode can be changed using the Roborun PC utility.

Open Loop Speed Control

In this mode, the controller delivers an amount of power proportional to the command information. The actual motor speed is not measured. Therefore the motor will slow down if there is a change in load as when encountering an obstacle and change in slope. This mode is adequate for most applications where the operator maintains a visual contact with the robot.

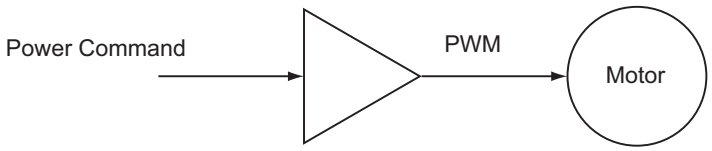


Figure 7-3: Open loop mode

Closed Loop Speed Control

In this mode, illustrated in Figure 7-4, optical encoder (typical) or an analog tachometer is used to measure the actual motor speed. If the speed changes because of changes in load, the controller automatically compensates the power output. This mode is preferred in precision motor control and autonomous robotic applications. Details on how to wire the tachometer can be found in "Connecting Tachometer to Analog Inputs" on page 50. Closed Loop Speed control operation is described in "Closed Loop Speed Mode" on page 113. On brushless motors, speed may be sensed directly from the motor's Hall or others internal Sensors and closed loop operation is possible without additional hardware.

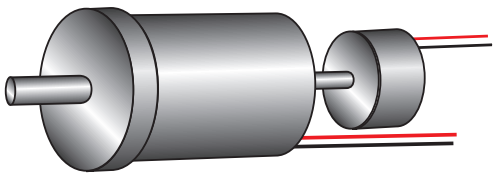


FIGURE 7-4. Motor with tachometer or Encoder for Closed Loop Speed operation

Closed Loop Speed Position Control

In this mode, the controller computes the position at which the motor must be at every 1ms. Then a position loop compares that expected position with the current position and applies the necessary power level in order for the motor to reach that position. This mode is especially effective for accurate control at very slow speeds. Details on this mode can be found in **Closed Loop Speed and Speed-Position Modes** on page 113

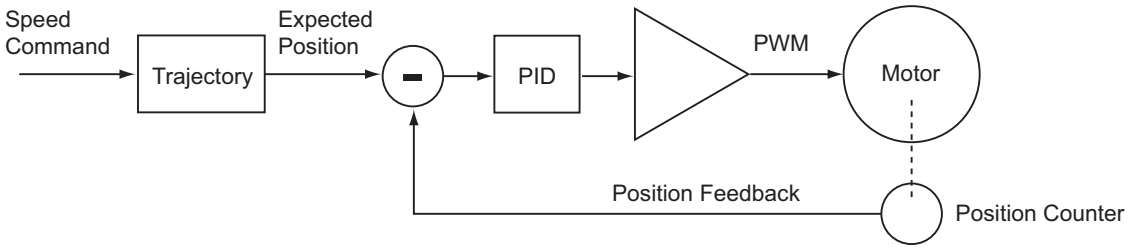


Figure 7-5: Closed Loop Speed Position mode

Closed Loop Position Relative Control

In this mode, illustrated in Figure 7-6, the axle of a geared down motor is typically coupled to a position sensor that is used to compare the angular position of the axle versus a desired position. The motor will move following a controlled acceleration up to a user defined velocity, and decelerate to smoothly reach the desired destination. This feature of the controller makes it possible to build ultra-high torque "jumbo servos" that can be used to drive steering columns, robotic arms, life-size models and other heavy loads. Details on how to wire the position sensing potentiometers and operating in this mode can be found in "Closed Loop Relative and Tracking Position Modes" on page 121.

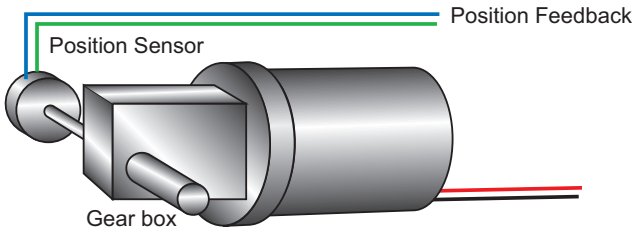


FIGURE 7-6. Motor with potentiometer assembly for position operation

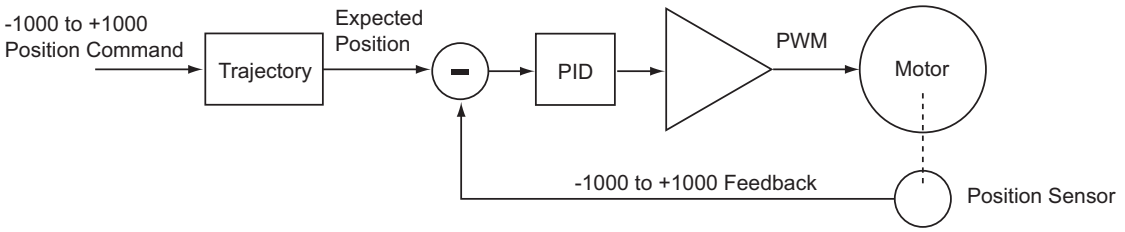


Figure 7-7. Closed Loop Position Relative mode

Closed Loop Count Position

In this mode, an encoder is attached to the motor as for the Speed Mode of Figure 7-8. Then, the controller can be instructed to move the motor to a specific number of counts, using a user-defined acceleration, velocity, and deceleration profile. Details on how to configure and use this mode can be found in "Closed Loop Count Position Mode" on page 131. On brushless motors, the hall sensors can be also be used for position measurement.

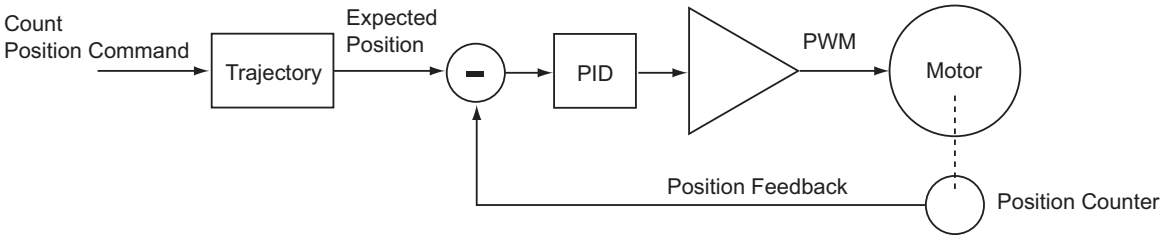


Figure 7-8: Closed Loop Count Position mode

Closed Loop Position Tracking

This modes uses the same feedback sensor mount as this of Figure 7-9. In this mode the motor will be moved until the final position measured by the feedback sensor matches the command. The motor will move as fast as it possibly can, using maximum physical acceleration. This mode is best for systems where the motor can be expected to move as fast as the command changes. Details on this operating mode can be found in "Closed Loop Relative and Tracking Position Modes" on page 121.

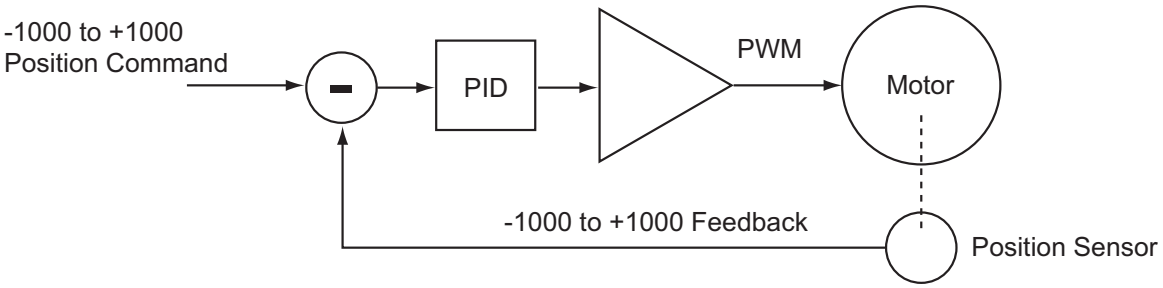


Figure 7-9: Closed Loop Position Tracking mode

Torque Mode

In this closed loop mode, the motor is driven in a manner that it produces a desired amount of torque regardless of speed. This is achieved by using the motor current as the feedback. Torque mode does not require any specific wiring. Detail on this operating mode can be found in "Closed Loop Torque Mode" on page 137.

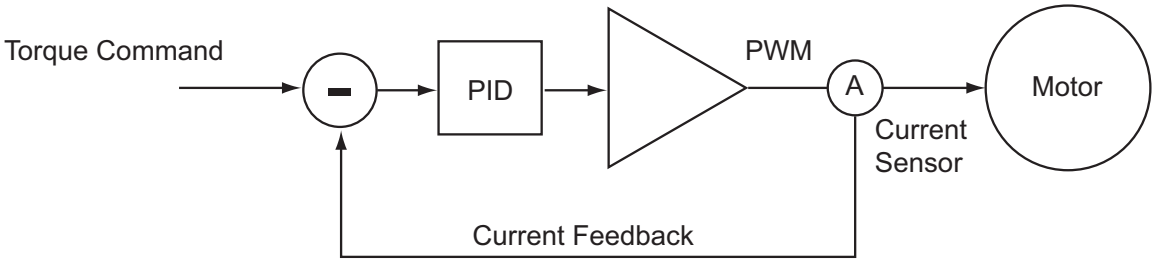


Figure 7-10: Closed Loop Torque mode

SECTION 8

Brushless Motor Connections and Operation

This section addresses installation an operating issues specific to brushless motors. It is applicable only to brushless motor controller models.

Introduction to Brushless Motors

Brushless motors, or more accurately Brushless DC Permanent Magnet Synchronous motors (since there are other types of motors without brushes) contain permanent magnets and electromagnets. The electromagnets are arranged in groups of three and are powered in sequence in order to create a rotating field that drives the permanent magnets. The electromagnets are located on the non-rotating part of the motor, which is normally in the motor casing for traditional motors, in which case the permanent magnets are on the rotor that is around the motor shaft. On hub motors, such as those found on electric bikes, scooters and some other electric vehicles, the electromagnets are on the fixed center part of the motor and the permanent magnets on the rotating outer part.

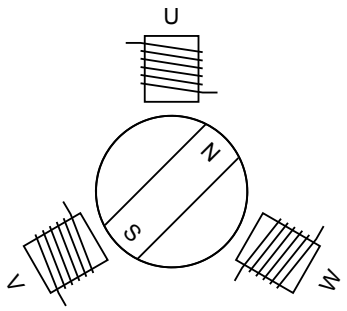


Figure 8-1. Permanent Magnet Synchronous Motor construction

As the name implies, Brushless motors differ from traditional DC motors in that they do not use brushes for commutating the electromagnets. Instead, it is up to the motor controller to apply, in sequence, current to each of the 3 motor windings in order to cause the rotor to spin. There are fundamentally two methods of generating the rotating magnetic field in the motor's winding:

- Trapezoidal Commutation
- Sinusoidal Commutation

Within each commutation method is then a method for detecting the actual position of the rotor in order to synchronize the generated rotating field. These are:

- Hall sensors
- Encoders (Absolute or relative)
- Sensorless

All Roboteq brushless controllers support Trapezoidal with Hall sensor feedback. Sinusoidal and alternative rotor detection techniques are available on selected models. Refer to the controller's datasheet to determine which modes are supported.

Number of Poles

One of the key characteristics of a brushless motor is the number of poles of permanent magnets pairs it contains. A full 3-phase cycling of motor's electromagnets will cause the rotor to move to the next permanent magnet pole. A full 3-phase cycle is known as electrical turn which will be different from the physical (mechanical) turn of the shaft if the motor number of pole pairs is greater than one: increasing the number of pole pairs will cause the motor to rotate more slowly for a given rate of change on the winding's phases.

The number of pole pairs is necessary for determining the number of turns a motor has done. It can also be used to measure the motor speed. The Roboteq controllers can measure both.

The number of pole pairs on a particular motor is usually found in the motor's specification sheet. The number of pole pairs can also be measured by applying a low DC current (around 1A) between any two wires of the 3 that go to the motor and then counting the number of cogs you feel when rotating the motor by hand for a full turn. It can also be determined by rotating the motor shaft by hand a full turn. Then take the number of counts reported by the hall counter, and divide it by 6.

The number of pole pairs is a configuration parameter that can be entered in the controller configuration (see "BPOL" in the command reference section). This parameter is not needed for basic motor operation with Hall Sensor feedback and can be left at its default value. It is needed if accurate speed reporting is required or to operate in Closed Loop Speed mode. The number of pole pairs in a critical configuration in sinusoidal mode.

Entering a negative number of pole pairs will reverse the measured speed and the count direction. It is useful when operating the motor in closed loop speed mode and if otherwise a negative speed is measured when the motor is moved in the positive direction.

Trapezoidal Switching

In trapezoidal switching, the controller applies current to two of the 3 motor wires, in turn and in alternating direction. A total of 6 combination of current flow are possible, resulting in the rotor getting a changing magnetic field every 30 degrees of electrical rotation. The controller must therefore know where the rotor is in relation to the electromagnets so that current can be applied to the correct winding at any given point in time. The simplest and most reliable method is to use three Hall sensors inside the motor. The diagram below shows the direction of the current in each of the motor's windings depending on the state of the 3 hall sensors.

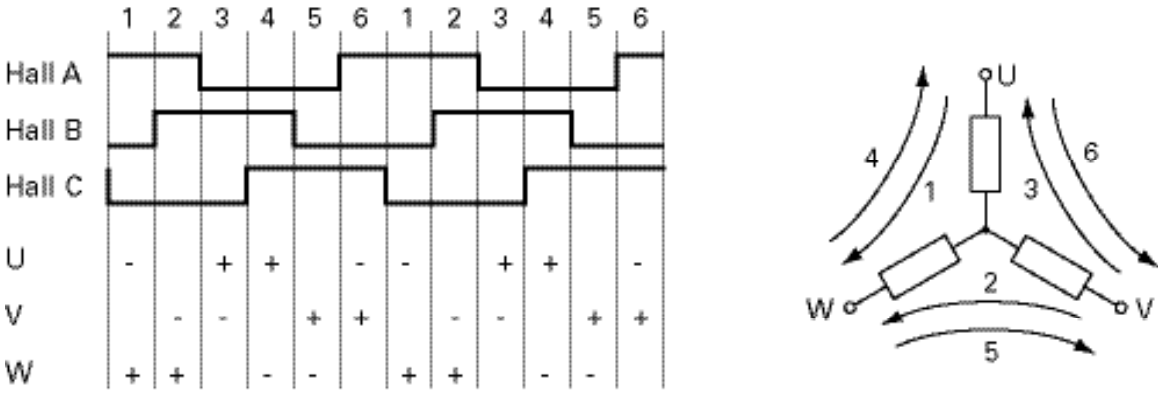


Figure 8-2. Hall sensors sequence

Hall Sensor Wiring

Hall sensors connection requires 5 wires on the motor:

- Ground
- Sensor1 Output
- Sensor2 Output
- Sensor3 Output
- + power supply

Sensor outputs are generally Open Collector, meaning that they require a pull up resistor in order to create the logic level 1. Pull up resistor of 4.7K ohm to +5V are incorporated inside all controllers. Additionally, 1nF capacitors to ground are present at the controller's input in order to remove high frequency spikes which may be induced by the switching at the motor wires.

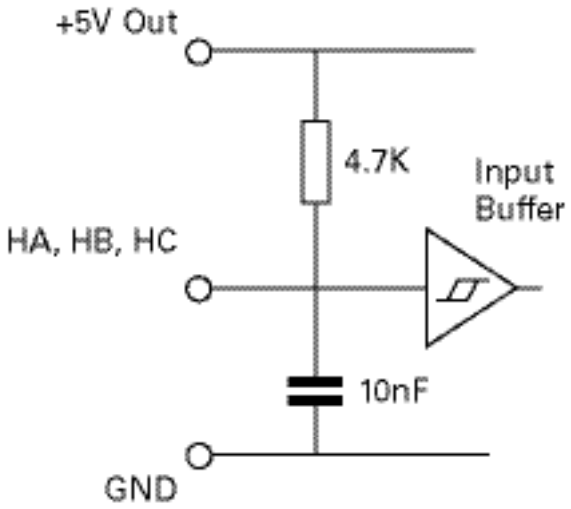


Figure 8-3. Hall sensor inputs equivalent circuit

Both 60 degrees and 120 degrees Hall sensors spacing, are supported (see "HPO" in the command reference section). Hall sensors can typically be powered over a wide voltage range. The controller supplies 5V for powering the Hall sensors.

Unless specified otherwise in the datasheet, Hall sensor connection to the controller is done using Molex Microfit 3.0 connectors. These high quality connectors provide a reliable connection and include a lock tab for secure operation. The connector pinout is shown in the controller model's datasheet.

Important Warning

Keep the Hall sensor wires away from the motor wires. High power PWM switching on the motor leads will induce spikes on the Hall sensor wires if located too close. On hub motors where the Hall sensor wires are inside the same cable as the motor power wires, separate the two sets of wires the nearest from the motor as possible.

Important Notice

Make sure that the motor sensors have a digital output with the signal either at 0 or at 1, as usually is the case. Sensors that output are slow changing analog signals will cause the motor to run imperfectly.

Hall Sensor Verification

The following query can be used to verify that the hall sensors are seen by the controller:

?HS

The reply is one or two numbers depending whether the controller is a single or dual channel. The values is between 0 and 7 with each bit representing the state of each of the HA, HB and HC sensors.

Turn the motor slowly by hand while sending frequent ?HS queries. Verify that all valid combinations appear at one time or the other and that none of the invalid combination ever show.

For 60 degrees spaced Hall sensors, 0-1- 3-4- 6-7 are valid combinations, while 2 and 5 are invalid combinations. For 120 degrees spaced sensors, 1-2- 3-4- 5-6 are valid combinations, while 0 and 7 are invalid combinations.

Note that HS query does not work on the first generation HBL and VBL family of products.

Hall Sensor Alignment and Wiring Order

It is very important that the hall sensors be precisely aligned vs the electromagnets inside the motor so that commutation be done exactly at the right time. Bad alignment will cause the motor to run inefficiently.

The order of the Hall sensors and these of the motor connections must match in order for the motor to spin. Unfortunately, there is no standard naming and ordering convention for brushless motors.

The Hall Sensor and Motor Phases naming convention used in Roboteq controllers is A, B and C for the sensors and U, V and W for the motor phases. When rotating the motor shaft clockwise by hand, the controllers expects the sensor A to be a mirror of the voltage generated between wires U and W, sensor B between V and U, sensor C between W and V. See figure 8-4. The sinewave voltage will be inverted when turning the motor in the opposite direction.

Alternatively, in order to synchronize the wiring order of the motor winding and the hall sensor wires, the HSM configuration command can be used (see "HSM" in the command reference section). For each hall sensor cable order and motor wire order, there are 6 combinations, one of which will make the motor spin smoothly and efficiently in both direction. Try each of the 6 available values of HSM (0-5) and retain the one that will make the motor spin in both directions while drawing the same low current.

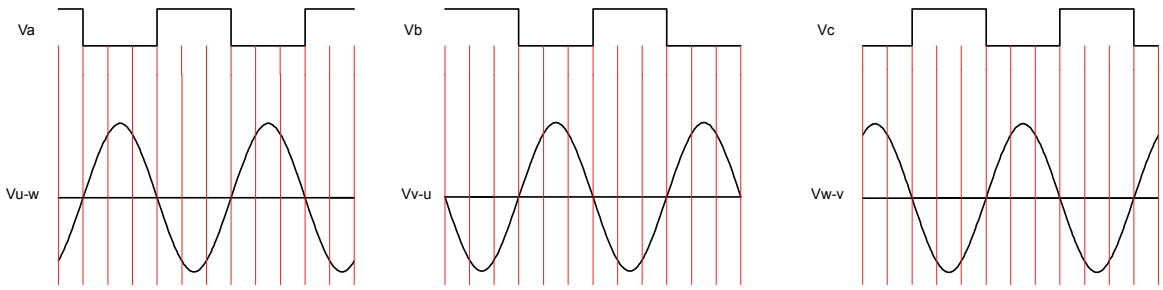


Figure 8-4. Relation between hall sensor and U V W windings

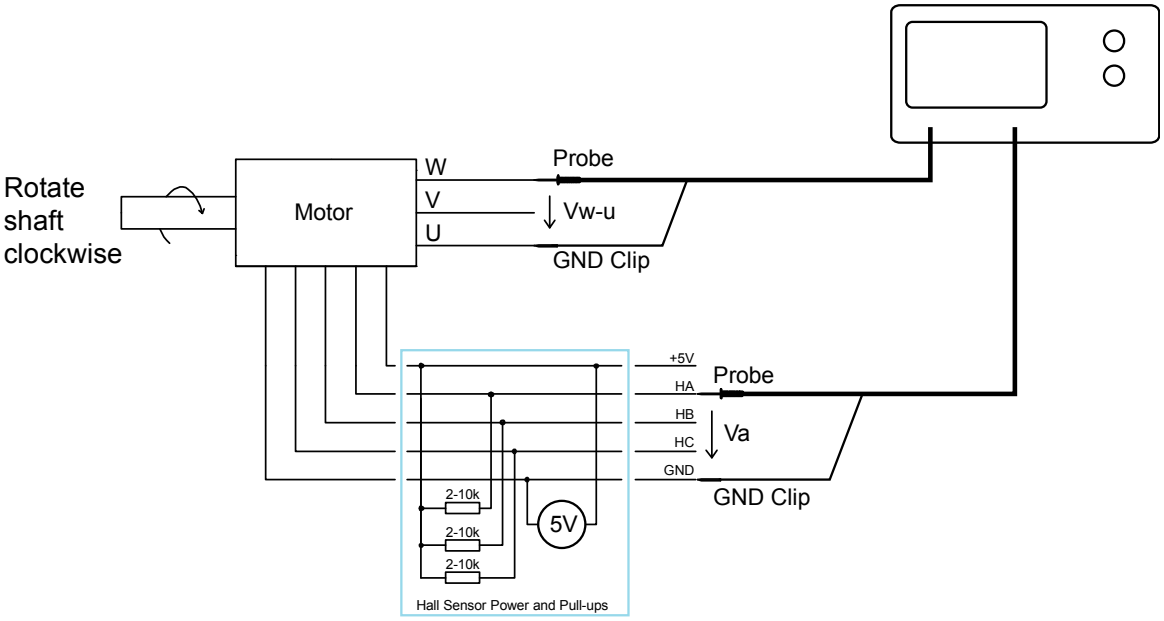


Figure 8-5. Use an oscilloscope and the circuit in figure to place the probes and generate these signals

Determining the Wiring Order Empirically

While probing with an oscilloscope gives the definite order, a simpler and quicker way may be to try all valid combination by trial and error. To do this, you can either connect the motor wires permanently and then try different combination of Hall sensor wiring, or you can connect the Hall sensors permanently and try different combinations of motor wiring. There is a total of 6 possible combinations of wiring three sensors on three controller inputs. There are also 6 possible combinations of wiring three motor wires on three controller outputs. Only one of the 6 combinations will work correctly and smoothly while allowing the controller to drive the motor in both directions.

The table below show the 6 possible combinations of connecting motor wires 1, 2 and 3 to the controller's U, V and W outputs.

Controller Output	Motor Wiring 1	Motor Wiring 2	Motor Wiring 3	Motor Wiring 4	Motor Wiring 5	Motor Wiring 6
U	1	1	2	2	3	3
V	2	3	1	3	1	2
W	3	2	3	1	2	1

Try the different combinations while applying a low amount of power (5 to 10%). Applying too high power may trigger the stall protection. Be careful not to have the motor output wires touch each other and create a short circuit. Once a combination that make the motor spin is found, increase the power level and verify that rotation is smooth, at very slow speed and at high speed and in both directions.

Important Notice

Beware that while only one combination is valid, there may be other combinations that will cause the motor to spin. When the motor spins with the wrong wiring combination, it will do so very inefficiently. Make sure that the motor spins equally smoothly in both directions. Try all 6 combinations and select the best.

Sensorless Trapezoidal Commutation

Some Roboteq controller models support sensorless trapezoidal commutation. As the name implies, the commutation is also made by applying current on two or the 3 motor wires in alternating manner. However, no hall or other sensor is used on the motor to tell the controller when to switch the phases. Instead, the rotor position is sensed by measure the motor's back EMF voltage on the one wire that is not energized at any one time (floating wire) during commutation. This technique is very effective and results in commutation characteristics and performance practically identical to switching using Hall sensors at medium and high speed.

Since it depends on the presence of back EMF – ie the voltage that is generated inside the motor windings as the rotor turns in the permanent magnets field – position can only be sensed if the rotor is spinning in the first place. The rotor position cannot be known when the motor is stopped or stalled. In Trapezoidal Sensorless, the motor is therefore started by applying an arbitrarily rotating field to the motor windings, making the rotor turn similarly to stepper motors. Once the motor has started to turn and achieve a speed sufficient to generate a detectable back EMF, the commutation is synchronized with the rotor position. For all practical purposes, therefore, Sensorless Trapezoidal is not usable in any system requiring precise control at slow speed, or high torque at stall or start.

Setting and Operating Trapezoidal Modes

Trapezoidal modes are selected via using the Switching Mode configuration menu in the Roborun PC utility, or by sending the configuration command.

^BMOD ch 0 for hall sensor commutation

^BMOD ch 2 for sensorless commutation

No other settings are necessary for the motor to run.

In the hall sensor mode, and if the sensor vs phase wiring is correct (see "Hall Sensor Alignment and Wiring Order" on page 95), motor will spin as soon as a power command is given.

In the sensorless mode the motor will spin regardless of the phase wiring order. If the motor spin in the opposite direction than the one desires, swap any two of the motor wires.

The number of poles setting is not necessary in order for the motor to run. The number of poles is only used to measure the motor's rotation speed. Enter a negative number of poles in order to change the speed polarity and count direction.

Sensorless Configuration and Calibration

The controller's default configuration will typically work with any motor. However, faster and more consistent motor startup will be achieved by performing these setup and calibration steps:

1. Make sure the battery volts and if possible the maximum load on the motor is set. If either changes the procedure will need to be repeated.
2. Configure motor channels as sensorless.
3. Set motor command 10 or -10 and check if the motor starts and rotates smoothly when using the default setting. If not modify Sensorless Start-Up Power (SSP) accordingly. Higher the motor friction, the higher the value of SSP should be.
4. Type on console %clmod 4 (for channels 1). This will cause the controller to enter the sensorless calibration mode.
5. Set Motor Command 10 or -10 and wait until the rotation of the motor becomes smooth and stable.
6. Wait for a couple of seconds and stop the motor.
7. Monitor the Hall Speed with motor command 10 and -10. Make sure the speed is the same in both directions symmetrical. If not then choose as last the motor command which gives the smallest speed.
8. Type on console %clmod 0 to exit the calibration mode
9. Type on console %eesav, in order to save the value on flash.

Startup should be quicker and more efficient after these steps. Calibration values can be viewed, and manually adjusted if needed, using the SST configuration.

Sensorless brushless motors only require their 3 wires to be connected to the controller's U, V and W terminals. The wires can be connected in any order. If the motor spins in the opposite direction than the desired one, simply invert any two motor wires. It is also possible to use the MDIR Motor Direction configuration parameter.

Verifying Commutation Timing

In trapezoidal modes, with an oscilloscope it is possible to verify that the commutation, either in Hall sensors or sensorless mode, is happening at the optimal time. On a motor driven by the motor controller, place a probe between ground and any of the motor phases. Verify that the voltage looks like the shape on the figure 8-6. Look for symmetrical ramps on the left and right.

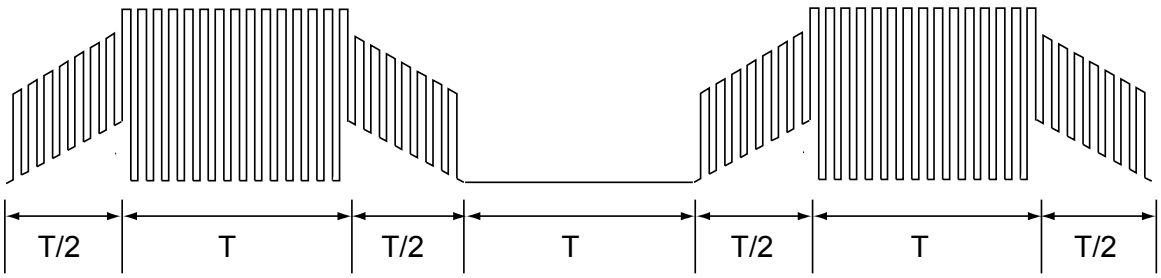


Figure 8-6. Ground to Phase voltage waveform on motor with correct commutation

An alternate method is to run the motor in the forward and then in the reverse direction. Verify that for a give command level in open loop, the motor reaches the identical speed and consumes the same amount of current.

Sinusoidal Commutation

In sinusoidal commutation, all three wires are permanently energized with a sinusoidal current that is 120 degrees apart on each phase as shown in figure 8-7.

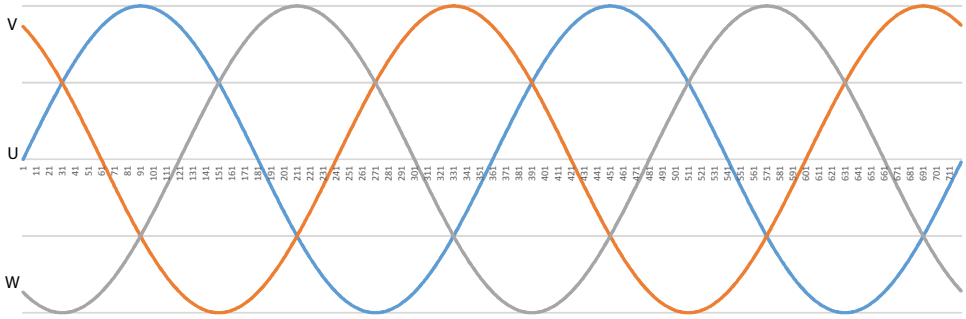


Figure 8-7. 3 phase current

As the motor turns, the phase on each wire is changed in order for the magnetic field to always be perpendicular, and therefore create the maximum radial force to the rotor.

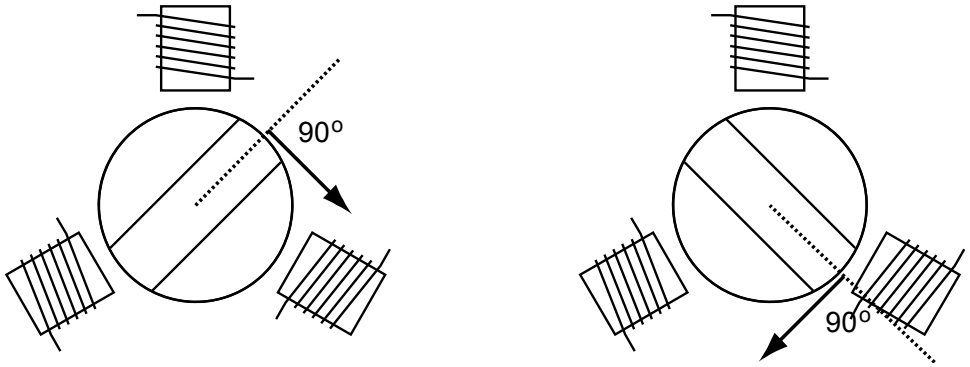


Figure 8-8. Magnetic field perpendicular to rotor magnets

The principle benefit of sinusoidal commutation is the quiet, rumble-free, motor operation resulting from the smoothly rotating and always aligned magnetic field.

Wiring Order

The angle sensing direction must match the rotating direction of the magnetic field generated by the UVW coils. If the motor does not spin and the sensors are correctly attached and calibrated, either change the SWD configuration command (see "SWD" in the command reference section), or swap to motor wires. Note that is will typically be necessary to adjust the angle sensor's 0 degree reference.

Angle Feedback Sensors

In order for the proper voltage and phase to be applied to each of the 3 motor wires, the rotor angular position must be known with precision at all times. Roboteq controllers support several techniques to achieve this.

Important Notice

The number of poles is a very important configuration parameter in sinusoidal mode. Using the wrong value will produce erratic behavior and possibly damage.

Incremental Encoder Feedback

A quadrature encoder can be used to determine the rotor position. Since encoders do not give an absolute position, a reference search sequence is necessary before any power is applied to the motor. The controller will automatically perform this search by applying a fixed amount of power between the U and V outputs to pull the rotor to the known positions. This reference search is done at power up or whenever the mode is switched to Sinusoidal with Encoder feedback. The search can also be initiated from the serial port or from a MicroBasic script. See below.

Optimally, the encoder should have a PPR that is at least 128 x the number of pole pairs. For example a motor with 4 pole pairs should have a 128 x 4 = 512 Pulse per revolution. This will result in 2048 counts for a full turn of the rotor, and therefore the electrical angle to be measured with 360 / 2048 * 4 = 0.7 degrees, resulting in a very smooth changing sinusoidal drive to the motor. A significantly lower resolution encoder will results in a stepping sinusoid. A higher resolution encoder will not improve the waveform.

Hall + Encoder Feedback

If the motor is fitted with Hall sensors and an Incremental Encoder, the controller can be configured to use both sensors together. In this mode, the operating mode is identical to when an Encoder alone is used for feedback, except that there is no need for the reference search sequence described above. When first energized, the motor will operate using the Hall sensor until the first change to the Hall pattern is detected. This will set the angle reference for the encoder. For this mode, it is critical that both the number of Encoder PPRs and the motor number of pole pairs be entered correctly. Both counters must count in the same direction.

Sinusoidal with Hall Sensor Feedback

In this mode, the Hall sensors are used to determine the angular position of the rotor. Since transitions of the Hall pattern occur at every 60 degrees only, the controller will estimate the current angle by interpolating in between two transition based on the current motor speed. This technique works well as long as speed is stable and changes are relatively slow. It also requires that the magnets and sensors are positioned with precision inside the motor, which is not always the case in low cost motors. Compared to Trapezoidal mode, this mode will result is quieter motor operation because of the sinusoidal commutation.

Sine/Cosine Analog Sensor Feedback

Some controller models can be interfaced to absolute position sensors with sine/cosine output. These sensors are usually made using Hall technology, or resolvers, and are built into the motor. They provide two analog voltage output that are 90 degrees apart. The angle is determined by measuring the voltage ratio between the two signals. The controller can compensate for differences in amplitudes between the two signals. Sin/cos sensors require a one-time setup and calibration.

Important Notice

Electrical noise on the sensor output will cause wrong angle readings. Shield the wires and keep them as far as possible from the motor wires. If noise persists, add

a 0.1uF ceramic capacitor between the input pin and ground pin on the controller's connector

Synchro Resolver Sensor Feedback

Synchro Resolvers are a form of Sine/Cosine sensor based on transformer technology. It is composed of a fixed primary coil, and two secondary coils that rotate with the rotor. The two secondaries are 90o from each other. A fixed frequency excitation voltage is fed in the primary. As the secondary coils turn, and take turn being parallel with the fixed primary, the voltage amplitude induced in each varies as shown in the figure below.

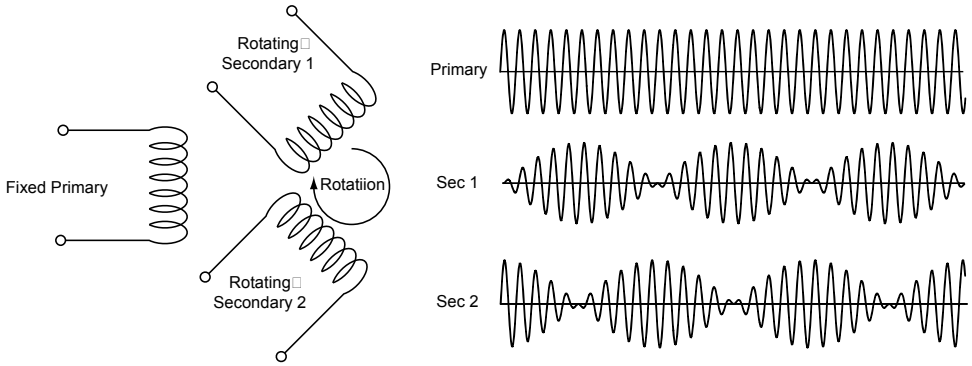


Figure 8-9. Resolver equivalent diagram and signals

Controllers models supporting resolvers use one outputs to generate the excitation. The secondaries are then fed to two analog inputs. Exact wiring depends on the controller model. Please consult datasheet or contact Roboteq. Resolvers require one time calibrations similar to these for the sin/cos sensors.

Digital Absolute Encoder (SPI) Feedback

Some advanced motors, like these made by Micromotor, incorporate an absolute position sensor with a high speed serial interface based on the SPI protocol. Controllers supporting SPI encoders with 12-bit resolution. SPI encoders give the angle's absolute position. Nevertheless, a calibration of the zero-angle reference must be done once in order to capture the mechanical offset of the sensor vs the actual 0 degrees position. See "Sinusoidal Zero-Angle Reference Search Process" on page 104

Sinusoidal Configurations and Calibrations

Sinusoidal mode is selected via the Switching Mode configuration menu in the Roborun PC utility, or by sending the configuration command:

^BMOD ch 1

Then must be selected the method for capturing the angle of the rotor and the motor spins. This is done using the Sinusoidal Angle Sensor configuration menu in the utility, or by sending the command:

^BFBK ch mode

Where mode:

0: Encoder

1: Hall

2: Hall+Encoder

3: SPI Sensor

4: Sin/Cos Sensor

5: Resolver

Each mode requires a various amount of additional setup and/or calibration as described in the following sections.

In sinusoidal mode, on some models the controller automatically operates in Field Oriented Control mode (see "Field Oriented Control (FOC)" on page 108) and requires additional settings for this.

Setup and Test Encoder Feedback Mode

Since Incremental Encoders do not give and absolute position, a reference search must be done every time the controller is powered up. This search is done by the controller under these conditions:

- Automatically, every time after power up
- When the controller switched from a different mode to sinusoidal mode with encoder feedback
- By sending the !BND ch command from the serial port or from a script

To do the reference search, the controller will energize the motor phases in a predetermined sequence in order to force the rotor to known positions. The details of this process is described in "Sinusoidal Zero-Angle Reference Search Process" on page 104.

Important Notice

The number of motor poles and encoder PPR are critical parameter for the encoder feedback mode to work. Make sure that these are correctly loaded in the configuration.

Before trusting that reference search will be successful at every power up, try repeatedly to send the manual bind (!BND) command from different starting position of the motor, under real-life load conditions. After reference search is completed, verify that the motor turns with the same efficiency in the forward and reverse direction.

Setup and Test Hall Encoder Feedback Mode

The Hall Encoder mode requires no calibration or special setup. Verify only that the correct number of poles and encoder PPR are loaded in the configuration.

The hall sensors and encoder must be wired so that their respective counter count in the same direction. To verify this, turn the motor by hand or run it in Trapezoidal mode with Hall sensor feedback. Observe the count directions in the PC utility.

Important Notice

The number of motor poles and encoder PPR are critical parameter for the Hall-Encoder feedback mode to work. Make sure that these are correctly loaded in the configuration.

Setup and Test the SPI Encoder Feedback Mode

SPI encoders give an absolute angle in digital form, serially to the controller. These sensors can be trusted to give an accurate angle measurement. However, they typically are not perfectly mechanically aligned with the motor's zero degree reference. Therefore a one-time reference calibration must be performed.

After enabling the Sinusoidal Mode and SPI Angle Feedback, verify first that the Hall Counter (which is shared in this case with the SPI sensor), displays a stable number that is different from zero. This will indicate that data is output from the sensor and captured by the controller. Rotate the motor by hand to verify that the counter changes.

Typically, SPI encoders are single pole, meaning that they give the angle value within one full mechanical turn. A multiple pole sensor would measure multiple full 360 degrees for every mechanical cycles. The number of sensor poles is a critical configuration parameter which must be set using the Sensor Poles menu. It can also be set from the console or serial port with

^SPOL ch poles

Setup and Test the Sin/Cos Encoder Feedback Mode

Sin/Cos encoders are absolute devices. A one-time setup and calibration must be performed in order to calibrate the encoder's voltage levels, and set the mechanical zero degree angle offset.

The first calibration step measures and stores the minimum and maximum voltages of the encoder's signals at of each of the controller's inputs:

After the controller is configured in Sinusoidal mode with Sin/Cos Feedback, from the console, type:

%CLMOD 2 for motor channel 1
%CLMOD 3 for motor channel 2

This will cause the controller to enter the calibration mode. Move the shaft of the motor slowly by hand in order to make a couple of full mechanical turns.

Then press %CLMOD 0 (for either motor channels) in order to get out of the calibration mode.

Pressing the command ~ZSMC you can see the calibration values (3 first values for motor 1 and the other 3 for motor 2). Verify that the values are different than 0.

In order to save the calibration values permanently to flash type

%CLSAV 321654987.

You can verify that the sensor works, enable the Angle capture in the Roborun chart. Then move the shaft by hand and verify that the reported angle smoothly ramps from 0 to 511 (512 = 360 electrical degrees). For additional help, you can verify that the sensor signals are received by the controller. Move the motor shaft by hand and check the sin/cos raw

values using ASI query. Verify that these value do change as the shaft is turned and that have a difference between the min and max values of at least 1000.

Once the sensor is verified to be working, a one-time calibration must be performed to captures the mechanical offset of the sensor. In most cases, a small difference exists between the 0 degrees from the sensor vs the actual 0 degrees of the motor. Verify that the motor shaft is rotating freely. Then perform a Zero Angle reference search.

Single Pole vs Multi Pole Sin/Cos sensors

Some sin/cos sensors will produce a full 360 degrees output for each full 360 mechanical turns. These are single pole sensors. Other sensors have multiple poles, meaning that the sine or cosine signal will perform two or more full 360 degrees cycles for every mechanical cycles. The number of sensor poles is a critical configuration parameter which must be set using the Sensor Poles menu. It can also be set from the console or serial port with

^SPOL ch poles

You can determine the number of sensor poles by following these steps:

1 After calibrating the sensor, set Motor Poles to 1 (^BPOL 1 1) and the Set Sensor Poles to 1 (^spol 1 1).

2 Make one full rotation of the motor shaft by hand and monitor Angle in Roborun Utility.

3 Check how many times the Angle range (0-511) rolls over. This gives the number of sensor poles.

4 Restore the correct values of motor and sensor poles

Sinusoidal Zero-Angle Reference Search Process

Most angle sensors will not give an accurate absolute position of the rotor. Incremental encoder give relative position by their nature and must be set with a reference angle at every power up.

Absolute sensors like SPI, resolvers or Sin/Cos are not always mounted with a precise zero-degree reference and must be calibrated at least once.

A reference search can be initiated manually by sending the serial command:

!BND 1 for channel 1
!BND 2 for channel 2

The controller will then respond by energizing the U, V and W coils with the voltages levels needed to force the rotor to move to predetermined positions. The sequence is +90, -90, +90, -90, +90 and back to -90 electrical degrees. The reference search is considered a success if the rotor correctly reached the last four end position.

For the reference search to work, the motor must be free to move at least a full electrical turn (mechanical turn divided by the number of pole pairs). If a brake is present, it must be disengaged during the search sequence.

The amount of current (ie torque) that the controller will apply to the motor for the search is set in the Reference Seek Power menu of the configuration utility, or the serial command:

^BZPW ch Amps*10

After each !BND command, if the process was successful, the response will be:

BND +

BADJ = nn **Will only return BADJ when using SPI, SSI, SinCos or resolver*

The number in BADJ represents the angle adjustment that has been detected and that must be saved in Flash for future operation

If the process was not successful, the response will be:

BND –

Followed or not by

BADJ=nn

If no BADJ value is displayed, this means that the sensor inputs are very noisy and no value could be captured.

If a BADJ value is displayed, it should not be accepted as entirely correct. You should try the !BND command again and/or adjust play manually with the BADJ value in order to have the optimal performance.

When the !BND fails and BND- is replied, the Bind Error LED will appear in red in the Run screen of the PC utility. The motor will then not be energized if a command is sent.

The BND fault flag is cleared when setting the BADJ manually or reading the BADJ value with the following commands, respectively:

^BADJ mm nn

~BADJ

Verify then that in open loop, the motor spins at the same speed in the forward or reverse direction when the same command is given with different signs. If the motor rotates at different speeds and/or draws a significantly different amount of current in each direction, the zero degree reference was not captured correctly.

Multi-poles Motor Considerations

On multi-poles motor there will be several locations around the full mechanical revolution where the rotor will settle during the reference search. Figure 8-10 below shows an example of a 2 poles pairs motor.

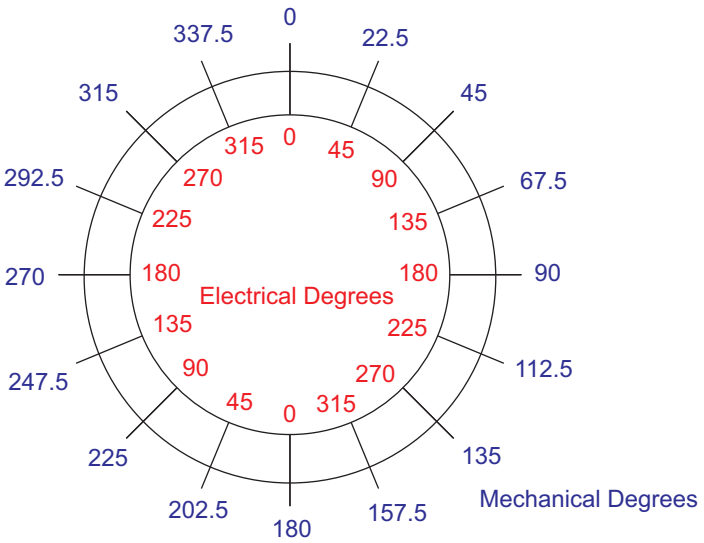


Figure 8-10. Mechanical vs electrical degrees

The reference search will settle on a given electrical angle location. This electrical angle value exists in 2 mechanical location on this motor. After performing a first search, rotate the motor shaft and repeat the search. On a perfectly constructed motor, the search will settle at the same electrical angle on any of the other poles. In practice, it is expected that the values will be off by one or two degrees from one pole to another. If the value is consistent from one measurement to another, and difference is larger a few degrees, this means the poles are not placed with precision in the motor and the motor will not run efficiently. If the difference is very large (20 degrees or more), it is likely that the angle sensor is not working correctly or that the number of poles of the motor and/or sensor are not configured correctly.

Important Notice

If the motor is loaded or if there is a lot of friction, the rotor may not be able to reach the zero angle during the zero-position search. The motor should not be operated unless it has.

When the zero degree search is done for capturing the offset of absolute sensors (e.g. sin/cos, resolver or SPI), the angle that is measured by the reference search can be viewed with the console command

~BADJ ch

The reported values is 0 for 0 degrees and 512 for 360 degrees.

Perform the !BND several times in a row and verify that the same value is captured every time.

Save the offset value permanently to memory with the command

%CLSAV 321654987

This step is only necessary for absolute sensor and must be performed only once.

Important Warning

In version 1.5 and lower of the firmware, the Zero Adjust Offset was stored in the configuration flash. The value will be lost, and a new calibration must be performed when installing version 1.6 of the firmware. In version 1.6 and newer, the value is stored in a dedicated section of Flash and will not be lost after firmware updates.

Operating Brushless Motors

Once the Hall sensors, motor power wires, and/or the Encoder are correctly connected to the controller, a brushless motor can be operated exactly like a DC motor and all other sections in this manual are applicable. In addition, the Hall sensors or encoders, provide extra information about the motor's state compared to DC motors. This information enables the additional features discussed below.

Stall Detection

The Hall sensors and the encoders can be used to detect whether the motor is spinning or not. The controller includes a safety feature that will stop the motor power if no rotation is detected while a given amount of power is applied for a certain time. Three combinations of power and time are available:

- 250ms at 10% power
- 500ms at 25% power
- 1s at 50% power

If the power applied is higher than the selected value and no motion is detected for the corresponding amount of time, the power to the motor is cut until the motor command is returned to 0. This function is controlled by the BLSTD - Brushless Stall Detection parameter (see "BLSTD - Brushless Stall Detection" in Command Reference section). Do not disable the stall protection.

A stall condition is indicated with the "Stall" LED on the Roborun PC utility screen.

In Trapezoidal modes using Hall sensors, the Stall detection looks for changes at any of the Hall sensors inputs. In Sinusoidal modes, the detection uses the speed measurement from the encoders.

Important Notice

In close loop modes, it is quite possible to have the motor stopped while power is applied to them. That could happen while stopped uphill, for example. Select the appropriate triggering level for your application

Speed Measurement using the angle feedback Sensors

Information from Hall, SPI, sin/cos sensors, (and even Sensorless) is used by the controller to compute the motor's rotation speed.

When Hall sensors are used, speed is determined by measuring the time between Hall sensor transitions. This measurement method is very accurate, but requires that the motor be well constructed and that the placement between sensors be accurate. On preci-

sion motors, this results in a stable speed being reported. On less elaborate motors, such as low-cost hub motors, the reported speed may oscillate by a few percent.

Speed measurement is very precise with digital absolute sensors (SPI). Sin/Cos sensors operating without noise also give a very precise value.

The motor's number of poles must be entered as a controller parameter in order to produce an accurate RPM value. See discussion above. The speed information can then be used as feedback in a closed loop system. Motor with a more precise Hall sensor positioning will work better in such a configuration than less precise motors.

If the reported speed is negative when the slider is moved in the positive direction, you can correct this by putting a negative number of poles in the motor configuration. This will be necessary in order to operate the motor in closed loop speed mode using hall sensor speed capture.

Distance Measurement using Hall, SPI or other Sensors

When Hall sensors are used, the controller automatically detects the direction of rotation, keeps track of the number of Hall sensor transition and updates a 32-bit up/down counter. The number of counts per revolution is computed as follows:

Counts per Revolution = Number of Poles * 6

With SPI or Sin/Cos sensors, the controller accumulates the angle data to recreate an accurate and high resolution 32-bit counter. For these sensors, the number of counts per revolution is:

Counts per Revolution = Number of Poles * 512

The counter information can then be read via the Serial/USB port, CAN bus, or can be used from a MicroBasic script. The counter can also be used to operate the brushless motor in a Closed Loop Position mode, within some limits.

Field Oriented Control (FOC)

In sinusoidal modes, using the rotor angle to determine the voltage to apply to each of the 3 motor phase works well at low frequencies, and therefore at low rotation speed. At higher speed, the effect of the winding inductance, back EMF and other effect from the motor rotation, create a shifting current. The resulting magnetic field is then no longer optimally perpendicular to the rotor's permanent magnets.

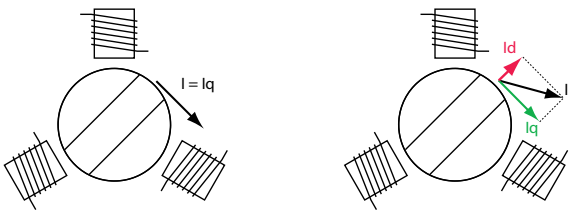


Figure 8-10. Perpendicular and non-perpendicular fields

As can be seen in figure 8-10, when the magnetic field is at an angle other than exactly perpendicular to the rotor's magnets, the rotor is pulled by a force that can be decomposed in two forces:

Lateral force causing torque, and therefore rotation. This force results from the from the Quadrature current Iq, which is also called Torque current

Parallel force that pulls the rotor outwards, creating no motion. This force results from the Direct Current Id, which is also called Flux current

Field Oriented Control is a technique that measures the useful Torque current and wasted Flux current component of the motor current. It then automatically adjust the power and phase applied to each motor wire in order to eliminate the wasted Flux current

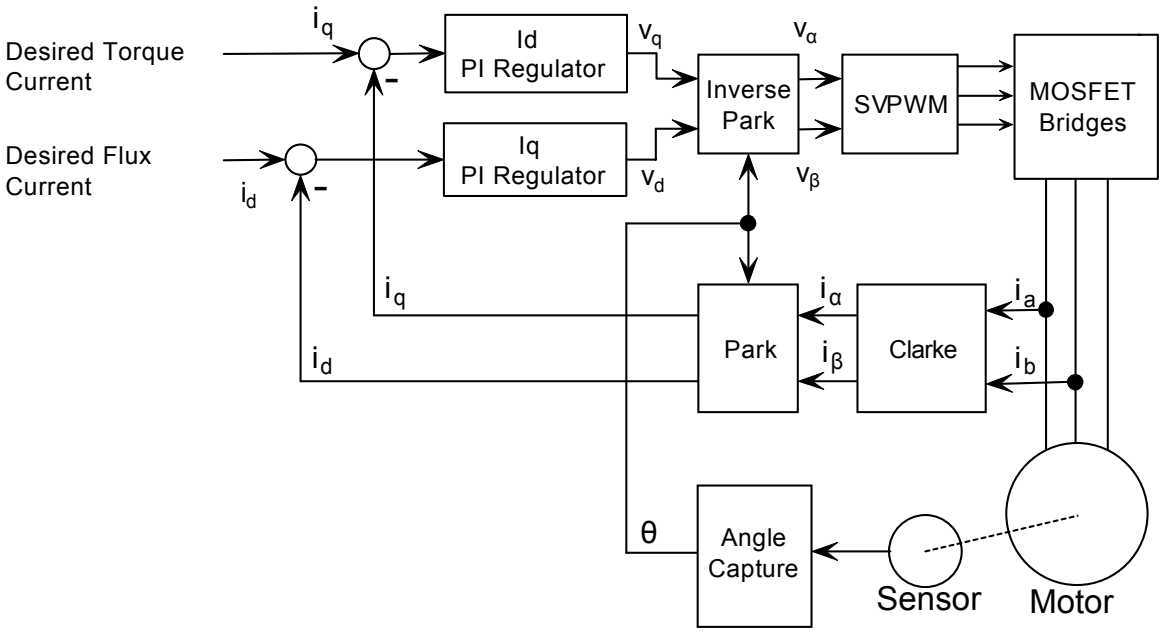


Figure 8-11. FOC operation

Field Oriented Control is available on selected models of Roboteq motor controllers. It is uses a classical implementation as described in the figure 8-11. The current in the motor phase is captured, along with the rotor's angle. From this are computed the useful Iq and wasteful Iq. Two Proportional-Integral (PI) regulators then work to control the power output so that the desired Torque (Iq) and Flux (Id) currents are met. The desired Flux current is typically set to 0, and so the regulator will work to totally eliminate the Flux current.

Both PI regulator have user-settable gains. While the factory default gains are suitable for most motors and applications, they can be modified with the FOC Parameters in the PC utility. They can also be changed with the console command:

For single Channel Controllers:

^KPF 1 nn = Proportional Gain for Channel 1 Flux
^KPF 2 nn = Proportional Gain for Channel 1 Torque

^KIF 1 nn = Integral Gain for Channel 1 Flux
^KIF 2 nn = Integral Gain for Channel 1 Torque

For dual Channel Controllers:

^KPF 1 nn = Proportional Gain for Channel 1 Flux
^KPF 2 nn = Proportional Gain for Channel 2 Flux
^KPF 3 nn = Proportional Gain for Channel 1 Torque
^KPF 4 nn = Proportional Gain for Channel 2 Torque

^KIF 1 nn = Integral Gain for Channel 1 Flux
^KIF 2 nn = Integral Gain for Channel 2 Flux
^KIF 3 nn = Integral Gain for Channel 1 Torque
^KIF 4 nn = Integral Gain for Channel 2 Torque

FOC Testing and Troubleshooting

In order to make sure that FOC is operating correctly, monitor values with the PC Utility:

- Motor Amps
- FOC Flux Amps
- FOC Torque Amps
- FOC Angle Correction

The indication of good performance are the following:

- FOC Quadrature Amps are close to 0.
- Motor Amps and FOC Torque Amps values are close.
- FOC Angle Correction is stable for stable motor Power.

Check also when changing motor power how fast FOC Flux Amps is corrected to zero. Tune FOC PI as necessary.

Field Weakening

Field weakening is a technique that is used to achieve faster motor rotation speed. This is done by having some Flux (Id) current, even though this also introduces some waste. Field Weakening is therefore possible on Roboteq controller by loading a non-zero setpoint for the Flux current. This can be done from the console, the serial port, or from a MicroBasic script with the command:

^TID ch Amps*10

The amount of Flux current should be different at low and high speed, typically starting with zero, and increasing after a given RPM threshold is reached. Below is an example of a MicroBasic script that changes the Flux setpoint according to such a rule

```
top:
Speed = abs(getvalue(_S, 1)) ' Read motor speed from Encoders
if (Speed > 5000) ' check if above 5000 RPM
FluxSetpoint = (Speed - 5000) / 100 ' 1A per 100 RPM above 5000
else
FluxSetpoint = 0 ' No Flux current below 5000 RPM
end if

if (FluxSetpoint > 100) then FluxSetpoint = 100 ' Cap to 10.0 Amps

setconfig(_TID, 1, FluxSetpoint) ' Apply Flux setpoint
wait(10)
goto top ' repeat every 10ms
```

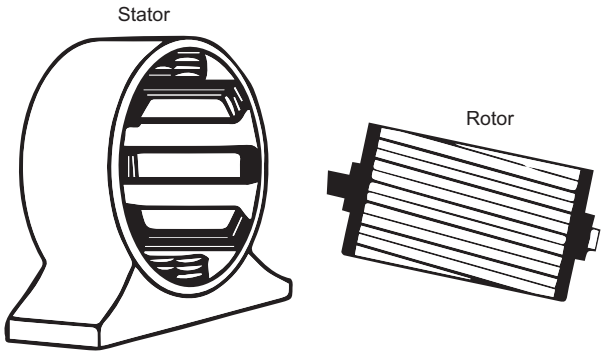
SECTION 9

AC Induction MotorOperation

This section discusses the controller's operating features and options when using three phase AC Induction motors.

Introduction to AC Induction Motors

Three phase induction motors are the most common types of electrical motors. They have a very simple construction composed of a stator covered with electromagnets, and a rotor composed of conductors shorted at each end, arranged as a "squirrel cage". They work on the principle of induction where a rotating electro-magnetic field it created by applying a three-phase current at the stators electromagnets. This in turn induces a current inside the rotor's conductors, which in turns produces rotor's magnetic field that tries to follow stator's magnetic field, pulling the rotor into rotation.



Benefits of AC Induction Motors are:

- Induction motors are simple and rugged in construction. They are more robust and can operate in any environmental condition.
- Induction motors are cheaper in cost due to simple rotor construction, absence of brushes, commutators, and slip rings

- They are maintenance free motors unlike dc motors due to the absence of brushes, commutators and slip rings.
- Induction motors can be operated in polluted and explosive environments as they do not have brushes which can cause sparks

Asynchronous Rotation and Slip

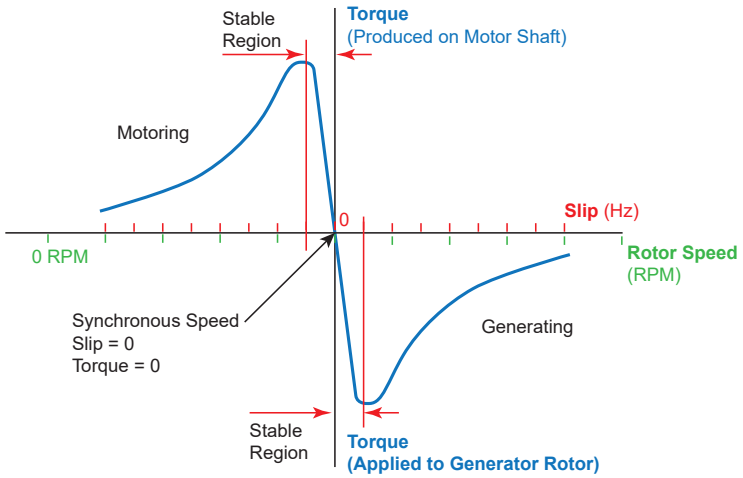
AC Induction motors are Asynchronous Machines meaning that the rotor does not turn at the exact same speed as the stator's rotating magnetic field. Some difference in the rotor and stator speed is necessary in order to create the induction into the rotor. The difference between the two is called the slip.

Slip is measured in Hertz. It is the difference of the frequency generated by the controller, and the rotor's frequency, as determined by the formula

f = ((RPM / 60) * NumberOfPoles)

Optimal slip varies from motor to motor and is in the range of typically 2 to 10Hz.

As seen from the figure below, when the slip is 0, i.e. the rotor turns at exactly the same speed as the stator field, torque totally disappears. Within the stable operating region, the Torque is proportional to the Slip. The torque and motor efficiency then quickly drops when the slip grows past its optimal value.



The main task of the motor controller is to generate a rotating magnetic field whose frequency and strength is such that the rotor will operate within the motor's optimal slip range. Three techniques are supported by Roboteq for a achieving this:

Scalar, Volts per Hertz (VPH)

Constant Slip

Field Oriented Control

Each of these techniques, benefits and limitations are described in following sections

Connecting the Motor

An AC Induction motors has just 3 power wires which must be connected to the controller's U V and W terminals. The connection order is not important. However, swapping any two motor connections will make the motor turn in the opposite direction.

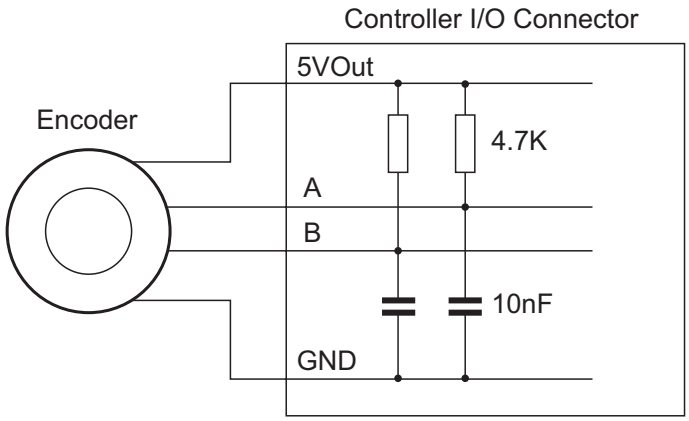
Selecting and Connecting the Encoder

A speed sensor must be used to measure and control the motor's slip when running in Constant Slip mode and Torque/Speed FOC mode. This is done using an incremental encoder. Most AC induction motors come with a built-in quadrature encoder. These encoders typically have a relatively low number of counts. 32 or 64 Pulses Per Revolution (PPR) rotation are typical values. A low count encoder results in low frequency pulses.

When using encoders up to 128 Pulses Per Revolution, the controller evaluates the rotation speed by measuring the time between encoder pulses. This results in a measurement with a resolution of 0.1Hz even at full speed.

When using encoders with higher PPR, speed is measured by counting the number of encoder signal transitions over a 10ms period. Prefer therefore a high-count encoder of around 1000 PPR for better speed measurement resolution.

Unless otherwise noted in the product's datasheet, all Roboteq's AC Induction Motor Controllers have pull up resistors that can connect to open collector encoder outputs. Controllers also have capacitors to help filter out any electrical noises that contribute to fake encoder readings.



Testing the Encoder

To test the encoder, use the PC utility to enable the encoder and set its number of Pulses Per Revolution (PPR). Go to the Utility's Run tab, enable the Encoder Count in the chart. Make a full turn of the motor shaft by hand. Verify that the counter has changed by the number of PPR * 4.

Prior to enabling Constant Slip or FOC Modes, operate the motor in open loop Volts per Hertz mode with slip control disabled. To disable slip control, set the encoder as No Action in the configuration menu.

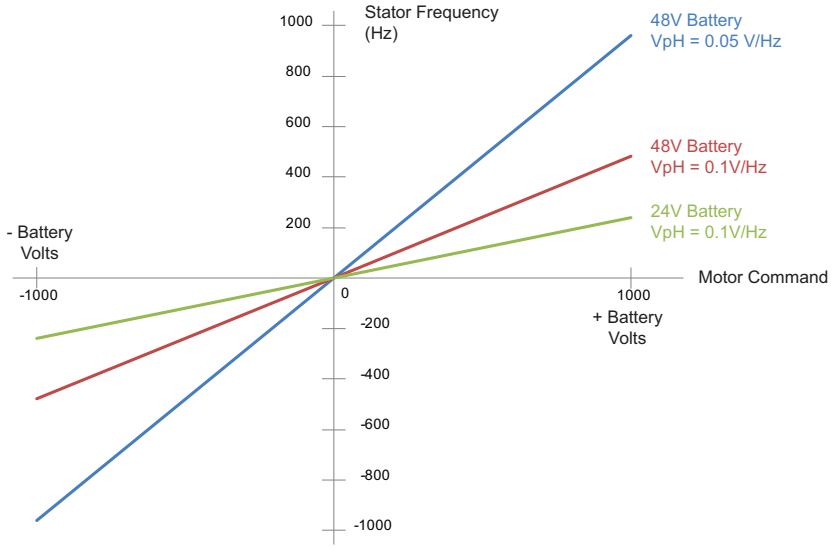
Apply a positive motor command. Verify that the motor shaft is moving in the desired direction. If the motor moves in the opposite direction, swap any two of the three motor cables.

If the motor moved in the desired direction, then verify that the encoder counter increments when a positive motor command is applied. If the counter decrements, then either swap the A and B encoder wires, or enter a negative number of PPRs in the encoder configuration.

Open Loop Variable Frequency Drive Operation

In its simplest operating mode, the controller will output to the motor a three-phase sinusoid whose voltage and frequency change together at a fixed ratio. This mode is called Scalar because of the fixed ratio between the Voltage and Frequency that is applied to the motor.

The ratio is set by the VPH - Volts Per Hertz configuration parameter.



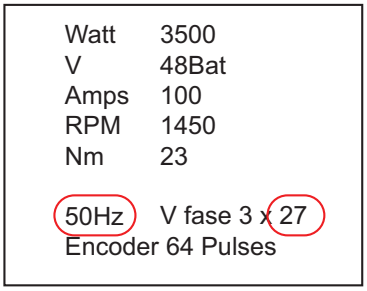
The figure above shows example of the resulting stator frequency for a given motor command. In open loop mode, Motor commands range from -1000 to +1000 and result in the output voltage to range between -VBat to +VBat respectively

As long as the motor is not overloaded, the rotor RPM will be

((Stator Frequency - Slip) / Number of Pole Pairs) * 60

Figuring the Motor's Volts per Hertz

Each motor has a value for the optimal Volts per Hertz ratio. It can be determined by the operating frequency and rated voltage written of the motor's label. The figure below shows values from a real motor.



For this motor, the VPH can be determined by dividing the 27 Volts per phase by the 50Hz frequency. In this case 0.54 Volts per Hertz.

Note that this value is for the optimal torque as rated on the label. If the load is a lot lighter, the VpH will be too high and result in excessive current consumption. If the load is a lot heavier, the VpH will be too low and the motor will not be able to drive it. The VpH will therefore need to be different than this computed based on actual load conditions. Always first monitor the motor consumption at no load. Adjust the VpH to a lower value if the no load current appears too high.

Maintaining Slip within Safe Range

Open Loop, or Scalar, mode does not require encoders for its operation. If the load is known to always be within the motor's max torque, the motor can be trusted to always be able to drive it. In this case, an encoder does not need to be connected. If an encoder is connected - to measure and report speed, for example - then it must be configured as "No Action" in the PC Utility.

For added safety, however, an encoder can be installed and enabled to measure the rotor's speed, and therefore the slip, in real-time. When the encoder is enabled and configured as "Feedback", the controller will lower the voltage and frequency if the slip exceeds twice the value stored in the Optimal Slip configuration.

Prior to enabling the encoder as Feedback, verify that the encoder count direction has the same polarity as the motor command.

Closed Loop Speed Mode with Constant Slip Control

In this mode, the controller will automatically adjust the voltage and frequency in order to reach and maintain a desired speed, even as the load is changing, while operating within the optimal slip range.

To configure this mode, first set the controller in open loop mode as described in the previous section. Verify that the encoder is working and is counting with the correct polarity.

Once the encoder is verified to work and the motor spins in open loop, follow these steps. Using the Roborun PC utility:

- Select Close Loop Constant Slip Mode

- Set the PID gains found in the Motor Output, Closed Loop Speed Parameters menus (do not use the FOC PID gains). Try first with gains of P=4, I=0.5, D=0. These values will produce adequate results in most cases. Additional turning may be needed.
- Set the Max RPM configuration to the speed that must be reached at full throttle (ie when command = 1000). Make sure to enter a value that is within the physical reach of the motor under the expected maximum load condition.
- Enter the lowest acceleration rate that is acceptable for the application. Rapid changes will create current surges and should therefore not be allowed to be higher than necessary.
- Save the settings to the controller.

The motor speed can now be set to be any value between 0 and plus/minus the maximum RPM configured above when sending a command ranging from -1000 to +1000 using the serial, analog or pulse inputs.

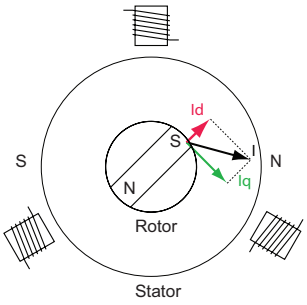
The motor speed can also be set to an absolute RPM value by sending the S (Speed) command via serial, USB, CAN or Scripting.

When exercising the motor with the PC utility, monitor the Slip, the Rotor RPM, Stator RPM and the Motor Amps. The Rotor RPM can be viewed in the Encoder RPM chart. The Stator RPM can be viewed in the Hall RPM chart.

The slip will stabilize at of the Optimal Slip setting.

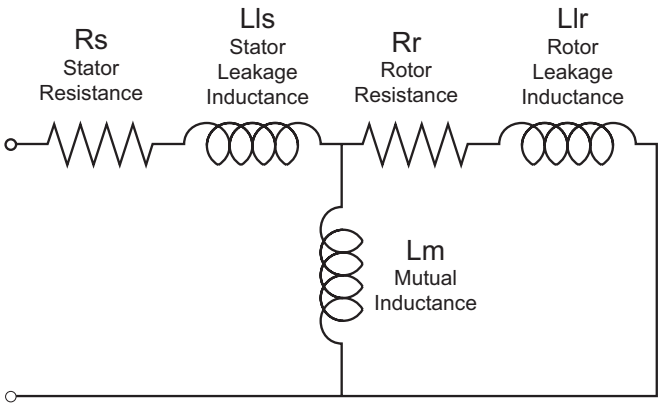
Field Oriented Control (FOC) mode Operation

Field Oriented Control (or Vector Drive) is a technique by which the magnetic field generated in the stator is adjusted in relation to the field induced in the rotor in a manner to generate optimal torque at all times and all load conditions.



Optimal rotation occurs when the magnetic field induced in the rotor is perpendicular with this of stator. Practically the fields the two fields are never exactly perpendicular. As shown on the diagram above, the angled field I is made of an outward pulling flux field (Id) and perpendicular pulling torque field. The torque field is the one that causes the rotation and that the controller will maximize. Flux field is not causing any rotation and therefore must be minimized. Some flux is necessary at all times, however, in order to create the induction in the rotor.

The challenge in induction motors is that the rotor flux's absolute position cannot be measured physically. It is determined mathematically using known speed, voltage and current, and a model representation of the motor's main parameters shown in the figure below.



These parameters include per phase rotor resistance 'Rr', rotor leakage inductance 'Llr', mutual inductance 'Lm' and rotor leakage inductance 'Llr'. Usually motor manufacturer will provide you an equivalent circuit of the induction motor that contains Rr, Rs, Lm, Llr, Lls

In FOC, therefore, rotor flux and motor torque can be individually controlled regardless of load and speed. FOC offers better dynamic performance, accurate current control and ensures maximum efficiency, unlike traditional scalar control methods such as Open Loop VpH and Constant Slip Control.

Under FOC operation, AC induction motors can be run in either FOC torque mode or FOC speed mode. FOC torque mode allows users to command a torque to motor in terms of Amps. While FOC speed will regulate the speed at the command/desired value.

Configuring FOC Torque Mode

To configure FOC mode, first set the controller in Open Loop (Volts per Hertz) mode as described in one of the previous sections. Verify that the motor is spinning in the desired direction and that encoder is working and is counting with the correct polarity. See Testing the Encoder section above.

Once the encoder is verified to work and the motor spins in open loop, follow these steps. Using the Roborun PC utility:

- Enter the motor parameters under the section "Motor Parameters" in RoboRun configuration. Usually motor manufacturer will provide you an equivalent circuit of the induction motor that contains Rr, Rs, Lm, Llr, Lls.
- Set the Flux Amps. In order to find the optimal flux amps, run the motor in Volts per Hertz (VpH) mode with small/no load using the motor's rated VpH ratio. Then watch the flux amps in the PC utility. Enter this value in the configuration. This flux amps can be increased for low speed/high torque requirement and can be decreased (Field Weakening) for high speed/ low torque requirement.
- Set the operating mode to FOC torque. Set Amps limit according to the application's need but do not exceed the motor specifications.
- Save the settings to the controller.
- Next step is to tune FOC (Flux and Torque) PID. Start with low proportional gain e.g. 0.1, and then set some Integral gain. Integral gain is more important in this case.
- Monitor and Record the Flux Amps and Torque Amps for the desired motor channel when tuning the FOC PID.

- Put some high load on the rotor and command a step Torque Amps from the slider bar (say 10A). Record the "FOC Torque Amps" reading on the chart. If the step response reaches the desired (10A) steady state fast enough then the PID is can be considered tuned. If it is slow then increase integral gain. If the Torque and Flux Amps show noise at high speed or motor produces noisy sound, then lower your proportional gain Kp.
- Once FOC/current PID is tuned, FOC torque mode is ready to operate and FOC speed mode can then be tuned. Note: It is important to know the value of Flux Amps the motor is designed to operate under. Flux Amps stay the same during entire FOC operation unless field weakening is used.

Now motor Torque can be set to any desired value from 0 to plus or minus the value stored in the Amps Limit configuration parameter, by sending a command of -1000 to +1000 using the slider, analog input, pulse input, scripting, CAN or any other command mode.

Note that in Torque Mode, the Max Speed RPM configuration parameter is used to limit the motor speed if the motor is not loaded and the desired torque is below the torque that can actually be reached by the motor under the current load conditions. For example, a torque command of 50A on an unloaded motor (that will never draw 50A) will cause the voltage to increase to maximum value, and therefore the motor to maximum speed, unless the speed is limited by the Max RPM parameter.

Configuring FOC Speed Mode

To configure FOC Speed mode, configure first the FOC Torque mode as described in the section above.

- Set the controller to FOC Speed Mode
- Tune speed loop PID in a similar manner as was done for FOC PID. Use the PID gains found in the Motor Output, Closed Loop Speed Parameters menus (do not use the FOC PID gains). It can be started with Kp term and introduce small Kd term. Once transient response on the graph seems reasonable then Ki can be used to get rid of steady state error.

Now motor Speed can be set to any desired value from 0 to plus or minus the value stored in the Max RPM configuration parameter, by sending a command of -1000 to +1000 using the slider, analog input, pulse input, scripting, CAN or any other command mode.

E.g. use the Roborun slider, or the console command

!G 1 800

to set motor RPM to 800 on channel 1 when MaxSpeed is set to 1000 RPM. Corresponding if MaxSpeed is set to 2000 RPM, any value on the slider will give 2 times RPM.

Speed can be also set as an absolute RPM value using the S command from Serial, USB, CAN or Microbasic

SECTION 10

Closed Loop Speed and Speed-Position Modes

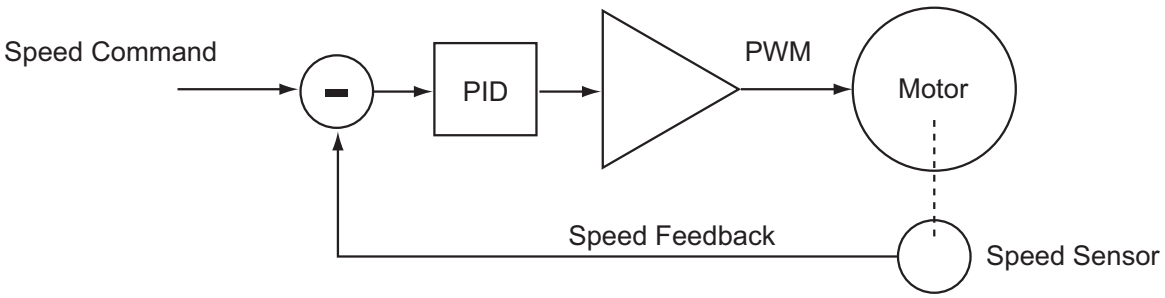
This section discusses the controller's Closed Loop Speed modes.

Modes Description

Close loop speed modes ensure that the motor(s) will run at a precise desired speed. If the speed changes because of changes in load, the controller automatically compensates the power output so that the motor maintains a constant speed. Two closed loop speed modes are available:

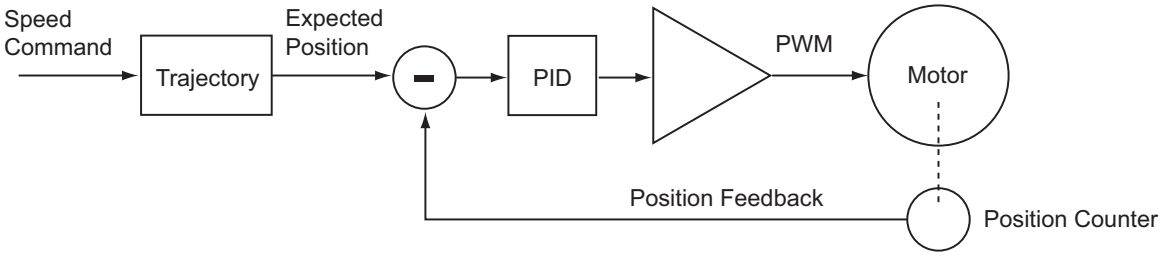
Closed Loop Speed Mode

This mode is the traditional closed loop technique where speed is measured with a speed sensor. The speed is compared to the desired speed and a PID control loop adjusts the power output up or down in order to reach and maintain that speed.



Closed Loop Speed Position Control

In this mode, the controller computes the position at which the motor must be at every 1ms. Then a PID compares that expected position with the current position and applies the necessary power level in order for the motor to reach that position. This mode is especially effective for accurate control at very slow speeds.



The controller incorporates a full-featured Proportional, Integral, Differential (PID) control algorithm for quick and stable speed control.

The closed loop speed mode and all its tuning parameters may be selected individually for each motor channel.

Motor Sensors

The controller can use a variety of sensors for measuring speed. For brushed DC, Digital Optical Encoders and Analog Tachometerss may be used. For Brushless motors, the Hall sensors and all other types of rotor sensors can be use in addition to Encoders and Tachometers. Digital Optical Encoders may be used to capture accurate motor speed.

Analog tachometers are another technique for sensing speed. See "Connecting Tachometer to Analog Inputs" on page 50

Tachometer or Encoder Mounting

Proper mounting of the speed sensor is critical for an effective and accurate speed mode operation. Figure 10-1 shows a typical motor and tachometer or encoder assembly. It is always preferable to have the encoder connected to the motor shaft rather than at the output of a gearbox. If the encoder must be mounted after a gear box consider the effect of the gear backlash. A higher count encoder will typically be required to compensate for the lower rotation speed.

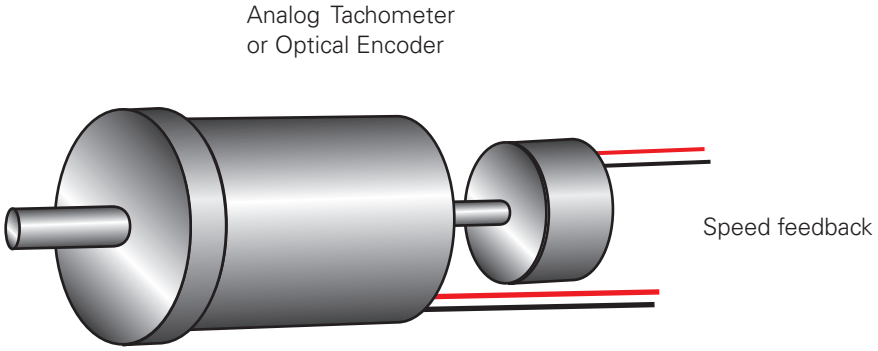


FIGURE 10-1. Motor and speed sensor assembly needed for Close Loop Speed mode

Tachometer wiring

The tachometer must be wired so that it creates a voltage at the controller's analog input that is proportional to rotation speed: 0V at full reverse, +5V at full forward, and 0 when stopped.

Connecting the tachometer to the controller is as simple as shown in the diagram below.

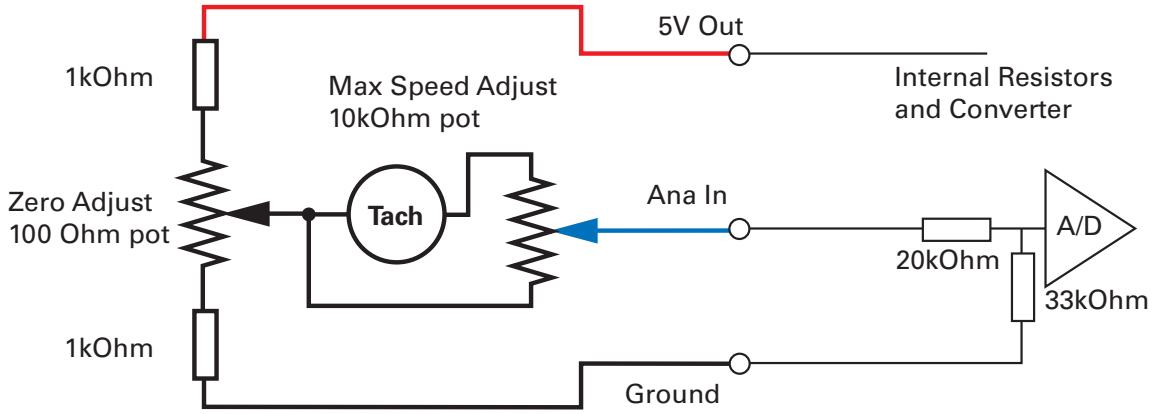


FIGURE 10-2. Tachometer wiring diagram

Brushless Hall Sensors as Speed Sensors

On brushless motor controllers, the Hall Sensors and most other type of rotor position sensors that are used to switch power around the motor windings, can also used to measure speed and distance traveled.

Speed is evaluated by measuring the time between transition of the Hall Sensors. A 32 bit up/down counter is also updated at each Hall Sensor transition.

Speed information picked up from the Hall Sensors can be used for closed loop speed operation without any additional hardware. Likewise, the position counter that is updated at every Hall transition can also be used to operate the motor in Speed Position mode.

Speed Sensor and Motor Polarity

The tachometer, encoder or brushless sensor (Hall, Sin/Cos, SPI) polarity (i.e. which rotation direction produces a positive or negative speed information) is related to the motor's rotation speed and the direction the motor turns when power is applied to it.

In the Closed Loop Speed mode, the controller compares the actual speed, as measured by the sensor, to the desired speed. If the motor is not at the desired speed and direction, the controller will apply power to the motor so that it turns faster or slower, until reached.

Important Warning

The speed sensor polarity must be such that a positive voltage is generated to the controller's input when the motor is rotating in the forward direction. If the polarity is inverted, this will cause the motor to run away to the maximum speed as soon as the controller is powered and eventually trigger the closed loop error and stop. If this protection is disabled, there will be no way of stopping it other than pressing the emergency stop button or disconnecting the power.

Determining the right polarity is best done experimentally using the Roborun utility (see "Using the Roborun Configuration Utility" on page 349) and following these steps:

1. Configure the controller in Open Loop Mode using the PC utility. This will cause the motor to run in Open Loop for now.
2. Configure the sensor you plan to use as speed feedback. If an analog tachometer is used, map the analog channel on which it is connected as "Feedback" for the selected motor channel. If an encoder is used, configure the encoder channel with the encoder's Pulses Per Revolution value. On brushless motor, if the rotor sensor (Hall, Sin/Cos, ..) sensors are used, configure the correct number of motor pole pairs.
3. Click on the Run tab of the PC utility. Configure the Chart recorder to display the speed information if an encoder is used. Display Feedback if an analog sensor is used.
4. Verify that the motor sliders are in the "0" (Stop) position.
5. If a tachometer is used, verify that the reported feedback value read is 0 when the motors are stopped. If not, adjust the Analog Center parameter.
6. Move the cursor of the desired motor to the right so that the motor starts rotating, and verify that a positive speed is reported. Move the cursor to the left and verify that a negative speed is reported.
7. If the reported speed polarity is the same as the applied command, the wiring is correct.
8. If the tachometer polarity is opposite of the command. If an encoder is used, swap its ChA and ChB outputs. Alternatively, swap the motor leads if using a brushed DC motor only. The speed polarity can also be inverted by entering a negative number of encoder PPR. On brushless motors, entering a negative number of poles will also invert the speed measured by the Hall, SinCos, or SPI sensor.
9. Set the controller operating mode to Closed Loop Speed mode using the Roborun utility.
10. Move the cursor and verify that speed stabilizes at the desired value. If speed is unstable, tune the PID values.

Important Warning

It is critically important that the tachometer or encoder wiring be extremely robust. If the speed sensor reports an erroneous speed or no speed at all, the controller will consider that the motor has not reached the desired speed value and will gradually increase the applied power to the motor until the closed loop error is triggered and the motor is then stopped.

Controlling Speed in Closed Loop

When using encoder feedback or Hall Sensor (brushless motor) feedback, the controller will measure and report speed as the motor's actual RPM value.

When using analog or pulse as input command, the command value will range from 0 to +1000 and 0 to -1000. In order for the max command to cause the motor to reach the de-

sired actual max RPM, an additional parameter must be entered in the encoder or brushless configuration. The Max RPM parameter is the speed that will be reported as 1000 when reading the speed in relative mode. Max RPM is also the speed the controller will attempt to reach when a max command of 1000 is applied.

When sending a speed command via serial, CANbus, scripting or USB, the command may be sent as a relative speed (0 to +/-1000) or actual RPM value.

PID Description

The controller performs both Closed Loop Speed modes using a full featured Proportional, Integral and Differential (PID) algorithm. This technique has a long history of usage in control systems and works on performing adjustments to the Power Output based on the difference measured between the desired speed or position (set by the user) and the actual speed or position (captured by the sensor on the motor).

Figure 9-3 shows a representation of the PID algorithm. Every 1 millisecond, the controller measures the actual motor speed or position and subtracts it from the desired speed or position to compute the error.

The resulting error value is then multiplied by a user selectable Proportional Gain. The resulting value becomes one of the components used to command the motor. The effect of this part of the algorithm is to apply power to the motor that is proportional with the difference between the current and desired speed or position: when far apart, high power is applied, with the power being gradually reduced as the motor moves to the desired speed or destination.

A higher Proportional Gain will cause the algorithm to apply a higher level of power for a given measured error thus making the motor react more quickly to changes in commands and/or motor load.

The Differential component of the algorithm computes the changes to the error from one 1 ms time period to the next. This change will be a relatively large number every time an abrupt change occurs on the desired speed value or the measured speed value. The value of that change is then multiplied by a user selectable Differential Gain and added to the output. The effect of this part of the algorithm is to give a boost of extra power when starting the motor due to changes to the desired speed or position value. The differential component will also help dampen any overshoot and oscillation.

The Integral component of the algorithm performs a sum of the error over time. In Speed mode, this component helps the controller reach and maintain the exact desired speed when the error is reaching zero (i.e. measured speed is near to, or at the desired value). In Speed Position mode, the Integral parameter can help maintain a slightly tighter difference between the desired and actual position, but makes no significant difference and can be omitted altogether.

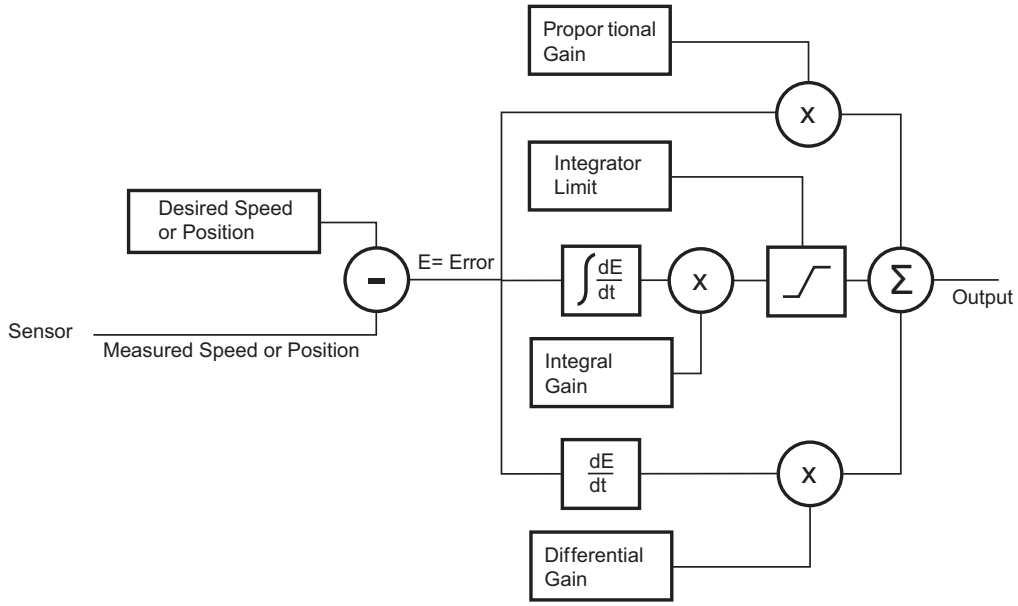


FIGURE 10-3. PID algorithm used in speed modes

PID tuning in Closed Loop Speed Mode

As discussed above, three parameters - Proportional Gain, Integral Gain, and Differential Gain - can be adjusted to tune the Closed Loop Speed control algorithm. The ultimate goal in a well tuned PID is a motor that reaches the desired speed quickly without overshoot or oscillation.

Because many mechanical parameters such as motor power, gear ratio, load and inertia are difficult to model, tuning the PID is essentially a manual process that takes experimentation.

The Roborun PC utility makes this experimentation easy by providing one screen for changing the Proportional, Integral and Differential gains and another screen for running and monitoring the motor. First, run the motor with the preset values. Then experiment with different values until a satisfactory behavior is found.

In Speed Mode, the Integral component of the PID is the most important and must be set first. The Proportional and Differential components will help improve the response time and loop stability.

Try initially to only use a small value of I and no P or D:

P = 0
I = 1
D = 0

These values practically always work, but they may cause the motor to be slow reaching the desired speed. Increase the I gain to improve responsiveness but keeping it below the level at which the motor begins to oscillate. Experiment then with adding P gain, and different values of I.

In the case where the load moved by the motor is not fixed, tune the PID with the minimum expected load and tune it again with the maximum expected load. Then try to find values that will work in both conditions. If the disparity between minimal and maximal possible loads is large, it may not be possible to find satisfactory tuning values. In this case, consider changing the PID gains on the fly during motor operation with serial/CAN commands of with a MicroBasic script

In slow systems, use the integrator limit parameter to prevent the integrator to reach saturation prematurely and create overshoots. Beware to set speeds that can physically be reached by the motor under load. If the motor is not physically able, there will be a loop error, which if it becomes too large, will cause a fault to be detected and the motor to be stopped.

PID Tuning in Speed Position Mode

As discussed, in Closed Loop Speed Position mode, every millisecond, the controller computes successive desired position. The PID then works to make the motor follow the computed trajectory. This mode works much better than the regular Closed Loop Speed mode when the motor must operate at very low speed. When the motor is stopped, it will maintain its position even if pulled, as for example on a robot stopped downhill.

The PID therefore must be tuned for position mode. In position mode, most of the work is done by the proportional gain. It acts essentially as an imaginary rubber belt between the controller's internal destination counter and the motor: the higher the difference, the more the belt is stretched, and the stronger the motor will turn. Once the imaginary belt has stiffened the motor will run at the desired speed.

Try initially with only a small amount of P gain

P = 2
I = 0
D = 0

With the controller configured in Speed Position mode and the motor stopped, do a first check of the PID's stiffness by attempting to rotate the motor by hand. It should feel increasingly hard to rotate away from the rest position. With a higher P gain, it will become harder to move than lower gains. As a rule of thumb, on a mobile robot, use a gain that makes it very hard to move the wheel more than a quarter turn away from the rest position. Test then by applying a speed command and verifying the motor runs smoothly under all load conditions.

The I and D gain can generally be omitted in Speed Position mode.

Beware to set speeds that can physically be reached by the motor under load. The Closed Loop Speed Position mode relies on the fact that the motor will actually be able to follow the computed trajectory. If the motor is not able, the controller will pause updating the destination counter until the motor caught up. This will result in inaccurate speed and can be a problem in mobile robot applications depending on precise control of their left and right side motor.

Error Detection and Protection

The controller will detect large tracking errors due to mechanical or sensor failures, and shut down the motor in case of problem in closed loop speed or position system. The detection mechanism looks for the size of the tracking error (desired position vs. actual position) and the duration the error is present. Three levels of sensitivity are provided in the controller configuration:

1: 250ms and Error > 100
2: 500ms and Error > 250
3: 1000ms and Error > 500

When an error is triggered, the motor channel is stopped until the error has disappeared or when the motor channel is reset to open loop mode. The error is cleared when a stop command is issued.

Clearing the loop error make the motor available for moving again. However this does not mean that the loop error will not happen again. Configuration tuning is necessary in order to prevent from having Loop Error again. The loop error value can be monitored in real time using the Roborun PC utility.

SECTION 11

Closed Loop Relative and Tracking Position Modes

This section describes the controller's Position Relative and Position Tracking modes, how to wire the motor and position sensor assembly and how to tune and operate the controller in these modes.

Modes Description

In these two position modes, the axle of a geared-down motor is coupled to a position sensor that is used to compare the angular position of the axle versus a desired position. The controller will move the motor so that it reaches this position.

This feature makes it possible to build ultra-high torque "jumbo servos" that can be used to drive steering columns, robotic arms, life-size models and other heavy loads.

The two position modes are similar and differ as follows:

Position Relative Mode

The controller accepts a command ranging from -1000 to +1000, from serial/USB, analog joystick, or pulse. The controller reads a position feedback sensor and converts the signal into a -1000 to +1000 feedback value at the sensor's min and max range respectively. The controller then moves the motor so that the feedback matches the command, using a controlled acceleration, set velocity and controlled deceleration. This mode requires several settings to be configured properly but results in very smoothly controlled motion.

Position Tracking Mode

This mode is identical to the Position Relative mode in the way that commands and feedback are evaluated. However, the controller will move the motor simply using a PID comparing the command and feedback, without controlled acceleration and as fast as possible.

This mode requires fewer settings but often results in a motion that is not as smooth and harder to control overshoots.

Selecting the Position Modes

The two position modes are selected by changing the Motor Control parameter to Closed Loop Position. This can be done using the corresponding menu in the Power Output tree in the Roborun utility. It can also be done using the associated serial (RS232/USB) command. See "MMOD" on page 329. The position mode can be set independently for each channel.

Position Feedback Sensor Selection

The controller may be used with the following kinds of sensors:

- Potentiometers
- Hall effect angular sensors
- Optical Encoders
- Hall sensor in brushless motor

The first two are used to generate an analog voltage ranging from 0V to 5V depending on their position. They will report an absolute position information at all times.

Modern position Hall sensors output a digital pulse of variable duty cycle. These sensors provide an absolute position value with a high precision (up to 12-bit) and excellent noise immunity. PWM output sensors are directly readable by the controller and therefore are a recommended choice.

Optical encoders report incremental changes from a reference which is their initial position when the controller is powered up or reset. Before they can be used for reporting position, the motors must be moved in open loop mode until a home switch is detected and resets the counter. Encoders offer the greatest positional accuracy possible.

Sensor Mounting

Proper mounting of the sensor is critical for an effective and accurate position mode operation. Figure 11-1 shows a typical motor, gear box, and sensor assembly.

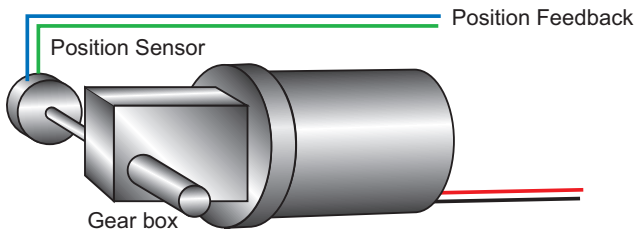


FIGURE 11-1. Typical motor/Potentiometer/assembly in Position Mode

The sensor is composed of two parts:

- a body which must be physically attached to a non-moving part of the motor assembly or the robot chassis, and
- an axle which must be physically connected to the rotating part of the motor you wish to position.

A gear box is necessary to greatly increase the torque of the assembly. It is also necessary to slow down the motion so that the controller has the time to perform the position control algorithm. If the gearing ratio is too high, however, the positioning mode will be very sluggish.

A good ratio should be such that the output shaft rotates at 1 to 10 rotations per second (60 to 600 RPM) when the motor is at full speed.

The mechanical coupling between the motor and the sensor must be as tight as possible. If the gear box is loose, the positioning will not be accurate and will be unstable, potentially causing the motor to oscillate.

Some sensors, such as potentiometers, have a limited rotation range of typically 270 degrees (3/4 of a turn), which will in turn limit the mechanical motion of the motor/potentiometer assembly. Consider using a multi-turn potentiometer as long as it is mounted in a manner that will allow it to turn throughout much of its range, when the mechanical assembly travels from the minimum to maximum position. When using encoders, best results are achieved when the encoder is mounted directly on the motor shaft.

Feedback Sensor Range Setting

Regardless the type of sensor used, feedback sensor range is scaled to a -1000 to +1000 value so that it can be compared with the -1000 to +1000 command range.

On analog and pulse sensors, the scaling is done using the min/max/center configuration parameters.

When encoders are used for feedback, the encoder count is also converted into a -1000 to +1000 range. In the encoder case, the scaling uses the Encoder Low Limit and Encoder High Limit parameters. See "Serial (RS232/USB) Operation" on page 141 for details on these configuration parameters. Beware that encoder counters produce incremental values. The encoder counters must be reset using the homing procedure before they can be used as position feedback sensors.

Important Notice

Potentiometers are mechanical devices subject to wear. Use better quality potentiometers and make sure that they are protected from the elements. Consider using a solid state hall position sensor in the most critical applications. Optical encoders may also be used, but require a homing procedure to be used in order to determine the zero position.

Important Warning

If there is a polarity mismatch, the motor will turn in the wrong direction and the position will never be reached. The motor will turn until the Closed Loop Error detection is triggered. The motor will then stop until the error disappears, the controller is set to Open Loop, or the controller is reset.

Determining the right polarity is best done experimentally using the Roborun utility (see "Using the Roborun Configuration Utility" on page 225) and following these steps:

1. Configure the controller in Open Loop Speed mode.
2. Configure the position sensor input channel as position feedback for the desired motor channel.
3. Click on the Run tab.
4. Enable the Feedback channel in the chart recorder.
5. Move the slider slowly in the positive direction and verify that the Feedback in the chart increases in value. If the Feedback value decreases, then the sensor is backwards and you should either invert using configuration commands, invert the sensor physically, it or swap the motor wires so that the motor turns in the opposite direction.
6. Move the sensor off the center position and observe the motor's direction of rotation.
7. Go to the max position and verify that the feedback value reaches 1000 a little before the end of the physical travel. Modify the min and max limits for the sensor input if needed.
8. Repeat the steps in the opposite direction and verify that the -1000 is reached a little before the end of the physical travel limit.

Important Safety Warning

Never apply a command that is lower than the sensor's minimum output value or higher than the sensor's maximum output value as the motor would turn forever trying to reach a position it cannot. Configure the Min/Max parameter for the sensor input so that a value of -1000 to +1000 is produced at both ends of the sensor travel.

Adding Safety Limit Switches

The Position mode depends on the position sensor providing accurate position information. If the sensor is damaged or one of its wires is cut, the motor may spin continuously in an attempt to reach a fictitious position. In many applications, this may lead to serious mechanical damage.

To limit the risk of such breakage, it is recommended to add limit switches that will cause the motor to stop if unsafe positions have been reached independent of the sensor reading. Any of the controller's digital inputs can be used as a limit switch for any motor channel.

An alternate method is shown in Figure 11-2. This circuit uses Normally Closed limit switches in series on each of the motor terminals. As the motor reaches one of the switches, the lever is pressed, cutting the power to the motor. The diode in parallel with the switch allows the current to flow in the reverse position so that the motor may be restarted and moved away from that limit.

The diode polarity depends on the particular wiring and motor orientation used in the application. If the diode is mounted backwards, the motor will not stop once the limit switch lever is pressed. If this is the case, reverse the diode polarity.

The diodes may be eliminated, but then it will not be possible for the controller to move the motor once either of the limit switches has been triggered.

The main benefit of this technique is its total independence on the controller's electronics and its ability to work in practically all circumstances. Its main limitation is that the switch and diode must be capable of handling the current that flows through the motor. Note that the current will flow though the diode only for the short time needed for the motor to move away from the limit switches.

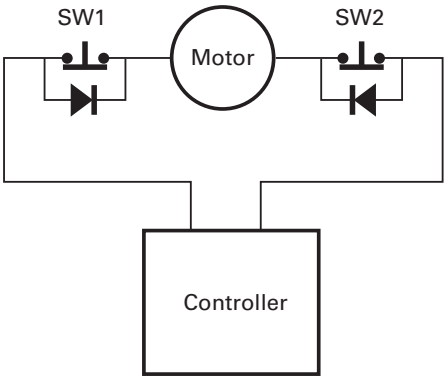


FIGURE 11-2. Safety limit switches interrupting power to motor

Important Warning

Limit switches must be used when operating the controller in Position Mode. This will significantly reduce the risk of mechanical damage and/or injury in case of damage to the position sensor or sensor wiring.

Using Current Trigger as Protection

The controller can be configured to trigger an action when current reaches a user configurable threshold for more than a set amount of time. This feature can be used to detect that a motor has reached a mechanical stop and is no longer turning. The triggered action can be an emergency stop or a simulated limit switch.

Operating in Closed Loop Relative Position Mode

This position algorithm allows you to move the motor from an initial position to a desired position. The motor starts with a controlled acceleration, reaches a desired velocity, and decelerates at a controlled rate to stop precisely at the end position. The graph below shows the speed and position vs. time during a position move.

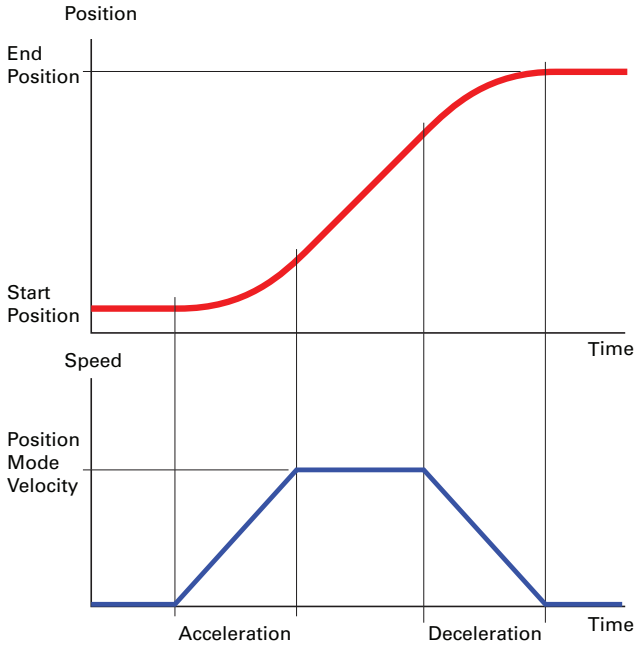


FIGURE 11-3.

When turning the controller on, the default acceleration, deceleration and velocity are parameters retrieved from the configuration EEPROM. In most applications, these parameters can be left unchanged and only change in commands used to control the change from one position to the other. In more sophisticated systems, the acceleration, deceleration and velocity can be changed on the fly using Serial/USB commands or from within a MicroBasic script.

When using Encoders as feedback sensors, the controller can accurately measure the speed and the number of motor turns that have been performed at any point in time. The complete positioning algorithm can be performed with the parameters described above.

When using analog or pulse sensors as feedback, the system does not have a direct way to measure speed or number of turns. It is therefore necessary to configure an additional parameter in the controller which determines the number of motor turns between the point the feedback sensor gives the minimum feedback value (-1000) to the maximum feedback value (+1000).

In the Closed Loop Relative Position mode, the controller will compute the position at which the motor is expected to be at every millisecond in order to follow the desired acceleration and velocity profile. This computed position becomes the setpoint that is compared with the feedback sensor and a correction is applied at every millisecond.

For troubleshooting, the computed position can be monitored in real time by enabling the Tracking channel in the PC utility's chart recorder.

Beware not to use accelerations and max velocity that are beyond the motor's physical reach at full load. This would result in a loop error which will stop the system if growing too large.

Operating in Closed Loop Tracking Mode

In this mode the controller makes no effort to compute a smooth, millisecond by millisecond position trajectory. Instead the current feedback position is periodically compared with the requested destination and power is applied to the motor using these two values in a PID control loop.

This mode will work best if changes in the commands are smooth and not much faster than what the motor can physically follow.

Position Mode Relative Control Loop Description

The controller performs the Relative Position mode using a full featured Proportional, Integral and Differential (PID) algorithm. This technique has a long history of usage in control systems and works on performing adjustments to the Power Output based on the difference measured between the desired position (set by the user) and the actual position (captured by the position sensor).

Figure 10-4 shows a representation of the PID algorithm. Every 1 millisecond, the controller measures the actual motor position and subtracts it from the desired position to compute the position error.

The resulting error value is then multiplied by a user selectable Proportional Gain. The resulting value becomes one of the components used to command the motor. The effect of this part of the algorithm is to apply power to the motor that is proportional with the distance between the current and desired positions: when far apart, high power is applied, with the power being gradually reduced and stopped as the motor moves to the final position. The Proportional feedback is the most important component of the PID in Position mode.

A higher Proportional Gain will cause the algorithm to apply a higher level of power for a given measured error, thus making the motor move quicker. Because of inertia, however, a faster moving motor will have more difficulty stopping when it reaches its desired position. It will therefore overshoot and possibly oscillate around that end position.

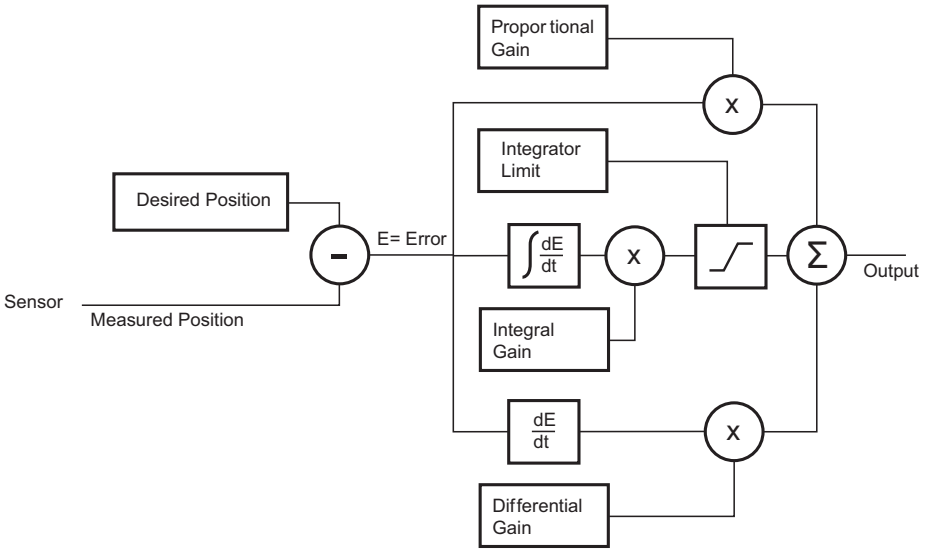


FIGURE 11-4. PID algorithm used in Position Mode

The Differential component of the algorithm computes the changes to the error from one ms time period to the next. This change will be a relatively large number every time an abrupt change occurs on the desired position value or the measured position value. The value of that change is then multiplied by a user-selectable Differential Gain and added to the output. The effect of this part of the algorithm is to give a boost of extra power when starting the motor due to changes to the desired position value. The differential component will also help dampen any overshoot and oscillation.

The Integral component of the algorithm performs a sum of the error over time. In the position mode, this component helps the controller reach and maintain the exact desired position when the error would otherwise be too small to energize the motor using the Proportional component alone. Only a very small amount of Integral Gain is typically required in this mode.

In systems where the motor may take a long time to physically move to the desired position, the integrator value may increase significantly causing then difficulties to stop without overshoot. The Integrator Limit parameter will prevent that value from becoming unnecessarily large.

PID tuning in Position Mode

As discussed above, three parameters - Proportional Gain, Integral Gain and Differential Gain - can be adjusted to tune the position control algorithm. The ultimate goal in a well tuned PID is a motor that reaches the desired position quickly without overshoot or oscillation.

Because many mechanical parameters such as motor power, gear ratio, load and inertia are difficult to model, tuning the PID is essentially a manual process that takes experimentation.

The Roborun PC utility makes this experimentation easy by providing one screen for changing the Proportional, Integral and Differential gains and another screen for running and monitoring the motor.

When tuning the motor, first start with the Integral and Differential Gains at zero, increasing the Proportional Gain until the motor overshoots and oscillates. Then add Differential gain until there is no more overshoot. If the overshoot persists, reduce the Proportional Gain. Add a minimal amount of Integral Gain. Further fine tune the PID by varying the gains from these positions.

To set the Proportional Gain, which is the most important parameter, use the Roborun utility to observe the three following values:

- Command Value
- Actual Position
- Applied Power

With the Integral Gain set to 0, the Applied Power should be:

Applied Power = (Command Value - Actual Position) * Proportional Gain

Experiment first with the motor electrically or mechanically disconnected and verify that the controller is measuring the correct position and is applying the expected amount of power to the motor depending on the command given.

Verify that when the Command Value equals the Actual Position, the Applied Power equals to zero. Note that the Applied Power value is shown without the sign in the PC utility.

In the case where the load moved by the motor is not fixed, the PID must be tuned with the minimum expected load and tuned again with the maximum expected load. Then try to find values that will work in both conditions. If the disparity between minimal and maximal possible loads is large, it may not be possible to find satisfactory tuning values.

Note that the controller uses one set of Proportional, Integral and Differential Gains for both motors, and therefore assumes that similar motor, mechanical assemblies and loads are present at each channel.

PID Tuning Differences between Position Relative and Position Tracking

The PID works the same way in both modes in that the desired position is compared to the actually measured position.

In the Closed Loop Relative mode, the desired position is updated every ms and so the PID deal with small differences between the two values.

In the Closed Loop Tracking mode, the desired position is changed whenever the command is changed by the user.

Tuning for both modes requires the same steps. However, the P, I and D values can be expected to be different in one mode or the other.

Loop Error Detection and Protection

The controller will detect large tracking errors due to mechanical or sensor failures, and shut down the motor in case of problem in closed loop speed or position system. The detection mechanism looks for the size of the tracking error (desired position vs. actual position) and the duration the error is present. Three levels of sensitivity are provided in the controller configuration:

1: 250ms and Error > 100
2: 500ms and Error > 250
3: 1000ms and Error > 500

When an error is triggered, the motor channel is stopped until the error has disappeared, the motor channel is reset to open loop mode.

The loop error can be monitored in real time using the Roborun PC utility.

SECTION 12

Closed Loop Count Position Mode

In the Closed Loop Position mode, the controller can move a motor a precise number of encoder counts, using a predefined acceleration, constant velocity, and deceleration. This mode requires that an encoder be mounted on the motor.

Mode description

The desired position is given in number of counts. Using acceleration, deceleration and top velocity, the controller computes the position at which the motor is expected to be at every one millisecond interval. A PID then computes the power to give to the motor in order to maintain that position. A comparator looks at the desired position and the computed current position and issues a Destination Reached flag. The figure below shows a representation of this mode.

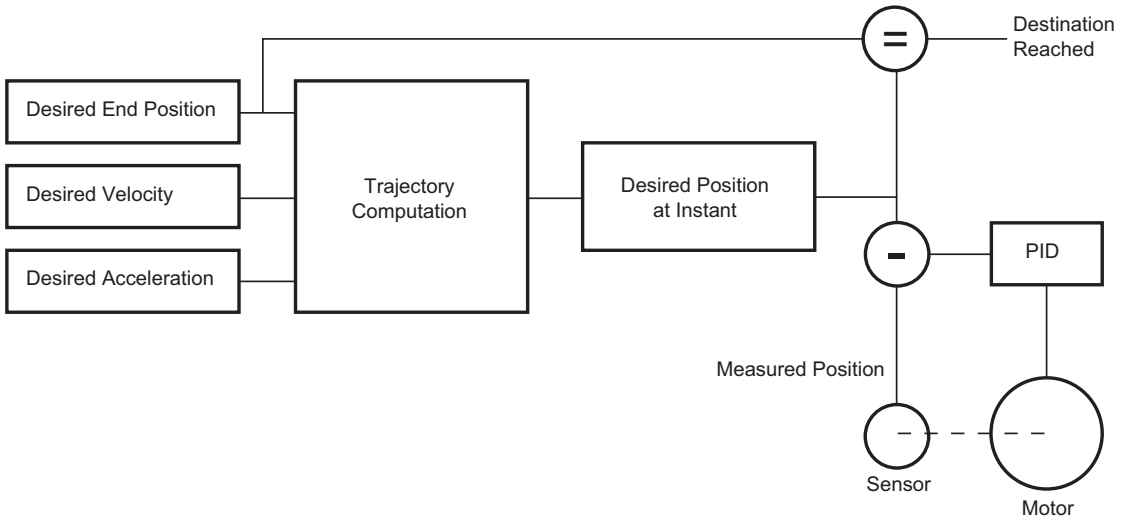


Figure 12-1 Closed Loop Position mode

Sensor Types and Mounting

In position mode, best results are achieved with encoders directly mounted on the motor shaft. Encoders can be:

- Quadrature encoders
- Hall Sensors built-in brushless motors
- Other rotor sensors built-in brushless motors

It is not advised to mount encoders at the output of a geared motor as the gear box often introduces backlash. If the encoder must be mounted at the output, then it must typically have a higher count to compensate the lower speed rotation at that location.

Quadrature encoders typically provide the highest resolution since they can be ordered with line resolution of several hundreds or thousands of counts per revolution. Hall encoders built in brushless motors give a relatively low, but often adequate count of 6* NumberOfPoles per mechanical resolution. Other brushless rotor sensors, such as SPI/SSI digital sensor, or sin/cos sensors will give up to 512 counts per pole and can therefore be used instead of encoders.

Encoder Home reference

Beware that encoders do not give an absolute position information. It is therefore necessary to perform a search of the zero reference position at least once after every power up. This is typically achieved by moving the motor up to a limit switch and loading the counter with a fixed value at that location. A home search sequence can easily be implemented using a MicroBasic script. The search and counter loading must be done while the motor is operated in open loop.

Important Warning

Changing the counter with a value while the motor is operated in closed loop can cause violent and dangerous jumps. Always revert to open loop to change the counter value.

Preparing and Switching to Closed Loop

To enter this mode you will first need to configure the encoder so that it is used as feedback for motor1, and feedback for motor2 on the other encoder in a dual motor system. On brushless motors, the rotor sensor (Hall, SPI, sin/cos) can be used as a position counter. Selecting "Other" will use the encoder if present and properly configured. Selecting "Hall" will enable the rotor sensor.

Use the PC Utility to set the default acceleration, deceleration and position mode velocity in the motor menu. These values can then be changed on the fly if needed.

While in Open Loop, enable the Speed channel in the Roborun Chart recorder. Move the slider in the positive direction and verify that the measured speed polarity is also positive. If a negative speed is reported, swap the two encoder wires to change the measured polarity, or swap the motor leads to make the motor spin in the opposite direction.

Then use the PC Utility to select the Closed Loop Position Mode. After saving to the controller, the motor will operate in Closed Loop and will attempt to go to the 0 counter position. Beware therefore that the motor has not already turned before switching to Closed Loop. Reset the counter if needed prior to closing the loop.

Count Position Commands

Moving the motor is done using a set of simple commands.

To go to an absolute encoder position value, use the !P command

To go to a relative encoder position count that is relative to the current position, use the !PR command.

The Acceleration, Deceleration and Velocity are fixed parameters that can be changes using the ^MAC, ^MDEC and ^MVEL configuration settings. These can also be changed on the fly, any time using the !AC and !DC commands.

The velocity can also be changed at any time using the !S command:

New position destination command can be issued at any time. If the previous destination is not reached while the new is sent, the motor will move to the new destination. If this causes a change of direction, the motor will do the change using the current acceleration and deceleration settings. See the Commands Reference section for details on all these commands

Position Command Chaining

It is possible to chain position commands in order to create seamless motion to a new position after an initial position is reached. To do this, the controller can store the next goto position with, optionally, a new set of acceleration, deceleration and velocity values.

The commands that set the "next" move are identical to these discussed in the previous section, with the addition of an "X" at the end. The full command list is:

!PX nn mm	Next position absolute
!PRX nn mm	Next position relative
!ACX nn mm	Next acceleration
!DCX nn mm	Next deceleration
!SX	Next velocity
Example:	!PX 1 -50000 will cause the motor to move to that new destination once the previous destination is reached. !PRX -10000 will cause the motor to move 10000 count back from the previous end destination. If the next acceleration, next deceleration or next velocity are not entered, the value(s) used for the previous motion will be used.

Beware that the next commands must be entered while the motor is moving, since the next commands will only be taken into account at the end of the current motion.

To chain more than two commands, use a MicroBasic script or an external program to load new "next" command when the previous "next" commands become active. The ?DR query can be used to detect that this transition has occurred and that a new next command can be sent to the controller.

The chart below shows a typical chaining flow.

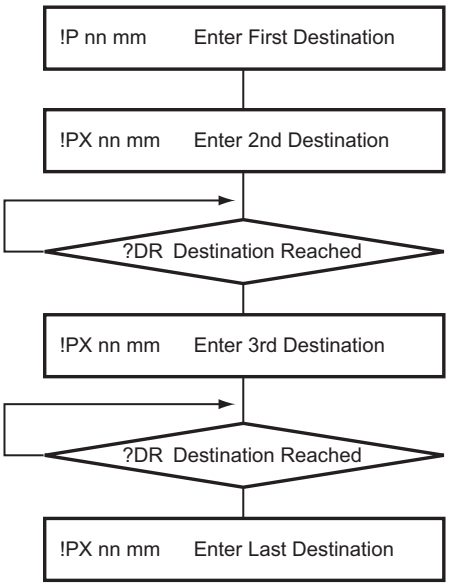


Figure 12-2 Command Chaining flow

Position Accuracy Considerations

In the position mode, the controller computes a trajectory that the motor then attempts to follow using a PID. For this technique to work well, the motor must first be physically able to run as fast as dictated by the trajectory calculation. If not, a loop error (ie desired position - actual position) will accumulate and eventually grow to trigger an error that will stop the motor. Make sure that the velocity setting is always under the max speed that can be reached by the motor while running at full load, in open loop.

Some difference between the desired and actual position, i.e. a loop error, is always to be expected when using a PID. The PID gains must be tuned to minimize the loop error while keeping smooth motion. The expected position and loop error can be monitored in real time using the PC utility's Tracking and Loop Error channels, respectively, in the chart recorder.

Beware that the Destination Reached flag will become true when the result of the trajectory computation equals the desired destination. In most practical situations, the motor will still be on its way to actually reach that destination. This can be an important consideration when chaining commands, as the new command will become active before the motor has actually reached the previous destination

PID Tunings

As long as the motor assembly can physically reach the acceleration and velocity, smooth motion will result with relatively little need for tuning. As for any position control loop, the dominant PID parameter is the Proportional gain with only little Integral gain and smaller or no Derivative gain. See "PID tuning in Position Mode"on page 128.

Loop Error Detection and Protection

The controller will detect large tracking errors due to mechanical or sensor failures, and shut down the motor in case of problem in closed loop speed or position system. The detection mechanism looks for the size of the tracking error (desired position vs. actual position) and the duration the error is present. Three levels of sensitivity are provided in the controller configuration:

1: 250ms and Error > 100

2: 500ms and Error > 250

3: 1000ms and Error > 500

When an error is triggered, the motor channel is stopped until the error has disappeared, the motor channel is reset to open loop mode. The error will also be cleared when sending a new Position Destination using the !P command

The loop error can be monitored in real time using the Roborun PC utility.

SECTION 13

Closed Loop Torque Mode

This section describes the controller's operation in Torque Mode.

Torque Mode Description

The torque mode is a special case of closed loop operation where the motor command controls the current that flows though the motor regardless of the motor's actual speed.

In an electric motor, the torque is directly related to the current. Therefore, controlling the current controls the torque.

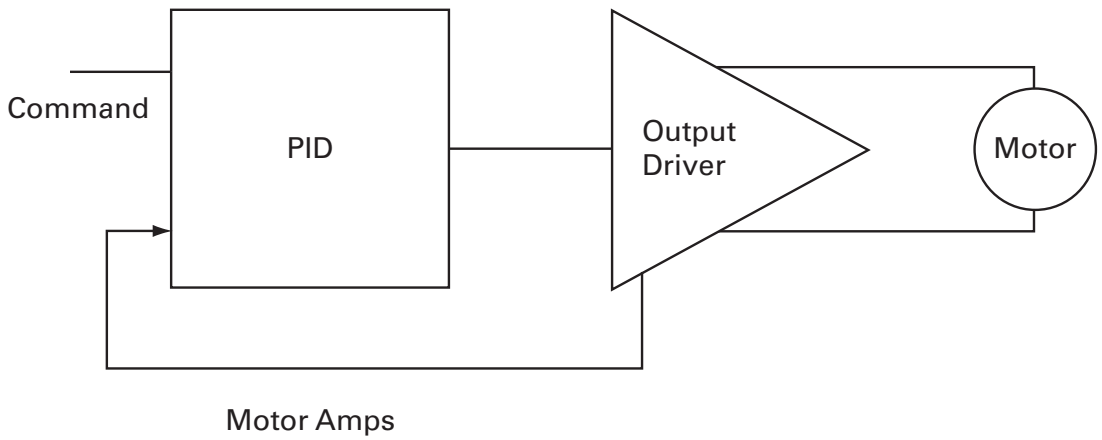


FIGURE 13-1. Torque mode

Torque mode is mostly used in electric vehicles since applying a higher command gives more "push", similarly to how a gas engine would respond to stepping on a pedal. Likewise, releasing the throttle will cause the controller to adjust the power output so that the zero amps flow through the motor. In this case, the motor will coast and it will take a negative command (i.e. negative amps) to brake the motor to a full stop.

Torque Mode Selection, Configuration and Operation

Use the PC utility and the menu "Operating Mode" to select Torque Mode. The controller will now use user commands from RS232, USB, Analog or Pulse to command the motor current.

Commands are ranging from -1000 to +1000. The command is then scaled using the amps limit configuration value.

For example, if the amps limit is set to 100A, a user command of 500 will cause the controller to energize the motor until 50A are measured. If the motor is little loaded and the desired current cannot be reached, the motor will run at full speed.

Torque Mode Tuning

In Torque Mode, the measured Motor Amps become the feedback in the closed loop system. The PID then operates the same way as in the other Closed Loop modes described in this manual (See "PID tuning in Position Mode" on page 128).

In most applications requiring torque mode, the loop response does not need to be very quick and good results can be achieved with a wide range of PID gains. The P and I gains are the primary component of the loop in this mode. Perform a first test using P=0, I=1 and D=0, and then adjust the I and P gain as needed until satisfactory results are reached. In brushless controllers operating in sinusoidal mode, torque mode uses the PID that is regulating the Field Oriented Control. The gains must be therefore set in the FOC menus. See also the KIF and KPF configuration commands in the Commands Reference section.

Configuring the Loop Error Detection

In Torque Mode, it is very likely that the controller will encounter situation where the motor is not sufficiently loaded in order to reach the desired amps. In this case, controller output will quickly rise to 100% while a significant Loop Error (i.e. desired amps - measured amps) is present. In the default configuration, the controller will shut down the power if a large loop error is present for more than a preset amount of time. This safety feature should be disabled in most systems using Torque Mode.

Torque Mode Limitations

The torque mode uses the Motor Amps and not the Battery Amps. See "Battery Current vs. Motor Current"on page 30. In most Roboteq controllers, Battery Amps is measured and Motor Amps is estimated. The estimation is fairly accurate at power level of 20% and higher. Its accuracy drops below 20% of PWM output and no motor current is measured at all when the power output level is 0%, even though current may be flowing in the motor, as it would be the case if the motor is pushed. The torque mode will therefore not operate with good precision at low power output levels.

Furthermore the resolution of the amps capture is limited to around 0.5% of the full range. On high current controller models, for example, amps are measured with 500mA increments. If the amps limit is set to 100A, this means the torque will be adjustable with a 0.5% resolution. If on the same large controller the amps limit is changed to 10A, the torque will be adjustable with the same 500mA granularity which will result in 5% resolution. For best

results use an amps limit that is at least 50% than the controller's max rating. On newer Brushless motor controllers, amps sensors are placed at the motor output and motor amps are measured directly. Torque mode will work effectively on these models.

Torque Mode Using an External Amps Sensor

The limitations described above can be circumvented using an external amps sensor device such as the Allegro Microsystems ACS756 family of hall sensors. These inexpensive devices can be inserted in series with one of the motor leads while connected to one of the controller's analog inputs. Since it is directly measuring the real motor amps, this sensor will provide accurate current information in all load and regeneration conditions. This technique only works for DC brushed motors. On brushless motors, the current in the motor wires is AC and therefore an external sensor cannot be used.

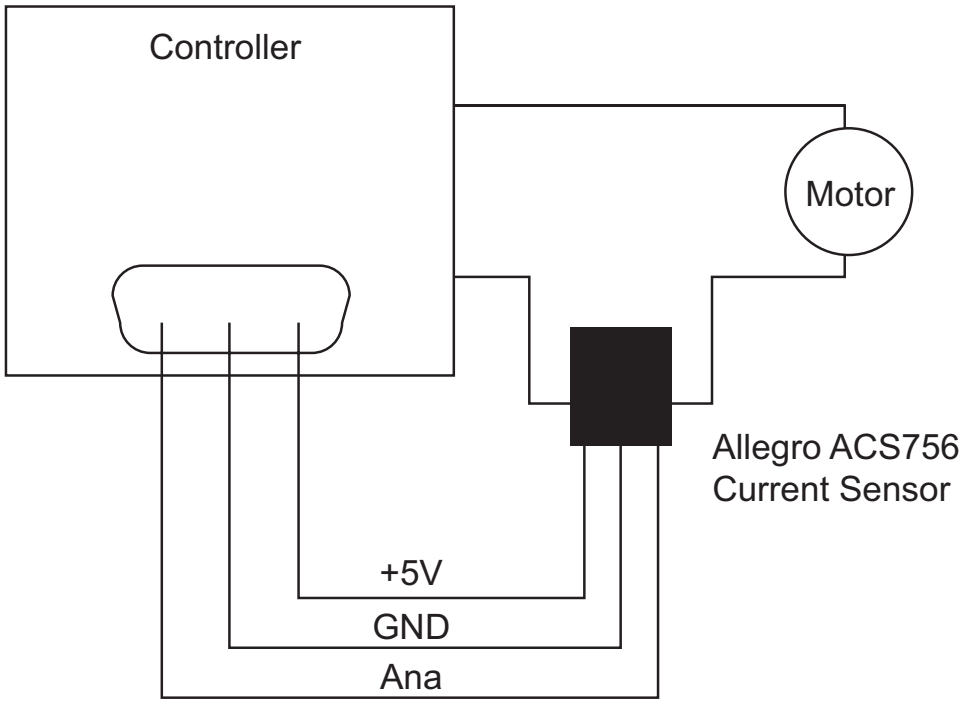


FIGURE 13-2. Torque external sensor

To operate in torque mode, simply configure the selected analog input range to this of the sensor's output at the min and max current that will correspond to the -1000 to +1000 command range. Configure the analog input as feedback for the selected motor channel. Then operate the controller in Position Tracking Mode (See "Position Tracking Mode" on page 121). While the controller will not actually be tracking position, it will adjust the output based on the command and sensor feedback exactly in the same fashion.

SECTION 14

Serial (RS232/ USB) Operation

This section describes the communication settings of the controller operating in the RS232 or USB mode. This information is useful if you plan to write your own controlling software on a PC or microcomputer.

The full set of commands accepted by the controller is provided in "Commands Reference" on page 209.

If you wish to use your PC simply to set configuration parameters and/or to exercise the controller, you should use the RoborunPlus PC utility.

Use and benefits of Serial Communication

The serial communication allows the controller to be connected to PCs, PLC, microcomputers or wireless modems. This connection can be used to both send commands and read various status information in real-time from the controller. The serial mode enables the design of complex motion control system, autonomous robots or more sophisticated remote controlled robots than is possible using the RC mode. RS232 commands are very precise and securely acknowledged by the controller. They are also the method by which the controller's features can be accessed and operated to their fullest extent.

When operating in RC or analog input, serial communication can still be used for monitoring or telemetry.

When connecting the controller to a PC, the serial mode makes it easy to perform simple diagnostics and tests, including:

- Sending precise commands to the motor
- Reading the current consumption values and other parameters
- Obtaining the controller's software revision and date
- Reading inputs and activating outputs
- Setting the programmable parameters with a user-friendly graphical interface
- Updating the controller's software

Serial Port Configuration

The controller's default serial communication port is set as follows:

- 115200 bits/s
- 8-bit data
- 1 Start bit
- 1 Stop bit
- No Parity

Communication is done without flow control, meaning that the controller is always ready to receive data and can send data at any time.

Connector RS232 Pin Assignment

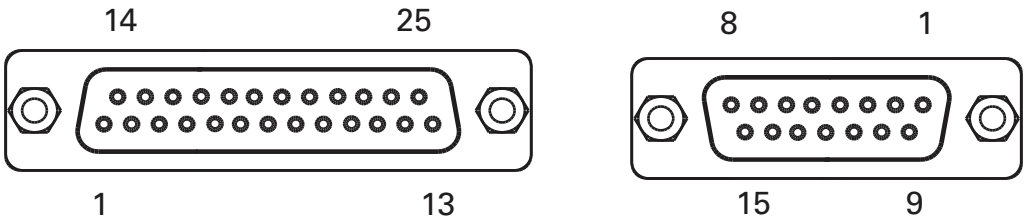


FIGURE 14-1. DB25 and DB15 connectors pin code locations

When used in the RS232 mode, the pins on the controller's DB15 or DB25 connector (depending on the controller model) are mapped as described in the table below

TABLE 14-1. RS232 Signals on DB15 and DB25 connectors §

Pin Number	Input or Output	Signal	Description
2	Output	Data Out	RS232 Data from Controller to PC
3	Input	Data In	RS232 Data In from PC
5	-	Ground	Controller ground

Setting Different Bit Rates

It is possible to set RS232 bit rate to lower values. This operation can only be done while the controller is connected via USB and only using manual commands from the console. Beware that once the bit rate is different than the default 115200, it will no longer be able to communicate with the PC utility if serial connection is used. From the Console, send the following commands:

^RSBR nn

where nn =

0: 115200
1: 57600
2: 38400
3: 19200
4: 9600

Make sure that the controller respond to this command with a +. Check that the value has been accepted by sending ~RSBR.

Send %EESAV from the console to store the new configuration to flash.

Cable configuration

The RS232 connection requires the special cabling as described in Figure 14-2. The 9-pin female connector plugs into the PC (or other microcontroller). The 15-pin or 25-pin male connector plugs into the controller.

It is critical that you do not confuse the connector's pin numbering. The pin numbers on the drawing are based on viewing the connectors from the front. Most connectors brands have pin numbers molded on the plastic.

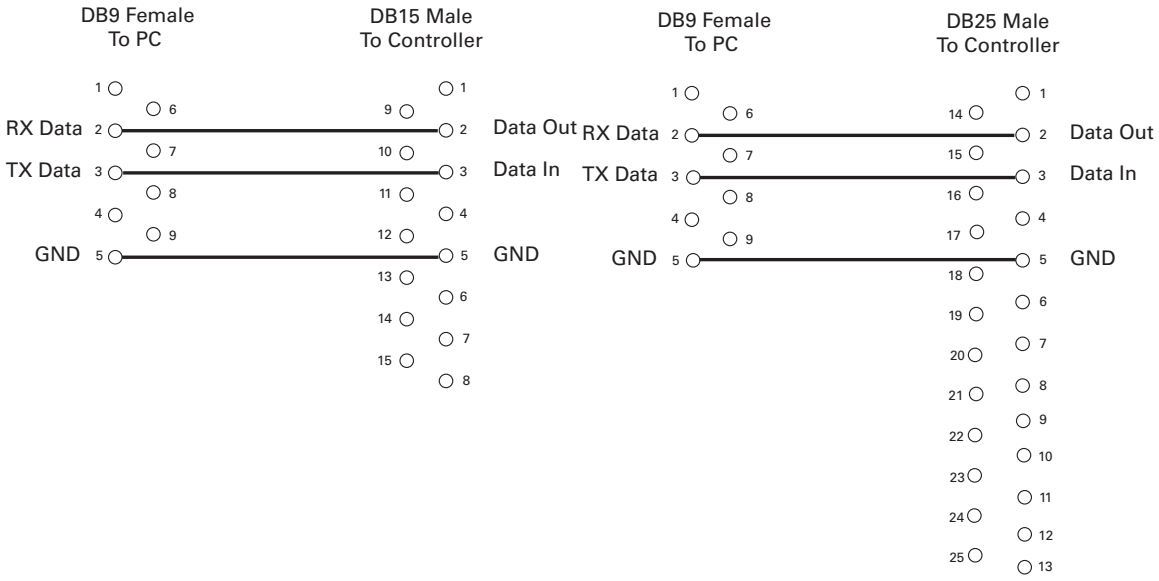


FIGURE 14-2. PC to controller RS 232 cable/connector wiring diagram

The 9 pin to 15 pin cable is provided by Roboteq for controllers with 15 pin connectors.

Controllers with 25 pins connectors are fitted with a USB port that can be used with any USB cables with a type B connector.

Extending the RS232 Cable

RS232 extension cables are available at most computer stores. However, you can easily build one using a 9-pin DB9 male connector, a 9-pin DB9 female connector and any 3-conductor cable. DO NOT USE COMMERCIAL 9-PIN TO 25-PIN CONVERTERS as these do not match the 25-pin pinout of the controller. These components are available at any electronics distributor. A CAT5 network cable is recommended, and cable length may be up to 100' (30m). Figure 14-3 shows the wiring diagram of the extension cable.

FIGURE 14-3. RS232 extension cable/connector wiring diagram

Connecting to Arduino and other TTL Serial Microcomputers

Aduino and similar microcomputers have a TTL serial port while Roboteq controllers have a full RS232 serial interface. RS232 has the following differences from TTL serial:

	RS232	TTL Serial
Voltage Levels	+10V/-10V	0-3V
Logic level	Inverted	Non-Inverted

A TTL to RS232 adapter must be therefore be used to convert to the Arduino serial interface. Newer Roboteq controller allow the RS232 signal to be non-inverted. Interfacing to Arduino or other TTL Serial interface can therefore be done with just a resistors, and 2 optional diodes as shown in the diagram below:

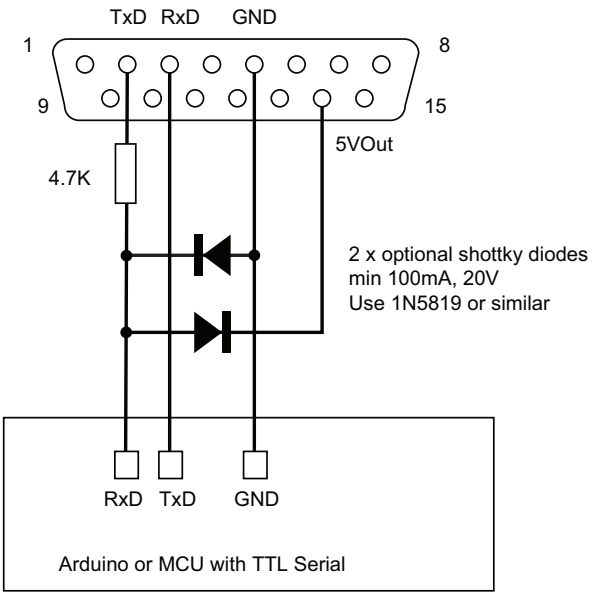


FIGURE 14-4. Simplified TTL to RS232 connection

The data sent from the TTL serial port are 0-3V and can be directly connected to the controller's RS232 input where it will be captured as valid 0-1 levels.

The data at the output of the controller is +/-10V. At the other end of the resistor, the voltage is clamped to around 0-3.3V by the protection diodes that are included in the Arduino MCU. However, to avoid any stress it is highly recommended to insert the 2 diodes shown on the diagram.

To operate, the RS232 output must be set to inverted. This must be done from the Console of the Roborun Utility while connected via USB. This will only work on newer controller models fitted with firmware version 1.6a or more recent.

From the Console, send the following commands:

^RSBR nn

where nn =

5: 115200 + Inverted RS232
6: 57600 + Inverted RS232
7: 38400 + Inverted RS232
8: 19200 + Inverted RS232
9: 9600 + Inverted RS232

Make sure that the controller respond to this command with a +. Check that the value has been accepted by sending ~RSBR. If a - is replied or if the value is different than the one entered, then the hardware and/or firmware does not support serial inverted and cannot be used with this circuit.

Send %EESAV from the console to store the new configuration to flash.

USB Configuration

USB is available on all Roboteq controller models and provides a fast and reliable communication method between the controller and the PC. After plugging the USB cable to the controller and the PC, the PC will detect the new hardware, and install the driver. Upon successful installation, the controller will be ready to use.

The controller will appear like another Serial device to the PC. This method was selected because of its simplicity, particularly when writing custom software: opening a COM port and exchanging serial data is a well documented technique in any programming language.

Note that Windows will assign a COM port number that is more or less random. The Roborun PC utility automatically scans all open COM ports and will detect the controller on its own. When writing your own software, you will need to account for this uncertainty in the COM port assignment.

Important Warning

Beware that because of its sophistication, the USB protocol is less likely to recover than RS232 should an electrical disturbance occur. We recommend using USB for configuration and monitoring, and use RS232 for field deployment. Deploy USB based system only after performing extensive testing and verifying that it operates reliably in your particular environment.

Command Priorities

The controller will respond to commands from one of three or four possible sources:

- Serial (RS232 or USB)
- Pulse
- Analog
- Spektrum Radio (when available)

One, two, three or all four command modes can be enabled at the same time. When multiple modes are enabled, the controller will select which mode to use based on a user selectable priority scheme. The priority mechanism is described in details in "Input Command Modes and Priorities" on page 73.

USB vs. Serial Communication Arbitration

Commands may arrive through the RS232 or the USB port at the same time. They are executed as they arrive in a first come first served manner. Commands that are arriving via USB are replied on USB. Commands arriving via the UART are replied on the UART. Redirection symbol for redirecting outputs to the other port exists (e.g. a command can be made respond on USB even though it arrived on RS232).

CAN Commands

Command arriving via CAN share the same priority as serial commands and may conflict with command arriving via serial or USB. CAN queries will not interfere with serial/USB operation.

Script-generated Commands

Commands that are issued from a user script are handled by the controller exactly as serial commands received via USB or RS232. Care must be taken that conflicting commands are not sent via the USB/serial at the same time that a different command is issued by the script.

Script commands are also subject to the serial Watchdog timer. Motors will be stopped and command input will switch according to the Priority table if the Watchdog timer is allowed to timeout.

Communication Protocol Description

The controller uses a simple communication protocol based on ASCII characters. Commands are not case sensitive. **?a** is the same as **?A**. Commands are terminated by carriage return (Hex 0x0d, '\r').

The underscore '_' character is interpreted by the controller as a carriage return. This alternate character is provided so that multiple commands can be easily concatenated inside a single string.

All other characters lower than 0x20 (space) have no effect.

Character Echo

The controller will echo back to the PC or Microcontroller every valid character it has received. If no echo is received, one of the following is occurring:

- echo has been disabled
- the controller is Off
- the controller may be defective

Command Acknowledgment

The controller will acknowledge commands in one of the two ways:

For commands that cause a reply, such as a configuration read or a speed or amps queries, the reply to the query must be considered as the command acknowledgment.

For commands where no reply is expected, such as speed setting, the controller will issue a "plus" character (**+**) followed by a Carriage Return after every command as an acknowledgment.

Command Error

If a command or query has been received, but is not recognized or accepted for any reason, the controller will issue a "minus" character (**-**) to indicate the error.

If the controller issues the "**-**" character, it should be assumed that the command was not recognized or lost and that it should be repeated.

Watchdog time-out

For applications demanding the highest operating safety, the controller should be configured to automatically switch to another command mode or to stop the motor (but otherwise remain fully active) if it fails to receive a valid command on its RS232 or USB ports, or from a MicroBasic Script for more than a predefined period.

By default, the watchdog is enabled with a timeout period of 1 second. Timeout period can be changed or the watchdog can be disabled by the user. When the watchdog is enabled and timeout expires, the controller will accept commands from the next source in the priority list. See Command Prioritieson page 154.

Controller Present Check

The controller will reply with an ASCII ACK character (0x06) anytime it receives a QRY character (0x05). This feature can be used to quickly scan a serial port and detect the presence, absence or disappearance of the controller. The QRY character can be sent at any time (even in the middle of a command) and has no effect at all on the controller's normal operation.

SECTION 15

CAN Networking on Roboteq Controllers

Some controller models are equipped with a standard CAN interface allowing up to 127 controllers to work together on a single twisted pair network at speeds up to 1Mbit/s.

Supported CAN Modes

Four CAN operating modes are available on Roboteq controllers:

1 - RawCAN
2 - MiniCAN
3 - CANopen
4 - RoboCAN

RawCAN is a low-level operating mode giving total read and write access to CAN frames. It is recommended for use in low data rate systems that do not obey to any specific standard. CAN frames are typically built and decoded using the MicroBasic scripting language.

MiniCAN is greatly simplified subset of CANopen, allowing, within limits, the integration of the controller into an existing CANopen network. This mode requires MicroBasic scripting to prepare and use the CAN data.

CANopen is the full Standard from CAN in Automation (CIA), based on the DS302 specification. It is the mode to use if full compliance with the CANopen standard is a primary requisite.

RoboCAN is a Roboteq proprietary meshed networking scheme allowing multiple Roboteq devices to operate together as a single system. This protocol is extremely simple and lean, yet practically limitless in its abilities. It is the preferred protocol to use by users who just wish to make multiple controllers work together with the minimal effort.

This section describes the RawCAN and MiniCAN modes.

Detailed descriptions of CANopen and RoboCAN can be found in specific sections of this manual.

Connecting to CAN bus

A CAN bus network is made of a stretch of two wires. A device can be put on a CANbus network by simply connecting it's CAN-High and CAN-Low lines to these of other devices on the network.

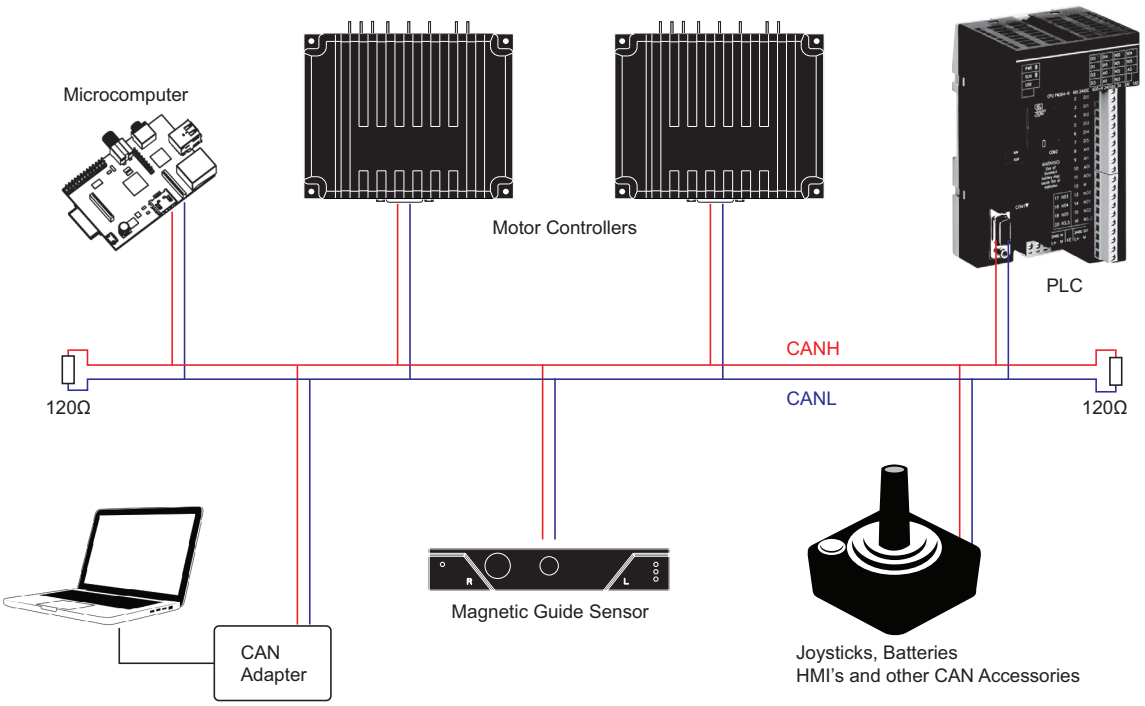


Figure 15-1: CAN Network topology

Resistors should be 120 ohm and located at each end of the cable. However, on a short network communication will take place with a single resistor of 100 to 200 ohm located anywhere on the network. Communication will not work if no resistor is present, or if its value is too high.

No ground connection is necessary in between nodes. However, the ground potential of each node must be within a few volts of each other. If all devices on the network are powered from the same power source, this can be expected to be the case.

CANbus will be operational upon enabling the desired CAN protocol and speed using the PC utility.

Important Warning

A ground difference up to around 10V is acceptable. A difference of 30V or higher can cause damage to one or more nodes. CANbus isolators must be used if a similar ground level cannot be guaranteed between nodes.

Introduction to CAN Hardware signaling

CANbus uses differential signals, which is where CAN derives its robust noise immunity and fault tolerance. The two signal lines of the bus, CANH and CANL, are biased to around 2.5 V. A logical "1" (also known as the dominant state) on the bus takes CANH around 1 V higher to around 3.5 V, and takes CANL around 1 V lower to 1.5 V, creating a typical 2V differential signal as shown in Figure 15-2.

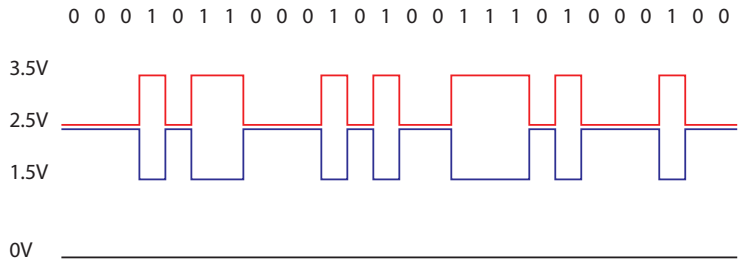


Figure 15-2: CANbus signaling

Differential signaling reduces noise coupling and allows for high signaling rates over twisted-pair cable. The High-Speed CANbus specifications (ISO 11898 Standard) are given for a maximum signaling rate of 1 Mbps with a bus length of 40 m with a maximum of 30 nodes. It also recommends a maximum unterminated stub length of 0.3 m.

CAN Bus Pinout

Depending on the controller model, the CAN signals are located on the 9-pin, 15-pin or 25-pin DSub connector. Refer to datasheet for details.

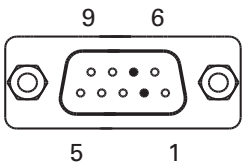


FIGURE 15-3. DB9.Connector pin locations

The pins on the DB9 connector are mapped as described in the table below.

TABLE 15-1. CAN Signals on DB9 connector

Pin Number	Signal	Description
2	CAN_L	CAN bus low
7	CAN_H	CAN bus high

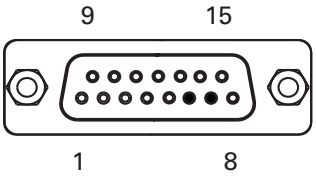


FIGURE 15-4. DB15 Connector pin locations

The pins on the DB15 connector are mapped as described in the table below.

TABLE 15-2. CAN Signals on DB15 connector

Pin Number	Signal	Description
6	CAN_L	CAN bus low
7	CAN_H	CAN bus high

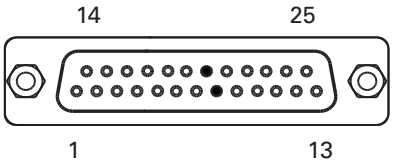


FIGURE 15-5. DB25 pin locations

The pins on the DB25 connector are mapped as described in the table below.

TABLE 15-3. CAN Signals od DB25 connector

Pin Number	Signal	Description
8	CAN_L	CAN bus low
20	CAN_H	CAN bus high

CAN and USB Limitations

On some controller models CAN and USB cannot operate at the same time. On controllers equipped with a USB connector, if simultaneous connection is not allowed, the controller will enable CAN if USB is not connected.

The controller will automatically enable USB and disable CAN as soon as the USB is connected to the PC. The CAN connection will then remain disabled until the controller is restarted with the USB unplugged.

See the controller model datasheet to verify whether simultaneous CAN and USB is supported.

Basic Setup and Troubleshooting

CANbus is very easy to setup: Simply connect the CANH and CANL to a pair of wires with at least one resistor somewhere along the cable. Enable the desired CAN protocol and speed using the PC utility.

If communication cannot be established, it can be difficult to determine the source of the problem. Here are a few ways to diagnose:

Cable polarity, integrity and termination resistor

Verify that the controller's CANH and CANL are connected to the CANH and CANL wire. Check cable continuity to every node. Verify the presence of a least one resistor and that its value is 120ohm (a value of 60 to 200 ohm would be acceptable)

Check CANbus activity using a voltmeter

The presence of CAN data traffic can be checked using a simple voltmeter and measuring the voltage between GND and CANH, and between GND and CANL. When CAN is disabled, both lines should have approximately the same voltage around 2.5V. When CAN is enabled with RoboCAN or MiniCAN protocol selected, the controller will send a continuous stream of data frames. This will cause the CANH voltage to rise above, and the CANL voltage to drop below, the 2.5V midpoint. If the idle and active voltages do not match the above, try again on the controller alone disconnected from the network but with a 100 to 200 ohm resistor across its CANH and CANL pins.

The CANOpen and RawCAN protocol should not be used for this test as these do not generate data traffic on their own and will not cause measurable voltage changes.

Check CANbus activity using a CAN sniffer

When working on a CAN system, it is highly recommended to make the acquisition of a USB to CAN adapter such as the PCAN-USB from Peak Systems. Connect the adapter to the CANH and CANL and run the sniffer software with the correct bit rate selected. The figure below shows the expected received data when a Roboteq device is on the network with MiniCAN protocol enabled.

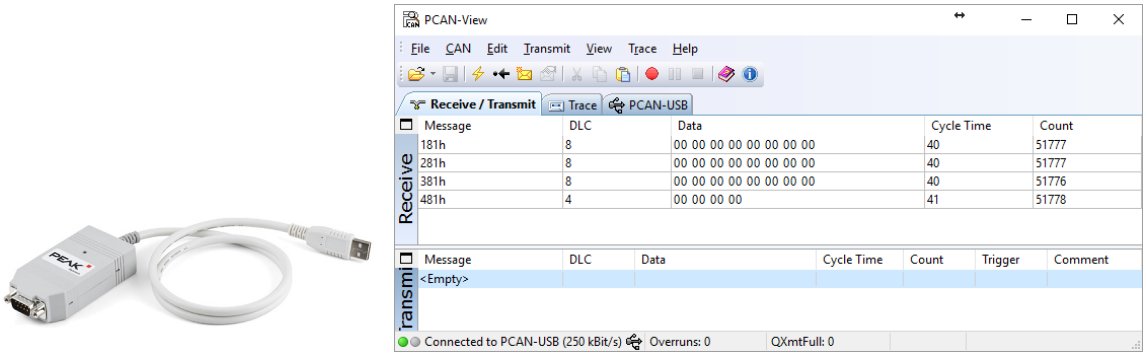


Figure 15-6 : USB to CAN adapter and MiniCAN frame capture

Mode Selection and Configuration

Mode selection is done using the CAN menu in the RoborunPlus PC utility.

Common Configurations

CAN Mode:	Used to select one of the 4 operating modes. Off disables all CAN receive and transmit capabilities.
Node ID:	CAN Node ID used for transmission from the controller. Value may be between 1 and 126 included.
Bit Rate:	Selectable bit rate. Available speeds are 1000, 800, 500, 250, and 125 kbit/s. Default is 125kbit and is the recommended speed for RawCAN and MiniCAN modes.
Heartbeat:	Period at which a Heartbeat frame is sent by the controller. The frame is CANopen compatible 0x700 + NodeID, with one data byte of value 0x05 (Status: Operational). The Heartbeat is sent in any of the selected modes. It can be disabled by entering a value of 0.

MiniCAN Configurations

ListenNodeID:	Filters to accept only packets sent by a specific node.
SendRate:	Period at which data frames are sent by the controller. Frames are structured as standard CANopen Transmit Process Data Objects (TPDOs). Transmission can be disabled by entering a value of 0.

RawCAN Configurations

In the RawCAN mode, incoming frames may be filtered or not by changing the ListenNodeID parameter that is shared with the MiniCAN mode. A value of 0 will capture all incoming frames and it will be up to the user to use the ones wanted. Any other value will cause the controller to capture only frames from that sender.

Using RawCAN Mode

In the RawCAN Mode, received unprocessed data packets can be read by the user. Likewise, the user can build a packet with any content and send it on the CAN network. A FIFO buffer will capture up to 16 frames.

CAN packets are essentially composed by a header and a data payload. The header is an 11 bit number that identifies the sender's address (bits 0 to 6) and a packet type (bits 7 to 10). Data payload can be 0 to 8 bytes long.

Checking Received Frames

Received frames are first loaded in the 16-frame FIFO buffer. Before a frame can be read, it is necessary to check if any frames are present in the buffer using the **?CF** query. The query can be sent from the serial/USB port, or from a MicroBasic script using the getvalue(_CF) function. The query will return the number of frames that are currently pending, and copy the oldest frame into the read buffer, from which it can then be accessed. Sending **?CF** again, copies the next frame into the read buffer.
The query usage is as follows:

Syntax: **?CF**

Reply: **CF**=number of frames pending

Reading Raw Received Frames

After a frame has been moved to the read buffer, the header, bytecount and data can be read with the **?CAN** query. The query can be sent from the serial/USB port, or from a MicroBasic script using the getvalue(_CAN, n) function. The query usage is as follows:

When the query is sent from serial or USB, without arguments, the controller replies by outputting all elements of the frame separated by colons.

Syntax: **?CAN [ee]**

Reply: **CAN**=header:bytecount:data0:data1: .... :data7

Where: **ee** = frame element
1 = header
2 = bytecount
3 to 10 = data0 to data7

Examples: Q: **?CAN**
R: **CAN=5:4:11:12:13:14:0:0:0:0**

Q: **?CAN 3**
R: **CAN=11**

Notes: Read the header to detect that a new frame has arrived. If header is different than 0, then a new frame has arrived and you may read the data.

After reading the header, its value will be 0 if read again, unless a new frame has arrived.

New CAN frames will not be received by the controller until a ?CAN query is sent to read the header or any other element.

Once the header is read, proceed to read the other elements of the received frame without delay to avoid data to be overwritten by a new arriving frame.

Transmitting Raw Frames

RawCAN Frames can easily be assembled and transmitted using the CAN Send Command !CS. This command can be used to enter the header, bytecount, and data, one element at a time. The frame is sent immediately after the bytecount is entered, and so it should be entered last.

Syntax: **!CS ee nn**

Where: **ee** = frame element
1 = header
2 = bytecount
3 to 10 = data0 to data7
nn = value

Examples:

!CS 1 5	Enter 5 in header
!CS 3 2	Enter 2 in Data 0
!CS 4 3	Enter 3 in Data 1
!CS 2 2	Enter 2 in bytecount. Send CAN data frame

Using MiniCAN Mode

MiniCAN is greatly simplified subset of CANopen. It only supports Heartbeat, and fixed map Received Process Data Objects (RPDOs) and Transmit Process Data Objects (TPDOs). It does not support Service Data Objects (SDOs), Network Management (NMT), SYNC or other objects.

Transmitting Data

In MiniCAN mode, data to be transmitted is placed in one of the controller's available Integer or Boolean User Variables. Variables can be written by the user from the serial/USB using !VAR for Integer Variables, or !B for Boolean Variables. They can also be written from MicroBasic scripts using the setcommand(_VAR, n) and setcommand(_B, n) functions. The value of these variables is then sent at a periodic rate inside four standard CANopen TPDO frames (TPDO1 to TPDO4). Each of the four TPDOs is sent in turn at the time period defined in the SendRate configuration parameter.

Header:

TPDO1: 0x180 + NodeID
TPDO2: 0x280 + NodeID
TPDO3: 0x380 + NodeID
TPDO4: 0x480 + NodeID

Data:

<table>
<tr><th></th><th>Byte1</th><th>Byte2</th><th>Byte3</th><th>Byte4</th><th>Byte5</th><th>Byte6</th><th>Byte7</th><th>Byte8</th></tr>
<tr><td>TPDO1</td><td colspan="4">VAR1</td><td colspan="4">VAR2</td></tr>
<tr><td>TPDO2</td><td colspan="4">VAR3</td><td colspan="4">VAR4</td></tr>
<tr><td>TPDO3</td><td colspan="2">VAR5</td><td colspan="2">VAR6</td><td colspan="2">VAR7</td><td colspan="2">VAR8</td></tr>
<tr><td>TPDO4</td><td>BVar 1-8</td><td>BVar 9-16</td><td>BVar 17-24</td><td>BVar 25-32</td><td colspan="4"></td></tr>
</table>

Byte and Bit Ordering:

Integer Variables are loaded into a frame with the Least Significant Byte first. Example 0x12345678 will appear in a frame as 0x78 0x56 0x34 0x12.

Boolean Variables are loaded in a frame as shown in the table above, with the lowest Boolean Variable occupying the least significant bit of each byte. Example Boolean Var 1 will appear in byte as 0x01.

Receiving Data

In MiniCAN mode, incoming frames headers are compared to the Listen Node ID number. If matched, and if the other 4 bits of the header identify the frame as a CANopen standard RPDO1 to RPDO4, then the data is parsed and stored in Integer or Boolean Variables according to the map below. The received data can then be read from the serial/USB using the ?VAR or ?B queries, or they can be read from a MicroBasic script using the getvalue(_VAR, n) or getvalue(_B, n) functions.

Header:

RPDO1: 0x200 + NodeID
RPDO2: 0x300 + NodeID
RPDO3: 0x400 + NodeID
RPDO4: 0x500 + NodeID

Data:

	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6	Byte7	Byte8
RPDO1	VAR9				VAR10			
RPDO2	VAR11				VAR12			
RPDO3	VAR13		VAR14		VAR15		VAR16	
RPDO4	BVar 33-40	BVar 41-48	BVar 49-56	BVar 57-64				

Byte and Bit Ordering:

Integer Variables are loaded from frame with the Least Significant Byte first. Example, a frame with data as 0x78 0x56 0x34 0x12 will load in an Integer Variable as 0x12345678.

Boolean Variables are loaded from a frame as shown in the table above, with the lowest Boolean Variable occupying the least significant bit of each byte. Example a received byte of 0x01 will set Boolean Var 33 and clear Vars 34 to 40.

MiniCAN Usage Example

MiniCAN can only be used with the addition of MicroBasic scripts that will give a meaning to the general variables in which the CAN data are stored. The following simple script uses VAR1 that is transported in RPDO1 as the incoming motor command and puts the Motor Amp VAR9 so that it is sent in TPDO1.

```
top:
speed = getvalue(_VAR, 9)
setcommand(_G, 1, speed)
motor_amp = getvalue(_A, 1)
setcommand(_VAR, 1, motor_amp)
wait(10)
goto top:
```

Note: This script does not check for loss of communication on the CAN bus. It is provided for information only.

SECTION 16

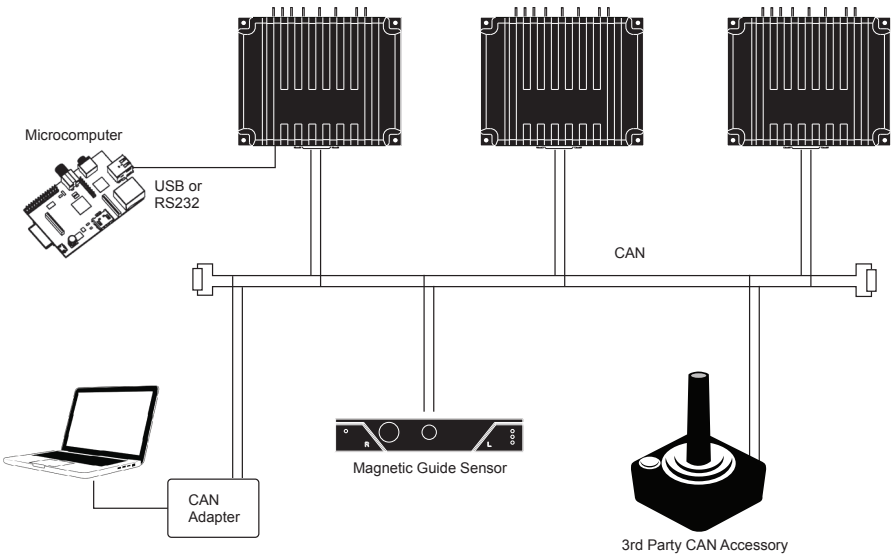
RoboCAN Networking

RoboCAN is a Roboteq proprietary meshed networking scheme allowing multiple Roboteq products to operate together as a single system. This protocol is extremely simple and lean, yet practically limitless in its abilities. It is the preferred protocol to use by user who just wish to make multiple controllers work together with the minimal effort.

In RoboCAN, every controller can send commands to, and can read operational data from, any other node on the network. One or more controller can act as a USB to CAN or Serial to CAN gateway, allowing several controllers to be thus managed from a single PC or microcomputer.

Using a small set of dedicated Microbasic function, scripts can be written to exchange data between controllers in order to create automation systems without the need for a PLC or external computer.

In addition, RoboCAN includes support for processing raw can data as defined in the RawCAN specification (See page 154), in order to incorporate simple CAN compatible 3rd party devices in the network.



Network Operation

RoboCAN requires only that a controller has a unique node number (other than 0) assigned and that the RoboCAN mode is selected and enabled. All nodes must be configured to operate at the same bit rate. Each enabled node will emit a special heartbeat at a set and unchangeable rate of 128ms so that each node can create and maintain a map of all nodes alive in the network.

RoboCAN via Serial & USB

Important notice: On many controller models, CAN and USB cannot be operated at the same time. Please see product datasheet to verify if this is the case on the model used. In case USB is not available, this section only applies to RS232 connections.

RoboCAN commands and queries can be sent from a USB or serial port using a modified syntax of the normal serial protocol: By simply adding the @ character followed by the node as a 2 digit hex address, a command or query is sent to the desired node. This scheme works with every Command (! Character), Query (?), Configuration setting (^), Configuration read (~), and most Maintenance commands (%)

Runtime Commands

Below is an Command example:

!G 1 500

This is the normal command for giving a 50% power level command to motor 1 of the controller that is attached to the computer.

@04!G 1 500

This will send the same 50% command to motor 1 of the controller at node address 4.

The reply to a local command is normally a + or - sign when a command is acknowledged or rejected in normal serial mode.

When a command is sent to a remote node, the reply is also a + or – sign. However, in addition, the reply can be a * sign to indicate that the destination node does not exist or is not alive. Note that the + sign only indicates that the command syntax is valid and that the destination node is alive.

Broadcast Command

Node address 00 is used to broadcast a command simultaneously to all the nodes in the network. For example

@00!G 1 500

Will apply 50% power to all motor 1 at all nodes, including the local node

Realtime Queries

Queries are handled the same way but the reply to a query includes the responding node's address. Below is a Query example:

?V 2

This is the normal query for reading the battery voltage of the local controller. The controller will reply V=123

@04?V 2

This will send the same query to node address 4

The reply of the remote node is @04 V=123

Replies to remote nodes queries are identical to these to a local controller with the exception of an added latency. Since the reply must be retrieved from the remote node depending on the selected bit rate, the reply may come up to 10ms after the query was sent.

Remote Queries restrictions

Remote queries can only return a single value whereas local queries can be used to read an array of values. For example

?AI

Is a local query that will return the values of all analog capture channels in a single string as

AI=123:234:345:567

@04?AI

Is a remote query and it will return only the first analog capture channel as

@04 AI=123

Remote queries are not being added in the Query history.

Broadcast remote queries are not supported. For example @00?V 1 will not be executed.

Queries that return strings, such as ?FID or ?TRN are not supported. They will return the value 0

See the Command Reference section in the manual for the complete list and description of available queries

Configurations Read/Writes

Configuration settings, like Amp Limit or Operating Modes can be read and changed on a remote node via the CAN bus. For example

@04^ALIM 1 250 will set the current limit of channel 1 of node 4 at 25.0A

@04~OVL will read the Overvoltage limit of node 4.

Note that changing a configuration via CAN only makes that change temporary until the remote controller is powered down. The %EESAV maintenance command must be send to the remote node to make the configuration change permanent.

A configuration write can be broadcast to all nodes simultaneously by using the node Id 00. For example

@00^OVL 250

Will set the overvoltage limit of all nodes at 25.0 Volts

Configuration reads cannot be broadcast.

See the Commands Reference section for the complete list and description of available configurations

Remote Configurations Read restrictions

Remote Configuration Reads can only return a single value whereas local Configuration Reads can be used to read an array of parameters. For example

~AMOD

Will return the operating mode of all analog capture channels in a single string as

AI=01:01:00:01:02

@04~AMOD

Will return only the mode first analog capture channel as

@04 AI=01

Configuration reads cannot be broadcast.

Remote Maintenance Commands

Maintenance Commands are not supported in RoboCAN.

Self Addressed Commands and Queries

For sake of consistency commands sent to the local node number are executed the same way as they would be on a remote node. However the no CAN frame is sent to the network. For example if node 04 receive the command

@04!G 1 500

No data will be sent on the network and it will be interpreted and executed the same way as

!G 1 500

RoboCAN via MicroBasic Scripting

A set of functions have been added to the MicroBasic language in order to easily send commands to, and read data from any other node on the network. Functions are also available to read and write configurations at a remote node. Maintenance commands are not supported.

Sending Commands and Configuration

Sending commands or configuration values is done using the functions

SetCANCommand(id, cc, ch, vv)

SetCANConfig(id, cc, ch, vv).

Where:

id is the remote Node Id in decimal

cc is the Command code, eg _G

ch is the channel number. Put 1 for commands that do not normally require a channel number

vv is the value

Example:

SetCANCommand(04, _G, 1, 500)

Will apply 50% power to motor 1 of node 4

SetCANConfig(0, _OVL, 1, 250)

Will set the overvoltage limit of all nodes to 25.0V. Note that even though the Overvoltage is set for the controller and does not normally require that a Channel, the value 1 must be put in order for the instruction to compile.

Script execution is not paused when one of these function is used. The frame is sent on the CAN network within one millisecond of the function call.

Reading Operating values Configurations

When reading an operating value such as Current Counter or Amps, or a configurations such as Overvoltage Limit from another node, since the data must be fetched from the network, and in order to avoid forcing a pausing of the script execution, data is accessed in the following manner:

1. Send a request to fetch the node data
2. Wait for data to be received
3. Read the data

The wait step can be done using one of the 3 following ways

1. Pause script execution for a few milliseconds using a wait() instruction in line.
2. Perform other functions and read the results a number of loop cycles later
3. Monitor a data ready flag

The following functions are available in microbasic for requesting operating values and configurations from a remote node.

FetchCANValue(id, cc, ch)

FetchCANConfig(id, cc, ch)

Where:

id is the remote Node Id in decimal
cc is the Command code, eg _G
cc is the channel number. Put 1 for commands that do not normally require a channel number

The following functions can be used to wait for the data to be ready for reading:

IsCANValueReady()

IsCANConfigReady()

These functions return a Boolean true/false value. They take no argument and apply to the last issued FetchCANValue or FetchCANConfig function

The retrieved value can then be read using the following functions:

ReadCANValue()

ReadCANConfig()

These functions return an integer value. They take no argument and apply to the last issued FetchCANValue or FetchCANConfig function

Below is a sample script that continuously reads and print the counter value of node 4

```
top:
FetchCANValue(4, _C, 1) ' request data from remote node
while(IsCANValueReady = false) ' wait until data is received
end while
Counter = ReadCANValue() ' read value
print (Counter, "\r") ' print value followed by new line
goto top ' repeat forever
```

Continuous Scan

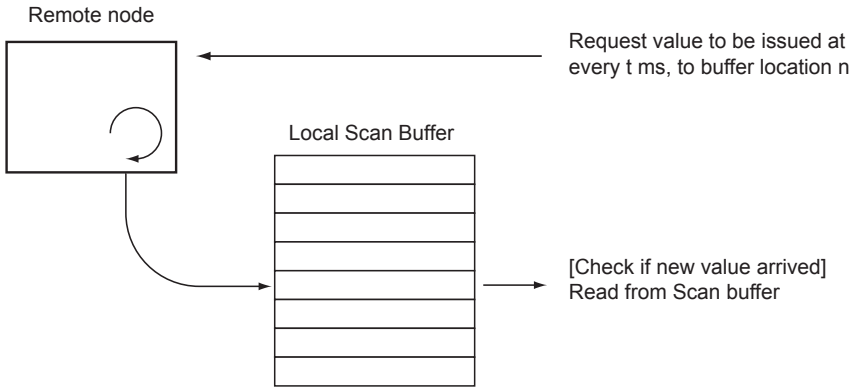
In many applications, it is necessary to monitor the value of an operating parameter on a remote node. A typical example would be reading continuously the value of a counter. In order to improve efficiency and reduce overhead, a technique is implemented to automatically scan a desired parameter from a given node, and make the value available for reading without the need to send a Fetch command.

A function is provided to initiate the automatic sending of a value from the remote node, at a specific periodic rate, and to be stored to user selected location in a receive buffer.

The remote node will then send the data continuously without further commands.

A function is then provided to detect the arrival of a new value in that buffer location, and another to read the value from that location.

Since the scan rate is known, the execution of the script can be timed so that it is not necessary to check the arrival of a new value.



A scan is initiated with the function:

ScanCANValue(id, cc, ch, tt, bb)

Where:

id is the remote Node Id in decimal

cc is the Query code, eg _V

ch is the channel number. Put 1 for queries that do not normally require a channel number

tt is the scan rate in ms

bb is the buffer location

The scan rate can be up to 255ms. Setting a scan rate of 0 stops the automatic sending from this node.

Unless otherwise specified, the buffer can store up to 32 values.

The arrival of a new value is checked with the function

IsScannedCANReady(aa)

Where

aa is the location in the scan buffer.

The function returns a Boolean true/false value

The new value is then read with the function

ReadScannedCANValue(aa)

Where

aa is the location in the scan buffer.

The function returns an integer value. If no new value was received since the previous read, the old value will be read.

The following example shows the use of the Scan functions

```
' Initiate scan of counter every 10ms from node 4 and store to
buffer location 0
ScanCANValue(4, _C, 1, 10, 0)
' initiate scan of voltage every 100ms from node 4 and store to
buffer location 1
ScanCANValue(5, _V, 1, 100, 1)

top:

wait(10) ' Executer loop every 10 ms

' check if scanned volts arrived
if(IsScannedCANReady(1))
   ' read and print volts
   Volts = ReadScannedCANValue(1)
   print (Volts,"\r")
end if

' No need to check if counter is ready since scan rate = loop cy-
cle
Counter = ReadScannedCANValue(0)
print (Counter,"\r")

goto top ' Loop continuously
```

Checking the presence of a Node

No error is reported in MicroBasic if an exchange is initiated with a node that does not exist. A command or configuration sent to a non-existent node will simply not be executed. A query sent to a non existing or dead node will return the value 0. A function is therefore provided for verifying the presence of a live node. A live node is one that sends the distinct RoboCAN heartbeat frame every 128ms. The function syntax is:

IsCANNodeAlive(id)

Where:

id is the remote Node Id in decimal
The function returns a Boolean true/false value.

Self Addressed Commands and Queries

Functions addressed to the local node have no effect. The following function **will not work** if executed on node 4

SetCANCommand(04, _G, 1, 500)

The regular function must be used instead

SetCommand(_G, 1, 500)

Broadcast Command

Node address 00 is used to broadcast a command, or a configuration write simultaneously to all the nodes in the network.

The local node, however, will not be reached by the broadcast command.

Remote MicroBasic Script Download

RoboCAN includes a mechanism for loading MicroBasic scripts into any node in the network. Use the "To Remote" button in the Scripting Tab of the Roborun PC utility. A window will pop-up asking for the destination node Id. Details of the command used to enter the download mode and transferring scripts is outside the scope of this manual.

SECTION 17

CANopen Interface

This section describes the configuration of the CANopen communication protocol and the commands accepted by the controller using the CANopen protocol. It will help you to enable CANopen on your Roboteq controller, configure CAN communication parameters, and ensure efficient operation in CANopen mode.

The section contains CANopen information specific to Roboteq controllers. Detailed information on the physical CAN layer and CANopen protocol can be found in the DS301 documentation.

Use and benefits of CANopen

CANopen protocol allows multiple controllers to be connected into an extensible unified network. Its flexible configuration capabilities offer easy access to exposed device parameters and real-time automatic (cyclic or event-driven) data transfer.

The benefits of CANopen include:

- Standardized in EN50325-4
- Widely supported and vendor independent
- Highly extensible
- Offers flexible structure (can be used in a wide variety of application areas)
- Suitable for decentralized architectures
- Wide support of CANopen monitoring tools and solutions

CAN Connection

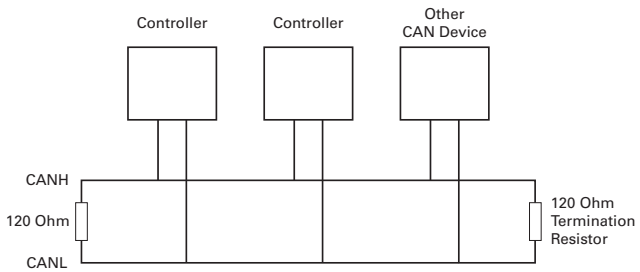


FIGURE 17-1. CAN connection

Connection to a CAN bus is as simple as shown on the diagram above. 120 Ohm Termination Resistors must be inserted at both ends of the bus cable. CAN network can be up to 1000m long. See CAN specifications for maximum length at the various bit rates.

CAN Bus Configuration

To configure communication parameters via the RoborunPlus PC utility, your controller must be connected to a PC via an RS232/USB port

Use the CAN menu in the Configuration tab in order to enable the CANopen mode. Additionally, the utility can be used to configure the following parameters:

- Node ID
- Bit rate
- Heartbeat (ms)
- Autostart
- TPDO Enable and Send rate

Node ID

Every CANopen network device must have a unique Node ID, between 1 and 127. The value of 0 is used for broadcast messaging and cannot be assigned to a network node.

Bit Rate

The CAN bus supports bit rates ranging from 10Kbps to 1Mbps. The default rate used in the current CANopen implementation is set to 125kbps. Valid bit bates supported by the controller are:

- 1000K
- 800K
- 500K
- 250K
- 125K

Heartbeat

A heartbeat message is sent to the bus in millisecond intervals. Heartbeats are useful for detecting the presence or absence of a node on the network. The default value is set to 1000ms.

Autostart

When autostart is enabled, the controller automatically enters the Operational Mode of CANopen. The controller autostart is enabled by default. Disabling the parameter will prevent the controller from starting automatically after the reset occurs. When disabled, the controller can only be enabled when receiving a CANopen management command.

Commands Accessible via CANopen

Practically all of the controller's real-time queries and real-time commands that can be accessed via Serial/USB communication can also be accessed via CANopen. The meaning, effect, range, and use of these commands is explained in detail in Commands Reference section of the manual.
All supported commands are mapped in a table, or Object Dictionary that is compliant with the CANopen specification. See "Object Dictionary" on page 181 for a complete set of commands.

CANopen Message Types

The controller operating in the CANopen mode can accept the following types of messages:

- Service Data Objects, or SDO messages to read/write parameter values
- Process Data Objects, or PDO mapped messages to automatically transmit parameters and/or accept commands at runtime
- Network Management, or NMT as defined in the CANopen specification

Service Data Object (SDO) Read/Write Messages

Runtime queries and runtime commands can be sent to the controller in real-time using the expedited SDO messages.

SDO messages provide generic access to Object Dictionary and can be used for obtaining parameter values on an irregular basis due to the excessive network traffic that is generated with each SDO request and response message.

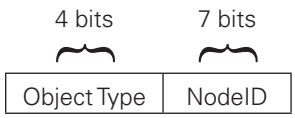
The list of commands accessible with SDO messages can be found in the "Object Dictionary" on page 181.

Transmit Process Data Object (TPDO) Messages

Transmit PDO (TPDO) messages are one of the two types of PDO messages that are used during operation.

TPDOs are runtime operating parameters that are sent automatically on a periodic basis from the controller to one or multiple nodes. TPDOs do not alter object data; they only read internal controller values and transmit them to the CAN bus.

TPDOs are identified on a CANopen network by the bit pattern in the 11-bit header of the CAN frame.



TPDO1: 0x180 + Node ID
TPDO2: 0x280 + Node ID
TPDO3: 0x380 + Node ID
TPDO4: 0x480 + Node ID

CANopen allows up to four TPDOs for any node ID. Unless otherwise specified in the product datasheet, TPDO1 to TPDO4 are used to transmit up to 8 user variables which may be loaded with any operating parameters using MicroBasic scripting.

Each of the 4 TPDOs can be configured to be sent at user-defined periodic intervals. This is done using the CTPS parameter (See "CTPS - CANOpen TPDO Send Rate" on page 363).

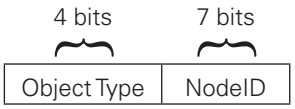
TABLE 17-1. Commands mapped on TPDOs

TPDO	Object Index-Sub	Size	Object Mapped
TPDO1	0x2106-1	S32	User VAR 1
	0x2106-2		User VAR 2
TPDO2	0x2106-3	S32	User VAR 3
	0x2106-4		User VAR 4
TPDO3	0x2106-5	S32	User VAR 5
	0x2106-6		User VAR 6
TPDO4	0x2106-7	S32	User VAR 7
	0x2106-8		User VAR 8
S32: signed 32-bit word			

Receive Process Data Object (RPDO) Messages

RPDOs are configured to capture runtime data destined to the controller.

RPDOs are CAN frames identified by their 11-bit header.



RPDO1: 0x200 + Node ID
RPDO2: 0x300 + Node ID
RPDO3: 0x400 + Node ID
RPDO4: 0x500 + Node ID

Roboteq CANopen implementation supports RPDOs. Unless otherwise specified in the product's datasheet, data received using RPDOs are stored in 8 user variables from where they can be processed using MicroBasic scripting.

TABLE 17-2. Commands mapped on RPDOs

RPDO	Object Index-Sub	Size	Object Mapped
RPDO1	0x2005-9	S32	User VAR 9
	0x2005-10		User VAR 10
RPDO2	0x2005-11	S32	User VAR 11
	0x2005-12		User VAR 12
RPDO3	0x2005-13	S32	User VAR 13
	0x2005-14		User VAR 14
RPDO4	0x2005-15	S32	User VAR 15
	0x2005-16		User VAR 16
S32: signed 32-bit word			

Object Dictionary

The CANopen dictionary shown in this section is subject to change. The CANopen EDS file can be downloaded from the roboteq web site.

The Object Dictionary given in the table below contains the runtime queries and runtime commands that can be accessed with SDO/PDO messages during controller operation.

TABLE 17-3. Motor Controllers Object Dictionary

Index	Sub (Hex)	Entry Name	Data Type & Access	Command Name
Runtime Commands				
0x2000	01	Set Motor Command, ch1	CG	CANGO
	02	Set Motor Command, ch2		
0x2001	01 to mm (1)	Set Position, ch.1	S32 WO	P
0x2002	01 to mm (1)	Set Velocity	S16 WO	S
0x2003	01 to ee (2)	Set Encoder Counter	S32 WO	C
0x2004	01 to mm (1)	Set Brushless Counter	S32 WO	CB
0x2005	01 -vv (3)	Set User Integer Variable	S32 WO	VAR
0x2006	01 to mm (1)	Set Acceleration	S32 WO	AC
0x2007	01 to mm (1)	Set Deceleration	S32 WO	DC
0x2008	00	Set All Digital Out bits	U8 WO	DS
0x2009	00	Set Individual Digital Out bits	U8 WO	D1
0x200A	00	Reset Individual Digital Out bits	U8 WO	D0
0x200B	01 to ee (2)	Load Home Counter	U8 WO	H
0x200C	00	Emergency Shutdown	U8 WO	EX
0x200D	00	Release Shutdown	U8 WO	MG
0x200E	00	Stop in all modes	U8 WO	MS
0x200F	01 to mm (1)	Set Pos Relative	S32 WO	PR
0x2010	01 to mm (1)	Set Next Pos Absolute	S32 WO	PX
0x2011	01 to mm (1)	Set Next Pos Relative	S32 WO	PRX
0x2012	01 to mm (1)	Set Next Acceleration	S32 WO	AX
0x2013	01 to mm (1)	Set Next Deceleration	S32 WO	DX
0x2014	01 to mm (1)	Set Next Velocity	S32 WO	SX
0x2015	01 to bb (4)	Set User Bool Variable	S32 WO	B
0x2017	00	Save Config to Flash	U8 WO	EES
Runtime Queries				
0x2100	01	Read Motor Amps	S16 RO	A
0x2101	01 to mm (1)	Read Actual Motor Command	S16 RO	M
0x2102	01 to mm (1)	Read Applied Power Level	S16 RO	P
0x2103	01 to ee (2)	Read Encoder Motor Speed, ch.1	S16 RO	S

TABLE 17-3. Motor Controllers Object Dictionary

Index	Sub	Entry Name	Data Type & Access	Command Name
0x2104	01 to ee (2)	Read Absolute Encoder Count	S32 RO	C
0x2105	01 to mm (1)	Read Absolute Brushless Counter	S32 RO	CB
0x2106	01 to vv (3)	Read User Integer Variable 1	S32 RO	VAR
0x2107	01 to ee (2)	Read Encoder Motor Speed as 1/1000 of Max	S16 RO	SR
0x2108	01 to ee (2)	Read Encoder Count Relative	S32 RO	CR
0x2109	01 to mm (1)	Read Brushless Count Relative	S32 RO	CBR
0x210A	01 to mm (1)	Read BL Motor Speed in RPM	S16 RO	BS
0x210B	01 to mm (1)	Read BL Motor Speed as 1/1000 of Max	S16 RO	BSR
0x210C	01 to mm (1)	Read Battery Amps	S16 RO	BA
0x210D	01 to 03	Read VInt, VBat, 5VOut	U16 RO	V
0x210E	00	Read All Digital Inputs	U32 RO	D
0x210F	01 to tt+1 (5)	Read MCU and Transistor temperature	S8 RO	T
0x2110	01 to mm (1)	Read Feedback	S16 RO	F
0x2111	00	Read Status Flags	U8 RO	FS
0x2112	00	Read Fault Flags	U8 RO	FF
0x2113	00	Read Current Digital Outputs	U8 RO	DO
0x2114	01 to mm (1)	Read Closed Loop Error	S32 RO	E
0x2115	01 to bb (4)	Read User Bool Variable	S32 RO	B
0x2116	01 to mm (1)	Read Internal Serial Command	S32 RO	CIS
0x2117	01 to mm (1)	Read Internal Analog Command	S32 RO	CIA
0x2118	01 to mm (1)	Read Internal Pulse Command	S32 RO	CIP
0x2119	00	Read Time	U32 RO	TM
0x211A	01 to 06	Read Spektrum Radio Capture	U16 RO	K
0x211B	01 to 06	Destination Pos Reached flag	U8 RO	DR
0x211D	01 to ss (9)	Read Magsensor Track Detect	U8 RO	MGD
0x211E	01 to ss*3 (9)	Read Magsensor Track Position,	U8 RO	MGT
0x211F	01 to ss*3 (9)	Read Magsensor Markers	U8 RO	MGM
0x2120	01 to ss (9)	Read Magsensor Status	U16 RO	MGS
0x2121	01 to ss (9)	Read Magsensor Gyroscope	S16 RO	MGY
0x2122	01 to mm (1)	Read Motor Status Flags	U16 RO	FM
0x2123	01 to mm (1)	Read Hall Sensor States	U8 RO	HS
0x6400	01 to dd (6)	Read Individual Digital Input	S32 RO	DI
0x2121	01 to 03	Read Magsensor Gyroscope	S16 RO	MGY
0x2122	01 to mm (1)	Read Motor Status Flags	U16 RO	FM
0x2123	01 to mm (1)	Read Hall Sensor States	U8 RO	HS
0x2125	01 to mm (1)	Read Destination Tracking	S32 RO	TR

TABLE 17-3. Motor Controllers Object Dictionary

Index	Sub	Entry Name	Data Type & Access	Command Name
0x2132	01 to mm (1)	Read Rotor Angle	S16 RO	ANG
0x2135	01 to mm (1)	Read FOC Angle Correction	S16 RO	FC
0x2136	01 to mm(1)	Read Slip	S16 RO	SL
0x6401	01 to aa (7)	Read Analog Input	S16 RO	AI
0x6402	01 to aa (7)	Read Analog Input Converted	S16 RO	AIC
0x6403	01 to pp (8)	Read Pulse Input	S16 RO	PI
0x6404	01 to pp (8)	Read Pulse Input Converted	S16 RO	PIC

Notes: Product-specific parameters. See datasheet
(1) mm: Max number of motors
(2) ee: Max number of encoders
(3) vv: Max number of user integer variables
(4) bb: Max number of user boolean variables
(5) tt: Number of internal temperature sensors
(6) dd: Number of digital inputs
(7) aa: Number of analog inputs
(8) pp: Number of pulse inputs
(9) ss: Max number of Magsensors supported

SDO Construction Details

CANOpen SDO frames can easily be created manually and used to send commands and queries to a Roboteq device. The directives below are a simplified description of the CANOpen SDO mechanism. For more details please advise the CANOpen standard.

A CANOpen command/query towards a Roboteq device can be analyzed as shown below:

		Payload					
		Byte0					
Header	DLC	bits 4-7	bits2-3	bits0-1	Byte1-2	Byte 3	Bytes4-7
0x600+nd	8	css	n	xx	index	subindex	data

- nd is the destination node id.
- ccs is the Client Command Specifier, if 2 it is command if 4 it is query.
- n is the Number of bytes in the data part, which do not contain data
- xx not necessary for basic operation. For more details advise CANOpen standard.
- index is the object dictionary index of the data to be accessed
- subindex is the subindex of the object dictionary variable
- data contains the data to be uploaded.

The Response from the roboteq device is as shown below:

Header	DLC	Payload					
		Byte0			Byte1-2	Byte 3	Bytes4-7
		bits 4-7	bits2-3	bits0-1			
0x580+nd	8	css	n	xx	index	subindex	Data

- nd is the source node id.
- ccs is the Client Command Specifier, if 4 it is query response, 6 it is a successful response to command, 8 is an error in message received.
- n is the Number of bytes in the data part, which do not contain data
- xx not necessary for the simplistic way. For more details advise CANOpen standard.
- index is the object dictionary index of the data to be accessed.
- subindex is the subindex of the object dictionary variable
- data contains the data to be uploaded. Applicable only if css=4.

SDO Example 1: Set Encoder Counter 2 (C) of node 1 value 10

- nd = 1, since the destination's node id is 1.
- ccs = 2, since it is a command.
- n = 0 since all 4 bytes of the data are used (signed32).
- index = 0x2003 and subindex = 0x02 according to object dictionary.

Header	DLC	Payload					
		Byte0			Byte1-2	Byte 3	Bytes4-7
		bits 4-7	bits2-3	bits0-1			
0x600+1	8	2	0	0	0x2003	0x02	0x0A
601h	8	20			03 20	02	0A 00 00 00

The respective response will be:

Header	DLC	Payload					
		Byte0			Byte1-2	Byte 3	Bytes4-7
		bits 4-7	bits2-3	bits0-1			
0x580+1	8	6	0	0	0x2003	0x02	0x00
581h	8	60			03 20	02	00 00 00 00

SDO Example 2: Activate emergency shutdown (EX) for node 12

- nd = 12, since the destination's node id is 12.
- ccs = 2, since it is a command.
- n = 3 since only one byte of the data is used (unsigned8).
- index = 0x200C and subindex = 0x00 according to object dictionary.

TABLE 17-4. Magnetic Guide Sensor Object Dictionary

Header	DLC	Payload					
		Byte0			Byte1-2	Byte 3	Bytes4-7
		bits 4-7	bits2-3	bits0-1			
0x600+12	8	2	3	0	0x200C	0x00	0x01
601Ch	8	2C			0C 20	00	01 00 00 00

The respective response will be:

Header	DLC	Payload					
		Byte0			Byte1-2	Byte 3	Bytes4-7
		bits 4-7	bits2-3	bits0-1			
0x580+1	8	6	0	0	0x200C	0x00	0x00
58Ch	8	60			0C 20	00	00 00 00 00

SDO Example 3: Read Battery Volts (V) of node 1.

- nd = 1, since the destination's node id is 1.
- ccs = 4, since it is a query.
- n = 2 since 2 bytes of the data are used (unsigned16).
- index = 0x210D and subindex = 0x02 according to object dictionary.

Header	DLC	Payload					
		Byte0			Byte1-2	Byte 3	Bytes4-7
		bits 4-7	bits2-3	bits0-1			
0x600+1	8	4	2	0	0x210D	0x02	0x00
601h	8	48			0D 21	02	0A 00 00 00

The respective response will be:

- nd = 1, since the source node id is 1.
- ccs = 4, since it is a query response.
- n = 2 since 2 bytes of the data are used (unsigned16).
- index = 0x210D and subindex = 0x02 according to object dictionary.
- data = 0x190 = 400 = 40 Volts.

Header	DLC	Payload					
		Byte0			Byte1-2	Byte 3	Bytes4-7
		bits 4-7	bits2-3	bits0-1			
0x580+1	8	4	2	xx	0x210D	0x02	0x190
581h	8	48			0D 21	02	90 01 00 00

SECTION 18

MicroBasic Scripting

One of the Roboteq products' most powerful and innovative features is their ability for the user to write programs that are permanently saved into, and run from the device's Flash Memory. This capability is the equivalent, for example, of combining the motor controller functionality and this of a PLC or Single Board Computer directly into the controller. Script can be simple or elaborate, and can be used for various purposes:

- **Complex sequences:**
  MicroBasic Scripts can be written to chain motion sequences based on the status of analog/digital inputs, motor position, or other measured parameters. For example, motors can be made to move to different count values based on the status of pushbuttons and the reaching of switches on the path.
- **Adapt parameters at runtime**
  MicroBasic Scripts can read and write most of the controller's configuration settings at runtime. For example, the Amps limit can be made to change during operation based on the measured heatsink temperature.
- **Create new functions**
  Scripting can be used for adding functions or operating modes that may be needed for a given application. For example, a script can compute the motor power by multiplying the measured Amps by the measured battery Voltage, and regularly send the result via the serial port for Telemetry purposes.
- **Autonomous operation**
  MicroBasic Scripts can be written to perform fully autonomous operations. For example the complete functionality of a line following robot can easily be written and fitted into the controller.

Script Structure and Possibilities

Scripts are written in a Basic-Like computer language. Because of its literal syntax that is very close to the every-day written English, this language is very easy to learn and simple scripts can be written in minutes. The MicroBasic scripting language also includes support for structured programming, allowing fairly sophisticated programs to be written. Several shortcuts borrowed from the C-language (++, +=, …) are also included in the scripting language and may be optionally used to write shorter programs.

The complete details on the language can be found in the MicroBasic Language Reference on page 195.

Source Program and Bytecodes

Programs written in this Basic-like language are interpreted into an intermediate string of Bytecode instructions that are then downloaded and executed in the controller. This two-step structure ensures that only useful information is stored in the controller and results in significantly higher performance execution over systems that interpret Basic code directly. This structure is for the most part entirely invisible to the programmer as the source editing is the only thing that is visible on the PC, and the translation and done in the background just prior to downloading to the controller.

Depending on the product, programs can be from 8192 to 32768 Bytecodes long. This translates to approximately 1500 to 6000 lines of MicroBasic source.

Variables Types and Storage

Scripts can store signed 32-bit integer variables and Boolean variable. Integer variables can handle values up to +/– 2,147,483,647. Boolean variables only contain a True or False state. The language also supports single dimensional arrays of integers and Boolean variables.

In total, up to 1024 or 4096 (depending on the product) Integer variables and up to 1024 Boolean variables can be stored in the controller. An array of n variables will take the storage space of n variables.

The language only works with Integer or Boolean values. It is not possible to store or manipulate decimal values. This constraint results in more efficient memory usage and faster script execution. This constraint is usually not a limitation as it is generally sufficient to work with smaller units (e.g. millivolts instead of Volts, or milliamps instead of Amps) to achieve the same precision as when working with decimals.

The language does not support String variables and does not have string manipulation functions. Basic string support is provided for the Print command.

Variable content after Reset

All integer variables are reset to 0 and all Boolean variables are reset to False after the controller is powered up or reset. When using a variable for the first time in a script, its value can be considered as 0 without the need to initialize it. Integer and Boolean variables are also reset whenever a new script is loaded.

When pausing and resuming a script, all variables keep the values they had at the time the script was paused.

Controller Hardware Read and Write Functions

The MicroBasic scripting language includes special functions for reading and writing configuration parameters. Most configuration parameters that can be read and changed using the Configuration Tab in the Roborun PC utility or using the Configuration serial commands, can be read and changed from within a script. The GetConfig and SetConfig functions are used for this purpose.

The GetValue function is available for reading real-time operating parameters such as Analog/Digital input status, Amps, Speed or Temperature.

The SetCommand function is used to send motor commands or to activate the Digital Outputs. Practically all controller parameters can be access using these 4 commands, typically by adding the command name as defined in the Serial (RS232/USB) Operation on page 141 preceded with the "_" character. For example, reading the Amps limit configuration for channel 1 is done using getvalue(_ALIM, 1).

See the MicroBasic Language Reference on page 143 for details on these functions and how to use them.

Timers and Wait

The language supports four 32-bit Timer registers. Timers are counters that can be loaded with a value using a script command. The timers are then counting down every millisecond independently of the script execution status. Functions are included in the language to load a timer, read its current count value, pause/resume count, and check if it has reached 0. Timers are very useful for implementing time-based motion sequences.

A wait function is implemented for suspending script execution for a set amount of time. When such an instruction is encountered, script execution immediately stops and no more time is allocated to script execution until the specified amounts of milliseconds have elapsed. Script execution resumes at the instruction that follows the wait.

Execution Time Slot and Execution Speed

MicroBasic scripts are executed in the free time that is available every 1ms, after the controller has completed all its motion control processing. The available time can therefore vary depending on the functions that are enabled or disabled in the controller configuration. For example more time is available for scripting if the controller is handling a single motor in open loop than if two motors are operated in closed loop with encoders. At the end of the allocated time, the script execution is suspended, motor control functions are performed, and scripts resumed. An execution speed averaging 50,000 lines of MicroBasic code, or higher, per second can be expected in most cases.

Protections

No protection against user error is performed at execution time. For example, writing or reading in an array variable with an index value that is beyond the 1024 or 4096 variables available in the controller may cause malfunction or system crash. Nesting more than 64 levels of subroutines (i.e. subroutines called from subroutines, …) will also cause potential problems. It is up to the programmer to carefully check the script's behavior in all conditions.

Print Command Restrictions

A print function is available in the language for outputting script results onto the serial or USB port. Since script execution is very fast, it is easy to send more data to the serial or USB port than can actually be output physically by these ports. The print command is therefore limited to 32 characters per 1ms time slot. Printing longer strings will force a 1ms pause to be inserted in the program execution every 32 characters and/or loss of characters.

Editing, Building, Simulating and Executing Scripts

Editing Scripts

An editor is available for scripting in the RoborunPlus PC utility. See Scripting Tab on page 368 (Roborun scripting) for details on how to launch and operate the editor.

The edit window resembles this of a typical IDE editor with, most noticeably, changes in the fonts and colors depending on the type of entry that is recognized as it is entered. This capability makes code easier to read and provides a first level of error checking.

Code is entered as free-form text with no restriction in term of length, indents use, or other.

Building Scripts

Building is the process of converting the Basic source code in the intermediate Bytecode language that is understood by the controller. This step is nearly instantaneous and normally transparent to the user, unless errors are detected in the program.

Build is called automatically when clicking on the "Download to Device" or "Simulate" buttons.

Building can be called independently by clicking on the "Build" button. This step is normally not necessary but it can be useful in order to compare the memory usage efficiency of one script compared to another.

Simulating Scripts

Scripts can be ran directly on the PC in simulation mode. Clicking on the Simulate button will cause the script to be built and launch a simulator in which the code is executed. This feature is useful for writing, testing and debugging scripts. The simulator works exactly the same way as the controller with the following exceptions.

- Execution speed is different.
- Controller configurations and operating parameters are not accessible from the simulator
- Controller commands cannot be sent from the simulator
- The four Timers operate differently in the simulator
- RoboCAN commands and queries have no effect

In the simulator, any attempt to read a Controller configuration (example Amps limit) or a Controller Runtime parameter (e.g. Volts, Temperature) will cause a prompt to be displayed for the user to enter a value. Entering no value and hitting Enter, will cause the same value that was entered last for the same parameter to be used. If this is the first time the user is prompted for a given parameter, 0 will be entered if hitting Enter with no data.

When a function in the simulator attempts to write a configuration or a command, then the console displays the parameter name and parameter value in the console.

Script execution in the simulator starts immediately after clicking on the Simulate button and the console window opens.

Simulated scripts are stopped when closing the simulator console.

Downloading MicroBasic Scripts to the controller

The Download to Device button will cause the MicroBasic script to be built and then transferred into the controller's flash memory where it will remain permanently unless overwritten by a new script.

The download process requires no other particular attention. There is no warning that a script may already be present in Flash. A progress bar will appear for the duration of the transfer which can be from a fraction of a second to a few seconds. When the download is completed successfully, no message is displayed, and control is returned to the editor A downloaded script cannot be read out..

An error message will appear only if the controller is not ready to receive or if an error occurred during the download phase.

Downloading a new script while a script is already running will cause the running script to stop execution. All variables will also be cleared when a new script is downloaded. When using multiple controllers over a CAN network with the RoboCAN protocol, it is possible to download the script into any node. Use the Download to Device button from the Scripting tab of the PC Utility.

In networked systems using the RoboCAN protocol, scripts can be loaded in any active node by using the Download to Remote button in the PC utility.

Saving and Loading Scripts in Hex Format

Compiled scripts can be saved as a .hex format file from the PC Utility. The bytecodes can then be loaded into the controller using the "Update Script" button on the Console tab. Using this technique is a good way of keeping the source code secret and/or safe while allowing field updates.

The bytecodes in the .hex file can also be loaded in the controller by any microcomputer using the following sequence:

Send the string:

%sld 321654987

the controller will reply with

HLD

to indicate it is waiting for data

then send the hex file, one line at a time. At the end of each line received, the controller will send a +

Beware that if no data is received for more than 1s, the controller will exit the HLD mode.

Executing MicroBasic Scripts

Once stored in the Controller's Flash memory, scripts can be executed either "Manually" or automatically every time the controller is started.

Manual launch is done by sending commands via the Serial or USB port. When connected to the PC running the PC utility, the launch command can be entered from the Console tab. The commands for running as stopping scripts are:

- **!r** : Start or Resume Script
- **!r 0**: Pause Script execution
- **!r 1**: Resume Script from pause point. All integer and Boolean variables have values they had at the time the script was paused.
- **!r 2**: Restarts Script from start. Set all integer variables to 0, sets all Boolean variables to False. Clears and stops the 4 timers.

On CAN networks running the RoboCAN protocol, a script on a remote node can be launched or stopped by using the above commands with the RoboCAN prefix. For example

- **@06!r** : Start or Resume Script on device at RoboCAN node 6

If the controller is connected to a microcomputer, it is best to have the microcomputer start script execution by sending the !r command via the serial port or USB.

Scripts can be launched automatically after controller power up or after reset by setting the Auto Script configuration to Enable in the controller configuration memory. When enabled, if a script is detected in Flash memory after reset, script execution will be enabled and the script will run as when the !r command is manually entered. Once running, scripts can be paused and resumed using the commands above.

Important Warning

Prior to set a script to run automatically at start-up, make sure that your script will not include errors that can make the controller processor crash. Once set to automatically start, a script will always start running shortly after power up. If a script contains code that causes system crash, the controller will never reach a state where it will be possible to communicate with it to stop the script and/or load a new one. If this ever happens, the only possible recovery is to connect the controller to a PC via the serial port and run a terminal emulation software. Immediately after receiving the Firmware ID, type and send !r 0 to stop the script before it is actually launched. Alternatively, you may reload the controller's firmware.

Debugging Microbasic Scripts

While running a script with the source code visible in the Scripting tab, it is possible to view the state of all variable in real time. Click on the "Inspect Variable" buttons and over the variable in the source code. The variable value will appear near the mouse. To see changes to the variable, move the mouse away and then back on the variable.

Using print statements in questionable parts of the code is also a very effective debug tool. Run script from the console in order to be able to view the script output.

Script Command Priorities

When sending a Motor or Digital Output command from the script, it will be interpreted by the controller the same way as a serial command (RS232 or USB). This means that the RS232 watchdog timer will trigger in if no commands are sent from the script within the

watchdog timeout. If a serial command is received from the serial/USB port at the same time a command is sent from the script, both will be accepted and this can cause conflicts if they are both relating to the same channel. Care must be taken to keep to avoid, for example, cases where the script commands one motor to go to a set level while a serial command is received to set the motor to a different level. To avoid this problem when using the Roborun PC utility, click on the mute button to stop commands sending from the PC.

Script commands also share the same priority level as Serial commands. Use the Command Priority Setting (See "Command Priorities" on page 146) to set the priority of commands issued from the script vs. commands received from the Pulse Inputs or Analog Inputs.

MicroBasic Scripting Techniques

Writing scripts for the Roboteq controllers is similar to writing programs for any other computer. Scripts can be called to run once and terminate when done. Alternatively, scripts can be written so that they run continuously.

Single Execution Scripts

These scripts are programs that perform a number of functions and eventually terminate. These kind of scripts can be summarized in the flow chart below. The amount of processing can be simple or very complex but the script has a clear begin and end.

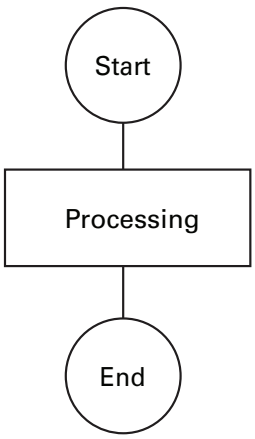


FIGURE 18-1. Single execution scripts

Continuous Scripts

More often, scripts will be active permanently, reacting differently based on the status of analog/ digital inputs, or operating parameters (Amps, Volts, Temperature, Speed, Count, …), and continuously updating the motor power and/or digital outputs. These scripts have a beginning but no end as they continuously loop back to the top. A typical loop construction is shown in the flow chart below.

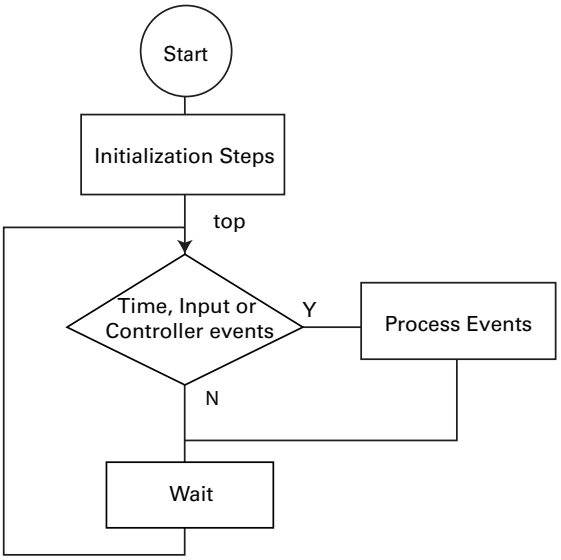


FIGURE 18-2. Continuous execution scripts

Often, some actions must be done only once when script starts running. This could be setting the controller in an initial configuration or computing constants that will then be used in the script's main execution loop.

The main element of a continuous script is the scanning of the input ports, timers, or controller operating parameters. If specific events are detected, then the script jumps to steps related to these events. Otherwise, no action is taken.

Prior to looping back to the top of the loop, it is highly recommended to insert a wait time. The wait period should be only as short as it needs to be in order to avoid using processing resources unnecessarily. For example, a script that monitors the battery and triggers an output when the battery is low does not need to run every millisecond. A wait time of 100ms would be adequate and keep the controller from allocating unnecessary time to script execution.

Optimizing Scripts for Integer Math

Scripts only use integer values as variables and for all internal calculation. This leads to very fast execution and lower computing resource usage. However, it does also cause limitation. These can easily be overcome with the following techniques.

First, if precision is needed, work with smaller units. In this simple Ohm-law example, whereas 10V divided by 3A results in 3 Ohm, the same calculation using different units will give a higher precision result: 10000mV divided by 3A results in 3333 mOhm

Second, the order in which terms are evaluated in an expression can make a very big difference. For example (10 / 20) * 1000 will produce a result of 0 while (10 * 1000)/20 produces 5000. The two expressions are mathematically equivalent but not if numbers can only be integers.

Script Examples

Several sample scripts are available from the download page on Roboteq's web site.

Below is an example of a script that continuously checks the heat sink temperature at both sides of the controller enclosure and lowers the amps limit to 50A when the average temperature exceeds 50oC. Amps limit is set at 100A when temperature is below 50o. Notice that as temperature is changing slowly, the loop update rate has been set at a relatively slow 100ms rate.

```
' This script regularity reads the current temperature at both sides
' of the heat sink and changes the Amps limit for both motors to 50A
' when the average temperature is above 50oC. Amps limit is set to
' 100A when temperature is below or equal to 50oC.
' Since temperature changes slowly, the script is repeated every 100ms

' This script is distributed "AS IS"; there is no maintenance
' and no warranty is made pertaining to its performance or applicability

top: ' Label marking the beginning of the script.

' Read the actual command value
Temperature1 = getvalue(_TEMP,1)
Temperature2 = getvalue(_TEMP,2)
TempAvg = (Temperature1 + Temperature2) / 2

' If command value is higher than 500 then configure
' acceleration and deceleration values for channel 1 to 200

if TempAvg > 50 then
        setconfig(_ALIM, 1, 500)
        setconfig(_ALIM, 2, 500)
else
' If command value is lower than or equal to 500 then configure
' acceleration and deceleration values for channel 1 to 5000
        setconfig(_ALIM, 1, 1000)
        setconfig(_ALIM, 2, 1000)
end if

' Pause the script for 100ms
wait(100)
' Repeat the script from the start
goto top
```

MicroBasic Language Reference

Introduction

The **Roboteq Micro Basic** is high level language that is used to generate programs that runs on Roboteq motor controllers. It uses syntax nearly like Basic syntax with some adjustments to speed program execution in the controller and make it easier to use.

Comments

A comment is a piece of code that is excluded from the compilation process. A comment begins with a single-quote character. Comments can begin anywhere on a source line, and the end of the physical line ends the comment. The compiler ignores the characters between the beginning of the comment and the line terminator. Consequently, comments cannot extend across multiple lines.

```
'Comment goes here till the end of the line.
```

Boolean

`True` and `False` are literals of the Boolean type that map to the true and false state, respectively.

Numbers

Micro Basic supports only integer values ranged from -2,147,483,648 (0x80000000) to 2,147,483,647 (0x7FFFFFFF).

Numbers can be preceded with a sign (+ or -), and can be written in one of the following formats:

- **Decimal Representation**

  Number is represented in a set of decimal digits (0-9).

  ```
  120          5622          504635
  ```

  Are all valid decimal numbers.

- **Hexadecimal Representation**

  Number is represented in a set of hexadecimal digits (0-9, A-F) preceded by 0x.

  ```
  0xA1          0x4C2          0xFFFF
  ```

  Are all valid hexadecimal numbers representing decimal values 161, 1218 and 65535 respectively.

- **Binary Representation**

  Number is represented in a set of binary digits (0-1) preceded by 0b.

  ```
  0b101          0b1110011          0b111001010
  ```

  Are all valid binary numbers representing decimal values 5, 115 and 458 respectively.

Strings

Strings are any string of printable characters enclosed in a pair of quotation marks. Non printing characters may be represented by simple or hexadecimal escape sequence. Micro Basic only handles strings using the Print command. Strings cannot be stored in variable and no string handling instructions exist.

- **Simple Escape Sequence**

  The following escape sequences can be used to print non-visible or characters:

Sequence	Description
\'	Single quote
\"	Double quote
\\	Backslash
\0	Null
\a	Alert
\b	Backspace
\f	Form feed
\n	New line
\r	Carriage return
\t	Horizontal tab
\v	Vertical tab

- **Hexadecimal Escape Sequence**
  Hexadecimal escape sequence is represented in a set of hexadecimal digits (0-9, A-F) preceded by \x in the string (such as \x10 for character with ASCII 16).

  Since a hexadecimal escape sequence can have a variable number of hex digits, the string literal "`\x123`" contains a single character with hex value 123. To create a string containing the character with hex value 12 followed by the character 3, one could write "`\x00123`".

So, to represent a string with the statement "Hello World!" followed by a new line, you may use the following syntax:

```
"Hello World!\n"
```

Blocks and Labels

A group of executable statements is called a statement block. Execution of a statement block begins with the first statement in the block. Once a statement has been executed, the next statement in lexical order is executed, unless a statement transfers execution elsewhere.

A label is an identifier that identifies a particular position within the statement block that can be used as the target of a branch statement such as `GoTo`, `GoSub` or `Return`.

Label declaration statements must appear at the beginning of a line. Label declaration statements must always be followed by a colon (:) as the following:

```
Print_Label:
    Print("Hello World!")
```

Label name should start with alphabetical character and followed by zero or more alphanumeric characters or underscore. Label names cannot start with underscore. Labels names cannot match any of Micro Basic reserved words.

Label names are case insensitive that is `PrintLabel` is identical to `printLabel`.

The scope of a label extends whole the program. Labels cannot be declared more than once in the program.

Variables

Micro Basic contains only two types of variable (`Integer` and `Boolean`) in addition to arrays of these types. Boolean and arrays must be declared before use, but `Integer` variables may not be declared unless you use the `Option Explicit` compiler directive.

```
Option Explicit
```

Variables can be declared using DIM keyword (see Dim (Variable Declaration) on page 200).

Variable name should start with alphabetical character and followed by zero or more alphanumeric characters or underscore. Variable names cannot start with underscore. Variable names cannot match any of Micro Basic reserved words.

Variable names are case insensitive, that is `VAR` is identical to `var`.

The scope of a variable extends whole the program. Variables cannot be declared more than once in the program.

Arrays

Arrays is special variables that holds a set of values of the variable type. Arrays are declared using DIM command (see Dim (Variable Declaration) on page 200).

To access specific element in the array you can use the indexer [] (square brackets). Arrays indices are zero based, so index of 5 refer to the 6th element of the array.

```
arr[0] = 10  'Set the value of the first element in the array to 10.

a = arr[5]   'Store the 6th element of the array into variable a.
```

Terminology

In the following sections we will introduce Micro Basic commands and how it is used, and here is the list of terminology used in the following sections:

- Micro Basic commands and functions will be marked in blue and cyan respectively.
- Anything enclosed in < > is mandatory and must be supplied.
- Anything enclosed in [ ] is optional, except for arrays where the square brackets is used as indexers.
- Anything enclosed in { } and separated by | characters are multi choice options.
- Any items followed by an ellipsis, ... , may be repeated any number of times.
- Any punctuation and symbols, except those above, are part of the structure and must be included.

var	is any valid variable name including arrays.
arr	is any valid array name.
expression	is any expression returning a result.

condition	is any expression returning a boolean result.
stmt	is single Micro Basic statement.
block	is zero or more Micro Basic statements.
label	is any valid label name.
n	is a positive integer value.
str	is a valid string literal.

Keywords

A keyword is a word that has special meaning in a language construct. All keywords are reserved by the language and may not be used as variables or label names. Below is a list of all Micro Basic keywords:

#define	And	AndWhile	As	Boolean
Continue	Dim	Do	Else	ElseIf
End	Evaluate	Exit	Explicit	False
For	GoSub	GoTo	If	Integer
Loop	Mod	Next	Not	Option
Or	Print	Return	Step	Terminate
Then	To	ToBool	True	Until
While	XOr			

Operators

Micro Basic provides a large set of operators, which are symbols or keywords that specify which operations to perform in an expression. Micro Basic predefines the usual arithmetic and logical operators, as well as a variety of others as shown in the following table.

Category	Operators						
Arithmetic	+	-	*	/	Mod		
Logical (boolean and bitwise)	And	Or	XOr	Not	True	False	
Increment, decrement	++	--					
Shift	<<	>>					
Relational	=	<>	<	>	<=	>=	
Assignment	=	+=	-=	*=	/=	<<=	>>=
Indexing	[]						

Micro Basic Functions

The following is a set of Micro Basic functions

Abs	Returns the absolute value of a given number.
Atan	Returns the angle whose arc tangent is the specified number.
Cos	Returns the cosine of the specified angle.
Sin	Returns the sine of the specified angle.
Sqrt	Returns the square root of a specified number.

Controller Configuration and Commands

The following is a set of device functions for interacting with the Controller:

SetConfig	Set a configuration parameter
SetCommand	Send a Real Time command
GetConfig	Read a configuration parameter
GetValue	Read an operating value

A set of similar commands are available for accessing/changing configurations, sending commands and reading operating values of remote nodes on CAN networks using the RoboCAN protocol.

Timers Commands

The following is a set of functions for interacting with the timers:

SetTimerCount	Set number of milliseconds for timer to count.
SetTimerState	Set state of a specific timer.
GetTimerCount	Read timer count.
GetTimerState	Read state of a specific timer.

Pre-Processor Directives (#define)

The #define creates a macro, which is the association of an identifier with a token expression. After the macro is defined, the compiler can substitute the token expression for each occurrence of the identifier in the source file.

```
#define <var> <expression>
```

The following example illustrates how use pre-processor directive:

```
#define CommandID _GO + 5
Print(CommandID)
```

Option (Compilation Options)

Micro Basic by default treats undeclared identifiers as integer variables. If you want the compilers checks that every variable used in the program is declared and generate compilation error if a variable is not previously declared, you may use Option explicit compiler option by pacing the following at the beginning of the program:

```
Option Explicit
```

Dim (Variable Declaration)

Micro Basic contains only two types of variable (Integer and Boolean) in addition to arrays of these types. Boolean and arrays must be declared before use, but Integer variables may not be declared unless you use the Option Explicit compiler directive.

```
Dim var As { Integer | Boolean }
```

The following example illustrates how to declare Integer variable:

```
Dim intVar As Integer
```

Arrays declaration uses a different syntax, where you should specify the array length between square brackets []. Array length should be integer value greater than 1.

```
Dim arr[n] As { Integer | Boolean }
```

The following example illustrates how to declare array of 10 integers:

```
Dim arr[10] As Integer
```

To access array elements (get/set), you may need to take a look to Arrays section (see Arrays on page 198).

Variable and arrays names should follow specification stated in the Variables section (see Variables on page 198).

If...Then Statement

- Line If

```
If <condition> Then <stmt> [Else <stmt>]
```

- Block If

```
If <condition> [Then]
      <block>
[ElseIf <condition> [Then]
      <block>]
[ElseIf <condition> [Then]
      <block>]
...
[Else
      <block>]
End If
```

An `If`...Then statement is the basic conditional statement. If the expression in the If statement is true, the statements enclosed by the `If` block are executed. If the expression is false, each of the `ElseIf` expressions is evaluated. If one of the `ElseIf` expressions evaluates to true, the corresponding block is executed. If no expression evaluates to true and there is an `Else` block, the `Else` block is executed. Once a block finishes executing, execution passes to the end of the `If...`Then statement.

The line version of the `If` statement has a single statement to be executed if the `If` expression is true and an optional statement to be executed if the expression is false. For example:

```
Dim a As Integer
Dim b As Integer

a = 10
b = 20
' Block If statement.
If a < b Then
    a = b
```

```
Else
    b = a
End If

' Line If statement
If a < b Then a = b Else b = a
```

Below is an example where `ElseIf` takes place:

```
If score >= 90 Then
    grade = 1
ElseIf score >= 80 Then
    grade = 2
ElseIf score >= 70 Then
    grade = 3
Else
    grade = 4
End If
```

For...Next Statement

Micro Basic contains two types of For...Next loops:

- **Traditional `For...Next:`**
  Traditional For...Next exists for backward compatibility with Basic, but it is not recommended due to its inefficient execution.

  Traditional For...Next is the same syntax as Basic For...Next statement.

- **C-Style `For...Next:`**
  This is a new style of For...Next statement optimized to work with Roboteq controllers and it is recommended to be used. It is the same semantics as C++ for loop, but with a different syntax.

  ```
  For <var> = <expression> AndWhile <condition> [Evaluate
  <stmt>]
      <block>
  Next
  ```

  The c-style for loop is executed by initialize the loop variable, then the loop continues while the condition is true and after execution of single loop the evaluate statement is executed then continues to next loop.

  ```
  Dim arr[10] As Integer
  For i = 0 AndWhile i < 10
      arr[i] = -1
  Next
  ```

  The previous example illustrates how to initialize array elements to -1.

  The following example illustrates how to use Evaluate to print even values from 0-10 inclusive:

  ```
  For i = 0 AndWhile i <= 10 Evaluate i += 2
      Print(i, "\n")
  Next
  ```

While/Do Statements

- **While...End While Statement**

```
While <condition>
    <block>
End While
```

Example:

```
a = 10
While a > 0
    Print("a = ", a, "\n")
    a--
End While
Print("Loop ended with a = ", a, "\n")
```

- **Do While...Loop Statement**

```
Do While <condition>
    <block>
Loop
```

The `Do While...Loop` statement is the same as functionality of the `While... End While` statement but uses a different syntax.

```
a = 10
Do While a > 0
    Print("a = ", a, "\n")
    a--
Loop
Print("Loop ended with a = ", a, "\n")
```

- **Do Until...Loop Statement**

```
Do Until <condition>
    <block>
Loop
```

Unlike `Do While...Loop` statement, Do `Until...Loop` statement exist the loop when the expression evaluates to true.

```
a = 10
Do Until a = 0
    Print("a = ", a, "\n")
    a--
Loop
Print("Loop ended with a = ", a, "\n")
```

- **Do...Loop While Statement**

```
Do
    <block>
Loop While <condition>
```

`Do...Loop While` statement grantees that the loop block will be executed at least once as the condition is evaluated and checked after executing the block.

```
a = 10
Do
    Print("a = ", a, "\n")
    a--
Loop While a > 0
Print("Loop ended with a = ", a, "\n")
```

- **Do...Loop Until Statement**

```
Do
        <block>
Loop Until <condition>
```

Unlike Do...Loop While statement, Do...Loop Until statement exist the loop when the expression evaluates to true.

```
a = 10
 Do
     Print("a = ", a, "\n")
     a--
 Loop Until a = 0
 Print("Loop ended with a = ", a, "\n")
```

Terminate Statement

The Terminate statement ends the execution of the program.

```
Terminate
```

Exit Statement

The following is the syntax of Exit statement:

```
Exit { For | While | Do }
```

An `Exit` statement transfers execution to the next statement to immediately containing block statement of the specified kind. If the `Exit` statement is not contained within the kind of block specified in the statement, a compile-time error occurs.

The following is an example of how to use Exit statement in While loop:

```
While a > 0
    If b = 0 Then Exit While
End While
```

Continue Statement

The following is the syntax of Continue statement:

```
Continue { For | While | Do }
```

A Continue statement transfers execution to the beginning of immediately containing block statement of the specified kind. If the `Continue` statement is not contained within the kind of block specified in the statement, a compile-time error occurs.

The following is an example of how to use Continue statement in While loop:

```
While a > 0
    If b = 0 Then Continue While
End While
```

GoTo Statement

A GoTo statement causes execution to transfer to the specified label. GoTo keyword should be followed by the label name.

```
GoTo <label>
```

The following example illustrates how to use GoTo statement:

```
GoTo Target_Label
Print("This will not be printed.\n")
Target_Label:
    Print("This will be printed.\n")
```

GoSub/Return Statements

GoSub used to call a subroutine at specific label. Program execution is transferred to the specified label. Unlike the GoTo statement, GoSub remembers the calling point. Upon encountering a Return statement the execution will continue the next statement after the GoSub statement.

```
GoSub <label>
```

```
Return
```

Consider the following example:

```
Print("The first line.")
GoSub PrintLine
Print("The second line.")
GoSub PrintLine
Terminate

PrintLine:
    Print("\n")
    Return
```

The program will begin with executing the first print statement. Upon encountering the GoSub statement, the execution will be transferred to the given **PrintLine** label. The program prints the new line and upon encountering the Return statement the execution will be returning back to the second print statement and so on.

ToBool Statement

Converts the given expression into boolean value. It will be return `False` if expression evaluates to zero, True otherwise.

```
ToBool(<expression>)

Consider the following example:

Print(ToBool(a), "\n")
```

The previous example will output `False` if value of a equals to zero, `True` otherwise.

Print Statement

Output the list of expression passed.

```
Print({str | expression | ToBool(<expression>)}[,{str | expression
| ToBool(<expression>)}]...)
```

The print statement consists of the `Print` keyword followed by a list of expressions separated by comma. You can use `ToBool` keyword to force print of expressions as `Boolean`. Strings are C++ style strings with escape characters as described in the Strings section (see Stringspage 196).

```
a = 3
b = 5
Print("a = ", a, ", b = ", b, "\n")
Print("Is a less than b = ", ToBool(a < b), "\n")
```

+ Operator

The + operator can function as either a unary or a binary operator.

```
+ expression
expression + expression
```

- Operator

The - operator can function as either a unary or a binary operator.

```
- expression
expression - expression
```

* Operator

The multiplication operator (*) computes the product of its operands.

```
expression * expression
```

/ Operator

The division operator (/) divides its first operand by its second.

```
expression * expression
```

Mod Operator

The modulus operator (Mod) computes the remainder after dividing its first operand by its second.

```
expression Mod expression
```

And Operator

The (`And`) operator functions only as a binary operator. For numbers, it computes the bitwise AND of its operands. For boolean operands, it computes the logical AND for its operands; that is the result is true if and only if both operands are true.

```
expression And expression
```

Or Operator

The (`Or`) operator functions only as a binary operator. For numbers, it computes the bitwise OR of its operands. For boolean operands, it computes the logical OR for its operands; that is, the result is false if and only if both its operands are false.

```
expression Or expression
```

XOr Operator

The (`XOr`) operator functions only as a binary operator. For numbers, it computes the bitwise exclusive-OR of its operands. For boolean operands, it computes the logical exclusive-OR for its operands; that is, the result is true if and only if exactly one of its operands is true.

```
expression XOr expression
```

Not Operator

The (Not) operator functions only as a unary operator. For numbers, it performs a bitwise complement operation on its operand. For boolean operands, it negates its operand; that is, the result is true if and only if its operand is false.

```
Not expression
```

True Literal

The `True` keyword is a literal of type `Boolean` representing the boolean value true.

False Literal

The `False` keyword is a literal of type `Boolean` representing the boolean value false.

++ Operator

The increment operator (++) increments its operand by 1. The increment operator can appear before or after its operand:

```
++ var
var ++
```

The first form is a prefix increment operation. The result of the operation is the value of the operand after it has been incremented.

The second form is a postfix increment operation. The result of the operation is the value of the operand before it has been incremented.

```
a = 10
Print(a++, "\n")
Print(a, "\n")
Print(++a, "\n")
Print(a, "\n")
```

The output of previous program will be the following:

```
10
11
12
12
```

-- Operator

The decrement operator (–) decrements its operand by 1. The decrement operator can appear before or after its operand:

```
-- var
var --
```

The first form is a prefix decrement operation. The result of the operation is the value of the operand after it has been decremented.

The second form is a postfix decrement operation. The result of the operation is the value of the operand before it has been decremented.

```
a = 10
Print(a--, "\n")
Print(a, "\n")
Print(--a, "\n")
Print(a, "\n")
```

The output of previous program will be the following:

```
10
9
8
8
```

<< Operator

The left-shift operator (<<) shifts its first operand left by the number of bits specified by its second operand.

```
expression << expression
```

The high-order bits of left operand are discarded and the low-order empty bits are zero-filled. Shift operations never cause overflows.

>> Operator

The right-shift operator (>>) shifts its first operand right by the number of bits specified by its second operand.

```
expression >> expression
```

<> Operator

The inequality operator (<>) returns false if its operands are equal, true otherwise.

```
expression <> expression
```

< Operator

Less than relational operator (<) returns true if the first operand is less than the second, false otherwise.

```
expression < expression
```

> Operator

Greater than relational operator (>) returns true if the first operand is greater than the second, false otherwise.

```
expression > expression
```

<= Operator

Less than or equal relational operator (<=) returns true if the first operand is less than or equal to the second, false otherwise.

```
expression <= expression
```

> Operator

Greater than relational operator (>) returns true if the first operand is greater than the second, false otherwise.

```
expression > expression
```

>= Operator

Greater than or equal relational operator (>=) returns true if the first operand is greater than or equal to the second, false otherwise.

```
expression >= expression
```

+= Operator

The addition assignment operator.

```
var += expression
```

An expression using the += assignment operator, such as

```
x += y
```

is equivalent to

```
x = x + y
```

-= Operator

The subtraction assignment operator.

```
var -= expression
```

An expression using the -= assignment operator, such as

```
x -= y
```

is equivalent to

```
x = x - y
```

*= Operator

The multiplication assignment operator.

```
var *= expression
```

An expression using the *= assignment operator, such as

```
x *= y
```

is equivalent to

```
x = x * y
```

/= Operator

The division assignment operator.

```
var /= expression
```

An expression using the /= assignment operator, such as

```
x /= y
```

is equivalent to

```
x = x / y
```

<<= Operator

The left-shift assignment operator.

```
var <<= expression
```

An expression using the <<= assignment operator, such as

```
x <<= y
```

is equivalent to

```
x = x << y
```

>>= Operator

The right-shift assignment operator.

```
var >>= expression
```

An expression using the >>= assignment operator, such as

x >>= y

is equivalent to

x = x >> y

[ ] Operator

Square brackets ([]) are used for arrays (see Arrays on page 198).

Abs Function

Returns the absolute value of an expression.

```
Abs(<expression>)
```

Example:

```
a = 5
b = Abs(a - 2 * 10)
```

Atan Function

Returns the angle whose arc tangent is the specified number.

Number is devided by 1000 before applying atan.

The return value is multiplied by 10.

```
Atan(<expression>)
```

Example:

```
angle = Atan(1000) '450 = 45.0 degrees
```

Cos Function

Returns the cosine of the specified angle.

The return value is multiplied by 1000.

```
Abs(<expression>)
```

Example:

```
value = Cos(0) '1000
[title] Sin Function
Returns the sine of the specified angle.
The return value is multiplied by 1000.
Sin(<expression>)
```

Example:

```
value = Sin(90) '1000
Sqrt Function
Returns the square root of a specified number.
The return value is multiplied by 1000.
Sqrt(<expression>)
```

Example:

```
value = Sqrt(2) '1414
```

GetValue

This function is used to read operating parameters from the controller at runtime. The function requires an Operating Item, and an optional Index as parameters. The Operating Item can be any one from the table below. The Index is used to select one of the Value Items in multi channel configurations. When accessing a unique Operating Parameter that is not part of an array, the index may be omitted, or an index value of 0 can be used.

Details on the various operating parameters that can be read can be found in the Controller's User Manual. (See "Serial (RS232/USB) Operation" on page 141)

```
GetValue(OperatingItem, [Index])

Current2 = GetValue(_BATAMPS, 2) ' Read Battery Amps for Motor 2

Sensor = GetValue(_ANAIN, 6) ' Read voltage present at Analog Input 1

Counter = GetValue(_BLCOUNTER) ' Read Brushless counter
```

SetCommand

This function is used to send operating commands to the controller at runtime. The function requires a Command Item, an optional Index and a Value as parameters. The Command Item can be any one from the table below. Details on the various commands, their effects and acceptable ranges can be found in the Controller's User Manual (See "Serial (RS232/USB) Operation" on page 141).

```
SetCommand(CommandItem, Value)

SetCommand(_GO, 1, 500) ' Set Motor 1 command level at 500

SetCommand(_DSET, 2) ' Activate Digital Output 2
```

SetConfig / GetConfig

These two functions are used to read or/and change one of the controller's configuration parameters at runtime. The changes are made in the controller's RAM and take effect immediately. Configuration changes are not stored in EEPROM.

```
SetConfig Set a configuration parameter
GetConfig Read a configuration parameter
```

Both commands require a Configuration Item, and an optional Index as parameters. The Configuration Item can be one of the valid controller configuration commands listed in the Command Reference Section. Refer to Set/Read Configuration Commands on page 210 for syntax. Simply add the underscore character "_" to read or write this configuration from within a script. The Index is used to select one of the Configuration Item in multi channel configurations. When accessing a configuration parameter that is not part of an array, index can be omitted or an index value of 0 can be used. Details on the various configurations items, their effects and acceptable values can be found in the Controller's User Manual.

Note that most but not all configuration parameters are accessible via the SetConfig or GetConfig function. No check is performed that the value you store is valid so this function must be handled with care.

When setting a configuration parameter, the new value of the parameter must be given in addition to the Configuration Item and Index.

GetConfig(ConfigurationItem, [Index], value)
SetConfig(ConfigurationItem, [Index])

```
Accel2 = GetConfig(_MAC, 2) ' Read Acceleration parameter for Motor 2
PWMFreq = GetConfig(_PWMF) ' Read Controller's PWM frequency
SetConfig(_MAC, 2, Accel2 * 2) ' Make Motor2 acceleration twice as slow
```

SetTimerCount/GetTimerCount

These two functions used to set/get timer count.

```
SetTimerCount(<index>, <milliseconds>)
GetTimerCount(<index>)
```

Where:

<index> : 0 - 4 for old controller models

0 - 7 for new controller models

<milliseconds> : number of milliseconds to count

SetTimerState/GetTimerState

These two functions used to set/get timer state (started or stopped).

```
SetTimerState(<index>, <state>)
GetTimerState(<index>)
```

Replace entire sentence with:

Where:

<index> : 0 - 4 for old controller models

0 - 7 for new controller models

<state> : 0 - Timer Running

1 - Timer has completed/stopped (reached 0ms)

Sending RoboCAN Commands and Configuration

Sending commands or configuration values to remote nodes on RoboCAN is done using the functions.

```
SetCANCommand(<id>, <cc>, <ch>, <vv>)
SetCANConfig(<id>, <cc>, <ch>, <vv>)
```

Where:
id is the remote Node Id in decimal.
cc is the Command code, eg. _G.
cc is the channel number. Put 1 for commands that do not normally require a channel number.
vv is the value.

Reading RoboCAN Operating Values Configurations

The following functions are available in Micro Basic for requesting operating values and configurations from a remote node on RoboCAN.

```
FetchCANValue(<id>, <cc>, <ch>)
FetchCANConfig(<id>, <cc>, <ch>)
```

Where:
id is the remote Node Id in decimal
cc is the Command code, eg. _G
cc is the channel number. Put 1 for commands that do not normally require a channel number.

The following functions can be used to wait for the data to be ready for reading.

```
IsCANValueReady()
IsCANConfigReady()
```
These functions return a Boolean true/false value. They take no argument and apply to the last issued `FetchCANValue` or `FetchCANConfig` function.

The retrieved value can then be read using the following functions.

```
ReadCANValue()
ReadCANConfig()
```
These functions return an integer value. They take no argument and apply to the last issued `FetchCANValue` or `FetchCANConfig` function.

RoboCAN Continuous Scan

A scan of a remote RoboCAN node is initiated with the function.

```
ScanCANValue(<id>, <cc>, <ch>, <tt>, <bb>)
```

Where:
id is the remote Node Id in decimal.
cc is the Query code, eg. _V.
cc is the channel number. Put 1 for commands that do not normally require a channel number.
tt is the scan rate in ms.
bb is the buffer location.
The scan rate can be up to 255ms. Setting a scan rate of 0 stops the automatic sending from this node.

Unless otherwise specified, the buffer can store up to 32 values.

The arrival of a new value is checked with the function.

```
IsScannedCANReady(<aa>)
```

Where:

aa is the location in the scan buffer.
The function returns a Boolean true/false value.

The new value is then read with the function.

```
ReadScannedCANValue(<aa>)
```

Where:
aa is the location in the scan buffer.
The function returns an integer value. If no new value was received since the previous read, the old value will be read.

Checking the Presence of a RoboCAN Node

No error is reported in MicroBasic if an exchange is initiated with a node that does not exist. A command or configuration sent to a non-existent node will simply not be executed. A query sent to a non existing or dead node will return the value 0. A function is therefore provided for verifying the presence of a live node. A live node is one that sends the distinct RoboCAN heartbeat frame every 128ms. The function syntax is:

```
IsCANNodeAlive(<id>)
```

Where:
id is the remote Node Id in decimal
The function returns a Boolean true/false value.

SECTION 19

Commands Reference

This section lists all the commands accepted by the controller. Commands are typically sent via the serial (RS232 or USB) ports (See "Serial (RS232/USB) Operation" on page 141). Except for a few maintenance commands, they can also be issued from within a user script written using the MicroBasic language (See "MicroBasic Scripting" on page 179).

Commands Types

The controller will accept and recognize four types of commands:

Runtime commands

These start with "!" when called via the serial communication (RS232 or USB), or using the setcommand() MicroBasic function. These are usually motor or operation commands that will have immediate effect (e.g. to turn on the motor, set a speed or activate digital output). Most of Runtime commands are mapped inside a CANopen Object Directory, allowing the controller to be remotely operated on a CANopen standard network (See "CANopen Interface" on page 172). See "Runtime Commands" on page 164 for the full list and description of these commands.

Runtime queries

These start with "**?**" when called via the serial communication (RS232 or USB), or using the getvalue() Microbasic function. These are used to read operating values at runtime (e.g. read Amps, Volts, power level, counter values). All runtime queries are mapped inside a CANopen Object Directory, allowing the controller to be remotely interrogated on a CANopen standard network (See "CANopen Interface" on page 172). See Runtime commands are commands that can be sent at any time during controller operation and are taken into consideration immediately. Runtime commands start with "!" and are followed by one to three letters. Runtime commands are also used to refresh the watchdog timer to ensure safe communication. Runtime commands can be called from a MicroBasic script using the setcommand() function..

Maintenance commands

These are only available trough serial (RS232 or USB) and start with "%". They are used for all of the maintenance commands such as (e.g. set the time, save configuration to EEPROM, reset, load default, etc.).

Set/Read Configuration commands

These start with "~" for read and "^" for write when called via the serial communication (RS232 or USB), or using the getconfig() and setconfig() MicroBasic functions. They are used to read or configure all the operating parameters of the controller (e.g. set or read amps limit). See "Set/Read Configuration Commands" on page 218 for the full list and description of these commands.

Runtime Commands

Runtime commands are commands that can be sent at any time during controller operation and are taken into consideration immediately. Runtime commands start with "!" and are followed by one to three letters. Runtime commands are also used to refresh the watchdog timer to ensure safe communication. Runtime commands can be called from a MicroBasic script using the setcommand() function.

TABLE 19-1. Runtime Commands

Command	Arguments	Description
AC	Channel Acceleration	Set Acceleration
AX	Channel Acceleration	Next Acceleration
B	VarNbr Value	Set User Boolean Variable
BND	[Channel]	Mutli-purpose Bind
C	Channel Value	Set Encoder Counters
CB	Channel Value	Set Brushless Counter
CG	Channel Value	Set Motor Command via CAN
CS	Element Value	CAN Send
D0	OutputNbr	Reset Individual Digital Out bits
D1	OutputNbr	Set Individual Digital Out bits
DC	Channel Deceleration	Set Deceleration
DS	Value	Set all Digital Out bits
DX	Channel Value	Next Decceleration
EES	None	Save Configuration in EEPROM
EX	None	Emergency Shutdown
G	Channel Value	Go to Speed or to Relative Position
H	Channel	Load Home counter
MG	None	Emergency Stop Release
MS	Channel	Stop in all modes
P	Channel Destination	Go to Absolute Desired Position
PR	Channel Delta	Go to Relative Desired Position
PRX	Channel Delta	Next Go to Relative Desired Position
PX	Channel Delta	Next Go to Absolute Desired Position
R	[Option]	MicroBasic Run
RC	Channel Value	Set Pulse Out
S	Channel Value	Set Motor Speed
SX	Channel Value	Next Velocity
VAR	VarNbr Value	Set User Variable

AC - Set Acceleration

Alias: ACCEL HexCode: 07 CANOpen id: 0x2006

Description:

Set the rate of speed change during acceleration for a motor channel. This command is identical to the MACC configuration command but is provided so that it can be changed rapidly during motor operation. Acceleration value is in 0.1 * RPM per second. When using controllers fitted with encoder, the speed and acceleration value are actual RPMs. Brushless motor controllers use the hall sensor for measuring actual speed and acceleration will also be in actual RPM/s. When using the controller without speed sensor, the acceleration value is relative to the Max RPM configuration parameter, which itself is a user-provided number for the speed normally expected at full power. Assuming that the Max RPM parameter is set to 1000, and acceleration value of 10000 means that the motor will go from 0 to full speed in exactly 1 second, regardless of the actual motor speed.

Syntax Serial: !AC cc nn

Syntax Scripting: setcommand(_AC, cc, nn)
setcommand(_ACCEL, cc, nn)

Number of Arguments: 2

Argument 1: Channel
Min: 1 Max: Total Number of Motors

Argument 2: Acceleration Type: Signed 32-bit
Min: 0 Max: 500000

Where:
cc = Motor channel
nn = Acceleration value in 0.1 * RPM/s

Example:

!AC 1 2000 : Increase Motor 1 speed by 200 RPM every second if speed is measured by encoder
!AC 2 20000 : Time from 0 to full power is 0.5s if no speed sensors are present and Max RPM is set to 1000

AX - Next Acceleration

Alias: NXTACC HexCode: 14 CANOpen id: 0x2012

Description:

This command is used for chaining commands in Position Count mode. It is similar to AC except that it stores an acceleration value in a buffer. This value will become the next acceleration the controller will use and becomes active upon reaching a previous desired position. If omitted, the command will be chained using the last used acceleration value.

Syntax Serial: !AX cc nn

Syntax Scripting: setcommand(_AX, cc, nn)
setcommand(_NXTACC, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Acceleration Type: Signed 32-bit

Min: 0 Max: 500000

Where:

cc = Motor channel
nn = Acceleration value in 0.1 * RPM/s

B - Set User Boolean Variable

Alias: BOOL HexCode: 16 CANOpen id: 0x2015

Description:

Set the state of user boolean variables inside the controller. These variables can then be read from within a user MicroBasic script to perform specific actions.

Syntax Serial: !B nn mm

Syntax Scripting: setcommand(_B, nn, mm)
setcommand(_BOOL, nn, mm)

Number of Arguments: 2

Argument 1: VarNbr

Min: 1 Max: Total nbr of Bool Vars

Argument 2: Value Type: Boolean

Min: 0 Max: 1

Where:

nn = Variable number

mm = 0 or 1

Note:
The total number of user variables depends on the controller model and can be found in the product datasheet.

BND - Mutli-purpose Bind

Alias: BIND HexCode: 1C CANOpen id:

Description:

This command is used to perform a, usually, one-time setup in several situations. When the controller is configured in sinusoidal mode for brushless motor and encoder feedback, !BND will energize the motor to a reference position and set the encoder counter to the zero degree reference angle that will remain active until power down. When used with Sin/Cos or SPI/SSI angle sensors the same reference search is performed but the captured zero-reference can then be stored into flash permanently. When used on controllers with Spektrum RC radio interface the BND command is used to pair the receiver with its transmitter.

Syntax Serial: !BND [cc]

Syntax Scripting: setcommand(_BND, cc)
setcommand(_BIND, cc)

Number of Arguments: 1

Argument 1: [Channel] Type: Unsigned 8-bit

Min: None Max: Total Number of Motors

Where:

cc = Motor channel

Example:

!BND 1 : Searches zero angle reference for motor 1 when in sinusoidal mode
!BND : Binds Spektrum receiver with its transmitter, on supporting controller models

C - Set Encoder Counters

Alias: SENCNTR HexCode: 04 CANOpen id: 0x2003

Description:

This command loads the encoder counter for the selected motor channel with the value contained in the command argument. Beware that changing the controller value while operating in closed-loop mode can have adverse effects.

Syntax Serial: !C [cc] nn

Syntax Scripting: setcommand(_C, cc, nn)
setcommand(_SENCNTR, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Encoders

Argument 2: Value Type: Signed 32-bit

Min: -2147M Max: +2147M

Where:

cc = Motor channel
nn = Counter value

Example:

!C 2 -1000 : Loads -1000 in encoder counter 2
!C 1 0 : Clears encoder counter 1

CB - Set Brushless Counter

Alias: SBLCNTR HexCode: 05 CANOpen id: 0x2004

Description:

This command loads the brushless counter with the value contained in the command argument. Beware that changing the controller value while operating in closed-loop mode can have adverse effects.

Syntax Serial: !CB [cc] nn

Syntax Scripting: setcommand(_CB, cc, nn)
setcommand(_SBLCNTR, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Value Type: Signed 32-bit

Min: -2147M Max: +2147M

Where:

cc = Motor channel
nn = Counter value

Example:

!CB 1 -1000 : Loads -1000 in brushless counter 1
!CB 2 0 : Clears brushless counter 2

CG - Set Motor Command via CAN

Alias: CANGO HexCode: 19 CANOpen id: 0x2000

Description:

This command is identical to the G (GO) command except that it is meant to be used for sending motor commands via CANOpen. See the G command for details

Syntax Serial: !CG cc nn

Syntax Scripting: setcommand(_CG, cc, nn)
setcommand(_CANGO, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Value Type: Signed 32-bit

Min: -1000 Max: +1000

Where:

cc = Motor channel
nn = Command value

CS - CAN Send

Alias: CANSEND HexCode: 18 CANOpen id:

Description:

This command is used in CAN-enabled controllers to build and send CAN frames in the RawCAN mode (See RawCAN section in manual). It can be used to enter the header, bytecount, and data, one element at a time. The frame is sent immediately after the byte-count is entered, and so it should be entered last.

Syntax Serial: !CS ee nn

Syntax Scripting: setcommand(_CS, ee, nn)
setcommand(_CANSEND, ee, nn)

Number of Arguments: 2

Argument 1: Element

Min: 1 Max: 10

Argument 2: Value Type: Unsigned 8-bit

Min: 0 Max: 255

Where:

ee =
1 : Header
2 : Bytecount
3 to 10 : Data0 to data7
nn = value

Example:

!CS 1 5 : Enter 5 in header
!CS 3 2 : Enter 2 in data 0
!CS 4 3 : Enter 3 in data 1
!CS 2 2 : Enter 2 in bytecount and send CAN frame

D0 - Reset Individual Digital Out bits

Alias: DRES HexCode: 09 CANOpen id: 0x200A

Description:

The D0 command will turn off the single digital output selected by the number that follows.

Syntax Serial: !D0 nn

Syntax Scripting: setcommand(_D0, nn)
setcommand(_DRES, nn)

Number of Arguments: 1

Argument 1: OutputNbr Type: Unsigned 8-bit

Min: 1 Max: Total number of Digital Outs

Where:

nn = Output number

Example:

!D0 2 : will deactivate output 2

Note:

Digital Outputs are Open Collector. Activating an outputs will force it to ground. Deactivating an output will cause it to float.

D1 - Set Individual Digital Out bits

Alias: DSET HexCode: 0A CANOpen id: 0x2009

Description:

The D1 command will activate the single digital output that is selected by the parameter that follows.

Syntax Serial: !D1 nn

Syntax Scripting: setcommand(_D1, nn)
setcommand(_DSET, nn)

Number of Arguments: 1

Argument 1: OutputNbr Type: Unsigned 8-bit

Min: 1 Max: Total number of Digital Outs

Where:

nn = Output number

Example:

!D1 1 : will activate output 1

Note:

Digital Outputs are Open Collector. Activating an outputs will force it to ground. Deactivating an output will cause it to float.

DC - Set Deceleration

Alias: DECEL HexCode: 08 CANOpen id: 0x2007

Description:

Set the rate of speed change during decceleration for a motor channel. This command is identical to the MDEC configuration command but is provided so that it can be changed rapidly during motor operation. Decceleration value is in 0.1 * RPM per second. When using controllers fitted with encoder, the speed and decceleration value are actual RPMs. Brushless motor controllers use the hall sensor for measuring actual speed and deccelleration will also be in actual RPM/s. When using the controller without speed sensor, the decceleration value is relative to the Max RPM configuration parameter, which itself is a user-provided number for the speed normally expected at full power. Assuming that the Max RPM parameter is set to 1000, and decceleration value of 10000 means that the motor will go from full speed to 0 in exactly 1 second, regardless of the actual motor speed.

Syntax Serial: !DC cc nn

Syntax Scripting: setcommand(_DC, cc, nn)
setcommand(_DECEL, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Deceleration Type: Signed 32-bit

Min: 0 Max: 500000

Where:

cc = Motor channel
nn = Deceleration value in 0.1 * RPM/s

Example:

!DC 1 2000 : Reduce Motor 1 speed by 200 RPM every second if speed is measured by encoder
!DC 2 20000 : Time from full power to stop is 0.5s if no speed sensors are present and Max RPM is set to 1000

DS - Set all Digital Out bits

Alias: DOUT HexCode: 09 CANOpen id: 0x2008

Description:

The D command will turn ON or OFF one or many digital outputs at the same time. The number can be a value from 0 to 255 and binary representation of that number has 1bit affected to its respective output pin.

Syntax Serial: !DS nn

Syntax Scripting: setcommand(_DS, nn)
setcommand(_DOUT, nn)

Number of Arguments: 1

Argument 1: Value Type: Unsigned 8-bit
Min: 0 Max: 255

Where:

nn = Bit pattern to be applied to all output lines at once

Example:

!DS 03 : will activate outputs 1 and 2. All others are off

Note:

Digital Outputs are Open Collector. Activating an outputs will force it to ground. Deactivating an output will cause it to float.

DX - Next Decceleration

Alias: NXTDEC HexCode: 15 CANOpen id: 0x2013

Description:

This command is used for chaining commands in Position Count mode. It is similar to DC except that it stores a decceleration value in a buffer. This value will become the next

decceleration the controller will use and becomes active upon reaching a previous desired position. If omitted, the command will be chained using the last used decceleration value.

Syntax Serial: !DX cc nn

Syntax Scripting: setcommand(_DX, cc, nn)
setcommand(_NXTDEC, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Value Type: Signed 32-bit

Min: 0 Max: 500000

Where:

cc = Motor channel
nn = Acceleration value

EES - Save Configuration in EEPROM

Alias: EESAV HexCode: 1B CANOpen id: 0x2017

Description:

This command causes any changes to the controller's configuration to be saved to Flash. Saved configurations are then loaded again next time the controller is powered on. This command is a duplication of the EESAV maintenance command. It is provided as a Real-Time command as well in order to make it possible to save configuration changes from within MicroBasic scripts.

Syntax Serial: !EES

Syntax Scripting: setcommand(_EES, 1)
setcommand(_EESAV, 1)

Number of Arguments: 0

Note:

Do not save configuration while motors are running. Saving to EEPROM takes several milliseconds, during which the control loop is suspended.
Number of EEPROM write cycles are limited to around 10000. Saving to EEPROM must be done scarcely.

EX - Emergency Stop

Alias: ESTOP HexCode: 0E CANOpen id: 0x200C

Description:

The EX command will cause the controller to enter an emergency stop in the same way as if hardware emergency stop was detected on an input pin. The emergency stop condition will remain until controller is reset or until the MG release command is received.

Syntax Serial: !EX

Syntax Scripting: setcommand(_EX, 1)
setcommand(_ESTOP, 1)

Number of Arguments: 0

G - Go to Speed or to Relative Position

Alias: GO HexCode: 00 CANOpen id: Use CG

Description:

G is the main command for activating the motors. The command is a number ranging 1000 to +1000 so that the controller respond the same way as when commanded using Analog or Pulse, which are also -1000 to +1000 commands. The effect of the command differs from one operating mode to another.

In Open Loop Speed mode the command value is the desired power output level to be applied to the motor.

In Closed Loop Speed mode, the command value is relative to the maximum speed that is stored in the MXRPM configuration parameter.

In Closed Loop Position Relative and in the Closed Loop Tracking mode, the command is the desired relative destination position mode.

The G command has no effect in the Position Count mode.

In Torque mode, the command value is the desired Motor Amps relative to the Amps Limit configuration parameters

Syntax Serial: !G [nn] mm

Syntax Scripting: setcommand(_G, nn, mm)
setcommand(_GO, nn, mm)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Value Type: Signed 32-bit

Min: -1000 Max: 1000

Where:

cc = Motor channel
nn = Command value

Example:

!G 1 500 : In Open Loop Speed mode, applies 50% power to motor channel 1
!G 1 500 : In Closed Loop Speed mode, assuming that 3000 is contained in Max RPM parameter (MXRPM), motor will go to 1500 RPM
!G 1 500 : In Closed Loop Relative or Closed Loop Tracking modes, the motor will move to 75% position of the total -1000 to +1000 motion range
!G 1 500 : In Torque mode, assuming that Amps Limit is 60A, motor power will rise until 30A are measured.

H - Load Home counter

Alias: HOME HexCode: 0D CANOpen id: 0x200B

Description:

This command loads the Home count value into the Encoder or Brushless Counters. The Home count can be any user value and is set using the EHOME and BHOME configuration parameters. Beware that loading the counter with the home value while the controller is operating in closed loop can have adverse effects.

Syntax Serial: !H [cc]

Syntax Scripting: setcommand(_H, cc)
setcommand(_HOME, cc)

Number of Arguments: 1

Argument 1: Channel Type: Unsigned 8-bit

Min: 1 Max: Total Number of Encoders

Where:

cc = Motor channel

Example:

!H 1: Loads encoder counter 1 and brushless counter 1 with their preset home values

MG - Emergency Stop Release

Alias: MGO HexCode: 0F CANOpen id: 0x200D

Description:

The MG command will release the emergency stop condition and allow the controller to return to normal operation. Always make sure that the fault condition has been cleared before sending this command

Syntax Serial: !MG

Syntax Scripting: setcommand(_MG, 1)
setcommand(_MGO, 1)

Number of Arguments: 0

MS - Stop in all modes

Alias: MSTOP HexCode: 10 CANOpen id: 0x200E

Description:

The MS command is similar to the EX emergency stop command except that it is applied to the specified motor channel

Syntax Serial: !MS [cc]

Syntax Scripting: setcommand(_MS, cc)
setcommand(_MSTOP, cc)

Number of Arguments: 1

Argument 1: Channel Type: Unsigned 8-bit

Min: 1 Max: Total Number of Motors

Where:

cc = Motor channel

P - Go to Absolute Desired Position

Alias: MOTPOS HexCode: 02 CANOpen id: 0x2001

Description:

This command is used in the Position Count mode to make the motor move to a specified encoder or hall count value.

Syntax Serial: !P [cc] nn

Syntax Scripting: setcommand(_P, cc, nn)
setcommand(_MOTPOS, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Destination Type: Signed 32-bit

Min: -2147M Max: +2147M

Where:

cc = Motor channel
nn = Absolute count destination

Example:

!P 1 10000 : make motor go to absolute count value 10000.

PR - Go to Relative Desired Position

Alias: MPOSREL HexCode: 11 CANOpen id: 0x200F

Description:

This command is used in the Position Count mode to make the motor move to an encoder count position that is relative to its current desired position.

Syntax Serial: PR [cc] nn

Syntax Scripting: setcommand(_PR, cc, nn)
setcommand(_MPOSREL, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Delta Type: Signed 32-bit

Min: -2147M Max: +2147M

Where:

cc = Motor channel
nn = Relative count position

Example:

!PR 1 10000 : while motor is stopped after power up and counter = 0, motor 1 will go to +10000

!PR 2 10000 : while previous command was absolute goto position !P 2 5000, motor will go to +15000

Note:

Beware that counter will rollover at counter values +/-2'147'483'648.

PRX - Next Go to Relative Desired Position

Alias: NXTPOSR HexCode: 13 CANOpen id: 0x2011

Description:

This command is similar to PR except that it stores a relative count value in a buffer. This value becomes active upon reaching a previous desired position and will become the next destination the controller will go to. See Position Command Chaining in manual.

Syntax Serial: !PRX [cc] nn

Syntax Scripting: setcommand(_PRX, cc, nn)
setcommand(_NXTPOSR, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Delta Type: Signed 32-bit

Min: -2147M Max: +2147M

Where:

cc = Motor channel
nn = Relative count position

Example:

!P 1 5000 followed by !PRX 1 -10000 : will cause motor to go to count position 5000 and upon reaching the destination move to position -5000.

PX - Next Go to Absolute Desired Position

Alias: NXTPOS HexCode: 12 CANOpen id: 0x2010

Description:

This command is similar to P except that it stores an absolute count value in a buffer. This value will become the next destination the controller will go to and becomes active upon reaching a previous desired position. See Position Command Chaining in manual.

Syntax Serial: !PX [nn] cc

Syntax Scripting: setcommand(_PX, nn, cc)
setcommand(_NXTPOS, nn, cc)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Delta Type: Signed 32-bit

Min: -2147M Max: +2147M

Where:

cc = Motor channel
nn = Absolute count position

Example:

!P 1 5000 followed by !PX 1 -10000 : will cause motor to go to count position 5000 and upon reaching the destination move to position -10000.

R - MicroBasic Run

Alias: BRUN HexCode: 0C CANOpen id: 0x2018

Description:

This command is used to start, stop and restart a MicroBasic script if one is loaded in the controller.

Syntax Serial: !R [nn]

Syntax Scripting: setcommand(_R, nn)
setcommand(_BRUN, nn)

Number of Arguments: 1

Argument 1: [Option] Type: Unsigned 8-bit

Min: None Max: 2

Where:

nn =
None : Start/resume script
0 : Stop script
1 : Start/resume script
2 : Reinitialize and restart script

RC - Set Pulse Out

Alias: RCOUT HexCode: 1A CANOpen id: 0x2016

Description:

Set the pulse widht on products with pulse outputs. Command ranges from -1000 to +1000, resulting in pulse widht of 1.0ms to 1.5ms respectively.

Syntax Serial: !RC cc nn

Syntax Scripting: setcommand(_RC, cc, nn)
setcommand(_RCOUT, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Number or Pulse Outs

Argument 2: Value Type: Signed 16-bit

Min: -1000 Max: 1000

Where:

cc = Channel number
nn = Value

S - Set Motor Speed

Alias: MOTVEL HexCode: 03 CANOpen id: 0x2002

Description:

In the Closed-Loop Speed mode, this command will cause the motor to spin at the desired RPM speed. In Closed-Loop Position modes, this commands determines the speed at which the motor will move from one position to the next. It will not actually start the motion.

Syntax Serial: !S [cc] nn

Syntax Scripting: setcommand(_S, cc, nn)
setcommand(_MOTVEL, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Value Type: Signed 32-bit

Min: -500000 Max: 500000

Where:

cc = Motor channel
nn = Speed value in RPM

Example:

!S 2500 : set motor 1 position velocity to 2500 RPM

SX - Next Velocity

Alias: NXTVEL HexCode: 17 CANOpen id: 0x2014

Description:

This command is used in Position Count mode. It is similar to S except that it stores a velocity value in a buffer. This value will become the next velocity the controller will use and becomes active upon reaching a previous desired position. If omitted, the command will be chained using the last used velocity value. See Position Command Chaining in manual.

Syntax Serial: !SX cc nn

Syntax Scripting: setcommand(_SX, cc, nn)
setcommand(_NXTVEL, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Value Type: Signed 32-bit

Min: -500000 Max: 500000

Where:

cc = Motor channel
nn = Velocity value

VAR - Set User Variable

Alias: VAR HexCode: 06 CANOpen id: 0x2005

Description:

This command is used to set the value of user variables inside the controller. These variables can be then read from within a user MicroBasic script to perform specific actions. The total number of variables depends on the controller model and can be found in the product datasheet. Variables are signed 32-bit integers.

Syntax Serial: !VAR nn mm

Syntax Scripting: setcommand(_VAR, nn, mm)
setcommand(_VAR, nn, mm)

Number of Arguments: 2

Argument 1: VarNbr
Min: 1 Max: Total nbr of User Variables

Argument 2: Value Type: Signed 32-bit
Min: -2147M Max: 2147M

Where:

nn = Variable number
mm = Value

Runtime Queries

Runtime queries can be used to read the value of real-time measurements at any time during the controller operation. Real-time queries are very short commands that start with "**?**" followed by one to three letters. In some instances, queries can be sent with or without a numerical parameter.

Without parameter, the controller will reply with the values of all channels. When a numerical parameter is sent, the controller will respond with the value of the channel selected by that parameter.

Example:

Q:**?T**
R: **T=20:30:40**

Q: **?T2**
R: **T=30**

All queries are stored in a history buffer that can be made to automatically recall the past 16 queries at a user-selectable time interval. See "Query History Commands" on page 271.

Routine queries can be sent from within a MicroBasic Script using the getvalue() function.

TABLE 19-2. Runtime Queries

Command	Argument	Description
A	Channel	Read Motor Amps
AI	InputNbr	Read Analog Inputs
AIC	InputNbr	Read Analog Input after Conversion
ANG	Channel	Read Rotor Angle
ASI	Channel	Read Raw Sin/Cos sensor
B	VarNbr	Read User Boolean Variable
BA	Channel	Read Battery Amps
BCR	Channel	Read Brushless Count Relative

TABLE 19-2. Runtime Queries

Command	Argument	Description
BS	Channel	Read BL Motor Speed in RPM
BSR	Channel	Read BL Motor Speed as 1/1000 of Max RPM
C	Channel	Read Encoder Counter Absolute
CAN	Element	Read Raw CAN frame
CB	Channel	Read Absolute Brushless Counter
CF	None	Read Raw CAN Received Frames Count
CIA	Channel	Read Converted Analog Command
CIP	Channel	Read Internal Pulse Command
CIS	Channel	Read Internal Serial Command
CL	Group	Read RoboCAN Alive Nodes Map
CR	Channel	Read Encoder Count Relative
D	None	Read Digital Inputs
DI	InputNbr	Read Individual Digital Inputs
DO	None	Read Digital Output Status
DR	Channel	Read Destination Reached
E	Channel	Read Closed Loop Error
F	Channel	Read Feedback
FC	Channel	Read FOC Angle Adjust
FF	None	Read Fault Flags
FID	None	Read Firmware ID
FM	Channel	Read Runtime Status Flag
FS	None	Read Status Flags
HS	Channel	Read Hall Sensor States
ICL	NodeId	Is RoboCAN Node Alive
K	Channel	Read Spektrum Receiver
LK	None	Read Lock status
M	Channel	Read Motor Command Applied
MA	AmpsChannel	Read Field Oriented Control Motor Amps
MGD	[SensorNumber]	Read Magsensor Track Detect
MGM	[SensorNumber]	Read Magsensor Markers
MGS	[SensorNumber]	Read Magsensor Status
MGT	[Channel]	Read Magsensor Track Position
MGY	[Channel]	Read Magsensor Gyroscope
P	Channel	Read Motor Power Output Applied
PI	InputNbr	Read Pulse Inputs
PIC	InputNbr	Read Pulse Input after Conversion
S	Channel	Read Encoder Motor Speed in RPM

TABLE 19-2. Runtime Queries

Command	Argument	Description
SCC	None	Read Script Checksum
SR	Channel	Read Encoder Speed Relative
T	SensorNbr	Read Temperature
TM	[Element]	Read Time
TR	[Channel]	Read Position Relative Tracking
TRN	None	Read Control Unit type and Controller Model
UID	Element	Read MCU Id
V	SensorNumber	Read Volts
VAR	VarNumber	Read User Integer Variable

A - Read Motor Amps

Alias: MOTAMPS HexCode: 00 CANOpen id: 0x2100

Description:

Measures and reports the motor Amps for all operating channels. Note that the current flowing through the motors is often higher than this flowing through the battery.

Syntax Serial: ?A [cc]

Argument: Channel
Min: 1 Max: Total Number of Motors

Syntax Scripting: result = getvalue(_A, cc)
result = getvalue(_MOTAMPS, cc)

Reply:

A = aa Type: Signed 16-bit Min: 0

Where:

cc = Motor channel
aa = Amps *10 for each channel

Example:

Q: ?A
R: A=100:200
Q: ?A 2
R: A=200

Note:

Single channel controllers will report a single value. Some power board units measure the Motor Amps and calculate the Battery Amps, while other models measure the Battery

Amps and calculate the Motor Amps. The measured Amps is always more precise than the calculated Amps. See controller datasheet to find which Amps is measured by your particular model.

AI - Read Analog Inputs

Alias: ANAIN HexCode: 10 CANOpen id: 0x6401

Description:

Reports the raw value in mV of each of the analog inputs that are enabled. Input that is disabled will report 0. The total number of Analog input channels varies from one controller model to another and can be found in the product datasheet.

Syntax Serial: ?AI [cc]

Argument: InputNbr
Min: 1 Max: Max Number of Analog Inputs

Syntax Scripting: result = getvalue(_AI, cc)
result = getvalue(_ANAIN, cc)

Reply:

AI=nn Type: Signed 16-bit Min: 0 Max: 5300

Where:

cc = Analog Input number
nn = Millivolt for each channel

AIC - Read Analog Input after Conversion

Alias: ANAINC HexCode: 23 CANOpen id: 0x6402

Description:

Returns value of an Analog input after all the adjustments are performed to convert it to a command or feedback value (Min/Max/Center/Deadband/Linearity). If an input is disabled, the query returns 0. The total number of Analog input channels varies from one controller model to another and can be found in the product datasheet.

Syntax Serial: ?AIC [cc]

Argument: InputNbr
Min: 1 Max: Total Number of Analog Inputs

Syntax Scripting: result = getvalue(_AIC, cc)
result = getvalue(_ANAINC, cc)

Reply:

AIC=nn Type: Signed 16-bit Min: -1000 Max: 1000

Where:

cc = Analog Input number
nn = Converted analog input value +/-1000 range

ANG - Read Rotor Angle

Alias: ANG HexCode: 42 CANOpen id: 0x2132

Description:

On brushless controller operating in sinusoidal mode, this query returns the real time value of the rotor's angle sensor of brushless motor. This query is useful for verifying troubleshooting sin/cos and SPI/SSI sensors. Angle are reported in 0-511 degrees.

Syntax Serial: ?ANG [cc]

Argument: Channel
Min: 1 Max: Total Number of Motors

Syntax Scripting: result = getvalue(_ANG, cc)

Reply:

ANG=nn Type: Unsigned 16-bit Min: 0 Max: 511

Where:

cc = Motor channel
nn = Rotor electrical angle

ASI - Read Raw Sin/Cos sensor

Alias: ASI HexCode: 33 CANOpen id:

Description:

Returns real time values of ADC connected to sin/cos sensors of each motor . This query is useful for verifying troubleshooting sin/cos sensors.

Syntax Serial: ?ASI [cc]

Argument: Channel
Min: 1 Max: 2 * Number of Motors

Syntax Scripting: result = getvalue(_ASI, cc)

Reply:

ASI=nn Type: Unsigned 16-bit Min: 0 Max: 4095

Where:

cc =
1 : Sin input 1
2 : Cos input 1
3 : Sin input 2
4 : Cos input 2
nn = ADC value

B - Read User Boolean Variable

Alias: BOOL HexCode: 16 CANOpen id: 0x6407

Description:

Read the value of boolean internal variables that can be read and written to/from within a user MicroBasic script. It is used to pass boolean states between user scripts and a microcomputer connected to the controller. The total number of user boolean variables varies from one controller model to another and can be found in the product datasheet.

Syntax Serial: ?B [nn]

Argument: VarNbr
Min: 1 Max: Total Number of Bool Variables

Syntax Scripting: result = getvalue(_B, nn)
result = getvalue(_BOOL, nn)

Reply:

B=bb Type: Boolean Min: 0 Max: 1

Where:

nn = Boolean variable number
bb = 0 or 1 state of the variable

BA - Read Battery Amps

Alias: BATAMPS HexCode: 0C CANOpen id: 0x210C

Description:

Measures and reports the Amps flowing from the battery in Amps * 10. Battery Amps are often lower than motor Amps.

Syntax Serial: ?BA [cc]

Argument: Channel:
Min: 1 Max: Total Number of Motors

Syntax Scripting: result = getvalue(_BA, cc)
result = getvalue(_BATAMPS, cc)

Reply:

BA=aa Type: Signed 16-bit Min: 0

Where:

cc = Motor channel
aa = Amps *10 for each channel

Example:

Q: ?BA R:
BA=100:200

Note:

Some controller models measure the Motor Amps and Calculate the Battery Amps, while other models measure the Battery Amps and calculate the Motor Amps. The measured Amps is always more precise than the calculated Amps. See controller datasheet to find which Amps is measured by your particular model.

BCR - Read Brushless Count Relative

Alias: BLRCNTR HexCode: 09 CANOpen id: 0x2109

Description:

Returns the amount of Hall sensor counts that have been measured from the last time this query was made. Relative counter read is sometimes easier to work with, compared to full counter reading, as smaller numbers are usually returned.

Syntax Serial: ?BCR [cc]

Argument: Channel
Min: 1 Max: Total Number of Motors

Syntax Scripting: result = getvalue(_BCR, cc)
result = getvalue(_BLRCNTR, cc)

Reply:

BCR=nn Type: Signed 32-bit Min: -2147M Max: 2147M

Where:

cc = Motor channel
nn = Value

BS - Read BL Motor Speed in RPM

Alias: BLSPEED HexCode: 0A CANOpen id: 0x210A

Description:

On brushless motor controllers, reports the actual speed measured using the motor's Hall sensors as the actual RPM value. To report RPM accurately, the correct number of motor poles must be loaded in the BLPOL configuration parameter.

Syntax Serial: ?BS [cc]

Argument: Channel
Min: 1 Max: Total Number of Motors

Syntax Scripting: result = getvalue(_BS, cc)
result = getvalue(_BLSPEED, cc)

Reply:

BS=nn Type: Signed 16-bit Min: -32768 Max: 32767

Where:

cc = Motor channel
nn = Speed in RPM

BSR - Read BL Motor Speed as 1/1000 of Max RPM

Alias: BLRSPEED HexCode: 0B CANOpen id: 0x210B

Description:

On brushless motor controllers, returns the measured motor speed as a ratio of the Max RPM configuration parameter. The result is a value of between 0 and +/-1000. Note that if the motor spins faster than the Max RPM, the return value will exceed 1000. However, a larger value is ignored by the controller for its internal operation. To report an accurate result, the correct number of motor poles must be loaded in the BLPOL configuration parameter.

Syntax Serial: ?BSR

Argument: Channel
Min: 1 Max: Total Number of Motors

Syntax Scripting: result = getvalue(_BSR,)
result = getvalue(_BLRSPEED,)

Reply:

BSR=nn Type: Signed 16-bit Min: -1000 Max: 1000

Where:

nn = Speed relative to max

Example:

Q: ?BSR
R: BSR=500: speed is 50%of the RPM value stored in the Max RPM configuration

C - Read Encoder Counter Absolute

Alias: ABCNTR HexCode: 04 CANOpen id: 0x2104

Description:

Returns the encoder value as an absolute number. The counter is 32-bit with a range of +/- 2147483648 counts.

Syntax Serial: ?C [cc]

Argument: Channel
Min: 1 Max: Total Number of Encoders

Syntax Scripting: result = getvalue(_C, cc)
result = getvalue(_ABCNTR, cc)

Reply:

C=nn Type: Signed 32-bit Min: -2147M Max: 2147M

Where:

cc = Encoder channel number
nn = Absolute counter value

CAN - Read Raw CAN frame

Alias: CAN HexCode: 27 CANOpen id:

Description:

This query is used in CAN-enabled controllers to read the content of a received CAN frame in the RawCAN mode. Data will be available for reading with this query only after a ?CF query is first used to check how many received frames are pending in the FIFO buffer. When the query is sent without arguments, the controller replies by outputting all elements of the frame separated by colons.

Syntax Serial: ?CAN [ee]

Argument: Element
Min: 1 Max: 10

Syntax Scripting: result = getvalue(_CAN, ee)

Reply:

CAN = dd1:dd2:dd3: ... :dd10 Type: Unsigned 16-bit Min: 0 Max: 255

Where:

ee = Byte in frame

dd1 = Header

dd2= Bytecount
dd3 to dd10 = Data0 to data7

Example:

Q: ?CAN
R: CAN=5:4:11:12:13:14:0:0:0:0
Q: ?CAN 3
R: CAN=11

CB - Read Absolute Brushless Counter

Alias: BLCNTR HexCode: 05 CANOpen id: 0x2105

Description:

On brushless motor controllers, returns the running total of Hall sensor transition value as an absolute number. The counter is 32-bit with a range of +/- 2147483648 counts.

Syntax Serial: ?CB [cc]

Argument: Channel
Min: 1 Max: Total Number of Motors

Syntax Scripting: result = getvalue(_CB, cc)
result = getvalue(_BLCNTR, cc)

Reply:

CB=nn Type: Signed 32-bit Min: -2147M Max: 2147M

Where:

cc = Motor channel
nn = Absolute counter value

CF - Read Raw CAN Received Frames Count

Alias: CF HexCode: 28 CANOpen id:

Description:

This query is used to read the number of received CAN frames pending in the FIFO buffer and copies the oldest frame into the read buffer, from which it can then be accessed using the ?CAN query. Sending ?CF again, copies the next frame into the read buffer. The controller can buffer up to 16 CAN frames

Syntax Serial: ?CF

Argument: None

Syntax Scripting: result = getvalue(_CF, 1)

Reply:

CF=nn Type: Unsigned 8-bit Min: 0 Max: 16

Where:

nn = Number of frames in receive queue

CIA - Read Converted Analog Command

Alias: CMDANA HexCode: 1A CANOpen id: 0x2117

Description:

Returns the motor command value that is computed from the Analog inputs whether or not the command is actually applied to the motor. The Analog inputs must be configured as Motor Command. This query can be used, for example, to read the command joystick from within a MicroBasic script or from an external microcomputer, even though the controller may be currently responding to RS232 or Pulse command because of a higher priority setting. The returned value is the raw Analog input value with all the adjustments performed to convert it to a command (Min/Max/Center/Deadband/Linearity).

Syntax Serial: ?CIA [cc]

Argument: Channel
Min: 1 Max: Total Number of Motors

Syntax Scripting: result = getvalue(_CIA, cc)
result = getvalue(_CMDANA, cc)

Reply:

CIA=nn Type: Signed 32-bit Min: -1000 Max: 1000

Where:

cc = Motor channel
nn = Command value in +/-1000 range

CIP - Read Internal Pulse Command

Alias: CMDPLS HexCode: 1B CANOpen id: 0x2118

Description:

Returns the motor command value that is computed from the Pulse inputs whether or not the command is actually applied to the motor. The Pulse input must be configured as Motor Command. This query can be used, for example, to read the command joystick from within a MicroBasic script or from an external microcomputer, even though the controller may be currently responding to RS232 or Analog command because of a higher priority setting. The returned value is the raw Pulse input value with all the adjustments performed to convert it to a command (Min/Max/Center/Deadband/Linearity).

Syntax Serial: ?CIP [cc]

Argument: Channel
Min: 1 Max: Total Number of Motors

Syntax Scripting: result = getvalue(_CIP, cc)
result = getvalue(_CMDPLS, cc)

Reply:

CIP=nn Type: Signed 32-bit Min: -1000 Max: 1000

Where:

cc = Motor channel
nn = Command value in +/-1000 range

CIS - Read Internal Serial Command

Alias: CMDSER HexCode: 19 CANOpen id: 0x2116

Description:

Returns the motor command value that is issued from the serial input or from a MicroBasic script whether or not the command is actually applied to the motor. This query can be used, for example, to read from an external microcomputer the command generated inside MicroBasic script, even though the controller may be currently responding to a Pulse or Analog command because of a higher priority setting.

Syntax Serial: ?CIS [cc]

Argument: Channel
Min: 1 Max: Total Number of Motors

Syntax Scripting: result = getvalue(_CIS, cc)
result = getvalue(_CMDSER, cc)

Reply:

CIS=nn Type: Signed 32-bit Min: -1000 Max: 1000

Where:

cc = channel
nn = command value in +/-1000 range

CL - Read RoboCAN Alive Nodes Map

Alias: CALIVE HexCode: 26 CANOpen id:

Description:

With CL it is possible to see which nodes in a RoboCAN are alive and what type of device is present at each node. A complete state of the network is represented in sixteen 32-bit numbers. Within each 32-bit word are 8 groups of 4-bits. The 4-bits contain the

done information. E.g. bits 0-3 of first number is for node 0, bits 8-11 of first number is for node 2, bits 4-7 of second number is for node 5 and bits 12-15 of fourth number is for node 11, etc.

Syntax Serial: ?CL nn

Argument: Group
Min: 1 Max: 16

Syntax Scripting: result = getvalue(_CL, nn)
result = getvalue(_CALIVE, nn)

Reply:

CL=mm Type: Unsigned 32-bit Min: 0 Max: 4194M

Where:

nn =
1 : nodes 0-3
2 : nodes 4-7
...
...
15 : nodes 120-123
16 : nodes 124-127
mm = 4 words of 4 bits. Each 4-bit word:
0b0000 : Inactive node
0b0001 : Active motor controller
0b0011 : Active magsensor
0b0101 : Active RIOX

CR - Read Encoder Count Relative

Alias: RELCNTR HexCode: 08 CANOpen id: 0x2108

Description:

Returns the amount of counts that have been measured from the last time this query was made. Relative counter read is sometimes easier to work with, compared to full counter reading, as smaller numbers are usually returned.

Syntax Serial: ?CR [cc]

Argument: Channel
Min: 1 Max: Total Number of Encoders

Syntax Scripting: result = getvalue(_CR, cc)
result = getvalue(_RELCNTR, cc)

Reply:

CR=nn Type: Signed 32-bit Min: -2147M Max: 2147

Where:

cc = Motor channel
nn = Counts since last read using ?CR

D - Read Digital Inputs

Alias: DIGIN HexCode: 0E CANOpen id: 0x210E

Description:

Reports the status of each of the available digital inputs. The query response is a single digital number which must be converted to binary and gives the status of each of the inputs. The total number of Digital input channels varies from one controller model to another and can be found in the product datasheet.

Syntax Serial: ?D

Argument: None

Syntax Scripting: result = getvalue(_D, 1)
result = getvalue(_DIGIN, 1)

Reply:

D=nn Type: Unsigned 32-bit

Where:

nn = b1 + b2*2 + b3*4 + ... +bn*2^n-1

Example:

Q: ?D
R: D=17 : Inputs 1 and 5 active, all others inactive

DI - Read Individual Digital Inputs

Alias: DIN HexCode: 0F CANOpen id: 0x6400

Description:

Reports the status of an individual Digital Input. The query response is a boolean value (0 or 1). The total number of Digital input channels varies from one controller model to another and can be found in the product datasheet.

Syntax Serial: ?DI [cc]

Argument: InputNbr
Min: 1 Max: Total Number of Digital Inputs

Syntax Scripting: result = getvalue(_DI, cc)
result = getvalue(_DIN, cc)

Reply:

DI=nn Type: Boolean Min: 0 Max: 1

Where:

cc = Digital Input number
nn = 0 or 1 state for each input

Example:

Q: ?DI
R: DI=1:0:1:0:1:0
Q: ?DI 1
R: DI=0

DO - Read Digital Output Status

Alias: DIGOUT HexCode: 17 CANOpen id: 0x6408

Description:

Reads the actual state of all digital outputs. The response to that query is a single number which must be converted into binary in order to read the status of the individual output bits. When querying an individual output, the reply is 0 or 1 depending on its status. The total number of Digital output channels varies from one controller model to another and can be found in the product datasheet.

Syntax Serial: ?DO

Argument: None

Syntax Scripting: result = getvalue(_DO, 1)
result = getvalue(_DIGOUT, 1)

Reply:

DO=nn Type: Unsigned 16-bit Min: 0 Max: 65536

Where:

nn = d1 + d2*2 + d3*4 + ... + dn * 2^n-1

Example:

Q: ?DO
R: DO=17 : Outputs 1 and 5 active, all others inactive

DR - Read Destination Reached

Alias: DREACHED HexCode: 22 CANOpen id: 0x211B

Description:

This query is used when chaining commands in Position Count mode, to detect that a destination has been reached and that the next destination values that were loaded in the

buffer have become active. The Destination Reached bit is latched and is cleared once it has been read.

Syntax Serial: ?DR [cc]

Argument: Channel
Min: 1 Max: Total Number of Motors

Syntax Scripting: result = getvalue(_DR, cc)
result = getvalue(_DREACHED, cc)

Reply:

DR=nn Type: Unsigned 8-bit Min: 0 Max: 1

Where:

cc = Motor channel
nn =
0 : Not yet reached
1 : Reached

E - Read Closed Loop Error

Alias: LPERR HexCode: 18 CANOpen id: 0x6409

Description:

In closed-loop modes, returns the difference between the desired speed or position and the measured feedback. This query can be used to detect when the motor has reached the desired speed or position. In open loop mode, this query returns 0.

Syntax Serial: ?E [cc]

Argument: Channel
Min: 1 Max: Total Number of Motors

Syntax Scripting: result = getvalue(_E, cc)
result = getvalue(_LPERR, cc)

Reply:

E=nn Type: Signed 32-bit Min: -2147M Max: 2147M

Where:

cc = Motor channel
nn = Error value

F - Read Feedback

Alias: FEEDBK HexCode: 13 CANOpen id: 0x6404

Description:

Reports the value of the feedback sensors that are associated to each of the channels in closed-loop modes. The feedback source can be Encoder, Analog or Pulse. Selecting the feedback source is done using the encoder, pulse or analog configuration parameters. This query is useful for verifying that the correct feedback source is used by the channel in the closed-loop mode and that its value is in range with expectations.

Syntax Serial: ?F [cc]

Argument: Channel
Min: 1 Max: Total Number of Motors

Syntax Scripting: result = getvalue(_F, cc)
result = getvalue(_FEEDBK, cc)

Reply:

F=nn Type: Signed 16-bit Min: -1000 Max: 1000

Where:

cc = Motor channel
nn = Feedback values

FC - Read FOC Angle Adjust

Alias: FC HexCode: 47 CANOpen id: 0x2135

Description:

Read in real time the angle correction that is currently applied by the Field Oriented algorithm in order achieve optimal performance

Syntax Serial: ?FC [cc]

Argument: Channel
Min: 1 Max: Total Number of Motors

Syntax Scripting: result = getvalue(_FC, cc)

Reply:

FC = nn Type: Signed 16-bit Min: -512 Max: 512

Where:

cc = Motor channel
nn = Angle correction

FF - Read Fault Flags

Alias: FLTFLAG HexCode: 15 CANOpen id: 0x6406

Description:

Reports the status of the controller fault conditions that can occur during operation. The response to that query is a single number which must be converted into binary in order to evaluate each of the individual status bits that compose it.

Syntax Serial: ?FF

Argument: None

Syntax Scripting: result = getvalue(_FF, 1)
result = getvalue(_FLTFLAG, 1)

Reply:

FF = f1 + f2*2 + f3*4 + ... + fn*2n-1
Type: Unsigned 8-bit Min: 0 Max: 255

Where:

f1 = Overheat
f2 = Overvoltage
f3 = Undervoltage
f4 = Short circuit
f5 = Emergency stop
f6 = Brushless sensor fault
f7 = MOSFET failure
f8 = Default configuration loaded at startup

Example:

Q: ?FF
R: FF=2 : Overvoltage fault

FID - Read Firmware ID

Alias: FID HexCode: 1E CANOpen id:

Description:

This query will report a string with the date and identification of the firmware revision of the controller.

Syntax Serial: ?FID

Argument: None

Syntax Scripting: result = getvalue(_FID, 1)

Reply:

FID=ss Type: String

Where:

ss = Firmware ID string

Example:

Q: ?FID
R: FID=Roboteq v1.6 RCB500 05/01/2016

FM - Read Runtime Status Flag

Alias: MOTFLAG HexCode: 30 CANOpen id: 0x2122

Description:

Report the runtime status of each motor. The response to that query is a single number which must be converted into binary in order to evaluate each of the individual status bits that compose it.

Syntax Serial: ?FM [cc]

Argument: Channel
Min: 1 Max: Total Number of Motors

Syntax Scripting: result = getvalue(_FM, cc)
result = getvalue(_MOTFLAG, cc)

Reply:

FM = f1 + f2*2 + f3*4 + ... + fn*2n-1

Type: Unsigned 16-bit Min: 0 Max: 255

Where:

cc = Motor channel
f1 = Amps Limit currently active
f2 = Motor stalled
f3 = Loop Error detected
f4 = Safety Stop active
f5 = Forward Limit triggered
f6 = Reverse Limit triggered
f7 = Amps Trigger activated

Example:

Q: ?FM 1
R: FM=6 : Motor 1 is stalled and loop error detected

Note:

f2, f3 and f4 are cleared when the motor command is returned to 0. When f5or f6 are on, the motor can only be commanded to go in the reverse direction.

FS - Read Status Flags

Alias: STFLAG HexCode: 14 CANOpen id: 0x6405

Description:

Report the state of status flags used by the controller to indicate a number of internal conditions during normal operation. The response to this query is the single number for all status flags. The status of individual flags is read by converting this number to binary and look at various bits of that number.

Syntax Serial: ?FS

Argument: None

Syntax Scripting: result = getvalue(_FS, 1)
result = getvalue(_STFLAG, 1)

Reply:

FS = f1 + f2*2 + f3*4 + ... + fn*2^n-1 Type: Unsigned 8-bit Min: 0 Max: 255

Where:

f1 = Serial mode
f2 = Pulse mode
f3 = Analog mode
f4 = Power stage off
f5 = Stall detected
f6 = At limit
f7 = Unused
f8 = MicroBasic script running

Note:

On controller models supporting Spektrum radio mode f4 is used to indicate Spektrum. f4 to f6 are shifted to f5 to f7

HS - Read Hall Sensor States

Alias: HSENSE HexCode: 31 CANOpen id: 0x2123

Description:

Reports that status of the hall sensor inputs. This function is mostly useful for trouble-shooting. When no sensors are connected, all inputs are pulled high and the value 7 will be replied. All inputs high and all inputs low (0) are invalid combinations. In normal conditions, all values from 1 to 6 should appear at one time or the other as the motor shaft is rotated

Syntax Serial: ?HS [cc]

Argument: Channel
Min: 1 Max: Total Number of Motors

Syntax Scripting: result = getvalue(_HS, cc)
result = getvalue(_HSENSE, cc)

Reply:

HS= ha + 2*hb + 4*hc Type: Unsigned 8-bit Min: 0 Max: 7

Where:

cc = channel
ha = hall sensor A
hb = hall sensor B
hc = hall sensor C
Example:
Q: ?HS 1
R: HS=5 : sensors A and C are high, sensor B is low

Note:

Function not available on HBLxxxxx products

ICL - Is RoboCAN Node Alive

Alias: ICL HexCode: 46 CANOpen id:

Description:

This query is used to determine if specific RoboCAN node is alive on CAN bus.

Syntax Serial: ?ICL cc

Argument: NodeId
Min: 1 Max: 127

Syntax Scripting: result = getvalue(_ICL, cc)

Reply:

ICL=nn Type: Unsigned 8-bit Min: 0 Max: 1

Where:

cc = Node Id
nn =
0 : Not present
1 : Alive

K - Read Spektrum Receiver

Alias: SPEKTRUM HexCode: 21 CANOpen id: 0x211A

Description:

On controller models with Spektrum radio support, this query is used to read the raw values of each of up to 6 receive channels. When signal is received, this query returns the value 0.

Syntax Serial: ?K [cc]

Argument: Channel
Min: 1 Max: 6

Syntax Scripting: result = getvalue(_K, cc)
result = getvalue(_SPEKTRUM, cc)

Reply:

K=nn Min: 0 Max: 1024

Where:

cc = Radio channel
nn = Raw joystick value, or 0 if transmitter is off or out of range

LK - Read Lock status

Alias: LOCKED HexCode: 1D CANOpen id:

Description:

Returns the status of the lock flag. If the configuration is locked, then it will not be possible to read any configuration parameters until the lock is removed or until the parameters are reset to factory default. This feature is useful to protect the controller configuration from being copied by unauthorized people.

Syntax Serial: ?LK

Argument: None

Syntax Scripting: result = getvalue(_LK, 1)
result = getvalue(_LOCKED, 1)

Reply:

LK=ff Type: Unsigned 8-bit Min: 0 Max: 1

Where:

ff =
0 : unlocked
1 : locked

M - Read Motor Command Applied

Alias: MOTCMD HexCode: 01 CANOpen id: 0x2101

Description:

Reports the command value that is being used by the controller. The number that is reported will be depending on which mode is selected at the time. The choice of one command mode vs. another is based on the command priority mechanism. In the RS232 mode, the reported value will be the command that is entered in via the RS232 or USB port and to which an optional exponential correction is applied. In the Analog and Pulse modes, this query will report the Analog or Pulse input after it is being converted using the min, max, center, deadband, and linearity corrections. This query is useful for viewing which command is actually being used and the effect of the correction that is being applied to the raw input.

Syntax Serial: ?M [cc]

Argument: Channel
Min: 1 Max: Total Number of Motors

Syntax Scripting: result = getvalue(_M, cc)
result = getvalue(_MOTCMD, cc)

Reply:

M=nn Type: Signed-16-bit Min: -1000 Max: 1000

Where:

cc = Motor channel
nn = Command value used for each motor. 0 to +/-1000 range

Example:

Q: ?M
R: M=800:-1000
Q: ?M 1 R:
M=800

MA - Read Field Oriented Control Motor Amps

Alias: MEMS HexCode: 25 CANOpen id: 0x211C

Description:

On brushless motor controllers operating in sinusoidal mode, this query returns the Torque (also known as Quadrature or Iq) current, and the Flux (also known as Direct, or Id) current. Current is reported in Amps x 10.

Syntax Serial: ?MA nn
Argument: AmpsChannel
Min: 1 Max: 2 * Total Number of Motors

Syntax Scripting: result = getvalue(_MA, nn)
result = getvalue(_MEMS, nn)

Reply:

MA=mm Type: Signed 16-bit

Where:

nn =
1 : Flux Amps 1 (Id)
2 : Torque Amps 1 (Iq)
3 : Flux Amps 2 (Id)
4 : Torque Amps 2 (Iq)
mm = Amps * 10

MGD - Read Magsensor Track Detect

Alias: MGDET HexCode: 29 CANOpen id: 0x211D

Description:

When one or more MGS1600 Magnetic Guide Sensors are connected to the controller, this query reports whether a magnetic tape is within the detection range of the sensor. If no tape is detected, the output will be 0. If only one sensor is connected to any pulse input, no argument is needed for this query. If more than one sensor is connected to pulse inputs and these inputs are enabled and configured in Magsensor MultiPWM mode, then the argument following the query is used to select the sensor

Syntax Serial: ?MGD [cc]

Argument: SensorNumber
Min: None Max: Total Number of Pulse Inputs

Syntax Scripting: result = getvalue(_MGD, cc)
result = getvalue(_MGDET, cc)

Reply:

MGD=nn Type: Unsigned 8-bit Min: 0 Max: 1

Where:

cc = (When only one sensor enabled)
None or 1 : Current sensor
cc = (When several sensors enabled)
1 : Sensor at pulse input 1
2 : Sensor at pulse input 2
...
p : Sensor at pulse input p
nn =
0 : No track detected
1 : Track detected

MGM - Read Magsensor Markers

Alias: MGMRKR HexCode: 2B CANOpen id: 0x211F

Description:

When one or more MGS1600 Magnetic Guide Sensors are connected to the controller, this query reports whether left or right markers are present under sensor.If only one sensor is connected to any pulse input this query will report the data of that sensor, regardless which pulse input it is connected to. If more than one sensor is connected to pulse inputs and these inputs are enabled and configured in Magsensor MultiPWM mode, then the argument following the query is used to select the sensor

Syntax Serial: ?MGM [cc]

Argument: SensorNumber
Min: 1 Max: 2 * Total Number of Pulse Inputs

Syntax Scripting: result = getvalue(_MGM, cc)
result = getvalue(_MGMRKR, cc)

Reply:

MGM=mm Type: Unsigned 8-bit Min: 0 Max: 1

Where:

cc = (When only one sensor enabled)
1 : Left Marker
2 : Right Marker
cc = (When several sensors enabled)
1 : Left Marker of sensor at pulse input 1
2 : Right Marker of sensor at pulse input 1
3 : Left Marker of sensor at pulse input 2
4 : Right Marker of sensor at pulse input 2
...
((p-1)* 2)+1 : Left Marker of sensor at pulse input p
((p-1)* 2)+2 : Right Marker of sensor at pulse input p
nn =
0 : No marker detected
1 : Marker detected

MGS - Read Magsensor Status

Alias: MGSTATUS HexCode: 2C CANOpen id: 0x2120

Description:

When one or more MGS1600 Magnetic Guide Sensors are connected to the controller, this query reports the state of the sensor. If only one sensor is connected to any pulse input, no argument is needed for this query. If more than one sensor is connected to pulse inputs and these inputs are enabled and configured in Magsensor MultiPWM mode, then the argument following the query is used to select the sensor.

Syntax Serial: ?MGS

Argument: SensorNumber
Min: None Max: Total Number of Pulse Inputs

Syntax Scripting: result = getvalue(_MGS,)
result = getvalue(_MGSTATUS,)

Reply:

MGS=f1 + f2*2 + f3*4 + ... + fn*2n-1 Type: Unsigned 16-bit

Where:

cc = (When only one sensor enabled)
None or 1 : Current sensor
cc = (When only several sensors enabled)
1 : Sensor at pulse input 1
2 : Sensor at pulse input 2

...

p : Sensor at pulse input p
f1 : Tape detect
f2 : Left marker present
f3 : Right marker present
f9 : Sensor active

MGT - Read Magsensor Track Position

Alias: MGTRACK HexCode: 2A CANOpen id: 0x211E

Description:

When one or more MGS1600 Magnetic Guide Sensors are connected to the controller, this query reports the position of the tracks detected under the sensor. If only one sensor is connected to any pulse input, the argument following the query selects which track to read. If more than one sensor is connected to pulse inputs and these inputs are enabled and configured in Magsensor MultiPWM mode, then the argument following the query is used to select the sensor. The reported position of the magnetic track in millimeters, using the center of the sensor as the 0 reference.

Syntax Serial: ?MGT cc

Argument: Channel
Min: 1 Max: 3 * Total Number of Pulse Inputs

Syntax Scripting: result = getvalue(_MGT, cc)
result = getvalue(_MGTRACK, cc)

Reply:

MGM = nn Type: Signed 16-bit

Where:

cc = (When only one sensor enabled)
1 : Left Track
2 : Right Track
3 : Active Track
cc = (When several sensors enabled)

1 : Left Track of sensor at pulse input 1
2 : Right Track of sensor at pulse input 1
3 : Active Track of sensor at pulse input 1
4 : Left Track of sensor at pulse input 2
5 : Right Track of sensor at pulse input 2
6 : Active Track of sensor at pulse input 2

...

((p-1)* 3)+1 : Left Track of sensor at pulse input p
((p-1)* 3)+2 : Right Track of sensor at pulse input p
((p-1)* 3)+3 : Active Track of sensor at pulse input p
nn = position in millimeters

MGY - Read Magsensor Gyroscope

Alias: MGYRO HexCode: 2D CANOpen id: 0x2121

Description:

When one or more MGS1600 Magnetic Guide Sensors are connected to the controller, this query reports the state of the optional gyroscope inside the sensor. If only one sensor is connected to any pulse input, no argument is needed for this query. If more than one sensor is connected to pulse inputs and these inputs are enabled and configured in Magsensor MultiPWM mode, then the argument following the query is used to select the sensor

Syntax Serial: ?MGY [cc]

Argument: Channel]
Min: None Max: Total Number of Pulse Inputs

Syntax Scripting: result = getvalue(_MGY, cc)
result = getvalue(_MGYRO, cc)

Reply:

MGY=nn Type: Signed 16-bit Min: -32768 Max: 32767

Where:

cc = (When only one sensor enabled)
None or 1 : Current sensor
cc = (When several sensors enabled)
1 : sensor at pulse input 1
2 : sensor at pulse input 2

...

p : sensor at pulse input p
nn = Gyroscope value

P - Read Motor Power Output Applied

Alias: MOTPWR HexCode: 02 CANOpen id: 0x2102

Description:

Reports the actual PWM level that is being applied to the motor at the power output stage. This value takes into account all the internal corrections and any limiting resulting from temperature or over current. A value of 1000 equals 100% PWM. The equivalent voltage at the motor wire is the battery voltage * PWM level.

Syntax Serial: ?P [cc]

Argument: Channel
Min: 1 Max: Total Number of Motors

Syntax Scripting: result = getvalue(_P, cc)
result = getvalue(_MOTPWR, cc)

Reply:

P=nn Type: Signed 16-bit Min: -1000 Max: 1000

Where:

cc = Motor channel
nn = 0 to +/-1000 power level

Example:

Q: ?P 1
R: P=800

PI - Read Pulse Inputs

Alias: PLSIN HexCode: 11 CANOpen id: 0x6402

Description:

Reports the value of each of the enabled pulse input captures. The value is the raw number in microseconds when configured in Pulse Width mode. In Frequency mode, the returned value is in Hertz. In Duty Cycle mode, the reported value ranges between 0 and 4095 when the pulse duty cycle is 0% and 100% respectively.

Syntax Serial: ?PI [cc]

Argument: InputNbr
Min: 1 Max: Total Number of Pulse Input

Syntax Scripting: result = getvalue(_PI, cc)
result = getvalue(_PLSIN, cc)

Reply:

PI=nn Type: Unsigned 16-bit Min: 0 Max: 65536

Where:

cc = Pulse capture input number

nn = Value

Note:

The total number of Pulse input channels varies from one controller model to another and can be found in the product datasheet.

PIC - Read Pulse Input after Conversion

Alias: PLSINC HexCode: 24 CANOpen id: 0x6404

Description:

Returns value of a Pulse input after all the adjustments were performed to convert it to a command or feedback value (Min/Max/Center/Deadband/Linearity). If an input is disabled, the query returns 0.

Syntax Serial: ?PIC [cc]

Argument: InputNbr
Min: 1 Max: Total Number of Pulse Input

Syntax Scripting: result = getvalue(_PIC, cc)
result = getvalue(_PLSINC, cc)

Reply:

PIC=nn Type: Signed 16-bit Min: -1000 Max: 1000

Where:

cc = Pulse input number
nn = Converted input value to +/-1000 range

S - Read Encoder Motor Speed in RPM

Alias: ABSPEED HexCode: 03 CANOpen id: 0x2103

Description:

Reports the actual speed measured by the encoders as the actual RPM value. To report RPM accurately, the correct Pulses per Revolution (PPR) must be

stored in the encoder configuration

Syntax Serial: ?S [cc]

Argument: Channel
Min: 1 Max: Total Number of Encoders

Syntax Scripting: result = getvalue(_S, cc)
result = getvalue(_ABSPEED, cc)

Reply:

S = nn Type: Signed 16-bit Min: -32768 Max: 32767

Where:

cc =Motor channel
nn = Speed in RPM

SCC - Read Script Checksum

Alias: SCC HexCode: 45 CANOpen id: 0x2133

Description:

Scans the script storage memory and computes a checksum number that is unique to each script. If not script is loaded the query outputs the value 0xFFFFFFFF. Since a stored script cannot be read out, this query is useful for determining if the correct version of a given script is loaded.

Syntax Serial: ?SCC

Argument: None

Syntax Scripting: result = getvalue(_SCC, 1)

Reply:

SCC = nn Type: Unsigned 32-bit

Where:

nn = Checksum number

SR - Read Encoder Speed Relative

Alias: RELSPEED HexCode: 07 CANOpen id: 0x2107

Description:

Returns the measured motor speed as a ratio of the Max RPM (MXRPM) configuration parameter. The result is a value of between 0 and +/1000. As an example, if the Max RPM is set at 3000 inside the encoder configuration parameter and the motor spins at 1500 RPM, then the returned value to this query will be 500, which is 50% of the 3000 max. Note that if the motor spins faster than the Max RPM, the returned value will exceed 1000. However, a larger value is ignored by the controller for its internal operation.

Syntax Serial: ?SR [cc]

Argument: Channel
Min: 1 Max: Total Number of Encoders

Syntax Scripting: result = getvalue(_SR, cc)
result = getvalue(_RELSPEED, cc)

Reply:

SR = nn Type: Signed 16-bit Min: -1000 Max: 1000

Where:

cc = Motor channel
nn = Speed relative to max

T - Read Temperature

Alias: TEMP HexCode: 12 CANOpen id: 0x6403

Description:

Reports the temperature at each of the Heatsink sides and on the internal MCU silicon chip. The reported value is in degrees C with a one degree resolution.

Syntax Serial: ?T [cc]

Argument: SensorNbr
Min: 1 Max: Total Number of Motors + 1

Syntax Scripting: result = getvalue(_T, cc)
result = getvalue(_TEMP, cc)

Reply:

T= cc Type: Signed 8-bit Min: -40 Max: 125

Where:

cc =
1 : MCU temperature
2 : Channel 1 side

3 : Channel 2 side
tt = temperature in degrees

Note:

On some controller models, additional temperature values may reported. These are measured at different points and not documented. You may safely ignore this extra data. Other controller models only have one heatsink temperature sensor and therefore only report one value in addition to the Internal IC temperature.

TM - Read Time

Alias: TIME HexCode: 1C CANOpen id: 0x2119

Description:

Reports the value of the time counter in controller models equipped with Real-Time clocks with internal or external battery backup. On older controller models, time is counted in a 32-bit counter that keeps track the total number of seconds, and that can be converted into a full day and time value using external calculation. On newer models, the time is kept in multiple registers for seconds, minutes, hours (24h format), dayofmonth, month, year in full

Syntax Serial: ?TM [ee]

Argument: Element
Min: None Max: 6

Syntax Scripting: result = getvalue(_TM, ee)
result = getvalue(_TIME, ee)

Reply:

TM = nn Type: Unsigned 32-bit Min: 0

Where:

ee = date element in new controller model
1 : Seconds
2 : Minutes
3 : Hours (24h format)
4 : Dayofmonth
5 : Month
6 : Year in full
nn = Value

TR - Read Position Relative Tracking

Alias: TRACK HexCode: 20 CANOpen id:

Description:

Reads the real-time value of the expected motor position in the position tracking closed loop mode and in speed position

Syntax Serial: ?TR [cc]

Argument: Channel
Min: 1 Max: Total Number of Motors

Syntax Scripting: result = getvalue(_TR, cc)
result = getvalue(_TRACK, cc)

Reply:

TR=nn Type: Signed 32-bit Min: -2147M Max: 2147M

Where:

cc = Motor channel
nn = Position

TRN - Read Control Unit type and Controller Model

Alias: TRN HexCode: 1F CANOpen id:

Description:

Reports two strings identifying the Control Unit type and the Controller Model type. This query is useful for adapting the user software application to the controller model that is attached to the computer.

Syntax Serial: ?TRN

Argument: None

Syntax Scripting: result = getvalue(_TRN, 1)

Reply:

TRN=ss Type: String

Where:

ss = Control Unit Id String:Controller Model Id String

Example:

Q: ?TRN

R:TRN=RCB500:HDC2460

UID - Read MCU Id

Alias: UID HexCode: 32 CANOpen id:

Description:

Reports MCU specific information. This query is useful for determining the type of MCU: 100 = STM32F10X, 300 = STM32F30X. The query also produces a unique Id number that is stored on the MCU silicon.

Syntax Serial: ?UID [ee]

Argument: Element
Min: 1 Max: 5

Syntax Scripting: result = getvalue(_UID, ee)

Reply:

UID = nn Type: Unsigned 32-bit Min: 1 Max: 4294M

Where:

ee = Data element
1 : MCU type
2 : MCU Device Id
3-5 : MCU Unique ID
nn = value

V - Read Volts

Alias: VOLTS HexCode: 0D CANOpen id: 0x210D

Description:

Reports the voltages measured inside the controller at three locations: the main battery voltage, the internal voltage at the motor driver stage, and the voltage that is available on the 5V output on the DSUB 15 or 25 front connector. For safe operation, the driver stage voltage must be above 12V. The 5V output will typically show the controllerâ€™s internal regulated 5V minus the drop of a diode that is used for protection and will be in the 4.7V range. The battery voltage is monitored for detecting the undervoltage or overvoltage conditions.

Syntax Serial: ?V [ee]

Argument: SensorNumber
Min: 1 Max: 3

Syntax Scripting: result = getvalue(_V, ee)
result = getvalue(_VOLTS, ee)

Reply:

V = nn Type: Unsigned 16-bit

Where:

ee =
1 : Internal volts
2 : Battery volts
3 : 5V output
nn = Volts * 10 for internal and battery volts. Milivolts for 5V output

Example:

Q: ?V
R:V=135:246:4730
Q: ?V 3
R:V=4730

VAR - Read User Integer Variable

Alias: VAR HexCode: 06 CANOpen id: 0x2106

Description:

Read the value of dedicated 32-bit internal variables that can be read and written to/from within a user MicroBasic script. It is used to pass 32-bit signed number between user scripts and a microcomputer connected to the controller. The total number of user integer variables varies from one controller model to another and can be found in the product datasheet.
Syntax Serial: ?VAR [ee]

Argument: VarNumber
Min: 1 Max: Total Number of User Variables

Syntax Scripting: result = getvalue(_VAR, ee)

Reply:

VAR=nn Type: Signed 32-bit Min: -2147M Max: 2147M

Where:

ee = Variable number
nn = Value

SL - Read Slip Frequency

Alias: SL HexCode: 48 CANOpen id: 0x2136

Description:

This query is only used in AC Induction boards. Read the value of the Slip Frequency between the rotor and the stator of an AC Induction motor.

Syntax Serial: ?SL [cc]

Argument: VarNumber
Min: 1 Max: Total Number of Motors

Syntax Scripting: result = getvalue(_SL, cc)

Reply:

SL=nn Type: Signed 16-bit Min: -32768 Max: 32768

Where:

cc = Motor channel

nn = Slip Frequency in Hertz * 10

Query History Commands

Every time a Real Time Query is received and executed, it is stored in a history buffer from which it can be recalled. The buffer will store up to 16 queries. If more than 16 queries are received, the new one will be added to the history buffer while the firsts are removed in order to fit the 16 query buffer.

Queries can then be called from the history buffer using manual commands, or automatically, at user selected intervals. This feature is very useful for monitoring and telemetry.

Additionally, the history buffer can be loaded with a set of user selected queries at power on so that the controller can automatically issue operating values immediately after power up. See "TELS - Telemetry String" configuration command for details on how to set up the startup Telemetry string.

A command set is provided for managing the history buffer. These special commands start with a "**#**" character.

TABLE 19-3. Query History Commands

Command	Description
#	Send the next value. Stop automatic sending
# C	Clear buffer history
# nn	Start automatic sending

- Send Next History Item / Stop Automatic Sending

A **#** alone will call and execute the next query in the buffer. If the controller was in the process of automatically sending queries from the buffer, then receiving a # will cause the sending to stop.

When a query is executed from the history buffer, the controller will only display the query result (e.g. A=10:20). It will not display the query itself.

Syntax:

#

Reply: **QQ**

Where:

QQ = is reply to query in the buffer.

C - Clear Buffer History

This command will clear the history buffer of all queries that may be stored in it. If the controller was in the process of automatically sending queries from the buffer, then receiving this command will also cause the sending to stop

Syntax:

 # C

Reply: None

nn - Start Automatic Sending

This command will initiate the automatic retrieving and execution of queries from the history buffer. The number that follows the command is the time in milliseconds between repetition. A single query is fetched and executed at each time interval.

Syntax:

 # nn

Reply: **QQ** at every nn time intervals

Where:

QQ = is reply to query in the buffer.
nn = time in ms

Range: **nn** = 1 to 32000ms

Maintenance Commands

This section contains a few commands that are used occasionally to perform maintenance functions.

TABLE 19-4. Maintenance Commands

Command	Arguments	Description
CLMOD	Key	Calibrate Sin/Cos sensors
CLRST	Key	Reset configuration to factory defaults
CLSAV	Key	Save calibrations to Flash
DFU	Key	Update Firmware via USB
EELD	None	Load Parameters from EEPROM
EERST	Key	Reset Factory Defaults
EESAV	None	Save Configuration in EEPROM
LK	Key	Lock Configuration Access
RESET	Key	Reset Controller
SLD	Key	Script Load
STIME	Time	Set Time
UK	Key	Unlock Configuration Access

CLMOD - Calibrate Sin/Cos sensors

Argument: Key

Description:
This command is used to enter the calibration mode for sin/cos sensors on brushless motor controllers. After calibration is complete, the sensor data must be saved using the %CLSAV command.

Syntax:
%CLMOD nn

Where:
0 : Exit Calibration Mode
2 : Calibrate SinCos Sensor for channel 1
3 : Calibrate SinCos Sensor for channel 2
4 : Calibrate Sensorless Start-up for channel 1
5 : Calibrate Sensorless Start-up for channel 2

CLRST - Reset configuration to factory defaults

Argument: Key

Description:
This command resets all configurations to their factory default

Syntax:
%CLRST safetykey

Where:
safetykey = 321654987

CLSAV - Save calibrations to Flash

Argument: Key

Description:
Saves changes to calibration to Flash. Calibration parameters are stored permanently until new values are stored.. This command must be used with care and must be followed by a 9-digit safety key to prevent accidental use.

Syntax:
%CLSAV safetykey

Where:
safetykey = 321654987

DFU - Update Firmware via USB

Argument: Key

Description:
Firmware update can be performed via the RS232 port or via USB. When done via USB, the DFU command is used to cause the controller to enter in the firmware upgrade mode. This command must be used with care and must be followed by a 9-digit safety key to prevent accidental use. Once the controller has received the DFU command, it will no longer respond to the PC utility and no longer be visible on the PC. When this mode is entered, you must launch the separate upgrade utility to start the firmware upgrade process.

Syntax:
%DFU safetykey

Where:
safetykey = 321654987

EELD - Load Parameters from EEPROM

Argument: None

Description:
This command reloads the configuration that are saved in EEPROM back into RAM and activates these settings.

Syntax:
%EELD

EERST - Reset Factory Defaults

Argument: Key

Description:
The EERST command will reload the controller's™ RAM and EEPROM with the factory default configuration. Beware that this command may cause the controller to no longer work in your application since all your configurations will be erased back to factory defaults. This command must be used with care and must be followed by a 9-digit safety key to prevent accidental use.

Syntax:
%EERST safetykey

Where:
safetykey = 321654987

EESAV - Save Configuration in EEPROM

Argument: None

Description:
Controller configuration that have been changed using any Configuration Command can then be saved in EEPROM. Once in EEPROM, it will be loaded automatically in the controller every time the unit is powered on. If the EESAV command is not called after changing a configuration, the configuration will remain in RAM and active only until the controller is turned off. When powered on again, the previous configuration that was in the EEPROM is loaded. This command uses no parameters

Syntax:
%EESAV

LK - Lock Configuration Access

Argument: Key

Description:
This command is followed by any user-selected secret 32-bit number. After receiving it, the controller will lock the configuration and store the key inside the controller, in area which cannot be accessed. Once locked, the controller will no longer respond to configuration reads. However, it is still possible to store or to set new configurations.

Syntax:
%LK secretkey

Where:
secretkey = 32-bit number (1 to 4294967296)

RESET - Reset Controller

Argument: Key

Description:
This command will cause the controller to reset similarly as if it was powered OFF and ON. This command must be used with care and must be followed by a 9-digit safety key to prevent accidental reset.

Syntax:
%RESET safetykey

Where:
safetykey = 321654987

SLD - Script Load

Argument: Key

Description:
After receiving this command, the controller will enter the script loading mode. It will reply with HLD and stand ready to accept script bytecodes in intel Hex Format. The exact download and data format is described in the MicroBasic section of the manual

Syntax:
%SLD

STIME - Set Time

Argument: Hours Mins Secs

Description:
This command sets the time inside the controller's™ clock that is available in some controller models. The clock circuit will then keep track of time as long as the clock remains under power. On older controller models, the clock is a single 32-bit counter in which the

number of seconds from a preset day and time is stored (for example 02/01/00 at 3:00). On newer model, the clock contains 6 registers for seconds, dates, minuted, hours, day-ofmonth, month, year. The command syntax will be different for each of these models.

Syntax:
%STIME nn : Older models%STIME ee nn : Newer models

Where:
Older models:nn = number of secondsNewer modelsee = 1: Seconds2: Minutes3: Mours (24h format)4: Dayofmonth5: Month6: Year in fullnn = Value

UK - Unlock Configuration Access

Argument: Key

Description:
This command will release the lock and make the configuration readable again. The command must be followed by the secret key which will be matched by the controller internally against the key that was entered with the LK command to lock the controller. If the keys match, the configuration is unlocked and can be read.

Syntax:
%UK secretkey

Where:
secretkey = 32-bit number (1 to 4294967296)

Set/Read Configuration Commands

These commands are used to set or read all the operating parameters needed by the controller for its operation. Parameters are loaded from EEPROM into RAM, from where they are and then used every time the controller is powered up or restarted.

Important Notices

The total number of configuration parameters is very large. To simplify the configuration process and avoid errors, it is highly recommended to use the RoborunPlus PC utility to read and set configuration.
Some configuration parameters may be absent depending on the presence or absence of the related feature on a particular controller model.

Setting Configurations

The general format for setting a parameter is the "**^**" character followed by the command name followed by parameter(s) for that command. These will set the parameter in the controller's RAM and this parameter becomes immediately active for use. The parameter can also be permanently saved in EEPROM by sending the **%EESAV** maintenance command.

Some parameters have a unique value that applies to the controller in general. For example, overvoltage or PWM frequency. These configuration commands are therefore followed by a single parameter:

^PWM 180 : Sets PWM frequency to 18.0 kHz
^OVL 400 : Sets Overvoltage limit to 40.0V

Other parameters have multiple value, with typically one value applying to a different channel. Multiple value parameters are numbered from 1 to n. For example, Amps limit for a motor channel or the configuration of an analog input channel.

^ALIM 1 250 : Sets Amps limit for channel 1 to 25.0A
^AMIN 4 2000 : Sets low range of analog input 4 to 2000

Using 0 as the first parameter value will cause all elements to be loaded with the same content.

^ADB 0 10 : Sets the deadband of all analog inputs to 10%

Important Notice

Saving configuration into EEPROM can take up to 20ms per parameter. The controller will suspend the loop processing during this time, potentially affecting the controller operation. Avoid saving configuration to EEPROM during motor operation.

Reading Configurations

Configuration parameters are read by issuing the "**~**" character followed by the command name and with an optional channel number parameter. If no parameter is sent, the controller will give the value of all channels. If a channel number is sent, the controller will give the value of the selected channel.

The reply to parameter read command is the command name followed by "**=**" followed by the parameter value. When the reply contains multiple values, then the different values are separated by "**:**". The list below describes every configuration command of the controller. For Example:

~ALIM : Read Amps limit for all channels

Reply: **ALIM= 750:650**

~ALIM 2: Read Amps limit for channel 2

Reply: **ALIM= 650**

Configuration parameters can be read from within a MicroBasic script using the getconfig() function. The setconfig() function is used to load a new value in a configuration parameter.

Important Warning

Configuration commands can be issued at any time during controller operation. Beware that some configuration parameters can alter the motor behavior. Change configurations with care. Whenever possible, change configurations while the motors are stopped.

Configuration Read Protection

The controller may be locked to prevent the configuration parameters to be read. Given the large number of possible configurations, this feature provides effective system-level copy protection. The controller will reply to configuration read requests only if the read protection is unlocked. If locked, the controller will respond a "-" character.

General Configuration and Safety

The commands in this group are used to configure the controller's general and safety settings.

TABLE 19-5. General and Safety Configurations

Command	Arguments	Description
ACS	Enable	Analog Center Safety
AMS	Enable	Analog within Min & Max Safety
BEE	Address Value	User Storage in Battery Backed RAM
BRUN	Enable	MicroBasic Auto Start
CLIN	Channel Linearity	Command Linearity
CPRI	Level Command	Command Priorities
DFC	Channel Value	Default Command value
ECHOF	OffOn	Enable/Disable Serial Echo
EE	Address Data	Store User Data in Flash
RSBR	BitRate	Set RS232 bit rate
RWD	Timeout	Serial Data Watchdog
SCRO	Port	Select Print output port for scripting
SKCTR	Channel Center	Spektrum Center
SKDB	Channel Deadband	Spektrum Deadband
SKLIN	Channel Linearity	Spektrum Linearity
SKMAX	Channel Max	Spektrum Max
SKMIN	Channel Min	Spektrum Min
SKUSE	Channel Port	Assign Spektrum port to motor command
TELS	String	Telemetry string

ACS - Analog Center Safety

HexCode: 0B

Description:
This parameter enables the analog safety that requires that the input be at zero or centered before it can be considered as good. This safety is useful when operating with a joystick and requires that the joystick be centered at power up before motors can be made to run. On mutli-channel controllers, this configuration acts on all analog command inputs, meaning that all joysticks must be centered before any one becomes active.

Syntax Serial: ^ACS nn
~ACS

Syntax Scripting: setconfig(_ACS, nn)

Number of Arguments: 1

Argument 1: Enable

Type: Unsigned 8-bit
Min: 0 Max: 1
Default: 1

Where:
nn =
0: Safety disabled
1: Safety enabled

AMS - Analog within Min & Max Safety

HexCode: 0C

Description:
This configuration is used to make sure that the analog input command is always within a user preset minimum and maximum safe value. It is useful to detect, for example, that the wire connection to a command potentiometer is broken. If the safety is enabled and the input is outside the safe range, the Analog input command will be considered invalid. The controller will then apply a motor command based on the priority logic..

Syntax Serial: ^AMS nn
~AMS

Syntax Scripting: setconfig(_AMS, nn)

Number of Arguments: 1

Argument 1: Enable

Type: Unsigned 8-bit
Min: 0 Max: 1
Default: 1 = Enabled

Where:
nn =
0: Disabled
1: Enabled

BEE - User Storage in Battery Backed RAM

HexCode: 64

Description:
Store and retrieve user data in battery backed RAM. Storage is quasi permanent, limited only by the on-board battery (usually several years) . Unlike storage in Flash using the EE configuration commands, there are no limits in the amount or frequency of read and write cycles with BEE. This feature is only available on selected models, see product data-sheet. Battery must be installed in the controller for storage to be possible.

Syntax Serial: ^BEE aa dd
~BEE aa

Syntax Scripting: setconfig(_BEE, aa, dd)

Number of Arguments: 2

Argument 1: Address

Min: 1 Max: Total Number of BEE

Argument 2: Value

Type: Signed 16-bit
Min: -32768 Max: 32767
Default: 0

Where:
aa = Address

dd = Data

Example:

^BEE 1 555 : Store value 555 in Battery Backed RAM location 1
~BEE 1: Read data from RAM location 1

BRUN - MicroBasic Auto Start

HexCode: 48

Description:
This parameter is used to enable or disable the automatic MicroBasic script execution when the controller powers up. When enabled, the controller checks that a valid script is present in Flash and will start its execution 2 seconds after the controller has become active. The 2 seconds wait time can be circumvented by putting 2 in the command argument. However, this must be done only on scripts that are known to be bug-free. A crashing script will cause the controller to continuously reboot with little means to recover.

Syntax Serial: ^BRUN nn
~BRUN

Syntax Scripting: setconfig(_BRUN, nn)

Number of Arguments: 1

Argument 1: Enable

Type: Unsigned 8-bit
Min: 0 Max: 2
Default: 0 = Disabled

Where:
nn =
0: Disabled
1: Enabled after 2 seconds
2: Enabled immediately

CLIN - Command Linearity

HexCode: 0D

Description:
This parameter is used for applying an exponential or a logarithmic transformation on the command input, regardless of its source (serial, pulse or analog). There are 3 exponential and 3 logarithmic choices. Exponential correction make the commands change less at the beginning and become stronger at the end of the command input range. The logarithmic correction will have a stronger effect near the start and lesser effect near the end. The linear selection causes no change to the input. A linearity transform is also available for all analog and pulse inputs. Both can be enabled although in most cases, it is best to use the Command Linearity parameter for modifying command profiles

Syntax Serial: ^CLIN cc nn
~CLIN [cc]

Syntax Scripting: setconfig(_CLIN, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Linearity

Type: Unsigned 8-bit
Min: 0 Max: 7
Default: 0 = Linear

Where:
cc = Motor channel

nn =
0: Linear (no change)
1: Exp weak
2: Exp medium
3: Exp strong
4: Log weak
5: Log medium
6: Log strong

Example:

^CLIN 1 1 : Sets linearity for channel 1 to exponential weak

CPRI - Command Priorities

HexCode: 07

Description:
This parameter contains up to 3 variables (4 on controllers with Spektrum radio support) and is used to set which type of command the controller will respond in priority and in which order. The first item is the first priority, second â€" second priority, third â€" third priority. Each priority item is then one of the three (four) command modes: Serial, Analog (Spektrum) or RC Pulse. See Command Priorities in the User Manual. Default prority orders are: 1-Serial, 2-Pulse, 3-None.

Syntax Serial: ^CPRI pp nn
~CPRI [pp]

Syntax Scripting: setconfig(_CPRI, pp, nn)

Number of Arguments: 2

Argument 1: Level

Min: 1 Max: 3 or 4
Default: See description

Argument 2: Command

Type: Unsigned 8-bit
Min: 0 Max: 2 or 3
Default: See description

Where:
pp = Priority rank

nn =
0: Serial
1: RC
2: Analog (or Spektrum)
3: None (or Alalog)
4: None

Example:

^CPRI 1 2 : Set Analog as first priority
~CPRI 2 : Read what command mode is second priority

Note:

USB, RS232, CAN and Microbasic commands share the "Serial" type. When serial commands come from different Serial source, they are executed in the order received.

DFC - Default Command value

HexCode: 0E

Description:
The default command values are the command applied to the motor when no valid command is fed to the controller. Value 1001 causes no change in position at power up until a new position command is received

Syntax Serial: ^DFC cc nn
~DFC [cc]

Syntax Scripting: setconfig(_DFC, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Value

Type: Signed 16-bit
Min: -1000 Max: 1001
Default: 0

Where:
cc : Motor channel

nn : Command value

Example:

^DFC 1 500 : Sets motor command to 500 when no command source are detected
^DFC 2 1001 : Motor takes present position as destination after power up. Motor doesn't move.

ECHOF - Enable/Disable Serial Echo

HexCode: 09

Description:
This command is used to disable/enable the echo on the serial or USB port. By default, the controller will echo everything that enters the serial communication port. By setting ECHOF to 1, commands are no longer being echoed. The controller will only reply to queries and the acknowledgements to commands can be seen.

Syntax Serial: ^ECHOF nn
~ECHOF

Syntax Scripting: setconfig(_ECHOF, nn)

Number of Arguments: 1

Argument 1: OffOn

Type: Unsigned 8-bit
Min: 0 Max: 1
Default: 0 = Echo on

Where:
nn =
0: Echo is enabled
1: Echo is disabled

Example:

^ECHOF 1 : Disable echo

EE - Store User Data in Flash

HexCode: 00

Description:
Read and write user-defined values that can be permanently stored in Flash. Storage area size is typically 32 x 16-bit words but can vary from one product to the other. The command alters data contained in a RAM area. The %EESAV Maintenance Command, or !EES Real Time Command must be used to copy the RAM array to Flash. The Flash is copied to RAM every time the device powers up.

Syntax Serial: ^EE aa dd
~EE aa

Syntax Scripting: setconfig(_EE, aa, dd)

Number of Arguments: 2

Argument 1: Address

Min: 1 Max: Total Number of Storage words

Argument 2: Data

Type: Signed 16-bit
Min: -32768 Max: +32767
Default: 0

Where:
aa = Address

dd = Data

Example:

^EE 1 555 : Store value 555 in RAM location 1
%EESAV or !EES : Copy data from temporary RAM to Flash
~EE 1 : Read data from RAM location 1

Note:

See product datasheet to know the total available EE storage.
Do not transfer to Flash with %EESAV or !EES at high frequency as the number of write cycles to Flash are limited to around 10000.
Avoid transfering to Flash while the product is performing critical operation
Write to address locations 1 and up. Writing at address 0 will fill all RAM location with the value

RSBR - Set RS232 bit rate

HexCode: 0A

Description:
Sets the serial communication bit rate of the RS232 port. Choices are one of five most common bit rates. On selected products, the port output can be inverted to allow a simplified connection to devices that have TTL serial ports instead of full RS232.

Syntax Serial: ^RSBR nn
~RSBR

Syntax Scripting: setconfig(_RSBR, nn)

Number of Arguments: 1

Argument 1: BitRate

Type: Unsigned 8-bit
Min: 0 Max: 4 or 9
Default: 0 = 115200

Where:
nn =
0: 115200
1: 57600

2: 38400
3:19200
4: 9600
5: 115200 + Inverted RS232
6: 57600 + Inverted RS232
7: 38400 + Inverted RS232
8: 19200 + Inverted RS232
9: 9600 + Inverted RS232

Example:

^RSBR 3 : sets baud rate at 19200

Note:

This configuration can only be changed while connected via USB or via scripting. After the baud rate has been changed, it will not be possible to communicate with the Roborun PC utility using the srial port until the rate is changed back to 115200. Slow bit rates may result in data loss if more characters are sent than can be handled. The inverted mode is only available on selected products.

RWD - Serial Data Watchdog

HexCode: 08

Description:
This is the Serial Commands watchdog timeout parameter. It is used to detect when the controller is no longer receiving commands and switch to the next priority level. Any Realtime Command arriving from RS232, USB, CAN or Microbasic Scripting, The watchdog value is a number in ms (1000 = 1s). The watchdog function can be disabled by setting this value to 0. The watchdog will only detect the loss of real-time commands that start with â€œ!â€. All other traffic on the serial port will not refresh the watchdog timer. As soon as a valid command is received, motor operation will resume at whichever speed motors were running prior to the watchdog timeout.

Syntax Serial: ^RWD nn
~RWD

Syntax Scripting: setconfig(_RWD, nn)

Number of Arguments: 1

Argument 1: Timeout
Type: Unsigneed 16-bit
Min: 0 Max: 65000
Default: 1000 = 1s

Where:
nn = Timeout value in ms

Example:

^RWD 2000 : Set watchdog to 2s
^RWD 0 : Disable watchdog

SCRO - Select Print output port for scripting

HexCode: 5E

Description:
Selects which port the print statement sends data to. When 0, the last port which received a valid character will be the one the script outputs to.

Syntax Serial: ^SCRO nn
~SCRO

Syntax Scripting: setconfig(_SRO, nn)

Number of Arguments: 1

Argument 1: Port
Type: Unsigned 8-bit
Min: 0 Max: 2
Default: 0 = Last used

Where:
nn =
0: Last used
1: Serial
2: USB

SKCTR - Spektrum Center

HexCode: 53

Description:
Value captured from Spektrum radio that will be considered as 0 command

Syntax Serial: ^SKCTR cc nn
~SKCTR [cc]

Syntax Scripting: setconfig(_SKCTR, cc)

Number of Arguments:

Argument 1: Channel

Min: 1 Max: 2

Argument 2: Center
Type: Unsigned 16-bit
Min: 0 Max: 1024
Default: 0

Where:
cc = Channel

nn = Center value

SKDB - Spektrum Deadband

HexCode: 54

Description:
Sets the deadband value for the Spektrum channel. It is defined as the percent number from 0 to 50% and defines the amount of movement from joystick or sensor around the center position before its converted value begins to change.

Syntax Serial: ^SKDB cc nn
~SKDB [cc]

Syntax Scripting: setconfig(_SKDB, cc)

Number of Arguments:

Argument 1: Channel

Min: 1 Max: 2

Argument 2: Deadband

Type: Unsigned 8-bit
Min: 0 Max: 50
Default: 0

Where:
cc = Channel

nn = Deadband

SKLIN - Spektrum Linearity

HexCode: 55

Description:
This parameter is used for applying an exponential or a logarithmic transformation a Spektrum command input. There are 3 exponential and 3 logarithmic choices. Exponential correction will make the commands change less at the beginning and become stronger at the end of the joystick movement. The logarithmic correction will have a stronger effect near the start and lesser effect near the end. The linear selection causes no change to the input.

Syntax Serial: ^SKLIN cc nn
~SKLIN [cc]

Syntax Scripting: setconfig(_SKLIN, cc)

Number of Arguments:

Argument 1: Channel

Min: 1 Max: 2

Argument 2: Linearity

Type: Unsigned 8-bit
Min: 0 Max: 6
Default: 0 = Linear

Where:
cc = Input channel number

nn =
0 : linear (no change)
1: exp weak
2: exp medium
3: exp strong
4: log weak
5: log medium
6: log strong

SKMAX - Spektrum Max

HexCode: 52

Description:
Value captured from Spektrum radio that will be considered as +1000 command

Syntax Serial: ^SKMAX cc nn
~SKMAX [cc]

Syntax Scripting: setconfig(_SKMAX, cc)

Number of Arguments:

Argument 1: Channel

Min: 1 Max: 2

Argument 2: Max

Type: Unsigned 16-bit
Min: 0 Max: 1024
Default: 0

Where:
cc = Channel

nn = Max value

SKMIN - Spektrum Min

HexCode: 51

Description:
Value captured from Spektrum radio that will be considered as -1000 command

Syntax Serial: ^SKMIN cc nn
~SKMIN [cc]

Syntax Scripting: setconfig(_SKMIN, cc)

Number of Arguments:

Argument 1: Channel

Min: 1 Max: 2

Argument 2: Min

Type: Unsigned 16-bit
Min: 0 Max: 1024
Default: 0

Where:
cc = Channel

nn: Min value

SKUSE - Assign Spektrum port to motor command

HexCode: 50

Description:
Chose which of the 6 joysticks from the Spektrum RC receiver is to be assigned to which motor command channel.

Syntax Serial: ^SKUSE cc nn
~SKUSE [cc]

Syntax Scripting: setconfig(_SKUSE, cc)

Number of Arguments:

Argument 1: Channel

Min: 1 Max: 2

Argument 2: Port

Type: Unsigned 8-bit
Min: 1 Max: 6

Where:
cc = Channel number

nn = Radio port

TELS - Telemetry String

HexCode: 47

Description:
This parameter command lets you enter the telemetry string that will be used when the controller starts up. The string is entered as a series of queries characters between a beginning and an ending quote. Queries must be separated by ":" colon characters. Upon the power up, the controller will load the query history buffer and it will automatically start executing commands and queries based on the information in this string. Strings up to 48 characters long can be stored in this parameter.

Syntax Serial: ^TELS "string"
~TELS

Syntax Scripting:
Number of Arguments: 1

Argument 1: Telemetry

Type: String
Min: "" Max: 48 characters string
Default: "" = Empty string

Where:
string = string of ASCII characters between quotes

Example:

^TELS "?A:?V:?T:#200" = Controller will issue Amps, Volts and temperature information automatically upon power up at 200ms intervals.

Analog, Digital, Pulse IO Configurations

These parameters configure the operating mode and how the inputs and outputs work.

TABLE 19-6. Input/Output Configurations

Command	Arguments	Description
ACTR	InputNbr Center	Set Analog Input Center (0) Level
ADB	InputNbr Deadband	Analog Deadband
AINA	InputNbr Use	Analog Input Use
ALIN	InputNbr Linearity	Analog Linearity
AMAX	InputNbr Max	Set Analog Input Max Range
AMAXA	InputNbr Action	Action at Analog Max
AMIN	InputNbr Min	Set Analog Input Min Range
AMINA	InputNbr Action	Action at Analog Min
AMOD	InputNbr Mode	Enable and Set Analog Input Mode
APOL	InputNbr Polarity	Analog Input Polarity
DINA	InputNbr Action	Digital Input Action
DINL	ActiveLevels	Digital Input Active Level
DOA	OutputNbr Action	Digital Output Action
DOL	ActiveLevels	Digital Outputs Active Level
PCTR	InputNbr Center	Pulse Center Range
PDB	InputNbr Deadband	Pulse Input Deadband
PINA	InputNbr Use	Pulse Input Use
PLIN	InputNbr Linearity	Pulse Linearity
PMAX	InputNbr Max	Pulse Max Range
PMAXA	InputNbr Action	Action on Pulse Max
PMIN	InputNbr Min	Pulse Min Range
PMINA	InputNbr Action	Action on Pulse Min
PMOD	InputNbr Mode	Pulse Mode Select
PPOL	InputNbr Polarity	Pulse Input Polarity

ACTR - Set Analog Input Center (0) Level

HexCode: 16

Description:
This parameter is the measured voltage on input that will be considered as the center or the 0 value. The min, max and center are useful to set the range of a joystick or of a feedback sensor. Internally to the controller, commands and feedback values are converted to 1000, 0, +1000.

Syntax Serial: ^ACTR cc nn
~ACTR [cc]

Syntax Scripting: setconfig(_ACTR, cc, nn)

Number of Arguments: 2

Argument 1: InputNbr

Min: 1 Max: Total Number of Analog Inputs

Argument 2: Center

Type: Unsigned 16-bit
Min: 0 Max: 10000
Default: 2500 mV

Where:
cc = Analog input channel

nn = 0 to 10000mV

Example:

^ACTR 3 2000 : Set Analog Input 3 Center to 2000mV

Note:

Center value must always be a number greater of equal to Min, and smaller or equal to Max
Make the center value the same as the min value in order to produce a converted output range that is positive only (0 to +1000)

ADB - Analog Deadband

HexCode: 17

Description:
This parameter selects the range of movement change near the center that should be considered as a 0 command. This value is a percentage from 0 to 50% and is useful to allow some movement of a joystick around its center position without change at the converted output

Syntax Serial: ^ADB cc nn
~ADB [cc]

Syntax Scripting: setconfig(_ADB, cc, nn)

Number of Arguments: 2

Argument 1: InputNbr

Min: 1 Max: Total Number of Analog Inputs

Argument 2: Deadband

Type: Unsigned 8-bit
Min: 0 Max: 50
Default: 5 = 5%

Where:
cc = Analog input channel

nn = Deadband in %

Example:

^ADB 6 10 : Sets Deadband for channel 6 at 10%

Note:

Deadband is not used when input is used as feedback

AINA - Analog Input Use

HexCode: 19

Description:
This parameter selects whether an input should be used as a command feedback or left unused. When selecting command or feedback, it is also possible to select which channel this command or feedback should act on. Feedback can be position feedback if potentiometer is used or speed feedback if tachometer is used. Embedded in the parameter is the motor channel to which the command or feedback should apply.

Syntax Serial: ^AINA cc (nn + mm)
~AINA [cc]

Syntax Scripting: setconfig(_AINA, cc, nn)

Number of Arguments: 2

Argument 1: InputNbr

Min: 1 Max: Total Number of Analog Inputs

Argument 2: Use

Type: Unsigned 8-bit
Min: 0 Max: 255
Default: 0 = No action

Where:
cc = Analog input channel

nn =
0: No action
1: Command
2: Feedback

mm =
mot1*16 + mot2*32 + mot3*48

Example:

^AINA 1 17: Sets Analog channel 1 as command for motor 1. I.e. 17 = 1 (command) +16 (motor 1)

ALIN - Analog Linearity

HexCode: 18

Description:
This parameter is used for applying an exponential or a logarithmic transformation on an analog input. There are 3 exponential and 3 logarithmic choices. Exponential correction will make the commands change less at the beginning and become stronger at the end of the joystick movement. The logarithmic correction will have a stronger effect near the start and lesser effect near the end. The linear selection causes no change to the input.

Syntax Serial: ^ALIN cc nn
~ALIN [cc]

Syntax Scripting: setconfig(_ALIN, cc, nn)

Number of Arguments: 2

Argument 1: InputNbr

Min: 1 Max: Total Number of Analog Inputs

Argument 2: Linearity

Type: Unsigned 8-bit
Min: 0 Max: 6
Default: 0 = Linear

Where:
cc = Analog input channel

nn =
0: Linear (no change)
1: Exp weak
2: Exp medium
3: Exp strong
4: Log weak
5: Log medium
6: Log strong

Example:

^ALIN 1 1 : Sets linearity for channel 1 to exp weak

AMAX - Set Analog Input Max Range

HexCode: 15

Description:
This parameter sets the voltage that will be considered as the maximum command value. The min, max and center are useful to set the range of a joystick or of a feedback sensor. Internally to the controller, commands and feedback values are converted to -1000, 0, +1000.

Syntax Serial: ^AMAX cc nn
~AMAX [cc]

Syntax Scripting: setconfig(_AMAX, cc, nn)

Number of Arguments: 2

Argument 1: InputNbr

Min: 1 Max: Total Number of Analog Inputs

Argument 2: Max

Type: Unsigned 16-bit
Min: 0 Max: 10000
Default: 4900 mV

Where:
cc = Analog input channel

nn = 0 to 10000mV

Example:

^AMAX 4 4500 : Set Analog Input 4 Max range to 4500mV

Note:

Analog input can capture voltage up to around 5.2V. Setting the Analog maximum above 5200 mV, means the conversion will never be able to reach +1000

AMAXA - Action at Analog Max

HexCode: 1B

Description:
This parameter selects what action should be taken if the maximum value that is defined in AMAX is reached. The list of action is the same as these of digital inputs. For example, this feature can be used to create â€œsoftâ€ limit switches, in which case the motor can be made to stop if the feedback sensor in a position mode has reached a maximum value.

Syntax Serial: ^AMAXA cc (aa + mm)
~AMAXA [cc]

Syntax Scripting: setconfig(_AMAXA, cc, aa)

Number of Arguments: 2

Argument 1: InputNbr

Min: 1 Max: Total Number of Analog Inputs

Argument 2: Action

Type: Unsigned 8-bit
Min: 0 Max: 255
Default: 0 = No action

Where:
cc = Analog input channel

aa =
0: No action
1: Safety stop
2: Emergency stop
3: Motor stop
4: Forward limit switch
5: Reverse limit switch
6: Invert direction
7: Run MicroBasic script
8: Load counter with home value

mm = mot1*16 + mot2*32 + mot3*48

Example:

^AMAXA 3 33 : Stops motor 2. I.e. 33 = 1 (safety stop) + 32 (motor2)

AMIN - Set Analog Input Min Range

HexCode: 14

Description:
This parameter sets the raw value on the input that will be considered as the minimum command value. The min, max and center are useful to set the range of a joystick or of a feedback sensor. Internally to the controller, commands and feedback values are converted to -1000, 0, +1000.

Syntax Serial: ^AMIN cc nn
~AMIN [cc]

Syntax Scripting: setconfig(_AMIN, cc, nn)

Number of Arguments: 2

Argument 1: InputNbr

Min: 1 Max: Total Number of Analog Inputs

Argument 2: Min

Type: Unsigned 16-bit
Min: 0 Max: 10000
Default: 100 mV

Where:
cc = Analog input channel

nn = 0 to 10000mV

Example:

^AMIN 5 250 : Set Analog Input 5 Min to 250mV

Note:

Analog input can capture voltage up to around 5.2V. Setting the Analog minimum between 5200 and 10000 mV means the conversion will always return 0

AMINA - Action at Analog Min

HexCode: 1A

Description:
This parameter selects what action should be taken if the minimum value that is defined in AMIN is reached. The list of action is the same as these of the DINA configuration command. For example, this feature can be used to create â€œsoftâ€ limit switches, in which case the motor can be made to stop if the feedback sensor in a position mode has reached a minimum value.

Syntax Serial: ^AMINA cc (aa + mm)
~AMINA [cc]

Syntax Scripting: setconfig(_AMINA, cc, aa)

Number of Arguments: 2

Argument 1: InputNbr

Min: 1 Max: Total Number of Analog Inputs

Argument 2: Action

Type: Unsigned 8-bit
Min: 0 Max: 255
Default: 0 = No action

Where:
cc = Analog input channel

aa =
0: No action
1: Safety stop
2: Emergency stop
3: Motor stop
4: Forward limit switch
5: Reverse limit switch
6: Invert direction
7: Run MicroBasic script
8: Load counter with home value

mm = mot1*16 + mot2*32 + mot3*48

Example:

^AMINA 2 33 : Stops motor 2. I.e. 33 = 1 (safety stop) + 32 (motor2)

AMOD - Enable and Set Analog Input Mode

HexCode: 13

Description:
This parameter is used to enable/disable an analog input pin. When enabled, it can be made to measure an absolute voltage from 0 to 5V, or a relative voltage that takes the 5V output on the connector as the 5V reference. The absolute mode is preferred whenever measuring a voltage generated by an outside device or sensor. The relative mode is the mode to use when a sensor or a potentiometer is powered using the controllerâ€™s 5V output of the controller. Using the relative mode gives a correct sensor reading even though the 5V output is imprecise.

Syntax Serial: ^AMOD cc nn
~AMOD [cc]

Syntax Scripting: setconfig(_AMOD, cc, nn)

Number of Arguments: 2

Argument 1: InputNbr

Min: 1 Max: Total Number of Analog Inputs

Argument 2: Mode

Type: Unsigned 8-bit
Min: 0 Max: 2
Default: 0 = Disabled

Where:
cc = Analog input channel

nn =
0: Disabled
1: Absolute
2: Relative

Example:

^AMOD 1 1 : Analog input 1 enabled in absolute mode

APOL - Analog Input Polarity

HexCode: 1C

Description:
Inverts the analog capture polarity value after conversion. When this configuration bit is cleared, the pulse capture is converted into a -1000 to +1000 command or feedback value. When set, the converted range is inverted to +1000 to -1000.

Syntax Serial: ^APOL cc nn
~APOL [cc]

Syntax Scripting: setconfig(_APOL, cc, nn)

Number of Arguments: 2

Argument 1: InputNbr

Min: 1 Max: Total Number of Analog Inputs

Argument 2: Polarity

Type: Unsigned 8-bit
Min: 0 Max: 1
Default: 0 = Non inverted

Where:
cc = Analog input channel

nn =
0: Not inverted
1: Inverted

DINA - Digital Input Action

HexCode: 0F

Description:
This parameter sets the action that is triggered when a given input pin is activated. The action list includes: limit switch for a selectable motor and direction, use as a deadman switch, emergency stop, safety stop or invert direction. Embedded in the parameter is the motor channel(s) to which the action should apply.

Syntax Serial: ^DINA cc (aa + [mm])
~DINA [cc]

Syntax Scripting: setconfig(_DINA, cc, aa)

Number of Arguments: 2

Argument 1: InputNbr

Min: 0 Max: Total Number of Digital Inputs

Argument 2: Action

Type: Unsigned 8-bit
Min: 0 Max: 255
Default: 0 = No actions

Where:
cc = Input channel number

aa =
0: No action
1: Safety stop
2: Emergency stop
3: Motor stop
4: Forward limit switch
5: Reverse limit switch
6: Invert direction
7: Run MicroBasic script
8: Load counter with home value

mm = mot1*16 + mot2*32 + mot3*48

Example:

^DINA 1 33 : Input 1 as safety stop for Motor 1. I.e. 33 = 1 (safety stop) + 32 (Motor1)

DINL - Digital Input Active Level

HexCode: 10

Description:
This parameter is used to set the active level for each Digital input. An input can be made to be active high or active low. Active high means that pulling it to a voltage will trigger an action. Active low means pulling it to ground will trigger an action. This parameter is a single number for all inputs.

Syntax Serial: ^DINL cc aa
~DINL [cc]

Syntax Scripting: setconfig(_DINL, cc, aa)

Number of Arguments: 1

Argument 1: ActiveLevels

Type: Unsigned 32-bit
Min: 0 Max: 2 ^ Total Number of Digital Inputs

Default: 0 = All Active high

Where:

cc = Digital input number

aa=
0: Active High
1: Active Low

Example:

^DINL 2 1 : Sets digital input 2 to active low

DOA - Digital Output Action

HexCode: 11

Description:
This configuration parameter will set what will trigger a given output pin. The parameter is a number in a list of possible triggers: when one or several motors are on, when one or several motors are reversed, when an Overvoltage condition is detected or when an Overtemperature condition is detected. Embedded in the parameter is the motor channel(s) to which the action should apply.

Syntax Serial: ^DOA cc aa
~DOA [cc]

Syntax Scripting: setconfig(_DOA, cc, aa)

Number of Arguments: 2

Argument 1: OutputNbr

Type: Unsigned 32-bit
Min: 1 Max: Total Number of Digital Outputs

Argument 2: Action

Min: 0
Default: See Note

Where:
cc = Output channel

aa =
0: Never

1: Motor on
2: Motor reversed
3: Overvoltage
4: Overtemperature
5: Mirror status LED
6: No MOSFET failure

Example:

^DOA 1 3 : Output 1 is active when Overvoltage is observed

Note:

Typical default configuration is Digital outputs 1 (2) are active when motor is on. Digital output 2 (3) when no MOSFET failure is detected.
To activate an output via serial command or from a Microbasic script, set that output to Never

DOL - Digital Outputs Active Level

HexCode: 12

Description:
This parameter configures whether an output should be set to ON or to OFF when it is activated.

Syntax Serial: ^DOL cc aa
~DOL

Syntax Scripting: setconfig(_DOL, cc, aa)

Number of Arguments: 1

Argument 1: ActiveLevels
Type: Unsigned 32-bit
Min: 0 Max: 2 ^ Total Number of Digital Outputs
Default: 0 = All active high

Where:
cc = Digital input number
aa=

0: On when active
1: Off when active

PCTR - Pulse Center Range

HexCode: 20

Description:
This defines the raw value of the measured pulse that would be considered as the 0 value inside the controller. The default value is 1500 which is the center position of the pulse in the RC radio mode.

Syntax Serial: ^PCTR cc nn
~PCTR [cc]

Syntax Scripting: setconfig(_PCTR, cc, nn)

Number of Arguments: 2

Argument 1: InputNbr

Min: 1 Max: Total Number of Pulse Inputs

Argument 2: Center

Type: Unsigned 16-bit
Min: 0 Max: 65536
Default: 1500us

Where:
cc = Pulse input number

nn = 0 to 65536us

PDB - Pulse Input Deadband

HexCode: 21

Description:
This sets the deadband value for the pulse capture. It is defined as the percent number from 0 to 50% and defines the amount of movement from joystick or sensor around the center position before its converted value begins to change.

Syntax Serial: ^PDB cc nn
~PDB [cc]

Syntax Scripting: setconfig(_PDB, cc, nn)

Number of Arguments: 2

Argument 1: InputNbr

Min: 1 Max: Total Number of Pulse Inputs

Argument 2: Deadband

Type: Unsigned 8-bit

Min: 0 Max: 50
Default: 5 = 5%

Where:
cc = Pulse input number

nn = Deadband in %

Note:

Deadband is not used when input is used as feedback

PINA - Pulse Input Use

HexCode: 23

Description:
This parameter selects whether an input should be used as a command feedback, position feedback or left unused. Embedded in the parameter is the motor channel that this command or feedback should act on. Feedback can be position feedback if potentiometer is used or speed feedback if tachometer is used.

Syntax Serial: ^PINA cc (nn + mm)
~PINA [cc]

Syntax Scripting: setconfig(_PINA, cc, nn)

Number of Arguments: 2

Argument 1: InputNbr

Min: 1 Max: Total Number of Pulse Inputs

Argument 2: Use
Type: Unsigned 8-bit
Min: 0 Max: 255
Default: See note

Where:
cc = Pulse input number

nn =
0: No action
1: Command
2: Feedback

mm =
mot1*16 + mot2*32 + mot3*48

Example:

^AINA 1 17: Sets Pulse input 1 as command for motor 1. I.e. 17 = 1 (command) +16 (motor 1)

Note:

Input 1 is generally enabled and set as motor command on single channel motor controllers. Inputs 1 and 2 are enabled and set as motor command on dual channel controllers

PLIN - Pulse Linearity

HexCode: 22

Description:
This parameter is used for applying an exponential or a logarithmic transformation on a pulse input. There are 3 exponential and 3 logarithmic choices. Exponential correction will make the commands change less at the beginning and become stronger at the end of the joystick movement. The logarithmic correction will have a stronger effect near the start and lesser effect near the end. The linear selection causes no change to the input.

Syntax Serial: ^PLIN cc nn
~PLIN [cc]

Syntax Scripting: setconfig(_PLIN, cc, nn)

Number of Arguments: 2

Argument 1: InputNbr

Min: 1 Max: Total Number of Pulse Inputs

Argument 2: Linearity

Type: Unsigned 8-bit
Min: 0 Max: 6
Default: 0 = Linear

Where:
cc = Pulse input number

nn =
0: Linear (no change)
1: Exp weak
2: Exp medium
3: Exp strong
4: Log weak
5: Log medium
6: Log strong

PMAX - Pulse Max Range

HexCode: 1F

Description:
This parameter defines the raw pulse measurement number that would be considered as the +1000 internal value to the controller. By default, it is set to 2000 which is the max pulse width of an RC radio pulse.

Syntax Serial: ^PMAX cc nn
~PMAX [cc]

Syntax Scripting: setconfig(_PMAX, cc, nn)

Number of Arguments: 2

Argument 1: InputNbr

Min: 1 Max: Total Number of Pulse Inputs

Argument 2: Max

Type: Unsigned 16-bit
Min: 0 Max: 65536
Default: 2000us

Where:
cc = Pulse input number

nn = 0 to 65536us

PMAXA - Action on Pulse Max

HexCode: 25

Description:
This parameter configures the action to take when the max value that is defined in PMAX is reached. The list of action is the same as in the DINA digital input action list. Embedded in the parameter is the motor channel(s) to which the action should apply.

Syntax Serial: ^PMAXA cc (aa + mm)
~PMAXA [cc]

Syntax Scripting: setconfig(_PMAXA, cc, aa)

Number of Arguments: 2

Argument 1: InputNbr

Min: 1 Max: Total Number of Pulse Inputs

Argument 2: Action

Type: Unsigned 8-bit
Min: 0 Max: 255
Default: 0 = No action

Where:
cc = Pulse input number

aa =
0: No action
1: Safety stop
2: Emergency stop
3: Motor stop
4: Forward limit switch
5: Reverse limit switch
6: Invert direction
7: Run MicroBasic script
8: Load counter with home value

mm = mot1*16 + mot2*32 + mot3*48

PMIN - Pulse Min Range

HexCode: 1E

Description:
This sets the raw value of the pulse capture that would be considered as the -1000 internal value to the controller. The value is in number of microseconds (1000 = 1ms). The default value is 1000 microseconds which is the typical minimum value on an RC radio pulse.

Syntax Serial: ^PMIN cc nn
~PMIN [cc]

Syntax Scripting: setconfig(_PMIN, cc, nn)

Number of Arguments: 2

Argument 1: InputNbr

Min: 1 Max: Total Number of Pulse Inputs

Argument 2: Min

Type: Unsigned 16-bit
Min: 0 Max: 65536
Default: 1000us

Where:
cc = Pulse input number

nn = 0 to 65536us

PMINA - Action on Pulse Min

HexCode: 24

Description:
This parameter selects what action should be taken if the minimum value that is defined in PMIN is reached. The list of action is the same as these of the DINA digital input actions. Embedded in the parameter is the motor channel(s) to which the action should apply.

Syntax Serial: ^PMINA cc (aa + mm)
~PMINA [cc]

Syntax Scripting: setconfig(_PMINA, cc, aa)

Number of Arguments: 2

Argument 1: InputNbr

Min: 1 Max: Total Number of Pulse Inputs

Argument 2: Action

Type: Unsigned 8-bit
Min: 0 Max: 255
Default: 0 = No action

Where:
cc = Pulse input number

aa =
0: No action
1: Safety stop
2: Emergency stop
3: Motor stop
4: Forward limit switch
5: Reverse limit switch
6: Invert direction
7: Run MicroBasic script
8: Load counter with home value

mm = mot1*16 + mot2*32 + mot3*48

PMOD - Pulse Mode Select

HexCode: 1D

Description:
This parameter is used to enable/disable the pulse input and select its operating mode, which can be: pulse with measurement, frequency or duty cycle. Inputs can be measured with a high precision over a large range of time or frequency. An input will be processed

and converted to a command or a feedback value in the range of -1000 to +1000 for use by the controller internally.

Syntax Serial: ^PMOD cc nn
~PMOD [cc]
Syntax Scripting: setconfig(_PMOD, cc, nn)

Number of Arguments: 2

Argument 1: InputNbr

Min: 1 Max: Total Number of Pulse Inputs

Argument 2: Mode

Type: Unsigned 8-bit
Min: 0 Max: 4
Default: See note

Where:
cc = Pulse input number

nn =
0: Disabled
1: Pulse width
2: Frequency
3: Duty cycle
4: Magsensor

Example:

^PMOD 4 4 : Sets Pulse input 4 in Multi-PWM for Robteq's MGS1600 magnetic guide sensor

Note:

Pulse width is designed for capturing RC radio commands. Pulse width must be beween 500us and 3000us, and repeat rate 50Hz or higher
Input 1 is generally enabled and in RC mode on single channel motor controllers. Inputs 1 and 2 are enabled on dual channel controllers
On some products, enabling a pulse input will cause a an offset voltage to be present when that same input is read as analog

PPOL - Pulse Input Polarity

HexCode: 26

Description:
Inverts the pulse capture value after conversion. When this configuration bit is cleared, the pulse capture is converted into a -1000 to +1000 command or feedback value. When set, the converted range is inverted to +1000 to -1000. Center value must always be a number greater of equal to Min, and smaller or equal to Max. Make the center value the same as the min value in order to produce a converted output range that is positive only (0 to +1000)

Syntax Serial: ^PPOL cc nn
~PPOL

Syntax Scripting: setconfig(_PPOL, cc, nn)

Number of Arguments: 2

Argument 1: InputNbr

Min: 1 Max: Total Number of Pulse Inputs

Argument 2: Polarity

Type: Unsigned 8-bit
Min: 0 Max: 1
Default: 0 = Non inverted

Where:
cc = Pulse input number

nn =
0: Not inverted
1: Inverted

Motor Configurations

This section covers the various configuration parameter applying to motor operations.

TABLE 19-7. Motor Configurations

Command	Arguments	Description
ALIM	Channel Limit	Amp Limit
ATGA	Channel Action	Amps Trigger Action
ATGD	Channel Delay	Amps Trigger Delay
ATRIG	Channel Level	Amps Trigger Level
BKD	Delay	Brake activation delay in ms
BLFB	Channel Sensor	Encoder or Hall Sensor Feedback for closed loop
BLSTD	Channel Mode	Stall Detection
CLERD	Channel Mode	Close Loop Error Detection
EHL	Channel Value	Encoder High Count Limit
EHLA	Channel Action	Encoder High Limit Action
EHOME	Channel Value	Encoder Counter Load at Home Position
ELL	Channel Value	Encoder Low Count Limit
ELLA	Channel Action	Encoder Low Limit Action
EMOD	Channel Use	Encoder Usage
EPPR	Channel Value	Encoder PPR Value
ICAP	Channel Cap	PID Integral Cap
KD	Channel Gain	PID Differential Gain
KI	Channel Gain	PID Integral Gain
KP	Channel Gain	PID Proportional Gain
MAC	Channel Acceleration	Motor Acceleration Rate
MDEC	Channel Deceleration	Motor Deceleration Rate
MMOD	Channel Mode	Operating Mode
MVEL	Channel Velocity	Default Position Velocity
MXMD	Mode	Separate or Mixed Mode Select
MXPF	Channel MaxPower	Motor Max Power Forward
MXPR	Channel MaxPower	Motor Max Power Reverse
MXRPM	Channel RPM	Max RPM Value
MXTRN	Channel Turns	Number of turns between limits
OVH	Voltage	Overvoltage hysteresis
OVL	Voltage	Overvoltage Cutoff Limit
PWMF	Frequency	PWM Frequency
THLD	Threshold	Short Circuit Detection Threshold
UVL	Voltage	Undervoltage Limit

ALIM - Amp Limit

HexCode: 2A

Description:
This is the maximum Amps that the controller will be allowed to deliver to a motor regardless the load of that motor. The value is entered in Amps multiplied by 10. The value is the Amps that are measured at the motor and not the Amps measured from a battery. When the motor draws current that is above that limit, the controller will automatically reduce the output power until the current drops below that limit.

Syntax Serial: ^ALIM cc nn
~ALIM [cc]

Syntax Scripting: setconfig(_ALIM, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Limit

Type: Unsigned 16-bit
Min: 10 Max: Max Amps in datasheet
Default: See note

Where:
cc = Motor channel

nn = Amps *10

Example:

^ALIM1 455: Set Amp limit for Motor 1 to 45.5A

Note:

Default value is typically set to 75% of the controller's max amps as defined in the datasheet

ATGA - Amps Trigger Action

HexCode: 2C

Description:
This parameter sets what action to take when the Amps trigger is activated. The list is the same as in the DINA digital input actions. Typical use for that feature is as a limit switch when, for example, a motor reaches an end and enters stall condition, the current will rise, and that current increase can be detected and the motor be made to stop until the direction is reversed. Embedded in the parameter is the motor channel(s) to which the action should apply.

Syntax Serial: ^ATGA cc (aa + mm)
~ATGA [cc]

Syntax Scripting: setconfig(_ATGA, cc, aa)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Action

Type: Unsigned 8-bit
Min: 10 Max: 255
Default: 0 = No action

Where:
cc = Motor channel

aa =
0 : No action
1: Safety stop
2: Emergency stop
3: Motor stop
4: Forward limit switch
5: Reverse limit switch
6: Invert direction
7: Run MicroBasic script
8: Load counter with home value

mm = mot1*16 + mot2*32 + mot3*48

ATGD - Amps Trigger Delay

HexCode: 2D

Description:
This parameter contains the time in milliseconds during which the Amps Trigger Level (ATRIG) must be exceeded before the Amps Trigger Action (ATGA) is called. This parameter is used to prevent Amps Trigger Actions to be taken in case of short duration spikes.

Syntax Serial: ^ATGD cc nn
~ATGD [cc]

Syntax Scripting: setconfig(_ATGD, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Delay

Type: Unsigned 16-bit

Min: 0 Max: 10000
Default: 500ms

Where:
cc = Motor channel

nn = Delay in ms

Example:

^ATGD 1 1000: Action will be triggered if motor Amps exceeds the value set with ATGL for more than 1000ms

ATRIG - Amps Trigger Level

HexCode: 2B

Description:
This parameter lets you select Amps threshold value that will trigger an action. This threshold must be set to be below the ALIM Amps limit. When that threshold is reached, then list of action can be selected using the ATGA parameter.

Syntax Serial: ^ATRIG cc nn
~ATRIG [cc]

Syntax Scripting: setconfig(_ATRIG, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Level

Type: Unsigned 16-bit
Min: 10 Max: Max Amps in datasheet
Default: Max Amps rating in datasheet

Where:
cc = Motor channel

nn = Amps *10

Example:

^ATRIG2 550: Set Amps Trigger to 55.0A

BKD - Brake activation delay in ms

HexCode: 0F

Description:
Set the delay in miliseconds from the time a motor stops and the time an output connected to a brake solenoid will be released. Applies to any Digital Ouput(s) that is configured as motor brake. Delay value applies to all motors in multi-channel products.

Syntax Serial: ^BKD nn
~BKD

Syntax Scripting: setconfig(_BKD, nn)

Number of Arguments: 1

Argument 1: Delay

Type: Unsigned 16-bit
Min: 0 Max: 65536
Default: 250 = 250ms

Where:
nn = Delay in milliseconds

Example:

^BKD 1 1000 : Causes the digital output to go off, and therefore activate the brake, 1.0s after motor stops being energized

BLFB - Encoder or Hall Sensor Feedback for closed loop

HexCode: 3B

Description:
This parameter is used to select which feedback sensor will be used to measure speed or positions. On brushless motors system equipped with optical encoders, this parameter lets you select the encoder or the brushless sensors (ie. Hall, Sin/Cos, or SPI) as the source of speed or position feedback. Encoders provide higher precision capture and should be preferred whenever possible. The choice "Other" is also used to select pulse or analog feedback in some position modes.

Syntax Serial: ^BLFB cc nn
~BLFB

Syntax Scripting: setconfig(_BLFB, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Sensor

Type: Unsigned 8-bit

Min: 0 Max: 1
Default: 0 = Other Sensor

Where:
cc = Motor channel

nn =
0: Other feedback
1: Brushless sensor feedback (Hall, SPI, Sin/Cos)

BLSTD - Stall Detection

HexCode: 3A

Description:
This parameter controls the stall detection of brushless motors and of brushed motors in closed loop speed mode. If no motion is sensed (i.e. counter remains unchanged) for a preset amount of time while the power applied is above a given threshold, a stall condition is detected and the power to the motor is cut until the command is returned to 0. This parameter allows three combination of time & power sensitivities. The setting also applies also when encoders are used in closed loop speed mode on brushed or brushless motors

Syntax Serial: ^BLSTD cc nn
~BLSTD [cc]

Syntax Scripting: setconfig(_BLSTD, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Mode
Type: Unsigned 8-bit
Min: 0 Max: 3
Default: 2 = 500ms at 25% Power

Where:
cc = Motor channel

nn =
0: Disabled
1: 250ms at 10% Power
2: 500ms at 25% Power
3: 1000ms at 50% Power

Example:

^BLSTD 2: Motor will stop if applied power is higher than 10% and no motion is detected for more than 250ms

CLERD - Close Loop Error Detection

HexCode: 38

Description:
This parameter is used to detect large tracking errors due to mechanical or sensor failures, and shut down the motor in case of problem in closed loop speed or position system. The detection mechanism looks for the size of the tracking error and the duration the error is present. This parameter allows three combination of time & error level. This parameter is also used to limit the loop error when operating in Count Position, and Speed Position modes. When enabled, the desired position (tracking) will stop progressing when the loop error is greater than 50% the detection threshold while power output is already at 100%.

Syntax Serial: ^CLERD cc nn
~CLERS

Syntax Scripting: setconfig(_CLERD, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motor Channels

Argument 2: Mode

Type: Unsigned 8-bit
Min: 0 Max: 3
Default: 2 = 500ms at Error > 250

Where:
cc = Motor channel

nn =
0: Detection disabled
1: 250ms at Error > 100
2: 500ms at Error > 250
3: 1000ms at Error > 500

Example:

^CLERD 2: Motor will stop if command - feedback is greater than 100 for more than 250ms

Note:

Disabling the loop error can lead to runaway or other dangerous conditions in case of sensor failure

EHL - Encoder High Count Limit

HexCode: 4C

Description:
Defines a maximum count value at which the controller will trigger an action when the counter goes above that number. This feature is useful for setting up virtual or â€œsoftâ€ limit switches .This value, together with the Low Count Limit, are also used in the position mode to determine the travel range when commanding the controller with a relative position command. In this case, the High Limit Count is the desired position when a command of 1000 is received.

Syntax Serial: ^EHL cc nn
~EHL [cc]

Syntax Scripting: setconfig(_EHL, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Encoders

Argument 2: Value

Type: Signed 32-bit
Min: -2147M Max: 2147M
Default: +20000

Where:
cc = Encoder channel

nn = Counter value

EHLA - Encoder High Limit Action

HexCode: 4E

Description:
This parameter lets you select what kind of action should be taken when the high limit count is reached on the encoder. The list of action is the same as in the DINA digital input action list Embedded in the parameter is the motor channel(s) to which the action should apply.

Syntax Serial: ^EHLA cc nn
~EHLA [cc]

Syntax Scripting: setconfig(_EHLA, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Encoders

Argument 2: Action

Type: Unsigned 8-bit
Min: 0 Max: 255
Default: 0 = No action

Where:
cc = Encoder channel

aa =
0: No action
1: Safety stop
2: Emergency stop
3: Motor stop
4: Forward limit switch
5: Reverse limit switch
6: Invert direction
7: Run MicroBasic script
8: Load counter with home value

mm = mot1*16 + mot2*32 + mot3*48

EHOME - Encoder Counter Load at Home Position

HexCode: 4F

Description:
Contains a value that will be loaded in the selected encoder counter when a home switch is detected, or when a Home command is received from the serial/USB, or issued from a MicroBasic script.

Syntax Serial: ^EHOME cc nn
~EHOME [cc]

Syntax Scripting: setconfig(_EHOME, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Encoders

Argument 2: Value

Type: Signed 32-bit
Min: -2147M Max: 2147M
Default: 0

Where:
cc = Encoder channel

nn = Counter value to be loaded

ELL - Encoder Low Count Limit

HexCode: 4B

Description:
Defines a minimum count value at which the controller will trigger an action when the counter dips below that number. This feature is useful for setting up virtual or â€œsoftâ€ limit switches.This value, together with the High Count Limit, are also used in the position mode to determine the travel range when commanding the controller with a relative position command. In this case, the Low Limit Count is the desired position when a command of -1000 is received.

Syntax Serial: ^ELL cc nn
~ELL [cc]

Syntax Scripting: setconfig(_ELL, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Encoders

Argument 2: Value

Type: Signed 32-bit
Min: -2147M Max: 2147M
Default: -20000

Where:
cc = Encoder channel

nn = Counter value

Example:

^ELL 1 -100000 : Set encoder 1 low limit to minus 100000

ELLA - Encoder Low Limit Action

HexCode: 4D

Description:
This parameter lets you select what kind of action should be taken when the low limit count is reached on the encoder. The list of action is the same as in the DINA digital input action list Embedded in the parameter is the motor channel(s) to which the action should apply.

Syntax Serial: ^ELLA cc (aa + mm)
~ELLA [cc]

Syntax Scripting: setconfig(_ELLA, cc, aa)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Encoders

Argument 2: Action

Type: Unsigned 8-bit
Min: 0 Max: 255
Default: 0 = No action

Where:
cc = Encoder channel

aa =
0: No action
1: Safety stop
2: Emergency stop
3: Motor stop
4: Forward limit switch
5: Reverse limit switch
6: Invert direction
7: Run MicroBasic script
8: Load counter with home value

mm = mot1*16 + mot2*32 + mot3*48

EMOD - Encoder Usage

HexCode: 49

Description:
This parameter defines what use the encoder is for. The encoder can be used to set command or to provide feedback (speed or position feedback). The use of encoder as feedback devices is the most common. Embedded in the parameter is the motor to which the encoder is associated.

Syntax Serial: ^EMOD cc (aa + mm)
~EMOD [cc]

Syntax Scripting: setconfig(_EMOD, cc, aa)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Encoders

Argument 2: Use

Type: Unsigned 8-bit
Min: 0 Max: 255
Default: 0 = Unused

Where:
cc = Encoder channel

aa =
0: Unused
1: Command
2: Feedback

mm =
mot1*16 + mot2*32 + mot3*48

Example:

^EMOD 1 18 = Encoder used as feedback for channel 1

EPPR - Encoder PPR Value

HexCode: 4A

Description:
This parameter will set the pulse per revolution of the encoder that is attached to the controller. The PPR is the number of pulses that is issued by the encoder when making a full turn. For each pulse there will be 4 counts which means that the total number of a counter increments inside the controller will be 4x the PPR value. Make sure not to confuse the Pulse Per Revolution and the Count Per Revolution when setting up this parameter. Entering a negative number will invert the counter and the measured speed polarity

Syntax Serial: ^EPPR cc nn
~EPPR [cc]

Syntax Scripting: setconfig(_EPPR, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Encoders

Argument 2: Value

Type: Signed 16-bit
Min: -32768 Max: 32767
Default: 100

Where:
cc = Encoder channel

nn = PPR value

Example:

^EPPR 2 200 : Sets PPR for encoder 2 to 200

ICAP - PID Integral Cap

HexCode: 32

Description:
This parameter is the integral cap as a percentage. This parameter will limit maximum level of the Integral factor in the PID. It is particularly useful in position systems with long travel movement, and where the integral factor would otherwise become very large because of the extended time the integral would allow to accumulate. This parameter can be used to dampen the effect of the integral parameter without reducing the gain. This parameter may adversely affect system performance in closed loop speed mode as the Integrator must be allowed to reach high values in order for good speed control.

Syntax Serial: ^ICAP cc nn
~ICAP [cc]

Syntax Scripting: setconfig(_ICAP, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Cap

Type: Unsigned 8-bit
Min: 1 Max: 100
Default: 100%

Where:
cc = Motor channel

nn = Integral cap in %

KD - PID Differential Gain

HexCode: 30

Description:
Sets the PID's Differential Gain for that channel. The value is set as the gain multiplied by 10. This gain is used in all closed loop modes. In Torque mode, when sinusoidal mode is selected on brushless contontrollers, the FOC's PID is used instead the this parameter has no effect.

Syntax Serial: ^KD cc nn
~KD [cc]

Syntax Scripting: setconfig(_KD, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Gain

Type: Unsigned 8-bit
Min: 0 Max: 255
Default: 0

Where:
cc = Motor channel

nn = Differential Gain *10

Example:

^KD 1 155: Set motor channel 1 Differential Gain to 15.5

Note:

Do not use default values. As a starting point, se P=2, I=0, D=0 in position modes (including Speed Position mode). Use P=0, I=1, D=0 in closed loop speed mode and in torque mode. Perform full tuning after that.

KI - PID Integral Gain

HexCode: 2F

Description:
Sets the PID's Integral Gain for that channel. The value is set as the gain multiplied by 10. This gain is used in all closed loop modes. In Torque mode, when sinusoidal mode is selected on brushless controllers, the FOC's PID is used instead the this parameter has no effect.

Syntax Serial: ^KI cc nn
~KI

Syntax Scripting: setconfig(_KI, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Gain

Type: Unsigned 8-bit
Min: 0 Max: 255
Default: 20 = 2.0

Where:
cc = Motor channel

nn = Integral Gain *10

Example:

^KI 1 155: Set motor channel 1 Integral Gain to 15.5

Note:

Do not use default values. As a starting point, se P=2, I=0, D=0 in position modes (including Speed Position mode). Use P=0, I=1, D=0 in closed loop speed mode and in torque mode. Perform full tuning after that.

KP - PID Proportional Gain

HexCode: 2E

Description:
Sets the PID's Proportional Gain for that channel. The value is set as the gain multiplied by 10. This gain is used in all closed loop modes. In Torque mode, when sinusoidal mode is selected on brushless controllers, the FOC's PID is used instead the this parameter has no effect.

Syntax Serial: ^KP cc nn
~KP

Syntax Scripting: setconfig(_KP, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Gain

Type: Unsigned 8-bit
Min: 0 Max: 255
Default: 20 = 2.0

Where:
cc = Motor channel

nn = Proportional Gain *10

Example:

^KP 1 155 = Set motor channel 1 Proportional Gain to 15.5

Note:

Do not use default values. As a starting point, se P=2, I=0, D=0 in position modes. Use P=0, I=1, D=0 in closed loop speed mode and in torque mode. Perform full tuning after that

On brushless motor controller with FOC support, KP is not used for torque control. A separate PID is used for current control

MAC - Motor Acceleration Rate

HexCode: 33

Description:
Set the rate of speed change during acceleration for a motor channel. This command is identical to the AC realtime command. Acceleration value is in 0.1*RPM per second. When using controllers fitted with encoder, the speed and acceleration value are actual RPMs. Brushless motor controllers use the hall sensor for measuring actual speed and acceleration will also be in actual RPM/s. When using the controller without speed sensor, the acceleration value is relative to the Max RPM configuration parameter, which itself is a user-provide number for the speed normally expected speed at full power. Assuming that the Max RPM parameter is set to 1000, and acceleration value of 10000 means that the motor will go from 0 to full speed in exactly 1 second, regardless of the actual motor speed.

Syntax Serial: ^MAC cc nn
~MAC [cc]

Syntax Scripting: setconfig(_MAC, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Acceleration
Type: Signed 32-bit
Min: 0 Max: 500000
Default: 10000 = 1000.0 RPM/s

Where:
cc = Motor channel

nn = Acceleration time in 0.1 RPM per seconds

MDEC - Motor Deceleration Rate

HexCode: 34

Description:
Set the rate of speed change during deceleration for a motor channel. This command is identical to the DC realtime command. Acceleration value is in 0.1*RPM per second. When using controllers fitted with encoder, the speed and deceleration value are actual RPMs. Brushless motor controllers use the hall sensor for measuring actual speed and acceleration will also be in actual RPM/s. When using the controller without speed sensor, the deceleration value is relative to the Max RPM configuration parameter,

which itself is a user-provide number for the speed normally expected speed at full power. Assuming that the Max RPM parameter is set to 1000, and deceleration value of 10000 means that the motor will go from full speed to 0 1 second, regardless of the actual motor speed.

Syntax Serial: ^MDEC cc nn
~MDEC [cc]

Syntax Scripting: setconfig(_MDEC, cc, nn)

Number of Arguments: 2

Argument 1: Channel
Type: Unsigned 8-bit
Min: 1 Max: Total Number of Motor Channels

Argument 2: Deceleration
Type: Signed 32-bit
Min: 0 Max: 500000
Default: 10000 = 1000.0 RPM/s

Where:
cc = Motor channel

nn = Deceleration time in 0.1 RPM per second

MDIR - Motor Direction

HexCode: 0x77

Description:

This parameter lets you set the motor direction to inverted or direct.

Syntax Serial: ^MDIR cc nn

Where:

cc = Motor Channel

nn = 0: Not inverted
1: Inverted

Syntax Scripting: setconfig(_MDIR, cc, nn)

MMOD - Operating Mode

HexCode: 27

Description:
This parameter lets you select the operating mode for that channel. See manual for description of each mode.

Syntax Serial: ^MMOD cc nn
~MMOD [cc]

Syntax Scripting: setconfig(_MMOD, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Mode

Type: Unsigned 8-bit
Min: 0 Max: 6
Default: 0 = Open loop

Where:
cc = Motor channel

nn =
0: Open-loop
1: Closed-loop speed
2: Closed-loop position relative
3: Closed-loop count position
4: Closed-loop position tracking
5: Torque
6: Closed-loop speed position

Example:

^MMOD 2 : Select Closed loop position relative

MVEL - Default Position Velocity

HexCode: 35

Description:
This parameter is the default speed at which the motor moves while in position mode. Values are in RPMs. To change velocity while the controller is in operation, use the !S run-time command.

Syntax Serial: ^MVEL cc nn
~MVEL [cc]

Syntax Scripting: setconfig(_MVEL, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Velocity

Type: Signed 32-bit
Min: 0 Max: 30000
Default: 1000 RPM

Where:
cc = Motor channel

nn = Velocity value in RPM

MXMD - Separate or Mixed Mode Select

HexCode: 05

Description:
Selects the mixed mode operation. It is applicable to dual channel controllers and serves to operate the two channels in mixed mode for tank-like steering. There are 3 possible values for this parameter for selecting separate or one of the two possible mixed mode algorithms. Details of each mixed mode is described in manual

Syntax Serial: ^MXMD nn
~MXMD

Syntax Scripting: setconfig(_MXMD, nn)

Number of Arguments: 1

Argument 1: Mode

Type: Unsigned 8-bit
Min: 0 Max: 2
Default: 0 = Separate

Where:
nn =
0: Separate
1: Mode 1
2: Mode 2

Example:

^MXMD 0 : Set mode to separate

MXPF - Motor Max Power Forward

HexCode: 28

Description:
This parameter lets you select the scaling factor for the PWM output, in the forward direction, as a percentage value. This feature is used to connect motors with voltage rating that is less than the battery voltage. For example, using a factor of 50% it is possible to connect a 12V motor onto a 24V system, in which case the motor will never see more than 12V at its input even when the maximum power is applied.

Syntax Serial: ^MXPF cc nn
~MXPF [cc]

Syntax Scripting: setconfig(_MXPF, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: MaxPower

Type: Unsigned 8-bit
Min: 25 Max: 100
Default: 100%

Where:
cc = Motor channel

nn = Max Power

MXPR - Motor Max Power Reverse

HexCode: 29

Description:
This parameter lets you select the scaling factor for the PWM output, in the reverse direction, as a percentage value. This feature is used to connect motors with voltage rating that is less than the battery voltage. For example, using a factor of 50% it is possible to connect a 12V motor onto a 24V system, in which case the motor will never see more than 12V at its input even when the maximum power is applied.

Syntax Serial: ^MXPR cc nn
~MXPR [cc]

Syntax Scripting: setconfig(_MXPR, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: MaxPower

Type: Unsigned 8-bit
Min: 25 Max: 100
Default: 100%

Where:
cc = Motor channel

nn = Max Power

MXRPM - Max RPM Value

HexCode: 36

Description:
Commands sent via analog, pulse or the !G command only range between -1000 to +1000. The Max RPM parameter lets you select which actual speed, in RPM, will be considered the speed to reach when a +1000 command is sent. In open loop, this parameter is used together with the acceleration and deceleration settings in order to figure the ramping time from 0 to full power.

Syntax Serial: ^MXRPM cc nn
~MXRPM [cc

Syntax Scripting: setconfig(_MXRPM, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: RPM

Type: Unsigned 16-bit
Min: 10 Max: 65535
Default: 1000 RPM

Where:
cc = Motor channel

nn = Max RPM value

MXTRN - Number of turns between limits

HexCode: 37

Description:
This parameter is used in position mode to measure the speed when an analog or pulse feedback sensor is used. The value is the number of motor turns between the feedback value of -1000 and +1000. When encoders are used for feedback, this parameter is automatically computed from the encoder configuration, and can thus be omitted. See â€œClosed Loop Relative and Tracking Position Modesâ€ for a detailed discussion.

Syntax Serial: ^MXTRN cc nn
~MXTRN [cc]
Syntax Scripting: setconfig(_MXTRN, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Turns

Type: Signed 32-bit
Min: 10 Max: 100000
Default: 10000 = 1000.0 turns

Where:
cc = Motor channel

nn = Number of turns * 10

Example:

^MXTRN 1 2000: Set max turns for motor 1 to 200.0 turns

OVH - Overvoltage hysteresis

HexCode: 42

Description:
This voltage gets subtracted to the overvoltage limit to set the voltage at which the overvoltage condition will be cleared. For instance, if the overvoltage limit is set to 500 (50.0) and the hysteresis is set to 50 (5.0V), the MOSFETs will turn off when the voltage reaches 50V and will remain off until the voltage drops under 45V

Syntax Serial: ^SXM nn
~SXM

Syntax Scripting: setconfig(_SXM, nn)

Number of Arguments: 1

Argument 1: Voltage

Type: Unsigned 8-bit
Min: 0 Max: 255 = 25.5V
Default: 50 = 5.0V

Where:
nn = Volts *10

Example:

^OVH 45 : Sets hysteresis at 4.5V

Note:

Make sure that overvoltage limit minus hysteresis is above the supply voltage.

OVL - Overvoltage Cutoff Limit

HexCode: 02

Description:
Sets the voltage level at which the controller must turn off its power stage and signal an Overvoltage condition. Value is in volts multiplied by 10 (e.g. 450 = 45.0V) . The power stage will turn back on when voltage dips below the Overvoltage Clearing threshold that is set with the the OVH configuration command.

Syntax Serial: ^OVL nn
~OVL

Syntax Scripting: setconfig(_OVL, nn)

Number of Arguments: 1

Argument 1: Voltage
Type: Unsigned 16-bit
Min: 100 = 10.0V Max: See Product Datasheet
Default: See Product Datasheet

Where:
nn = Volts *10

Example:

^OVL 400 : Set Overvoltage limit to 40.0V

Note:

On firmware versions 1.5 and earlier, no hysteresis exists and the overvoltage condition is cleared as soon as the voltage dips below the overvoltage limit.

PWMF - PWM Frequency

HexCode: 06

Description:
This parameter sets the PWM frequency of the switching output stage. It can be set from 1 kHz to 20 kHz. The frequency is entered as kHz value multiplied by 10 (e.g. 185 = 18.5 kHz). Beware that a too low frequency will create audible noise and would result in lower performance operation.

Syntax Serial: ^PWMF nn
~PWMF

Syntax Scripting: setconfig(_PWMF, nn)

Number of Arguments: 1

Argument 1: Frequency

Type: Unsigned 16-bit
Min: 100 Max: 500
Default: 160 = 16.0kHz

Where:
nn = PWM Frequency *10

Example:

^PWMF 200 := Set PWM frequency to 20kHz

Note:

Do not change the default PWM frequency when operating brushless motors in sinusoidal mode.

THLD - Short Circuit Detection Threshold

HexCode: 04

Description:
This configuration parameter sets the threshold level for the short circuit detection. There are 4 sensitivity levels from 0 to 3.

Syntax Serial: ^THLD nn
~THLD

Syntax Scripting: setconfig(_THLD, nn)

Number of Arguments: 1

Argument 1: Threshold

Type: Unsigned 8-bit
Min: 0 Max: 3
Default: 1 = Medium Sensitivity

Where:
nn =
0: Very high sensitivity
1: Medium sensitivity
2: Low sensitivity
3: Short circuit protection disabled

Example:

^THLD 1 : Set short circuit detection sensitivity to medium.

Note:

You should never disable the short circuit protection.

UVL - Undervoltage Limit

HexCode: 03

Description:
Sets the voltage below which the controller will turn off its power stage. The voltage is entered as a desired voltage value multiplied by 10. Undervoltage condition is cleared as soon as voltage rises above the limit.

Syntax Serial: ^UVL nn
~UVL

Syntax Scripting: setconfig(_UVL, nn)

Number of Arguments: 1

Argument 1: Voltage

Type: Unsigned 16-bit
Min: 50 = 5.0V Max: Max Voltage in Product Datasheet
Default: 50 = 5.0V

Where:
nn = Volts *10

Example:

^UVL 100 : Set undervoltage limit to 10.0 V

Brushless Specific Commands

TABLE 19-8. Brushless Specific Commands

Command	Arguments	Description
BADJ	Channel Angle	Brushless zero angle
BADV	Channel Value	Brushless timing angle adjust
BFBK	Channel Sensor	Brushless feedback sesnor
BHL	Channel Value	Brushless Counter High Limit
BHLA	Channel Action	Brushless Counter High Limit Action
BHOME	Channel Value	Brushless Counter Load at Home Position
BLL	Channel Value	Brushless Counter Low Limit
BLLA	Channel Action	Brushless Counter Low Limit Action
BMOD	Channel Mode	Brushless operating mode
BPOL	Channel NbrPoles	Number of pole pairs of Brushless Motor and Speed Polarity

TABLE 19-8. Brushless Specific Commands

Command	Arguments	Description
BZPW	Channel Amps	Brushless zero seek power level
HPO	InputNbr Value	Hall Type
HSM	InputNbr Value	Hall Sensor Map
KIF	AmpsChannel Gain	FOC PID Integral Gain
KPF	AmpsChannel Gain	FOC PID Proportional Gain
SPOL	Channel Poles	Sin/Cos or Resolver number of poles
SSP	MotorPower	Sensorless Start-Up Power
SST	Ticks	Sensorless Start-Up Time
SWD	InputNbr Value	Swap Windings
TID	Channel Amps	FOC Target Id
ZSMC	InputNbr Value	SinCos Calibration

BADJ - Brushless zero angle

HexCode: 60

Description:
In sinusoidal mode and SIn/Cos and SPI feedback sensors are used, this configuration command stores results of automatic zero degrees angle search after performing the !BND command. The angle represents the mechanical offset between the sensor's zero position and the rotor's zero position. The value is in electrical degrees ranging from 0 to 511 for a full electrical turn. The value can then be fine tuned manually. The BADJ values are stored permanently in the calibration section of the controller's flash memory so that they are not lost when updating firmware.

Syntax Serial: ^BADJ cc nn
~BADJ [cc]

Syntax Scripting: setconfig(_BADJ, cc)

Number of Arguments:

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Angle

Type: Signed 16-bit
Min: -511 Max: 511
Default: 0

Where:
cc = Motor channel

nn = Angle

Example:

^BADJ 1 220 : Manually set the zero to 220 degrees
%CLSAV 3216549987 : Save change permanently to non-voltatile calibration memory space

Note:

Use %CLSAV to save the values to EEPROM. Clicking on Save to Controller on the PC Utility will not save the data.

BADV - Brushless timing angle adjust

HexCode: 61

Description:
When operating in sinusoidal mode, this parameter shifts by number of degrees to the 3 phases rotating magnetic field. This value works symetrically to produce the same results in both rotation direction. The value is in electrical degrees ranging from 0 to 511 for a full electrical turn.

Syntax Serial: ^BADV cc nn
~BADV [cc]

Syntax Scripting: setconfig(_BADV, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Value

Type: Signed 16-bit
Min: -511 Max: 511

Default: 0

Where:
cc = Motor channel

nn = Angle

Example:

^BADV 1 20 : Advance motor 1 timing by 20 degrees

BFBK - Brushless feedback sesnor

HexCode: 63

Description:
Selects the type of rotor angle sensor to be used for brushless motors when operated in sinusoidal mode.

Syntax Serial: ^BFBK cc nn
~BFBK [cc]

Syntax Scripting: setconfig(_BFBK, cc)

Number of Arguments:

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Sensor

Type: Unsigned 8-bit
Min: 0 Max: 4
Default: 0 = Encoder

Where:
cc = Motor channel

nn =
0: Encoder
1: Hall
2: Hall + Encoder
3: SPI
4: Sin/Cos

BHL - Brushless Counter High Limit

HexCode: 3E

Description:
This parameter allows you to define a minimum brushless count value at which the controller will trigger an action when the counter rises above that number. This feature is useful for setting up virtual or â€œsoftâ€ limit switches. This value, together with the Low Count Limit, are also used in the position mode to determine the travel range when commanding the controller with a relative position command. In this case, the Low Limit Count is the desired position when a command of 1000 is received

Syntax Serial: ^BHL cc nn
~BHL [cc]

Syntax Scripting: setconfig(_BHL, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Value

Type: Signed 32-bit
Min: -2147M Max: +2147M
Default: 20000

Where:
cc = Motor channel

nn = Counter value

Example:

^BHL 10000 : Set brushless counter high limit

Note:

Counter is not an absolute position. A homing sequence is necessary to set a reference position.

BHLA - Brushless Counter High Limit Action

HexCode: 40

Description:
This parameter lets you select what kind of action should be taken when the high limit count is reached on the brushless counter. The list of action is the same as in the DINA digital input action list. Embedded in the parameter is the motor channel(s) to which the action should apply.

Syntax Serial: ^BHLA cc nn
~BHLA [cc]

Syntax Scripting: setconfig(_BHLA, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motor

Argument 2: Action

Type: Unsigned 8-bit
Min: 0 Max: 255
Default: 0 = No action

Where:
cc = Motor channel

aa =
0 : No action
1: Safety stop
2: Emergency stop
3: Motor stop

4: Forward limit switch
5: Reverse limit switch
6: Invert direction
7: Run MicroBasic script
8: Load counter with home value

mm = mot1*16 + mot2*32 + mot3*48

Example:

^BHLA 1 36 : Forward limit switch for motor 2 (5 + 32)

BHOME - Brushless Counter Load at Home Position

HexCode: 3C

Description:
This parameter contains a value that will be loaded in the brushless hall sensor counter when a home switch is detected, or when a Home command is received from the serial/USB, or issued from a MicroBasic script.

Syntax Serial: ^BHOME cc nn
~BHOME [cc]

Syntax Scripting: setconfig(_BHOME, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Value

Type: Signed 32-bit
Min: -2147M Max: +2147M
Default: 0

Where:
cc = Motor channel

nn = Counter value to be loaded

Example:

^BHOME 1 10000 : load brushless counter with 10000 when Home command is received

Note:

Change counter only while in open loop if brushless counter is used for speed or position feedback

BLL - Brushless Counter Low Limit

HexCode: 3D

Description:
This parameter defines a minimum brushless count value at which the controller will trigger an action when the counter dips below that number. This feature is useful for setting up virtual or â€œsoftâ€ limit switches. This value, together with the High Count Limit, are also used in the position mode to determine the travel range when commanding the controller with a relative position command. In this case, the Low Limit Count is the desired position when a command of -1000 is received

Syntax Serial: ^BLL cc nn
~BLL [cc]

Syntax Scripting: setconfig(_BLL, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Value

Type: Signed 32-bit
Min: -2147M Max: +2147M
Default: -20000

Where:
cc = Motor channel

nn = Counter value

Example:

^BLL 1 -10000 : Set motor 1 brushless counter low limit

Note:

Counter is not an absolute position. A homing sequence is necessary to set a reference position.

BLLA - Brushless Counter Low Limit Action

HexCode: 3F

Description:
This parameter lets you select what kind of action should be taken when the low limit count is reached on the brushless counter. The list of action is the same as in the DINA digital input action list. Embedded in the parameter is the motor channel(s) to which the action should apply.

Syntax Serial: ^BLLA cc aa
~BLLA [cc]

Syntax Scripting: setconfig(_BLLA, cc, aa)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Action

Type: Unsigned 8-bit
Min: 0 Max: 255
Default: 0 = No action

Where:
cc = Motor channel

aa =
0: No action
1: Safety stop
2: Emergency stop
3: Motor stop
4: Forward limit switch
5: Reverse limit switch
6: Invert direction
7: Run MicroBasic script
8: Load counter with home value

mm = mot1*16 + mot2*32 + mot3*48

Example:

^BLLA 1 37 : Reverse limit switch for motor 2 (5 + 32)

BMOD - Brushless operating mode

HexCode: 5F

Description:
Selects the operating mode when controlling brushless motors. Additional settings apply for each mode.

Syntax Serial: ^BMOD cc nn
~BMOD [cc]

Syntax Scripting: setconfig(_BMOD, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Mode

Type: Unsigned 8-bit
Min: 0 Max: 2
Default: 0 = Trapezoidal

Where:
cc = Motor channel

nn =
0: Trapezoidal
1: Sinusoidal
2: Sensorless
3: AC Induction

Note:

After changing this setting, the motor will perform a reference searched when selecting sinusoidal mode with encoder feedback.

BPOL - Number of Pole Pairs and Speed Polarity of Brushless Motor

HexCode: 39

Description:
This parameter is used to define the number of pole pairs of the brushless motor connected to the controller. This value is used to convert the hall sensor transition counts into actual RPM and number of motor turns. Entering a negative number will invert the counter and the measured speed polarity.

Syntax Serial: ^BPOL cc nn
~BPOL

Syntax Scripting: setconfig(_BPOL, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Number of Pole Pairs

Type: Signed 8-bit
Min: -127 Max: +127
Default: 2

Where:
cc = Motor channel

nn = Number of pole pairs

BZPW - Brushless zero seek power level

HexCode: 62

Description:
Sets the level of Amps to be applied to the motor coils during the zero-angle reference search in sinusoidal mode. Zero reference is automatically initiated every time the controller is powered up when sinusoidal with encoder feedback is selected. Zero reference search is initiated manually with the !BND command in sinusoidal mode with sin/cos and SPI feedback.

Syntax Serial: ^BZPW cc nn
~BZPW [cc]

Syntax Scripting: setconfig(_BZPW, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Amps

Type: Unsigned 16-bit
Min: 0
Default: 50 = 5.0A

Where:
cc = Motor channel

nn = Amps x 10

HPO - Hall Sensor Position

HexCode: A5

Description:

This parameter selects the Hall sensor spacing in the motor. Practically all brushless motors use Hall sensors with 120 degrees spacing. Some motors have Hall sensors with 60 degrees. Change this parameter only if the motor's manual clearly specifies 60 degrees spacing.

Syntax Serial: ^HPO cc nn
~HPO [cc]

Syntax Scripting: setconfig(_HPO, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Hall Position

Type: Unsigned 8-bit

Min: 0 Max: 1

Default: 0

Where:

cc = Motor channel

nn = Hall Sensor Position

0: 120degree

1: 60degree

Example:

^HPO 1 1: Configure that the Hall Sensor of motor 1 are spaced by 60 degrees.

HSM - Hall Sensor Map

HexCode: A3

Description:

Configure this parameter to match the ABC hall sensor cable pattern with the UVW motor windings wire pattern connected to the controller. For each hall sensor cable order and motor wire order, there are 6 combinations, one of which will make the motor spin smoothly and efficiently in both directions. Try each of the 6 available values of HSM (0-5) and retain the one that will make the motor spin in both directions while drawing the same low current.

Syntax Serial: ^HSM cc nn

~ HSM [cc]

Syntax Scripting: setconfig(_HSM, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Hall Sensor Map

Type: Unsigned 8-bit

Min: 0 Max: 5

Default: 0

Where:

cc = Motor channel

nn = Motor's Hall Sensor Map

Example:

^HSM 1 1: Set Hall Sensor Map for motor 1 to value 1.

KIF - FOC PID Integral Gain

HexCode: 8E

Description:
On brushless motor controller operating in sinusoidal mode, this parameter sets the Integral gain in the PI that is used for Field Oriented Control. Two gains can be set for each motor channel, in order to control the Flux and Torque current.

Syntax Serial: ^KIF cc nn
~KIF [cc]

Syntax Scripting: setconfig(_KIF, cc)

Number of Arguments:

Argument 1: AmpsChannel

Min: 1 Max: 2 * Total Number of Motors

Argument 2: Gain

Type: Unsigned 8-bit
Min: 0 Max: 255

Where:
cc (single channel) =
1: Flux Gain
2: Torque Gain

cc (dual channel) =
1: Flux Gain for motor 1
2: Flux Gain for motor 2
3: Torque Gain for motor 1
4: Torque Gain for motor 2

nn = Gain * 10

KPF - FOC PID Proportional Gain

HexCode: 8D

Description:
On brushless motor controller operating in sinusoidal mode, this parameter sets the Proportional gain in the PI that is used for Field Oriented Control. Two gains can be set for each motor channel, in order to control the Flux and Torque current.

Syntax Serial: ^KIF cc nn
~KIF [cc]

Syntax Scripting: setconfig(_KIF, cc)

Number of Arguments:

Argument 1: AmpsChannel

Min: 1 Max: 2 * Total Number of Motors

Argument 2: Gain

Type: TYPE_ID_U8
Min: 0 Max: 255
Default: 5

Where:
cc (single channel) =
1: Flux Gain
2: Torque Gain

cc (dual channel) =
1: Flux Gain for motor 1
2: Flux Gain for motor 2
3: Torque Gain for motor 1
4: Torque Gain for motor 2

nn = Gain * 10

SPOL - Sin/Cos or Resolver number of poles

HexCode: 41

Description:
Number of poles of the Sin/Cos or resolver angle sensor used in sinusoidal mode with brushless motors

Syntax Serial: ^SPOL cc nn
~SPOL [cc]

Syntax Scripting: setconfig(_SPOL, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Number

Type: Unsigned 8-bit
Min: 1 Max: 255
Default: 1

Where:
cc = Motor channel

nn = Number of poles

SSP - Sensorless Start-Up Power

HexCode: 93

Description:
This parameter sets the start-up Power in Sensorless mode. It is the minimum power to apply to the motor in order to make it start. The value is number from 0 to 1000 which represents 0 - 100% of PWM.

Syntax Serial: ^SSP cc nn
~SSP [cc]

Syntax Scripting: setconfig(_SSP, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Power

Type: Unsigned 16-bit
Min: 0 Max: 1000
Default: 75

Where:
cc = Motor channel

nn = Startup Motor Power

Example:

^SSP 1 150 : Set Start-Up motor power for motor 1 to 15.0% PWM Level

SST - Sensorless Start-Up Time

HexCode: 94

Description:
This parameter is used to define the initial period of the commutation timer in Sensorless mode. The smaller this value the quicker the initial commutation frequency. This value is determined by executing the sensorless start-up calibration, and can be modified accordingly depending on the specifications of the motor. The value is number from 0 to 65535.

Syntax Serial: ^SST cc nn
~SST [cc]

Syntax Scripting: setconfig(_SST, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Time

Type: Unsigned 16-bit
Min: 0 Max: 65535
Default: 65535

Where:
cc = Motor channel

nn = Startup Time

Example:

^SST 1 20000: Set Start-Up Time of the commutation timer for motor1 to 20000 ticks.

SWD - Swap Windings

HexCode: A4

Description:

This parameter is used in sinusoidal mode and will swap the UVW so that the motor turns in the opposite direction. Configure this parameter to match the sensor (encoder, Sin/Cos, SPI/SSI, Resolver) counting direction with the motor rotation direction. This configuration change is similar to swapping two of the motor wires on the controller.

Syntax Serial: ^SWD cc nn
~ SWD [cc]

Syntax Scripting: setconfig(_SWD, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Swap Windings

Type: Unsigned 0-bit

Min: 0 Max: 1

Default: 0

Where:

cc = Motor channel

nn = Motor's Swap Windings

0: Angle up-counting for clockwise direction

1: Angle down-counting for clockwise direction

Example:

^SWD 1 1: Set angle down-counting for clockwise direction for motor 1.

TID - FOC Target Id

HexCode: 8F

Description:
In brunshless motors operating in sinusoidal mode, this command sets the desired Flux (also known as Direct Current Id) for Field Oriented Control. This value must be 0 in typical application. A non-zero value creates field weakening and can be used to achieve higher rotation speed

Syntax Serial: ^TID cc nn
~TID [cc]

Syntax Scripting: setconfig(_TID, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Amps

Type: Signed 32-bit
Min: 0
Default: 0

Where:
cc = Motor Channel

nn = Amps * 10

ZSMC - SinCos Calibration

HexCode: 46

Description:
Shows Sin/Cos calibration value that are captured after the completion of the auto calibration step. Values are not to be altered manually. When non-zero values are returned after querying ZSMC, this indicates that a calibration has been successfuly completed at one time or another. Values are permanently stored in the calibration Flash area after sending %CLSAV 321654987

Syntax Serial: ^ZSMC cc nn
~ZSMC [cc]

Syntax Scripting: setconfig(_ZSMC, cc)

Number of Arguments:

Argument 1: InputNbr

Min: 1 Max: 6

Argument 2: Value

Type: Signed 16-bit

Where:
cc =
1: Sine Zero Point for motor 1
2: Cosine Zero Point for motor 1
3: Cosine/Sine Ratio for motor 1
4: Sine Zero Point for motor 2
5: Cosine Zero Point for motor 2
6: Cosine/Sine Ratio for motor 2

nn = Calibration value

AC Induction Specific Command

TABLE 19-9. AC Induction Specific Command

Command	Arguments	Description
ILM	Inductance	Mutual Inductance
ILLR	Inductance	Rotor Leakage Inductance
IRR	Resistance	Rotor Resistance
MPW	MotorPower	Minimum Power
MXS	SlipFrequency	Optimal Slip Frequency
RFC	Channel Amps	Rotor Flux Current
VPH	VoltsperHertz	AC Induction Motor Volts per HZ

VPH - AC Induction Volts per Hertz

HexCode: 95

Description:
This parameter is only used for AC Induction controllers. Each motor has as specification a Volts per Hertz value with which the frequency can be determined when specific voltage is applied.

Syntax Serial: ^VPH cc nn
~VPH [cc]

Syntax Scripting: setconfig(_VPH, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: VoltsPerHz

Type: Unsigned 16-bit
Min: 0 Max: 65535
Default: 20000

Where:
cc = Motor channel

nn = Motor's Volts per Hertz * 1000

Example:

^VPH 1 200: Set Volts per Hertx to value 0.200

ILM - Mutual Inductance

HexCode: 9B

Description:

This parameter is only used for AC Induction controllers when operating in FOC mode and contains motor's mutual inductance (coupled to both stator and rotor).

Syntax Serial: ^ILM cc nn

~ ILM [cc]

Syntax Scripting: setconfig(_ILM, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Mutual Inductance

Type: Unsigned 32-bit

Min: 0 Max: 10000

Default: 10

Where:

cc = Motor channel

nn = Motor's Mutual Inductance in µH.

Example:

^RFC 1 961: Set Mutual Inductance of motor 1 to value 961µH.

ILLR - Rotor Leakage Inductance

HexCode: 9A

Description:

This parameter is only used for AC Induction controllers when operating in FOC mode and contains the rotor's per phase leakage inductance of the motor. This value can be obtained from the motor supplier.

Syntax Serial: ^ILLR cc nn

~ ILLR [cc]

Syntax Scripting: setconfig(_ILLR, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Rotor Leakage Inductance

Type: Unsigned 32-bit

Min: 0 Max: 10000

Default: 10

Where:

cc = Motor channel

nn = Motor's Rotor Leakage Inductance in µH.

Example:

^RFC 1 67: Set Rotor Leakage Inductance of motor 1 to value 67µH.

IRR - Rotor Resistance

HexCode: 99

Description:

This parameter is only used for AC Induction controller when operating in FOC mode and contains the resistance per phase of the rotor. This value can be obtained from the motor supplier.

Syntax Serial: ^IRR cc nn

~ IRR [cc]

Syntax Scripting: setconfig(_IRR, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Rotor Resistance

Type: Unsigned 32-bit

Min: 1 Max: 500000

Default: 20000

Where:

cc = Motor channel

nn = Motor's Rotor Resistance in micro-ohm.

Example:

^IRR 1 24500: Set Rotor Resistance of motor 1 to value 24500μΩ.

MPW - Minimum Power

HexCode: 97

Description:

This parameter is only used for AC Induction controllers when operating in Volts per Hertz mode. It defines a minimum PWM output value so that there is always a minimal of rotor flux to create induction.

Syntax Serial: ^MPW cc nn

~MPW [cc]

Syntax Scripting: setconfig(_MPW, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Minimum Power

Type: Unsigned 16-bit

Min: 0 Max: 1000

Default: 100

Where:

cc = Motor channel

nn = Motor's Minimum Power in % of PWM Level

Example:

^MPW 1 200: Set Minimum Power for motor 1 to value 20.0% PWM Level.

MXS - Optimal Slip Frequency

HexCode: 96

Description:

This parameter is only used for AC Induction controllers. The optimal slip is the value that the controller will work to maintain while operating in Constant Slip mode.

Syntax Serial: ^MXS cc nn

~MXS [cc]

Syntax Scripting: setconfig(_MXS, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Optimal Slip Frequency

Type: Unsigned 16-bit

Min: 0 Max: 65535

Default: 50

Where:

cc = Motor channel

nn = Motor's Optimal Slip Frequency in Hertz * 10

Example:

^MXS 1 60: Set Optimal Slip for motor 1 to value 6.0Hz

RFC - Rotor Flux Current

HexCode: 98

Description:

This parameter is only used for AC Induction controller. This value is the stator current component (Id) for rotor flux production when FOC modes are selected.

Syntax Serial: ^RFC cc nn

~ RFC [cc]

Syntax Scripting: setconfig(_RFC, cc, nn)

Number of Arguments: 2

Argument 1: Channel

Min: 1 Max: Total Number of Motors

Argument 2: Rotor Flux Current

Type: Unsigned 16-bit

Min: 0 Max: 500

Default: 10

Where:

cc = Motor channel

nn = Motor's Rotor Flux Current in Amps * 10

Example:

^RFC 1 50: Set Rotor Flux Current for motor 1 to value 5A.

CAN Communication Commands

This section describes all the configuration parameters uses for CANbus operation.

TABLE 19-10. CANbus Commands

Command	Arguments	Description
CAS	Rate	CANOpen Auto start
CBR	BitRate	CAN Bit Rate
CEN	Mode	CAN Enable
CHB	HeartBeat	CAN Heartbeat
CLSN	Address	CAN Listening Node
CNOD	Address	CAN Node Address
CSRT	Rate	MiniCAN SendRate
CTPS	TPDOnbr Rate	CANOpen TPDO SendRate

CAS - CANOpen Auto start

HexCode: 5A

Description:
Determines if device is an active CANOpen at power up. When set, unit is active on CANOpen at power up without the need to receive a start command.

Syntax Serial: ^CAS nn
~CAS

Syntax Scripting: setconfig(_CAS, nn)

Number of Arguments: 1

Argument 1: Rate
Type: Unsigned 8-bit
Min: 0 Max: 1
Default: 0 = Off

Where:
nn =
0: Device is inactive
1: Device is active on CANOpen at power-up

CBR - CAN Bit Rate

HexCode: 58

Description:
Sets the CAN bus bit rate

Syntax Serial: ^CBR nn
~CBR

Syntax Scripting: setconfig(_CBR, nn)

Number of Arguments: 1

Argument 1: BitRate
Type: Unsigned 8-bit
Min: 0 Max: 5
Default: 3 = 250K

Where:
nn =
0: 1000K
1: 800K
2: 500K
3: 250K
4: 125K

CEN - CAN Enable

HexCode: 56

Description:
Enables CAN and selects the CAN protocol

Syntax Serial: ^CEN nn
~CNOD

Syntax Scripting: setconfig(_CEN, nn)

Number of Arguments: 1

Argument 1: Mode
Type: Unsigned 8-bit
Min: 0 Max: 5

Where:
nn =
0: Disabled
1: CANOpen
2: MiniCAN
3: RawCAN
4: RoboCAN
5: MiniJ1939

CHB - CAN Heartbeat

HexCode: 59

Description:
Sets the rate in miliseconds at which the controller will send a heartbeat frame on the CAN bus. Heartbeat is sent when either MiniCAN, RawCAN, CANOpen are selected. A dedicated, non-user-alterable Heartbeat frame is sent when RoboCAN is selected

Syntax Serial: ^CHB nn

Syntax Scripting: setconfig(_CHB, nn)

Number of Arguments: 1

Argument 1: HeartBeat
Type: Unsigned 16-bit
Min: 0 Max: 65536
Default: 100ms

Where:
nn = Heartbeat rate in ms

CLSN - CAN Listening Node

HexCode: 5B

Description:
In RawCAN and MiniCAN mode, this parameter filters the incoming frames in order to capture only these originating from a given node address. In RawCAN, entering 0 disables the filter and will cause all incoming frames to be captured

Syntax Serial: ^CLSN nn
~CSLD

Syntax Scripting: setconfig(_CLSN, nn)

Number of Arguments: 1

Argument 1: Address
Type: Unsigned 8-bit
Min: 0 Max: 127
Default: Product dependent

Where:
nn =
0: Listent to all nodes (RawCAN only)
1-127: Capture frames from specific node id only

CNOD - CAN Node Address

HexCode: 57

Description:
Stores the product's address on the CAN bus

Syntax Serial: ^CNOD nn
~CNOD

Syntax Scripting: setconfig(_CNOD, nn)

Number of Arguments: 1

Argument 1: Address
Type: Unsigned 8-bit
Min: 0 Max: 127
Default: See datasheet

Where:
nn = Node address

CSRT - MiniCAN SendRate

HexCode: 5C

Description:
Rate in ms at which MiniCAN frames are sent

Syntax Serial: ^CSRT nn
~CSRT

Syntax Scripting: setconfig(_CSRT, nn)

Number of Arguments: 1

Argument 1: Rate

Type: Unsigned 8-bit
Min: 0 Max: 65536
Default: 100ms

Where:
nn = Rate in ms. No frames sent. if value is 0

CTPS - CANOpen TPDO SendRate

HexCode: 5D

Description:
Sets the send rate for each of the 4 TPDOs when CANOpen is enabled.

Syntax Serial: ^CTPS nn mm

Syntax Scripting: setconfig(_CTPS, nn, mm)

Number of Arguments: 2

Argument 1: TPDOnbr

Min: 1 Max: 4

Argument 2: Rate

Type: Unsingned 16-bit
Min: 0 Max: 65536
Default: 0 = Off

Where:
nn = TPDO number, 1 to 4

mm = Rate in ms

Note:

If mm = 0, the TPDO is not transmitted

SECTION 20

Using the Roborun Configuration Utility

A PC-based Configuration Utility is available, free of charge, from Roboteq. This program makes configuring and operating the controller much more intuitive by using pull-down menus, buttons and sliders. The utility can also be used to update the controller's software in the field as described in "Updating the Controller's Firmware" on page 241.

System Requirements

To run the utility, the following is needed:

- PC compatible computer running any recent version of Windows
- A USB connector for controllers with USB connectivity
- If communicating with the controller via RS232, an unused serial communication port on the computer with a 9-pin, female connector for controllers using RS232 communication
- An Internet connection for downloading the latest version of the Roborun Utility or the Controller's Firmware

If the PC is not equipped with an RS232 serial port, one may be added using a USB to RS232 converter.

Downloading and Installing the Utility

The Configuration Utility must be obtained from the Support page on Roboteq's web site at www.roboteq.com.

- Download the program and run the file setup.exe inside the Roborun Setup folder
- Follow the instructions displayed on the screen

- After the installation is complete, run the program from your Start Menu > Programs > Roboteq

The controller does not need to be connected to the PC to start the Utility. For installations on older versions of Windows, it may be necessary to install .NET Framework version 3.5. On Windows 10 systems, you may need to enable .net framework version 3.5.

The Roborun+ Interface

The Roborun+ utility is provided as a tool for easily configuring the Roboteq controller and running it for testing and troubleshooting purposes.

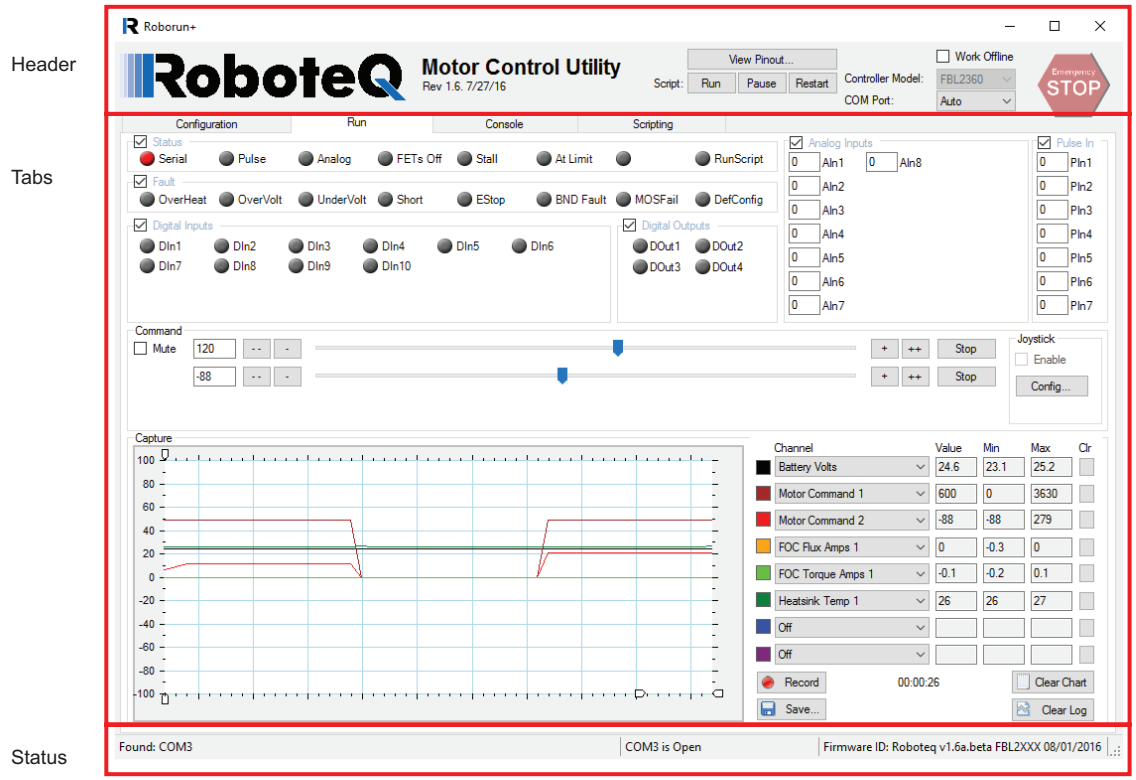


FIGURE 20-1. The Roborun+ Interface

The screen has a **header**, **status bar** and 4 tabs:

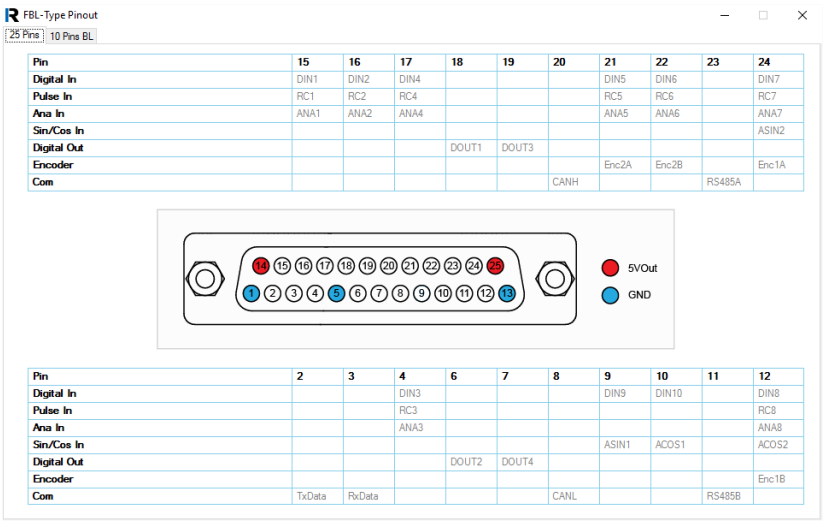
- **Configuration tab** for setting all the different configuration parameters;
- **Run tab** for testing and monitoring the status of the controller at runtime;
- **Console tab** for performing a number of low-level operations that are useful for upgrading, testing and troubleshooting;
- **Scripting tab** for writing, simulating, and downloading custom scripts to the controller.

Header Content

The header is always visible and contains an "**Emergency Stop**" button that can be hit at any time to stop the controller's operation. Hitting the button again will resume the controller operation.

The header also displays inside a text box the Controller type that has been detected

The **"View Pinout"** button will pop open a window showing the pinout of the detected controller model. For each analog, digital or pulse input/output, the table shows the default label (e.g. DIN1, AIN2, ...) or a user defined label (e.g. Limit1, eStop, ...). User definition of label names for I/O pins is done in the Configuration tab.



Pin	15	16	17	18	19	20	21	22	23	24
Digital In	DIN1	DIN2	DIN4				DIN5	DIN6		DIN7
Pulse In	RC1	RC2	RC4				RC5	RC6		RC7
Ana In	ANA1	ANA2	ANA4				ANA5	ANA6		ANA7
Sin/Cos In										ASIN2
Digital Out				DOUT1	DOUT3					
Encoder							Enc2A	Enc2B		Enc1A
Com						CANH			RS485A	

Pin	2	3	4	6	7	8	9	10	11	12
Digital In			DIN3				DIN9	DIN10		DIN8
Pulse In			RC3							RC8
Ana In			ANA3							ANA8
Sin/Cos In							ASIN1	ACOS1		ACOS2
Digital Out				DOUT2	DOUT4					
Encoder										Enc1B
Com	TxData	RxData				CANL			RS485B	

FIGURE 20-2. Pinout view pop-up window

Clicking in the **Work Offline checkbox** allows you to manually select a controller model and populate the Configuration and Run trees with the features and functions that are available for that model. Working offline is useful for creating/editing configuration profiles without the need to have an actual controller attached to the PC.

The **COM Port** pull down menu lets you manually select the communication port. In the Auto mode, the PC will scan all the available ports and look for a controller. Use the manual mode when more than one controller is attached, or when connected to the controller via a RF modem.

The **Run, Pause, Restart** buttons are used to control script execution.

Status Bar Content

The status bar is located at the bottom of the window and is split in 4 areas. From left to right:

- List of COM ports found on the PC
- COM port used for communication with the controller. "Port Open" indicates that communication with the controller is established.

- Firmware ID string as reported by the controller. Contains revision number and date.
- Connected/Disconnected LED. When lit green, it indicates that the communication with the controller is OK.

Program Launch and Controller Discovery

After launching the Roborun Utility, if the controller is connected, or after you connect the controller, the Roborun will automatically scan all the PC's available communication ports.

The automatic scanning is particularly useful for controllers connected via USB, since it is not usually possible to know ahead of time which communication port the PC will assign to the controller.

If a controller is found on any of those ports, Roborun will:

- Display the controller model in the window header.
- Display the Connection COM port number, report the Firmware revision, and turn on the Connect LED in the Status bar.
- Pop up a message box asking you if you wish to read the configuration.

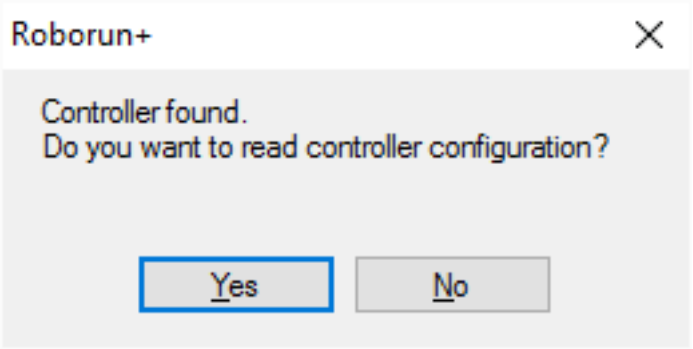


FIGURE 20-3. Pop up message when Controller is detected

Answering 'Yes', the Roborun will read all the configuration parameters that are stored into the controller's memory.

Note: If two or more controllers are connected to the same PC, Roborun will only detect one. Roborun will normally first detect the one assigned to the lowest COM port number, however, this is not entirely predictable. It is recommended that you only connect one controller at a time when using the PC utility.

Configuration Tab

The configuration tab is used to read, modify and write the controller's many possible operating modes. It provides a user friendly interface for viewing and editing the configuration parameters described in "Set/Read Configuration Commands" on page 210.

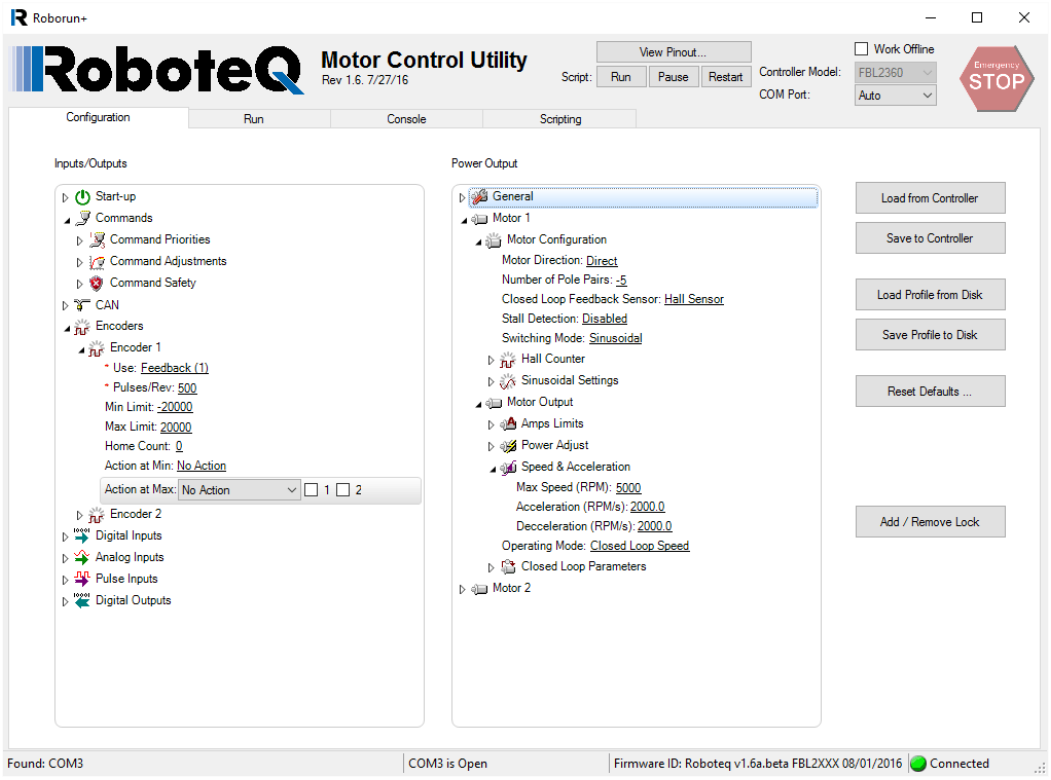


FIGURE 20-4. Configuration tab

The configuration tab contains two configuration trees: the one on the left deals mostly with the I/O and control signals, while the tree on the right deals with the power output and motor parameters. The exact content and layout of a tree depends on the controller model that is detected.

The trees are, for the most part, self explanatory and easy to follow.

Each node will expand when clicking on the small triangle next to it. When selecting a tree item, the value of that item will show up as an underscored value. Clicking on it enables a menu list or a free-form field that you can select to enter a new configuration values.

After changing a configuration, an orange star * appears next to that item, indicating that this parameter has been changed, but not yet saved to the controller.

Clicking on the **"Save to the controller"** button, moves this parameter into the controller's RAM and it becomes effective immediately. This also saves the parameter into the controller's EEPROM so that it is loaded the next time the controller is powered up again.

Entering Parameter Values

Depending on the node type, values can be entered in one of many forms:

- Numerical
- Boolean (e.g. Enable/Disable)

- Selection List
- Text String

When entering a numerical value, that value is checked against the allowed minimum and maximum range for that parameter. If the entered value is lower than the minimum, then the minimum value will be used instead, if above the maximum, then the maximum value will be used as the entered parameter.

Boolean parameters, such as Enabled/Disabled will appear as a two-state menu list.

Some parameters, like Commands or Actions have the option to apply to one or the other of the motor channels. For this type of parameters, next to the menu list are checkboxes – one for each of the channels. Checking one or the other tells the controller to which channel this input or action should apply.

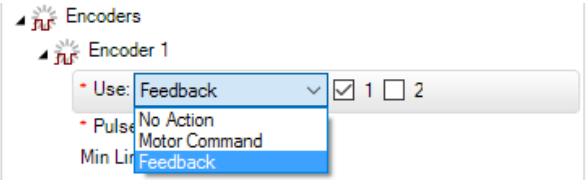


FIGURE 20-5. Parameter applying to one or more tabs channels

String parameters are entered in plain text and they are checked against the maximum number of characters that are allowed for that string. If entering a string that is longer, the string is truncated to the maximum number of allowed characters.

Important Notice about Decimals

The use of Period vs Coma when entering a decimal configuration value depends on the regional settings of Windows. On USA PC's, use periods. On European PC's use comas. If unsure, load the configuration back from the controller after changing and saving. Verify that the value that was stored in the controller is the one that was entered.

Automatic Analog and Pulse input Calibration

Analog and Pulse inputs can be configured to have a user-defined minimum, maximum and center range. These parameters can be viewed and edited manually by expanding the Range subnode.

The minimum, maximum and center values can also be captured automatically by clicking on the "Calibrate" link.

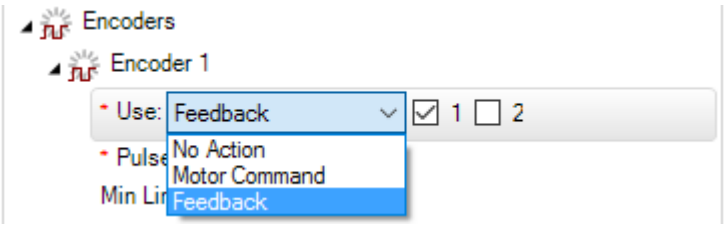


FIGURE 20-6. Min/Max/Center parameters and auto calibrations for Analog and Pulse inputs

When clicking on the **"Calibrate"** link, a window pops up that displays a bar showing the live value of that analog or pulse input in real time.

The window contains three cursors that move in relation to the input, capturing the minimum and maximum detected values. It is possible to further manually adjust further these settings by moving the sliders. The Center value will be either the value of the inputs (or the joystick position) at the time when clicking on the **"Done"** button. The Center value can also be automatically computed to be the middle between Min and Max when enabling the **"Auto Center"** checkbox. Clicking on **"Reset"** resets the Min, Max and Center sliders and lets you restart the operation.

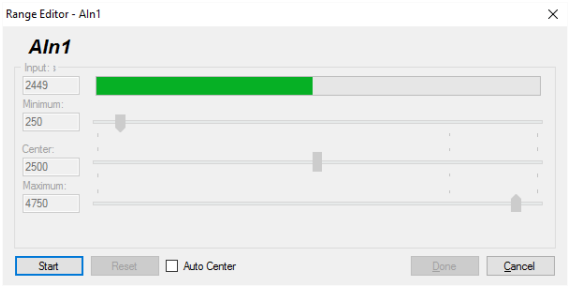


FIGURE 20-7. Auto calibration window

After clicking on the **"Done"** button, the capture values will appear in the Min, Max and Center nodes in the tree with the orange * next to them, indicating that they have changed but not yet be saved in the controller. At this point, they can be adjusted further manually and saved in the controller.

Input/Output Labeling

Each analog, digital or pulse input/output, is given default label (e.g. DIN1, AIN2, ...). Alternatively, it is possible to assign or a user defined label name (e.g. Limit1, eStop, ...) to each of these signals. This label will then appear in the Run Tab next to the LED or Value box. The label will also appear in the Pin View window (See Figure 67, "Pinout view pop-up window," on page 227). Custom labels make it much easier to monitor the controller's activity in the Run tab.

FIGURE 20-8. Labeling an Input/Output

To label an Input or Output, simply select it in the tree. A text field will appear in which you can enter the label name. Beware that while it is possible to enter a long label, names with more than 8 letters will typically appear truncated in the Run tab.

Loading, Saving Controller Parameters

The buttons on the right of the Configuration tab let you load parameters from the controller at any time and save parameters typically after a new parameter has been changed in the trees.

You can save a configuration profile to disk and load it back into the tree.

The **"Reset Defaults ..."** button lets you reset the controller back to the factory settings. This button will also clear the custom labels if any were created.

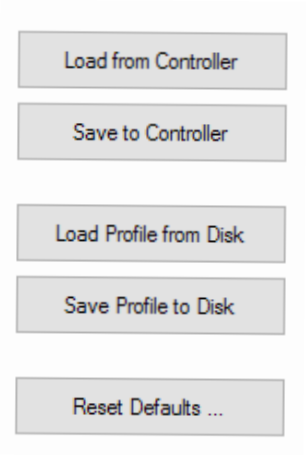


FIGURE 20-9. Loading & Saving parameters button

Locking & Unlocking Configuration Access

The **"Add/Remove Lock"** button is used to lock the configuration so that it cannot be read by unauthorized users. Given the many configuration possibilities of the controller, this locking mechanism can provide a good level of Intellectual Property protection to the system integrator.

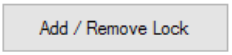


FIGURE 20-10. Add/Remove Lock button

If the controller is not already locked, clicking on this buttons pops up a window in which you can enter a secret number. The number is a 32-bit value and so can range from 1 to 4294967296.

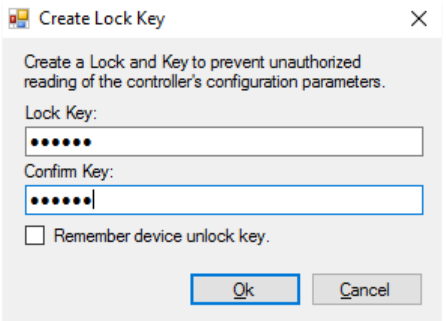


FIGURE 20-11. Lock creation window

That secret number gets stored inside the controller with no way to read it.

Once locked, any time there is an attempt to read the controller configuration (as for example, when the controller is first detected), a message box will pop open to indicate that the configuration cannot be read. The user is prompted to enter the key to unlock the controller and read the configuration.

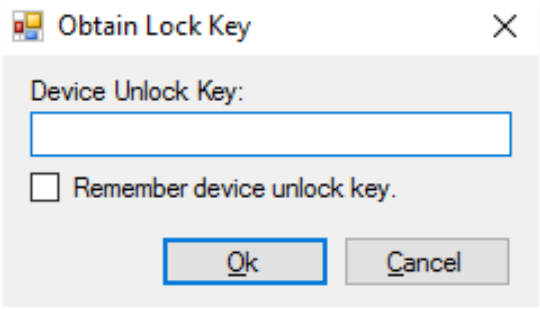


FIGURE 20-12 Controller unlock window

Note that configuration can be set even when the controller is locked, only read cannot be performed.

Configuration Parameters Grouping & Organization

The total number of configuration parameters is quite large. While most system will operate well using the default values, when change is necessary, viewing and editing parameters is made easy thanks to a logical graphical organization of these parameters inside collapsible tree lists.

The configuration tab contains two trees. The left tree includes all parameters that deal with the Analog, Digital, Pulse I/O, encoder and communication. The right tree includes all parameters related to the power drive section. The exact content of the trees changes according to the controller that is attached to the PC.

Startup Parameters

This menus defines the controller's behavior immediately after startup.

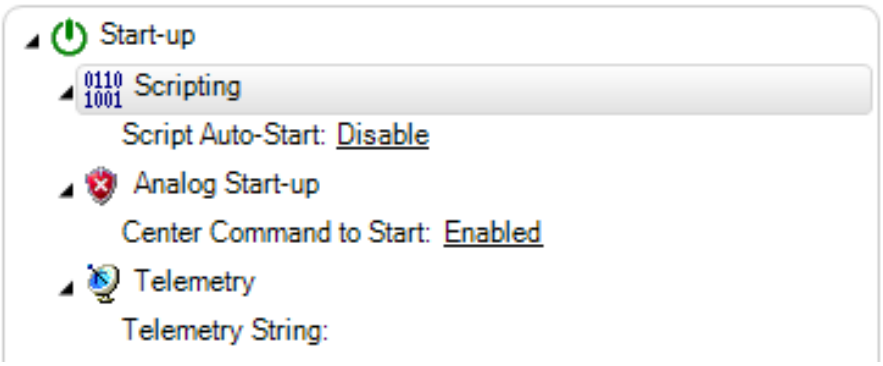


FIGURE 20-13. Startup Menus

The Script Autostart enables or disables script execution. Make sure that the script is bug free before enabling.

Then a number of Command Safety parameters can also be configured. These are the Watchdog timeout when receiving Serial commands, and the safety ranges for analog commands.

The Telemetry parameter contains the string that is executed whenever controller is first powered up. This parameter is typically composed of a series of real-time queries that the controller automatically and periodically perform. Queries must be separated with the ":" colon character. The string is normally terminated with the command to repeat ("#") followed by the repeated rate in milliseconds. See "TELS - Telemetry String" on page 198 and "Query History Commands"on page 263 for details on Telemetry

Commands Parameters

In the commands menu we can set the command priorities, the linearization or exponentiation that must be performed on that input.

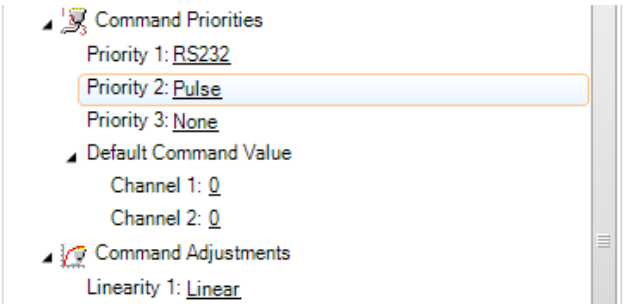


FIGURE 20-14. Commands parameters

A number of Command Safety parameters can be configured. These are the Watchdog timeout when receiving Serial commands, and the safety ranges for pulse and analog commands.

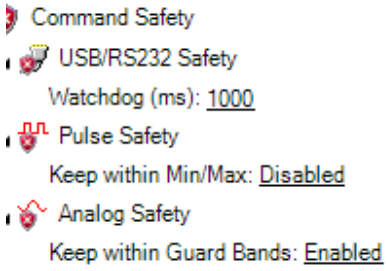


FIGURE 20-15. Command Safety parameters

CAN Communication Parameters

CANbus node address, bit rate, choice of protocol and other parameter can be set from this set of menus.

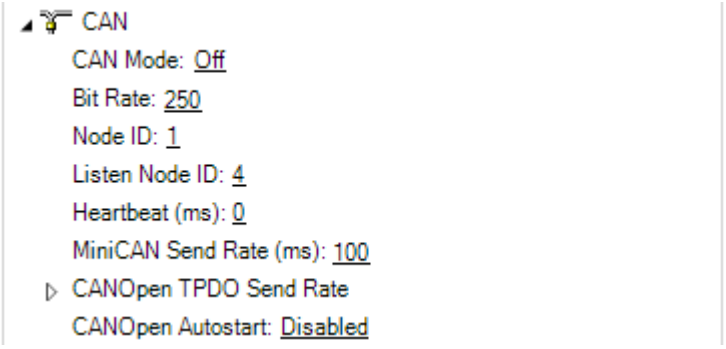


FIGURE 20-16. Can Menus

Encoder Parameters

In the Encoder node are all the parameters relevant to the usage of the encoder. The first parameter is the Use and is used to select what this encoder will be used for and to which motor channel it applies. Additional parameters let you set a number of Pulse Per Revolution, Maximum Speed and actions to do when certain limit counts are reached.

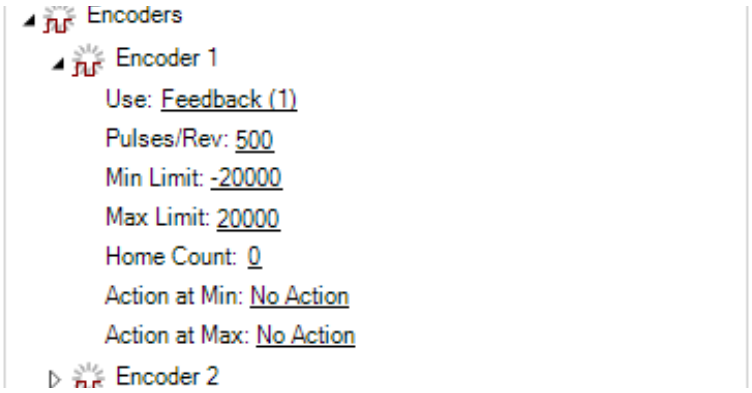


FIGURE 20-17. Encoder parameters

Digital Input and Output Parameters

For Digital inputs, you can set the Active Level and select which action input should cause when it is activated and on which motor channel that action should apply.

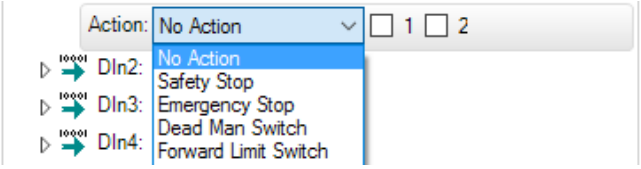


FIGURE 20-18. Digital Input parameters

For Digital Output, you can set the Active Level and the trigger source that will activate the Output.

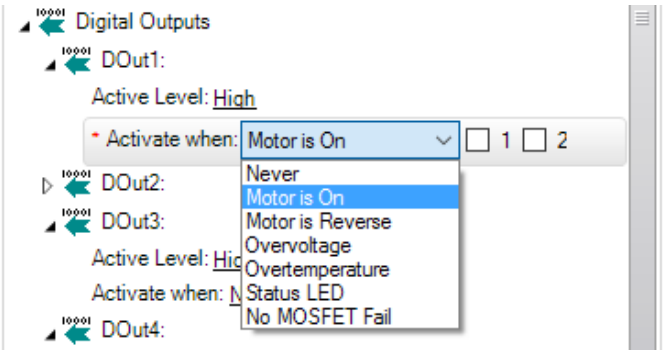


FIGURE 20-19. Digital Out Menu

Analog Input Parameters

For Analog inputs, all the parameters that can be selected include the enabling and conversion type what this input should be used for and for which channel the input range limits the deadband and which actions to perform when the minimum or maximum values are reached.

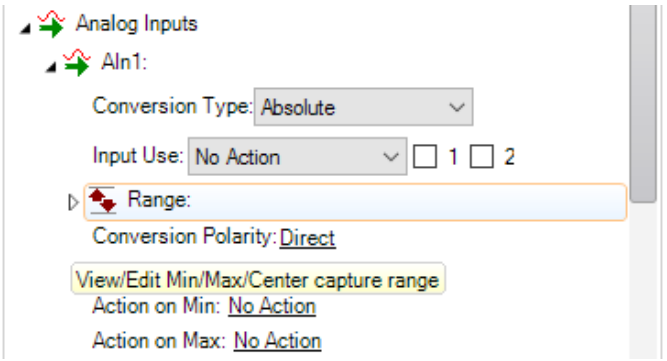


FIGURE 20-20. AnalogIn Menu

Pulse Input Parameters

For Pulse inputs, the tree lets us enable that input and select what it is used for and what type of capture it is to make. The range, deadband and actions to take on when Min and Max are reached is also selectable.

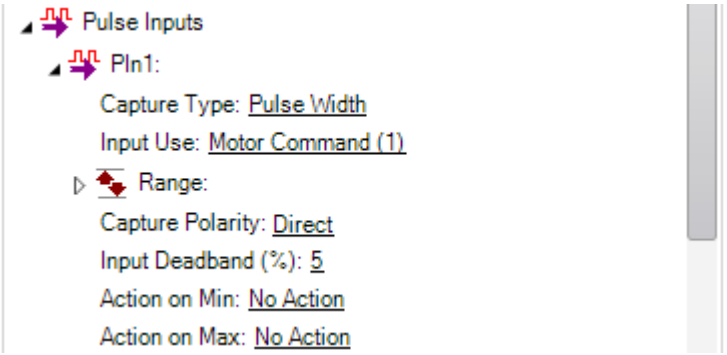


FIGURE 20-21. Puksein Menu

Power Output Parameters

The on the right side of the configuration screen are the parameters that relate to the motor driver and power stage of the controller.

General Settings

There is one tree for setting parameters that apply to all channels of the controller. These are: the PWM Frequency, the low and high side Voltage Limits, the Short Circuit Protection and the mixed mode.

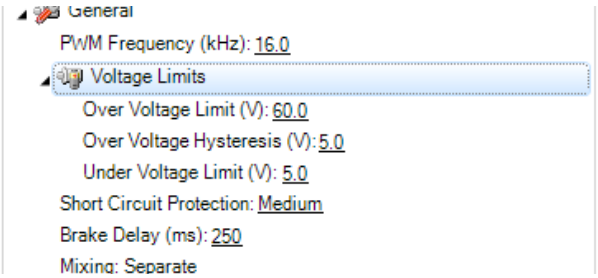


FIGURE 20-22. General Power Stage configuration parameters

Motor Parameters

The parameters for each motor are typically duplicated so that they can be set separately for each motor.

The Motor Configuration group contains menus for configuring the motor's characteristics, and especially these of brushless motors.

The Motor Output group contains menus for setting Amps limits, Acceleration/Deceleration, operating modes, and Control Loop gains and other operating parameters

Details on each of the possible configurations can be found throughout this manual.

Run Tab

The Run tab lets you exercise the motors and visualize all the inputs and outputs of the controller.

A powerful chart recorder is provided to plot real-time controller parameters on the PC, and/or log to a file for later analysis.

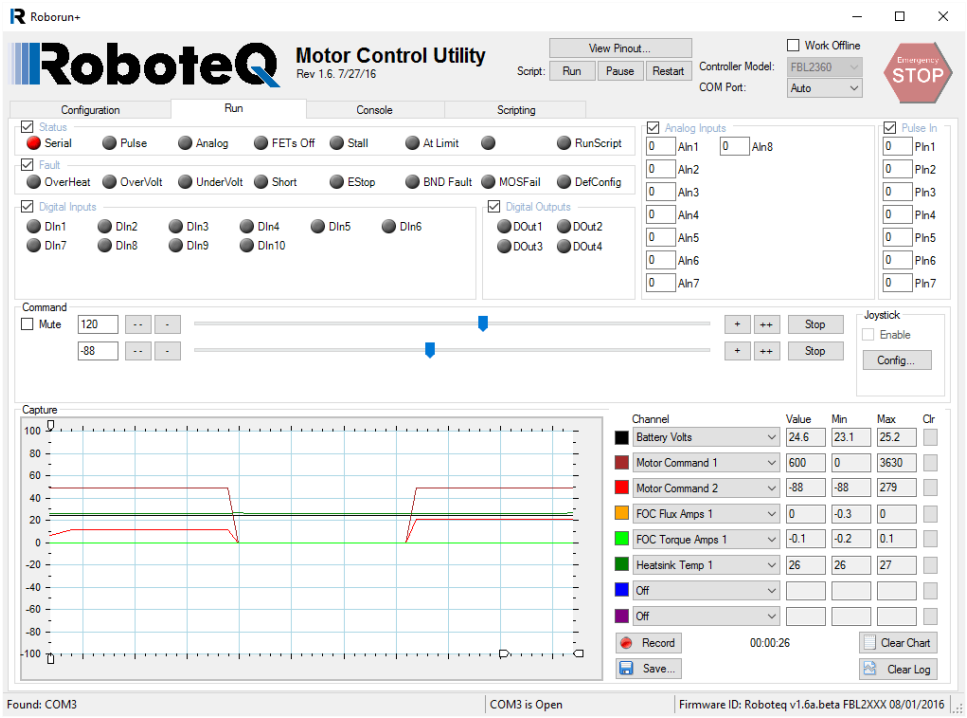


FIGURE 20-23. RUN tab

Each group of monitored parameters can be disabled with a checkbox at the upper left corner of their frame. By default, all are enabled. Disabling one or more will increase the capture resolution in the chart and log of the remaining ones.

Status and Fault Monitoring

Status LEDs show the real-time state of key operating flags. The meaning of each LED is displayed next to it and can vary from one controller to another.

The Fault LEDs indicate all fault conditions. Any one LED that is lit will cause the controller to disable the power to all motor output channels. The meaning of each LED is displayed next to it and can vary from one controller to another.

The Def Config Fault LED indicates that an invalid configuration is read from the controller and the controller has reverted to its factory default configuration. This would be an extremely unlikely occurrence, but if it happens, reload your custom configuration and verify that the new configuration is not lost when restarting the controller a few times. If the controller loses its configuration, this means it is faulty that it should not be used.

The DefConfig Fault LED will also turn on the first time the controller is restarted after a new firmware release has be installed and default configuration first reloaded.

Applying Motor Commands

The command sliders will cause the command value to be applied to the controller. Clicking on the "+", "++", "-", "--" buttons lets you fine-tune the command that is applied to the controller. The numerical value can be entered manually by entering a number in the text box.

The "Mute" checkbox can be selected to stop all commands from being sent to the controller. When this is done, only parameter reads are performed. When commands are muted and if the watchdog timer is enabled, the controller will detect a loss of commands arriving from the serial port and depending on the priorities it will switch back to the RC or Analog mode.

If a USB Joystick is connected to the PC and the "Enable" box is checked, the slider will update in real-time with the captured joystick position value. This makes it possible to operate the motor with the joystick. The "Configure Joystick" button lets you perform additional adjustments such as inverting and swapping joystick input.

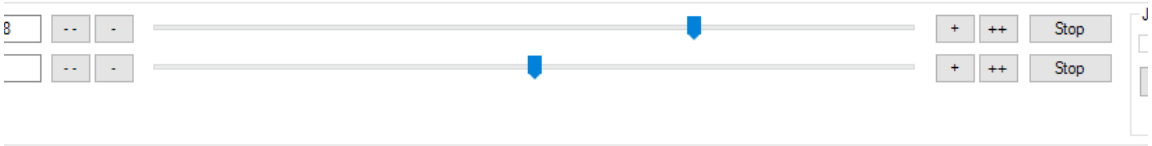


FIGURE 20-24

Digital, Analog and Pulse Input Monitoring

The status of Digital inputs and the value Analog and Pulse can be monitored in real-time. Analog and Pulse inputs will update only if the selected channel is enabled. The labels for the digital inputs, digital outputs, analog inputs and pulse inputs can be made to take the value that has been entered in the configuration tree as described in Input/Output Labeling. Using a nickname for that signal makes it easier to monitor that information.

Digital Output Activation and Monitoring

The Digital output LEDs reflect the actual state of each of the controller's Output. If an output is not changed by the controller using one of the available automatic Output Triggers (see "DOA" on page 200), clicking on the LED will cause the selected output to toggle On and Off.

Using the Chart Recorder

A powerful chart recorder is provided for real-time capture and plotting of operating parameters. This chart can display up to eight operating parameters at the same time. Each of the chart's channels has a pull-down menu that shows all of the operating parameters that can be viewed and plotted. The colors can be changed by clicking on the color icon and selecting another color.

When selecting a parameter to display, this parameter will appear in the chart and change in real-time. The three boxes show a numerical representation of the actual value and the Min and Max value reached by this input. Clicking on the "Clear" button for that channel

resets the Min and Max. The chart can be paused or it can be cleared and the recorded values can be saved in an Excel format for later analysis.

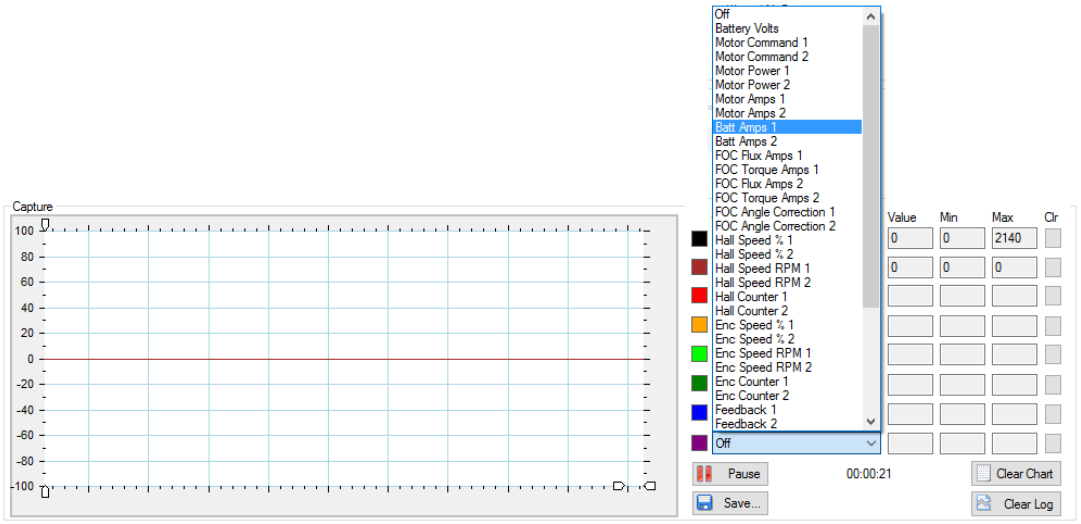


FIGURE 20-25. Chart recorder

"Handles" on the left vertical axis may be used to zoom in a particular vertical range. Similar handles on the horizontal axis can be used to change the scrolling speed of the chart.

Console Tab

The console tab is useful for practicing low-level commands and viewing the raw data exchanged by the controller and the PC. The Console tab also contains the buttons for performing field updates of the controller.

Text-Mode Commands Communication

The console mode allows you to send low-level commands and view the raw controller responses. Ten text fields are provided in which you can type commands and send them in any sequence by clicking on the respective "Send" button. All the traffic that is exchanged by the controller and the PC is logged in the console box on the right. It is then possible to copy that information and paste it into a word processor or an Excel spreadsheet for further analysis.

The "Stop" button sends the "#" command to the controller and will stop the automatic query updating if it is currently active.

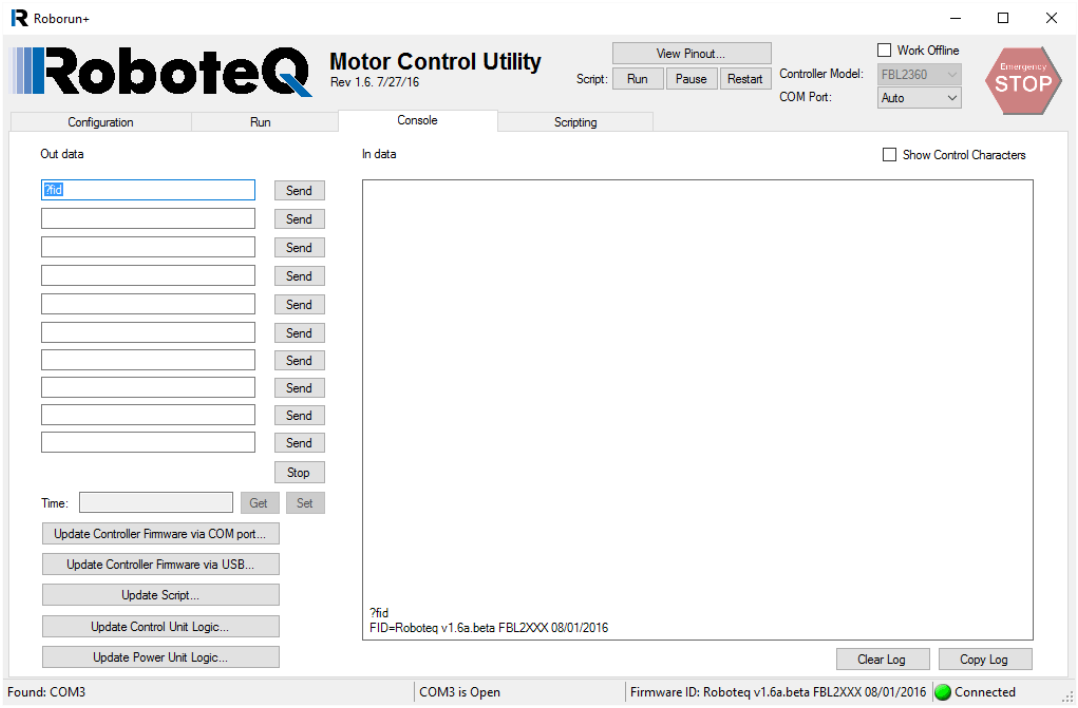


FIGURE 20-26. Console tab

Updating the Controller's Firmware

The controller's firmware can be updated in the field. This function allows the controller to be always be up-to date with the latest features or to install custom firmware. Update can be done via the serial port or via USB.

To update the controller firmware via the serial port, click on the "Update Controller Firmware via COM port" button and you can let controller automatically process the update after you have browsed for and selected the new firmware file. The log and checkboxes show the progress of the operation.

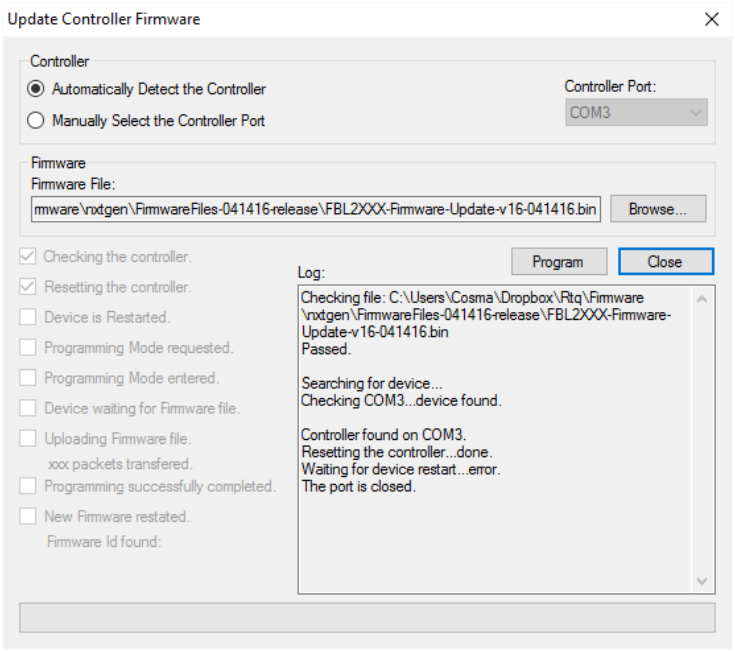


FIGURE 20-27. Update Controller Firmware window

When updating via USB, click on the "Update Controller firmware with USB". This will cause the COM port to close and the device to disappear from PC utility. The controller then enters a special update mode and will automatically launch the Roboteq "DFU Loader" utility that is found in the Start menu. Selecting and updating the file will perform the firmware update via USB. After completion, cycling power will restart the controller. It will then be found by the PC utility.

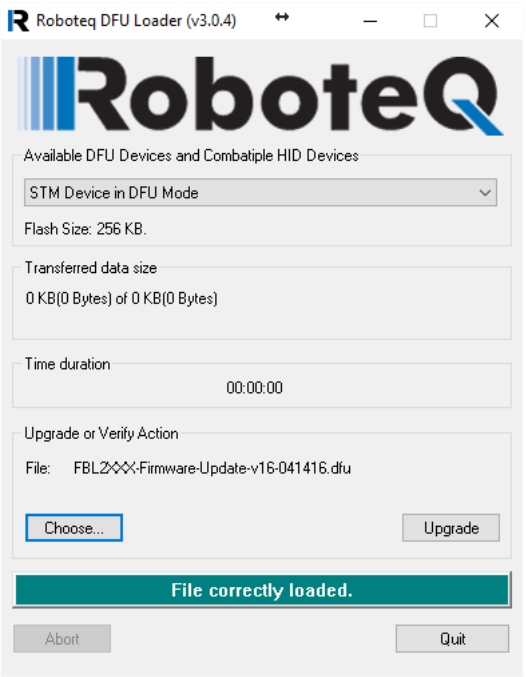


FIGURE 20-28. Dfu Loader

Updating Script

It is possible to load a new script into the controller using the "Update Script" button. After clicking, select a script object file in .hex format. The hex file is generated from the Scripting tab.

Updating the Controller Logic

Some controller models have one or two programmable logic parts which can also be updated in the field. Updating the logic must only be done only using the COM port, when the power stage is off and the controller is powered only with the power control wire. No I/O must be connected on the front connectors either. COM port number must range between 1 and 10. Use the Device Manager to reassign the port number if higher.

To update the logic, click on the "Update Power Board Logic" or "Update Controller Logic", select the file and click on the "Program" button. The log shows the steps that are taking place during the process. The process last approximately 60 sec., do not cancel the programming in the middle of programming even if it looks that there is no progress. Cancel only after over a minute of inactivity. Never turn off the power while programming is in progress.

After updating the logic, you should turn off and turn on the controller in order for the changes to be fully accounted for.

Scripting Tab

One of the controller's most powerful and innovative features is the ability for the user to write programs that are permanently saved into, and run from the controller's Flash Memory. This capability is the equivalent of combining the motor controller functionality and this of a PLC or Single Board Computer directly into the controller. The scripting tab is used to write, simulate, and download custom scripts to the controller.

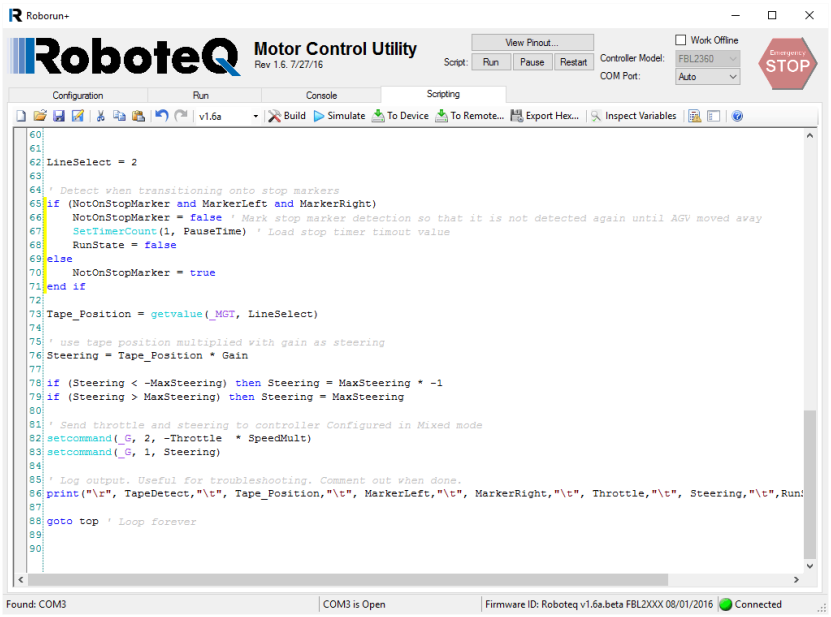


FIGURE 20-29. Scripting window

Edit Window

The main window in this tab is used to enter the scripts. The editor automatically changes the color and style of the entered text so that comments, keywords, commands and text strings are immediately recognizable. The editor has simple text editing features needed to write source code. More information on the scripting language and its capabilities can be found in the "MicroBasic Language Reference" on page 187.

Download to Device button

Clicking on the "To Device" button will cause the source code to be immediately interpreted in low level instructions that are understandable by the controller. If no errors are found during the translation, the code is automatically transferred in the controller's flash memory where it is then ready for execution.

Download to Remote Device button

Clicking on the "To Remote" button will cause the source code to be interpreted and downloaded to a remote controller on a RoboCAN network. After clicking a pop up window will list in a pull down menu all controllers found alive on the CAN network. Select the node you wish the script to be downloaded to.

Build button

Clicking on this button will cause the source code to be immediately interpreted in low level instructions that are understandable by the controller. A window then pops up showing the result of the translation. The code is not downloaded into the controller. This command is generally not needed. It may be used to see how many bytes will be taken by the script inside the controller's flash.

Exporting Script Object Hex Files

It is possible to save the compiled code of a given script. This way a script can be loaded in a controller without giving away the source code. To do this, click on the Export Hex button. The Hex file can then be loaded from the Console tab using the Update Script button.

Simulation button

Clicking on the **"Simulate"** button will cause the source code to be interpreted and run in simulation mode on the PC. This function is useful for simplifying script development and debug. The simulator will operate identically to the real controller except for all commands that normally read or write controller configuration and operation data. For these commands, the simulated program will prompt the programmer for values to be entered manually, or output data to the console.

Correcting Compilation Errors

When building or trying to download a script that contains errors, the compile errors will be listed in the bottom half of the window. Double clicking on the error will move the cursor to the place in the source code where the error was found.

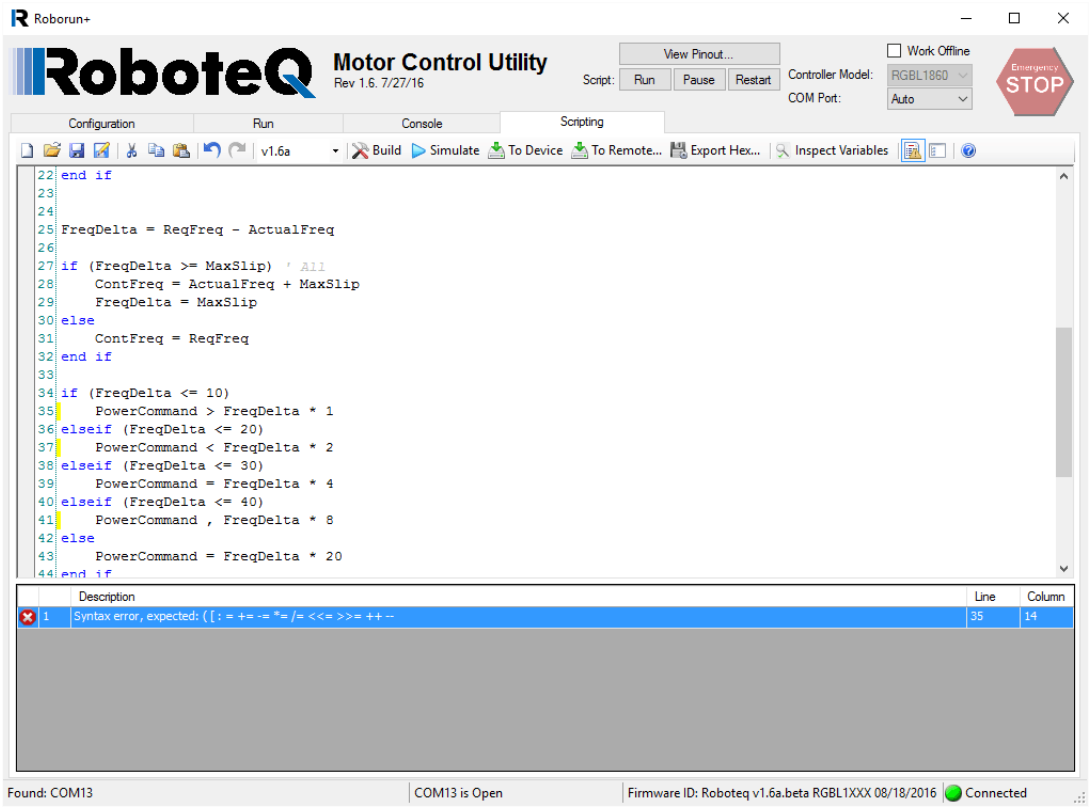


FIGURE 20-30. Script compile error

Beware that not all programming errors are detected. Be especially careful with variable names. Use the #option explicit directive to enforce variable declarations. Beware not to mix setconfig() and setcommand() when changing a configuration or a command. A faulty script can cause the controller to crash. Enable the scripting Auto Start configuration only on known working scripts.

Executing Scripts

Scripts are not automatically executed after the transfer. To execute manually, you must Run or Restart buttons that are in the Utility's header. Alternatively, click on the Console click on the Console tab and send the !r command via the console. Unless a script includes print statements, it will run silently with no visible signs in the console. Clicking on !r 0 will stop a script, !r or !r 1 will resume a stopped script. !r 2 will clear all variables and restart a script. The Runscript LED in the Run tab will be on when script is running.

Executing a script on a remote controller on a CANbus network using the RoboCAN protocol s done using the @nn!r command, where nn is the remote node address in hex format.

Debugging Scripts

A number of techniques can be used to debug a script that is not behaving as expected.

You can view the value of variable in real time during program execution by clicking on the Inspect Variables button. Then hover the mouse over a variable in the program listing. The variable value will be read and displayed at the mouse location. The variable value is read only once when first hovering over the variable. To read the value again, move the mouse away and return over that variable.

Embedding print statements is another common technique. Place print statements in specific places of the script to verify that a given part of the code gets executed. Print the value of variables you wish to see. To avoid large data dumps on the screen, add code to print conditionally, for example when a variable changes or reaches a given value range.