R&S®RTB2000
Digital Oscilloscope
User Manual

1333.1611.02 ─ 02

User Manual

ROHDE&SCHWARZ

This manual describes the following R&S®RTB2000 models:

- R&S®RTB2002 (1333.1005K02)
- R&S®RTB2004 (1333.1005K04)

Mühldorfstr. 15, 81671 München, Germany
Phone: +49 89 41 29 - 0
Fax: +49 89 41 29 12 164
Email: info@rohde-schwarz.com
Internet: www.rohde-schwarz.com

Throughout this manual, products from Rohde & Schwarz are indicated without the ® symbol, e.g. R&S®RTB is indicated as R&S RTB2000.

Basic Safety Instructions

Always read through and comply with the following safety instructions!

All plants and locations of the Rohde & Schwarz group of companies make every effort to keep the safety standards of our products up to date and to offer our customers the highest possible degree of safety. Our products and the auxiliary equipment they require are designed, built and tested in accordance with the safety standards that apply in each case. Compliance with these standards is continuously monitored by our quality assurance system. The product described here has been designed, built and tested in accordance with the EC Certificate of Conformity and has left the manufacturer’s plant in a condition fully complying with safety standards. To maintain this condition and to ensure safe operation, you must observe all instructions and warnings provided in this manual. If you have any questions regarding these safety instructions, the Rohde & Schwarz group of companies will be happy to answer them.

Furthermore, it is your responsibility to use the product in an appropriate manner. This product is designed for use solely in industrial and laboratory environments or, if expressly permitted, also in the field and must not be used in any way that may cause personal injury or property damage. You are responsible if the product is used for any purpose other than its designated purpose or in disregard of the manufacturer's instructions. The manufacturer shall assume no responsibility for such use of the product.

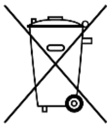
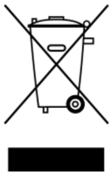
The product is used for its designated purpose if it is used in accordance with its product documentation and within its performance limits (see data sheet, documentation, the following safety instructions). Using the product requires technical skills and, in some cases, a basic knowledge of English. It is therefore essential that only skilled and specialized staff or thoroughly trained personnel with the required skills be allowed to use the product. If personal safety gear is required for using Rohde & Schwarz products, this will be indicated at the appropriate place in the product documentation. Keep the basic safety instructions and the product documentation in a safe place and pass them on to the subsequent users.

Observing the safety instructions will help prevent personal injury or damage of any kind caused by dangerous situations. Therefore, carefully read through and adhere to the following safety instructions before and when using the product. It is also absolutely essential to observe the additional safety instructions on personal safety, for example, that appear in relevant parts of the product documentation. In these safety instructions, the word "product" refers to all merchandise sold and distributed by the Rohde & Schwarz group of companies, including instruments, systems and all accessories. For product-specific information, see the data sheet and the product documentation.

Safety labels on products

The following safety labels are used on products to warn against risks and dangers.

Symbol	Meaning	Symbol	Meaning
	Notice, general danger location Observe product documentation		ON/OFF Power
	Caution when handling heavy equipment		Standby indication
	Danger of electric shock		Direct current (DC)

Symbol	Meaning	Symbol	Meaning
	Caution ! Hot surface	~	Alternating current (AC)
	Protective conductor terminal To identify any terminal which is intended for connection to an external conductor for protection against electric shock in case of a fault, or the terminal of a protective earth	≂	Direct/alternating current (DC/AC)
	Earth (Ground)		Class II Equipment to identify equipment meeting the safety requirements specified for Class II equipment (device protected by double or reinforced insulation)
	Frame or chassis Ground terminal		EU labeling for batteries and accumulators For additional information, see section "Waste disposal/Environmental protection", item 1.
	Be careful when handling electrostatic sensitive devices		EU labeling for separate collection of electrical and electronic devices For additional information, see section "Waste disposal/Environmental protection", item 2.
	Warning! Laser radiation For additional information, see section "Operation", item 7.		

Signal words and their meaning

The following signal words are used in the product documentation in order to warn the reader about risks and dangers.

DANGER	Indicates a hazardous situation which, if not avoided, will result in death or serious injury.
WARNING	Indicates a hazardous situation which, if not avoided, could result in death or serious injury.
CAUTION	Indicates a hazardous situation which, if not avoided, could result in minor or moderate injury.
NOTICE	Indicates information considered important, but not hazard-related, e.g. messages relating to property damage. In the product documentation, the word ATTENTION is used synonymously.

These signal words are in accordance with the standard definition for civil applications in the European Economic Area. Definitions that deviate from the standard definition may also exist in other economic areas or military applications. It is therefore essential to make sure that the signal words described here are always used only in connection with the related product documentation and the related product. The use of signal words in connection with unrelated products or documentation can result in misinterpretation and in personal injury or material damage.

Operating states and operating positions

The product may be operated only under the operating conditions and in the positions specified by the manufacturer, without the product's ventilation being obstructed. If the manufacturer's specifications are not observed, this can result in electric shock, fire and/or serious personal injury or death. Applicable local or national safety regulations and rules for the prevention of accidents must be observed in all work performed.

1. Unless otherwise specified, the following requirements apply to Rohde & Schwarz products: predefined operating position is always with the housing floor facing down, IP protection 2X, use only indoors, max. operating altitude 2000 m above sea level, max. transport altitude 4500 m above sea level. A tolerance of ±10 % shall apply to the nominal voltage and ±5 % to the nominal frequency, overvoltage category 2, pollution degree 2.
2. Do not place the product on surfaces, vehicles, cabinets or tables that for reasons of weight or stability are unsuitable for this purpose. Always follow the manufacturer's installation instructions when installing the product and fastening it to objects or structures (e.g. walls and shelves). An installation that is not carried out as described in the product documentation could result in personal injury or even death.
3. Do not place the product on heat-generating devices such as radiators or fan heaters. The ambient temperature must not exceed the maximum temperature specified in the product documentation or in the data sheet. Product overheating can cause electric shock, fire and/or serious personal injury or even death.

Electrical safety

If the information on electrical safety is not observed either at all or to the extent necessary, electric shock, fire and/or serious personal injury or death may occur.

1. Prior to switching on the product, always ensure that the nominal voltage setting on the product matches the nominal voltage of the mains-supply network. If a different voltage is to be set, the power fuse of the product may have to be changed accordingly.
2. In the case of products of safety class I with movable power cord and connector, operation is permitted only on sockets with a protective conductor contact and protective conductor.
3. Intentionally breaking the protective conductor either in the feed line or in the product itself is not permitted. Doing so can result in the danger of an electric shock from the product. If extension cords or connector strips are implemented, they must be checked on a regular basis to ensure that they are safe to use.
4. If there is no power switch for disconnecting the product from the mains, or if the power switch is not suitable for this purpose, use the plug of the connecting cable to disconnect the product from the mains. In such cases, always ensure that the power plug is easily reachable and accessible at all times. For example, if the power plug is the disconnecting device, the length of the connecting cable must not exceed 3 m. Functional or electronic switches are not suitable for providing disconnection from the AC supply network. If products without power switches are integrated into racks or systems, the disconnecting device must be provided at the system level.
5. Never use the product if the power cable is damaged. Check the power cables on a regular basis to ensure that they are in proper operating condition. By taking appropriate safety measures and carefully laying the power cable, ensure that the cable cannot be damaged and that no one can be hurt by, for example, tripping over the cable or suffering an electric shock.

6. The product may be operated only from TN/TT supply networks fuse-protected with max. 16 A (higher fuse only after consulting with the Rohde & Schwarz group of companies).
7. Do not insert the plug into sockets that are dusty or dirty. Insert the plug firmly and all the way into the socket provided for this purpose. Otherwise, sparks that result in fire and/or injuries may occur.
8. Do not overload any sockets, extension cords or connector strips; doing so can cause fire or electric shocks.
9. For measurements in circuits with voltages V_{rms} > 30 V, suitable measures (e.g. appropriate measuring equipment, fuse protection, current limiting, electrical separation, insulation) should be taken to avoid any hazards.
10. Ensure that the connections with information technology equipment, e.g. PCs or other industrial computers, comply with the IEC 60950-1 / EN 60950-1 or IEC 61010-1 / EN 61010-1 standards that apply in each case.
11. Unless expressly permitted, never remove the cover or any part of the housing while the product is in operation. Doing so will expose circuits and components and can lead to injuries, fire or damage to the product.
12. If a product is to be permanently installed, the connection between the protective conductor terminal on site and the product's protective conductor must be made first before any other connection is made. The product may be installed and connected only by a licensed electrician.
13. For permanently installed equipment without built-in fuses, circuit breakers or similar protective devices, the supply circuit must be fuse-protected in such a way that anyone who has access to the product, as well as the product itself, is adequately protected from injury or damage.
14. Use suitable overvoltage protection to ensure that no overvoltage (such as that caused by a bolt of lightning) can reach the product. Otherwise, the person operating the product will be exposed to the danger of an electric shock.
15. Any object that is not designed to be placed in the openings of the housing must not be used for this purpose. Doing so can cause short circuits inside the product and/or electric shocks, fire or injuries.
16. Unless specified otherwise, products are not liquid-proof (see also section "Operating states and operating positions", item 1). Therefore, the equipment must be protected against penetration by liquids. If the necessary precautions are not taken, the user may suffer electric shock or the product itself may be damaged, which can also lead to personal injury.
17. Never use the product under conditions in which condensation has formed or can form in or on the product, e.g. if the product has been moved from a cold to a warm environment. Penetration by water increases the risk of electric shock.
18. Prior to cleaning the product, disconnect it completely from the power supply (e.g. AC supply network or battery). Use a soft, non-linting cloth to clean the product. Never use chemical cleaning agents such as alcohol, acetone or diluents for cellulose lacquers.

Operation

1. Operating the products requires special training and intense concentration. Make sure that persons who use the products are physically, mentally and emotionally fit enough to do so; otherwise, injuries or material damage may occur. It is the responsibility of the employer/operator to select suitable personnel for operating the products.

2. Before you move or transport the product, read and observe the section titled "Transport".
3. As with all industrially manufactured goods, the use of substances that induce an allergic reaction (allergens) such as nickel cannot be generally excluded. If you develop an allergic reaction (such as a skin rash, frequent sneezing, red eyes or respiratory difficulties) when using a Rohde & Schwarz product, consult a physician immediately to determine the cause and to prevent health problems or stress.
4. Before you start processing the product mechanically and/or thermally, or before you take it apart, be sure to read and pay special attention to the section titled "Waste disposal/Environmental protection", item 1.
5. Depending on the function, certain products such as RF radio equipment can produce an elevated level of electromagnetic radiation. Considering that unborn babies require increased protection, pregnant women must be protected by appropriate measures. Persons with pacemakers may also be exposed to risks from electromagnetic radiation. The employer/operator must evaluate workplaces where there is a special risk of exposure to radiation and, if necessary, take measures to avert the potential danger.
6. Should a fire occur, the product may release hazardous substances (gases, fluids, etc.) that can cause health problems. Therefore, suitable measures must be taken, e.g. protective masks and protective clothing must be worn.
7. Laser products are given warning labels that are standardized according to their laser class. Lasers can cause biological harm due to the properties of their radiation and due to their extremely concentrated electromagnetic power. If a laser product (e.g. a CD/DVD drive) is integrated into a Rohde & Schwarz product, absolutely no other settings or functions may be used as described in the product documentation. The objective is to prevent personal injury (e.g. due to laser beams).
8. EMC classes (in line with EN 55011/CISPR 11, and analogously with EN 55022/CISPR 22, EN 55032/CISPR 32)
   - Class A equipment:
     Equipment suitable for use in all environments except residential environments and environments that are directly connected to a low-voltage supply network that supplies residential buildings
     Note: Class A equipment is intended for use in an industrial environment. This equipment may cause radio disturbances in residential environments, due to possible conducted as well as radiated disturbances. In this case, the operator may be required to take appropriate measures to eliminate these disturbances.
   - Class B equipment:
     Equipment suitable for use in residential environments and environments that are directly connected to a low-voltage supply network that supplies residential buildings

Repair and service

1. The product may be opened only by authorized, specially trained personnel. Before any work is performed on the product or before the product is opened, it must be disconnected from the AC supply network. Otherwise, personnel will be exposed to the risk of an electric shock.

2. Adjustments, replacement of parts, maintenance and repair may be performed only by electrical experts authorized by Rohde & Schwarz. Only original parts may be used for replacing parts relevant to safety (e.g. power switches, power transformers, fuses). A safety test must always be performed after parts relevant to safety have been replaced (visual inspection, protective conductor test, insulation resistance measurement, leakage current measurement, functional test). This helps ensure the continued safety of the product.

Batteries and rechargeable batteries/cells

If the information regarding batteries and rechargeable batteries/cells is not observed either at all or to the extent necessary, product users may be exposed to the risk of explosions, fire and/or serious personal injury, and, in some cases, death. Batteries and rechargeable batteries with alkaline electrolytes (e.g. lithium cells) must be handled in accordance with the EN 62133 standard.

1. Cells must not be taken apart or crushed.
2. Cells or batteries must not be exposed to heat or fire. Storage in direct sunlight must be avoided. Keep cells and batteries clean and dry. Clean soiled connectors using a dry, clean cloth.
3. Cells or batteries must not be short-circuited. Cells or batteries must not be stored in a box or in a drawer where they can short-circuit each other, or where they can be short-circuited by other conductive materials. Cells and batteries must not be removed from their original packaging until they are ready to be used.
4. Cells and batteries must not be exposed to any mechanical shocks that are stronger than permitted.
5. If a cell develops a leak, the fluid must not be allowed to come into contact with the skin or eyes. If contact occurs, wash the affected area with plenty of water and seek medical aid.
6. Improperly replacing or charging cells or batteries that contain alkaline electrolytes (e.g. lithium cells) can cause explosions. Replace cells or batteries only with the matching Rohde & Schwarz type (see parts list) in order to ensure the safety of the product.
7. Cells and batteries must be recycled and kept separate from residual waste. Rechargeable batteries and normal batteries that contain lead, mercury or cadmium are hazardous waste. Observe the national regulations regarding waste disposal and recycling.
8. Follow the transport stipulations of the carrier (IATA-DGR, IMDG-Code, ADR, RID) when returning lithium batteries to Rohde & Schwarz subsidiaries.

Transport

1. The product may be very heavy. Therefore, the product must be handled with care. In some cases, the user may require a suitable means of lifting or moving the product (e.g. with a lift-truck) to avoid back or other physical injuries.
2. Handles on the products are designed exclusively to enable personnel to transport the product. It is therefore not permissible to use handles to fasten the product to or on transport equipment such as cranes, fork lifts, wagons, etc. The user is responsible for securely fastening the products to or on the means of transport or lifting. Observe the safety regulations of the manufacturer of the means of transport or lifting. Noncompliance can result in personal injury or material damage.

3. If you use the product in a vehicle, it is the sole responsibility of the driver to drive the vehicle safely and properly. The manufacturer assumes no responsibility for accidents or collisions. Never use the product in a moving vehicle if doing so could distract the driver of the vehicle. Adequately secure the product in the vehicle to prevent injuries or other damage in the event of an accident.

Waste disposal/Environmental protection

1. Specially marked equipment has a battery or accumulator that must not be disposed of with unsorted municipal waste, but must be collected separately. It may only be disposed of at a suitable collection point or via a Rohde & Schwarz customer service center.
2. Waste electrical and electronic equipment must not be disposed of with unsorted municipal waste, but must be collected separately.
   Rohde & Schwarz GmbH & Co. KG has developed a disposal concept and takes full responsibility for take-back obligations and disposal obligations for manufacturers within the EU. Contact your Rohde & Schwarz customer service center for environmentally responsible disposal of the product.
3. If products or their components are mechanically and/or thermally processed in a manner that goes beyond their intended use, hazardous substances (heavy-metal dust such as lead, beryllium, nickel) may be released. For this reason, the product may only be disassembled by specially trained personnel. Improper disassembly may be hazardous to your health. National waste disposal regulations must be observed.
4. If handling the product releases hazardous substances or fuels that must be disposed of in a special way, e.g. coolants or engine oils that must be replenished regularly, the safety instructions of the manufacturer of the hazardous substances or fuels and the applicable regional waste disposal regulations must be observed. Also observe the relevant safety instructions in the product documentation. The improper disposal of hazardous substances or fuels can cause health problems and lead to environmental damage.

For additional information about environmental protection, visit the Rohde & Schwarz website.

Customer Support

Technical support – where and when you need it

For quick, expert help with any Rohde & Schwarz equipment, contact one of our Customer Support Centers. A team of highly qualified engineers provides telephone support and will work with you to find a solution to your query on any aspect of the operation, programming or applications of Rohde & Schwarz equipment.

Up-to-date information and upgrades

To keep your instrument up-to-date and to be informed about new application notes related to your instrument, please send an e-mail to the Customer Support Center stating your instrument and your wish. We will take care that you will get the right information.

Europe, Africa, Middle East

Phone +49 89 4129 12345
customersupport@rohde-schwarz.com

North America

Phone 1-888-TEST-RSA (1-888-837-8772)
customer.support@rsa.rohde-schwarz.com

Latin America

Phone +1-410-910-7988
customersupport.la@rohde-schwarz.com

Asia/Pacific

Phone +65 65 13 04 88
customersupport.asia@rohde-schwarz.com

China

Phone +86-800-810-8228 /
+86-400-650-5896
customersupport.china@rohde-schwarz.com

ROHDE&SCHWARZ

Contents

1 Preface

1.1 For Your Safety

The R&S RTB2000 is an oscilloscope which is designed for measurements on circuits that are only indirectly connected to the mains or not connected at all. It is not rated for any measurement category. The instrument is designed for indoor use in industrial areas.

The instrument must be controlled by personnel familiar with the potential risks of measuring electrical quantities. Applicable local or national safety regulations and rules for the prevention of accidents must be observed.

Safety information is part of the product documentation. It warns you about the potential dangers and gives instructions how to prevent personal injury or damage caused by dangerous situations. Safety information is provided as follows:

- The "Basic Safety Instructions" in different languages are delivered as a printed brochure with the instrument.
- Throughout the documentation, safety instructions are provided when you need to take care during setup or operation.

⚠ WARNING

Risk of injury

The instrument must be used in an appropriate manner to prevent electric shock, fire, personal injury, or damage:

- Do not open the instrument casing.
- Do not use the instrument if the instrument casing, the display or any probe or accessory are damaged. If you detect or suspect any damage, have the instrument or accessory inspected by qualified service personnel.
- Do not operate the instrument in wet, damp or explosive atmospheres. Make sure that the instrument, cables and connectors are completely dry before connecting the inputs.
- Do not exceed the voltage limits given in Chapter 2.2.1.1, "Input Connectors", on page 21.

NOTICE

Risk of instrument damage

An unsuitable operating site or test setup can damage the instrument and connected devices. Ensure the following operating conditions before you switch on the instrument:

- Read and observe the "Basic Safety Instructions" delivered as a printed brochure with the instrument. In addition, read and observe the safety instructions in the following sections.
- Observe the operating conditions specified in the data sheet. Note that the general safety instructions also contain information on operating conditions.
- Position the instrument as described in the following sections.
  Make sure that all fan openings are unobstructed and the airflow perforations are unimpeded. The minimum distance from the wall is 10 cm.
- Signal levels at the input connectors are all within the specified ranges.
- Signal outputs are correctly connected and are not overloaded.

NOTICE

Risk of electrostatic discharge (ESD)

Electrostatic discharge (ESD) can damage the electronic components of the instrument and the device under test (DUT). ESD is most likely to occur when you connect or disconnect a DUT or test fixture to the instrument's test ports. To prevent ESD, use a wrist strap and cord and connect yourself to the ground, or use a conductive floor mat and heel strap combination.

For details, refer to the basic safety instructions delivered as a printed brochure with the instrument.

Electromagnetic interference (EMI) may affect the measurement results.

To suppress generated electromagnetic interference (EMI):

- Use suitable shielded cables of high quality. For example, use double-shielded RF and LAN cables.
- Always terminate open cable ends.
- Note the EMC classification in the data sheet.

1.2 Documentation Overview

This section provides an overview of the R&S RTB2000 user documentation.

1.2.1 Manuals and Instrument Help

You find the manuals on the product page at:

www.rohde-schwarz.com/manual/rtb2000

Getting started manual

Introduces the R&S RTB2000 and describes how to set up the product. A printed English version is included in the delivery.

User manual

Contains the description of all instrument modes and functions. It also provides an introduction to remote control, a complete description of the remote control commands with programming examples, and information on maintenance and instrument interfaces. Includes the contents of the getting started manual.

The *online version* of the user manual provides the complete contents for immediate display on the internet.

Instrument help

The help offers quick, context-sensitive access to the functional description directly on the instrument.

Basic safety instructions

Contains safety instructions, operating conditions and further important information. The printed document is delivered with the instrument.

Instrument security procedures manual

Deals with security issues when working with the R&S RTB2000 in secure areas.

Service manual

Describes the performance test for checking the rated specifications, module replacement and repair, firmware update, troubleshooting and fault elimination, and contains mechanical drawings and spare part lists. The service manual is available for registered users on the global Rohde & Schwarz information system (GLORIS, https://gloris.rohde-schwarz.com).

1.2.2 Data Sheet and Brochure

The data sheet contains the technical specifications of the R&S RTB2000. It also lists the options with their order numbers and optional accessories. The brochure provides an overview of the instrument and deals with the specific characteristics.

See www.rohde-schwarz.com/brochure-datasheet/rtb2000

1.2.3 Calibration Certificate

The document is available on https://gloris.rohde-schwarz.com/calcert. You need the device ID of your instrument, which you can find on a label on the rear panel.

1.2.4 Release Notes and Open Source Acknowledgment

The release notes list new features, improvements and known issues of the current firmware version, and describe the firmware installation. The open source acknowledgment document provides verbatim license texts of the used open source software.

See www.rohde-schwarz.com/firmware/rtb2000. The open source acknowledgment documant can also be read directly on the instrument.

1.3 Conventions Used in the Documentation

1.3.1 Typographical Conventions

The following text markers are used throughout this documentation:

Convention	Description
"Graphical user interface elements"	All names of graphical user interface elements on the screen, such as dialog boxes, menus, options, buttons, and softkeys are enclosed by quotation marks.
KEYS	Key names are written in capital letters.
`File names, commands, program code`	File names, commands, coding samples and screen output are distinguished by their font.
Input	Input to be entered by the user is displayed in italics.
Links	Links that you can click are displayed in blue font.
"References"	References to other parts of the documentation are enclosed by quotation marks.

1.3.2 Conventions for Procedure Descriptions

When describing how to operate the instrument, several alternative methods may be available to perform the same task. In this case, the procedure using the touchscreen is described. Any elements that can be activated by touching can also be clicked using an additionally connected mouse. The alternative procedure using the keys on the instrument or the on-screen keyboard is only described if it deviates from the standard operating procedures.

The term "select" may refer to any of the described methods, i.e. using a finger on the touchscreen, a mouse pointer in the display, or a key on the instrument or on a keyboard.

1.3.3 Notes on Screenshots

When describing the functions of the product, we use sample screenshots. These screenshots are meant to illustrate as much as possible of the provided functions and possible interdependencies between parameters. The shown values may not represent realistic usage scenarios.

The screenshots usually show a fully equipped product, that is: with all options installed. Thus, some functions shown in the screenshots may not be available in your particular product configuration.

2 Getting Started

2.1 Preparing for Use

2.1.1 Unpacking and Checking the Instrument

1. Inspect the package for damage.

   If the packaging material shows any signs of stress, notify the carrier who delivered the instrument.

2. Carefully unpack the instrument and the accessories.

3. Check the equipment for completeness. See "Delivery contents" on page 16.

4. Check the equipment for damage.
   If there is damage, or anything is missing, immediately contact the carrier as well as your distributor. Make sure not to discard the box and packing material.

Packing material

Retain the original packing material. If the instrument needs to be transported or shipped at a later date, you can use the material to protect the control elements and connectors.

Delivery contents

The delivery package contains the following items:

- R&S RTB2000 digital oscilloscope
- R&S RT-ZP03 probes (2x for R&S RTB2002; 4x for R&S RTB2004)
- Country-specific power cable
- Printed "Getting Started" manual
- Printed "Basic Safety Instructions" brochure

2.1.2 Positioning the Instrument

The instrument is designed for use under laboratory conditions. It can be used in standalone operation on a bench top or can be installed in a rack.

For standalone operation, place the instrument on a horizontal bench with even, flat surface. The instrument can be used in horizontal position, or with the support feet on the bottom extended.

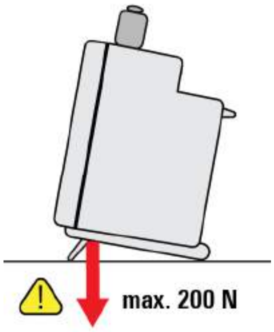
The instrument can be installed in a 19" rack mount using a rack mount kit. The order number of the rack mount kit is given in the data sheet. The installation instructions are part of the rack mount kit.

CAUTION

Risk of injury if feet are folded out

The feet may fold in if they are not folded out completely or if the instrument is shifted. This may cause damage or injury.

- Fold the feet completely in or completely out to ensure stability of the instrument. Never shift the instrument when the feet are folded out.
- When the feet are folded out, do not work under the instrument or place anything underneath.
- The feet can break if they are overloaded. The overall load on the folded-out feet must not exceed 200 N.



NOTICE

Risk of instrument damage due to overheating

An insufficient airflow can cause the R&S RTB2000 to overheat, which may impair the measurement results, disturb the operation, and even cause damage.

- Ensure that all fan openings are unobstructed and that the airflow perforations are unimpeded. The minimum distance to a wall is 10 cm.
- When placing several instruments side by side, keep a minimum distance of 20 cm between the instruments. Ensure that the instruments do not draw in the preheated air from their neighbors.
- When mounting the instrument in a rack, observe the instructions of the rack manufacturer to ensure sufficient airflow and avoid overheating.

2.1.3 Starting the Instrument

2.1.3.1 Powering On

The R&S RTB2000 can be used with different AC power voltages and adapts itself automatically to it.

The nominal ranges are:

- 100 V to 240 V AC at 50 Hz to 60 Hz
- 0.95 A to 0.5 A
- max. 60 W

CAUTION

Risk of injury

Connect the instrument only to an outlet that has a ground contact.

Do not use an isolating transformer to connect the instrument to the AC power supply.

1. Connect the power cable to the AC power connector on the rear panel of the R&S RTB2000.
2. Connect the power cable to the socket outlet.
3. Switch the main power switch at the rear of the instrument to position I.

   The STANDBY key lights up. The key is located in the bottom left corner of the front panel.

You can leave the main power switch on to preserve your last instrument settings. To disconnect from power supply, power off the instrument.

2.1.3.2 Starting Up and Shutting Down

To start up the instrument

1. Make sure that the R&S RTB2000 is connected to the AC power supply and the main power switch on the rear panel is in position I.
2. Press the STANDBY key. The key is located in the bottom left corner of the front panel.

   The instrument performs a system check and starts the firmware. If the previous session was terminated regularly, the oscilloscope uses the last settings.

Table 2-1: Colors of the STANDBY key

Green	Instrument is on: firmware is working
Yellow	Standby: instrument is off, main power switch is on

Warm-up and prepare the instrument

Make sure that the instrument has been running and warming up before you start the self-alignment and the measurements. The minimum warm-up time is about 20 min.

To shut down the instrument to standby state

► Press the STANDBY key.

All current settings are saved, and the software shuts down. Now it is safe to power off the instrument.

2.1.3.3 Powering Off

Powering off is required only if the instrument must be disconnected from all power supplies.

1. If the instrument is running, press the STANDBY key on the front panel to shut down the instrument.
2. Switch the main power switch at the rear of the instrument to position 0.
3. Disconnect the AC power cable from the AC power supply.

NOTICE

Risk of losing data

If you switch off the running instrument using the rear panel switch or by disconnecting the power cord, the instrument loses its current settings. Furthermore, program data may be lost.

Press the Standby key first to shut down the application properly.

2.1.4 Replacing the Fuses

The instrument is protected by a fuse. You can find it on the rear panel between the main power switch and AC power supply.

Type of fuse: Size 5x20 mm, 250V~, T2.5H (slow-blow), IEC60127-2/5

WARNING

Shock hazard

Before replacing a fuse, make sure that the instrument is switched off and disconnected from all power supplies. Always use fuses supplied by Rohde & Schwarz as spare parts, or fuses of the same type and rating.

1. Pull the fuse holder out of its slot on the rear panel.

2. Exchange the fuse.
3. Insert the fuse holder carefully back in its slot until it latches.

2.2 Instrument Tour

2.2.1 Front Panel

Figure 2-1 shows the front panel of the R&S RTB2000. The function keys are grouped in functional blocks to the right of the display.

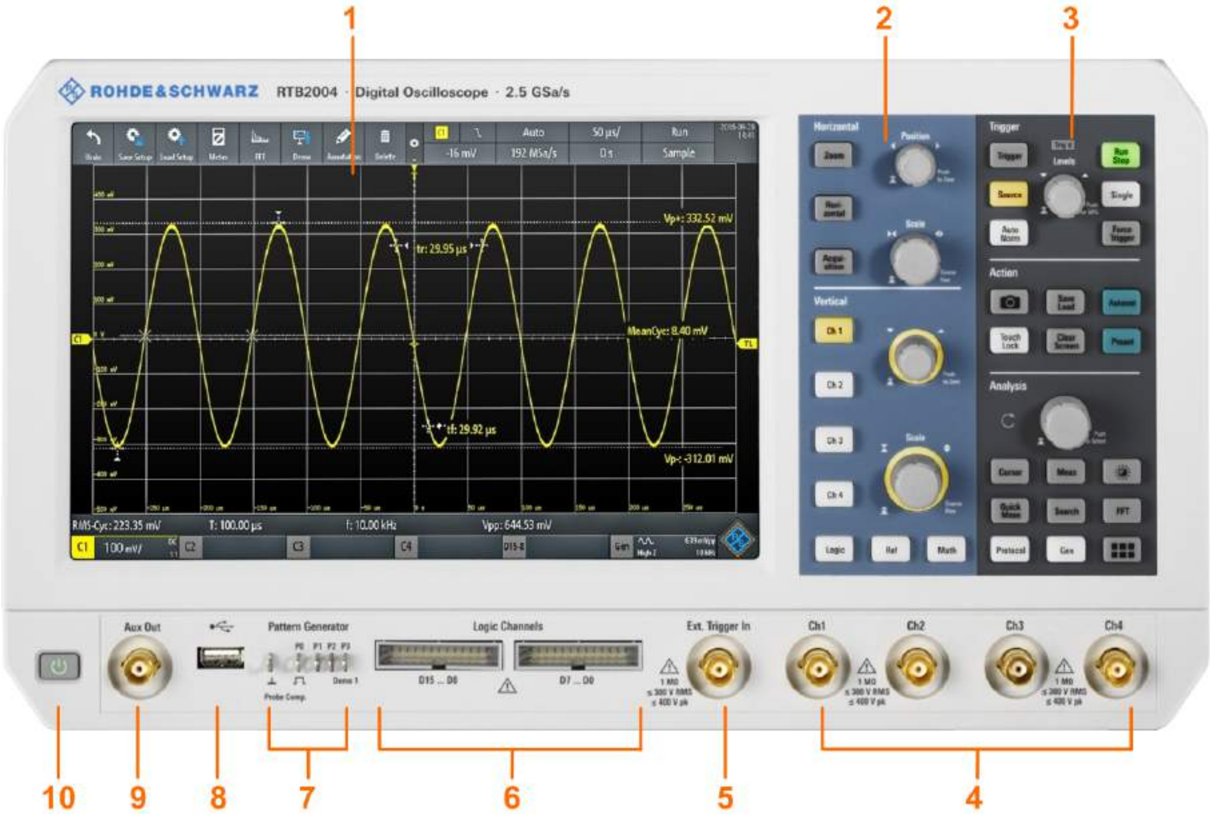
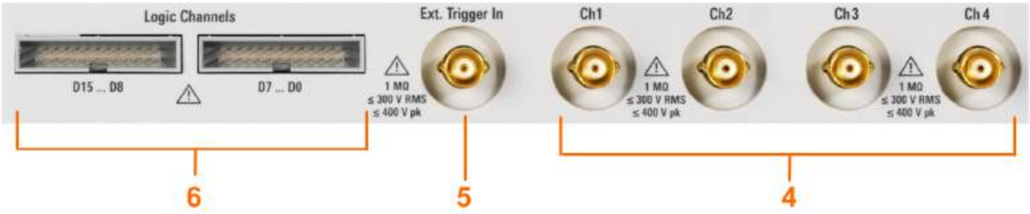


Figure 2-1: Front panel of R&S RTB2004 with 4 input channels

1 = Display
2 = Horizontal and vertical setup controls
3 = Trigger settings, action and analysis controls
4 = Analog input channels (2 channels at R&S RTB2002, 4 channels at R&S RTB2004)
5 = External trigger input
6 = Logic probe connectors (option R&S RTB-B1)
7 = Connectors for probe compensation and optional pattern generator (R&S RTB-B6)
8 = USB connector
9 = Aux Out connector
10 = STANDBY key

2.2.1.1 Input Connectors



BNC inputs (4 and 5)

The R&S RTB2000 has two or four channel inputs (4) to connect the input signals. The external trigger input (5) is used to control the measurement by an external signal. The trigger level can be set from -5 V to 5 V.

The input impedance of all BNC inputs is 1 MΩ.

⚠ WARNING

Risk of electrical shock - maximum input voltages

The maximum input voltage on *channel inputs* must not exceed 400 V (peak) and 300 V (RMS).

For the *external trigger input*, the maximum input voltage is 400 V (peak) and 300 V (RMS).

Transient overvoltages must not exceed 400 V (peak).

Voltages higher than 30 V (RMS) or 42 V (peak) or 60 V DC are regarded as hazardous contact voltages. When working with hazardous contact voltages, use appropriate protective measures to preclude direct contact with the measurement setup:

- Use only insulated voltage probes, test leads and adapters.
- Do not touch voltages higher than 30 V (RMS) or 42 V (peak) or 60 V DC.

⚠ CAUTION

Risk of injury and instrument damage

The instrument is not rated for any measurement category. When measuring in circuits with transient overvoltages of category II, III or IV circuits, make sure that no such overvoltages reach the R&S RTB2000 input. Therefore, use only probes that comply with DIN EN 61010-031. When measuring in category II, III or IV circuits, always insert a probe that appropriately reduces the voltage so that no transient overvoltages higher than 400 V (peak) are applied to the instrument. For detailed information, refer to the documentation and safety information of the probe manufacturer.

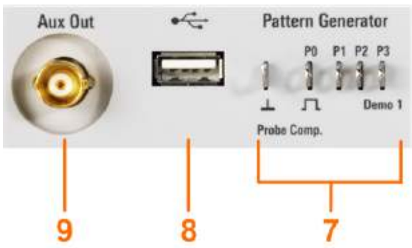
Explanation: According to section AA.2.4 of EN 61010-2-030, measuring circuits without any measurement category are intended for measurements on circuits which are not connected to the mains system.

Logic probe (6)

The connectors for logic channels can be used if the Mixed Signal Option R&S RTB-B1 is installed. The option provides connectors for two logical probes with 8 digital channels each (D0 to D7 and D8 to D15).

The maximum input voltage is 40 V (peak) at 100 kΩ input impedance. The maximum input frequency for a signal with the minimum input voltage swing and medium hysteresis of 800 mV (Vpp) is 300 MHz.

2.2.1.2 Other Connectors on the Front Panel



PATTERN GENERATOR (7)
Connectors for the pattern generator P0, P1, P2, P3.

The "Demo 1" signal is intended for demonstration purposes.

PROBE COMP. (7)
Probe compensation terminal to support adjustment of passive probes to the oscilloscope channel.

⎍ Square wave signal for probe compensation.

⊥ Ground connector for probes.

USB type A (8)
USB 2.0 type A interface to connect a mouse or a keyboard, or a USB flash drive for storing and reloading instrument settings and measurement data, and to update the firmware.

AUX OUT (9)
Multi-purpose BNC output that can function as pass/fail and trigger output, output of 10 MHz reference frequency, and as waveform generator (with option R&S RTB-B6).

2.2.2 Rear Panel

Figure 2-2 shows the rear panel of the R&S RTB2000 with its connectors.

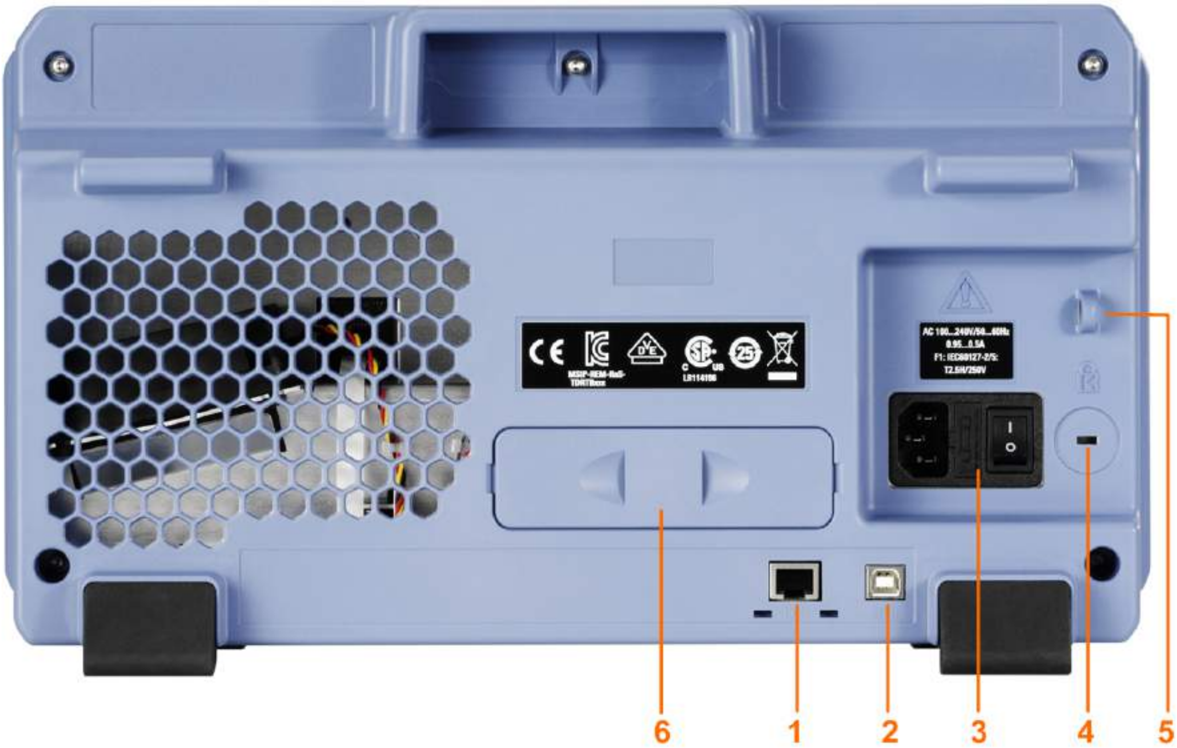


Figure 2-2: Rear panel view of R&S RTB2000

1 = LAN connector
2 = USB connector, type B
3 = AC power supply connector and main power switch
4 = Kensington lock slot to secure the instrument against theft
5 = Loop for lock to secure the instrument against theft
6 = not used

LAN (1)
8-pin connector RJ-45 used to connect the instrument to a Local Area Network (LAN). It supports up to 1 Gbit/s.

USB type B (2)
USB 2.0 interface of type B (device USB) for remote control of the instrument.

Note: Electromagnetic interference (EMI) can affect the measurement results. To avoid any impact, use only USB connecting cables with a maximum length of 1 m.

AC supply: mains connector and main power switch (3)
The instrument supports a wide range power supply. It automatically adjusts to the correct range for the applied voltage. There is no line voltage selector.

The AC main power switch disconnects the instrument from the AC power line.

2.3 Operating Basics

2.3.1 Display Overview

The touchscreen display of the instrument shows the waveforms and measurement results, and also information and everything that you need to control the instrument.

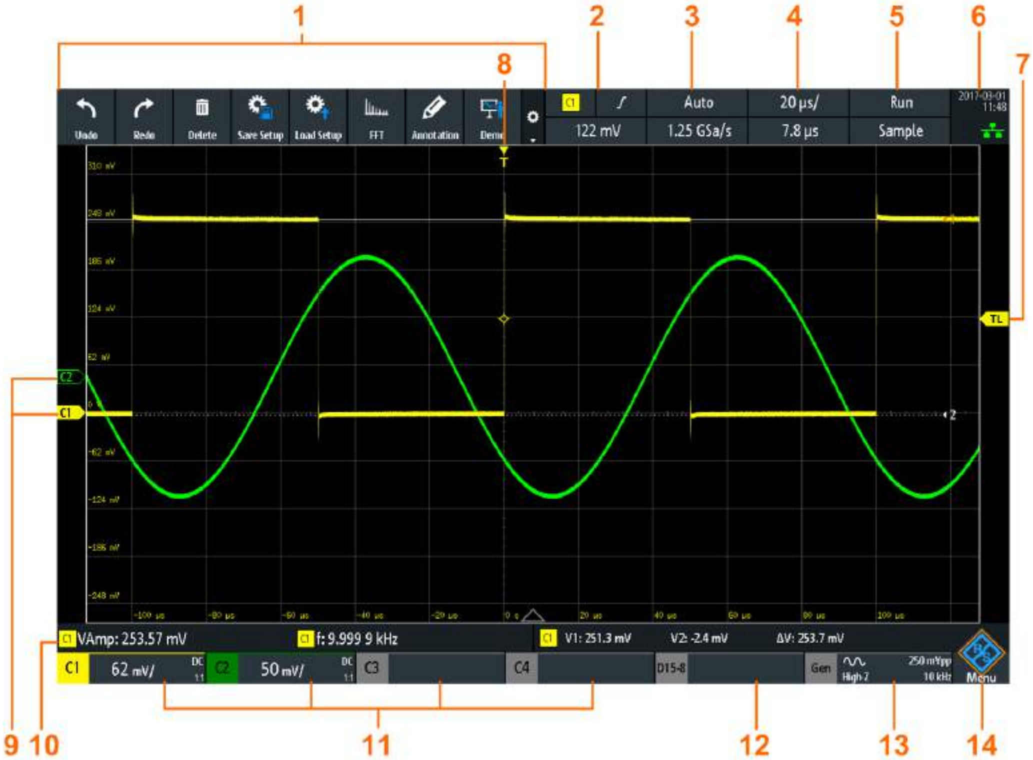


Figure 2-3: Display of the R&S RTB2004

1 = toolbar
2 = trigger source, main trigger parameter (here: slope for edge trigger), trigger level
3 = trigger mode and sample rate
4 = horizontal scale (time scale) and horizontal position
5 = acquisition status and acquisition mode
6 = date, time, education mode if active (here: off), LAN connection status (green = connected, grey = not connected, yellow = connecting)
7 = trigger level marker, has the color of the trigger source
8 = trigger position marker, has the color of the trigger source
9 = channel markers indicate the ground levels; channel C1 is selected, i.e. it has the focus
10 = measurement results (here: automatic measurements on the left, cursor measurements on the right)
11 = vertical settings of active analog channels: vertical scale, bandwidth limitation (no indicator = full bandwidth, B_W= limited frequency), coupling (AC, DC, ground), probe attenuation. Channel 1 is selected.
12 = logic channels (requires option R&S RTB-B1)
13 = waveform generator settings (requires option R&S RTB-B6)
14 = menu button

2.3.2 Selecting the Application

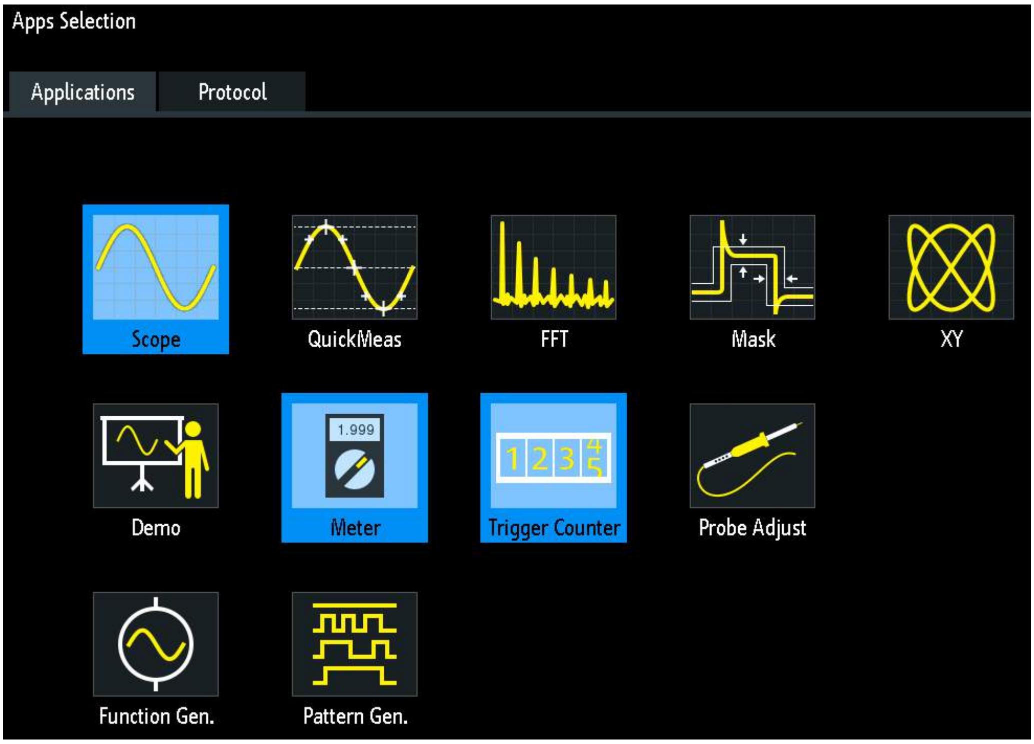
The "Apps Selection" dialog provides fast access to all available applications.

► There are several ways to open the "Apps Selection" dialog:

- Press the APPS SELECTION key.
- Tap the "Menu" rhomb icon in the lower right corner of the screen.

  Scroll down.
  Select "Apps".



2.3.3 Using the Touchscreen

2.3.3.1 Accessing Functionality Using the Main Menu

Using the touchscreen of the R&S RTB2000 is as easy as using your mobile phone. To open the main menu, tap the "Menu" button - that is the R&S logo in the right bottom corner of the display.

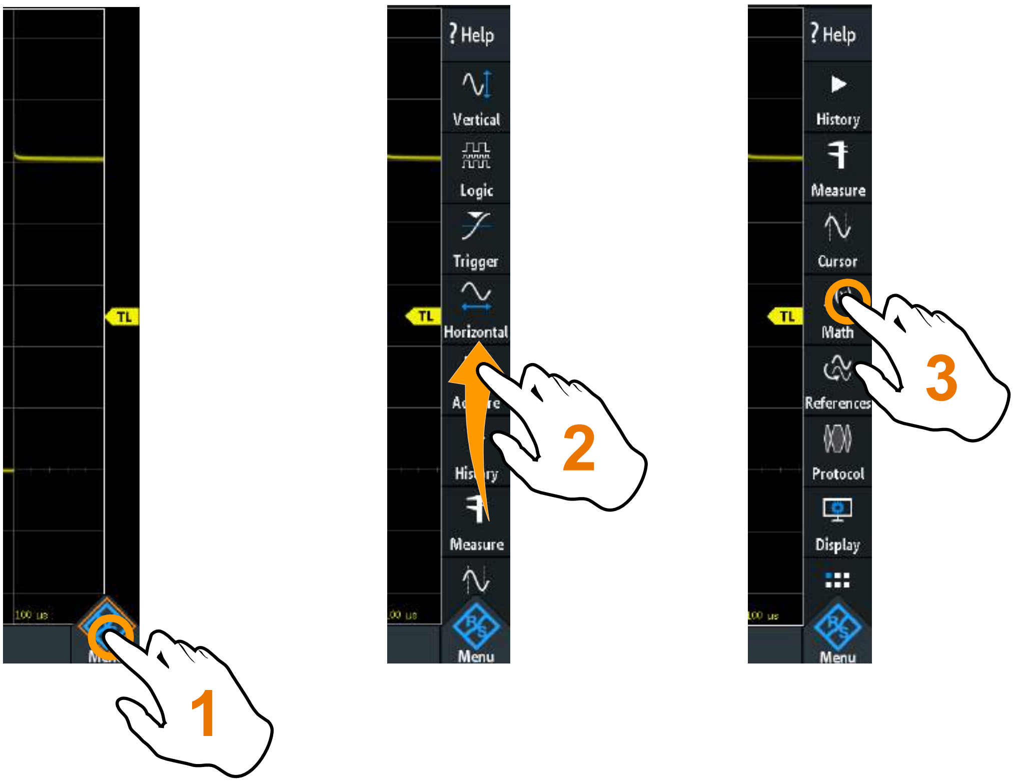


Figure 2-4: Open the main menu and select a menu item

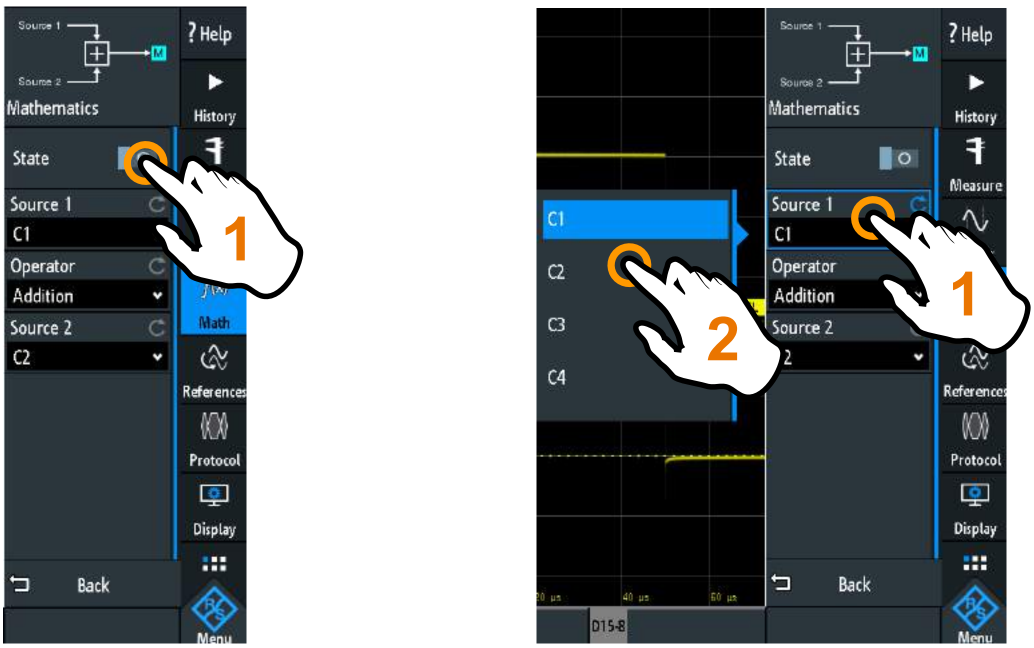


Figure 2-5: Switch on or off (left) and select a parameter value (right)

► To close the menu:

Tap "Back", or tap into the diagram outside the menu.

2.3.3.2 Accessing Functionality Using Shortcuts

The labels in information bar at the top of the display, the channel labels and also the results at the bottom provide shortcuts to the most important settings. If you tap a label, a short menu opens, the keypad for numerical entry, the setting toggles, or the corresponding menu opens. The response depends on the selected parameter.

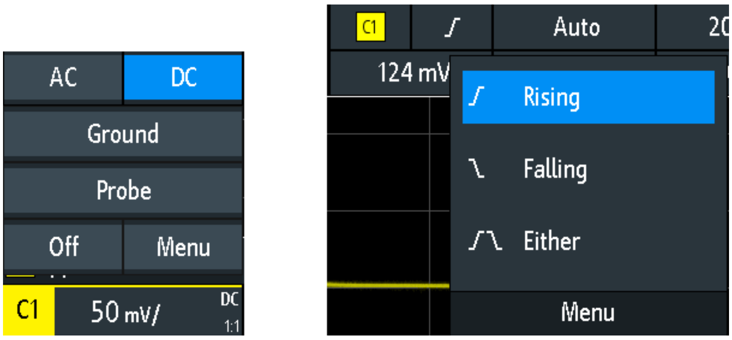


Figure 2-6: Short menus for channel (left) and trigger slope (right)

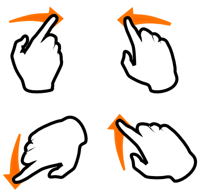
From the short menu, you can also open the corresponding comprehensive menu.
You can also switch off the channels.

2.3.3.3 Entering Data

To enter exact numerical values, the instrument provides an on-screen keypad. For text input, the on-screen keyboard works in the same way.

Figure 2-7: Enter numerical value and unit

2.3.3.4 Using Gestures



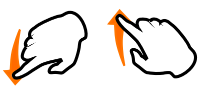
Drag one finger

Drag *horizontally* in the diagram to change the horizontal position of all waveforms. In frequency domain, the center frequency is changed.

Drag *vertically* in the diagram to change the vertical position of the selected waveform.

To adjust the vertical position of each waveform, the trigger level, and the trigger position, drag the corresponding marker on the display.

To drag a cursor line, tap the line and drag it to the required position.

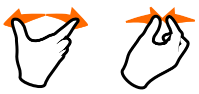


Swipe one finger

Swipe in the menu to scroll it.

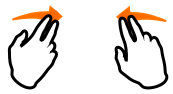
Spread and pinch two fingers

Spread or pinch two fingers in *vertical* direction to change the vertical scale of the selected waveform.



Spread or pinch two fingers in *horizontal* direction to change the horizontal scale of all waveforms. In frequency domain, the frequency span is changed.

Swipe two fingers



If the history option R&S RTB-K15 is installed, swipe two fingers in the diagram to scrolls through the history segments.

2.3.4 Front Panel Keys

For an overview of the front panel keys, see figure 2-1 on page 20.

The keys and knobs at the front panel are grouped in functional blocks:

- Horizontal section: see Chapter 3.3.1, "HORIZONTAL Controls", on page 44.
- Vertical section: see Chapter 3.2.1, "VERTICAL Controls", on page 36.
- Trigger section: see Chapter 4.1, "TRIGGER Controls", on page 51
- Action section, see Chapter 2.3.4.1, "Action Controls", on page 29.
- Analysis section, see Chapter 2.3.4.2, "Analysis Controls", on page 30.

2.3.4.1 Action Controls

The Action keys set the instrument to a defined state, and provide save and load functions.

CAMERA
Saves screenshots, waveforms and/or settings according to the configuration in SAVE LOAD > "onetouch".

SAVE LOAD
Opens the "File" menu, where you can:

- Save instrument settings, waveforms, reference waveforms, and screenshots
- Restore (load) data which were saved before
- Import and export settings and reference waveforms
- Configure the screenshot output
- Configure the behavior of the CAMERA key

TOUCH LOCK
Locks the touchscreen to prevent unintended use. When the touchscreen is off, the key is illuminated. Press again to unlock the touchscreen.

CLEAR SCREEN
Deletes all waveforms, annotations and the measurement results of deleted waveforms. All settings remain unchanged.

Remote command:
`DISPlay:CLEar[:SCReen]` on page 231

2.3.4.2 Analysis Controls

The controls in the ANALYSIS functional block open various menus for signal analysis.

NAVIGATION
The function of this universal rotary knob depends on the usage context:
- If selection menu is open: turn the knob to select a value.
- If a numerical value is selected in the menu, and the keypad is closed: turn the knob to set a value.
- If the cursors are selected, press the key to select a cursor line. Turn the knob to change the position of the selected cursor line.
- If an on-screen keypad or on-screen keyboard is open: turn the knob until the required character is highlighted, then press the knob to apply the selection.

CURSOR
Enables the cursor with the last configured cursor setup. The second keypress opens the "Cursor" menu. If the menu is open, pressing the key turns off the cursor and closes the menu.

MEAS
Opens the "Measure" menu, where you can configure up to 4 parallel measurements. Available measurement types depend on the type of the selected waveform.

INTENSITY
Opens the "Intensities" menu to adjust the luminosity of display elements and the persistence.

QUICKMEAS
Displays the results of basic automatic measurements for the selected channel below the grid and directly on the waveform.

Press the key to stop quick measurements.

Note: Channels other than the selected one are switched off in quick measurement mode. When you activate quick measurements, cursor measurements are automatically deactivated. Deactivate quick measurements before selecting the cursors.

SEARCH
Enables the search with the last configured setup. The second keypress opens the "Search" menu, where you can perform a search for various events in an acquisition - for example, peaks or specific width conditions - and analyze the search results.

FFT
Activates the spectrum analysis functions with the last configured setup. The second keypress opens the "FFT" menu.

To deactivate spectrum analysis, press the FFT key until the time domain waveform is displayed.

PROTOCOL
Opens the "Bus" menu, which contains the configuration of serial and parallel buses and the settings for decoding the signals. Key function requires at least one of the protocol options R&S RTB-B1, R&S RTB-K1, -K2, or -K3.

GEN
Opens the "Function Generator" menu, where you can create various waveforms. Key function requires option R&S RTB-B6.

APPS SELECTION
Opens the "Apps Selection" dialog where you can select the required application or protocol for your task, for example, mask testing or CAN protocol.

2.3.5 Using the Toolbar

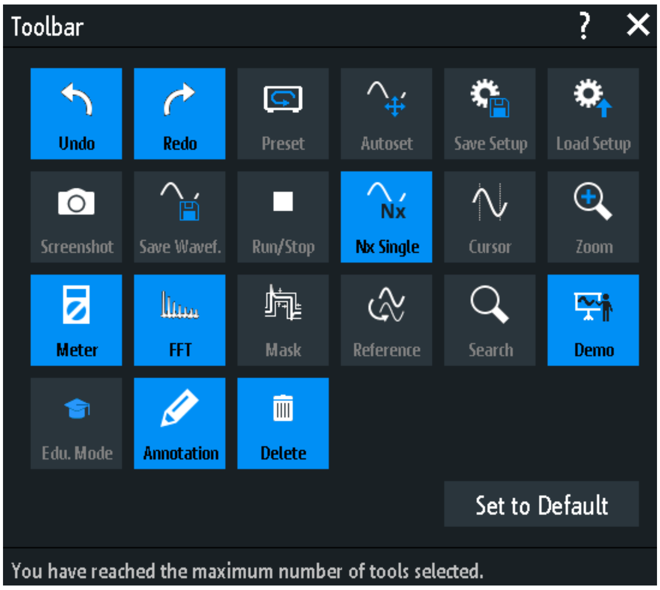
The toolbar at the top of the display provides direct access to important control and measurement functions. The selected function is highlighted. By default, the toolbar shows the most frequently used functions. You can configure the content of the toolbar so that only the required functions are displayed..

Some of the toolbar functions are one-click actions. These actions are performed immediately when you tap the icon. Other toolbar functions are interactive actions. When you tap an interactive action, a message informs you what to do next.

Configuring the Toolbar

1. Tap the "Toolbar Setup" icon.

2. Disable the functions that you do not need.
3. Tap the functions that you need. You can select maximum 8 functions.



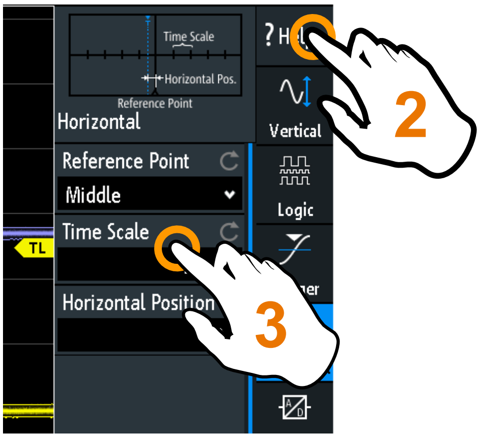
4. Close the dialog box.

2.3.6 Getting Help

In most menus and dialogs, graphics explain the meaning of the selected setting. For further information, you can open the help, which provides functional description of selected setting.

To open the help window

1. Tap the "Menu" icon in the lower right corner of the screen.
2. Tap "Help" on the top of the main menu.
3. Tap the setting for which you need information.



To close the help window

► Tap "Help" on the top of the main menu, or tap the "Close" icon in the upper right corner of the help window.

3 Waveform Setup

This chapter describes how to connect and set up probes, to adjust the horizontal and vertical settings, and to control the acquisition.

3.1 Connecting Probes and Displaying a Signal

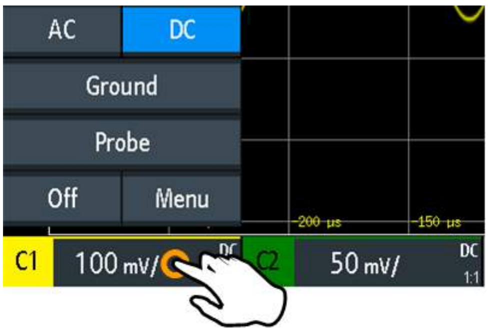
NOTICE

Risk of instrument damage

Make sure to set the attenuation factor on the instrument according to the probe being used. Otherwise, the measurement results do not reflect the actual voltage level, and you might misjudge the actual risk.

The attenuation of the probes that are delivered with the instrument, and the default attenuation factor of the instrument are 10:1. If you use only the delivered probes and did not change the attenuation factor, no attenuation adjustment is required.

1. Connect the probes first to the channel inputs, and then to the DUT.
2. Tap the label of the used channel in the bottom line of the display.



3. Tap "Probe".
4. Select the attenuation factor of the probe.
   The probe's attenuation factor is indicated on the probe.

   Note: If you measure current using a shunt resistor as a current sensor, you have to multiply the V/A-value of the resistor by the attenuation of the probe. For example, if a 1 Ω resistor and a 10:1 probe is used, the V/A-value of the resistor is 1 V/A. The attenuation factor of the probe is 0.1, and the resulting current probe attenuation is 100 mV/A.
5. If you connect several probes, repeat steps 2 to 4 for the remaining channels.
6. Press the PRESET key.
7. Press the AUTOSET key.

PRESET
Resets the instrument to the default state, without analyzing the signal. The previous user-defined configuration is removed and all channels except for channel 1 are disabled.

Remote command:
`*RST`

AUTOSET
Analyzes the enabled analog channel signals, and adjusts the horizontal, vertical, and trigger settings to display stable waveforms.

Remote command:
`AUToscale` on page 173

3.2 Vertical Setup

The controls and parameters of the vertical system adjust the vertical scale and position of the waveform, and the waveform display. The probe settings also belong to the vertical setup.

The channel labels at the bottom of the display show the basic vertical settings: vertical scale (for example, channel 3 in the figure below: 500 mV/div), coupling (AC), probe attenuation (10:1), and bandwidth (if limited). Clipping of a waveform is indicated by orange arrows. The label of the selected channel has a brighter colored line on the top.

Figure 3-1: Channel labels. Channel 3 is selected. Channel 1 waveform is clipped.

There are several ways to adjust vertical settings:

- Use the controls in the Vertical functional block of the front panel to select the channel, to scale the waveform, and to set the offset.
- Drag one finger vertically on the screen to change the offset of the selected channel waveform.
- spread or pinch two fingers in vertical direction to change the vertical scale of the selected waveform.
- Use the short menu to adjust coupling and the probe.
- Use the comprehensive menu to adjust all vertical settings.

3.2.1 VERTICAL Controls

CH <N>
For each analog channel, a channel key is available. The key is illuminated in the channel color, if the channel is on.

The effect of the keypress depends on state of the channel:
- If channel is off: Turns on the channel and selects it. The rotary knobs alongside light up in the channel color.
- If the channel is on and in focus (selected): Opens its vertical setup menu of the channel.
- If the channel is on but not in focus (not selected): Selects the channel waveform.
- If the channel is selected and the menu is open: Pressing the key turns off the channel.

Remote command:
`CHANnel<m>:STATe` on page 175

OFFSET / POSITION (UPPER KNOB)
The rotary knob adjusts the offset of an analog channel, or the vertical position of a math or reference waveform, serial bus, or logic pod.

The knob lights up in the color of the selected waveform. Turn clockwise to move up the waveform. Pressing the key sets the value to zero.

Remote command:
`CHANnel<m>:OFFSet` on page 176
`CALCulate:QMATh:POSition` on page 199
`REFCurve<m>:VERTical:POSition` on page 202

SCALE
Sets the vertical scale in Volts per division to change the displayed amplitude of the selected waveform. For analog waveforms, the scale value is shown in the waveform label at the bottom. The knob lights up in the color of the selected waveform.

Turn SCALE clockwise to stretch the waveform. Doing so, the scale value V/div decreases. Press the knob to toggle between fine and coarse adjustment.

To get the maximum resolution of the waveform amplitude, make sure that the wave-forms cover most of the screen's height.

Remote command:
CHANnel<m>:SCALe on page 175
CALCulate:QMATh:SCALe on page 199
REFCurve<m>:VERTical:SCALe on page 202

LOGIC
Enables the logic channels. The second keypress opens the menu, where you can select and configure digital channels for analysis. If the menu is open, pressing the key disables the logic channels.

Key function requires MSO option R&S RTB-B1.

LOGIC is described in .

REF
Displays the reference waveforms with their last configuration. The key works in the same way as the channel keys, see "CH <N>" on page 36.

Reference wavforms are described in Chapter 5.3, "Reference Waveforms", on page 72.

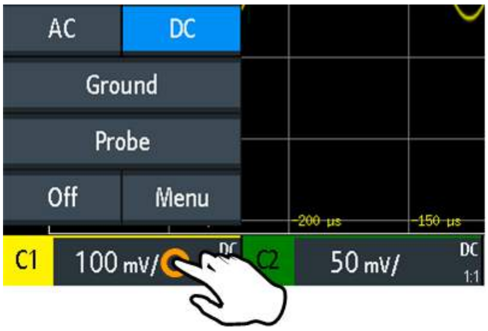
MATH
Enables the math waveform, a waveform calculated from the captured data. The key works in the same way as the channel keys, see "CH <N>" on page 36.

Mathematics is described in Chapter 5.2, "Mathematics", on page 69.

3.2.2 Short Menu for Analog Channels

To adjust the probe and the coupling, you can use the short menu. Here you can also open the comprehensive menu, and switch off the channel.

► To open the short menu for a channel, tap the channel label in the bottom line of the display.
If the channel was not selected, tap twice: Once to select the waveform, and next to open the short menu.



Functions in the short menu:

- "AC | DC": see "Coupling" on page 38
- "Ground" on page 39
- "Probe": opens the "Probe" menu, see
- "Off": turns off the channel.
- "Menu": opens the comprehensive "Vertical" menu.

3.2.3 Vertical Settings

The comprehensive "Vertical" menu contains all vertical settings.

► To open the menu for a channel, press the corresponding channel key.
If the channel was active but not selected, press twice: Once to select the waveform, and next to open the short menu.

The "Vertical" menu is also available in the main menu.

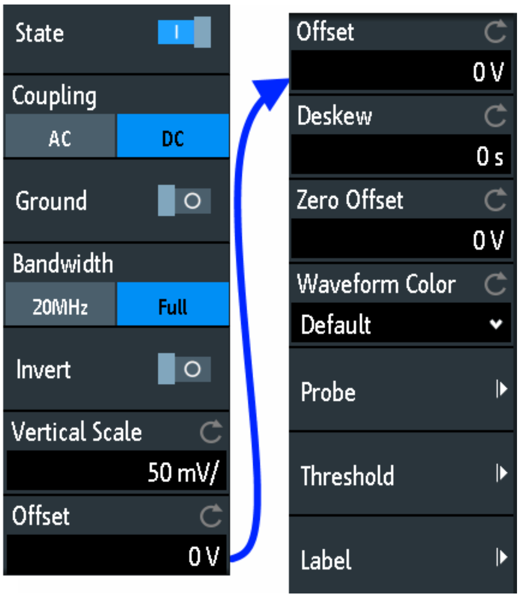


Figure 3-2: Vertical setup dialog, here split into two halves

State
Switches the selected channel on or off.

Remote command:
`CHANnel<m>:STATe` on page 175

Coupling
Selects the input coupling, which influences the signal path between input connector and the following internal signal stage. The current coupling of each channel is shown in the waveform labels below the grid.

"AC" AC coupling is useful if the DC component of a signal is of no interest. AC coupling blocks the DC component of the signal so that the waveform is centered on zero volts.

"DC" With DC coupling, the input signal passes unchanged, all signal components are shown.

Remote command:
`CHANnel<m>:COUPling` on page 176

Ground

Connects the input to a virtual ground. All channel data is set to 0 V. Ground connection is labeled with ⊥. The coupling is not affected by the ground setting.

Remote command:
`CHANnel<m>:COUPling` on page 176

Bandwidth

Selects the bandwidth limit. The specified full bandwidth indicates the range of frequencies that the instrument can acquire and display accurately with less than 3 dB attenuation.

For analog applications, the highest signal frequency determines the required oscilloscope bandwidth. The oscilloscope bandwidth should be at least 3 times higher than the maximum frequency included in the analog test signal to measure the amplitude without aliasing.

Most test signals are more complex than a simple sine wave and include several spectral components. A digital signal, for example, is built up of several odd harmonics. For digital signals, the oscilloscope bandwidth should be at least 5 times higher than the clock frequency to be measured.

The oscilloscope is not an autonomous system. You need a probe to measure the signal, and the probe has a limited bandwidth, too. The combination of oscilloscope and probe creates a system bandwidth. To reduce the effect of the probe on the system bandwidth, the probe bandwidth should exceed the bandwidth of the oscilloscope, the recommended factor is 1.5 x oscilloscope bandwidth.

"20 MHz" Frequency limit. Higher frequencies are removed to reduce noise. Limited bandwidth is indicated by "B_W" in the waveform label.

"Full" At full bandwidth, all frequencies in the specified range are acquired and displayed. Full bandwidth is used for most applications.

Remote command:
`CHANnel<m>:BANDwidth` on page 177

Invert

Turns the inversion of the signal amplitude on or off. To invert means to reflect the voltage values of all signal components against the ground level. Inversion affects only the display of the signal but not the trigger.

For example: if the oscilloscope triggers on the rising edge, the trigger is not changed by inversion, but the actually rising edge is displayed as falling edge.

Inversion is indicated in the waveform labels by line above the channel name.

Remote command:
`CHANNel<m>:POLarity` on page 177

Vertical Scale
Sets the vertical scale in Volts per division to change the displayed amplitude of the selected waveform. The current value is shown in the waveform label below the grid.

Vertical scale directly affects the resolution of the waveform amplitude. To get the full resolution of the ADC, set up the waveforms to cover most of the height of the diagram.

Remote command:
`CHANNel<m>:SCALe` on page 175

Offset
The offset voltage is used to correct an offset-affected signal. The vertical center of the selected channel is shifted by the offset value and the signal is repositioned within the diagram area.

Use the offset to measure small AC voltages that are overlaid by higher DC voltages. Unlike AC coupling, the DC part of the signal is not lost with offset setting. The device under test is not affected. The offset always must be set manually, it is not included in the autoset process.

Remote command:
`CHANNel<m>:OFFSet` on page 176

Deskew
Sets a time delay for the selected channel.

Deskew compensates delay differences between channels caused by the different length of cables, probes, and other sources. Correct deskew values are important for accurate triggering. Signals that are routed over lines with different lengths have a different propagation delay. This delay may lead to a non-synchronous waveform display. For example, a coax cable with a length of 1 meter has a propagation delay of typically 5.3 ns.

Remote command:
`CHANNel<m>:SKEW` on page 177

Zero Offset
Differences in DUT and oscilloscope ground levels can cause larger zero errors, which affect the waveform. If the DUT is ground-referenced, the "Zero Offset" corrects the zero error and sets the probe to the zero level.

You can assess the zero error by measuring the mean value of a signal that returns zero.

Remote command:
`CHANNel<m>:ZOFFset[:VALue]` on page 178

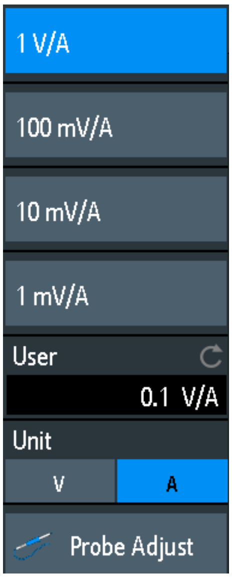
Waveform Color
Selects the color scale for the display of the waveform. Each scale comprises a set of colors, where each color represents a certain frequency of occurrence.

"Temperature"	Display in temperature colors. Blue corresponds to rare occurrences of the samples, while white indicates frequent ones.
"Rainbow"	Display in rainbow colors. Blue corresponds to rare occurrences of the samples, while red indicates frequent ones.
"Fire"	Display in fire colors. Yellow corresponds to rare occurrences of the samples, while red indicates frequent ones.
"Default"	Displays the waveform in its default monochrome color.

3.2.4 Probe Settings

In the probe menu, you set the probe attenuation for the selected channel. You can select a default factor, for example "10:1", or enter a user-defined value.

Access: CH <N> > "Probe" (scroll down). Or: short menu > "Probe"



User
If default values do not fit, you can enter an arbitrary attenuation factor in the range between 0.001:1 and 1000:1. The vertical scaling and measured values are multiplied by this factor so that the displayed values are equal to the undivided measured signal values.

Remote command:
`PROBe<m>:SETup:ATTenuation:MANual` on page 180

Unit
Selects the unit that the probe can measure.
- V - for voltage measurements
- A - for current measurements

Remote command:
`PROBe<m>:SETup:ATTenuation:UNIT` on page 180

Probe Adjust
Starts the probe adjustment procedure. A wizard explains the adjustment step by step.

3.2.5 Threshold Settings

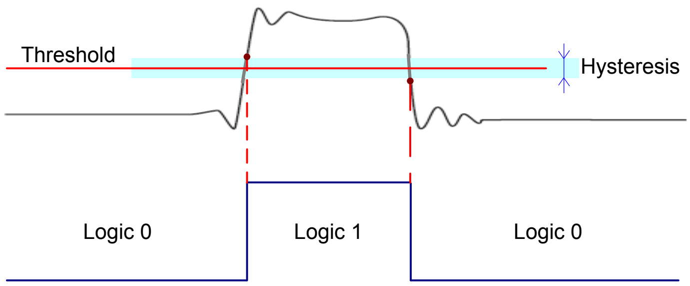
A threshold is used for digitization of analog signals. If the signal value is higher than the threshold, the signal state is high (1 or true for the Boolean logic). Otherwise, the signal state is considered low (0 or false) if the signal value is below the threshold.

Access: CH <N> > "Threshold" (scroll down).

Threshold
A threshold is used for digitization of analog signals. If the signal value is higher than the threshold, the signal state is high (1 or true for the Boolean logic). Otherwise, the signal state is considered low (0 or false) if the signal value is below the threshold.

Remote command:
`CHANnel<m>:THReshold` on page 178

Hysteresis
To avoid the change of signal states due to noise, set the hysteresis. If the signal jitters inside the hysteresis range and crosses the threshold, no state transition occurs.



The numerical values of "Small", "Medium", and "Large" hysteresis correspond to the vertical scale.

Remote command:
`CHANnel<m>:THReshold:HYSTeresis` on page 179

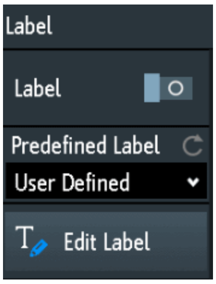
Find Threshold
The instrument analyzes the channel and sets the threshold for digitization. If no level can be found, the existing value remains unchanged, and you can set the thresholds manually.

Remote command:
`CHANnel<m>:THReshold:FINDlevel` on page 179

3.2.6 Label Settings

In the "Label" menu, you can define a name label for the selected waveform.

Access: CH <N> > "Label" (scroll down).



Label
Activates or deactivates the label display. The label is shown at the waveform on the right edge of the display.

Remote command:
`CHANnel<m>:LABel:STATe` on page 179

Predefined Label
Selects a predefined label text. You can edit the text with "Edit Label".

Edit Label
Opens on-screen keypad to enter a label text. If you previously have selected a text from the library, it is already written in the entry line, and you can modify it.

The maximum name length is 8 characters, and only ASCII characters provided on the on-screen keypad can be used.

Remote command:
`CHANnel<m>:LABel` on page 179

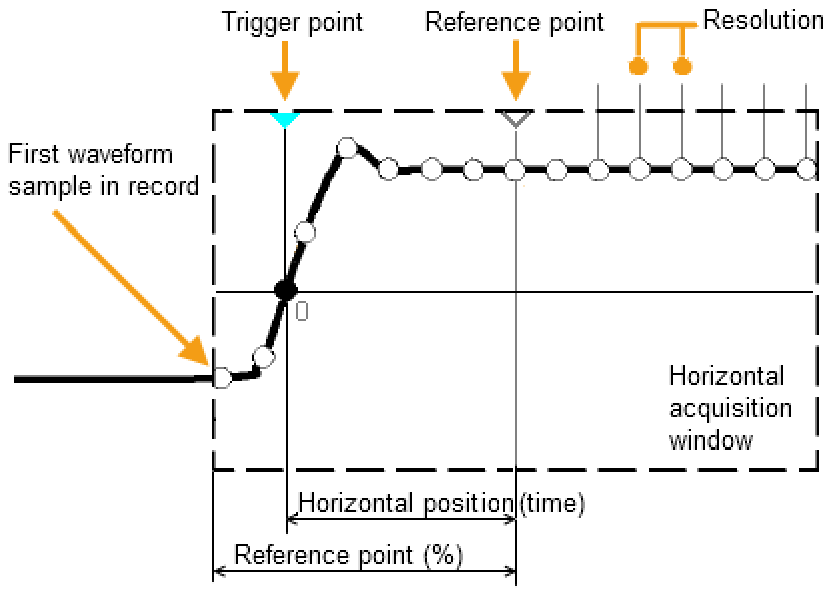
3.3 Horizontal Setup

Horizontal settings, also known as timebase settings, adjust the waveforms in horizontal direction.

Typically, the trigger is the determining point of the waveform record. In many scenarios, you want to analyze the waveform some time before or after the trigger. To adjust the horizontal acquisition window to the waveform section of interest, you can use the following parameters:

- The **horizontal position** defines the time distance of the trigger point (the zero point of the diagram) to the reference point. Changing the horizontal position, you can move the trigger point, even outside the screen.

- The **reference point** is the rescaling center of the time scale on the screen. If you modify the time scale, the reference point remains fixed on the screen, and the scale is stretched or compressed to both sides of the reference point.



Unlike vertical settings, which are waveform-specific, the horizontal settings apply to all active waveforms.

There are several ways to adjust horizontal settings:

- Use the controls in the Horizontal functional block of the front panel to scale the waveforms, and to set the position.
- Drag one finger horizontally on the screen to change the horizontal position. Spread or pinch two fingers to change the horizontal scale.
- Use shortcuts to adjust scale and position.
- Use the comprehensive menu to adjust all horizontal settings.

3.3.1 HORIZONTAL Controls

POSITION
Changes the trigger position, the time distance from the trigger point to the reference point (trigger offset). The trigger point is the zero point of the diagram. Thus, you can set the trigger point even outside the diagram and analyze the signal some time before or after the trigger.

Turn clockwise to move the position to the right, and press the knob to reset the value to zero. The current value is shown in the information bar.

In zoom and FFT, the knob sets the position in the active diagram. Tap the diagram that you want to adjust. If a zoom is active, either the position of the zoom window or the trigger position is changed. In an FFT diagram, the knob changes the center frequency in frequency domain, or the trigger position in time domain.

Remote command:
`TIMebase:POSition` on page 181
`REFCurve<m>:HORizontal:POSition` on page 202
`TIMebase:ZOOM:TIME` on page 198

SCALE
Adjusts the time scale of the horizontal axis for all signals, also known as timebase.

Turn clockwise to stretch the waveforms - the scale value time/div decreases. Press the knob to toggle between coarse and fine scale adjustment. The current value is shown in the information bar.

In a zoom diagram, the knob changes the zoom scale. In an FFT diagram, the knob changes the span. Tap the diagram that you want to adjust.

Remote command:
`TIMebase:SCALe` on page 181
`REFCurve<m>:HORizontal:SCALe` on page 202
`TIMebase:ZOOM:SCALe` on page 197

ZOOM
Enables or disables the zoom with the last configuration.

See also: .Chapter 5.1, "Zoom", on page 67

Remote command:
`TIMebase:ZOOM:STATe` on page 197

HORIZONTAL
Opens the menu to configure horizontal scale, position, and reference point. The current scale and position is shown in the top information bar.

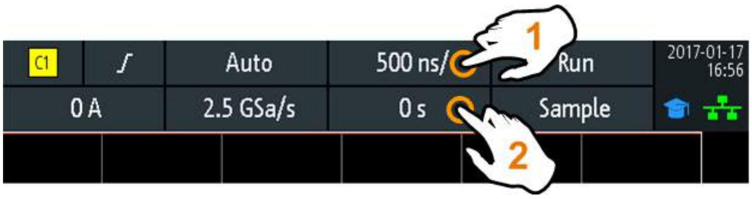
If zoom is active, you can find also the zoom scale and zoom position in this menu.

ACQUISITION
Opens the "Acquisition" menu. Here you control the data processing - how the waveform is built from the captured samples. The current acquisition mode is shown in the top information bar.

See also: Chapter 3.4, "Acquisition Setup", on page 47.

3.3.2 Shortcuts for Horizontal Settings

To adjust the horizontal scale and the position, you can use the shortcuts on the top of the display. The labels show the current values.

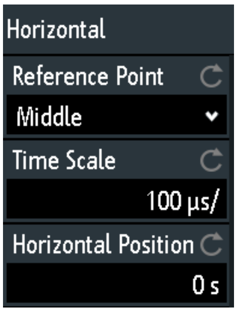


1 = adjust horizontal scale
2 = adjust horizontal position

3.3.3 Horizontal Settings

The comprehensive "Horizontal" menu contains all horizontal settings. In zoom mode, also zoom settings are listed in the menu.

► To open the menu, press the HORIZONTAL key.



Reference Point
Defines the time reference point in the diagram. It is indicated by a gray triangle outline at the bottom of the diagram.

The reference point is the rescaling center of the time scale on the screen. If you modify the time scale, the reference point remains fixed on the screen, and the scale is stretched or compressed to both sides of the reference point.

The reference point defines which part of the waveform is shown. By default, the reference point is displayed in the center of the window, and you can move it to the left or right.

Remote command:
`TIMebase:REFerence` on page 181

Time Scale
Defines the time scale of the horizontal axis for all signals, also known as timebase. The scaling is indicated in the information bar above the grid.

Remote command:
`TIMebase:SCALe` on page 181

Horizontal Position

Defines the trigger position, the time distance from the trigger point to the reference point (trigger offset). The trigger point is the zero point of the diagram. Changing the horizontal position, you can move the trigger, even outside the screen.

If you want to see a section of the waveform some time before or after the trigger, enter this time as horizontal position. The requested waveform section is shown around the reference point. Use positive values to see waveform sections after the trigger - the waveform and the diagram origin move to the left.

The value is indicated in the information bar above the grid.

Remote command:
`TIMebase:POSition` on page 181

3.4 Acquisition Setup

During an acquisition, the R&S RTB2000 captures the signal and converts it to digital samples. The digital samples are processed according to the acquisition settings. The result is a waveform record that is displayed on the screen and stored in memory.

The number of waveform samples in one waveform record is called the record length. The rate of recording waveform samples - the number of waveform samples per second - is the sample rate. The higher the sample rate, the better is the resolution and the more details of the waveform are visible.

A sufficient resolution is essential for correct reconstruction of the waveform. If the signal is undersampled, aliasing occurs - a false waveform is displayed. To avoid aliasing and accurately reconstruct a signal, the sample rate must be at least 3 to 5 times the fastest frequency component of the signal.

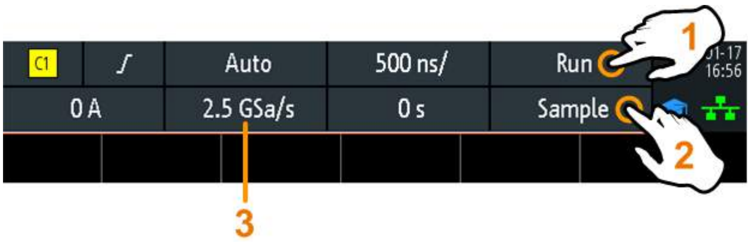
There are several ways to adjust and control acquisition:

- Use the controls in the Trigger functional block of the front panel to start and stop acquisition. See Chapter 4.1, "TRIGGER Controls", on page 51.
- Use shortcuts to adjust the acquisition mode, and to perform a single acquisition.
- Use the comprehensive menu to adjust all acquisition settings.

► To start or stop acquisition, use the RUN STOP and SINGLE keys in the Trigger section at the front panel.

3.4.1 Shortcuts for Acquisition Settings

To adjust the acquisition mode, and to perform a single acquisition, you can use the shortcuts on the top of the display. The labels show the current values.

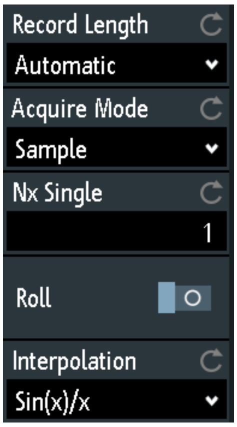


1 = start or stop a continuous acquisition, or start a single acquisition if SINGLE is active
2 = adjust the acquisition mode
3 = shows the current sample rate for information

3.4.2 Acquisition Settings

Acquisition settings define the processing of the captured samples in the instrument. The current acquisition mode and sample rate are shown in the top information bar.

► To adjust acquisition settings, press the ACQUISITION key.



Record Length
The instrument acquires the signals with an either automatically or selected record length. Record length is the number of waveform samples that are stored in one waveform record.

With automatic record length, the instrument combines sample rate and record length to acquire at maximum sample rate. In connection with persistence, this mode can display rare signal anomalies.

Each predefined record length corresponds to a maximum number of history segments, which are stored in the instrument's memory. If option R&S RTB-K15 is installed, you can display the history segments.

Remote command:
`ACQuire:POINts:AUTomatic` on page 182
`ACQuire:POINts[:VALue]` on page 183

Acquire Mode

Defines how the waveform is built from the captured samples. There are two general methods to build the waveform record: sample decimation and waveform arithmetic.

Sample decimation reduces the data stream of the ADC to a stream of waveform points with lower sample rate and a less precise time resolution. The R&S RTB2000 uses decimation, if the waveform sample rate is less than the ADC sample rate. The acquisition modes "Peak Detect" and "High Resolution" are decimation methods.

Waveform arithmetic builds the resulting waveform from several consecutive acquisitions of the signal. The acquisition modes "Average" and "Envelope" are arithmetic methods.

"Sample"	Usually, most signals are displayed optimally with this acquisition mode but very short glitches might remain undiscovered by this method. If the sample rate of the waveform is less than the ADC sample rate, the instrument reduces the number of samples: one of n samples in a sample interval is recorded as waveform point, the other samples are discarded (decimation). Conversely, if the sample rate of the waveform is higher than the ADC sample rate, the instrument adds waveform points to the captured samples using an interpolation method.
"Peak Detect"	The minimum and the maximum of n samples are recorded as waveform points, the other samples are discarded. Thus the instrument can detect fast signal peaks at slow time scale settings that would be missed with other acquisition modes.
"High Resolution"	The average of n captured sample points is recorded as one waveform sample. Averaging reduces the noise, the result is a more precise waveform with higher vertical resolution.
"Average"	The average is calculated from the data of the current acquisition and a number of consecutive acquisitions before. The method reduces random noise. It requires a stable, triggered and repetitive signal. The number of acquisitions for average calculation is defined with "No. of Averages" on page 50.
"Envelope"	Each acquisition is done in sample decimation mode, and the minimum and maximum values over some consecutive acquisitions build the envelope. The resulting diagram shows two envelope waveforms below and above the normal waveform: the minimums (floor) and maximums (roof), representing the borders in which the signal occurs. this method is useful, for example, if the waveform is noisy but the noise is not relevant for the measurement.
"Envelope + PD"	Each acquisition is done in peak detect decimation mode, and the most extreme values of all consecutive acquisitions build the envelope. This method is more precise than "Envelope".

Remote command:
`ACQuire:TYPE` on page 184
`CHANnel<m>:ARIThmetics` on page 184
`CHANnel<m>:TYPE` on page 183
`ACQuire:PEAKdetect` on page 185
`ACQuire:HRESolution` on page 185

No. of Averages

Defines the number of waveforms used to calculate the average waveform, if "Acquire Mode" = "Average". The higher the number, the better the noise is reduced.

To restart the average calculation, press the CLEAR SCREEN key.

Remote command:
`ACQuire:AVERage:COUNt` on page 185
`ACQuire:AVERage:RESet` on page 186

Nx Single

Sets the number of waveforms that are acquired with a SINGLE acquisition.

Remote command:
`ACQuire:NSINgle:COUNt` on page 173

Roll

Enables the roll mode.

The roll mode moves the captured input data on the display from the right to the left. The instrument shows the waveform immediately, without waiting for the complete acquisition of the waveform record. The roll mode displays the untriggered, continuous signal.

Remote command:
`TIMebase:ROLL:ENABle` on page 186

Interpolation

Selects the interpolation method if interpolation is required to get the defined record length.

"Sin(x)/x"	Two adjacent ADC sample points are connected by a sin(x)/x curve, and also the adjoining sample points are considered by this curve. The interpolated points are placed on the resulting curve. This interpolation method is the default method. It is precise and shows the best signal curve.
"Linear"	Two adjacent ADC sample points are connected by a straight line, the interpolated points are placed on the line. You see a polygonal waveform similar to the real signal, and also the ADC sample points as vertexes.
"Sample-Hold"	The ADC sample points are displayed like a histogram. For each sample interval, the voltage is taken from the sample point and considered as constant, and the intervals are connected with vertical lines. Thus, you see the discrete values of the ADC.

Remote command:
`ACQuire:INTerpolate` on page 186

4 Trigger

Triggering means to capture the interesting part of the relevant waveforms. Choosing the right trigger type and configuring all trigger settings correctly allows you to detect various incidents in signals.

A trigger occurs if the trigger conditions are fulfilled. The instrument acquires continuously and keeps the sample points to fill the pretrigger part of the waveform record. When the trigger occurs, the instrument continues acquisition until the posttrigger part of the waveform record is filled. Then it stops acquiring and displays the waveform. When a trigger is recognized, the instrument does not accept another trigger until the acquisition is complete.

Trigger conditions include:

- Source of the trigger signal (channel)
- Trigger type and its setup
- Trigger mode

In addition, the horizontal position of the trigger point and the reference point are important to display the interesting part of the signal. See Chapter 3.3, "Horizontal Setup", on page 43.

The trigger level and position are marked in the grid. The markers have the color of the trigger source. Information on the most important trigger settings is shown in the upper information bar.

There are several ways to set up the trigger:

- Use the controls in the Trigger functional block of the front panel.
- Use shortcuts to adjust the trigger source, trigger mode, and main parameters of the trigger type.
- Use the comprehensive menu to select the trigger type and to adjust all trigger settings.

4.1 TRIGGER Controls

The keys and the rotary knob in the Trigger functional block adjust the trigger and start or stop acquisition.

The green LED above the LEVELS knob lights up when the instrument triggers.

TRIGGER
Opens the "Trigger" menu.

SOURCE
Changes the analog trigger source. Press the key repeatedly until the required source is selected. If a digital source was selected in the "Trigger" menu, the key opens the menu.

The key lights up in the color of the selected channel, and the selected source is shown in the information bar.

Remote command:
`TRIGger:A:SOURce` on page 188

AUTO NORM
Toggles the trigger mode between "Auto" and "Norm". The key lights up in red if the trigger mode is "Norm". The current mode is also shown in the information bar.

"Auto" The instrument triggers repeatedly after a time interval if the trigger conditions are not fulfilled. If a real trigger occurs, it takes precedence. This mode helps to see the waveform even before the trigger is set. The waveform on the screen is not synchronized, and successive waveforms are not triggered at the same point of the waveform.

"Norm" The instrument acquires a waveform only if a trigger occurs, that is, if all trigger conditions are fulfilled. If no trigger occurs, no waveform is acquired and the last acquired waveform is displayed. If no waveform was captured before, nothing is displayed.

Remote command:
`TRIGger:A:MODE` on page 188

LEVELS
The rotary knob changes the trigger level. Turn clockwise to move up the trigger level.

Pressing the knob sets the level to 50% of the signal amplitude.

Remote command:
`TRIGger:A:LEVel<n>[:VALue]` on page 190
`TRIGger:A:FINDlevel` on page 190

FORCE TRIGGER
Provokes an immediate single acquisition. Use this key if the acquisition is running in normal mode and no valid trigger occurs. Thus you can confirm that a signal is available and use the waveform display to determine how to trigger on it.

RUN STOP
Starts and stops the continuous acquisition. A green light indicates a running acquisition. A red light shows that acquisition is stopped. At slow timebases, a yellow light indicates that the acquisition is completed.

The status is shown also at the right end of the information bar: "Run", "Complete", "Trig?" (waiting for trigger, in normal trigger mode) or "Not ready" (working).

Remote command:
RUN on page 173
RUNContinous on page 173
STOP on page 174
ACQuire:STATe on page 174

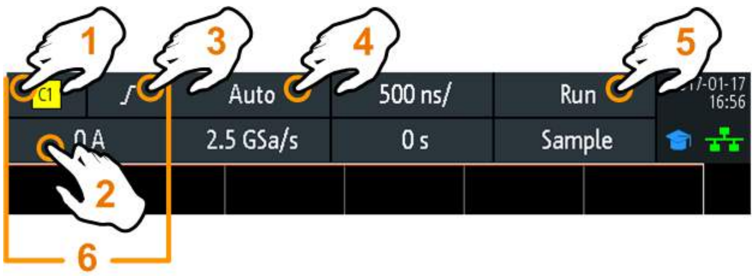
SINGLE
Starts a specified number of acquisitions. A white light indicates that the instrument is in single mode. The information bar shows "Complete" if the acquisition has been finished.

To set the number of acquisitions, press the ACQUISITION key and enter "Nx Single".

Remote command:
SINGle on page 173
RUNSingle on page 173

4.2 Shortcuts for Trigger Settings

To adjust the trigger source, mode, and trigger type specific settings, you can use the shortcuts on the top of the display. The labels show the current values.



1 = adjust the trigger source
2 = open the keypad to enter the value of the trigger level or threshold
3 = adjust slope or polarity
4 = adjust the trigger mode
5 = start or stop a continuous acquisition, or start a single acquisition if SINGLE is active
6 = available settings depend on the trigger type

4.3 General Trigger Settings

General trigger settings are independent of the trigger type. They are highlighted in the above figure and described in the current section. The other trigger settings are specific for individual trigger types, and they are described in the following sections.

Trigger Mode

Toggles the trigger mode between "Auto" and "Auto". The trigger mode determines the behavior of the instrument if no trigger occurs. The current setting is shown in the information bar.

"Auto" The instrument triggers repeatedly after a time interval if the trigger conditions are not fulfilled. If a real trigger occurs, it takes precedence. This mode helps to see the waveform even before the trigger is set. The waveform on the screen is not synchronized, and successive waveforms are not triggered at the same point of the waveform.

"Norm" The instrument acquires a normal waveform only, if a trigger occurs, that is, if all trigger conditions are fulfilled. If no trigger occurs, no waveform is acquired and the last acquired waveform is displayed. If no waveform was captured before, nothing is displayed.

Remote command:
`TRIGger:A:MODE` on page 188

Trigger Type

Selects the trigger type.

"Edge"	Triggers on signal edges. See Chapter 4.4, "Edge Trigger", on page 56.
"Width"	Triggers on pulse width. See Chapter 4.5, "Width Trigger", on page 57.
"Video"	Triggers on various PAL, NTSC and HDTV standard video signals. See Chapter 4.6, "Video Trigger", on page 60.
"Pattern"	Triggers on logical combinations of the input channels. See Chapter 4.7, "Pattern Trigger", on page 62.
"Timeout"	Triggers on signal level timeout. See Chapter 4.8, "Timeout Trigger", on page 64.
"Line"	The line trigger uses the waveform of the power supply's alternating line voltage (typically 50 Hz or 60 Hz AC) as the trigger signal source. Use this trigger to detect issues related to the frequency of the power grid. The line trigger does not have any settings.
"Serial Bus"	Triggers on a serial bus. Requires that at least one protocol option R&S RTB-K1, -K2, or -K3 is installed, a serial bus is configured, and a decoded signal is available. See Chapter 9.1.1, "Protocol - Common Settings", on page 114.

Remote command:
`TRIGger:A:TYPE` on page 189

Source
Selects the trigger source.

"C1, C2, C3, C4"	Select one of the analog input channels as trigger source.
"D0 to D15"	Select one of the digital channels as trigger source if MSO option R&S RTB-B1 is installed.
"Extern"	Sets the external trigger input on the front panel as trigger source.
"B1, B2"	Serial buses 1 or 2, used for triggering on protocols. Only available, if the trigger type "Serial Bus" is selected.

Remote command:
`TRIGger:A:SOURce` on page 188

Hold Off, Hold Off Time
Enables the hold off and defines the "Hold Off Time". The next trigger occurs only after the hold off time has passed.

The trigger hold off defines when the next trigger event is recognized after the current trigger event. Thus, it affects the next trigger to occur after the current one. Hold off helps to obtain stable triggering when the oscilloscope is triggering on undesired events.

Remote command:
`TRIGger:A:HOLDoff:MODE` on page 189
`TRIGger:A:HOLDoff:TIME` on page 190

4.4 Edge Trigger

The edge trigger is the most common trigger type. The trigger occurs when the signal from the trigger source passes the trigger level in the specified direction (slope).

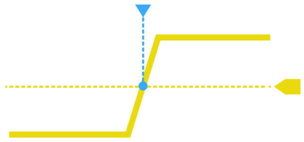
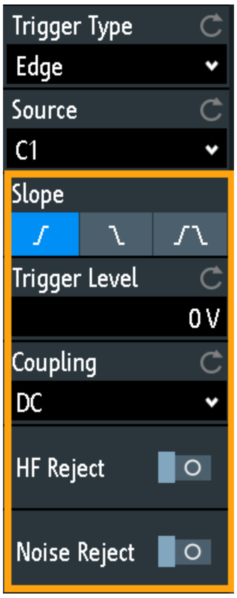


Figure 4-1: Edge trigger event with positive slope (rising edge)

► TRIGGER > "Trigger Type" = "Edge"



Slope
Sets the edge direction for the trigger. You can trigger on:

- rising edge, that is a positive voltage change
- falling edge, that is a negative voltage change
- rising and falling edge

Remote command:
`TRIGger:A:EDGE:SLOPe` on page 190

Trigger Level, Threshold
Sets the voltage level or threshold for the trigger.

You can also drag the trigger level marker on the display, or turn the Levels knob. To set the trigger level to 50% of the signal amplitude, press the Levels knob.

For width and timeout trigger, the trigger level is the threshold of the trigger source.

Remote command:
`TRIGger:A:LEVel<n>[:VALue]` on page 190
`TRIGger:A:FINDlevel` on page 190

Coupling
Sets the coupling for the trigger source.

"AC"	Alternating current coupling. A highpass filter removes the DC offset voltage from the trigger signal.
"DC"	Direct current coupling. The trigger signal remains unchanged.
"LF Reject"	Sets the trigger coupling to high frequency. A 15 kHz highpass filter removes lower frequencies from the trigger signal. Use this mode only with very high frequency signals.

Remote command:
`TRIGger:A:EDGE:COUPling` on page 191

HF Reject
Enables or disables an additional 5 kHz lowpass filter in the trigger path. This filter removes higher frequencies and is available with AC and DC coupling.

You can use either "HF Reject" or "Noise Reject".

Remote command:
`TRIGger:A:EDGE:FILTer:HFReject` on page 191

Noise Reject
Enables or disables an additional 100 MHz lowpass filter in the trigger path. This filter removes higher frequencies and is available with AC and DC coupling.

You can use either "HF Reject" or "Noise Reject".

Remote command:
`TRIGger:A:EDGE:FILTer:NREJect` on page 191

4.5 Width Trigger

The width trigger compares the pulse width (duration) with given time limits. It detects pulses with an exact pulse width, pulses shorter or longer than a given time, and also pulses inside or outside the allowable time range. The pulse width is measured at the trigger level.

You can use the width trigger, for example, to trigger on glitches.

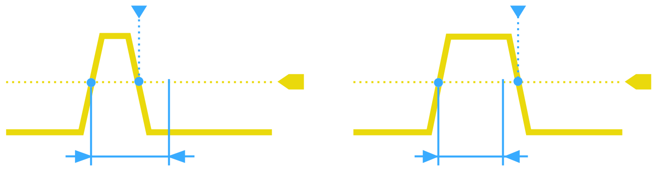


Figure 4-2: Pulse width is shorter (left) or longer (right) than a given duration (also known as glitch trigger)

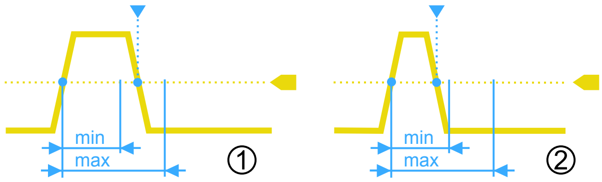


Figure 4-3: Pulse width is inside or outside an allowable time range

1 = Inside: min width < pulse < max width
2 = Outside: pulse < min width OR pulse > max width

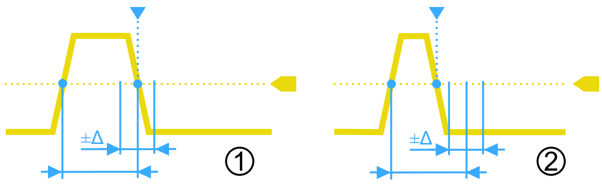
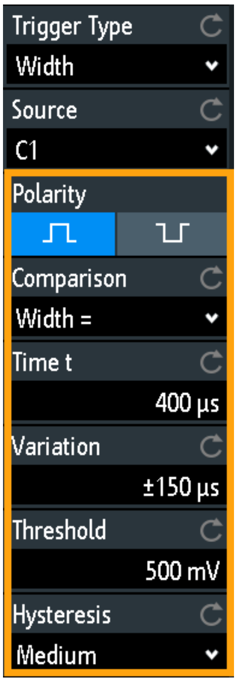


Figure 4-4: Pulse width is equal or unequal to a given duration, with optional tolerance

1 = Equal: width-Δ < pulse < width+Δ
2 = Unequal: pulse < width-Δ OR pulse > width+Δ

► TRIGGER > "Trigger Type" = "Width"



Polarity

Sets the polarity of the pulse. You can trigger on:

- positive going pulse, the width is defined from the rising to the falling slopes.
- negative going pulse, the width is defined from the falling to the rising slopes.

Remote command:
`TRIGger:A:WIDTh:POLarity` on page 192

Comparison

Sets how the measured pulse width is compared with the given limits.

"Width >"	Triggers on pulse width longer than the reference "Time t".
"Width <"	Triggers on pulse width shorter than the reference "Time t".
"Width ="	Triggers on pulse width equal to the reference "Time t" if "Variation" Δt = 0. If "Variation" ≠ 0, this setting triggers on pulses within the range t±Δt.
"Width ≠"	Triggers on pulses unequal to the reference "Time t", if "Variation" Δt = 0. If "Variation" ≠ 0, this setting triggers on pulses outside a range *t ± Δt*.

"Inside", "Outside" — Triggers on pulses inside or outside a range specified with "Time t1" and "Time t2".
This method is an alternative setting to the range definition with "Time t" and "Variation". The values are interdependent. "Variation" and "Time t" are adjusted, if you change t1 and t2, and vice versa.

Remote command:
`TRIGger:A:WIDTh:RANGe` on page 192

Time t
Sets the reference time, the nominal value for comparison settings "Width >", "Width <", "Width =", and "Width ≠".

Remote command:
`TRIGger:A:WIDTh:WIDTh` on page 192

Variation
Sets a range Δt to the reference "Time t", if comparison is set to "Width =" or "Width ≠". The instrument triggers on pulses inside or outside the range t±Δt.

Remote command:
`TRIGger:A:WIDTh:DELTa` on page 193

Time t1, Time t2
Set the lower and upper time limits defining the time range if "Width =" or "Width ≠" is set for comparison. "Time t" and "Variation" are adjusted accordingly.

Remote command:
`TRIGger:A:WIDTh:RANGe` on page 192
`TRIGger:A:WIDTh:DELTa` on page 193

Threshold
Threshold of the trigger source channel, used as trigger level for the width trigger.

See also "Threshold" on page 42 and "Trigger Level, Threshold" on page 56.

Remote command:
`TRIGger:A:LEVel<n>[:VALue]` on page 190
`CHANnel<m>:THReshold` on page 178

Hysteresis
Hysteresis of the trigger source channel, see "Hysteresis" on page 42.

Remote command:
`CHANnel<m>:THReshold:HYSTeresis` on page 179

4.6 Video Trigger

The video or TV trigger is used to analyze analog baseband video signals. You can trigger on baseband video signals from standard definition and high definition standards connected to an analog channel input or to the external trigger input.

The trigger level is determined and set automatically by the instrument.

First select the standard and the signal polarity, then decide to trigger on lines or fields and enter the specific settings.

► TRIGGER > "Trigger Type" = "Video"

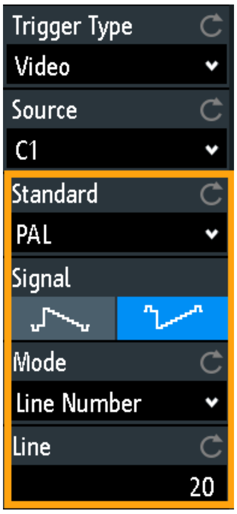


Figure 4-5: Video trigger menu

Standard

Selects the color television standard.

You can trigger on various standard-definition television (SDTV) signals:

- "PAL"
- "NTSC"
- "SECAM"
- "PAL-M"
- "SDTV 576i" (PAL and SECAM)

High-definition television (HDTV) standards are indicated by the number of active lines and the scanning system:

- "HDTV 720p"
- "HDTV 1080p" (p for progressive scanning)
- "HDTV 1080i" (i for interlaced scanning)

Remote command:

`TRIGger:A:TV:STANdard` on page 193

Signal

Selects the polarity of the signal. Note that the sync pulse has the opposite polarity. If the video modulation is positive, the sync pulses are negative. If the modulation is negative, sync pulses are positive. The edges of the sync pulses are used for triggering, therefore incorrect polarity setting causes a sporadic triggering by the video information.

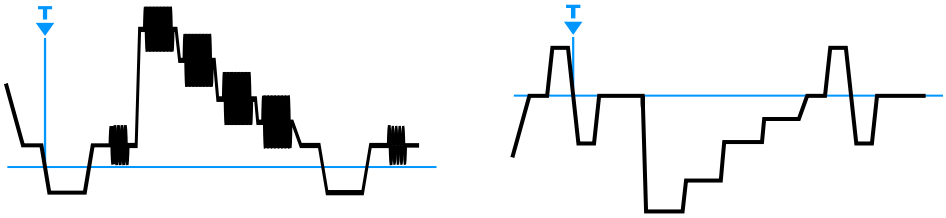


Figure 4-6: Positive video signal with negative bi-level sync pulse (SDTV, left) and negative signal with positive tri-level sync pulse (HDTV, right)

Remote command:
TRIGger:A:TV:POLarity on page 193

Mode

Selects from the following the trigger conditions:

"All Frames" The oscilloscope triggers on the beginning of all video signal frames.

"Odd Frames" The oscilloscope triggers on the beginning of video signal frames with an odd frame number.

"Even Frames" The oscilloscope triggers on the beginning of video signal frames with an even frame number.

"All Lines" The oscilloscope triggers on the beginning of all video signal lines.

"Line Number" Enables triggerin on an exact "Line" number.

Remote command:
TRIGger:A:TV:FIELd on page 194

Line

Sets an exact line number if "Mode" is "Line Number". The oscilloscope triggers exactly on the beginning of the selected line in any field.

Remote command:
TRIGger:A:TV:LINE on page 194

4.7 Pattern Trigger

The pattern trigger is a logic trigger. It provides any logical combination of the input channels and supports you in verifying the operation of digital logic. Additionally, you can set a time limitation to the pattern. Thus you can also trigger on bus patterns of parallel buses.

The channel pattern is configured in the "Logic Editor" dialog box.

► TRIGGER > "Trigger Type" = "Pattern" > "Edit Pattern"

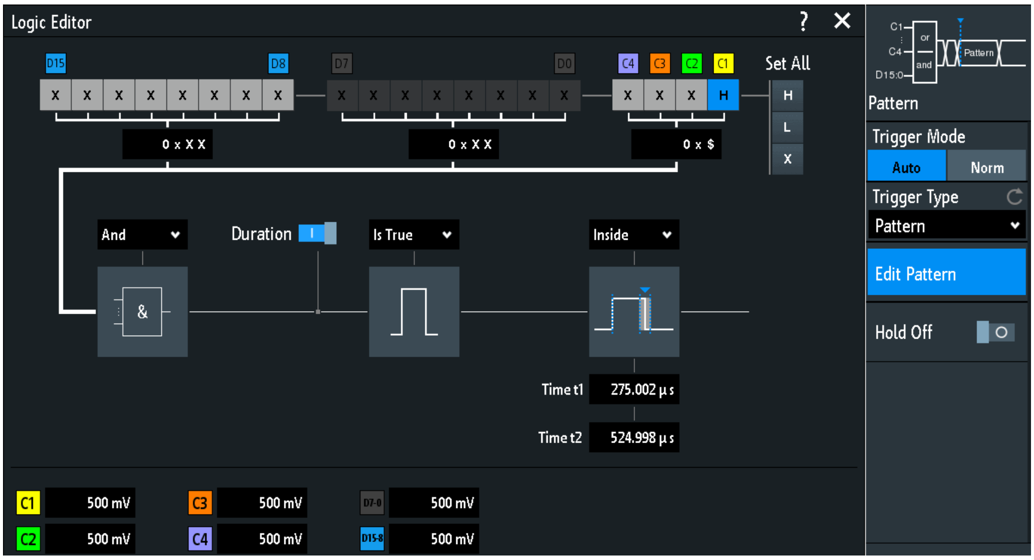


Figure 4-7: Pattern trigger with logic editor

H | L | X, Set All

Defines the pattern by selecting the state "H" (high), "L" (low) or "X" (do not care) for each active analog and digital channel.

The word length of the pattern depends on the number of available analog and digital channels.

Analog channels: 2 bit for 2-channel instruments, 4 bit for 4-channel instruments.

Digital (16 bit): the logic channels D0, D1,...,D15 are only available with MSO option R&S RTB-B1.

Thus the pattern can have 2, 4, 18, or 20 bits.

Use "Set All" to set all channels to the same state.

Remote command:
`TRIGger:A:PATTern:SOURce` on page 195

And | Or

Sets the logical combination of the channel states.

"AND"	All defined states must be true.
"OR"	At least one of the defined states must be true.

Remote command:
`TRIGger:A:PATTern:FUNCtion` on page 195

Duration
The switch has the following two effects:

- Selects the mode of the True | False comparison.
- Enables or disables the Time limitation.

True | False
Defines whether the instrument triggers on fulfillment of the logical condition, or on violation.

- If Duration = on, the instrument triggers when the logic combination "Is True" or "Is False" for a specified time duration.
- If Duration = off, the instrument triggers when the logic combination is found in the signal ("Goes True"), or if it disappears ("Goes False").

Remote command:
`TRIGger:A:PATTern:CONDition` on page 195

Time limitation
To set a time limitation for the pattern, you have several possibilities. They are similar to the setting of a pulse width, see Chapter 4.5, "Width Trigger", on page 57.

- "Timeout" and "Time t"
  Define a minimum time during which the signals match the pattern condition.
- "Width >" or "Width <" and "Time t"
  Triggers if the pattern condition changes before or after the specified time.
- "Width =", "Time t1" and "Variation"
  Triggers if the pattern condition is fulfilled for a duration "Time t1" ± "Variation".
- "Width ≠", "Time t1" and "Variation"
  Triggers if the pattern condition is fulfilled for a duration shorter than "Time t1" - "Variation", or longer than "Time t1" + "Variation".
- "Inside", "Time t1" and "Time t2"
  Triggers if the pattern condition is fulfilled for a duration between "Time t1" and "Time t2". These settings are an alternative setting to the definition with "Width =". The time values are interdependent and adjusted accordingly.
- "Outside", "Time t1" and "Time t2"
  Triggers if the pattern condition is fulfilled for a duration shorter than "Time t1", or longer than "Time t2". These settings are an alternative setting to the definition with "Width ≠". The time values are interdependent and adjusted accordingly.

Remote command:
`TRIGger:A:PATTern:MODE` on page 196
`TRIGger:A:PATTern:WIDTh:RANGe` on page 196
`TRIGger:A:PATTern:WIDTh[:WIDTh]` on page 197
`TRIGger:A:PATTern:WIDTh:DELTa` on page 197

4.8 Timeout Trigger

The timeout trigger checks if the signal stays above or below the threshold voltage for a specified time lapse. In other words, the trigger occurs if the trigger source signal does not cross the threshold during the specified time.

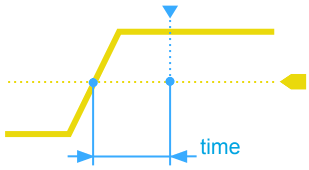


Figure 4-8: Timeout trigger with range Stays High

► TRIGGER > "Trigger Type" = "Timeout"

Figure 4-9: Timeout trigger menu

Range
Selects the relation of the signal level to the threshold:

Stays High	The signal level stays above the trigger level.
Stays Low	The signal level stays below the trigger level.
Stays High| Low	The signal level stays above or below the trigger level.

Time
Defines the time limit for the timeout at which the instrument triggers.

Threshold
Threshold of the trigger source channel, used as trigger level for the timeout trigger.

See also "Threshold" on page 42 and "Trigger Level, Threshold" on page 56.

Remote command:
`TRIGger:A:LEVel<n>[:VALue]` on page 190
`CHANnel<m>:THReshold` on page 178

Hysteresis
Hysteresis of the trigger source channel, see "Hysteresis" on page 42.

Remote command:
`CHANNel<m>:THReshold:HYSTeresis` on page 179

5 Waveform Analysis

5.1 Zoom

The zoom magnifies a part of the waveform to view more details. The zoom is applied to all active analog and digital channels and math waveforms. The waveforms are displayed with a shorter time scale while the vertical scale remains unchanged.

► To activate the zoom, press the ZOOM key.

When you activate the zoom, two windows are displayed: the original waveform diagram at the top, and the zoom window at the bottom.

5.1.1 Using the Zoom

There are several ways to adjust the zoom:

- Use finger gestures on the screen.
- Use the horizontal SCALE and POSITION knobs.
- Use the menu to enter exact numerical values. See Chapter 5.1.2, "Zoom Settings", on page 69.
  Alternatively, tap the zoom scale or zoom position label in the zoom window and enter a value on the keypad.

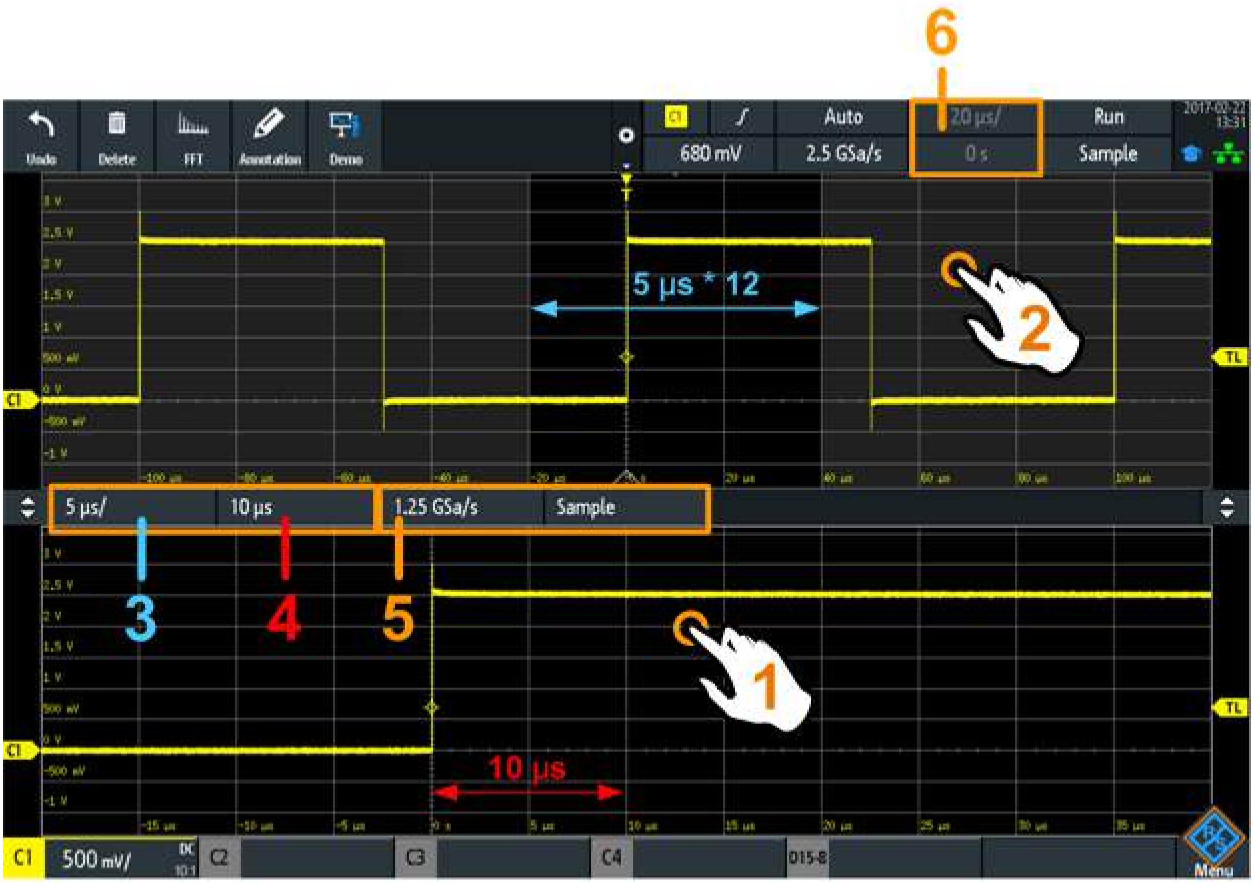


Figure 5-1: Zoom display: zoom is in the bottom window, normal waveform in the upper window

1	= tap to activate zoom settings
2	= tap to activate normal waveform settings
3 (blue)	= zoom scale and width of the zoom area
4 (red)	= zoom position
5	= Sample rate in zoom window
6	= horizontal scale and position of the normal waveform

To adjust the zoom using gestures

1. To change the zoom position, drag one finger horizontally in the zoom window.
2. To change the zoom scale and width of the zoom area, spread or pinch two fingers in horizontal direction.

To adjust the zoom using the horizontal rotary knobs

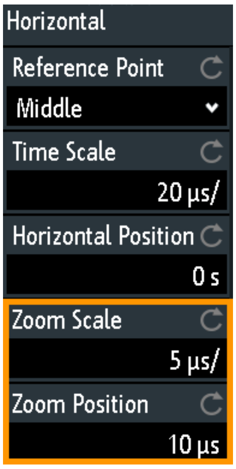
1. To set the focus to the zoom window (lower window), tap in the zoom.
2. To change the zoom scale and width of the zoom area, turn the horizontal SCALE scale knob.
3. To change the zoom position, turn the POSITION knob.
4. To set the focus to the normal waveform, tap the upper window.

Now the knobs are applied to the normal waveform and adjust time scale and horizontal position of the waveform.

5.1.2 Zoom Settings

Zoom settings are listed in the "Horizontal" menu.

1. If the zoom is off, press the ZOOM key to activate the zoom.
2. Press the HORIZONTAL key.



Zoom Scale
Defines the horizontal scale for the zoom window in seconds per division. The scaling determines the width of the zoom area (12 divisions * scaling per division), the timebase of the zoom window. The zoom area is indicated in the original waveform window.

Remote command:
`TIMebase:ZOOM:SCALe` on page 197

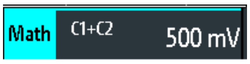
Zoom Position
Defines the distance of the trigger point to the reference point in the zoom window. The value determines the position of the zoom area in the upper window.

Remote command:
`TIMebase:ZOOM:TIME` on page 198

5.2 Mathematics

A math waveform is a calculated waveform. You can calculate it out of two analog channels using several predefined operations.

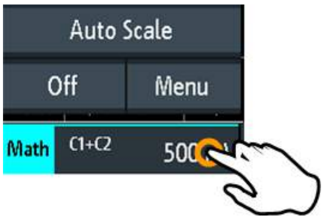
The waveform label at the bottom of the display shows the main settings of the math waveform: sources, operation, and vertical scale.



You can analyze math waveforms in the same way as channel waveforms: use zoom, perform automatic and cursor measurements, and save as reference waveform.

To configure math waveforms

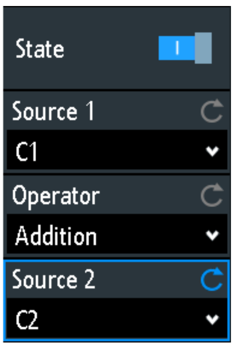
1. To enable the math waveform, press the MATH key.
2. To define the math waveform:
   a) Press the MATH key to open the "Math" menu.
   b) Select the source (operands).
   c) Select the mathematical operation.
   See also: Chapter 5.2.1, "Math Waveform Settings", on page 70.
3. To adjust vertical scale and position, use the rotary knobs in the Vertical section of the front panel. See: Chapter 3.2.1, "VERTICAL Controls", on page 36.
4. To autoscale the math waveform, use the short menu.



5.2.1 Math Waveform Settings

The "Math" menu provides functions to configure a calculated waveform.

► To open the "Math" menu:
   a) Tap the menu icon in the lower right corner of the screen.
   b) Scroll down. Select "Math".



State
Activates the mathematics function and displays the resulting math waveform.

Remote command:
`CALCulate:QMATH:STATe` on page 198

Source 1, Source 2

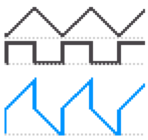
Define the first and the second source for the mathematical operation (operands). The sources can be any active analog channel.

Remote command:
`CALCulate:QMATh:SOURce<m>` on page 199

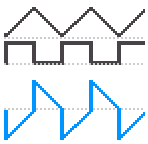
Operator

Defines the operation to be performed on the specified sources.

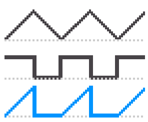
"Addition" Adds the values of the two sources: *Source1* + *Source2*.



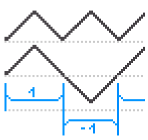
"Subtraction" Subtracts the values of source 2 from the values of source 1: *Source1* - *Source2*



"Multiplication" Multiplies the values of the two sources: *Source1* * *Source2*



"Division" Divides the values of the first source by the values of the second source: *Source1* / *Source2*
If the second source has small amplitudes, the math result increases quickly. If the second source crosses zero, the result would be a range of +∞ to -∞. In this case, instead of 0 V, the calculation function uses the value that the least significant bit (LSB) of the second operand represents. For an 8-bit value, for example, 1/256 is used.



Remote command:
`CALCulate:QMATh:OPERation` on page 199

5.3 Reference Waveforms

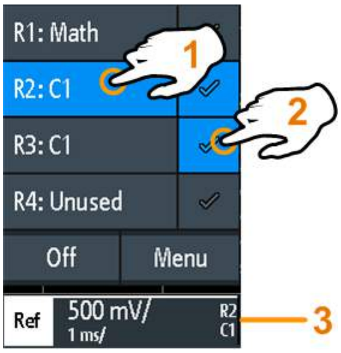
To compare waveforms and analyze differences between them, you can display reference waveforms.

Reference waveforms are waveform data stored in the internal reference storages. Four reference waveforms are available and can be displayed: R1 to R4.

The display of a reference waveform is independent from the display of the source waveform; you can change the vertical and also horizontal scales and positions. The current scale values are shown in the waveform label of the reference waveform.

Short menu

The short menu shows the status of all reference waveforms.



1 = select a reference waveform
2 = display a reference waveform
3 = Reference waveform label with vertical and horizontal scale, reference number and source waveform

File format

Waveforms can be saved as reference waveforms. The file format is TRF. Files can be saved to and loaded from internal memory or external USB flash device. If the TRF file is saved to internal storage, the amount of waveform data is limited to 256 kB (without settings and header data).

TRF is the specific binary format for reference waveforms of the R&S RTB2000. It contains the amplitude value of each sample that is displayed on the sreen (8 bit or 16 bit long). For peak-detect waveforms, 2 values per sample are saved. The file contains also time information (time of the first sample and the sample interval) and current instrument settings.

The data can be loaded as reference waveform for further use on the instrument. It is not intended for analysis outside the R&S RTB2000. The settings are only available for load if the file was stored to the internal storage and never written to a USB flash device.

5.3.1 Using References

To create and display a reference waveform

1. To activate the reference waveform and open the "References" menu, press the REF key twice.
2. To create a reference waveform from an active waveform:
   a) Select the "Source" waveform.
   b) Select the target "Reference".
   c) Tap "Copy"

   The new reference waveform is created on top of its origin, and it has the focus.
3. To change the scaling and position, use the horizontal and vertical POSITION and SCALE knobs.

   See also:
   - Chapter 3.2.1, "VERTICAL Controls", on page 36
   - Chapter 3.3.1, "HORIZONTAL Controls", on page 44

To save a waveform as reference waveform

You can save any active waveform directly as reference waveform to a file.

1. To open the "References" menu, tap the menu icon and select "References".
2. Tap "Save Reference".
3. Select the waveform that you want to save: "Source".
4. Tap "Destination".
5. Select the "Location" (internal or USB).
6. If you save the file on USB flash device, you can set a target folder.
   a) Double-tap the target folder. If the folder does not exist, you can create a new one.
      The folder opens.
   b) Tap "Accept Dir." .
7. Enter the "File Name".
8. Optionally, add a comment.
9. Tap "Save"
10. Close the dialog box.

To load a reference waveform

1. To open the "References" menu, tap the menu icon and select "References".
2. Select the target "Reference" waveform.
3. Tap "Load Reference".

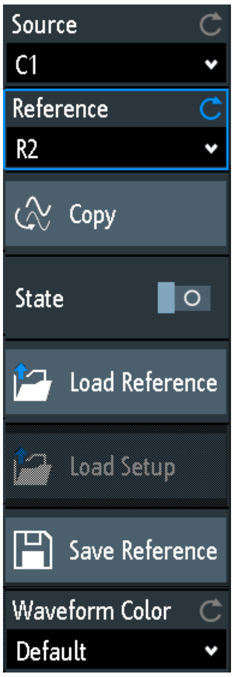
4. Select the "Location", the folder, and the reference file.
5. Tap "Load".

   The instrument writes the waveform data to the selected reference waveform and displays it.

5.3.2 Settings for Reference Waveforms

► To open the "References" menu:

a) Tap the menu icon in the lower right corner of the screen.
b) Scroll down. Select "References".



Source

Defines the source of the reference waveform. Any active channel, math or reference waveform can be selected.

Remote command:
REFCurve<m>:SOURce on page 200
REFCurve<m>:SOURce:CATalog? on page 200

Reference
Selects one of the four possible reference waveforms.

Copy
Copies the "Source" waveform to the selected reference waveform. The reference waveform is kept until you update it or load another waveform to the reference.

Remote command:
REFCurve<m>:UPDate on page 201

State
Activates the reference waveform and displays it.

Remote command:
REFCurve<m>:STATe on page 201

Load Reference
Provides functions to load a reference waveform.

Select the "Location" of the waveform file (internal or USB), and the file. Tap "Load Reference".

You can also delete obsolete files in the dialog box.

Remote command:
REFCurve<m>:LOAD on page 201

Load Setup
Loads the device settings that were used to obtain the stored reference waveform. The settings are only available if the file was stored to the internal storage and never written to a USB flash device.

Load the reference waveform first, and then the settings. If settings were not stored, "Load Setup" is not active.

Remote command:
REFCurve<m>:LOAD:STATe on page 202

Save Reference
Opens a dialog box to save a waveform as reference waveform:

"Source"	Select the waveform to be saved. You can save any active analog channel, math or reference waveform, or logic pod.
"Destination"	Select the "Location" (internal directory or USB flash device), and the target directory.
"File Name"	Enter the filename. If a file with the same filename already exists in the destination directory, it will be overwritten without notification.
"Comment"	Optionally, enter text to describe the waveform.
"Save"	Saves the data.

Remote command:
`REFCurve<m>:SAVE` on page 201

Waveform Color
Selects a color for the reference waveform. The default color is white. You can select another monochrome color, or a color scale.

The color scales are described in "Waveform Color" on page 40.

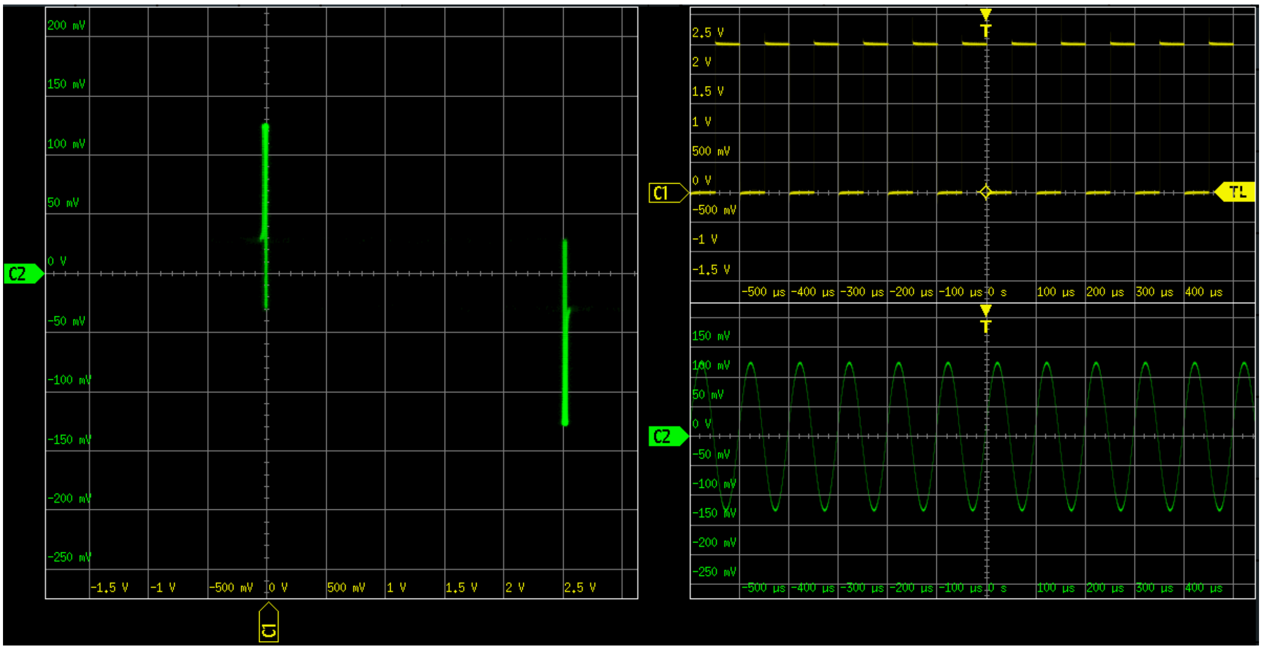
5.4 XY-Diagram

XY-diagrams combine the voltage levels of two waveforms in one diagram. They use the amplitude of a second waveform as the x-axis, rather than a timebase. Thus, you can measure phase shift, for example. With harmonically related signals, the resulting XY-diagrams are Lissajous patterns. XY-diagrams can also be used to display the IQ representation of a signal.

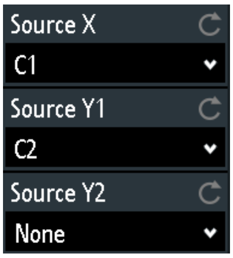
Together with the XY-diagram, the time diagrams of the source signals are displayed in separate grids. It is also possible to define two source signals in y-direction for comparison.

1. Press the APPS SELECTION key.
2. Select "XY".
3. Make sure that the signals, the trigger, and the acquisition are set up correctly. The required menus are available in XY-mode.

Remote command: `DISPlay:MODE` on page 203



To analyze the signal in the XY-diagram, you can use cursor measurements. You can select specific cursor measurement types:"Voltage X", "Voltage Y1", "Voltage Y2" use 2 cursor lines, "Voltage X-Y1" and "Voltage X-Y2" use 4 cursor lines.



Source X

Defines the source to be displayed in x-direction in an XY-diagram, replacing the usual timebase. The source can be any of the analog channels.

Remote command:
`DISPlay:XY:XSOurce` on page 203

Source Y1

Defines the first signal to be displayed in y-direction in an XY-diagram. The source can be any of the active analog channels.

Remote command:
`DISPlay:XY:Y1Source` on page 203

Source Y2

Defines an optional second source to be displayed in y-direction in an XY-diagram. The source can be any of the analog channels. The setting is only relevant for 4-channel R&S RTB2000 instruments.

Remote command:
`DISPlay:XY:Y2Source` on page 204

6 Measurements

6.1 Quick Measurements

Quick measurement performs a set of automatic measurements on the selected input channel. The measurements cannot be configured. The results are displayed directly at the waveform (WF) or in the bottom result line (L) and are updated continuously.

If the instrument detects a period in the signal, the quick measurement measures the first cycle and displays the results. If no period is detected, it measures the complete waveform.

► Press the QUICKMEAS key to activate quick measurement.

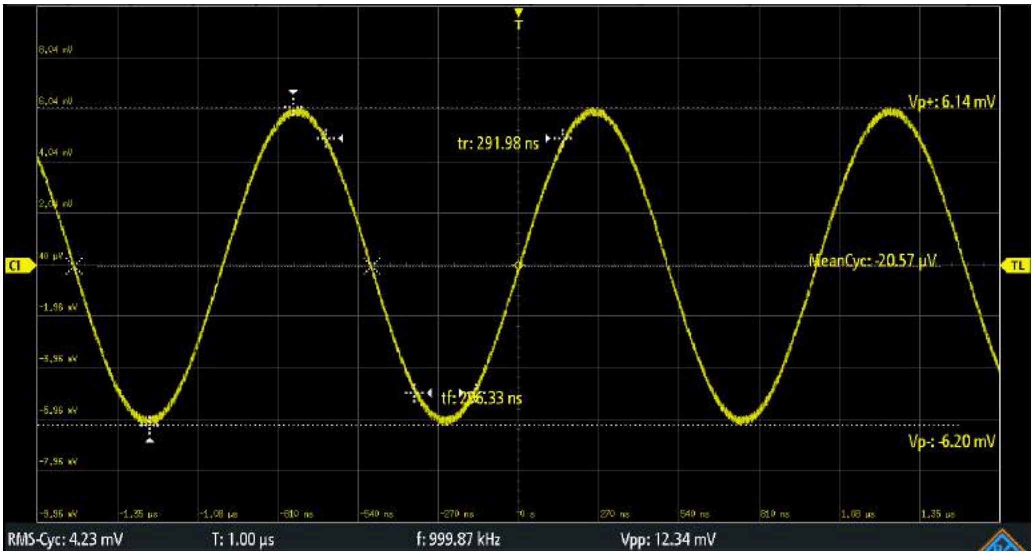


Table 6-1: Results of quick measurement

Label	Description	Display
Vp+	Positive peak value	WF
Vp-	Negative peak value	WF
tr	Rising time of the first rising edge	WF
tf	Falling time of the first falling edge	WF
MeanCyc	Mean value	WF
RMS-Cyc	RMS	L
T	Period length	L
f	Frequency	L
Vpp	Peak to peak value	L

Quick measurement is not available on math and reference waveforms. Channels other than the selected one are switched off in quick measurement mode. When quick measurement is active, cursor measurements are not possible, but you can use automatic measurements in parallel.

► Press the QUICKMEAS key again to deactivate quick measurement.

The results are deleted on the display.

Remote commands:

- `MEASurement:AON` on page 204
- `MEASurement:AOFF` on page 204
- `MEASurement:ALL[:STATe]` on page 204
- `MEASurement:AREsult?` on page 204

6.2 Automatic Measurements

You can perform up to four different measurements simultaneously.

To configure automatic measurements in the Measure menu

1. Press the MEAS key.
2. In the menu, select the "Meas. Place", the number of the measurement that you want to configure.
3. If the measurement is off, enable "Measure <n>".
4. Select the measurement type:
   a) Tap "Type"
   b) Select the tab of the required measurement category.
   c) Select the measurement type.

   The measurement types are described in Chapter 6.2.2, "Measurement Types", on page 80.
5. Select the "Source".
   The selection list shows all possible sources. If the waveform is not active, it is activated automatically when selected as measurement source.
6. Some measurement types require additional settings. Scroll down the menu, and adjust the additional settings if necessary.
   See also: Chapter 6.2.3, "Settings for Automatic Measurements", on page 84.

6.2.1 Measurement Results

The measurement results are shown in a line below the grid.

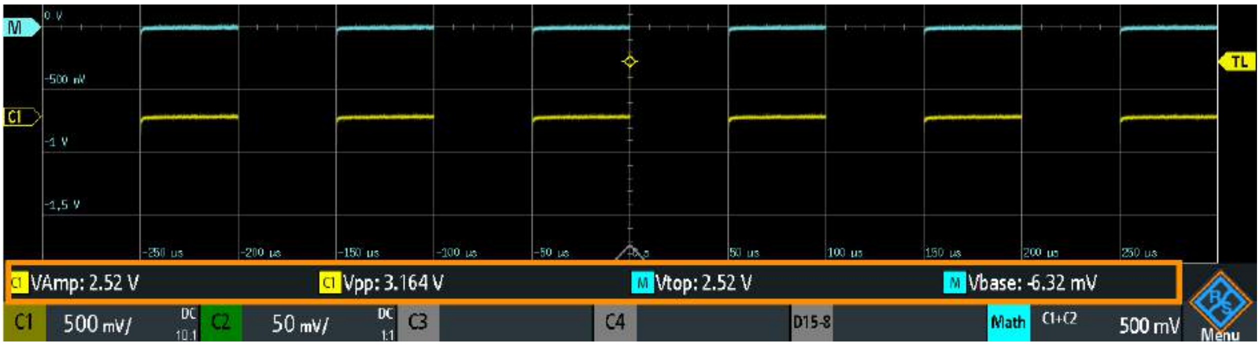


Figure 6-1: Results of four active measurements

If a result cannot be determined, "?" is displayed. Adjust the horizontal and vertical settings if the instrument cannot measure.

If the measurement result is outside the measurement range and clipping occurs, the results are marked with "clipping+" or "clipping-". Adjust the vertical scale to get valid results.

In addition to the current measurement results, you can enable a statistic evaluation. It returns the current, minimum and maximum measurement values, the average and standard deviation, and the number of measured waveforms. The results are shown in a separate tab below the grid.

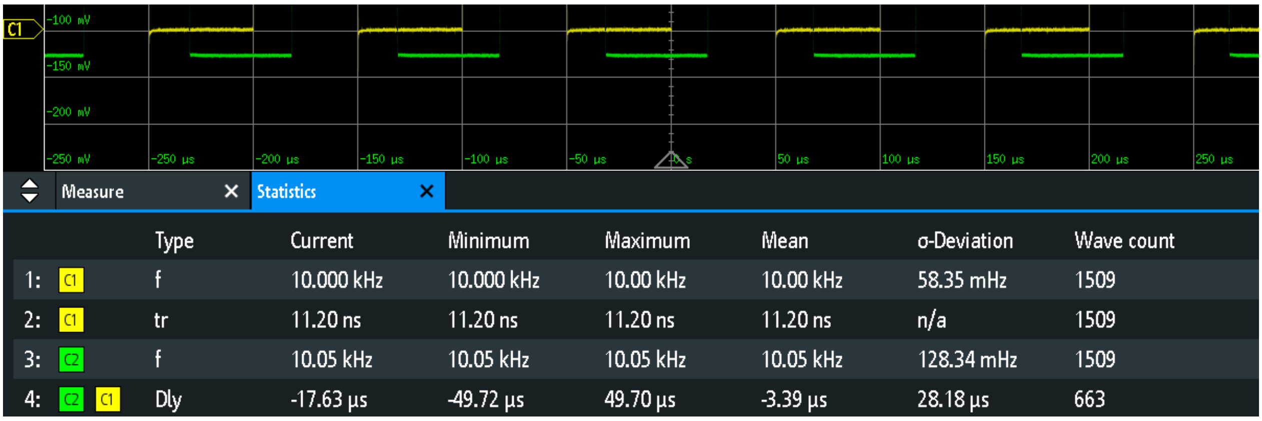


Figure 6-2: Statistic results of four active measurements

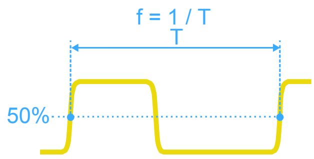
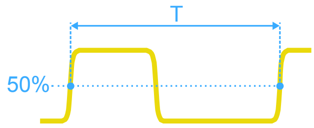
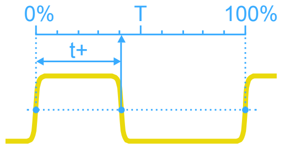
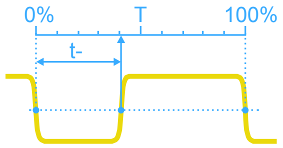
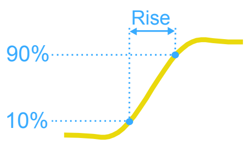
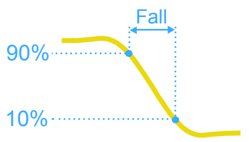
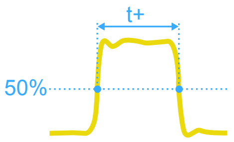
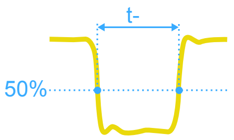
Remote commands are described in:

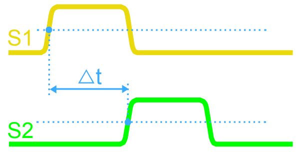
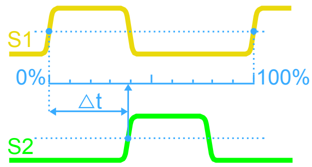
- Chapter 10.7.2.2, "Measurements Results", on page 209

6.2.2 Measurement Types

The R&S RTB2000 provides many measurement types to measure time and amplitude characteristics, and to count pulses and edges.

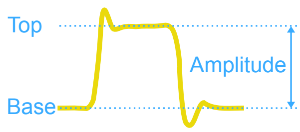
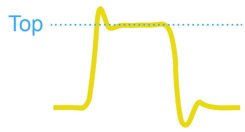
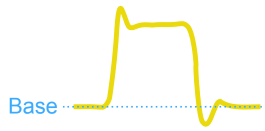
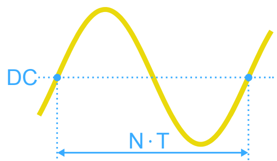
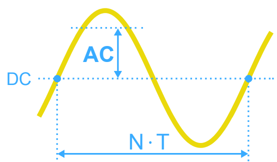
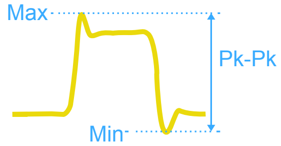
6.2.2.1 Horizontal Measurements (Time)

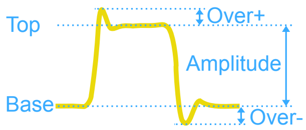
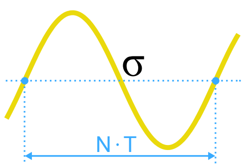
Meas. type	Symbol	Description	Graphic / formula
Frequency	f in Hz	Frequency of the signal, reciprocal value of the measured first period.	
Period	T in s	Time of the first period, measured on the 50% level. The measurement requires at least one complete period of the signal.	
Duty cycle +	Dty+ in %	Width of the first positive pulse in relation to the period in %. The measurement requires at least one complete period of the signal.	Dty+ = t+ / T * 100% 
Duty cycle -	Dty- in %	Width of the first negative pulse in relation to the period in %. The measurement requires at least one complete period of the signal.	Dty- = t- / T * 100% 
Rise time	tr in s	Rise time of the first rising edge, the time it takes the signal to rise from the 10% level to the 90% level.	
Fall time	tf in s	Fall time of the first falling edge, the time it takes the signal to fall from the 90% level to the 10% level.	
Positive pulse width	PW+ in s	Duration of the first positive pulse: time between a rising edge and the following falling edge measured on the 50% level.	
Negative pulse width	PW- in s	Duration of the first negative pulse: time between a falling edge and the following rising edge measured on the 50% level.	

Meas. type	Symbol	Description	Graphic / formula
Delay	Dly in s	Time difference between two slopes of the same or different waveforms, measured on the 50% level. Not available for cursor measurements	
Phase	Phs in °	Phase difference between two waveforms, measured on the 50% level. Not available for cursor measurements	Phase = Δt / T * 360° 

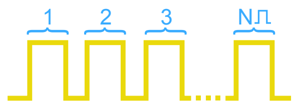
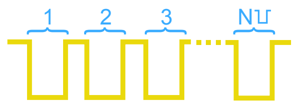
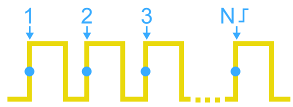
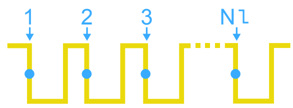
6.2.2.2 Vertical Measurements (Amplitude)

The unit of most amplitude measurement results depends on the measured source.

Meas. type	Symbol	Description	Graphic / formula
Amplitude	VAmp	Difference between the top level and the base level of the signal. The measurement requires at least one complete period of the signal.	
Top level	Vtop	High level of the displayed waveform - the upper maximum of the sample distribution, or the mean value of the high level of a square wave without overshoot. The measurement requires at least one complete period of the signal.	
Base level	Vbase	Low level of the displayed waveform - the lower maximum of the sample distribution, or the mean value of the low level of a square wave without overshoot. The measurement requires at least one complete period of the signal.	
Mean cycle	MeanCyc in V	Mean value of the left-most signal period.	
RMS cycle	RMS-Cyc in V	RMS (root mean square) value of the voltage of the left-most signal period.	
Peak to peak	Vpp	Difference of maximum and minimum values.	

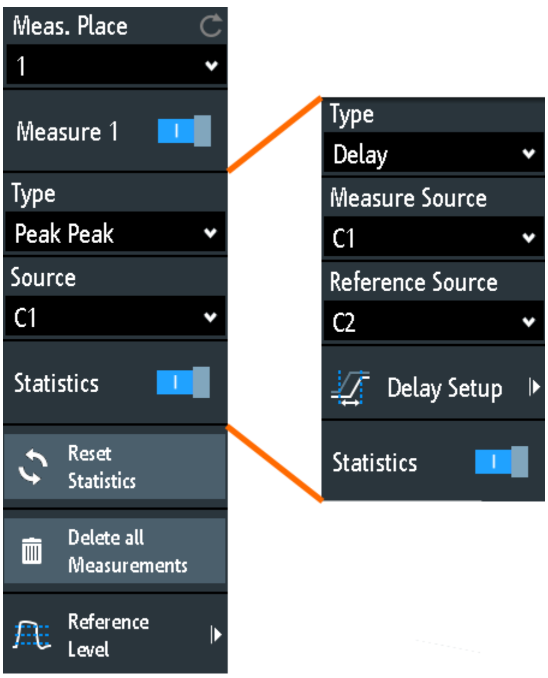
Meas. type	Symbol	Description	Graphic / formula
Peak+	Vp+	Maximum value within the displayed waveform.	
Peak-	Vp-	Minimum value within the displayed waveform.	
Overshoot	+Ovr -Ovr in %	Overshoot of a square wave after a rising or falling edge. It is calculated from measurement values top level, base level, local maximum, local minimum, and amplitude.	$\text{Over+} = \frac{\text{Max}_{\text{local}} - \text{Top}}{\text{Amplitude}} \cdot 100\%$ $\text{Over}- = \frac{\text{Base} - \text{Min}_{\text{local}}}{\text{Amplitude}} \cdot 100\%$ 
Mean value	Mean	Arithmetic average of the complete displayed waveform.	$\text{Mean} = \frac{1}{N}\sum_{k=1}^{N} x_k$
RMS value	RMS	RMS (root mean square) value of the voltage of the complete displayed waveform.	$\text{RMS} = \sqrt{\frac{1}{N}\sum_{k=1}^{N} {x_k}^2}$
σ-Std. deviation	σ	Standard deviation of the displayed waveform.	$\sigma = \sqrt{\frac{1}{N-1}\sum_{k=1}^{N} (x_k - \text{Mean})^2}$
σ-Std. dev. cycle	σ-Cyc	Standard deviation of one cycle, usually of the first, left-most signal period.	
Crest factor	Crest	The crest factor is also known as peak-to-average ratio. It is the maximum value divided by the RMS value of the displayed waveform.	$\text{Crest} = \frac{\text{Max} \mid x_k \mid}{\text{RMS}}$

6.2.2.3 Counting

Meas. type	Symbol	Description	Graphic / formula
Positive pulse	CntP+	Number of positive pulses on the display. The mean value of the signal is determined. If the signal passes the mean value, an edge is counted. A positive pulse is counted if a rising edge and a following falling edge are detected.	
Negative pulse	CntP-	Number of negative pulses on the display. The mean value of the signal is determined. If the signal passes the mean value, an edge is counted. A negative pulse is counted if a falling edge and a following rising edge are detected.	
Positive slope	CntS+	Number of rising edges on the display. The instrument determines the mean value of the signal and counts an edge every time the signal passes the mean value in the specified direction.	
Negative slope	CntS-	Number of falling edges on the display. The instrument determines the mean value of the signal and counts an edge every time the signal passes the mean value in the specified direction.	

6.2.3 Settings for Automatic Measurements

► To open the "Measure" menu, press the MEAS key.



In the measurement menu, you can configure up to 4 parallel measurements (also called measurement places). Available measurement types depend on the type of the selected waveform.

Meas. Place
Selects one of the four available measurement places to be configured or activated.

Measure <n>
Activates or deactivates the selected measurement.

Remote command:
`MEASurement<m>[:ENABle]` on page 205

Type
Defines the measurement type to be performed on the selected source. Depending on the type, different results are displayed in the result line.

Select the tab of the required measurement category, and then the measurement type. The "Basic" tab provides the most common measurements: peak to peak, period, frequency, rise time, fall time, mean cycle, and RMS cycle.

Remote command:
`MEASurement<m>:MAIN` on page 205

Source
Selects an analog channel, reference or math waveform as the source of the selected measurement. If MSO option R&S RTB-B1 is installed, active digital channels are available as measurement sources.

If the waveform is not active, it is activated automatically when selected as measurement source.

Remote command:
`MEASurement<m>:SOURce` on page 207

Measure Source, Reference Source
Set the source waveforms for delay and phase measurement, where two sources are required.

Remote command:
`MEASurement<m>:SOURce` on page 207

Delay Setup: Measure Source and Reference Source
Set the edges to be used for delay measurement. You can measure the delay between two rising edges, two falling edges, between rising and next falling edge, and vice versa.

Remote command:
`MEASurement<m>:DELay:SLOPe` on page 208

Statistics
Activates or deactivates the statistical evaluation for the selected measurement.

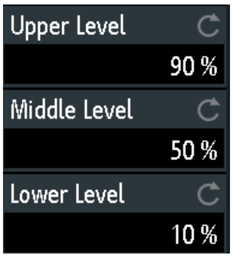
Remote command:
`MEASurement<m>:STATistics[:ENABle]` on page 208

Reset Statistics
Deletes the statistical results for all measurements, and starts a new statistical evaluation if the acquisition is running.

Remote command:
`MEASurement<m>:STATistics:RESet` on page 209

Delete all Measurements
Deactivates all active measurements.

Reference Level



Set the lower and upper reference levels for rise and fall time measurements. Sets also the middle reference level used for phase and delay measurements. The levels are defined as percentages of the high signal level. The settings are valid for all measurement places.

Remote command:
`REFLevel:RELative:MODE` on page 214
`REFLevel:RELative:LOWer` on page 214
`REFLevel:RELative:MIDDle` on page 215
`REFLevel:RELative:UPPer` on page 214

6.3 Cursor Measurements

The cursor measurement determines the results at the current cursor positions. You can set the cursor lines manually at fixed positions, or they can follow the waveform.

Available results depend on the cursor type and the type of the waveform.

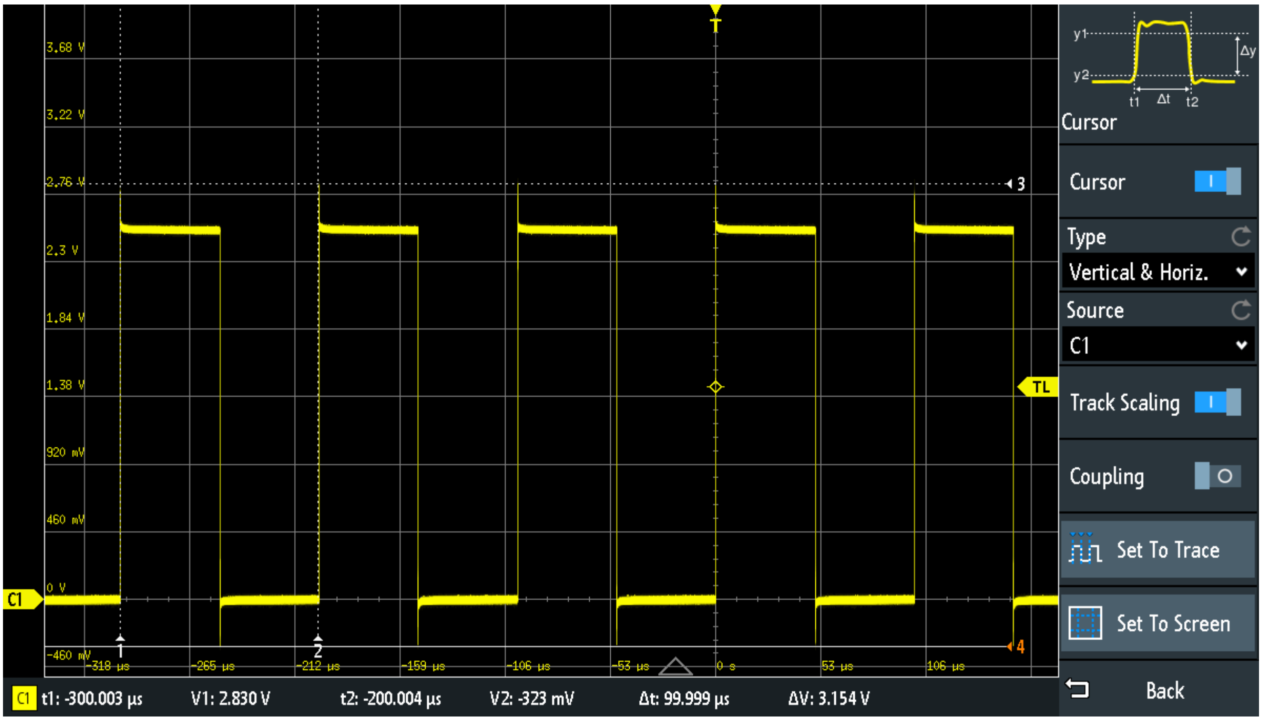


Figure 6-3: Cursor measurement with vertical and horizontal cursors and Set To Trace

Results = below the grid
Cursor lines 1, 2, 3 = not active
Cursor line 4 = active, can be moved by turning the NAVIGATION knob

To configure cursor measurements

1. Press the CURSOR key.

   The cursors are activated with the latest setting.

2. Press the CURSOR key again.

   The "Cursor" menu opens.

3. Select the cursor "Type".

4. Select the "Source", the waveform you want to measure.

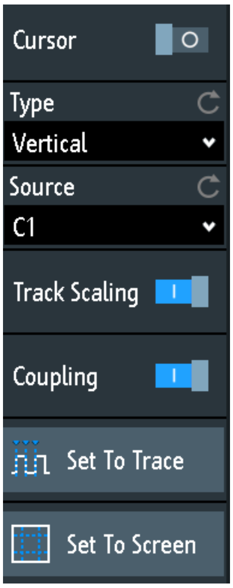
5. Set additional settings if necessary: Track Scaling, Coupling, Set To Trace, or Set To Screen.

6. To change the position of a cursor line, you can use several methods:
   - Drag the cursor line on the screen.
   - Press the NAVIGATION knob repeatedly until the required cursor line is active (marked with a solid line).
     Turn the knob to move the line.
   - Tap the corresponding result value in the result line at the bottom.
     The keypad opens, and you can enter an exact value.

6.3.1 Cursor Settings

► To open the "Cursor" menu:

a) Tap the "Menu" icon in the lower right corner of the screen.
b) Scroll down. Select "Cursor".



Cursor
Activates or deactivates the cursor measurement.

Remote command:
`CURSor<m>:STATe` on page 215

Type
Selects the cursor type. Depending on the type, different results are displayed in the result line at the bottom of the display.

The cursor lines can be set to the required position using the "Navigation" rotary knob, or by dragging a cursor line on the screen.

"Horizontal" Sets two horizontal cursor lines and measures the voltage values at the cursor positions, and the difference between the cursor lines.
Results: V1, V2, ΔV (for current measurements: A1, A2, ΔA, for FFT measurements: L in dBm)

"Vertical" Sets two vertical cursor lines and measures the time from the trigger point to each cursor line, the time between the cursor lines and the frequency calculated from that time.
Results: t1, t2, Δt, 1/Δt (for FFT measurements: frequencies)

"Vertical & Horiz."	Combines the "Horizontal" cursor and "Vertical" cursor measurements. Two horizontal and two vertical cursor lines are set. The voltages and times are measured at the cursor positions, as well as the delta of the voltage and time values. Results: t1, t2, Δt, V1, V2, ΔV
"V-Marker"	Sets two vertical cursors and measures the values of the waveform at the crossing points of the cursor lines and the waveform. Also, the differences of the two values in x- and y-direction are displayed. Results: t1, V1, t2, V2, Δt, ΔV

Remote command:
`CURSor<m>:FUNCtion` on page 216
`CURSor<m>:TRACking[:STATe]` on page 217 (V-Marker)

Source
Defines the source of the cursor measurement as one of the active waveforms.

You can use cursors on analog input signals, math waveform, reference waveforms, XY-diagram, and FFT waveform.

If option R&S RTB -B1 is installed, you can use the vertical cursor to measure individual logic channels, and the V-Marker to measure pods.

Remote command:
`CURSor<m>:SOURce` on page 216

Track Scaling
If enabled, the cursor lines are adjusted when the vertical or horizontal scales are changed. The cursor lines keep their relative position to the waveform.

If disabled, the cursor lines remain on their position on the display if the scaling is changed.

Remote command:
`CURSor<m>:TRACking:SCALe[:STATe]` on page 218

Coupling
If enabled, the cursors lines are coupled and moved together.

Press the NAVIGATION key to select whether both cursors or one cursor is moved. If coupling is disabled, pressing the NAVIGATION key toggles the single cursor lines.

Remote command:
`CURSor<m>:XCOupling` on page 218
`CURSor<m>:YCOupling` on page 218

Set To Trace
Autoset for cursor lines, sets the cursor lines to typical points of the waveform depending on the selected cursor type. For example, for voltage measurement ("Horizontal"), the cursor lines are set to the upper and lower peaks of the waveform. For time measurement ("Vertical"), the cursor lines are set to the edges of two consecutive positive or two consecutive negative pulses.

Remote command:
`CURSor<m>:SWAVe` on page 218

Set To Screen
Resets the cursors to their initial positions. Reset is helpful if the cursors have disappeared from the display or need to be moved for a larger distance.

Remote command:
`CURSor<m>:SSCReen` on page 218

7 General Instrument Setup

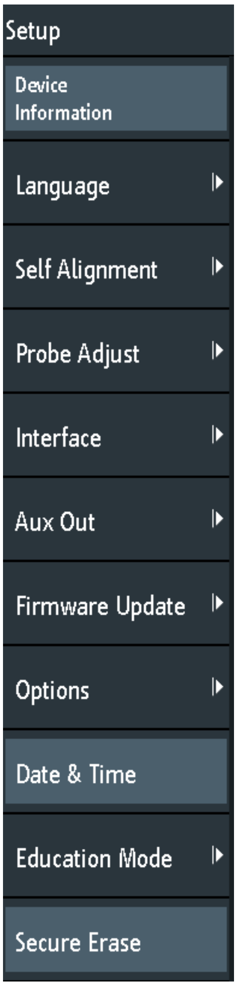
The general instrument settings are available in all operating modes.

7.1 Instrument Settings

► To open the "Setup" menu:

a) Tap the "Menu" rhomb icon in the lower right corner of the screen.

b) Scroll down. Select "Setup".



Device Information
Displays information on the instrument, such as its serial number, the installed firmware version and hardware information. This information is required if you have a support request. The dialog also contains a link to the "Open Source Acknowledgment".

Language
See Chapter 7.6, "Setting the Data, Time and Language", on page 99.

Self Alignment
See Chapter 7.5, "Performing a Self-Alignment", on page 98.

Probe Adjust
Opens the wizard for probe compensation. You can find this function also when you press the APPS SELECTION key.

See: Chapter 7.7, "Adjusting Passive Probes", on page 100.

Interface
Activates or deactivates additional instrument interfaces. Use these interfaces to communicate with the instrument, for example to read out data or automate the measuring station. USB and Ethernet (LAN) interfaces are installed in the rear panel. After selecting an interface, tap "Parameter" to define additional parameters.

USB ← Interface
Activates the type B USB interface on the rear panel for remote control. This USB interface provides a simple way to connect the instrument to a PC. The USB 2.0 standard is supported. Use a connection cable that is suitable for a type B USB interface.

See also: Chapter 8.2, "USB Connection", on page 105.

Ethernet ← Interface
Activates the Ethernet interface on the rear panel, which allows connecting the instrument to various other devices. Access to the instrument is controlled via its IP address.

By default, the instrument is set to use DHCP. If the instrument cannot find a DHCP server, it takes about two minutes until the Ethernet parameters are available.

See also: Chapter 8.1, "LAN Connection", on page 103.

Parameter ← Interface
Opens a dialog to configure Ethernet parameters, or to select the USB connection depending on the selected interface.

Aux Out

Opens the "Aux Out" menu to define which signals are generated at the AUX OUT front connector.

"Off" Disables the auxiliary output.

"Trigger Out" Outputs a pulse when the instrument triggers.

"10 MHz" Outputs a 10 MHz reference frequency.

"Function Generator"
Outputs the waveform specified in the "Function Generator" dialog.

"Mask Violation"
Outputs a pulse when a mask is violated.
This setting is only available if a mask is specified in the "Mask" dialog.

Remote command:
`TRIGger:OUT:MODE` on page 240

Firmware Update

See Chapter 7.9, "Updating the Firmware", on page 102.

Options

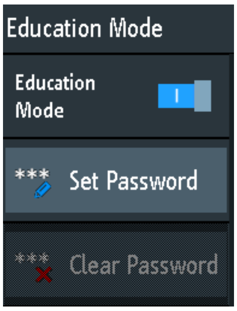
See Chapter 7.8, "Options", on page 101.

Date & Time

See Chapter 7.6, "Setting the Data, Time and Language", on page 99.

Education Mode

Disables several functions for educational purposes or enables these functions for normal usage.



"Education Mode"
: If enabled, the autoset, quick measurement and automatic measurement are disabled and not available. The active education mode is indicated in the upper right corner by a doctoral cap icon.

"Set Password"
: You can enter a password to prevent unauthorized activation or deactivation of the education mode.

"Clear Password"
: Deletes the password and allows all users enabling or disabling the education mode.

Remote command:
`SYSTem:EDUCation:PRESet` on page 238

Secure Erase

Deletes current instrument configuration data and user data from the internal storage (for example, reference files, equation sets, masks). Calibration data remains in the storage.

Use this function before you send the instrument to the service. If the instrument is used in a secured environment, the function ensures that all sensitive data is removed before the instrument leaves the secured area.

Unintended "Secure Erase" is prevented by a notification that explains what happens if you proceed. To start "Secure Erase", select "Yes", otherwise select "No". Do not turn off the instrument before the erasing process has been completed.

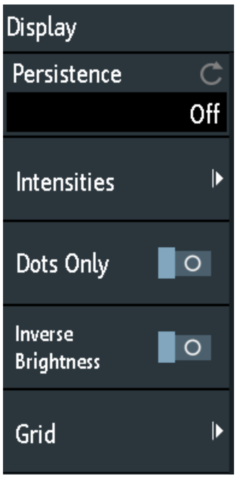
7.2 Display Settings

► To delete all waveforms and measurement results from the display, press the CLEAR SCREEN key.

► To open the "Display" menu:

a) Tap the "Menu" icon in the lower right corner of the screen.

b) Scroll down. Select "Display".



► To remove all waveforms and results from the display, press the CLEAR SCREEN key at the front panel.

Persistence
Defines the persistence (afterglow effect) of the waveform on the display.

"Off"	Deactivates persistence.
"Manual"	User-defined persistence according to "Time" setting.
"Infinite"	Activates persistence with infinite duration. Each new data point remains on the screen infinitely until this setting is changed or the persistence is cleared

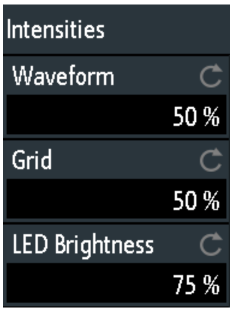
Remote command:
`DISPlay:PERSistence:TYPE` on page 231

Time ← Persistence
Specifies the afterglow duration if "Persistence" is set to "Manual". Each new data point remains on the screen for the time defined here. Values range from 50 ms (= default) to 12.8 s.

Remote command:
`DISPlay:PERSistence:TIME` on page 231

Intensities
Provides functions to define the brightness (relative luminous intensity) of display elements and control LEDs.

You can also open this menu directly using the INTENSITY key.



Waveform ← Intensities
Defines the brightness of the waveform lines in the diagram. Enter a percentage between 0 (barely visible) and 100% or turn the NAVIGATION knob to adjust the waveform brightness directly. The default value is 50%.

Remote command:
`DISPlay:INTensity:WAVeform` on page 233

Grid ← Intensities
Defines the brightness of the grid lines in the diagram. Enter a percentage between 0 (barely visible) and 100% or turn the NAVIGATION knob to adjust the grid brightness directly. The default value is 50%.

Remote command:
`DISPlay:INTensity:GRID` on page 233

LED Brightness ← Intensities
Defines the intensity of illuminated front panel keys and rotary knobs in percent.

Remote command:
`DISPlay:INTensity:BACKlight` on page 233

Dots Only
If activated, only the individual data points are displayed. If deactivated, the individual data points are connected by a line.

Remote command:
`DISPlay:STYLe` on page 234

Inverse Brightness
Inverts the brightness level of the signals. Normally, values that occur frequently are brighter than rare values. This setting inverts this behavior: Rare values are brighter than frequent values. Use this setting in combination with persistence to detect rare values within the waveform.

Remote command:
`DISPlay:PALette` on page 234

Grid

Defines how the grid is displayed.

"Lines"	Displays the grid as horizontal and vertical lines.
"Reticle"	Displays crosshairs instead of a grid.
"Off"	Removes the grid from the display.

Remote command:
`DISPlay:GRID:STYLe` on page 233

Annotation ← Grid
Enables or disables display of scale values and units for the x-axis and y-axis at the grid lines. Per default, grid labels are enabled.

Track Grid ← Grid
If enabled, the grid moves with the waveforms, if you change the waveform's position in horizontal or vertical direction.

If disabled (= default), the grid remains centered on the display, if you change the waveform's position.

7.3 Resetting the Instrument

Reset is helpful if the instrument is in undefined condition and cannot be operated.

To reset all waveform and measurement settings:

► Press Preset.

Preset does not change the display settings, for example, intensities and brightness. To reset these settings, restore the factory settings.

To restore the factory settings:

1. Press Save Load.

2. Tap "Setup".
3. Tap "Factory Default".

7.4 Locking the Touchscreen

The Touch Lock key locks the touchscreen to prevent unintended use. When the touchscreen is off, the key is illuminated. Press again to unlock the touchscreen.

7.5 Performing a Self-Alignment

The self-alignment aligns the data from several input channels vertically and horizontally to synchronize the timebases, amplitudes and positions.

Recommendation on performing the self-alignment:

- When putting the instrument into operation for the first time
- After a firmware update
- Once a week
- When major temperature changes occur (> 5°)

NOTICE

Warm-up and prepare the instrument

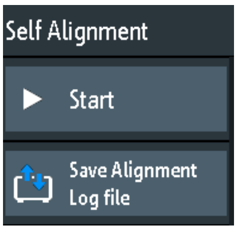
Make sure that the instrument has been running and warming up before you start the self-alignment. The minimum warm-up time is about 20 min.

Before the self-alignment, remove all probes, leads, and other connected lines from the instrument input.

1. Remove all probes, leads, and other connected lines from the instrument inputs.
2. Open the "Setup" menu.
3. Tap "Self Alignment"
4. Tap "Start".

   The alignment can take up to 15 minutes.

Description of settings



Start
Starts the internal self-calibration of the instrument. Status information is displayed on the screen.

Remote command:
`CALibration` on page 235

Save Alignment Log file
The log file records the results of the self-alignment. You save the log file.

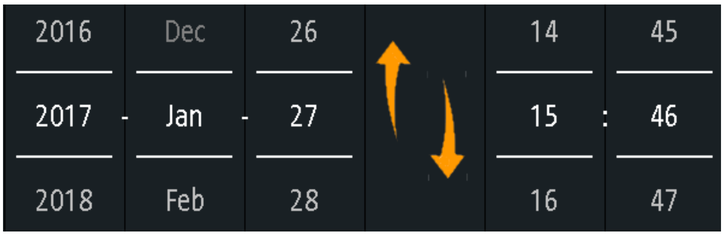
Remote command:
`CALibration:STATe?` on page 235

7.6 Setting the Data, Time and Language

The instrument has a date and time clock. You can adjust the clock to the local time, and you can select the display language. Supported languages are listed in the data sheet. The help is provided in English. A reboot of the instrument is not necessary.

To set date and time

1. Open the "Setup" menu.
2. Scroll down the menu. Tap "Date & Time".
3. Select the date: Scroll the year, month, and day columns until the required date is displayed.
4. Select the time: Scroll the hour and minute columns until the required time is displayed.



5. Tap "Save".

To set the language

1. Open the "Setup" menu.
2. Tap "Language".
3. Select the language.

   The language is changed immediately.

Description of settings

Language
Selects the language in which the button labels and other screen information is displayed. The help is available only in English.

Remote command:
`DISPlay:LANGuage` on page 231

Date & Time
Provides a dialog to set the current date and time in the instrument.

Remote command:
`SYSTem:DATE` on page 235
`SYSTem:TIME` on page 236

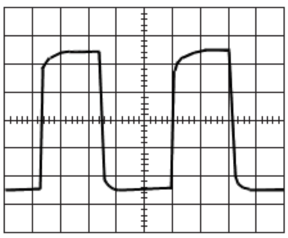
7.7 Adjusting Passive Probes

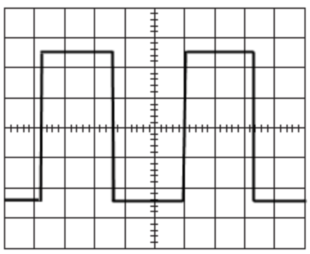
Passive probes, which are delivered with the instrument, are already pre-compensated to the R&S RTB2000 characteristics, and a compensation procedure is not required.

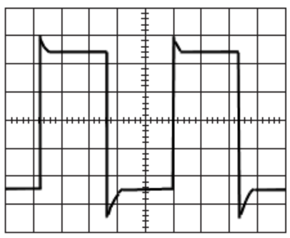
If you use another passive probe, it is necessary to compensate it when it is connected to the instrument the first time. Compensation matches the probe cable capacitance to the oscilloscope input capacitance to assure good amplitude accuracy from DC to upper bandwidth limit frequencies. A poorly compensated probe reduces the performance of the probe-oscilloscope system and introduces measurement errors resulting in distorted waveforms and inaccurate results.

Two connector pins for compensation are located at the front panel. The left pin is on ground level. The next pin supplies a square wave signal for the adjustment.

1. Press the APPS SELECTION key.
2. Tap "Probe Adjust".
3. Follow the instructions of the wizard. It guides you through the compensation process.
   Use the compensation trimmer of the probe to get optimum square wave response. For details, refer to the documentation of your probe.


undercompensated


optimum


overcompensated

7.8 Options

All options are activated by license keys. No additional installation or hardware change is required.

Unregistered licenses

Unregistered licenses are not assigned to a particular instrument. The instrument accepts only registered licenses. If your license is delivered unregistered, use the online tool R&S License Manager to register the license for your instrument. The registration of a permanent license is irreversible, so ensure that you register it for the correct instrument. The address of the tool is https://extranet.rohde-schwarz.com/service.

The "Active Options" tab provides information on installed software options. Here you can install new options or deactivate existing options using license keys.

The "Inactive Options" tab lists all deactivated and expired options.

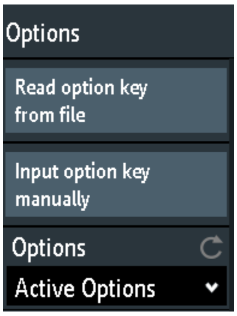
The "Deactivated Options" tab shows all deactivated options with their deactivation information and provides a function to export the deactivation response. The response is required by the R&S License Manager.

7.8.1 Activating Options

Consult your sales representative and provide the material number, serial number, and the device ID of your instrument to get a license key. You find this information in "Setup" menu > "Device Information".

The license key is provided in written form or in a file. Unregistered licenses must be registered in the R&S License Manager before they can be activated on the instrument.

1. If you received the option key in a file, save the file to a USB flash drive.
2. Connect the drive to the R&S RTB2000.
3. Tap the "Menu" icon in the lower right corner of the screen.
4. Scroll down the menu. Tap "Setup".
5. Select "Options".
6. If you received a key in written form, tap "Input option key manually". Enter the key. If you received a key in digital form as a file, tap "Read option key from file". Select path `/USB_FRONT` and the option key file.



7. If you want to activate several options, repeat step 5 for each option.
8. Restart the instrument.

7.9 Updating the Firmware

Your instrument is delivered with the latest firmware version. Firmware updates are provided on the Internet at www.rohde-schwarz.com/firmware/rtb2000. Along with the firmware file, you find the Release Notes describing the improvements and modifications.

Make sure to update the firmware if a new version is available.

1. Download the firmware installation file `RTB200*.fwu` to a USB flash drive.
2. Connect the USB flash drive to the USB connector at the front of the instrument.
3. Tap the "Menu" icon in the lower right corner of the screen.
4. Scroll down the menu. Tap "Setup".
5. Select "Firmware Update"
   Now you can see an info window with information about the installed and new firmware and front controller firmware. If you have no newer firmware than the installed one, a message appears.
6. Tap "Execute" to start the firmware update.

   Wait until the update has finished. After installation, the instrument restarts automatically.

8 Network Connections and Remote Operation

8.1 LAN Connection

The R&S RTB2000 is equipped with a network interface and can be connected to an Ethernet LAN (local area network). A LAN connection is necessary for remote control of the instrument, and for access from a computer using a web browser.

Connecting the instrument to the LAN

1. Connect the LAN cable to the LAN connector at the rear panel of the instrument.
2. Open the "Setup" menu.
3. Tap "Interface".

   If the menu items are grayed, the connection failed. Check the connection of the LAN cable and the network availability.
4. Tap "Ethernet" to select LAN connection.
5. Tap "Parameter".

   You see all connection details on the display, and you can save them to a file.

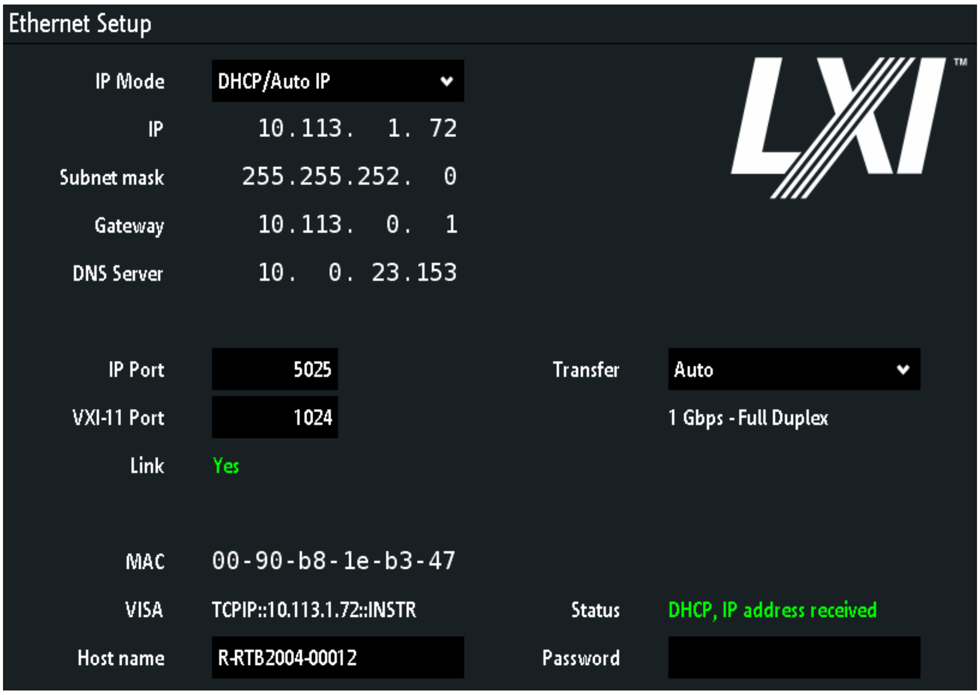


Figure 8-1: Example of the Ethernet setup dialog with various address settings

Description of settings

IP Mode

Selects the Internet protocol mode:

- "Manual": To be used if the network does not support dynamic host configuration protocol (DHCP). The addresses must be set manually.
- "DHCP/Auto IP" enables DHCP for automatic network parameter distribution and shows the values of these parameters. By default, the instrument is configured to use dynamic configuration and obtain all address information automatically. Thus, it is safe to establish a physical connection to the LAN without any previous instrument configuration.
  Note that refreshing the values (for example after disconnecting the LAN cable and reconnecting it) may take a while, depending on the network responsiveness.

Remote command:
`SYSTem:COMMunicate:INTerface:ETHernet:DHCP` on page 238

IP, Subnet mask, Gateway, DNS Server

Show or specify:

- The instrument's IP address.
- The IP subnet mask used by the instrument.
- The IP gateway used by the instrument.
- The address of the domain name server.

Remote command:
`SYSTem:COMMunicate:INTerface:ETHernet:IPADdress` on page 239
`SYSTem:COMMunicate:INTerface:ETHernet:SUBNet` on page 239
`SYSTem:COMMunicate:INTerface:ETHernet:GATeway` on page 239

IP Port, VXI-11 Port
Specify the IP port number (default = 5025) and the VXI-11 port number (default = 1024).

Remote command:
`SYSTem:COMMunicate:INTerface:ETHernet:IPPort` on page 239
`SYSTem:COMMunicate:INTerface:ETHernet:HTTPport` on page 239

Link
"Yes", if the instrument is connected to a local area network via the LAN interface on the rear panel.

"No", if no LAN connection is detected.

Transfer
Enables automatic transfer speed selection and shows the currently selected value.

Alternatively, you can select one of the predefined settings that corresponds to your network data rate.

Remote command:
`SYSTem:COMMunicate:INTerface:ETHernet:TRANsfer` on page 240

MAC, VISA
Show the instrument's media access control address, and the virtual instrument software architecture (VISA) address that is used to address the instrument in remote control.

Remote command:
`SYSTem:COMMunicate:INTerface:ETHernet:MACaddress?` on page 240

Host name
Shows or specifies the name of the host server (if available), to which the instrument is connected via LAN.

Status
Shows the connection status, for example "Allocating network address" or "DHCP, IP address received".

Password
Specifies an optional password for remote access to the instrument.

8.2 USB Connection

In addition to a LAN connection, you can use the USB connector at the rear panel to access the instrument via USB.

Connecting the instrument using USB

1. Connect the USB cable to the USB type B connector at the rear panel of the instrument, and to the computer.

2. Open the "Setup" menu.
3. Tap "Interface".

4. Tap "USB" to select USB connection.
5. Tap "Parameter".
6. Select the USB mode.
   - USB TMC (Test & Measurement Class)
   - USB VCP (Virtual Com Port)
   - USB MTP (Media Transfer Protocol)

USB TCM
USB TCM means USB Test & Measurement Class. You can use this interface for remote control of the instrument using SCPI commands. USB TCM requires a VISA installation on the controlling computer. VISA is used to access the instrument and to send remote commands.

Rohde & Schwarz provides the standardized I/O software library R&S VISA for communication via TCP/IP (LAN: HiSlip, VXI-11) or USB (USBTMC) interfaces. R&S VISA is available for download at the Rohde & Schwarz website http://www.rohde-schwarz.com/rsvisa.

USB VCP
USB VCP uses the virtual COM port (VCP) to communicate with the measuring instrument. You can use any terminal program to send SCPI commands. USB VCP requires the installation of the USB VCP driver on the controlling computer. The driver is available for download at the Rohde & Schwarz website.

USB MTP
USB MTP is the USB media transfer protocol. It is a solution to load data from the oscilloscope to the computer. USB MTP does not need a driver installation. If the instrument and the computer are connected with a USB cable and USB MTP is selected as interface, you can see the oscilloscope in the computer's Device Manager as portable instrument.

8.3 Remote Access Using a Web Browser

The R&S RTB2000 firmware contains a web server. If a LAN connection is established, you can access the instrument remotely using a web browser on the control computer.

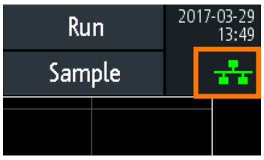
The browser access allows you to:

- Check instrument data
- Control the instrument remotely
- Print screenshots
- Send remote commands
- Save waveform and instrument data
- Check network settings

8.3.1 Accessing the Instrument Using a Web Browser

To access the R&S RTB2000, you need a LAN connection and the IP address of the instrument.

1. Obtain the IP address of the R&S RTB2000:
   - Tap the green network icon in the top right corner of the screen.

   - "Setup" menu > "Interface" > "Ethernet" > "Parameter" > "IP".
2. Open an Internet browser on the control computer.
3. Enter the IP address of the R&S RTB2000 in the address line:
   http//:xxx.yyy.zzz.xxx.

   The "Instrument Home" page opens.

8.3.2 Instrument Home

The "Instrument Home" page provides information on the instrument and the LAN connection.

8.3.3 Screenshot

The "Screenshot" page shows a copy of the instrument's display. It also provides instrument control functions and screenshot settings.

Instrument control

- "Run" and "Stop" = start and stop continuous acquisition, same as RUN STOP key on the instrument.
- "Single" = Single key on the instrument
- "Autoset" = AUTOSET key on the instrument
- "Preset" = PRESET key on the instrument

Screenshots

- "Auto refresh" and "Update"
  Get the current screen content from the instrument. With "Auto refresh", you can set the interval of automatic updates.
- "Format" and "Color mode":
- Set the file format and color mode of the screenshot.

► To save the screenshot, *right-click the picture* and select "Save image as".

8.3.4 SCPI Device Control

On the "SCPI Device Control" page, you can check how the transfer of remote commands is working.

You can enter a single command, for example; `*IDN?`, and transmit it with "Send". Do not press the ENTER key.

If the sent command has an error, an error message is created in the background, and you do not get any response. You can see the error messages using "Last Error Message" and "All Error Messages"

8.3.5 Save/Recall

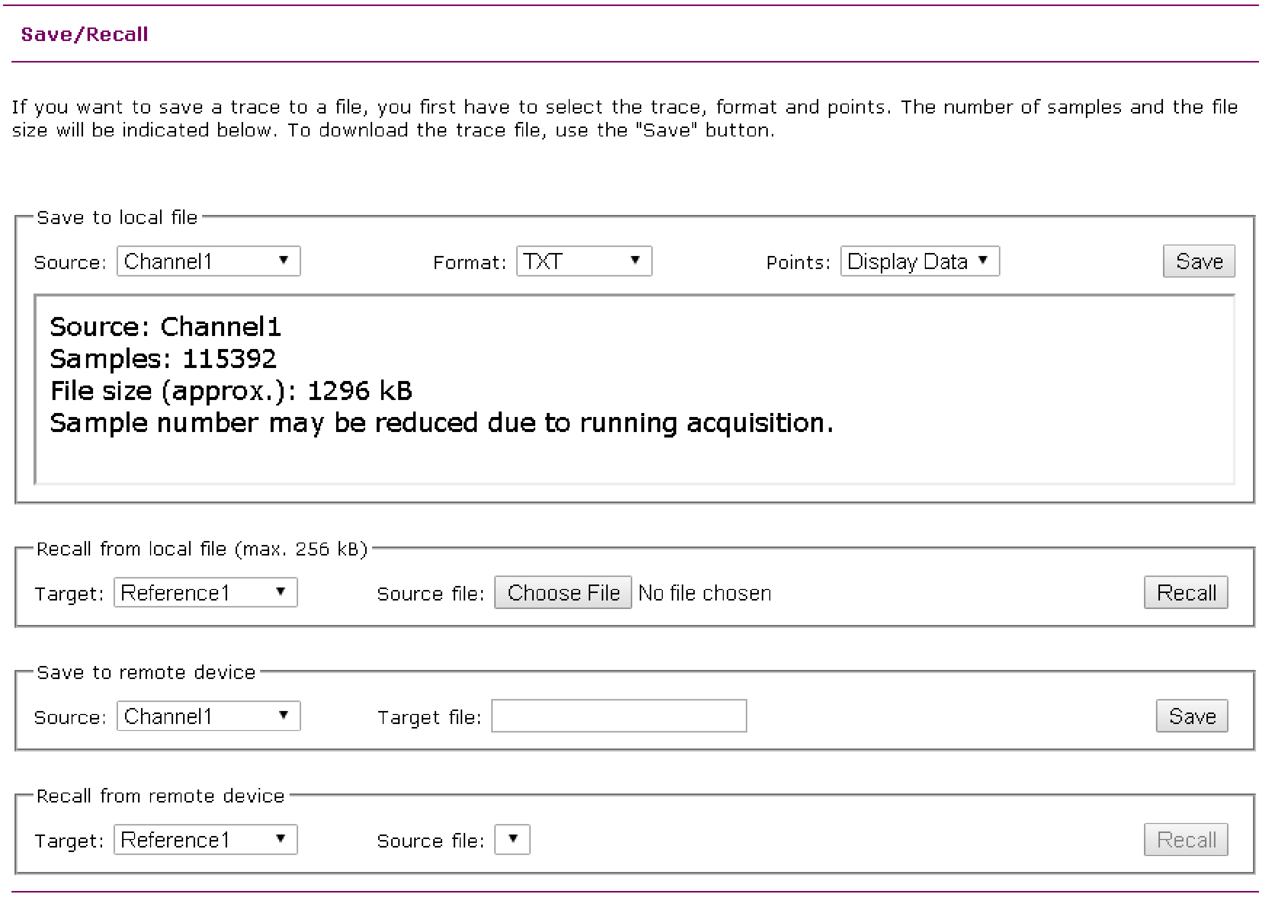
On the "Save/Recall" page, you can save waveform data and instrument settings to a file - either on the computer (local file) or on the instrument (remote device). On the computer, the default storage directory is the download folder, but you can change the directory using the download functions of your browser. On the instrument, the files are saved in the internal storage.

You can also load reference waveforms and instrument settings from file to the instrument.

To save data to a file on the computer

1. Select the waveform or the device settings in the "Source" list.
2. Select the file "Format".

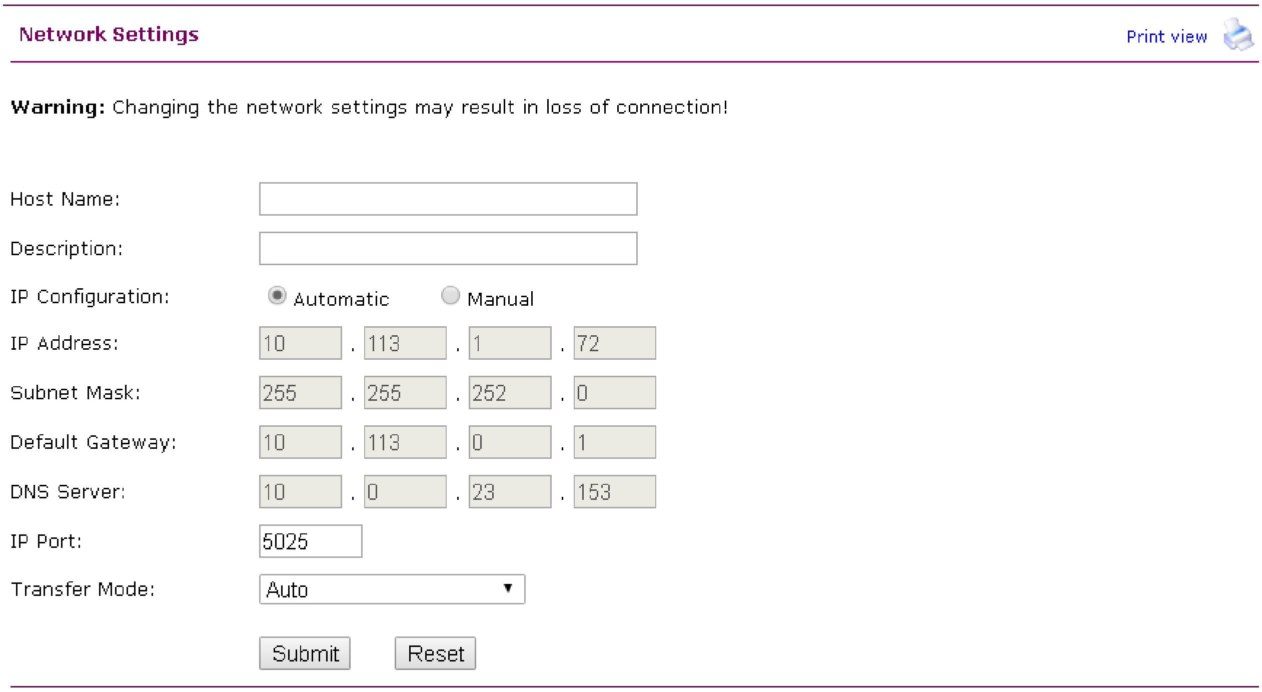
   See also:
   - Chapter 5.3, "Reference Waveforms", on page 72
3. For analog and digital channels, select the "Data" scope to be written.
4. Click "Save".



8.3.6 Network Settings

On the "Network Setting" page, you can change the port settings, switch off DHCP address and enter an IP address in a more comfortable way than directly on the instrument. To take effect of the changes, "Submit" them to the instrument.

"Reset" removes all modified values that were not yet sent to the instrument.



8.3.7 Change Password

On the "Change Password" page, you can change or remove the password to protect remote access to the instrument. Alternatively, you can change the password in the Ethernet settings dialog on the instrument.

8.3.8 Livescreen

You see a live image of the instrument's display. Controlling the instrument is not possible. Use this page for demo purposes, for example.

To return to the page menu, click "Back".

8.3.9 Remote Front Panel

On the "Remote Front Panel" page, you can remotely operate the instrument using the emulated front panel. A live image of the instrument is shown. You can use the keys, the knobs and the menus in the same way as directly on the instrument.

To return to the page menu, click "Back".

9 Serial Bus Analysis

Using the R&S RTB2000 and additional options, you can analyze the following serial protocols:

- SPI (Serial Peripheral Interface with 3 lines) and SSPI (Serial Peripheral Interface with 2 lines) - requires option R&S RTB-K1
  See Chapter 9.2, "SPI/SSPI Bus (Option R&S RTB-K1)", on page 121.
- I²C (Inter-Integrated Circuit bus) - requires option R&S RTB-K1
  See Chapter 9.3, "I²C (Option R&S RTB-K1)", on page 129.
- UART/RS232 (EIA-232 serial interface) - requires option R&S RTB-K2
  See Chapter 9.4, "UART / RS232 (Option R&S RTB-K2)", on page 137.
- CAN (Controller Area Network) - requires option R&S RTB-K3
  See Chapter 9.5, "CAN (Option R&S RTB-K3)", on page 143.
- LIN (Local Interconnect Network) - requires option R&S RTB-K3
- See Chapter 9.6, "LIN R&S RTB-K3", on page 155.

To analyze parallel buses, you need MSO option R&S RTB2000-B1 to get the logic channels.

9.1 Basics of Protocol Analysis

The analysis of serial data consists of three main steps:

- Protocol configuration:
  Select the protocol type, and configure the input line as well as the protocol-specific settings.
- Decoding:
  Select the display format of the decoded data. The digitized signal data is displayed on the screen together with the decoded content of the messages in combs.
  You can scale the signal display and zoom into it to see it in more detail.
  You can also list the decoded results in tabular form in the "Protocol" mode.
- Triggering:
  You can trigger on various events that are typical for the configured bus type, for example, on start and stop of messages, on specific addresses, or on serial patterns.
- Search:
  On CAN and LIN buses, you can search for events, similar to the trigger. The search finds all matching events in an acqisition, while the trigger finds only the trigger event.

Analysis can be performed on analog input channels, and - if MSO option R&S RTB-B1 is installed - on digital channels.

You can configure 2 protocol buses and select one of the configured buses for analysis.

9.1.1 Protocol - Common Settings

► To open the protocol setup, press the Protocol key.

The common settings in the "Protocol" menu define the bus type and open further menus to adjust the display of the decoded bus signal.

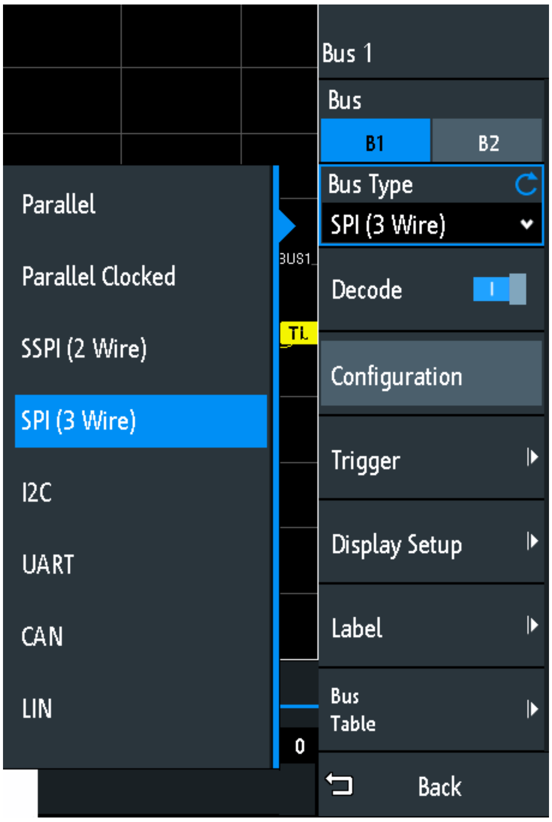


Figure 9-1: Protocol menu with bus types expanded

Bus
Selects the bus.

Bus Type
Defines the bus or interface type for analysis.

The following bus or interface types are available with a full set of options:
- Parallel
- Parallel Clocked

- SPI (2 Wire)
- SSPI (3 Wire)
- I²C
- UART
- CAN
- LIN

Remote command:
`BUS<b>:TYPE` on page 242

Decode
Enables protocol decoding for the selected bus.

Remote command:
`BUS<b>:STATe` on page 242

Configuration
Opens a configuration dialog for the selected protocol.

The following chapters describe manual protocol configuration:
- Chapter 9.2.2, "SPI/SSPI Configuration", on page 122
- Chapter 9.3.2, "I²C Configuration", on page 131
- Chapter 9.4.2, "UART Configuration", on page 138
- Chapter 9.5.1, "CAN Configuration", on page 144
- Chapter 9.6.2, "LIN Configuration", on page 156

Trigger
Opens the trigger setup for the selected protocol.

The following chapters describe protocol triggering:
- Chapter 9.2.3, "SPI/SSPI Trigger", on page 125
- Chapter 9.3.3, "I²C Trigger", on page 132
- Chapter 9.4.3, "UART Trigger", on page 139
- Chapter 9.5.2, "CAN Trigger", on page 145
- Chapter 9.6.3, "LIN Trigger", on page 157

Troggering on parallel buses is not possible.

Note: Selecting "Trigger" in the protocol menu automatically enables protocol decoding.

Display Setup
Opens a menu to define display settings, e.g. data formats, that are valid for all protocol types.

See Chapter 9.1.2, "Display Settings", on page 116.

Label List
Opens a menu to load and apply a list with symbolic names of addresses or identifiers. Only available for CAN and LIN.

See Chapter 9.1.3, "Label List", on page 116.

Bus Table
Opens a menu to define bus table settings for the decoded frames of the acquisition.

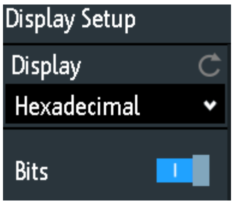
See Chapter 9.1.4, "Bus Table: Decode Results", on page 119.

Label
Opens a menu to define a label for the selected bus.

See Chapter 9.1.5, "Bus Labels", on page 120.

9.1.2 Display Settings

Access: PROTOCOL > "Display Setup"



Display
Selects the decoding format of the data: Binary, Hexadecimal, Decimal, Octal or ASCII.

Remote command:
`BUS<b>:FORMat` on page 242

Bits
Enables displaying the individual bit lines above the decoded bus line.

Remote command:
`BUS<b>:DSIGnals` on page 243

9.1.3 Label List

For all protocols using ID or address identification, it is possible to create label lists containing addresses or IDs, a symbolic name for each node (symbolic label), and some protocol-specific information.

You can load label lists, and activate its usage for decoding. As a result, the decoded signal shows the symbolic label instead of the ID or address values, so it is easy to identify the messages of the different bus nodes.

You can also also use the label list to trigger on an identifier or address. Instead of entering the value, you select the name, which is defined in the label list.

The format of label list files is PTT.

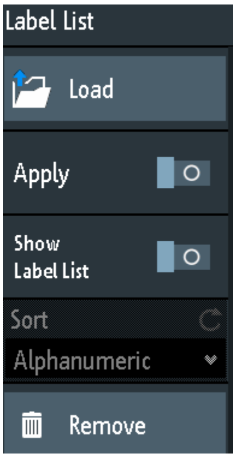
Label lists are protocol-specific. They are described in the corresponding protocol chapters:

- Chapter 9.5.3, "CAN Label List", on page 150
- Chapter 9.6.5, "LIN Label List", on page 163

9.1.3.1 Using Label Lists

To load a label list and display the labels

1. Save the label list file on a USB flash drive.
2. Press the PROTOCOL key.
3. Configure the protocol.
4. In the "Bus" menu, select "Label List".



5. Select "Load".
6. Navigate to the label list file, select it, and tap "Load".
7. To read the label list, tap "Show Label List".
8. To see the node labels in the display of the decoded data, tap "Apply".

To trigger on an identifier or address using the label

Prerequisites: The bus is configured, decoding is enabled, and a decoded signal is visible.

1. Open the "Bus" menu.
2. Select "Trigger".
3. Set the following trigger settings:
   a) "<Protocol> Trigger" = "Identifier", or "Identifier + Data", or "Address", or "Address and Data".
   b) Tap "Symbolic ID".
   c) Select the label. The list provides all symbolic names that are defined in the loaded file.
4. Close the dialog.
5. Set the trigger mode to "Normal".

9.1.3.2 Content and Format of the PTT File

Label lists are stored as PTT (protocol translation table) files. The PTT file format is an extension of the CSV format (comma-separated values). You can edit it with standard editors, for example, with MS Excel or a text editor.

The PTT file has three types of lines:

- Comment lines begin with a hash character #. A hash character at any other position in the line is treated like a standard character.
- Command lines begin with a commercial at character @. An @ character at any other position in the line is treated like a standard character.
- Standard lines are the lines that not qualify as comment or command lines. They build the core of the label list.

Command lines

Command lines define the version of the PTT file and the protocol name:

- @FILE_VERSION: must appear exactly once in the file
- @PROTOCOL_NAME: must appear at least once in the file. Thus, one file can contain several label lists for different protocols.

```
# --- Start of PTT file
@FILE_VERSION  = 1.0
@PROTOCOL_NAME = i2c
[... Label list for I2C]
@PROTOCOL_NAME = can
[... Label list for CAN]
# --- End of PTT file
```

Standard lines

Standard lines define the contents of the label list. The rules for standard lines follow the csv convention, they are:

- Values are separated by commas
- Space characters following a delimiter are ignored
- Values with a special character (comma, newline, or double quote) must be enclosed in double quotes
- Text in double quotes must be escaped by double quote characters

The format of the numeric value is indicated by a suffix. The following formats are supported:

Format	Suffix	Example
Decimal	<empty> d	`106, DeviceName` `106d, DeviceName`
Hexadecimal	h	`6Ah, DeviceName` or prefix: `0x6A, DeviceName`

Format	Suffix	Example
Octal	o	`152o, DeviceName`
Binary	b	`01101010b, DeviceName`

The maximum supported word size for (unsigned) integers is 64 bits.

```
# --- Start of PTT file
@FILE_VERSION  = 1.0
@PROTOCOL_NAME = i2c
#    Following two lines are equal:
7,01h,Temperature
7,01h, Temperature
#    A comma must be enclosed in double quotes:
7,01h,"Temperature, Pressure, and Volume"
#    A double quote must also be enclosed in double quotes:
7,7Fh,"Highspeed ""Master"" 01"
#    Following lines yield the same result:
7d,0x11,Pressure
7h,11h,Pressure
0x7,17d,Pressure
7,17,Pressure
```

9.1.4 Bus Table: Decode Results

Access: PROTOCOL > "Bus Type" = any serial bus > "Decode" = on > "Bus Table"

The bus table shows the detailed decoded data for each frame of the acquisition. At running acquisition, the table results are updated continuously.

To open the bus table

1. In the "Bus" menu, select "Bus Table".
2. Select "Bus Table".

   The menu entry gets highlighted, and the bus table is shown below the diagram.

To navigate in the bus table

1. To adjust the table size, drag up or down one of the arrow buttons on the left or right.
2. Stop the acquisition.
3. In the "Bus Table" menu, select "Track Frame".
4. Tap a frame in the bus table.

   The start of the selected frame is marked by a line and rhomb, and the marker with the decoded data is moved to the center of the diagram.

Bus Table
Displays or hides a table of decoded signal data.

Remote command:
BUS<b>:RESult on page 244

Track Frame
If enabled, the selected frame in the bus table is automatically synchronized with the waveform display.

The function is only available if the acquisition has been stopped.

Frame time difference
If selected, the time shown in the bus table is a frame's time difference to the previous frame. The column is indicated with "Time diff.". If the setting is disabled, the absolute time in releation to the trigger point is shown in the "Start Time" column.

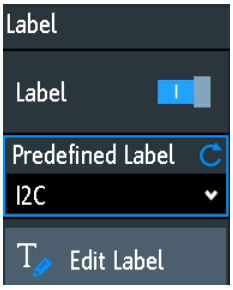
Save
Opens the "Save" menu to save the decoded data in a CSV file (comma-separated list).

9.1.5 Bus Labels

A bus label is a name of a bus. The bus label is shown on the right side of the display at bus signal, and in the bus table.

Do not confuse "Label" and "Label List". The "Label" names the bus, while the "Label List" contains the names of bus nodes identified by addresses or identifiers.

Access: PROTOCOL > "Label"



Label
Displays or hides the bus label. The bus label is shown on the right side of the display at bus signal, and in the bus table.

The bus and its label are only visible, if "Decode" is enabled.

You can enter a label text in several ways:
- Select a string from the library list at "Predefined Label".
- Enter a user-defined text using "Edit Label".

Remote command:
BUS<b>:LABel:STATe on page 243

Predefined Label
Selects a bus label from the following list:
- SPI
- SSPI
- I2C
- UART
- CAN
- LIN
- PARALLEL
- ADDRESS
- DATA
- RS232

Edit Label
Enter a user-defined name to be displayed with the selected bus in the diagram, and in the bus table. The maximum name length is 8 characters. You can use only ASCII characters provided on the on-screen keyboard.

Remote command:
`BUS<b>:LABel` on page 242

9.2 SPI/SSPI Bus (Option R&S RTB-K1)

9.2.1 The SPI Protocol

A 4-channel instrument is required for full support of the SPI protocol.

The Serial Peripheral Interface SPI is used for communication with slow peripheral devices, in particular, for transmission of data streams.

Main characteristics of SPI are:
- Master-slave communication
- No device addressing; The slave is accessed by a chip select, or slave select line.
- No acknowledgement mechanism to confirm receipt of data
- Duplex capability

Most SPI buses have four lines, two data and two control lines:
- Clock line to all slaves (SCLK)
- Slave Select or Chip Select line (SS or CS)
- Master data output, slave data input (MOSI or SDI)
- Master data input, slave data output (MISO or SDO)

When the master generates a clock and selects a slave device, data may be transferred in either or both directions simultaneously.

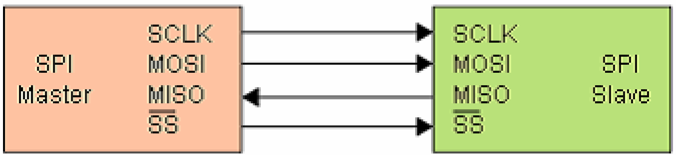


Figure 9-2: Simple configuration of SPI bus

The data bits of a message are grouped by following criteria:

- A word contains a number of successive bits. The word length is defined in the protocol configuration.
- A frame contains a number of successive words, at least one word.

For SPI buses, the R&S RTB2000 provides the following trigger possibilities:

- On frame start
- On frame end
- On a specified bit in the message
- On a serial pattern at a specified position

9.2.2 SPI/SSPI Configuration

Access: PROTOCOL > "Bus Type" = "SPI/SSPI" > "Configuration"

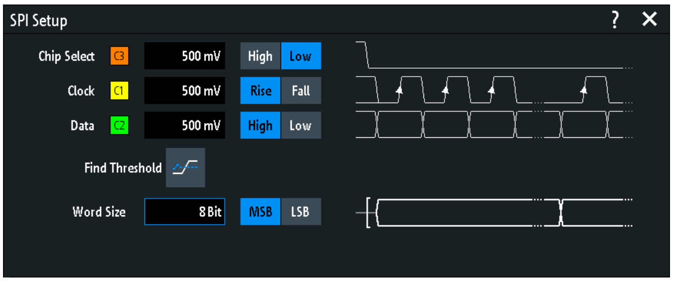


Figure 9-3: SPI (3 wire) setup dialog

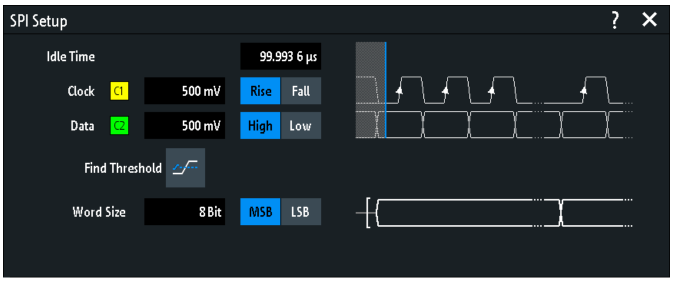


Figure 9-4: SSPI (2 wire) setup dialog

These dialogs offer the following settings:

Chip Select
Only available in the SPI setup.

Selects the input channel of the chip select (CS) line.

If the MSO option R&S RTB-B1 is installed, you can also use digital channels as source.

Remote command:
`BUS<b>:SPI:CS:SOURce` on page 245

Idle Time
Only available in the SSPI setup.

Sets the burst idle time, during which the data and clock lines are low. The default idle time is 100 µs.

A new frame begins when the idle time has expired and the clock line has been inactive during that time. If the time interval between the data words is shorter than the idle time, the words are part of the same frame.

Remote command:
`BUS<b>:SSPI:BITime` on page 250

Clock
Selects the input channel of the SPI or SSPI clock line.

If the MSO option R&S RTB-B1 is installed, you can also use digital channels as source.

Remote command:
`BUS<b>:SPI:CLOCk:SOURce` on page 245
`BUS<b>:SSPI:CLOCk:SOURce` on page 248

Data
Selects the input channel of the MOSI line, of the optional MISO line, or of the data line if only one data line is used.

If the MSO option R&S RTB-B1 is installed, you can also use digital channels as source.

Remote command:
`BUS<b>:SPI:CS:POLarity` on page 245
`BUS<b>:SPI:DATA:SOURce` on page 246
`BUS<b>:SPI:MOSI:SOURce` on page 246
`BUS<b>:SPI:MISO:SOURce` on page 246
`BUS<b>:SSPI:DATA:SOURce` on page 249

BUS<b>:SSPI:MOSI:SOURce on page 249
BUS<b>:SSPI:MISO:SOURce on page 249
BUS<b>:SPI:DATA:POLarity on page 247
BUS<b>:SPI:MOSI:POLarity on page 247
BUS<b>:SPI:MISO:POLarity on page 247
BUS<b>:SSPI:DATA:POLarity on page 249
BUS<b>:SSPI:MOSI:POLarity on page 249
BUS<b>:SSPI:MISO:POLarity on page 250

Polarity
Selects if the transmitted data or the chip select signal is high active (high = 1) or low active (low = 1).

For CS, the default is low active.

For data, the default is high active.

Remote command:
BUS<b>:SPI:DATA:POLarity on page 247
BUS<b>:SPI:MOSI:POLarity on page 247
BUS<b>:SPI:MISO:POLarity on page 247
BUS<b>:SSPI:DATA:POLarity on page 249
BUS<b>:SSPI:MOSI:POLarity on page 249
BUS<b>:SSPI:MISO:POLarity on page 250

Slope
Selects if data is sampled on the rising or falling slope of the clock. The clock slope marks the begin of a new bit.

Remote command:
BUS<b>:SPI:CLOCk:POLarity on page 246
BUS<b>:SSPI:CLOCk:POLarity on page 248

Threshold, Find Threshold
Set the signal threshold for the source channel. Enter a value, or use Find Threshold to set the threshold to the middle reference level of the measured amplitude.

For analog channels, you can find the value also in the "Vertical" menu > "Channel <n>" >"Threshold"

For logic channels, you can find the value also in the "Logic" menu > "Threshold".

Remote command:
CHANnel<m>:THReshold on page 178
CHANnel<m>:THReshold:FINDlevel on page 179

Word Size
Sets the word length (or symbol size), which is the number of bits in a message. The maximum word length is 32 bit.

You can also define the bit order, which determines if the data of the messages starts with "MSB" (most significant bit) or "LSB" (least significant bit).

Remote command:
`BUS<b>:SPI:SSIZe` on page 247
`BUS<b>:SSPI:SSIZe` on page 250
`BUS<b>:SPI:BORDer` on page 247
`BUS<b>:SSPI:BORDer` on page 250

9.2.3 SPI/SSPI Trigger

9.2.3.1 Triggering on SPI/SSPI Buses

Prerequisites: The SPI or SSPI bus is configured. After configuration, the trigger type "Serial Bus" is available in the "Trigger" > "Source" menu. See Chapter 9.2.2, "SPI/SSPI Configuration", on page 122.

Triggers are only available, if "Decode" is enabled.

To trigger on SPI or SSPI:

1. Press the PROTOCOL key in the analysis area of the front panel.
2. Select your "Bus Type":
   - "SPI (3 Wire)" or
   - "SSPI (2 Wire)"
3. Select "Trigger"

   This selection automatically enables "Decode", opens the "SPI Trigger" menu, sets the "Trigger Type" to "Serial Bus" and displays the "SPI Trigger" condition below the protocol setup dialog.
4. At "SPI Trigger", select the required trigger condition:
   - "Frame Start": beginning of the message
   - "Frame End": end of the message
   - "Bit <x>": a specified bit inside the message
   - "Serial Pattern": a bit pattern in the message
5. If "Bit <x>" is selected, enter the bit number at "Bit Offset": min. 0 Bit, max. 32,767 Bit.
6. If "Serial Pattern" is selected, the SPI trigger setup dialog expands to define the serial pattern.

9.2.3.2 SPI/SSPI Trigger Settings

Access: PROTOCOL > "Bus Type" = "SPI" or "SSPI" > "Trigger" > "Source"

Selecting "Trigger" in the protocol menu automatically enables protocol decoding.

For general trigger functions, see Chapter 4.3, "General Trigger Settings", on page 54.

SPI Trigger

Selects the trigger condition.

"Frame Start" Sets the trigger to the start of the message:

- For SPI, the frame starts when the chip select signal CS changes to the active state.
- For SSPI, the frame starts when the idle time has expired.

"Frame End" Sets the trigger to the end of the message.

- For SPI, the frame ends when the chip select signal CS changes to the inactive state.
- For SSPI, the frame ends when the idle time has expired after the last clock and no new clock appeared during that time.

"Bit <x>" Sets the trigger to the specified bit number.
See also "Bit Offset" on page 127.

"Serial Pattern" Opens a trigger setup dialog to configure the bit pattern to be triggered at.

Remote command:
`TRIGger:A:SPI:MODE` on page 251

Serial Pattern ← SPI Trigger

The dialog shown below is opened together with either the SPI setup dialog or the SSPI setup dialog:

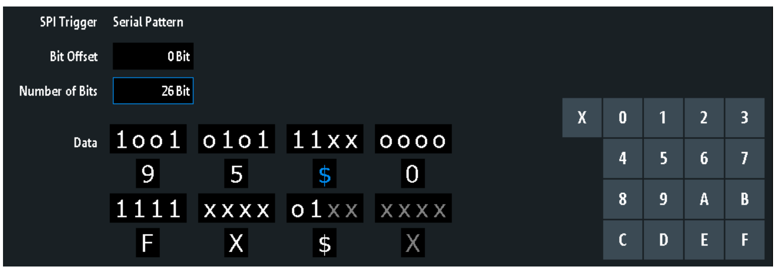


Figure 9-5: Trigger setup dialog with an example of an SPI or SSPI serial pattern

"Bit Offset" = see Bit Offset
"Number of Bits" = see Number of Bits
"Data" = Binary and hex values of the pattern, see below and Data
9 = Hex value of the 1st nibble, with the binary value 1001
5 = Hex value of the 2nd nibble, with the binary value 0101

$ (blue)	= Hex value of the 3rd nibble, which includes some "X" bits (the blue color indicates that the keypad is active for this nibble)
0	= Hex value of the 4th nibble, with the binary value 0000
F	= Hex value of the 5th nibble, with the binary value 1111
X (white)	= The 6th nibble is a "don't care" nibble, as it consists of "X" bits, only
$ (white)	= The 7th nibble is only half contained in the specified pattern length of 26 bits
X (gray)	= The 8th nibble is not contained in the specified pattern

To open an on-screen keypad for entering the hexadecimal value of any nibble (half byte, set of four bits), tap the character below this nibble. To open an on-screen keypad for entering the binary value of any bit, tap this bit.

If a nibble contains 1, 2 or 3 "X" bits (don't care), the nibble value is represented by the character "$". If all 4 bits of a nibble are "X", the nibble itself is "don't care", represented by the character "X".

As soon as the instrument detects the specified data pattern, it sets the trigger to the first bit of this pattern.

Remote command:
`TRIGger:A:SPI:PATTern` on page 251

Bit Offset ← Serial Pattern ← SPI Trigger

Specifies the number of bits before the first bit of the pattern. These bits are ignored. The first bit after CS is Bit 0.

The minimum offset is 0 bit, the maximum offset is 32,767 bits. You can use the NAVIGATION knob to set the bit offset.

For example, with bit offset = 2, Bit 0 and Bit 1 after CS are ignored, and the pattern starts with Bit 2.

"Bit Offset" is also used for SPI Trigger > "Bit <x>".

Remote command:
`TRIGger:A:SPI:POFFset` on page 252

Number of Bits ← Serial Pattern ← SPI Trigger

Defines the length of the serial pattern in bits, see SPI Trigger. The minimum length is 1 bit, the maximum length is 32 bits. You can use the NAVIGATION knob to set the number of bits.

Note: Entering data bits beyond the specified length of the pattern automatically adjusts the "Number of Bits" to include all entered bits.

Remote command:
`TRIGger:A:SPI:PLENgth` on page 252

Data ← Serial Pattern ← SPI Trigger

Specifies the data pattern as shown in SPI Trigger. To specify a longer pattern than in this example, either just enter bits beyond the specified length, or first increase the Number of Bits.

Remote command:
`TRIGger:A:SPI:PATTern` on page 251

9.2.4 SPI/SSPI Decode Results

If the option is installed, the "Decode" function is available.

When the configuration of the serial bus is complete, the signal can be decoded:

1. In the "Bus" menu, enable "Decode".
2. In the "Display" menu, select additional result display settings, see also Chapter 9.1.2, "Display Settings", on page 116.
3. In the "Bus Table" menu, enable the display of the "Bus Table".

The instrument captures and decodes the signal according to the standard definition and the configuration settings.

The color-coding of the various protocol sections and errors simplifies the interpretation of the visual display. The decode information condenses or expands, depending on the horizontal scale. Various data formats are available to show the result values.

The figure above shows a decoded SSPI signal and the "Bus Table". The first frame has fourteen words and the second eight words.

Table 9-1: Content of the SPI/SSPI bus table

Column	Description
Start time	Time of the frame start in relation to the trigger point
Length	Number of words in the frame
Data	Hexadecimal values of the data words
State	Overall state of the frame

Remote commands are described in Chapter 10.10.2.4, "SPI and SSPI - Decode Results", on page 252.

9.3 I²C (Option R&S RTB-K1)

The Inter-Integrated Circuit is a simple, low-bandwidth, low-speed protocol used for communication between on-board devices, for example, in LCD and LED drivers, RAM, EEPROM, and others.

9.3.1 The I²C Protocol

This chapter provides an overview of protocol characteristics, data format, address types and trigger possibilities. For detailed information, read the "I2C-bus specification and user manual" available on the NXP manuals web page at http://www.nxp.com/.

I²C characteristics

Main characteristics of I²C are:

- Two-wire design: serial clock (SCL) and serial data (SDA) lines
- Master-slave communication: the master generates the clock and addresses the slaves. Slaves receive the address and the clock. Both master and slaves can transmit and receive data.
- Addressing scheme: each slave device is addressable by a unique address. Multiple slave devices can be linked together and can be addressed by the same master.
- Read/write bit: specifies if the master will read (=1) or write (=0) the data.
- Acknowledge: takes place after every byte. The receiver of the address or data sends the acknowledge bit to the transmitter.

The R&S RTB2000 supports all operating speed modes: high-speed, fast mode plus, fast mode, and standard mode.

Data transfer

The format of a simple I²C message (frame) with 7 bit addressing consists of the following parts:

- Start condition: a falling slope on SDA while SCL is high
- 7-bit address of the slave device that either will be written to or read from
- R/W bit: specifies if the data will be written to or read from the slave

- ACKnowledge bits: is issued by the receiver of the previous byte if the transfer was successful
  Exception: At read access, the master terminates the data transmission with a NACK bit after the last byte.
- Data: a number of data bytes with an ACK bit after every byte
- Stop condition: a rising slope on SDA while SCL is high

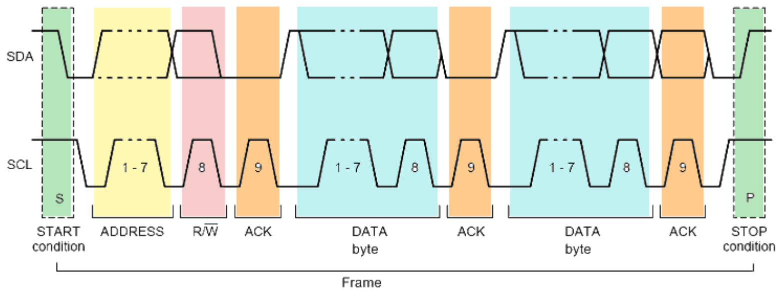


Figure 9-6: I2C write access with 7-bit address

Address types: 7-bit and 10-bit

Slave addresses can be 7 or 10 bits long. A 7-bit address requires one byte, 7 bits for the address followed by the R/W bit.

A 10-bit address for write access requires two bytes: the first byte starts with the reserved sequence 11110, followed by the two MSB of the address and the write bit. The second byte contains the remaining 8 LSB of the address. The slave acknowledges each address byte.

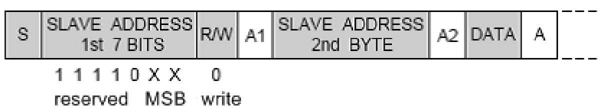


Figure 9-7: 10-bit address, write access

A 10-bit address for read access requires three bytes. The first two bytes are identical to the write access address. The third byte repeats the address bits of the first byte and sets the read bit.

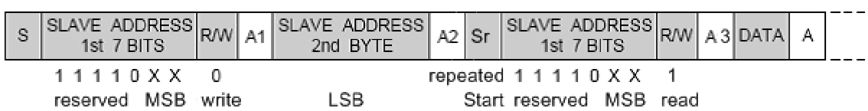


Figure 9-8: 10-bit address, read access

Trigger

The R&S RTB2000 can trigger on various parts of I²C messages. The data and clock lines must be connected to the input channels, triggering on math and reference waveforms is not possible.

You can trigger on:

- Start or stop condition

- Repeated start condition
- Transfer direction (read or write)
- Bytes with missing acknowledge bit
- Specific slave address
- Specific data pattern in the message

9.3.2 I²C Configuration

Access: PROTOCOL > "Bus Type" = "I2C" > "Configuration"

The following configuration dialog opens:

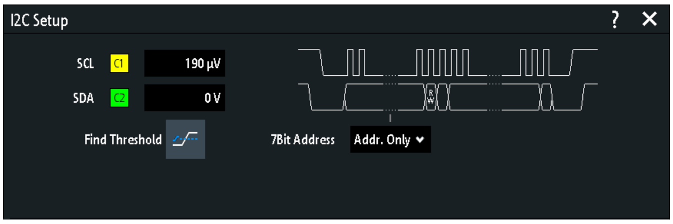


Figure 9-9: I2C setup dialog

The dialog offers the following settings:

SCL
Selects the source channel to which the clock line is connected.

If the MSO option R&S RTB-B1 is installed, you can also use digital channels as source.

Remote command:
`BUS<b>:I2C:CLOCk:SOURce` on page 257

SDA
Selects the source channel to which the data line is connected.

If the MSO option R&S RTB-B1 is installed, you can also use digital channels as source.

Remote command:
`BUS<b>:I2C:DATA:SOURce` on page 257

Threshold, Find Threshold
Set the signal threshold for the source channel. Enter a value, or use Find Threshold to set the threshold to the middle reference level of the measured amplitude.

For analog channels, you can find the value also in the "Vertical" menu > "Channel <n>" >"Threshold"

For logic channels, you can find the value also in the "Logic" menu > "Threshold".

Remote command:
`CHANnel<m>:THReshold` on page 178
`CHANnel<m>:THReshold:FINDlevel` on page 179

9.3.3 I²C Trigger

9.3.3.1 Triggering on I²C

Prerequisites: The I²C bus is configured. After configuration, the trigger type "Serial Bus" is available in the "Trigger" > "Source" menu. See Chapter 9.3.2, "I²C Configuration", on page 131.

Triggers are only available, if "Decode" is enabled.

To trigger on I²C:

1. Press the PROTOCOL key in the analysis area of the front panel.
2. Select the "Bus Type" "I²C".
3. Select "Trigger"
   This selection automatically enables "Decode", opens the "I2C Trigger" menu, sets the "Trigger Type" to "Serial Bus" and **displays the "I2C Trigger" condition** below the protocol setup dialog.
4. At "I2C Trigger", select the required trigger condition:
   - "Start": beginning of the message
   - "Stop": end of the message
   - "Restart": repeated start condition
   - "~Acknowledge": transfer of data bits is not acknowledged
   - "Address and Data":
5. If "Address and Data" is selected, the I²C trigger setup dialog expands to define the serial pattern.

9.3.3.2 I²C Trigger Settings

Access: PROTOCOL > "Bus Type" = I2C > "Trigger" > "Source"

Selecting "Trigger" in the protocol menu automatically enables protocol decoding.

For general trigger functions, see Chapter 4.3, "General Trigger Settings", on page 54.

I2C Trigger

Selects the trigger condition.

"Start" Sets the trigger to the start of the message. The start condition is a falling slope on SDA while SCL is high.

"Stop" Sets the trigger to the end of the message. The stop condition is a rising slope on SDA while SCL is high.

"Restart" Sets the trigger to a repeated start - when the start condition occurs without previous stop condition. This can happen when a master sends multiple messages without releasing the bus.

"~Acknowledge" Missing acknowledgement: the instrument triggers, if the slave does not send the acknowledge bit. Acknowledging takes place after every byte. If the transfer failed, at the moment of the acknowledge bit, the SDA line is on high level during the high period of the clock pulse.

"Address and Data" Opens a trigger setup dialog to configure the bit pattern to be triggered at.
See "I2C Trigger" on page 133.

Remote command:
`TRIGger:A:I2C:MODE` on page 257

Address and Data ← I2C Trigger

The dialog shown below is opened together with the I2C setup dialog:

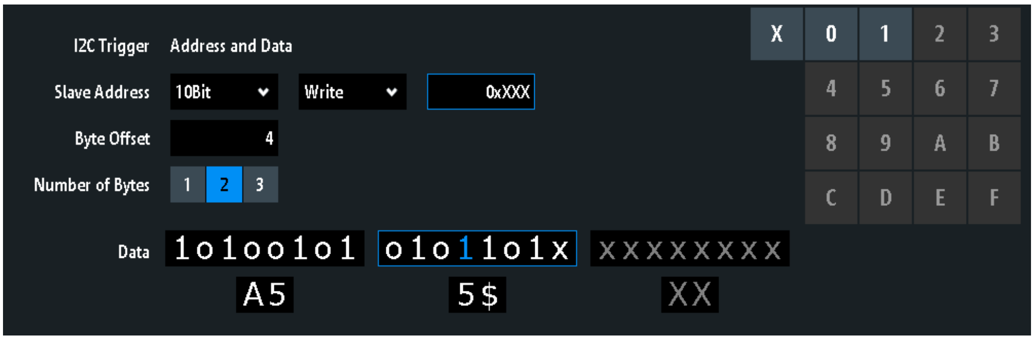


Figure 9-10: Trigger setup dialog with an example of an I2C serial pattern

"Slave Address" = see Slave Address
"Byte Offset" = see Byte Offset
"Number of Bytes" = see Number of Bytes
"Data" = Binary and hex values of the pattern, see below and Data
A5 = Hex value of the 1st byte, with the binary value 10100101
5$ = Hex value of the 2nd byte, where the 1st nibble has the binary value 0101 and the 2nd nibble is represented by the "$" character, as it includes one "X" bit (don't care)
1 (blue) = Selected bit in the 2nd byte, where the blue color indicates that the keypad is active for this bit
XX (gray) = The 3rd byte is not contained in the specified pattern

To open an on-screen keypad for entering the hexadecimal value of any byte (set of eight bits), tap one of the characters below this byte. To open an on-screen keypad for entering the binary value of any bit, tap this bit.

If a nibble (half byte) contains 1, 2 or 3 "X" bits (don't care), the nibble value is represented by the character "$". If all 4 bits of a nibble are "X", the nibble itself is "don't care", represented by the character "X".

As soon as the instrument detects the specified data pattern, it sets the trigger to the first bit of this pattern.

Slave Address ← Address and Data ← I2C Trigger
Specifies three properties of the slave address:

- Toggles the length of the slave address: "7Bit" or "10Bit".
- Toggles the trigger condition between "Read" and "Write" access of the master.
  The read/write bit is the 8th bit of the first address byte of a frame
- Sets the address of the slave device in hexadecimal format. You can set a precise address, or trigger on any address with "0xXX" (7Bit address, maximum "0x7F") or "0xXXX" (10Bit address, maximum "0x3FF"). "X" cannot be assigned to a specified bit.

Remote command:
`TRIGger:A:I2C:AMODe` on page 258
`TRIGger:A:I2C:ACCess` on page 258
`TRIGger:A:I2C:ADDRess` on page 259

Byte Offset ← Address and Data ← I2C Trigger
Sets the number of offset bytes to be ignored after the end of the address bytes. The first byte of interest is the first byte after the offset bytes.

The minimum offset is 0 Byte, the maximum offset is 4,095 Bytes.

Remote command:
`TRIGger:A:I2C:POFFset` on page 260

Number of Bytes ← Address and Data ← I2C Trigger
Sets the number of full bytes you want to trigger on. Maximum 3 bytes are possible.

Note: Entering data bits beyond the specified length of the pattern automatically adjusts the "Number of Bytes" to include all full bytes with entered bits.

Remote command:
`TRIGger:A:I2C:PLENgth` on page 259

Data ← Address and Data ← I2C Trigger
Specifies the data pattern as shown in "I2C Trigger" on page 133. To specify a longer pattern than in this example, either just enter bits beyond the specified length, or first select a higher Number of Bytes.

Remote command:
`TRIGger:A:I2C:PATTern` on page 259

9.3.4 I2C Label List

Label lists are protocol-specific. Label lists for ^{2}C are available in CSV and PTT format.

An I^{2}C label file contains three values for each address:

- Address type, 7-bit or 10-bit long
- Address value
- Symbolic label: name of the address, specifiing its function in the bus network.

Example: I^{2}C PTT file

```
# ----------------------------------------------------------------------------
@FILE_VERSION  = 1.00
@PROTOCOL_NAME = i2c
# ---------------------------------------------------------------------------
# Labels for I2C protocol
#   Column order: Identifier type, Identifier value, Label
# ---------------------------------------------------------------------------
7,0x1E,Voltage
7,38h,Pressure
7,2Ah,Temperature
7,16h,Speed
7,118,Acceleration
7,07h,HighSpeed_Master_0x3
7,51h,EEPROM
10,3A2h,DeviceSetup
10,1A3h,GatewayStatus
10,06Eh,LeftSensor
# ----------------------------------------------------------------------------
```

For general information on label lists, see Chapter 9.1, "Basics of Protocol Analysis", on page 113.

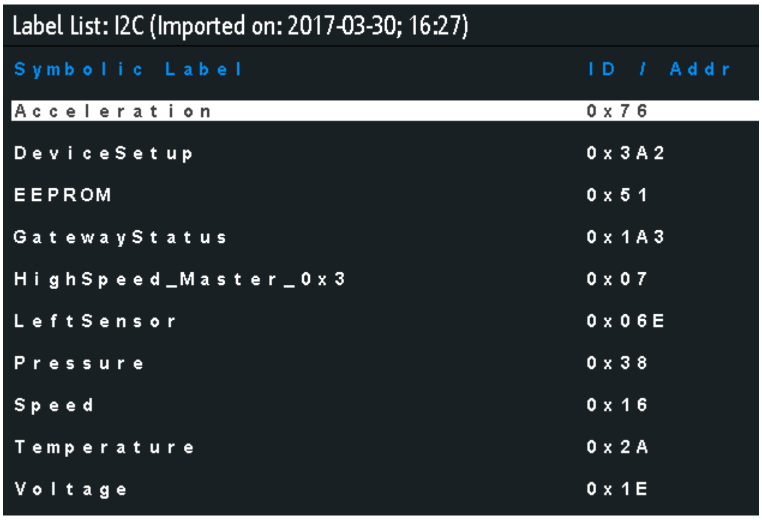


Figure 9-11: Label list for I2C

9.3.5 I2C Decode Results

If the option is installed, the "Decode" function is available.

When the configuration of the serial bus is complete, the signal can be decoded:

1. In the "Bus" menu, enable "Decode".
2. In the "Display" menu, select additional result display settings, see also Chapter 9.1.2, "Display Settings", on page 116.
3. In the "Bus Table" menu, enable the display of the "Bus Table".

The instrument captures and decodes the signal according to the standard definition and the configuration settings.

The color-coding of the various protocol sections and errors simplifies the interpretation of the visual display. The decode information condenses or expands, depending on the horizontal scale. Various data formats are available to show the result values.

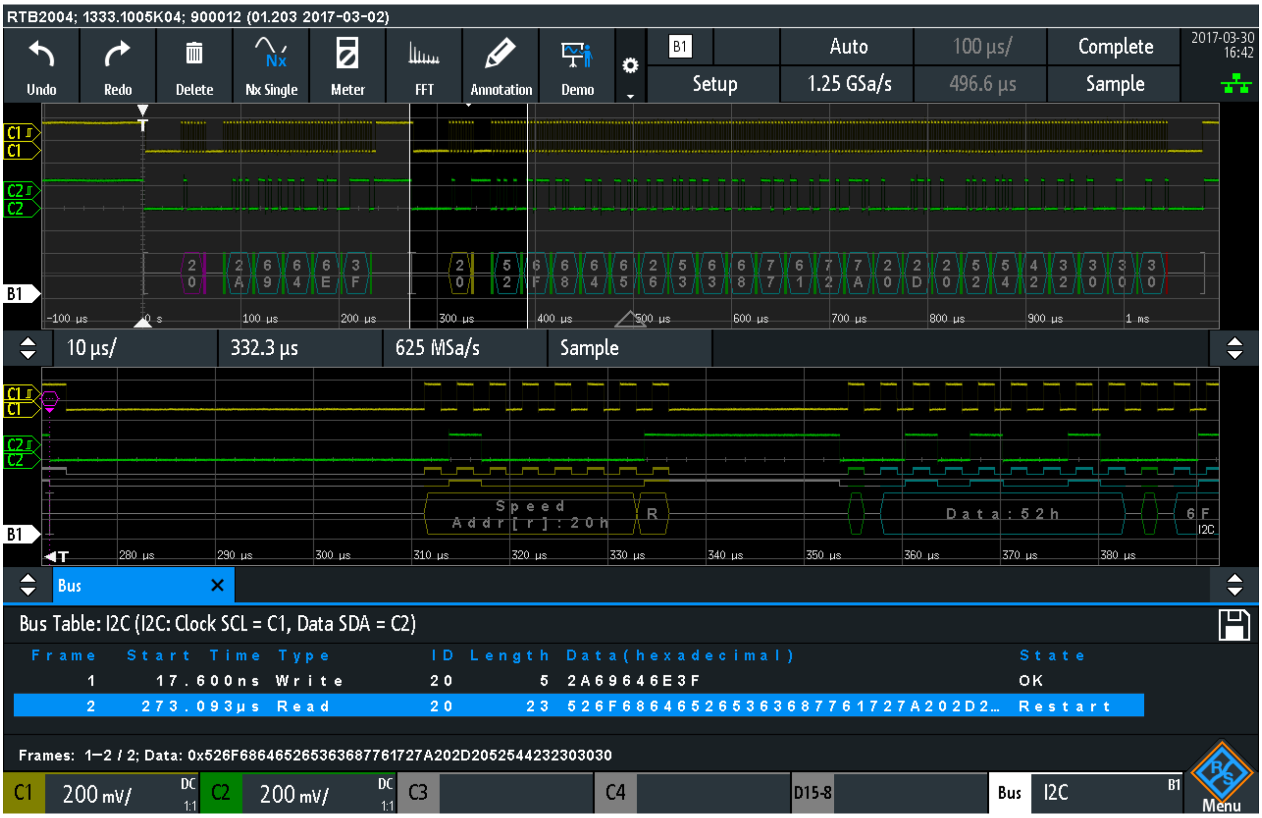


Figure 9-12: Decoded and binary I2C signal, and bus table with decode results

gray brackets = start and end of the frame
violet = address
blue = correct data words
green = acknowledge bit, ok

The figure above shows a decoded I2C signal and the "Bus Table".

Table 9-2: Content of the I²C frame table

Column	Description
Start time	Time of the frame start in relation to the trigger point
Type	Value of the R/W bit, read or write access
ID	Hexadecimal value of the address
Length	Number of words in the frame
Data	Hexadecimal values of the data words
State	Overall state of the frame

Remote commands are described in Chapter 10.10.3.3, "I²C - Decode Results", on page 260.

9.4 UART / RS232 (Option R&S RTB-K2)

9.4.1 The UART / RS232 Interface

The Universal Asynchronous Receiver/Transmitter UART converts a word of data into serial data, and vice versa. It is the base of many serial protocols like of RS-232. The UART uses only one line, or two lines for transmitter and receiver.

Data transfer

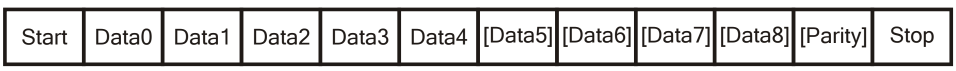


Figure 9-13: Bit order in a UART word (symbol)

- The start bit is a logic 0.
- The stop bits and the idle state are always logic 1.

The UART protocol has no clock for synchronization. The receiver synchronizes by means of the start and stop bits, and the bit rate that must be known to the receiver.

Trigger

The R&S RTB2000 can trigger on specified parts of UART serial signals:

- Start bit
- Parity errors, and breaks
- A serial pattern at any or a specified position

9.4.2 UART Configuration

Access: PROTOCOL > "Bus Type" = "UART" > "Configuration"

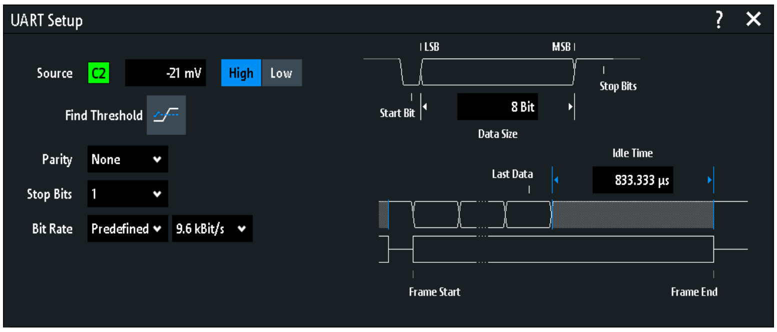


Figure 9-14: UART setup dialog

The dialog offers the following settings:

Source

Selects the input channel of the receive (Rx) line, of the optional transmit (Tx) line, or of the data line if only one data line is used.

If the MSO option R&S RTB-B1 is installed, you can also use digital channels as source.

Remote command:
`BUS<b>:UART:DATA:SOURce` on page 267

Polarity

Selects if the transmitted data is high active (high = 1) or low active (low = 1).

High active is used, for example, for control signals, while low active is defined for data lines (RS-232).

Remote command:
`BUS<b>:UART:DATA:POLarity` on page 268
`BUS<b>:UART:POLarity` on page 267

Threshold, Find Threshold

Set the signal threshold for the source channel. Enter a value, or use Find Threshold to set the threshold to the middle reference level of the measured amplitude.

For analog channels, you can find the value also in the "Vertical" menu > "Channel <n>" >"Threshold"

For logic channels, you can find the value also in the "Logic" menu > "Threshold".

Remote command:
`CHANnel<m>:THReshold` on page 178
`CHANnel<m>:THReshold:FINDlevel` on page 179

Parity

Defines the optional parity bit that is used for error detection.

"None" No parity bit is used.

"Even" The parity bit is set to "1" if the number of data bits set to "1" is odd. Adding the parity bit makes the data word's parity even.

"Odd" The parity bit is set to "1" if the number of data bits set to "1" is even. Adding the parity bit makes the data word's parity odd.

Remote command:
`BUS<b>:UART:PARity` on page 268

Stop Bits

Sets the number of stop bits: 1 or 1.5 or 2 stop bits are possible.

Remote command:
`BUS<b>:UART:SBIT` on page 269

Bit Rate

Sets the number of transmitted bits per second.

"Predefined" Selects from a list of predefined bit rates between 300 Bit/s and 1 MBit/s.

"User" Specifies an individual bit rate with values between 150 and 39,062,500.

Remote command:
`BUS<b>:UART:BAUDrate` on page 269

Data Size

Sets the number of data bits of a word in a range from 5 to 9 bits.

Remote command:
`BUS<b>:UART:SSIZe` on page 268

Idle Time

Sets the minimal time between two data frames (packets), that is, between the last stop bit and the start bit of the next frame.

Remote command:
`BUS<b>:UART:BITime` on page 269

9.4.3 UART Trigger

9.4.3.1 Triggering on UART

Prerequisites: The UART bus is configured. After configuration, the trigger type "Serial Bus" is available in the "Trigger" > "Source" menu. See Chapter 9.4.2, "UART Configuration", on page 138.

Triggers are only available, if "Decode" is enabled.

To trigger on UART:

1. Press the PROTOCOL key in the analysis area of the front panel.
2. Select the "Bus Type" "UART".
3. Select "Trigger"

   This selection automatically enables "Decode", opens the "UART Trigger" menu, sets the "Trigger Type" to "Serial Bus" and displays the "UART Trigger" condition below the protocol setup dialog.
4. At "UART Trigger", select the required trigger condition:
   - "Start Bit" or "Frame Start": next start bit or first start bit after idle time
   - "Frame Start"
   - "Frame Error"
   - "Symbol <n>": frame number in a data stream
   - "Break": a start bit not followed by a stop bit
   - "Parity Error"
   - "Pattern": serial pattern of 1, 2, 3 or 4 symbols at a defined position in the data stream
   - "Any Symbol": pattern of data bits anywhere in a data stream
5. If "Pattern" or "Any Symbol" is selected, the UART trigger setup dialog expands to define the serial pattern or the symbol.

9.4.3.2 UART Trigger Settings

Access: PROTOCOL > "Bus Type" = UART > "Trigger" > "Source"

Selecting "Trigger" in the protocol menu automatically enables protocol decoding.

For general trigger functions, see Chapter 4.3, "General Trigger Settings", on page 54.

UART Trigger

Selects the trigger condition.

"Start Bit"	Sets the trigger to the start bit. The start bit is the first logical 0 after a stop bit.
"Frame Start"	Sets the trigger to the beginning of a frame. The frame start is the first start bit after the idle time.
"Frame Error"	The instrument triggers, if a frame error occurs.
"Symbol <n>"	Sets the trigger to the specified symbol - the n-th word - in a frame (package).
"Break"	Triggers if a start bit is not followed by a stop bit, the data line remains at logic 0 for longer than a UART word.
"Parity Error"	Triggers on a parity error indicating a transmission error. This requires that Parity is activated in the UART configuration: "Parity" = "Even" or "Odd", not "None".
"Pattern"	See "UART Trigger" on page 140
"Any Symbol"	Opens a submenu to trigger if a pattern occurs in a symbol at any position in a frame. You can enter the pattern in binary or hex, the functions are the same as for "Pattern" setting: ● Select Bit ● State ● Value

Remote command:
`TRIGger:A:UART:MODE` on page 270

Pattern ← UART Trigger

Opens a trigger setup dialog to configure a serial pattern of subsequent symbols at a defined position in the frame to be triggered at. The dialog shown below is opened together with the UART setup dialog:

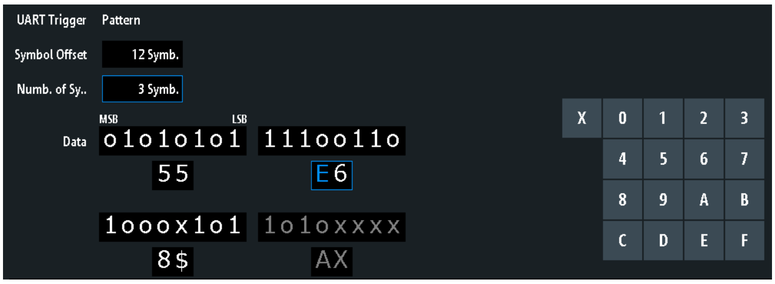


Figure 9-15: Trigger setup dialog with an example of a UART serial pattern

"Symbol Offset"	= see Symbol Offset
"Numb. of Symb."	= see Numb. of Symb.
"Data"	= Binary and hex values of the pattern, see below and Data
55	= Hex value of the 1st symbol, with the binary value 01010101
E6	= Hex value of the 2nd symbol, with the binary value 11100110
E (blue)	= Selected nibble in the 2nd symbol, where the blue color indicates that the keypad is active for this nibble
8$	= Hex value of the 3rd symbol, where the 1st nibble has the binary value 1000 and the 2nd nibble is represented by the "$" character, as it includes one "X" bit (don't care)
AX (gray)	= The 4th symbol is not contained in the specified pattern

To open an on-screen keypad for entering the hexadecimal value of any symbol (byte, set of eight bits), tap one of the characters below this symbol. To open an on-screen keypad for entering the binary value of any bit, tap this bit.

If a nibble (half byte) contains 1, 2 or 3 "X" bits (don't care), the nibble value is represented by the character "$". If all 4 bits of a nibble are "X", the nibble itself is "don't care", represented by the character "X".

As soon as the instrument detects the specified data pattern, it sets the trigger to the first bit of this pattern.

Symbol Offset ← Pattern ← UART Trigger
Sets the number of symbols to be ignored before the serial pattern after the end of the address byte.

The minimum offset is 0 symbol, the maximum offset is 4,095 symbols.

Remote command:
`TRIGger:A:UART:POFFset` on page 271

Numb. of Symb. ← Pattern ← UART Trigger
Sets the number of symbols (full bytes) you want to trigger on. The minimum is 1 symbol, a maximum of 4 symbols is possible.

Note: Entering data bits beyond the specified length of the pattern automatically adjusts the "Number of Bytes" to include all full bytes with entered bits.

Remote command:
`TRIGger:A:UART:PLENgth` on page 270

Data ← Pattern ← UART Trigger
Specifies the data pattern as shown in UART Trigger. To specify a longer pattern than in this example, either just enter bits beyond the specified length, or first select a higher Numb. of Symb..

Remote command:
`TRIGger:A:UART:PATTern` on page 270

9.4.4 UART Decode Results

If the option is installed, the "Decode" function is available.

When the configuration of the serial bus is complete, the signal can be decoded:

1. In the "Bus" menu, enable "Decode".
2. In the "Display" menu, select additional result display settings, see also Chapter 9.1.2, "Display Settings", on page 116.
3. In the "Bus Table" menu, enable the display of the "Bus Table".

The instrument captures and decodes the signal according to the standard definition and the configuration settings.

The color-coding of the various protocol sections and errors simplifies the interpretation of the visual display. The decode information condenses or expands, depending on the horizontal scale. Various data formats are available to show the result values.

Figure 9-16: Decoded UART signal

The figure above shows six frames of a UART signal and the "Bus Table".

Table 9-3: Content of the UART frame table

Column	Description
Start time	Time of the frame start in relation to the trigger point
Data	Hexadecimal values of the data words
State	Overall state of the frame

Remote commands are described in Chapter 10.10.4.3, "UART - Decode Results", on page 271.

9.5 CAN (Option R&S RTB-K3)

CAN is the Controller Area Network, a bus system designed by Bosch for use within automotive network architecture, for example, for brake, power train and engine management. Today, it is also used in many other systems, for example, in industrial machines, aerospace, subsea, merchant marine .

9.5.1 CAN Configuration

Access: PROTOCOL > "Bus Type" = "CAN" > "Configuration"

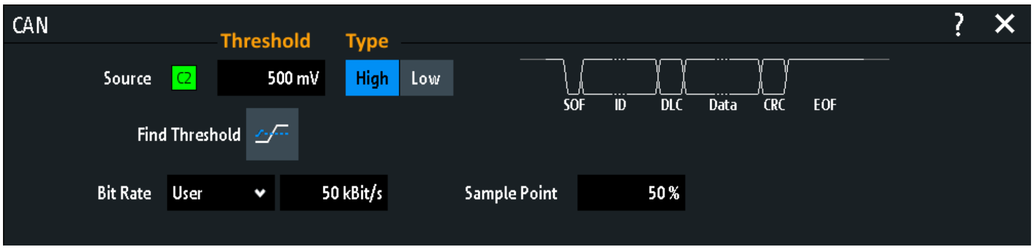


Figure 9-17: CAN setup dialog

The dialog offers the following settings:

Source

Sets the source of the data line. All channel waveforms can be used.

If the MSO option R&S RTB-B1 is installed, you can also use digital channels as source.

Remote command:
`BUS<b>:CAN:DATA:SOURce` on page 275

Threshold, Find Threshold

Set the signal threshold for the source channel. Enter a value, or use Find Threshold to set the threshold to the middle reference level of the measured amplitude.

For analog channels, you can find the value also in the "Vertical" menu > "Channel <n>" >"Threshold"

For logic channels, you can find the value also in the "Logic" menu > "Threshold".

Remote command:
`CHANnel<m>:THReshold` on page 178
`CHANnel<m>:THReshold:FINDlevel` on page 179

Type

Selects the CAN-High or CAN-Low line. CAN uses both lines for differential signal transmission.

If you measure with a differential probe, connect the probe to both CAN-H and CAN-L lines and select "High".

If you use a single-ended probe, connect the probe to either CAN_L or CAN_H and select "High" or "Low" accordingly.

Remote command:
`BUS<b>:CAN:TYPE` on page 275

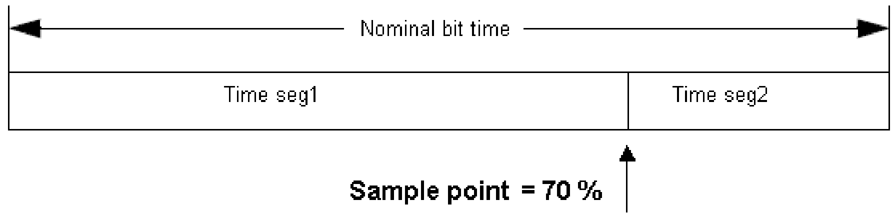
Bit Rate
Sets the number of transmitted bits per second. The maximum bit rate for High Speed CAN is 1 Mbit/s. The bit rate is uniform and fixed for a given CAN bus.

"Predefined" To select a bit rate from the list of predefined values, set "Bit rate" to "Predefined" and select a value from the list.

"User" To set another value, set "Bit rate" to "User" and enter a bit/s value.

Remote command:
`BUS<b>:CAN:BITRate` on page 276

Sample Point
Sets the position of the sample point within the bit in percent of the nominal bit time. The sample point divides the nominal bit period into two distinct time segments, which are used for resynchronization of the clock.



The CAN bus interface uses an asynchronous transmission scheme. The standard specifies a set of rules to resynchronize the local clock of a CAN node to the message.

Remote command:
`BUS<b>:CAN:SAMPlepoint` on page 275

9.5.2 CAN Trigger

9.5.2.1 Triggering on CAN

Prerequisites: The CAN bus is configured. See Chapter 9.5.1, "CAN Configuration", on page 144.

To trigger on CAN signals:

1. Press the PROTOCOL key in the analysis area of the front panel.
2. Select the "Bus Type" = "CAN".

3. Select "Trigger".

   This selection has several effects:
   - Enables decoding, if necessary.
   - Opens the "CAN Trigger" menu.
   - Sets the "Trigger Type" to "Serial Bus" and the trigger source to the selected bus.
   - Displays the "CAN Trigger" condition in the dialog box, below the protocol setup.

4. At "CAN Trigger", select the required trigger type:
   - "Start of Frame": first edge of synchronization bit
   - "End of Frame": frame number in a data stream
   - "Frame": error, overload, data or remote frame
   - "Error": stuff bit, form, acknowledgment, CRC
   - "Identifier": specific message identifier or identifier range
   - "Identifier and Data": combination of identifier and data condition

5. If "Identifier" or "Identifier and Data" is selected, the CAN trigger setup dialog expands to define the serial pattern.

9.5.2.2 CAN Trigger Settings

Access: PROTOCOL > "Bus Type" = "CAN" > "Trigger" > "Source"

Selecting "Trigger" in the protocol menu automatically enables protocol decoding.

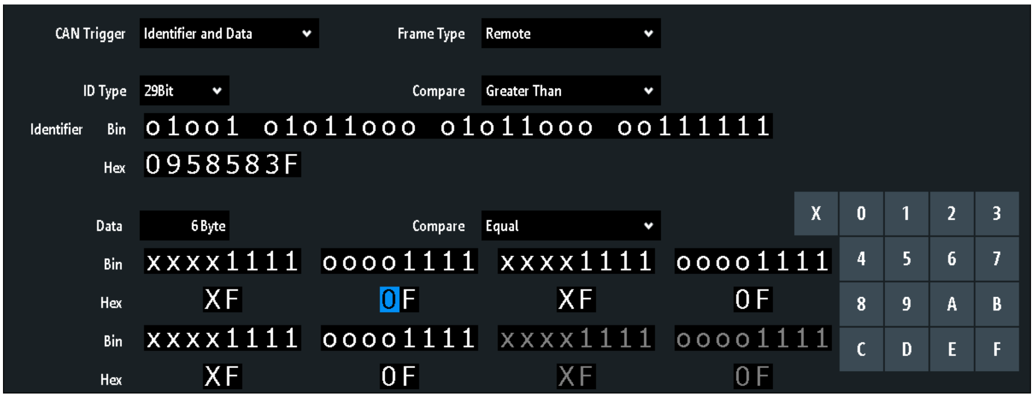


Figure 9-18: Trigger setup dialog with an example of CAN identifier and data patterns

"CAN Trigger"	= trigger on "Identifier and Data"
"Identifier"	= trigger on 29-bit identifiers greater than the specified identifier
"Data"	= trigger on the specified 6-byte data pattern
0 (blue)	= Selected nibble in the 2nd byte of the data pattern, where the blue color indicates that the keypad is active for this nibble

For general trigger functions, see Chapter 4.3, "General Trigger Settings", on page 54.

CAN Trigger
Selects the trigger mode.

"Start of Frame" Triggers on the first edge of the dominant SOF bit (synchronization bit).

"End of Frame" Triggers on the end of the frame (7 recessive bits).

"Frame" Triggers on the frame type that is selected with "Frame"
See: "Frame" on page 147.

"Error" Triggers on a frame error. An error frame is sent by a node that has detected an error.
See: "Error" on page 148.

"Identifier" Triggers on a specific message identifier or an identifier range.
If a label list with node names was loaded and applied in the bus configuration, you can select simply the "Symbolic ID" instead of entering the numeric identifier.
See: "Identifier condition" on page 149.

"Identifier and Data" Triggers on a combination of identifier and data condition. The instrument triggers at the end of the last byte of the specified data pattern.
See: "Identifier condition" on page 149 and "Data condition" on page 149.

Remote command:
`TRIGger:A:CAN:TYPE` on page 276

Frame
Select the frame type to be triggered on.

"Data" Frame for data transmission.
The identifier format ("ID Type") is also considered.

"Remote" A remote frame initiates the transmission of data by another node.
The frame format is the same as of data frames, but without the data field.
The identifier format ("ID Type") is also considered.

"Data or Remote" Triggers on remote frames and on data frames.
The identifier format ("ID Type") is also considered.

"Error" Triggers on any error frame.

"Overload" An overload frame is sent by a node that needs a delay between data and/or remote frames.

Remote command:
`TRIGger:A:CAN:FTYPe` on page 277

ID Type
Selects the length of the identifier: 11 bit for CAN base frames or 29 bits for CAN extended frames. Select "Any" if the identifier type is not relevant.

Remote command:
`TRIGger:A:CAN:ITYPe` on page 277

Error
Identifies various errors in the frame. You can select one or more error types as trigger condition.

Remote command:
`TRIGger:A:CAN:TYPE` on page 276

Stuff Bit ← Error
The following frame segments are coded by the bit stuffing method:
- Start of frame
- Arbitration field
- Control field
- Data field
- CRC sequence

The transmitter automatically inserts a complementary bit into the bitstream when it detects five consecutive bits of identical value in the bitstream to be transmitted. A stuff error occurs when the 6^{th} consecutive equal bit level in the mentioned fields is detected.

Remote command:
`TRIGger:A:CAN:BITSterror` on page 279

Form ← Error
A form error occurs when a fixed-form bit field contains one or more illegal bits.

Remote command:
`TRIGger:A:CAN:FORMerror` on page 280

Acknowledge ← Error
An acknowledgment error occurs when the transmitter does not receive an acknowledgment - a dominant bit during the "Ack" slot.

Remote command:
`TRIGger:A:CAN:ACKerror` on page 279

CRC ← Error
CAN uses the Cyclic Redundancy Check (CRC), which is a complex checksum calculation method. The transmitter calculates the CRC and sends the result in the CRC sequence. The receiver calculates the CRC in the same way. A CRC error occurs when the calculated result differs from the received value in the CRC sequence.

Remote command:
`TRIGger:A:CAN:CRCerror` on page 279

Identifier condition

The identifier condition consists of the following settings:
- ID Type
- Comparison
- Identifier value

Compare ← Identifier condition

Sets the identifier comparison condition: If the identifier pattern contains at least one X (do not care), you can trigger on values equal or not equal to the specified value. If the pattern contains only 0 and 1, you can also trigger on a range greater than or lower than the specified value.

Remote command:
`TRIGger:A:CAN:ICONdition` on page 278

Bin / Hex pattern ← Identifier condition

Defines the identifier or data pattern in binary and hexadecimal format. To set an individual binary bit or hex nibble (half byte), tap it and enter it via the on-screen keypad.

"Bin"	String containing the binary pattern with a maximum of 64 bits. Characters 0, 1 and X are allowed.
"Hex"	String containing the hexadecimal pattern with a maximum of 8 bytes. Characters 0 to F and X are allowed.

Remote command:
`TRIGger:A:CAN:IDENtifier` on page 278
`TRIGger:A:CAN:DATA` on page 279

Data condition

The data condition consists of the following settings:
- Length of the data pattern
- Comparison
- Data pattern, see "Bin / Hex pattern" on page 149

Data ← Data condition

Defines the length of the data pattern - the number of bytes in the pattern.

Remote command:
`TRIGger:A:CAN:DLC` on page 278

Compare ← Data condition

Sets the data comparison condition. If the pattern contains at least one X (do not care), you can trigger on values equal or not equal to the specified value. If the pattern contains only 0 and 1, you can also trigger on a range greater than or lower than the specified value.

Remote command:
`TRIGger:A:CAN:DCONdition` on page 278

9.5.3 CAN Label List

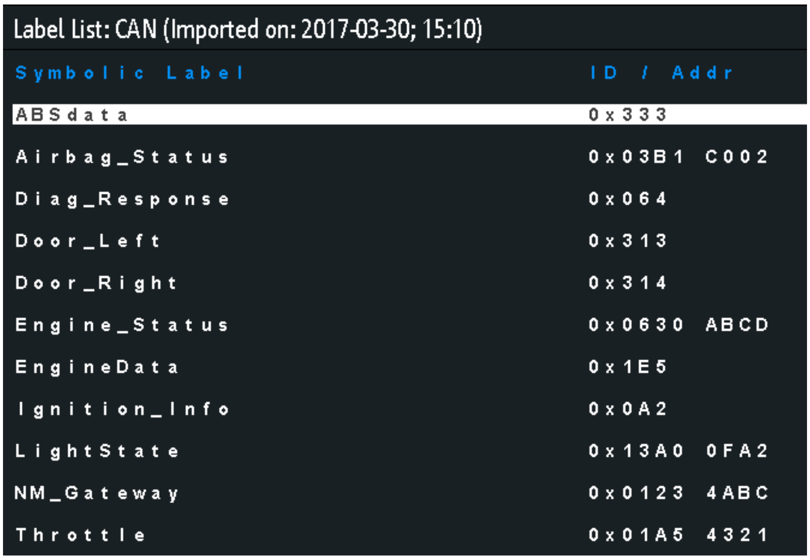
PTT and CSV files are protocol-specific. A PTT label file for CAN protocols contains three values for each identifier:

- Identifier type, 11-bit or 29-bit long
- Identifier value
- Label, symbolic name of the identifier, specifying its function in the bus network.

Example: CAN PTT file

```
# ----------------------------------------------------------------------------
@FILE_VERSION  = 1.00
@PROTOCOL_NAME = can
# ---------------------------------------------------------------------------
# Labels for CAN protocol
#   Column order: Identifier type, Identifier value, Label
# ---------------------------------------------------------------------------
11,064h,Diag_Response
11,1E5h,EngineData
11,0A2h,Ignition_Info
11,1BCh,TP_Console
11,333h,ABSdata
11,313h,Door_Left
11,314h,Door_Right
29,01A54321h,Throttle
29,13A00FA2h,LightState
29,0630ABCDh,Engine_Status
29,03B1C002h,Airbag_Status
29,01234ABCh,NM_Gateway
# ----------------------------------------------------------------------------
```

For general information on label lists, see Chapter 9.1, "Basics of Protocol Analysis", on page 113.



Label List: CAN (Imported on: 2017-03-30; 15:10)

Symbolic Label	ID / Addr
ABSdata	0x333
Airbag_Status	0x03B1 C002
Diag_Response	0x064
Door_Left	0x313
Door_Right	0x314
Engine_Status	0x0630 ABCD
EngineData	0x1E5
Ignition_Info	0x0A2
LightState	0x13A0 0FA2
NM_Gateway	0x0123 4ABC
Throttle	0x01A5 4321

Figure 9-19: Label list for CAN

9.5.4 CAN Decode Results

If the option is installed, the "Decode" function is available.

When the configuration of the serial bus is complete, the signal can be decoded:

1. In the "Bus" menu, enable "Decode".
2. In the "Display" menu, select additional result display settings, see also Chapter 9.1.2, "Display Settings", on page 116.
3. In the "Bus Table" menu, enable the display of the "Bus Table".

The instrument captures and decodes the signal according to the standard definition and the configuration settings.

The color-coding of the various protocol sections and errors simplifies the interpretation of the visual display. The decode information condenses or expands, depending on the horizontal scale. Various data formats are available to show the result values.

Figure 9-20: Decoded CAN signal with bus table and applied label list

violet = identifier
gray = DLC, data length code
blue = data words
red = error occured, error frame

The figure above shows a decoded CAN signal and the "Bus Table".

Table 9-4: Content of the CAN frame table

Column	Description
Time Diff.	Time of frame start in relation to the trigger point
Type	Frame type: Data, Remote, Error, or Overload
ID	Identifier value, hexadecimal value
DLC	Data length code, number of data bytes
Data	Hexadecimal values of the data bytes
CRC	Hexadecimal value of the Cyclic Redundance Check (checksum)
State	Overall state of the frame.

Remote commands are described in Chapter 10.10.5.3, "CAN - Decode Results", on page 280.

9.5.5 Search on Decoded CAN Data

Using the search functionality, you can find the same events in the decoded data which you also can trigger on. Unlike trigger, the search finds all events in an acquisition that fulfill the search condition.

1. Configure the bus correctly
2. Acquire decoded data.
3. Press the key.
4. Select the "Search Type" = "Protocol".
5. Select the "Source": the bus that is configured for CAN protocol.
6. Select the "Event" you want to search for.
7. Enter additional settings, depending on the event.

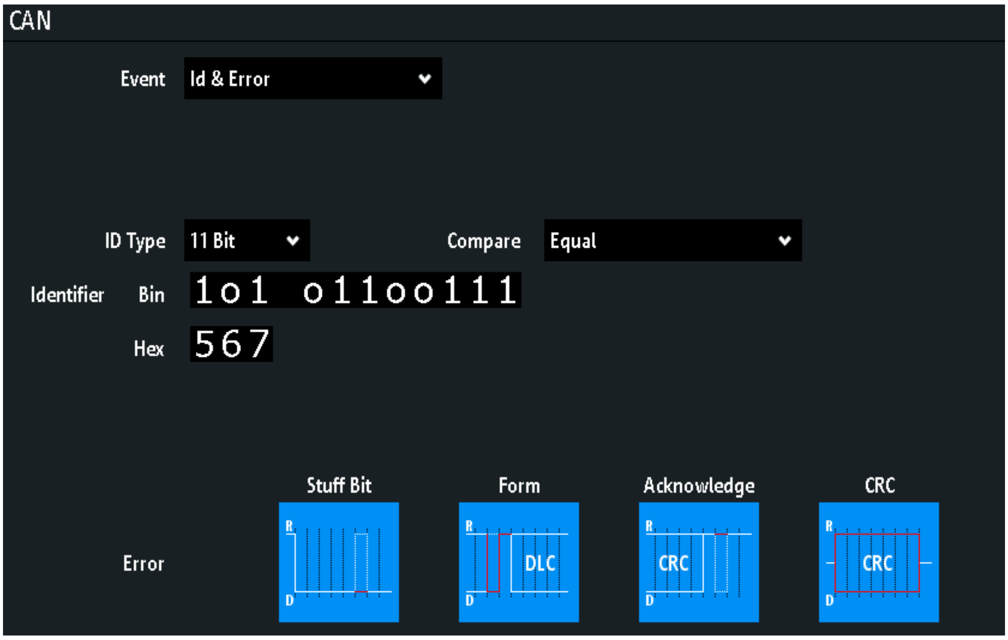


Figure 9-21: Search on CAN bus for frames with identifier 567 (hex) that have an error

Event
Sets the event or combination of events to be searched for. Depending on the selected event, additional settings are displayed.

Remote command:
SEARch:PROTocol:CAN:CONDition on page 286

Frame Setup
Selects the frame type to be searched for.

If you search for remote or data frames, the search considers also the ID type, the length of the identifier. The setting is only available if "Event" = "Frame" is selected.

Remote command:
SEARch:PROTocol:CAN:FRAMe on page 287

Error

Selects the error type to be searched for. You can select one or more error types as search condition. The error types are the same as in the CAN trigger setup, see "Error" on page 148.

If you search for remote or data frames, the search considers also the ID type, the length of the identifier. The setting is only available if "Event" = "Error" or "Error & ID" is selected.

Remote command:
`SEARch:PROTocol:CAN:ACKerror` on page 288
`SEARch:PROTocol:CAN:BITSterror` on page 288
`SEARch:PROTocol:CAN:CRCerror` on page 288
`SEARch:PROTocol:CAN:FORMerror` on page 288

Frame Type

Selects the frame type to be searched for, if "Event" = "Identifier" is selected. You can search for data and or remote frames.

Remote command:
`SEARch:PROTocol:CAN:FTYPe` on page 289

Identifier condition

Settings to define the identifier pattern, if "Event" = "Identifier" or "ID & Data" or "ID & Error" is selected.

After setting the "ID Type" and the "Compare" condition, you can enter the identifier value by setting the state high, low, or X (do not care) for each single bit. Alternatively, you can enter a hexadecimal value for each half byte. The settings are the same as for the setup of the identifier trigger, see also "Identifier condition" on page 149.

If a label list with node names was loaded and applied in the bus configuration, you can select the node name from the list instead of entering the numeric identifier. The instrument triggers on the identifier of the selected node.

Remote command:
`SEARch:PROTocol:CAN:ITYPe` on page 289
`SEARch:PROTocol:CAN:ICONdition` on page 289
`SEARch:PROTocol:CAN:IDENtifier` on page 289

Data condition

Settings to define the data pattern to be searched, if "Event" = "ID & Data" is selected.

After setting the "Data" length and the "Compare" condition, you can enter the data value by setting the state high, low, or X (do not care) for each single bit. Alternatively, you can enter a hexadecimal value for each half byte. The settings are the same as for the setup of the data trigger, see also "Data condition" on page 149.

Remote command:
`SEARch:PROTocol:CAN:DLENgth` on page 289
`SEARch:PROTocol:CAN:DCONdition` on page 290
`SEARch:PROTocol:CAN:DATA` on page 290

9.6 LIN R&S RTB-K3

The Local Interconnect Network (LIN) is a simple, low-cost bus system used within automotive network architectures. LIN is usually a sub-network of a CAN bus. The primary purpose of LIN is the integration of uncritical sensors and actuators with low bandwidth requirements. Common applications in a motor vehicle are the control of doors, windows, wing mirrors, and wipers.

9.6.1 The LIN Protocol

This chapter provides an overview of protocol characteristics, frame format, identifiers and trigger possibilities. For detailed information, order the LIN specification on http://www.lin-subbus.org/ (free of charge).

LIN characteristics

Main characteristics of LIN are:

- Single-wire serial communications protocol, based on the UART byte-word interface
- Single master, multiple slaves - usually up to 12 nodes
- Master-controlled communication: master coordinates communication with the LIN schedule and sends identifier to the slaves
- Synchronization mechanism for clock recovery by slave nodes without crystal or ceramics resonator

The R&S RTB2000 supports several versions of the LIN standard: v1.3, v2.0, v2.1 and the American SAE J2602.

Data transfer

Basic communication concept of LIN:

- Communication in an active LIN network is always initiated by the master.
- Master sends a message header including the synchronization break, the synchronization byte, and the message identifier.
- The identified node sends the message response: one to eight data bytes and one checksum byte.
- Header and response form the message frame.

The data is transmitted in bytes using the UART byte-word interface without the parity bit. Each byte consists of a start bit, 8 bits and a stop bit.

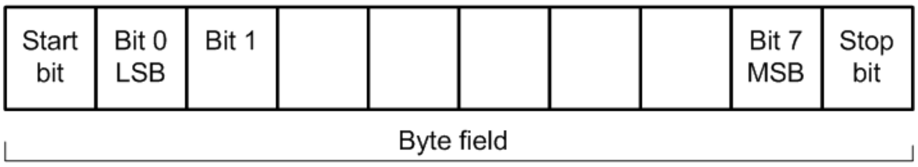


Figure 9-22: Structure of a byte field

Data bytes are transmitted LSB first.

The identifier byte consists of 6 bits for the frame identifier and two parity bits. This combination is known as protected identifier.

Trigger

The R&S RTB2000 can trigger on various parts of LIN frames. The data line must be connected to an input channel, triggering on math and reference waveforms is not possible.

You can trigger on:

- Frame start (synchronization field)
- Specific slave identifier or identifier range
- Data pattern in the message
- Wake up signal
- Checksum error (error in data), parity error (error in identifier)

9.6.2 LIN Configuration

Access: PROTOCOL > "Bus Type" = "LIN" > "Configuration"

Figure 9-23: LIN setup dialog

These dialogs offer the following settings:

Source

Sets the source of the data line. All channel waveforms can be used.

If the MSO option R&S RTB-B1 is installed, you can also use digital channels as source.

Remote command:
`BUS<b>:LIN:DATA:SOURce` on page 291

Data Type
Defines the idle state of the bus. The idle state is the recessive state and corresponds to a logic 1.

Remote command:
`BUS<b>:LIN:POLarity` on page 291

Threshold, Find Threshold
Set the signal threshold for the source channel. Enter a value, or use Find Threshold to set the threshold to the middle reference level of the measured amplitude.

For analog channels, you can find the value also in the "Vertical" menu > "Channel <n>" >"Threshold"

For logic channels, you can find the value also in the "Logic" menu > "Threshold".

Remote command:
`CHANnel<m>:THReshold` on page 178
`CHANnel<m>:THReshold:FINDlevel` on page 179

Version
Selects the version of the LIN standard that is used in the DUT. The setting mainly defines the checksum version used during decoding.

The most common version is LIN 2.x. For mixed networks, or if the standard is unknown, set the LIN standard to "Any".

Remote command:
`BUS<b>:LIN:STANdard` on page 291

Bit Rate
Sets the number of transmitted bits per second. The maximum bit rate is 20 kbit/s.

"Predefined"	To select a bit rate from the list of predefined values, set "Bit rate" to "Predefined" and select a value from the list. Minimum is 1.2 kBit/s, maximum is 19.2 kBit/s.
"User"	To set another value, set "Bit rate" to "User" and enter a bit/s value. Minimum is 100, maximum is 5.040323 M.

Remote command:
`BUS<b>:LIN:BITRate` on page 291

9.6.3 LIN Trigger

9.6.3.1 Triggering on LIN

Prerequisites: The LIN bus is configured. After configuration, the trigger type "Serial Bus" is available in the "Trigger" > "Source" menu. See Chapter 9.6.2, "LIN Configuration", on page 156.

Triggers are only available, if "Decode" is enabled.

To trigger on LIN:

1. Press the PROTOCOL key in the analysis area of the front panel.
2. Select the "Bus Type" "LIN".
3. Select "Trigger"

   This selection automatically enables "Decode", opens the "LIN Trigger" menu, sets the "Trigger Type" to "Serial Bus" and displays the "LIN Trigger" conditions below the protocol configuration settings.
4. At "LIN Trigger", select the required trigger condition:
   - "Start of Frame": stop bit of the sync field
   - "Wake Up": after a wakeup frame
   - "Error": checksum, parity or synchronization
   - "Identifier": specific message identifier or identifier range
   - "Identifier and Data": combination of identifier and data condition
5. If "Identifier" or "Identifier and Data" is selected, the CAN trigger setup dialog expands to define the serial pattern.

9.6.3.2 LIN Trigger Settings

Access: PROTOCOL > "Bus Type" = LIN > "Trigger" > "Source"

Selecting "Trigger" in the protocol menu automatically enables protocol decoding.

For general trigger functions, see Chapter 4.3, "General Trigger Settings", on page 54.

LIN Trigger
Specifies the trigger mode.

Remote command:
`TRIGger:A:LIN:TYPE` on page 292

Start of Frame ← LIN Trigger
Triggers on the stop bit of the synchronization field.

Remote command:
`TRIGger:A:LIN:TYPE` on page 292

Wake Up ← LIN Trigger
Triggers after a wakeup frame.

Remote command:
`TRIGger:A:LIN:TYPE` on page 292

Error ← LIN Trigger
Identifies various errors in the frame. You can select one or more error types as trigger condition.

Checksum ← Error ← LIN Trigger
Triggers on a checksum error. The checksum verifies the correct data transmission. It is the last byte of the frame response. The checksum includes not only the data but also the protected identifier (PID).

Remote command:
`TRIGger:A:LIN:CHKSerror` on page 293

Parity ← Error ← LIN Trigger
Triggers on a parity error. Parity bits are the bits 6 and 7 of the identifier. They verify the correct transmission of the identifier.

Remote command:
`TRIGger:A:LIN:IPERror` on page 293

Synchronization ← Error ← LIN Trigger
Triggers if synchronization caused an error.

Remote command:
`TRIGger:A:LIN:SYERror` on page 293

Identifier ← LIN Trigger
Sets the trigger to a specific message identifier or an identifier range. Only the 6 bit identifier without parity bits is considered, not the protected identifier.

For an example, see Figure 9-24 (where a data pattern is also specified according to the selection).

Remote command:
`TRIGger:A:LIN:TYPE` on page 292

Identifier ← Identifier ← LIN Trigger

Defines the identifier pattern in binary and hexadecimal format. To set an individual binary bit or hex nibble (half byte), tap it and enter it via the on-screen keypad.

"Bin"	String containing the binary pattern with a maximum of 64 bits. Characters 0, 1 and X are allowed.
"Hex"	String containing the hexadecimal pattern with a maximum of 8 bytes. Characters 0 to F and X are allowed.

Remote command:
`TRIGger:A:LIN:IDENtifier` on page 293

Compare ← Identifier ← LIN Trigger

Sets the identifier comparison condition: If the identifier pattern contains at least one X (don't care), you can trigger on values equal or not equal to the specified value. If the pattern contains only 0 and 1, you can also trigger on a range greater than or lower than the specified value.

Remote command:
`TRIGger:A:LIN:ICONdition` on page 293

Identifier and Data ← LIN Trigger

Opens a dialog with LIN Trigger Settings and Data pattern settings below the LIN Configuration dialog:

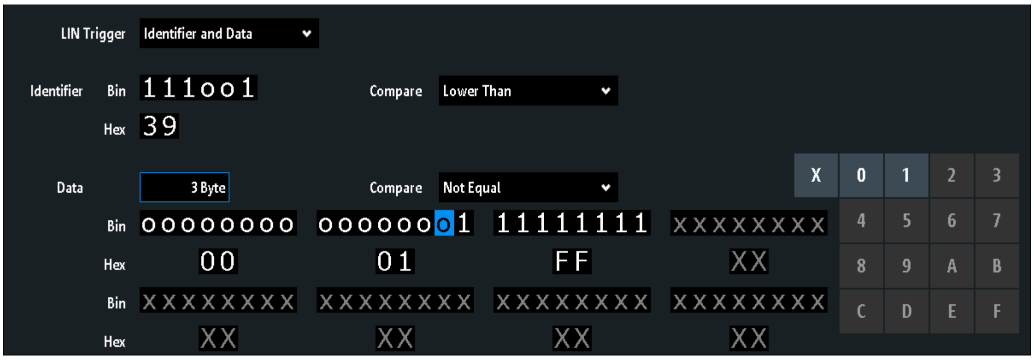


Figure 9-24: Trigger setup dialog with an example of CAN identifier and data patterns

"LIN Trigger"	= see LIN Trigger Settings
"Identifier"	= see "Identifier" on page 159
"Data"	= see Data
o (blue)	= Selected bit in the 2nd byte of the data pattern, where the blue color indicates that the keypad is active for this bit

Remote command:
`TRIGger:A:LIN:TYPE` on page 292

Data ← LIN Trigger

Defines the length of the data pattern - the number of bytes in the pattern.

Remote command:
`TRIGger:A:LIN:DLENgth` on page 294

Compare ← LIN Trigger
Sets the comparison condition: If the pattern contains at least one X (don't care), you can trigger on values equal or not equal to the specified value. If the pattern contains only 0 and 1, you can also trigger on a range greater than or lower than the specified value.

Remote command:
`TRIGger:A:LIN:DCONdition` on page 294

Bin / Hex ← LIN Trigger
Specifies the data pattern to be triggered. To set an individual binary bit or hexadecimal nibble (half byte), tap it and enter it via the on-screen keypad. Make sure to specify complete bytes.

"Bin"	String containing the binary pattern with a maximum of 64 bits. Characters 0, 1 and X are allowed.
"Hex"	String containing the hexadecimal pattern with a maximum of 8 bytes. Characters 0 to F and X are allowed.

Remote command:
`TRIGger:A:LIN:DATA` on page 294

9.6.4 Search on Decoded LIN Data

1. Configure the bus correctly
2. Acquire decoded data.
3. Press the key.
4. Select the "Search Type" = "Protocol".
5. Select the "Source": the bus that is configured for LIN protocol.
6. Select the "Event" you want to search for.
7. Enter additional settings, depending on the event.

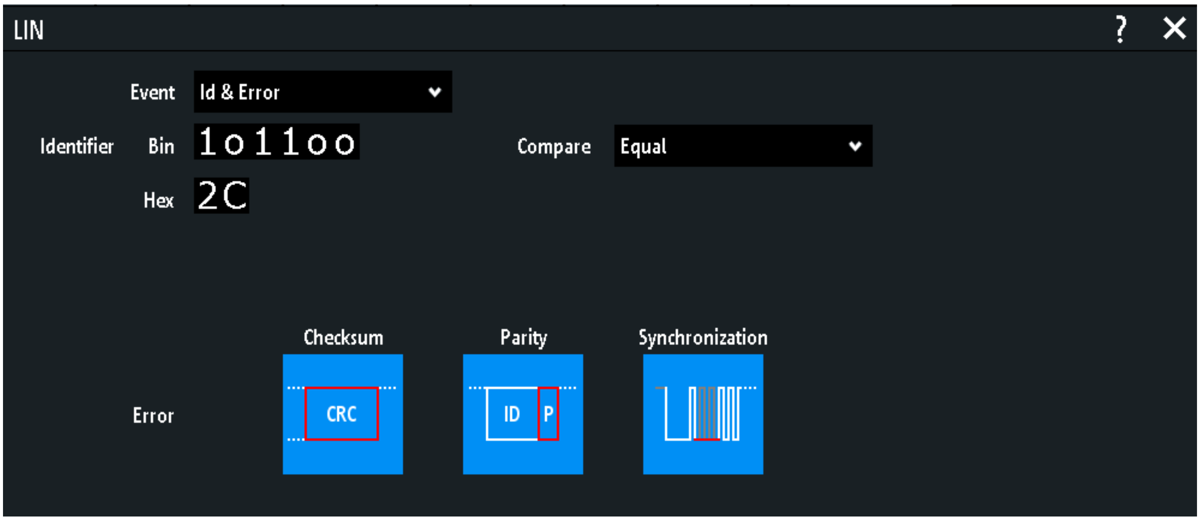


Figure 9-25: Search on LIN bus for frames with identifier 2C (hex) that have an error

Event

Sets the event or combination of events to be searched for. Depending on the selected event, additional settings are displayed.

Remote command:
`SEARch:PROTocol:LIN:CONDition` on page 300

Frame Setup

Selects the frame type to be searched for.

Remote command:
`SEARch:PROTocol:CAN:FRAMe` on page 287

Error

Selects the error type to be searched for. You can select one or more error types as search condition. The error types are the same as in the LIN trigger setup, see "LIN Trigger" on page 159.

The setting is only available if "Event" = "Error" or "Error & ID" is selected.

Remote command:
`SEARch:PROTocol:LIN:CHKSerror` on page 301
`SEARch:PROTocol:LIN:IPERror` on page 301
`SEARch:PROTocol:LIN:SYERror` on page 301

Identifier condition

Settings to define the identifier pattern, if "Event" = "Identifier" or "ID & Data" or "ID & Error" is selected.

After setting the "Identifier" and the "Compare" condition, you can enter the identifier value by setting the state high, low, or X (do not care) for each single bit. Alternatively, you can enter a hexadecimal value for each half byte. The settings are the same as for the setup of the identifier trigger, see also Identifier.

Remote command:
`SEARch:PROTocol:LIN:ICONdition` on page 302
`SEARch:PROTocol:LIN:IDENtifier` on page 302

Data condition
Settings to define the data pattern to be searched, if "Event" = "ID & Data" is selected.

After setting the "Data" length and the "Compare" condition, you can enter the data value by setting the state high, low, or X (do not care) for each single bit. Alternatively, you can enter a hexadecimal value for each half byte. The settings are the same as for the setup of the data trigger, see also LIN Trigger.

Remote command:
`SEARch:PROTocol:LIN:DLENgth` on page 302
`SEARch:PROTocol:LIN:DCONdition` on page 302
`SEARch:PROTocol:LIN:DATA` on page 303

9.6.5 LIN Label List

Label lists are protocol-specific. Label lists for LIN are available in CSV and PTT format.

A LIN label file contains two values for each identifier:

- Identifier value
- Symbolic name for the identifier

Example of a LIN PTT file

```
# ----------------------------------------------------------------------------
@FILE_VERSION = 1.0
@PROTOCOL_NAME = lin
# ----------------------------------------------------------------------------
# Labels for LIN protocol
#   Column order: Identifier, Label
# ----------------------------------------------------------------------------
# Labels for standard addresses
0x3F,Temperature
1Ch,Left brake
20h,Right brake
# Following ID is provided as integer
33,Mirror
0x37,Indoor lights
# Labels for reserved addresses
0x3C,Master_Request_Frame
0x3D,Slave_Response_Frame
# ----------------------------------------------------------------------------
```

For general information on label lists, see Chapter 9.1, "Basics of Protocol Analysis", on page 113.

Label List: LIN (Imported on: 2017-03-30; 16:50)

Symbolic Label	ID / Addr
Dashboard	0x03
Door controller	0x2E
Gateway	0x02
Indoor lights	0x37
Master_Request_Frame	0x3C
Mirror	0x01
Reserved_Frame	0x3F
Slave_Response_Frame	0x3D
Temperature	0x04
User_Defined_Frame	0x3E

Figure 9-26: Label list for LIN

9.6.6 LIN Decode Results

If the option is installed, the "Decode" function is available.

When the configuration of the serial bus is complete, the signal can be decoded:

1. In the "Bus" menu, enable "Decode".
2. In the "Display" menu, select additional result display settings, see also Chapter 9.1.2, "Display Settings", on page 116.
3. In the "Bus Table" menu, enable the display of the "Bus Table".

The instrument captures and decodes the signal according to the standard definition and the configuration settings.

The color-coding of the various protocol sections and errors simplifies the interpretation of the visual display. The decode information condenses or expands, depending on the horizontal scale. Various data formats are available to show the result values.

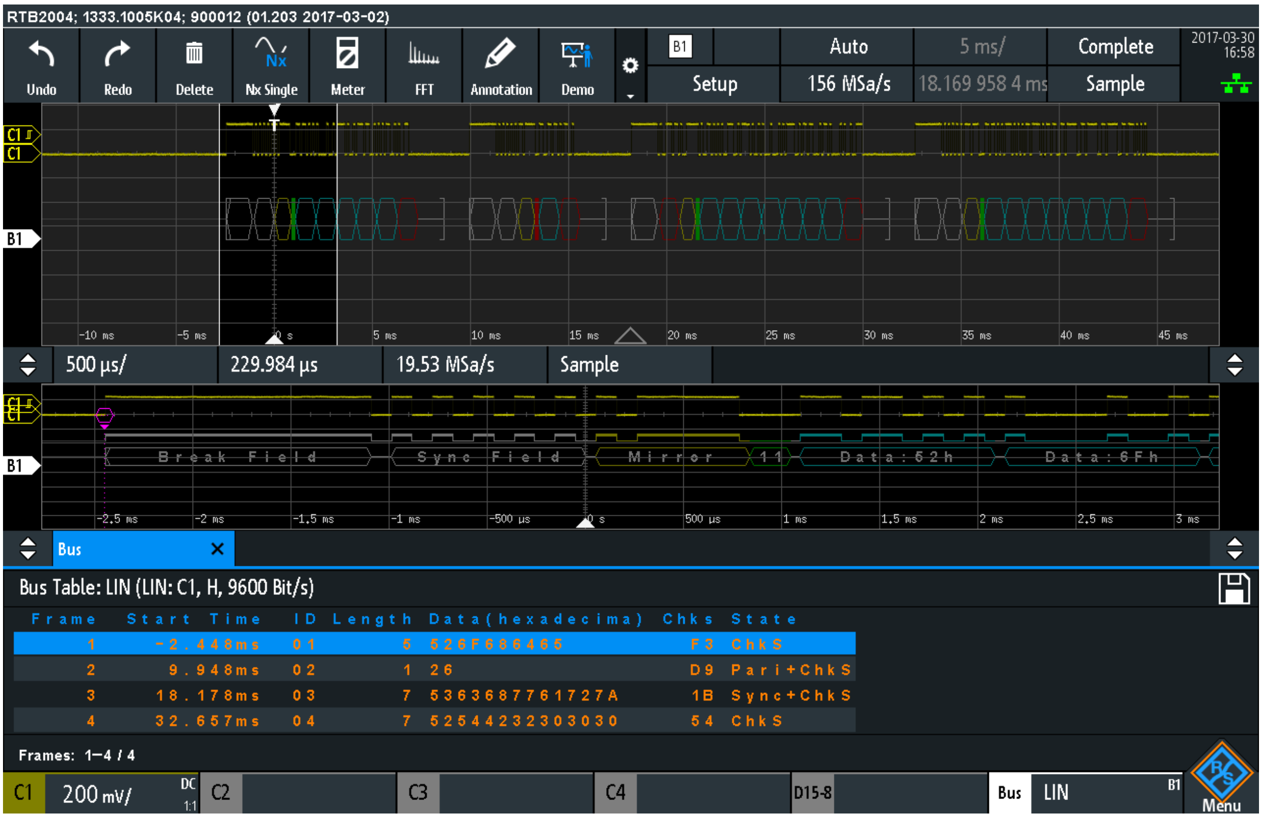


Figure 9-27: Decoded LIN signal with frame table and applied label list

gray = synchronization break, synchronization byte, correct checksum
yellow = identifier
green = parity bits
blue = data words (UART words)

The figure above shows a decoded LIN signal and the "Bus Table".

Table 9-5: Content of the LIN frame table

Column	Description
Start time	Time of frame start in relation to the trigger point
ID	Identifier value, hexadecimal value
Length	Number of data bytes
Data	Hexadecimal values of the data bytes
Chks	Checksum value
State	Overall state of the frame.

Remote commands are described in Chapter 10.10.6.3, "LIN - Decode Results", on page 294.

10 Remote Control Commands

This chapter provides the description of all remote commands available for R&S RTB2000. The commands are sorted according to the menu structure of the instrument. A list of commands in alphabetical order ist given in the "List of Commands" at the end of this documentation.

10.1 Conventions used in Command Description

Note the following conventions used in the remote command descriptions:

- **Command usage**
  If not specified otherwise, commands can be used both for setting and for querying parameters.
  If a command can be used for setting or querying only, or if it initiates an event, the usage is stated explicitly.
- **Parameter usage**
  If not specified otherwise, a parameter can be used to set a value and it is the result of a query.
  Parameters required only for setting are indicated as **Setting parameters**.
  Parameters required only to refine a query are indicated as **Query parameters**.
  Parameters that are only returned as the result of a query are indicated as **Return values**.
- **Conformity**
  Commands that are taken from the SCPI standard are indicated as **SCPI confirmed**. All commands used by the R&S RTB2000 follow the SCPI syntax rules.
- **Asynchronous commands**
  A command which does not automatically finish executing before the next command starts executing (overlapping command) is indicated as an **Asynchronous command**.
- **Reset values (*RST)**
  Default parameter values that are used directly after resetting the instrument (`*RST` command) are indicated as ***RST** values, if available.
- **Default unit**

This is the unit used for numeric values if no other unit is provided with the parameter.

10.2 Programming Examples

10.2.1 Data Export

10.2.1.1 Reading Waveform Data in Real Format

Set data format and sample range, read channel header and data.

Command description in Chapter 10.8.1, "Transfer of Waveform Data", on page 221.

```
* Connected to: TCPIP0::192.168.1.1::inst0::INSTR
SYST:ERR?
<-- 0,"No error"
*IDN?
<-- Rohde&Schwarz,RTM1052,1305.0008K52/101489,04.502

*RST
CHAN:TYPE HRES            // Set high resolution mode (16 bit data)
TIM:SCAL 1E-7             // Set time base
FORM REAL                 // Set REAL data format
FORM:BORD LSBF            // Set little endian byte order
CHAN:DATA:POIN DMAX       // Set sample range to memory data in displayed time range
SING;*OPC?                // Start single acquisition
<--  1
CHAN:DATA:HEAD?           // Read header
<--  -4.9980E-07,5.0000E-07,5000,1    // Xstart, Xstop, record length in samples
CHAN:DATA?                // Read channel data
<--  #520000>??[>??[>??[>??[>??[>??...   // Binary block data,
                                         // 4-byte floating point number/sample
```

10.2.1.2 Reading Waveform Data in Unsigned Integer Format

Read the channel header, the waveform conversion data, set the UINT binary data format and read the channel data.

Command description in: Chapter 10.8.1, "Transfer of Waveform Data", on page 221.

```
*RST
TIM:SCAL 1E-7
```

```
CHAN:DATA:POIN DMAX        // Set data range
SING;*OPC?
<--  1
CHAN:DATA:HEAD?            // Read header
<--  -4.9980E-07,5.0000E-07,5000,1    // Xstart, Xstop, record length in samples
CHAN:DATA:YRES?            // Read vertical resolution
<--  8
CHAN:DATA:YOR?             // Read voltage value for binary value 0
<--  -2.549999943E-2
CHAN:DATA:XOR?             // Read time of the first sample
<--  -4.998000058E-7
CHAN:DATA:XINC?            // Read time between two adjacent samples
<--  2.000000023E-10
FORM UINT,8;FORM?          // Set data format to unsigned integer, 8 bit
<--  UINT,8
CHAN:DATA:YINC?            // Read voltage value per bit
<--  1.999999949E-4
CHAN:DATA?                 // Read channel data
<--  128,125,120...        // 5000 bytes total
FORM UINT,16;FORM?         // Change data format to unsigned integer, 16 bit
<--  UINT,16
CHAN:DATA:YINC?            // Read voltage value per bit
<--  7.812499803E-7
CHAN:DATA?                 // Read channel data
<--  32768,32000,30720... // 10000 bytes total
```

Note the following correlations:

- The number of received data values matches the number of samples indicated in the header.
- The time of the first sample (XORigin) matches the start time Xstart indicated in the header.
- The Y-increment adjusts to the data length defined in the data format (8 or 16 bit).

Data conversion

Definition: the sample numbers start with *0* and end with *record length - 1*.

Sample time

$t_n = n * xIncrement + xOrigin$

First sample: $t_0 = -4.998000058E-7$ (= Xstart)

Last sample: $t_{4999} = 4999 * 2E^{-10} - 4.998E^{-7} = 5.0\ E^{-7}$ (= Xstop)

Sample value

$Y_n = yOrigin + (yIncrement * byteValue_n)$

The format `UINT,8` has the data range 0 to 255. The voltage value for byte value 128 is:

$Y_n = -2.55E^{-2} + (2E^{-4} * 128) = 0.0001$

The center of the display at position 0 div always has the byte value 127.5. The corresponding voltage value is:

$Y_n = -2.55E^{-2} + (2E^{-4} * 127.5) = 0$

8-bit and 16-bit data

At the end of the above example, the 8-bit waveform is read as 16-bit data, for example, *0xFF* is read *0xFF00*, or *0x1A* is read *0x1A00*. The *yOrigin* value is the same in both cases, but the *yIncrement* differs.

	8-bit data	16-bit data	Result
*yIncrement * byteValue$_n$*	$2e^{-4}$ * 128	$7{,}8125E^{-7}$ * 32768	0,0256 V
	$2e^{-4}$ * 125	$7{,}8125E^{-7}$ * 32000	0,025 V

In the reverse case, if a 16-bit waveform is read with 8-bit data format, data precision may be reduced. Data values ar truncated, and only the more significiant bits remain. For example, the 16-bit data *0xabcd* is read *0xab* in 8-bit format, and *cd* is lost.

10.2.2 Function Generator

Configure and output a sine waveform.

Command description in: Chapter 10.11.1, "Function Generator", on page 303.

```
*RST
:WGEN:FUNC SIN            // Selects Sine function
:WGEN:VOLT 700E-3         // Sets the amplitude
:WGEN:FREQ 1.00E+06       // Sets the frequency
:WGEN:OUTP:LOAD R50       // Sets the user load
:WGEN:OUTP 1              // Outputs the sine waveform
```

10.3 Common Commands

Common commands are described in the IEEE 488.2 (IEC 625-2) standard. These commands have the same effect and are employed in the same way on different devices. The headers of these commands consist of "*" followed by three letters. Many common commands are related to the Status Reporting System.

Available common commands:

***CAL?**

Performs a self-alignment of the instrument and then generates a status response. Return values ≠ 0 indicate an error.

Usage: Query only

***CLS**

Clear status

Sets the status byte (STB), the standard event register (ESR) and the `EVENt` part of the `QUEStionable` and the `OPERation` registers to zero. The command does not alter the mask and transition parts of the registers. It clears the output buffer.

Usage: Setting only

***ESE** <Value>

Event status enable

Sets the event status enable register to the specified value. The query returns the contents of the event status enable register in decimal form.

Parameters:

<Value> Range: 0 to 255

***ESR?**

Event status read

Returns the contents of the event status register in decimal form and subsequently sets the register to zero.

Return values:

<Contents> Range: 0 to 255

Usage: Query only

***IDN?**

Identification

Returns the instrument identification.

Return values:

<ID> "Rohde&Schwarz,<device type>,<serial number>,<firmware version>"

Example: `Rohde&Schwarz,RTB2004,1333.1005k04/900012, 01.203`

Usage: Query only

***OPC**

Operation complete

Sets bit 0 in the event status register when all preceding commands have been executed. This bit can be used to initiate a service request. The query form writes a "1" into the output buffer as soon as all preceding commands have been executed. This is used for command synchronization.

***OPT?**

Option identification query

Queries the options included in the instrument. For a list of all available options and their description refer to the data sheet.

Return values:

<Options> The query returns a list of options. The options are returned at fixed positions in a comma-separated string. A zero is returned for options that are not installed.

Usage: Query only

***PSC** <Action>

Power on status clear

Determines whether the contents of the `ENABle` registers are preserved or reset when the instrument is switched on. Thus a service request can be triggered when the instrument is switched on, if the status registers ESE and SRE are suitably configured. The query reads out the contents of the "power-on-status-clear" flag.

Parameters:

<Action> 0 | 1

0
The contents of the status registers are preserved.

1
Resets the status registers.

***RST**

Reset

Sets the instrument to a defined default status. The default settings are indicated in the description of commands.

Usage: Setting only

***SRE** <Contents>

Service request enable

Sets the service request enable register to the indicated value. This command determines under which conditions a service request is triggered.

Parameters:

<Contents> Contents of the service request enable register in decimal form. Bit 6 (MSS mask bit) is always 0.

Range: 0 to 255

***STB?**

Status byte query

Reads the contents of the status byte in decimal form.

Usage: Query only

***TRG**

Trigger

Triggers all actions waiting for a trigger event. In particular, *TRG generates a manual trigger signal. This common command complements the commands of the `TRIGger` subsystem.

Usage: Event

***WAI**

Wait to continue

Prevents servicing of the subsequent commands until all preceding commands have been executed and all signals have settled (see also command synchronization and `*OPC`).

Usage: Event

10.4 Waveform Setup

10.4.1 Automatic Setup

AUToscale

Performs an autoset process for analog channels: analyzes the enabled analog channel signals, and adjusts the horizontal, vertical, and trigger settings to display stable waveforms

Usage: Event
Asynchronous command

10.4.2 Starting and Stopping Acquisition

RUN
RUNContinous

Starts the continuous acquisition.

Usage: Event
Asynchronous command

SINGle
RUNSingle

Starts a defined number of acquisitions. The number of acquisitions is set with `ACQuire:NSINgle:COUNt`.

Usage: Event
Asynchronous command

ACQuire:NSINgle:COUNt <NSingleCount>

Sets the number of waveforms acquired with `RUNSingle`.

Parameters:

<NSingleCount> Number of waveforms.

Range: 1 to maximum number that depends on the record length.

*RST: 1

STOP

Stops the running acquistion.

Usage: Event
Asynchronous command

ACQuire:STATe

Sets or queries the acquisition state of the instrument.

Parameters:

<AcquisitionState> RUN | STOPping | COMPlete | BREak

RUN | STOP | COMPlete | BREak

RUN
Set: Starts the acquisition.
Read: The acquisition is running.

STOPping
Set: Stops the acquisition when it is finished.
Read: Acquisition is stopped.

COMPlete
Set: Not available.
Read: The current acquisition is finished and completed.

BREak
Set: Immediate interrupt of current acquisition.
Read: acquisition is finished but interrupted.

10.4.3 Vertical Settings

CHANnel<m>:STATe <State>

Switches the channel signal on or off.

Suffix:

<m>	1..4 Selects the input channel. The number of channels depends on the instrument.

Parameters:

<State>	ON | OFF

CHANnel<m>:AON

Switches all analog channels on.

Suffix:

<m>	The suffix is irrelevant.
Usage:	Event

CHANnel<m>:AOFF

Switches all analog channels off.

Suffix:

<m>	The suffix is irrelevant.
Usage:	Event

CHANnel<m>:SCALe <Scale>

Sets the vertical scale for the indicated channel.

Suffix:

<m>	1..4 Selects the input channel. The number of channels depends on the instrument.

Parameters:

<Scale>	Scale value, given in Volts per division. Range: 1e-3 to 10 (without probe attenuation) *RST: 5e-3 Default unit: V/div

CHANnel<m>:RANGe <Range>

Sets the voltage range across the all vertical divisions of the diagram. Use the command alternatively instead of `CHANnel<m>:SCALe`.

Suffix:

<m> 1..4
Selects the input channel. The number of channels depends on the instrument.

Parameters:

<Range> Voltage range value

Range: 8e-3 to 80 (without probe attenuation)
*RST: 40e-3
Default unit: V

CHANnel<m>:OFFSet <Offset>

Sets the offset voltage, which is subtracted to correct an offset-affected signal.

Suffix:

<m> 1..4
Selects the input channel. The number of channels depends on the instrument.

Parameters:

<Offset> Offset value

Range: Depend on vertical scale and probe attenuation.
Increment: Depends on vertical scale and probe attenuation.
*RST: 0
Default unit: V

CHANnel<m>:COUPling <Coupling>

Selects the connection of the indicated channel signal - coupling and termination.

Suffix:

<m> 1..4
Selects the input channel. The number of channels depends on the instrument.

Parameters:

<Coupling> DCLimit | ACLimit | GND

DCLimit
DC coupling passes the input signal unchanged.

ACLimit
Removes the DC offset voltage from the input signal.

GND
Connection to a virtual ground. All channel data is set to o V.

CHANnel<m>:BANDwidth <BandwidthLimit>

Selects the bandwidth limit for the indicated channel.

Suffix:

<m> 1..4
Selects the input channel. The number of channels depends on the instrument.

Parameters:

<BandwidthLimit> FULL | B20

FULL
Use full bandwidth.

B20
Limit to 20 MHz. Higher frequencies are removed to reduce noise.

*RST: FULL

CHANnel<m>:POLarity <Polarity>

Turns the inversion of the signal amplitude on or off. To invert means to reflect the voltage values of all signal components against the ground level. Inversion affects only the display of the signal but not the trigger.

Suffix:

<m> 1..4
Selects the input channel. The number of channels depends on the instrument.

Parameters:

<Polarity> NORMal | INVerted

*RST: NORM

CHANnel<m>:SKEW <Skew>

Sets a delay for the selected channel.

Deskew compensates delay differences between channels caused by the different length of cables, probes, and other sources. Correct deskew values are important for accurate triggering.

Suffix:

<m> 1..4
Selects the input channel. The number of channels depends on the instrument.

Parameters:

<Skew> Deskew value

Default unit: s

CHANnel<m>:ZOFFset[:VALue] <ZeroOffset>

Sets the zero offset.

Differences in DUT and oscilloscope ground levels may cause larger zero errors affecting the waveform. If the DUT is ground-referenced, the "Zero Offset" corrects the zero error and sets the probe to the zero level.

You can assess the zero error by measuring the mean value of a signal that should return zero.

Suffix:

<m> 1..4
Selects the input channel. The number of channels depends on the instrument.

Parameters:

<ZeroOffset> *RST: 0
Default unit: V

CHANnel<m>:OVERload <Overload>

Retrieves the overload status of the specified channel from the status bit. When the overload problem is solved, the command resets the status bit.

Suffix:

<m> 1..4
Selects the input channel. The number of channels depends on the instrument.

Parameters:

<Overload> ON | OFF

Use OFF to reset the overload status bit.

*RST: OFF

Example:

`CHANnel2:OVERload?`
Queries the overload status of channel 2.
`CHANnel2:OVERload OFF`
Resets the overload status bit.

CHANnel<m>:THReshold <Threshold>

Threshold value for digitization of analog signals. If the signal value is higher than the threshold, the signal state is high (1 or true for the Boolean logic). Otherwise, the signal state is considered low (0 or false) if the signal value is below the threshold.

Suffix:

<m> 1..4
Selects the input channel. The number of channels depends on the instrument.

Parameters:

<Threshold> Often used values are:
TTL: 1.4 V
ECL: -1.3 V
CMOS: 2.5 V

Default unit: V

CHANnel<m>:THReshold:FINDlevel

The instrument analyzes the channel and sets the threshold for digitization.

Suffix:

<m> 1..4
Selects the input channel. The number of channels depends on the instrument.

Usage: Event

CHANnel<m>:THReshold:HYSTeresis <ThresholdHysteresis>

Defines the size of the hysteresis to avoid the change of signal states due to noise.

Suffix:

<m> 1..4
Selects the input channel. The number of channels depends on the instrument.

Parameters:

<ThresholdHysteresis> SMALl | MEDium | LARGe

Values correspond to the vertical scale

*RST: SMAL

CHANnel<m>:LABel <Label>

Specifies a name for the selected channel.

Suffix:

<m> 1..4
Selects the input channel. The number of channels depends on the instrument.

Parameters:

<Label> String value

String with max. 8 characters, only ASCII characters can be used

---

CHANnel<m>:LABel:STATe

Shows or hides the channel name.

Suffix:
<m> 1..4
Selects the input channel. The number of channels depends on the instrument.

Parameters:
<State> ON | OFF
*RST: OFF

10.4.4 Probes

PROBe<m>:SETup:ATTenuation:UNIT <Unit>

Selects the unit that the probe can measure.

Suffix:
<m> 1..4
Selects the input channel. The number of channels depends on the instrument.

Parameters:
<Unit> V | A

PROBe<m>:SETup:ATTenuation:MANual <ManualAttenuation>

Sets the attenuation or gain of the probe.

Suffix:
<m> 1..4
Selects the input channel. The number of channels depends on the instrument.

Parameters:
<ManualAttenuation> Range: 0.001 to 10000
*RST: 1

10.4.5 Horizontal Settings

TIMebase:SCALe <TimeScale>

Sets the horizontal scale for all channel and math waveforms.

Parameters:

<TimeScale>

Range: 1e-9 to 50; lower limits are possible if zoom or FFT is enabled.
Increment: 1e-9
*RST: 100e-6
Default unit: s/div

TIMebase:POSition <Offset>

Defines the trigger position, the time distance from the trigger point to the reference point (trigger offset). The trigger point is the zero point of the diagram. Changing the horizontal position, you can move the trigger, even outside the screen.

See also: `TIMebase:REFerence` on page 181

Parameters:

<Offset>

Range: Depends on time base setting
Increment: 0.01
*RST: 0
Default unit: s

TIMebase:REFerence <ReferencePoint>

Defines the time reference point in the diagram. The reference point is the rescaling center of the time scale on the screen. If you modify the time scale, the reference point remains fixed on the screen, and the scale is stretched or compressed to both sides of the reference point.

The reference point defines which part of the waveform is shown. By default, the reference point is displayed in the center of the window, and you can move it to the left or right.

See also: `TIMebase:POSition` on page 181

Parameters:

<ReferencePoint> 8.33 | 50 | 91.67

8.33 = left position (1 div); 50 = middle position; 91.67 = right position (11 div).

*RST: 50
Default unit: %

TIMebase:ACQTime <AcquisitionTime>
TIMebase:RANGe <AcquisitionTime>

Defines the time of one acquisition, that is the time across the 10 divisions of the diagram: *Timebase Scale*10*.

Parameters:

<AcquisitionTime> Range and increment depend on time base and other settings

Range: 250e-12 to 500
Increment: 1e-12
Default unit: s

TIMebase:DIVisions?

Queries the number of horizontal divisions on the screen.

Return values:

<HorizDivCount> Returns 12 divisions.

Usage: Query only

TIMebase:RATime?

Queries the real acquisition time used in the hardware. If FFT analysis is performed, the value can differ from the adjusted acquisition time (`TIMebase:ACQTime`).

Return values:

<HWAcqTime> Range: Depends on various settings
Default unit: s

Usage: Query only

10.4.6 Acquisition Settings

ACQuire:POINts:AUTomatic <AutoRecordLength>

Enables or disables the automatic record length. The instrument sets a value that fits to the selected timebase.

If you set a specific value with ACQuire:POINts[:VALue], the automatic assignment of a record length is turned off.

Parameters:

<AutoRecordLength> ON | OFF

Example:

```
ACQ:POIN:AUT ON
TIM:SCAL 1e-9
ACQ:POIN?;:SYST:ERR:ALL?
-> received 10000;0,"No error"
TIM:SCAL 5e-3
ACQ:POIN?;:SYST:ERR:ALL?
-> received 20000000;0,"No error"
```

ACQuire:POINts[:VALue]

Defines a record length value, the number of recorded waveform points in a segment.

The command turns ACQuire:POINts:AUTomatic OFF.

If ACQuire:POINts:AUTomatic is turned ON, the query ACQuire:POINts? returns the automatically set record length.

Each predefined record length corresponds to a maximum number of history segments, which are stored in the instrument's memory. If option R&S RTB-K15 is installed, you can display the history segments.

Available record length values are:

- 10 kSa (13107 history segments)
- 20 kSa (6553 history segments)
- 50 kSa (2621 history segments)
- 100 kSa (1456 history segments)
- 200 kSa (771 history segments)
- 500 kSa (319 history segments)
- 1 MSa (159 history segments)
- 2 MSa (80 history segments)
- 5 MSa (32 history segments)
- 10 MSa (16 history segments)
- 20 MSa (8 history segments)

Parameters:

<RecordLength> Record length in Sa.
If the entered value differs from the predefined values, the instrument sets the closest value.

CHANnel<m>:TYPE <DecimationMode>

Selects the method to reduce the data stream of the ADC to a stream of waveform points with lower sample rate.

Suffix:

<m> 1..4
The command affects all channels regardless of the indicated channel number. The suffix can be omitted.

Parameters:

<DecimationMode> SAMPle | PDETect | HRESolution

SAMPle
Input data is acquired with a sample rate which is aligned to the time base (horizontal scale) and the record length.

PDETect
Peak Detect: the minimum and the maximum of n samples in a sample interval are recorded as waveform points.

HRESolution
High resolution: The average of n sample points is recorded as waveform point.

*RST: SAMPle

ACQuire:TYPE <AcquisitionType>

Sets the type of the aquisition mode.

Parameters:

<AcquisitionType> REFresh | AVERage | ENVelope

REFresh
The aquisitions are displayed as they are done.

AVERage
The aquisitions are averaged.

ENVelope
The envelope of a repetitive signal is shown, representing the borders in which the signal occurs.

CHANnel<m>:ARIThmetics <TrArith>

Selects the method to build the resulting waveform from several consecutive acquisitions of the signal.

Suffix:

<m> 1..4
The command affects all channels regardless of the indicated channel number. The suffix can be omitted.

Parameters:

<TrArith> OFF | ENVelope | AVERage

OFF
The data of the current acquisition is recorded according to the decimation settings.

ENVelope
Detects the minimum and maximum values in an sample interval over a number of acquisitions.

AVERage
Calculates the average from the data of the current acquisition and a number of acquisitions before. The number of used acquisitions is set with `ACQuire:AVERage:COUNt`.

*RST: OFF

ACQuire:PEAKdetect <PeakDetect>

Enables or disables the peak detect acquisition mode.

You can use this command alternatively to `CHANnel<m>:TYPE`.

Parameters:

<PeakDetect> AUTO | OFF

*RST: OFF

ACQuire:HRESolution <HighRes>

Enables or disables the high resolution acquisition mode.

You can use this command alternatively to `CHANnel<m>:TYPE`.

Parameters:

<HighRes> AUTO | OFF

*RST: OFF

ACQuire:NSINgle:COUNt <NSingleCount>

Sets the number of waveforms acquired with `RUNSingle`.

Parameters:

<NSingleCount> Number of waveforms.

Range: 1 to maximum number that depends on the record length.

*RST: 1

ACQuire:AVERage:COUNt

Defines the number of waveforms used to calculate the average waveform. The higher the number, the better the noise is reduced.

Parameters:

<AverageCount>	Range:	2 to 100,000
	*RST:	2

ACQuire:AVERage:RESet

Deletes the waveform and restarts the average calculation.

Usage: Event

ACQuire:AVERage:COMPlete?

Returns the state of averaging.

Return values:

<AverageComplete> 0 | 1

0
The number of acquired waveforms is less than the number required for average calculation. See ACQuire:AVERage:COUNt on page 185.

1
The instrument acquired a sufficient number of waveforms to determine the average.

Usage: Query only

TIMebase:ROLL:ENABle <Roll>

Enables the roll mode.

Parameters:

<Roll> ON | OFF

*RST: OFF

ACQuire:INTerpolate <InterpolationType>

Defines the interpolation mode.

See also: "Interpolation" on page 50

Parameters:

<InterpolationType> SINX | LINear | SMHD

LINear
Linear interpolation between two adjacent sample points.

SINX
Interpolation by means of a sin(x)/x curve.

SMHD
Sample & hold causes a histogram-like interpolation.

*RST: SINX

ACQuire:POINts:ARATe?

Retrieves the sample rate of the ADC, that is the number of points that are sampled by the ADC in one second.

Return values:

<ACDsampleRate> ADC sample rate

Default unit: Hz

Usage: Query only

ACQuire:SRATe? <SampleRate>

Returns the sample rate, that is the number of recorded waveform samples per second.

Parameters:

<SampleRate> Default unit: Sa/s

Usage: Query only

10.4.7 Waveform Data

Use the following commands are described in Chapter 10.8.1.1, "Analog Channels", on page 221:

- `FORMat[:DATA]` on page 222
- `CHANnel<m>:DATA?` on page 223
- `CHANnel<m>:DATA:HEADer?` on page 223
- `CHANnel<m>:DATA:POINts` on page 224
- `CHANnel<m>:DATA:ENVelope?` on page 225
- `CHANnel<m>:DATA:ENVelope:HEADer?` on page 226
- `CHANnel<m>:DATA:XINCrement?` on page 227
- `CHANnel<m>:DATA:XORigin?` on page 226
- `CHANnel<m>:DATA:YINCrement?` on page 227
- `CHANnel<m>:DATA:YORigin?` on page 227
- `CHANnel<m>:DATA:YRESolution?` on page 228
- `CHANnel<m>:DATA:ENVelope:XINCrement?` on page 227
- `CHANnel<m>:DATA:ENVelope:XORigin?` on page 226
- `CHANnel<m>:DATA:ENVelope:YINCrement?` on page 227
- `CHANnel<m>:DATA:ENVelope:YORigin?` on page 227
- `CHANnel<m>:DATA:ENVelope:YRESolution?` on page 228

10.5 Trigger

10.5.1 General Trigger Settings

This section describes general trigger commands that are independent of the trigger type.

TRIGger:A:MODE <TriggerMode>

Sets the trigger mode. The trigger mode determines the behavior of the instrument if no trigger occurs.

Parameters:

<TriggerMode> AUTO | NORMal

AUTO
The instrument triggers repeatedly after a time interval if the trigger conditions are not fulfilled. If a real trigger occurs, it takes precedence.

NORMal
The instrument acquires a waveform only if a trigger occurs.

*RST: AUTO

TRIGger:A:SOURce <Source>

Sets the trigger source for the selected A trigger type.

Parameters:

<Source> CH1 | CH2 | CH3 | CH4 | EXTernanalog | LINE | SBUS1 | SBUS2 | D0..D15

CH1 | CH2 | CH3 | CH4
One of the analog input channels is the trigger source. Available channels depend on the instrument type.

EXTernanalog
External trigger input on the front panel

LINE
AC power supply line for the line trigger

SBUS1 | SBUS2
Serial bus 1 or 2
Requires at least one protocol option for serial bus (R&S RTB-K1 to K3)

D0..D15
Digital channels D0 to D15, can be used as trigger sources for edge, width, timeout and pattern trigger. Require MSO option R&S RTB-B1.

TRIGger:A:TYPE <Type>

Sets the trigger typer.

Parameters:

<Type> EDGE | WIDTh | TV | BUS | LOGic | LINE

EDGE
Edge trigger

WIDTh
Width trigger

TV
Video trigger

BUS
Requires at least one protocol option for serial bus (R&S RTB-K1 to K3)

LOGic
Pattern trigger, logic trigger

LINE
Trigger on power supply line

TRIGger:A:HOLDoff:MODE <HoldOffMode>

Enables or disables the holdoff time.

Parameters:

<HoldOffMode> TIME | OFF

*RST: Off

TRIGger:A:HOLDoff:TIME <HoldOffTime>

Defines the holdoff time. The next trigger occurs only after the holdoff time has passed.

Parameters:

<HoldOffTime> Default unit: s

10.5.2 Edge Trigger

TRIGger:A:EDGE:SLOPe <Slope>

Sets the slope for the edge trigger.

Parameters:

<Slope> POSitive | NEGative | EITHer

POSitive
Rising edge, a positive voltage change

NEGative
Falling edge, a negative voltage change

EITHer
The rising as well as the falling edge

*RST: POSitive

TRIGger:A:LEVel<n>[:VALue] <Level>

Sets the trigger threshold voltage for edge, width, and timeout trigger.

Suffix:

<n> 1..5
Selects the trigger input. 1...4 select the corresponding analog channel, 5 is the external trigger input. The number of channels depends on the instrument.

Parameters:

<Level> Range: Depends on vertical scale.
Default unit: V

TRIGger:A:FINDlevel

Sets the trigger level to 50% of the signal amplitude.

Usage: Event

TRIGger:A:EDGE:COUPling <Coupling>

Sets the coupling for the trigger source.

Parameters:

<Coupling> DC | AC | LFReject

DC
Direct current coupling. The trigger signal remains unchanged.

AC
Alternating current coupling. A highpass filter removes the DC offset voltage from the trigger signal.

LFReject
Sets the trigger coupling to high frequency. A 15 kHz highpass filter removes lower frequencies from the trigger signal. Use this mode only with very high frequency signals.

*RST: DC

TRIGger:A:EDGE:FILTer:HFReject <State>

Enables or disables an additional 5 kHz lowpass filter in the trigger path. This filter removes higher frequencies and is available with AC and DC coupling.

To folter out higher frequencies, you can use either this command or `TRIGger:A:EDGE:FILTer:NREJect`.

Parameters:

<State> ON | OFF

*RST: OFF

TRIGger:A:EDGE:FILTer:NREJect <State>

Turns an additional 100 MHz lowpass filter in the trigger path on or off. This filter removes higher frequencies and is available with AC and DC coupling.

To folter out higher frequencies, you can use either this command or `TRIGger:A:EDGE:FILTer:HFReject`.

Parameters:

<State> ON | OFF

*RST: OFF

10.5.3 Width Trigger

To set the trigger level (threshold), use:

- `TRIGger:A:LEVel<n>[:VALue]` on page 190
  `CHANnel<m>:THReshold` on page 178
- `TRIGger:A:FINDlevel` on page 190
  `CHANnel<m>:THReshold:FINDlevel` on page 179

- `CHANNel<m>:THReshold:HYSTeresis` on page 179

TRIGger:A:WIDTh:POLarity <Polarity>

Sets the polarity of the pulse.

Parameters:

<Polarity> POSitive | NEGative

POSitive
Positive going pulse, the width is defined from the rising to the falling slopes.

NEGative
Negative going pulse, the width is defined from the falling to the rising slopes.

*RST: POSitive

TRIGger:A:WIDTh:RANGe <RangeMode>

Defines how the measured pulse width is compared with the given limits.

Parameters:

<RangeMode> WITHin | OUTSide | SHORter | LONGer

WITHin | OUTSide
Triggers on pulses inside or outside a range defined by *time ± delta*. The time is specified with `TRIGger:A:WIDTh:WIDTh`, the range around is defined with `TRIGger:A:WIDTh:DELTa`.
To trigger on an exact value ("Width =" or "Width ≠", set the range to 0 ("Variation", `TRIGger:A:WIDTh:DELTa`).

SHORter | LONGer
Triggers on pulses shorter or longer than a time set with `TRIGger:A:WIDTh:WIDTh`.

*RST: LONGer

TRIGger:A:WIDTh:WIDTh <Time1>

For the ranges WITHin and OUTSide (defined using `TRIGger:A:WIDTh:RANGe`), the <Time1> defines the center of a range which is defined by the limits ±<Delta> (set with `TRIGger:A:WIDTh:DELTa`).

For the ranges SHORter and LONGer, the width defines the maximum and minimum pulse width, respectively.

Parameters:

<Time1> Center value, maximum value or minimum value depending on the defined range type.

Range: 20E-9 to 6.87194685440
Increment: Depends on the <Time1> value
*RST: 20E-9

TRIGger:A:WIDTh:DELTa <Delta>

Defines a variation range around the width value specified using `TRIGger:A:WIDTh:WIDTh`.

Parameters:

<Delta> Variation ±Δt

Range: Minimum is 0. Maximum depends on the defined pulse width (TRIG:A:WIDTH:WITDH).

10.5.4 Video/TV Trigger

TRIGger:A:TV:STANdard <Standard>

Selects the color television standard.

Parameters:

<Standard> PAL | NTSC | SECam | PALM | I576 | P720 | P1080 | I1080

PALM = PAL-M
I576 = SDTV 576i (PAL and SECAM)
P720 | P1080 = HDTV 720/1080p (progressive scanning)
I1080 = HDTV 1080i (interlaced scanning)

*RST: PAL

TRIGger:A:TV:POLarity <Polarity>

Selects the polarity of the signal. Note that the sync pulse has the opposite polarity. The edges of the sync pulses are used for triggering,

See also: "Signal" on page 62

Parameters:

<Polarity>	POSitive | NEGative **POSitive** If the video modulation is positive, the sync pulses are negative. **NEGative** If the modulation is negative, sync pulses are positive. *RST: NEGative

---

TRIGger:A:TV:FIELd <Field>

Sets the trigger on the beginning of the video signal fields, or on the beginning of video signal lines.

Parameters:

<Field>	EVEN | ODD | ALL | LINE | ALINe **EVEN | ODD** Triggers only on the field start of even or odd fields. Only available for interlaced scanning. **ALL** All fields, triggers on the frame start (progressive scanning) or any field start (interlaced scanning). **LINE** Triggers on the beginning of a specified line in any field. The line number is set with `TRIGger:A:TV:LINE`. **ALINe** Triggers on the beginning of all video signal lines. *RST: ALL

TRIGger:A:TV:LINE <Line>

Sets an exact line number if `TRIGger:A:TV:FIELd` is set to LINE.

Parameters:

<Line>	Range: 1 to 525 (NTSC, PAL-M); 625 (PAL, SECAM, SDTV I-576); 750 (HDTV P720); 1125 (HDTV I1080, HDTV P1080) Increment: 1 *RST: 1

10.5.5 Pattern Trigger

10.5.5.1 Pattern Definition

TRIGger:A:PATTern:SOURce <SourceString>

Sets the state for each channel.

Parameters:

<SourceString> String containing 0, 1, or X for each channel.

1: high, the signal voltage is higher than the trigger level.
0: low, the signal voltage is lower than the trigger level.
X: Don't care. the channel does not affect the trigger.
Without MSO option R&S RTB-B1, the pattern has 4 or 2 bits, depending on the number of channels: <C1><C2>[<C3><C4>].
With MSO option, the pattern has 20 or 18 bits: <C1><C2>[<C3><C4>]<D0><D1><D2>...<D15>.

Example: Without MSO option:

```
TRIG:A:PATT:SOUR "1X10"
```

C1 and C3 is set to high, C4 to low, and C2 does not matter (don't care).

Example: With MSO option:

```
TRIG:A:PATT:SOUR "XXXX111101010011XXXX"
```

Analog channels C1 to C4 do not matter (don't care). Digital channels D0 to D11 are set to high or low, D12 to D15 do not matter.

TRIGger:A:PATTern:FUNCtion <Function>

Sets the logical combination of the channel states .

Parameters:

<Function> AND | OR

AND
The required states of all channels must appear in the input signal at the same time.

OR
At least one of the channels must have the required state.

*RST: AND

TRIGger:A:PATTern:CONDition <ConditionString>

Defines whether the instrument triggers on fulfillment of the logical condition, or on violation.

Parameters:

<ConditionString> ""TRUE"" | ""FALSE""

String parameter

*RST: ""TRUE""

10.5.5.2 Time Limitation

TRIGger:A:PATTern:MODE <PatternMode>

Disables the time limitation or sets the time comparison mode.

Parameters:

<PatternMode> OFF | TIMeout | WIDTh

OFF
Disables the time limitation.

TIMeout
Defines how long at least the result of the state pattern condition must be true or false.

WIDTh
Defines a time range for keeping up the true result of the pattern condition. The range is defined using `TRIGger:A:PATTern:WIDTh:RANGe`.

TRIGger:A:PATTern:WIDTh:RANGe <PatternRange>

Selects how the time limit for the pattern condition is defined.

The time is specified using `TRIGger:A:PATTern:WIDTh[:WIDTh]`, the range around is specified using `TRIGger:A:PATTern:WIDTh:DELTa`.

Parameters:

<PatternRange> WITHin | OUTSide | SHORter | LONGer

WITHin
Triggers if the pattern condition remains unchanged longer than *Time - Delta* and shorter than *Time + Delta*.

OUTSide
Triggers if the pattern condition remains unchanged either shorter than *Time - Delta* or longer than *Time + Delta*.

SHORter | LONGer
Triggers if the pattern condition changes before or after the specified time.

TRIGger:A:PATTern:WIDTh[:WIDTh] <PatternWidth>

For the ranges WITHin and OUTSide, the <PatternWidth> defines the center of a range which is defined by the limits ±<Delta>.

For the ranges SHORter and LONGer, the pattern width defines the maximum and minimum values, respectively.

Parameters:

<PatternWidth> Default unit: s

TRIGger:A:PATTern:WIDTh:DELTa <PatternDelta>

Defines a range around the pattern width value specified using `TRIGger:A:PATTern:WIDTh[:WIDTh]`.

Parameters:

<PatternDelta> Default unit: s

10.6 Waveform Analysis

10.6.1 Zoom

TIMebase:ZOOM:STATe <ZoomState>

Switches the zoom on or off.

Parameters:

<ZoomState> ON | OFF

*RST: OFF

TIMebase:ZOOM:SCALe <ZoomScale>

Defines the horizontal scale for the zoom window in seconds per division, the timebase of the zoom window. The scaling determines the width of the zoom area (12 divisions * scaling per division).

Parameters:

<ZoomScale>	Range:	Depends on various settings
	*RST:	50e-6
	Default unit:	s/div

TIMebase:ZOOM:TIME <Time>

Defines the distance of the trigger point to the reference point in the zoom window. The value determines the position of the zoom area that is displayed in the zoom window.

Parameters:

<Time>	*RST:	0
	Default unit:	s

TIMebase:ZOOM:POSition <Position>

Defines the position of the zoom window in the upper window.

Parameters:

<Position>	Range:	Depends on the zoom time base, from nearly 0 to 100 % for large zoom.
	*RST:	50
	Default unit:	%

10.6.2 Mathematics

To get the data of a math waveform, use the following commands, which are described in :

- `CALCulate:QMATh:DATA?` on page 229
- `CALCulate:QMATh:DATA:HEADer?` on page 229
- `CALCulate:QMATh:DATA:XINCrement?` on page 227
- `CALCulate:QMATh:DATA:XORigin?` on page 226
- `CALCulate:QMATh:DATA:YINCrement?` on page 227
- `CALCulate:QMATh:DATA:YORigin?` on page 227
- `CALCulate:QMATh:DATA:YRESolution?` on page 228

CALCulate:QMATH:STATe <State>

Activates the mathematics function and displays the resulting math waveform.

Parameters:

<State>	ON | OFF

CALCulate:QMATh:SOURce<m> <Source>

Defines the first and the second source for the mathematical operation (operands). The sources can be any active analog channel.

Suffix:

<m>	1..2 Selects the source.

Parameters:

<Source>	CH1 | CH2 | CH3 | CH4

Example:

```
CALC:QMAT:SOUR1 CH2
CALC:QMAT:SOUR2 CH1
```

CALCulate:QMATh:OPERation <Operation>

Defines the operation that calculates the math waveform

Parameters:

<Operation>	ADD | SUB | MUL | DIV

Example:

```
CALC:QMAT:SOUR1 CH2
CALC:QMAT:SOUR2 CH1
CALC:QMAT:OPER SUB
```

Subtracts the values of channel 1 from the values of channel 2.

CALCulate:QMATh:POSition <Position>

Sets the vertical position of the math waveform.

Parameters:

<Position>	Position value, given in divisions.

CALCulate:QMATh:SCALe <Scale>

Sets the vertical scale of the math waveform.

Parameters:

<Scale>	Scale value, given in Volts per division

10.6.3 Reference Waveforms

In all REFCurve:... commands, the suffix <m> selects the reference waveform.

To get the waveform data, use the following commands:

- `REFCurve<m>:DATA?` on page 229
- `REFCurve<m>:DATA:HEADer?` on page 230
- `REFCurve<m>:DATA:XINCrement?` on page 227

- `REFCurve<m>:DATA:Xorigin?` on page 226
- `REFCurve<m>:DATA:YINCrement?` on page 228
- `REFCurve<m>:DATA:Yorigin?` on page 227
- `REFCurve<m>:DATA:YRESolution?` on page 228

REFCurve<m>:SOURce <Source>

Defines the source of the reference waveform.

Suffix:

<m> 1..4
Selects the reference waveform

Parameters:

<Source> CH1 | CH2 | CH3 | CH4 | MA1 | RE1 | RE2 | RE3 | RE4 | D70 | D158

Any active channel, math, or reference waveform. CH3 and CH4 are only available with 4-channel R&S RTB2000 oscilloscopes. D70 | D158 sources require MSO option R&S RTB-B1.

*RST: CH1

REFCurve<m>:SOURce:CATalog?

Returns the source waveform.

Suffix:

<m> 1..4
Selects the reference waveform.

Parameters:

<Source Catalogue> CH1 | CH2 | CH3 | CH4 | MA1 | RE1 | RE2 | RE3 | RE4 | POD1 | POD2

See `REFCurve<m>:SOURce` on page 200.

Usage: Query only

REFCurve<m>:STATe

Displays or hides the selected reference waveform.

Suffix:
<m> 1..4
Selects the reference waveform.

Parameters:
<State> ON | OFF
*RST: OFF

REFCurve<m>:UPDate

Updates the selected reference by the waveform defined with `REFCurve<m>:SOURce`.

Suffix:
<m> 1..4
Selects the reference waveform.

Usage: Event

REFCurve<m>:SAVE <Filename>

Stores the reference waveform in the specified file.

Suffix:
<m> 1..4
Selects the reference waveform.

Setting parameters:
<Filename> String with path and file name

Usage: Setting only

REFCurve<m>:LOAD <Filename>

Loads the waveform data from the indicated reference file to the reference waveform.

To load the correspondent instrument settings, use `REFCurve<m>:LOAD:STATe` on page 202.

Suffix:
<m> 1..4
Selects the reference waveform.

Setting parameters:
<Filename> String with path and file name

Usage: Setting only

REFCurve<m>:LOAD:STATe

Loads the instrument settings in addition to the reference waveform data. The waveform data must be loaded before the settings, see `REFCurve<m>:LOAD` on page 201.

The settings are only available if the file was stored to the internal storage and never written to a USB flash device.

Suffix:

<m>	1..4 Selects the reference waveform.

Usage: Event

REFCurve<m>:HORizontal:POSition <Position>

Changes the horizontal position of the reference waveform independently of the channel waveform settings.

Suffix:

<m>	1..4 Selects the reference waveform.

Parameters:

<Position>	Default unit: s

REFCurve<m>:HORizontal:SCALe <Scale>

Changes the horizontal scale (timebase) of the reference waveform independently of the channel waveform settings.

Suffix:

<m>	1..4 Selects the reference waveform.

Parameters:

<Scale>	Default unit: s/div

REFCurve<m>:VERTical:POSition <Position>

Changes the vertical position of the reference waveform.

Suffix:

<m>	1..4 Selects the reference waveform.

Parameters:

<Position>	Default unit: div

REFCurve<m>:VERTical:SCALe <Scale>

Changes the vertical scale of the reference waveform.

Suffix:

<m> 1..4

Selects the reference waveform.

Parameters:

<Scale> Default unit: V/div

10.6.4 XY-Waveforms

DISPlay:MODE <Mode>

Sets the diagram mode.

Parameters:

<Mode> YT | XY

YT

Default time diagram with a time axis in x-direction and the signal amplitudes displayed in y-direction.

XY

XY-diagram, combines the voltage levels of two waveforms in one diagram.

*RST: YT

DISPlay:XY:XSOurce <Source>

Defines the source to be displayed in x-direction in an XY-diagram, replacing the usual time base.

Parameters:

<Source> CH1 | CH2 | CH3 | CH4

CH3 and CH4 are only available with 4-channel R&S RTB2000 oscilloscopes.

*RST: CH1

DISPlay:XY:Y1Source <Source>

Defines the first source to be displayed in y-direction in an XY-diagram.

Parameters:

<Source> CH1 | CH2 | CH3 | CH4

CH3 and CH4 are only available with 4-channel R&S RTB2000 oscilloscopes.

*RST: CH2

DISPlay:XY:Y2Source <Source>

Defines an optional second source to be displayed in y-direction in an XY-diagram. The command is only relevant for 4-channel R&S RTB2000 instruments.

Parameters:

<Source>	NONE | CH1 | CH2 | CH3 | CH4	
	*RST:	NONE

10.7 Measurements

10.7.1 Quick Measurements

MEASurement:AON

Starts the quick measurement.

Usage: Event

MEASurement:AOFF

Stops the quick measurement.

Usage: Event

MEASurement:ALL[:STATe]

Starts or stops the quick measurement and sets the status bit.

Parameters:

<State>	ON | OFF	
	*RST:	OFF

MEASurement:ARESult?

Returns the results of the quick measurement.

Return values:

<Data> List of values

Quick measurement results are listed in the following order: PEAK (Vpp), UPE (Vp+), LPE (Vp-), CYCR (RMS-Cyc), CYCM (MeanCyc), PER (T), FREQ (f), RTIM (tr), FTIM (tf).

Usage: Query only

10.7.2 Automatic Measurements

10.7.2.1 Measurement Settings

MEASurement<m>[:ENABle] <State>

Activates or deactivates the selected measurement.

Suffix:

<m> 1..4
Selects the measurement.

Parameters:

<State> ON | OFF

*RST: OFF

MEASurement<m>:MAIN <MeasType>

Defines the measurement type to be performed on the selected source. To query the results, use `MEASurement<m>:RESult[:ACTual]?`.

Suffix:

<m> 1..4
Selects the measurement.

Parameters:

<MeasType> FREQuency | PERiod | PEAK | UPEakvalue | LPEakvalue | PPCount | NPCount | RECount | FECount | HIGH | LOW | AMPLitude | MEAN | RMS | RTIMe | FTIMe | PDCYcle | NDCYcle | PPWidth | NPWidth | CYCMean | CYCRms | STDDev | CYCStddev | DELay | PHASe | BWIDth | POVershoot | NOVershoot

See also: Chapter 6.2.2, "Measurement Types", on page 80.

FREQuency
Frequency of the signal. The result is based on the length of the left-most signal period within the displayed section of the waveform of the selected channel.

PERiod
Length of the left-most signal period within the displayed section of the waveform of the selected channel.

PEAK
Peak-to-peak value within the displayed section of the waveform of the selected channel.

UPEakvalue
Maximum (upper) value within the displayed section of the waveform of the selected channel.

LPEakvalue
Minimum (lower) value within the displayed section of the waveform of the selected channel.

PPCount | NPCount
Counts positive or negative pulses.

RECount | FECount
Counts the number of rising or falling edges.

HIGH | LOW
Mean value of the high or low level of a square wave.

AMPLitude
Amplitude of a square wave.

MEAN
Mean voltage value of the complete displayed waveform of the selected channel.

RMS
RMS (root mean square) voltage value of the complete displayed waveform of the selected channel.

RTIMe | FTIMe
Rise or falling time of the left-most rising edge within the displayed section of the waveform of the selected channel. The reference level for this measurement is set with `REFLevel:RELative:MODE`.

PDCycle | NDCycle
Positive or negative duty cycle.

PPWidth | NPWidth

Width of positive or negative pulses.

CYCMean
Mean voltage value of the left-most signal period of the waveform of the selected channel.

CYCRms
RMS (root mean square) voltage value of the left-most signal period of the waveform of the selected channel.

STDDev
Standard deviation of the waveform.

CYCStddev
Standard deviation of one cycle, usually of the first, left-most signal period.

DELay
Time difference between two edges of the same or different waveforms. The waveforms are selected with `MEASurement<m>:SOURce`, and the edges with `MEASurement<m>:DELay:SLOPe`.

PHASe
Phase difference between two waveforms (time difference/ period * 360). The waveforms are selected with `MEASurement<m>:SOURce`.

BWIDth
Burst width, the duration of one burst, measured from the first edge to the last edge that crosses the middle reference level.

POVershoot | NOVershoot
Positive and negative overshoot of a square wave.

*RST: PEAK

MEASurement<m>:SOURce <SignalSource>[,<SignalSource2>]

Selects one of the active signal, reference or math channels as the source(s) of the selected measurement. Available sources depend on the selected measurement type.

Suffix:

<m> 1..4
Selects the measurement place.

Parameters:

<SignalSource> CH1..4 | MA1 | RE1..4 | D0..15

Waveform to be measured, required for all measurement types. For delay and phase measurements, it is the "Measure Source".

CH1 | CH2 | CH3 | CH4
Active signal channels 1 to 4

MA1
Active math channel

RE1 | RE2 | RE3 | RE4
Active reference channels 1 to 4

D0..D15
Active digital channels D0...D15. Only available, if MSO option R&S RTB-B1 is installed.

<SignalSource2> None | CH1..4 | MA1 | RE1..4 | D0..15

Second waveform, reference source that is required for delay and phase mesurements ("Reference Source").

MEASurement<m>:DELay:SLOPe <SignalSlope>,<ReferenceSlope>

Sets the edges to be used for delay measurement. The associated waveforms are defined with `MEASurement<m>:SOURce`.

Parameters:

<SignalSlope> POSitive | NEGative

Slope of first waveform ("Measure Source").

*RST: POS

<ReferenceSlope> POSitive | NEGative

Slope of the reference waveform ("Reference Source").

*RST: POS

MEASurement<m>:STATistics[:ENABle] <StatisticEnable>

Activates or deactivates the statistical evaluation for all active measurements.

Suffix:

<m> 1..4
The suffix is irrelevant.

Parameters:

<StatisticEnable> ON | OFF

*RST: OFF

MEASurement<m>:STATistics:RESet

Deletes the statistical results for all measurements, and starts a new statistical evaluation if the acquisition is running. The waveform count is set to 0 and all measurement values are set to NAN.

Suffix:

<m> 1..4
The suffix is irrelevant.

Usage: Event

10.7.2.2 Measurements Results

You can query the statistical results using the `MEAS:STAT` commands.

To export statistical results to a csv file, use the `EXP:MEAS:STAT` commands. Note that export of statistics is possible only remotely, but not in manual operation.

MEASurement<m>:RESult[:ACTual]? [<MeasType>]

Returns the result of the specified measurement type.

Suffix:

<m> 1..4
Selects the measurement place.

Query parameters:

<MeasType> FREQuency | PERiod | PEAK | UPEakvalue | LPEakvalue | PPCount | NPCount | RECount | FECount | HIGH | LOW | AMPLitude | MEAN | RMS | RTIMe | FTIMe | PDCYcle | NDCYcle | PPWidth | NPWidth | CYCMean | CYCRms | STDDev | CYCStddev | DELay | PHASe | BWIDth | POVershoot | NOVershoot

Specifies the measurement type, see `MEASurement<m>:MAIN` on page 205. If you omit the parameter, the result of the last measurement setup is returned.

Return values:
<Value> Measurement result. If no measurement was executed, no value (NAN) is returned.

Usage: Query only

MEASurement<m>:RESult:AVG? <AverageValue>

Returns the average value of the current measurement series.

The number of waveforms used for calculation is defined with `MEASurement<m>:STATistics:WEIGht`.

Suffix:
<m> 1..4
Selects the measurement place.

Query parameters:
<AverageValue> Statistic value

Usage: Query only

MEASurement<m>:RESult:STDDev? <StandardDeviation>

Returns the statistical standard deviation of the current measurement series.

The number of waveforms used for calculation is defined with `MEASurement<m>:STATistics:WEIGht`.

Suffix:
<m> 1..4
Selects the measurement place.

Query parameters:
<StandardDeviation> Statistic value

Usage: Query only

MEASurement<m>:RESult:NPEak? <NegativePeak>

Returns the minimum measurement result of the current measurement series.

Suffix:
<m> 1..4
Selects the measurement place.

Query parameters:
<NegativePeak> Minimum measurement result

Usage: Query only

MEASurement<m>:RESult:PPEak? <PositivePeak>

Returns the maximum measurement result of the current measurement series.

Suffix:

<m>	1..4 Selects the measurement place.

Query parameters:

<PositivePeak>	Maximum measurement result

Usage: Query only

MEASurement<m>:RESult:WFMCount? <WaveformCount>

Returns the current number of measured waveforms.

The query for MIN and MAX values is not possible.

Suffix:

<m>	1..4 Selects the measurement place.

Query parameters:

<WaveformCount>	Number of measured waveforms

Usage: Query only

MEASurement<m>:STATistics:WEIGht <AverageCount>

Sets the number of measured waveforms used for calculation of average and standard deviation. Sets also the size of the statistics buffer.

Suffix:

<m>	1..4 Selects the measurement place.

Parameters:

<AverageCount>	Range: 2 to 1000 Increment: 1 *RST: 1000

MEASurement<m>:STATistics:VALue:ALL?

Returns all values from the statistics buffer.

Note: Valid buffered values can only be read if the acquisition is stopped. As long as the acquisition is running, the buffer contents is changing and the buffered values are not valid for reading.

Suffix:

<m>	1..4 Selects the measurement place.

Return values:

<ValueList>	Comma separated List of Values Comma-separated list of statistical values

Usage: Query only

MEASurement<m>:STATistics:VALue<n>?

Returns the n^{th} statistical value from the indicated buffer place.

Note: Valid buffered values can only be read if the acquisition is stopped. As long as the acquisition is running, the buffer contents is changing and the buffered values are not valid for reading.

Suffix:

<m> 1..4
Selects the measurement place.

<n> *
Buffer place. The buffer size is limited by `MEASurement<m>:STATistics:WEIGht`.

Return values:

<StatisticValue> Statistical value

Usage: Query only

EXPort:MEASurement<m>:STATistics:NAME

Defines the path and filename of the statistics file. The file format is CSV. If the file already exists, it will be overwritten without notice.

Suffix:

<m> 1..4
Selects the measurement place.

Parameters:

<FileName> String parameter

EXPort:MEASurement<m>:STATistics:SAVE

Saves statistical results of the indicated measurement place to the file that is defined by the `EXPort:MEASurement<m>:STATistics:NAME` command.

Suffix:

<m> 1..4
Selects the measurement place.

Usage: Event

See also: `EXPort:MEASurement:STATistics:ALL:SAVE` on page 213.

EXPort:MEASurement:STATistics:ALL:NAME

Defines the path and filename of the statistics file. The file format is CSV. If the file already exists, it will be overwritten.

Parameters:
<FileName> String parameter

EXPort:MEASurement:STATistics:ALL:SAVE

Saves statistical results of all measurement places to the file that is defined by the `EXPort:MEASurement:STATistics:ALL:NAME` command.

Example: The file contains general information, statistical results, long term statistics, and the individual values that are used to calculate the statistics. The number of values is "Average No."

```
"Vendor","Rohde&Schwarz",
"Device/Mat.-No.","RTM2022 / 5710.0999k22",
"Serial No.","900001",
"Firmware Version","01.601",
"Date","2016-11-18 / 16:40:27",

"Meas. Place",,"1",,"2",,"3",,
"Type",,"Frequency",,"Mean Value",,"Frequency",,
"Source 1",,"CH1",,"CH1",,"CH2",,
"Source 2",,,,,,,,,
"Wave count",,42,,39,,37,,
"Current",,4.998250e+05,,5.648727e-01,,4.998250e+05,,
"Average No.",,1.000000e+03,,1.000000e+03,,1.000000e+03,,
"Minimum",,4.997501e+05,,5.633875e-01,,4.997501e+05,,
"Maximum",,4.998250e+05,,5.650349e-01,,4.998250e+05,,
"Mean",,4.998179e+05,,5.642045e-01,,4.998169e+05,,
"σ-Deviation",,2.199706e+01,,3.677224e-04,,2.326898e+01,,
"Time of first value",,,,,,,,,
"Time of last value",,,,,,,,,
"Long term Minimum",,4.997501e+05,,5.633875e-01,,4.997501e+05,,
"Long term Maximum",,4.998250e+05,,5.650349e-01,,4.998250e+05,,
"Long term Mittelwert",,4.998179e+05,,5.642045e-01,,4.998169e+05,,
"Long term σ-Deviation",,2.226370e+01,,3.725295e-04,,2.358995e+01,,
"Long term start time",,,,,,,,,
"Long term end Time",,,,,,,,,

"Index","Time Offset","Value","Time Offset","Value",
"Time Offset","Value",
1,,4.998250e+05,,5.649274e-01,,4.997501e+05,
2,,4.998250e+05,,5.649072e-01,,4.998250e+05,
3,,4.998250e+05,,5.650349e-01,,4.998250e+05,
4,,4.998250e+05,,5.641094e-01,,4.998250e+05,
5,,4.998250e+05,,5.640586e-01,,4.998250e+05,
6,,4.997501e+05,,5.642784e-01,,4.998250e+05,
7,,4.998250e+05,,5.637245e-01,,4.998250e+05,...
```

Usage: Event

10.7.2.3 Reference Levels

REFLevel:RELative:MODE <RelativeMode>

Sets the lower and upper reference levels for rise and fall time mesurements (cursor and automatic mesurements) as well as the middle reference level for phase and delay measurements. The levels are defined as percentages of the high signal level. The setting is valid for all measurement places.

Parameters:

<RelativeMode> TEN | TWENty | FIVE | USER

TEN: 10, 50 and 90%
TWENty: 20, 50 and 80%
FIVE: 5, 50 and 95 %
USER: levels are defined with `REFLevel:RELative:LOWer`, `REFLevel:RELative:MIDDle` and `REFLevel:RELative:UPPer`.

*RST: TEN

Example:

```
REFL:REL:MODE TWENty
MEAS2:MAIN RTIM
```

Sets the reference levels for all measurements and measures the rise time between these levels for measurement place 2:
lower reference level = 20% of high signal level
upper reference level = 80% of high signal level

REFLevel:RELative:LOWer <LowerLevel>
REFLevel:RELative:UPPer <UpperLevel>

Set the lower and upper reference levels for rise and fall time mesurements (cursor and automatic mesurements) if `REFLevel:RELative:MODE` is set to `USER`. The levels are defined as percentages of the high signal level. They are valid for all measurements.

Parameters:

<LowerLevel> *RST: 10
Default unit: %

<UpperLevel> *RST: 90
Default unit: %

REFLevel:RELative:MIDDle <MiddleLevel>

Set the middle reference level that is used for phase and delay measurements, if `REFLevel:RELative:MODE` is set to `USER`. The level is defined as percentages of the high signal level. The setting is valid for all measurements.

Parameters:

<MiddleLevel>	*RST:	50
	Default unit:	%

10.7.3 Cursor Measurements

10.7.3.1 Cursor Settings

CURSor<m>:AOFF

Switches the cursor off.

Suffix:

<m> 1, the suffix is irrelevant.

Usage: Event

CURSor<m>:STATe <State>

Activates or deactivates the cursor measurement.

Suffix:

<m> 1, the suffix is irrelevant.

Parameters:

<State> ON | OFF

*RST: OFF

CURSor<m>:SOURce <Source>

Defines the source of the cursor measurement.

Suffix:

<m> 1, the suffix is irrelevant.

Parameters:

<Source> CH1 | CH2 | CH3 | CH4 | MA1 | RE1 | RE2 | RE3 | RE4 | XY1 | XY2 | D70 | D158 | D0..15

CH1 | CH2 | CH3 | CH4
Active analog channel waveform 1 to 4

MA1
Active math waveform

RE1 | RE2 | RE3 | RE4
Active reference waveform 1 to 4

XY1 | XY2
Active XY-waveform

D0..15
Active digital channels D0 to D15, available if MSO option R&S RTB-B1 is installed.
On individual digital channels, only vertical (time) cursor measurements are possible.

D70 | D158
Active digital channels D0...D7 (pod 1) and D8...D15 (pod 2).
Only available, if MSO option R&S RTB-B1 is installed. On pods, only V-marker measurement is possible.

CURSor<m>:FUNCtion <Type>

Defines the cursor measurement type.

Suffix:

<m> 1, the suffix is irrelevant.

Parameters:

<Type> HORizontal | VERTical | HVERtical

To set the V-marker measurement, use `CURSor<m>:TRACking[:STATe]`.

*RST: VERTical

Value	Description	Queries for results
HORizontal	Sets two horizontal cursor lines and measures the voltages at the two cursor positions and the delta of the two values.	CURSor<m>:Y1Position CURSor<m>:Y2Position CURSor<m>:YDELta[:VALue]? CURSor<m>:YDELta:SLOPe?
VERTical	Sets two vertical cursor lines and measures the time from the trigger point to each cursor, the time between the two cursors and the frequency calculated from that time.	CURSor<m>:X1Position CURSor<m>:X2Position CURSor<m>:XDELta[:VALue]? CURSor<m>:XDELta:INVerse?
HVERtical	Combines the HORizontal cursor and VERTical cursor measurements. Two horizontal and two vertical cursor lines are set and the voltages and time from the trigger point are measured at the cursor positions, as well as the delta of the voltage and time values.	CURSor<m>:Y1Position CURSor<m>:Y2Position CURSor<m>:YDELta[:VALue]? CURSor<m>:X1Position CURSor<m>:X2Position CURSor<m>:XDELta[:VALue]?

CURSor<m>:TRACking[:STATe] <State>

If set to ON, the V-Marker cursor measurement is enabled.

Suffix:

<m> 1, the suffix is irrelevant.

Parameters:

<State> ON | OFF

*RST: OFF

CURSor<m>:X1Position <Xposition1>
CURSor<m>:X2Position <Xposition2>

The commands specify or return the positions of vertical cursor lines on the x-axis (time, frequency for FFT).

Suffix:

<m> 1, the suffix is irrelevant.

Parameters:

<Xposition1>
<Xposition2> Range: Depends on the current instrument settings, for example, horizontal position.

Default unit: s

CURSor<m>:Y1Position <Yposition1>
CURSor<m>:Y2Position <Yposition2>

The commands specify or return the positions of horizontal cursor lines on the y-axis (voltage, current, level for FFT).

Suffix:

<m> 1, the suffix is irrelevant.

Parameters:

<Yposition2> Range: Depends on the current instrument settings.
Increment: 0.01
Default unit: V

CURSor<m>:YCOupling <Coupling>
CURSor<m>:XCOupling <Coupling>

If enabled, the cursor lines are coupled so that the distance between the two lines remains the same if one cursor is moved.

Suffix:

<m> 1, the suffix is irrelevant.

Parameters:

<Coupling> ON | OFF
*RST: OFF

CURSor<m>:SWAVe

Autoset for cursor lines, sets the cursor lines to typical points of the waveform depending on the selected cursor type. For example, for voltage measurement ("Horizontal"), the cursor lines are set to the upper and lower peaks of the waveform. For time measurement ("Vertical"), the cursor lines are set to the edges of two consecutive positive or two consecutive negative pulses.

Suffix:

<m> 1, the suffix is irrelevant.

Usage: Event

CURSor<m>:SSCReen

Resets the cursors to their initial positions. This is helpful if the cursors have disappeared from the display or need to be moved for a larger distance.

Suffix:

<m> 1, the suffix is irrelevant.

Usage: Event

CURSor<m>:TRACking:SCALe[:STATe] <State>

Enables the adjustment of cursor lines if the vertical or horizontal scales are changed.

Suffix:

<m> 1, the suffix is irrelevant.

Parameters:

<State> ON | OFF

ON
Cursor lines keep their relative position to the waveform.

OFF
Cursor lines remain on their position on the display if the scaling is changed.

*RST: OFF

CURSor<m>:SPPeak<n>
CURSor<m>:SNPeak<n>

Set the cursor line to the previous / next peak, respectively. The command is only available for FFT waveforms.

Suffix:

<m> 1, the suffix is irrelevant.

<n> 1..2
Selects the cursor line.

Usage: Event

10.7.3.2 Cursor Measurement Results

To get the measurement values of vertical cursor lines (time, frequency for FFT), use:

- `CURSor<m>:X1Position` on page 217
- `CURSor<m>:X2Position` on page 217

To get the measurement values of horizontal cursor lines (voltage, current, level for FFT), use:

- `CURSor<m>:Y1Position` on page 217
- `CURSor<m>:Y2Position` on page 217

CURSor<m>:RESult?

Returns the measurement result. Make sure to set `CURSor<m>:FUNCtion` correctly.

Suffix:

<m> 1, the suffix is irrelevant.

Return values:

<Value> Measurement result

Usage: Query only

CURSor<m>:XDELta[:VALue]?

Returns the time difference between two vertical cursor lines (Δt).

Suffix:

<m>	1, the suffix is irrelevant.

Return values:

<Delta>	Range: -100E24 to 100E24 Increment: 0.1 Default unit: s

Usage: Query only

CURSor<m>:XDELta:INVerse?

Returns the inverse time difference between the two cursors (1/Δt, frequency).

Suffix:

<m>	1, the suffix is irrelevant.

Return values:

<DeltaInverse>	Range: -100E24 to 100E24 Increment: 0.1 Default unit: 1/s

Usage: Query only

CURSor<m>:YDELta[:VALue]?

Queries the delta of the values in y-direction at the two cursor lines.

Suffix:

<m>	1, the suffix is irrelevant.

Return values:

<YDelta>	Delta value

Usage: Query only

CURSor<m>:YDELta:SLOPe?

Returns the inverse value of the vertical difference (e.g. voltage difference) - the reciprocal of the vertical distance of two horizontal cursor lines: *1/ΔV*.

Suffix:

<m>	1, the suffix is irrelevant.

Return values:

<Slope>	Inverse value

Usage: Query only

10.8 Documenting Results

This chapter describes commands on how to transfer data from the instrument to a computer, how to export data to file, how to print and save screenshots, and how to manage measurement settings.

10.8.1 Transfer of Waveform Data

This chapter describes data transfer commands that have effect on other commands in different applications of the instrument, and transfer commands that work in the same way.

10.8.1.1 Analog Channels

FORMat[:DATA] <DataFormat>,<Accuracy>

Defines the format for data export with

- `CHANnel<m>:DATA?` on page 223
- `CHANnel<m>:DATA:ENVelope?` on page 225
- `CALCulate:QMATh:DATA?` on page 229
- `REFCurve<m>:DATA?` on page 229

Parameters:

<DataFormat> ASCii | REAL | UINTeger

ASCii
List of values, for example, 1.23,1.22,1.24,..
<Accuracy> is 0 which means that the instrument selects the number of digits to be returned. The query returns ASC,0.

REAL
Binary format. <Accuracy> is 32. The query returns REAL,32.
The data is stored as binary data (Definite Length Block Data according to IEEE 488.2). Each waveform value is formatted in 32 Bit IEEE 754 Floating-Point-Format.
The schema of the result string is as follows:
`#41024<value1><value2>…<value n>` with:
`#4` = number of digits of the following number (= 4 in the example)
`1024` = number of following data bytes (= 1024 in the example)
`<value>` = 4-byte floating point values

UINTeger
Unsigned integer format, binary values with length 8 bit (1 byte per sample), 16 bit (2 bytes per sample) or 32 bit (4 bytes per sample): `UINT,8` or `UINT,16` or `UINT,32`.
The data range for `UINT,8` is 0 to 255, the data range for `UINT,16` is 0 to 65.535 and for `UINT,32` is $2^{32} - 1$.
The schema of the result string is the same as for REAL format.
For data conversion, you need the results of following commands:
`...:DATA:XORigin?`; `...:DATA:XINCrement?`; `..:DATA:Yorigin?`; `...:DATA:YINCrement?`; `...:DATA:YRESolution?`. They are described below in this chapter. The way of data conversion is described in Chapter 10.2.1.2, "Reading Waveform Data in Unsigned Integer Format", on page 167.
32 bit data is relevant for average waveforms if averaging 512 or 1024 waveforms. The resulting data is 17 bits long (512 waveforms) or 18 bit (1024 waveforms).

*RST: ASC

<Accuracy> 0 | 8 | 16 | 32
Length of a data value in bit
0 - for ASC only
32 - for REAL
8 | 16 | 32 - for UINT
*RST: 0

Example: Set the ASCII data format:
`FORM ASC`

Example: Query for data format:
`FORM?`
`-> ASC,0`

Example: Set the unsigned integer format, 16 bit data length:
`FORM UINT,16`

CHANnel<m>:DATA?

Returns the data of the analog channel waveform for transmission from the instrument to the controlling computer. The waveforms data can be used in MATLAB, for example.

To set the export format, use FORMat[:DATA] on page 222.

To set the range of samples to be returned, use CHANnel<m>:DATA:POINts.

For envelope waveforms, use the CHANnel<m>:DATA:ENVelope? command.

Suffix:
<m> 1..4
Selects the input channel. The number of channels depends on the instrument.

Return values:
<Data> List of values according to the format settings - the voltages of recorded waveform samples.

Example:
```
FORM ASC
CHAN1:DATA?
-0.125000,-0.123016,-0.123016,-0.123016,
-0.123016,-0.123016,...
```

Example: See Chapter 10.2.1, "Data Export", on page 167

Usage: Query only

CHANnel<m>:DATA:HEADer?

Returns information on the channel waveform. For envelope waveforms, use the CHANnel<m>:DATA:ENVelope:HEADer? command.

Table 10-1: Header data

Position	Meaning	Example
1	XStart in s	-9.477E-008 = - 94,77 ns
2	XStop in s	9.477E-008 = 94,77 ns
3	Record length of the waveform in Samples	120000
4	Number of values per sample interval, usually 1.	1

Suffix:

<m> 1..4
Selects the input channel. The number of channels depends on the instrument.

Parameters:

<DataHeader> Comma-separated value list
Example: `-9.477E-008,9.477E-008,120000,1`

Usage: Query only

CHANnel<m>:DATA:POINts <PointSelection>

As a setting, the command selects a range of samples that will be returned with `CHANnel<m>:DATA?` and `CHANnel<m>:DATA:ENVelope?`. As a query, it returns the number of returned samples for the selected range.

Depending on the current settings, the memory can contains more data samples than the screen is able to display. In this case, you can decide which data will be saved: samples stored in the memory or only the displayed samples.

Note: The sample range can only be changed in STOP mode. If the acquisition is running, DEF is always used automatically. If the acquisition has been stopped, data can be read from the memory, and all settings are available.

Suffix:

<m> 1..4
The command affects all channels, and the suffix is irrelevant.

Setting parameters:

<PointSelection> DEFault | MAXimum | DMAXimum

Sets the range for data queries.

DEFault
Waveform points that are visible on the screen. At maximum waveform rate, the instrument stores more samples than visible on the screen, and DEF returns less values than acquired.

MAXimum
All waveform samples that are stored in the memory. Only available if acquisition is stopped.

DMAXimum
Display maximum: Waveform samples stored in the current waveform record but only for the displayed time range. At maximum waveform rate, the instrument stores more samples than visible on the screen, and DMAX returns more values than DEF. Only available if acquisition is stopped.

*RST: DEFault

Return values:

<Points> Number of data points in the selected range.

Default unit: Samples

Example:

```
CHAN:DATA:POIN DEF
CHAN:DATA:POIN?;:CHAN2:DATA:POIN?
```
Returned values: `10416;10416`
```
CHAN:DATA:POIN DMAX
CHAN:DATA:POIN?;:CHAN2:DATA:POIN?
```
Returned values: `124992;124992`
```
CHAN:DATA:POIN MAX
CHAN:DATA:POIN?;:CHAN2:DATA:POIN?
```
Returned values: `4194302;4194302`

Example:

See Chapter 10.2.1.1, "Reading Waveform Data in Real Format", on page 167

CHANnel<m>:DATA:ENVelope?

Returns the data of the envelope. The envelope consists of two waveforms. The waveforms data can be used in MATLAB, for example.

Use this command only for envelope waveforms. For other channel waveforms use `CHANnel<m>:DATA?`.

To set the export format, use `FORMat[:DATA]`.

To set the range of samples to be returned, use `CHANnel<m>:DATA:POINts`.

Suffix:

<m> 1..4
Selects the input channel. The number of channels depends on the instrument.

Parameters:
<EnvelopeData> List of values according to the format settings - the voltages of the envelope points. The list contains two values for each sample interval.

Usage: Query only

CHANnel<m>:DATA:ENVelope:HEADer?

Returns information on the envelope waveform.

Use this command only for envelope waveforms. for all other channel waveforms use `CHANnel<m>:DATA:HEADer?`.

Table 10-2: Header data

Position	Meaning	Example
1	XStart in s	-9.477E-008 = - 94,77 ns
2	XStop in s	9.477E-008 = 94,77 ns
3	Number of samples	120000
4	Number of values per sample interval. For envelope waveforms the value is 2.	2

Suffix:
<m> 1..4
Selects the input channel. The number of channels depends on the instrument.

Parameters:
<EnvelopeHeader> Comma-separated value list
Example: `-9.477E-008,9.477E-008,200000,2`

Usage: Query only

CHANnel<m>:DATA:XORigin?
CHANnel<m>:DATA:ENVelope:XORigin?
CALCulate:QMATh:DATA:XORigin?
MASK:DATA:XORigin?
DIGital<m>:DATA:XORigin?
REFCurve<m>:DATA:Xorigin?

Return the time of the first sample of the indicated waveform.

The commands are relevant for data conversion if binary data format is defined (FORM UINT, 8|16|32).

Suffix:
<m> 1..4

Return values:
<Xorigin> Time in s

Example: See Chapter 10.2.1.2, "Reading Waveform Data in Unsigned Integer Format", on page 167

Usage: Query only

CHANnel<m>:DATA:XINCrement?
CHANnel<m>:DATA:ENVelope:XINCrement?
CALCulate:QMATh:DATA:XINCrement?
MASK:DATA:XINCrement?
DIGital<m>:DATA:XINCrement?
REFCurve<m>:DATA:XINCrement?

Return the time difference between two adjacent samples of the indicated waveform.

The commands are relevant for data conversion if binary data format is defined (FORM UINT, 8|16|32).

Suffix:
<m> 1..4

Return values:
<Xincrement> Time in s

Example: See Chapter 10.2.1.2, "Reading Waveform Data in Unsigned Integer Format", on page 167

Usage: Query only

CHANnel<m>:DATA:YORigin?
CHANnel<m>:DATA:ENVelope:YORigin?
CALCulate:QMATh:DATA:YORigin?
MASK:DATA:YORigin?
DIGital<m>:DATA:YORigin?
REFCurve<m>:DATA:Yorigin?

Return the voltage value for binary value 0 of the indicated waveform.

The commands are relevant for data conversion if binary data format is defined (FORM UINT, 8|16|32).

Suffix:
<m> 1..4

Return values:
<Yorigin> Voltage in V

Example: See Chapter 10.2.1.2, "Reading Waveform Data in Unsigned Integer Format", on page 167

Usage: Query only

CHANnel<m>:DATA:YINCrement?
CHANnel<m>:DATA:ENVelope:YINCrement?
CALCulate:QMATh:DATA:YINCrement?

MASK:DATA:YINCrement?
DIGital<m>:DATA:YINCrement?
REFCurve<m>:DATA:YINCrement?

Return the voltage value per bit of the indicated waveform.

The commands are relevant for data conversion if binary data format is defined (FORM UINT, 8|16|32).

Suffix:

<m>	1..4

Return values:

<Yincrement>	Voltage in V
Example:	See Chapter 10.2.1.2, "Reading Waveform Data in Unsigned Integer Format", on page 167
Usage:	Query only

CHANnel<m>:DATA:YRESolution?
CHANnel<m>:DATA:ENVelope:YRESolution?
CALCulate:QMATh:DATA:YRESolution?
MASK:DATA:YRESolution?
DIGital<m>:DATA:YRESolution?
REFCurve<m>:DATA:YRESolution?

Return the vertical bit resolution of the indicated waveform.

The commands are relevant for data conversion if binary data format is defined (FORM UINT, 8|16|32).

Suffix:

<m>	1..4

Return values:

<Yresolution>	For default waveforms, the resolution is 8 bit. If high resolution, average or filter are set for the waveform, the resolution is 16 bit.
Example:	See Chapter 10.2.1.2, "Reading Waveform Data in Unsigned Integer Format", on page 167
Usage:	Query only

10.8.1.2 Math Waveforms

In addition to the commands described below, consider also the following commands:

- `CALCulate:QMATh:DATA:XINCrement?` on page 227
- `CALCulate:QMATh:DATA:XORigin?` on page 226
- `CALCulate:QMATh:DATA:YINCrement?` on page 227
- `CALCulate:QMATh:DATA:YORigin?` on page 227
- `CALCulate:QMATh:DATA:YRESolution?` on page 228

CALCulate:QMATh:DATA?

Returns the data of the math waveform points for transmission from the instrument to the controlling computer. The waveforms data can be used in MATHLAB, for example.

To set the export format, use `FORMat[:DATA]` on page 222.

Return values:

<Data> List of values according to the format settings - voltages, or magnitudes of a spectrum.

Usage: Query only

CALCulate:QMATh:DATA:HEADer?

Returns information on the math waveform.

Table 10-3: Header data

Position	Meaning	Example
1	XStart in s	-9.477E-008 = - 94,77 ns
2	XStop in s	9.477E-008 = 94,77 ns
3	Record length of the waveform in Samples	120000
4	Number of values per sample interval, usually 1.	1

Parameters:

<Header> Comma-separated value list

Example: `-9.477E-008,9.477E-008,120000,1`

Usage: Query only

10.8.1.3 Reference Waveforms

In addition to the commands described below, consider also the following commands:

- `REFCurve<m>:DATA:XINCrement?` on page 227
- `REFCurve<m>:DATA:Xorigin?` on page 226
- `REFCurve<m>:DATA:YINCrement?` on page 228
- `REFCurve<m>:DATA:Yorigin?` on page 227
- `REFCurve<m>:DATA:YRESolution?` on page 228

REFCurve<m>:DATA?

Returns the data of the reference waveform for transmission from the instrument to the controlling computer. The waveforms data can be used in MATLAB, for example.

To set the export format, use `FORMat[:DATA]` on page 222.

Suffix:

<m> 1..4

Selects the reference waveform, the internal reference storage.

Return values:
<Data> List of values according to the format settings.

Usage: Query only

REFCurve<m>:DATA:HEADer?

Returns information on the reference waveform.

Table 10-4: Header data

Position	Meaning	Example
1	XStart in s	-9.477E-008 = - 94,77 ns
2	XStop in s	9.477E-008 = 94,77 ns
3	Record length of the waveform in Samples	200000
4	Number of values per sample interval, usually 1.	1

Suffix:
<m> 1..4
Selects the reference waveform, the internal reference storage.

Parameters:
<Header> Comma-separated value list
Example: `-9.477E-008,9.477E-008,200000,1`

Usage: Query only

10.9 General Instrument Setup

10.9.1 Display Settings

DISPlay:LANGuage <Language>

Selects the language in which the button labels and other screen information is displayed.

Parameters:

<Language> ENGLish | GERMan | FRENch | SPANish | RUSSian | SCHinese | TCHinese | JAPanese | KORean | ITALian | PORTuguese | CZECh | POLish

Supported languages are listed in the "Specifications" data sheet.

*RST: ENGL

DISPlay:CLEar[:SCReen]

Deletes all waveforms and measurement results.

Usage: Event

DISPlay:PERSistence:TYPE <Type>

Defines how long every new data point remains on the screen.

Parameters:

<Type> OFF | TIME | INFinite

OFF
Deactivates persistence.

TIME
Data points remain on the screen for the duration defined with `DISPlay:PERSistence:TIME`.

INF
Data points remain on the screen infinitely until persistence is set to OFF.

*RST: OFF

DISPlay:PERSistence:TIME <Time>

Persistence time if persistence is active (`DISPlay:PERSistence[:STATe]` is set to `TIME`.

Each new data point in the diagram area remains on the screen for the duration defined here. .

Parameters:

<Time>	Persistence time Range: 50e-3 to 12.8 Increment: 50e-3 *RST: 50e-3 Default unit: s

DISPlay:PERSistence:CLEar

Removes the displayed persistent waveform from the screen.

Usage: Event

DISPlay:PERSistence[:STATe] <State>

Defines whether the waveform persists on the screen or whether the screen is refreshed continuously.

Parameters:

<State>	ON | OFF **ON** The waveform persists for the time defined using `DISPlay:PERSistence:TIME`. **OFF** The waveform does not persist on the screen. Only the currently measured values are displayed. *RST: OFF

DISPlay:PERSistence:INFinite <InfinitePersistence>

Sets the persistence time to infinite if `DISPlay:PERSistence[:STATe]` is ON. each new data point remains on the screen infinitely until this setting is changed or the persistence is cleared.

Parameters:

<InfinitePersistence>	ON | OFF *RST: OFF

DISPlay:DIALog:CLOSe

Closes an open message box.

Usage: Event

DISPlay:DIALog:MESSage <MessageText>

Sends a message text to the instrument and displays it in a message box.

To close the message box, use `DISPlay:DIALog:CLOSe`.

Setting parameters:

<MessageText> String

String that contains the message.

Example:
```
DISP:DIAL:MESS 'My message'
DISP:DIAL:CLOS
```

Usage: Setting only

DISPlay:GRID:STYLe <Style>

Defines how the grid is displayed.

Parameters:

<Style> LINes | RETicle | NONE

LINes
Displays the grid as horizontal and vertical lines.

RETicle
Displays crosshairs instead of a grid.

NONE
No grid is displayed.

*RST: LIN

DISPlay:INTensity:BACKlight <Intensity>

Defines the intensity of illuminated front panel keys and rotary knobs.

Parameters:

<Intensity> Value in percent

Range: 10 to 100
Increment: 1
*RST: not available, *RST does not change the intensity
Default unit: %

DISPlay:INTensity:GRID <Intensity>

Defines the brightness of the grid lines in the diagram.

Parameters:

<Intensity> Range: 0 to 100
Increment: 1
*RST: not available, *RST does not change the intensity
Default unit: %

DISPlay:INTensity:WAVeform <Intensity>

Defines the brightness of the waveform lines in the diagram.

Parameters:

<Intensity>	Range: 0 to 100 Increment: 1 *RST: not available, *RST does not change the intensity Default unit: %

DISPlay:PALette <Palette>

Sets the color and brightness of the displayed waveform samples depending on their cumulative occurance.

Parameters:

<Palette> NORMal | INVerse

NORMal
Values that occur frequently are brighter than rare values.

INVerse
Rare values are brighter than frequent values, inverse to the NORMal brightness.

FColor
Rare values are displayed in blue, while more frequent values are red and very frequent values are displayed in yellow or white, with various colors inbetween.

IFColor
Inverses the FColor setting: rare values are yellow or white while frequent values are blue.

*RST: NORM

DISPlay:STYLe <Style>

Defines how the waveform data is displayed

Parameters:

<Style> VECTors | DOTS

VECTors
Individual data points are connected by a line.

DOTS
Only the data points are displayed.

*RST: VECT

10.9.2 System Settings

CALibration

`Calibration` starts the self-alignment process. It can take several minutes. Consider your timeout settings.

`Calibration?` returns information on the state of the self-alignment. Return values ≠ 0 indicate an error.

Same as `*CAL?`.

Return values:
<SelfAlignment> Numeric status indicator

CALibration:STATe?

Returns the overall state of the self-alignment.

Return values:
<SelfAlignmentState> NOALignment | RUN | ERRor | OK | ABORt

NOALignment: no self-aligment was performed. Relevant for service operations.
RUN: self-aligment is running
ERRor: an error occured.
OK: self-aligment has been performed successfully
ABORt: self-aligment has been cancelled

Usage: Query only

SYSTem:NAME

Defines an instrument name.

Parameters:
<Name> String with max. 20 characters

SYSTem:DATE <Year>,<Month>,<Day>

Specifies the internal date for the instrument.

Parameters:

<Year>	Increment: 1 Default unit: a
<Month>	Range: 1 to 12 Increment: 1
<Day>	Range: 1 to 31 Increment: 1 Default unit: d
Usage:	SCPI confirmed

SYSTem:TIME <Hour>,<Minute>,<Second>

Specifies the internal time for the instrument.

Parameters:

<Hour>	Range: 0 to 23 Increment: 1 Default unit: h
<Minute>	Range: 0 to 59 Increment: 1 Default unit: min
<Second>	Range: 0 to 59 Increment: 1 Default unit: s
Usage:	SCPI confirmed

SYSTem:COMMunicate:INTerface[:SELect]

Selects the interface for remote control and web browser access (ETHernet only).

Parameters:

<Interface>	USB | ETHernet

SYSTem:BEEPer:CONTrol:STATe

Enables or disables a sound for general control events, e.g. changing the measurement type in the "Measure" menu.

Parameters:

<ControlBeep>	ON | OFF

SYSTem:BEEPer:ERRor:STATe

Enables or disables the beep if an error occurs.

Parameters:

<ErrorBeep>	ON | OFF

SYSTem:BEEPer:TRIG:STATe

Enables or disables the beep if a trigger occurs.

Parameters:

<TriggerBeep> ON | OFF

SYSTem:BEEPer[:IMMediate]

Generates an immediate beep. You can use this command, for example, to locate the instrument.

Usage: Event

SYSTem:SET <Setup>

Defines or queries the device settings that can be saved and load manually with FILE > "Device Settings".

Parameters:

<Setup> 488.2 block data

Usage: SCPI confirmed

SYSTem:ERRor[:NEXT]?

Returns the oldest item of the error/event queue and removes it from the queue.

Return values:

<Error> Error/event_number,"Error/event_description>[;Device-dependent info]"

Example: `0,"No error"`

Usage: Query only
SCPI confirmed

SYSTem:ERRor:ALL?

Returns a list of all error/event numbers and their description, and removes it from the error/event queue.

Return values:

<ErrorList> List of ErrorFormat

List of: Error/event_number,"Error/event_description>[;Device-dependent info]"
If the queue is empty, the response is 0,"No error"

Usage: Query only
SCPI confirmed

SYSTem:PRESet

Resets the instrument to the default state, has the same effect as *RST.

Usage: Event

SYSTem:EDUCation:PRESet

Deletes the password of the education mode.

Usage: Event

SYSTem:DFPRint?

Returns the device footprint of the instrument. The device footprint contains the configuration of the instrument, installed modules, installed software and software licenses. This information is written in the device footprint xml file might be useful in case of maintenance or support request.

Return values:

<DeviceFootprint> Block Data

Information as block data.

Usage: Query only

SYSTem:TREE?

REturns a list of the implemented remote commands.

Return values:

<SystemTree> List of commands

Usage: Query only

10.9.3 LAN Settings

The following commands take effect if `SYSTem:COMMunicate:INTerface[:SELect]` is set to `ETHernet`.

SYSTem:COMMunicate:INTerface:ETHernet:DHCP

Enables DHCP for automatic network parameter distribution.

Parameters:

<DHCP> ON | OFF

OFF
Use the following commands to specify connection parameters:
SYSTem:COMMunicate:INTerface:ETHernet:IPADdress
on page 239
SYSTem:COMMunicate:INTerface:ETHernet:SUBNet
on page 239
SYSTem:COMMunicate:INTerface:ETHernet:GATeway
on page 239

SYSTem:COMMunicate:INTerface:ETHernet:IPADdress
SYSTem:COMMunicate:INTerface:ETHernet:SUBNet
SYSTem:COMMunicate:INTerface:ETHernet:GATeway

Return or specify.

- IP address of the instrument.
- IP subnet mask used by the instrument.
- IP gateway used by the instrument.

Parameters:

<FirstByte>	Range:	0 to 255
	Increment:	1
<SecondByte>	Range:	0 to 255
	Increment:	1
<ThirdByte>	Range:	0 to 255
	Increment:	1
<FourthByte>	Range:	0 to 255
	Increment:	1

SYSTem:COMMunicate:INTerface:ETHernet:IPPort <IPPort>

Returns or specifies the IP port number (default = 5025).

Parameters:

<IPPort> Range: 1024 to 65535

SYSTem:COMMunicate:INTerface:ETHernet:HTTPport <HTTPport>

Returns or specifies the VXI-11 port number (default = 1024).

Parameters:

<HTTPport> Range: 0 to 65535

SYSTem:COMMunicate:INTerface:ETHernet:TRANsfer <TransferMode>

Enables automatic transfer speed selection, or selects one of the predefined settings that corresponds to your network data rate.

Parameters:

<TransferMode> AUTO | FD10 | FD100 | HD10 | HD100

AUTO
Automatic transfer speed

FD10 | FD100 | HD10 | HD100
FD = full duplex, HD = half duplex
10 = 10 Mbps, 100 = 100 Mbps

SYSTem:COMMunicate:INTerface:ETHernet:MACaddress?

Returns the instrument's media access control address.

Return values:

<MACaddress> String data

String parameter

Usage: Query only

10.9.4 USB Settings

The following command takes effect if `SYSTem:COMMunicate:INTerface[:SELect]` is set to `USB`.

SYSTem:COMMunicate:INTerface:USB:CLASs

Selects the USB mode.

- USB TMC (Test & Measurement Class)
- USB VCP (Virtual Com Port)
- USB MTP (Media Transfer Protocol)

Parameters:

<USBClass> TMC | VCP | MTP

10.9.5 Trigger Out

TRIGger:OUT:MODE <OutputMode>

Defines which signals are generated at the AUX OUT front connector.

Parameters:

<OutputMode> OFF | TRIGger | REFerence | MASK | GENerator

OFF
No output

TRIGger
Outputs a pulse when the instrument triggers.

Outputs a 10 MHz reference frequency.

MASK
Outputs a pulse when a mask is violated. This function is only available if a mask is specified.

GENerator
Outputs the waveform specified using the function generator (requires option R&S RTB-B6)

*RST: OFF

TRIGger:OUT:PLENgth <PulseLength>

Defines the pulse width of the pulse at the AUX OUT front connector (at trigger event or mask viaolation).

Parameters:

<PulseLength> *RST: 1E-6

TRIGger:OUT:POLarity <Polarity>

Defines the polarity of the pulse at the AUX OUT front connector (at trigger event or mask viaolation).

Parameters:

<Polarity> POSitive | NEGative

*RST: POS

10.10 Serial Bus Analysis

10.10.1 General

BUS<b>:TYPE <Type>

Defines the bus or interface type for analysis. All buses require special option to the instrument.

Suffix:

<b> 1 | 2

Parameters:

<Type> PARallel | CPARallel | I2C | SPI | SSPI | UART | CAN | LIN

*RST: PARallel

BUS<b>:STATe <State>

Switches protocol decoding on or off.

Suffix:

<b> 1 | 2

Parameters:

<State> ON | OFF

*RST: OFF

BUS<b>:FORMat <Format>

Sets the decoding format for the display on the screen.

Suffix:

<b> 1 | 2

Parameters:

<Format> ASCii | HEXadecimal | BINary | DECimal | OCTal

*RST: HEX

BUS<b>:LABel <Label>

Defines an additional name label for the selected bus. The maximum name length is 8 characters, and only ASCII characters provided on the on-screen keypad can be used.

Suffix:

<b> 1..2
Selects the bus.

Parameters:

<Label> String value

BUS<b>:LABel:STATe <State>

Displays or hides the bus label. The bus label is shown on the the right side of the display.

Suffix:

<b> 1..2
Selects the bus.

Parameters:

<State> ON | OFF
*RST: ON

BUS<b>:DSIGnals <BitsSignals>

Displays the individual bit lines above the decoded bus line.

Suffix:

<b> 1 | 2

Parameters:

<BitsSignals> ON | OFF
*RST: ON

BUS<b>:DSIZe <DisplaySize>

Sets the height of the decoded bus signal on the sreen.

Suffix:

<b> 1 | 2

Parameters:

<DisplaySize>	SMALl | MEDium | LARGe | DIV2 | DIV4 **DIV2 | DIV4** 2 or 4 divisions **SMALl | MEDium | LARGe** Size of indicated bus is smaller than 2 div. *RST: MEDium

---

BUS<b>:POSition <Position>

Sets the vertical position of the decoded bus signal in divisions on the sreen.

Suffix:

<b>	1 | 2

Parameters:

<Position>	Range: 5 to -5 Increment: 0.02 *RST: -3.5 Default unit: DIV

BUS<b>:RESult <ShowResultTable>

Displays or hides the table of decode results.

Suffix:

<b>	1 | 2

Parameters:

<ShowResultTable>	ON | OFF

10.10.2 SPI and SSPI (Option R&S RTB-K1)

The Serial Peripheral Interface (SPI) is used for communication with slow peripheral devices, in particular, for transmission of data streams.

SSPI is a Simplified SPI configuration without chip select line.

A 4-channel instrument is required for full support of the SPI and SSPI protocols.

The SPI/SSPI protocol requires two bus lines (bus 1 and 2 or bus 3 and 4), so the number of buses (suffix <b>) is reduced. Bus 2 and/or bus 4 is not available.

10.10.2.1 SPI - Configuration

Start the bus configuration with the threshold setting. Use one of the following commands:

- `CHANnel<m>:THReshold:FINDlevel` on page 179
- `CHANnel<m>:THReshold` on page 178

In all `BUS<b>:SPI...` commands, the suffix <b> selects the bus.

BUS<b>:SPI:CS:SOURce <Source>

Selects the input channel of the chip select line.

Suffix:

<b> 1 | 2

Parameters:

<Source> CH1 | CH2 | CH3 | CH4 | D0..D15

*RST: CH1

BUS<b>:SPI:CS:POLarity <Polarity>

Selects whether the chip select signal is high active (high = 1) or low active (low = 1).

Suffix:

<b> 1 | 2

Parameters:

<Polarity> POSitive | NEGative

POSitive = high active
NEGative = low active

*RST: NEGative

BUS<b>:SPI:CLOCk:SOURce <Source>

Selects the input channel of the clock line.

Suffix:

<b>	1 | 2

Parameters:

<Source>	CH1 | CH2 | CH3 | CH4 | D0..D15
	*RST: CH1

BUS<b>:SPI:CLOCk:POLarity <Polarity>

Selects if data is stored with the rising or falling slope of the clock. The slope marks the begin of a new bit.

Suffix:

<b>	1 | 2

Parameters:

<Polarity>	POSitive | NEGative
	POSitive: rising slope NEGative: falling slope
	*RST: POS

BUS<b>:SPI:MOSI:SOURce <MosiSource>
BUS<b>:SPI:DATA:SOURce <Source>

Selects the input channel of the MOSI line, or of the data line if only one data line is used.

Suffix:

<b>	1 | 2

Parameters:

<Source>	CH1 | CH2 | CH3 | CH4 | D0..D15
	D0..D15: requires MSO option R&S RTB2000-B1
	*RST: CH1

BUS<b>:SPI:MISO:SOURce <MisoSource>

Selects the input channel of the optional MISO line.

Suffix:

<b>	1 | 2

Parameters:

<MisoSource>	CH1 | CH2 | CH3 | CH4 | NONE | D0..D15
	*RST: NONE

BUS<b>:SPI:MOSI:POLarity <MosiPolarity>
BUS<b>:SPI:DATA:POLarity <Polarity>

Selects whether transmitted data is high active (high = 1) or low active (low = 1) on the MOSI line, or on the data line if only one data line is used.

Selects whether transmitted data is high active (high = 1) or low active (low = 1) on the data line.

Suffix:
<b> 1 | 2

Parameters:
<Polarity> POSitive | NEGative

POSitive = high active
NEGative = low active

*RST: POSitive

BUS<b>:SPI:MISO:POLarity <MisoPolarity>

Selects whether transmitted data is high active (high = 1) or low active (low = 1) on the MISO line.

Suffix:
<b> 1 | 2

Parameters:
<MisoPolarity> ACTLow | ACTHigh

*RST: ACTH

BUS<b>:SPI:BORDer <BitOrder>

Defines if the data of the messages starts with MSB (most significant bit) or LSB (least significant bit).

Suffix:
<b> 1 | 2

Parameters:
<BitOrder> MSBFirst | LSBFirst

*RST: MSBFirst

BUS<b>:SPI:SSIZe <SymbolSize>

Sets the word length, the number of bits in a message.

Suffix:
<b> 1 | 2

Parameters:

<SymbolSize>	Range: 4 to 32 Increment: 1 *RST: 8 Default unit: Bit

10.10.2.2 SSPI - Configuration

Start the bus configuration with the threshold setting. Use one of the following commands:

- CHANnel<m>:THReshold:FINDlevel on page 179
- CHANnel<m>:THReshold on page 178

In all BUS<b>:SSPI... commands, the suffix <b> selects the bus.

BUS<b>:SSPI:CLOCk:SOURce <Source>

Selects the input channel of the clock line.

Suffix:

<b>	1 | 2

Parameters:

<Source>	CH1 | CH2 | CH3 | CH4 | D0..D15 CH3 and CH4 are only available with 4-channel R&S RTB2000 oscilloscopes. *RST: CH1

BUS<b>:SSPI:CLOCk:POLarity <Polarity>

Selects if data is stored with the rising or falling slope of the clock. The slope marks the begin of a new bit.

Suffix:

<b>	1 | 2

Parameters:

<Polarity>	POSitive | NEGative POSitive: rising slope NEGative: falling slope *RST: POSitive

BUS<b>:SSPI:MOSI:SOURce <MosiSource>
BUS<b>:SSPI:DATA:SOURce <Source>

Selects the input channel of the MOSI line, or of the data line if only one data line is used.

Suffix:

<b>	1 | 2

Parameters:

<Source>	CH1 | CH2 | CH3 | CH4 | D0..D15 CH3 and CH4 are only available with 4-channel R&S RTB2000 oscilloscopes. *RST: CH1

BUS<b>:SSPI:MISO:SOURce <MisoSource>

Selects the input channel of the optional MISO line.

Suffix:

<b>	1 | 2

Parameters:

<MisoSource>	CH1 | CH2 | CH3 | CH4 | NONE | D0..D15 *RST: NONE

BUS<b>:SSPI:MOSI:POLarity <MosiPolarity>
BUS<b>:SSPI:DATA:POLarity <Polarity>

Selects whether transmitted data is high active (high = 1) or low active (low = 1) on the MOSI line, or on the data line if only one data line is used.

Suffix:

<b>	1 | 2

Parameters:

<Polarity>	POSitive | NEGative POSitive = high active NEGative = low active *RST: POSitive

BUS<b>:SSPI:MISO:POLarity <MisoPolarity>

Selects whether transmitted data is high active (high = 1) or low active (low = 1) on the MISO line.

Suffix:

<b>	1 | 2

Parameters:

<MisoPolarity>	ACTLow | ACTHigh
	*RST: ACTH

BUS<b>:SSPI:BITime <BurstIdleTime>

Within the idle time the data and clock lines are low. A new frame begins when the idle time has expired and the clock line has been inactive during that time. If the time interval between the data words is shorter than the idle time, the words are part of the same frame.

Suffix:

<b>	1 | 2

Parameters:

<BurstIdleTime>	Range:	16e-9 to 838.832e-6
	Increment:	16e-9
	*RST:	100e-6
	Default unit:	s

BUS<b>:SSPI:BORDer <BitOrder>

Defines if the data of the messages starts with MSB (most significant bit) or LSB (least significant bit).

Suffix:

<b>	1 | 2

Parameters:

<BitOrder>	MSBFirst | LSBFirst
	*RST: MSBFirst

BUS<b>:SSPI:SSIZe <SymbolSize>

Sets the word length, the number of bits in a message.

Suffix:

<b>	1 | 2

Parameters:

<SymbolSize>	Range:	4 to 32
	Increment:	1
	*RST:	8
	Default unit:	Bit

10.10.2.3 SPI and SSPI - Trigger

To configure the protocol trigger, make sure to set first:

- `TRIGger:A:TYPE` to `BUS`
- `TRIGger:A:SOURce` to `SBUS1 | SBUS2`

TRIGger:A:SPI:MODE <Mode>

Specifies the trigger mode for SPI/SSPI protocols.

Parameters:

<Mode> BSTart | BEND | NTHBit | PATTern

BSTart
Burst start, sets the trigger event to the start of the frame. The frame starts when the chip select signal CS changes to the active state.

BEND
Burst end, sets the trigger event to the end of the message.

NTHBit
Sets the trigger event to the specified bit number. To define the bit number, use `TRIGger:A:SPI:POFFset`.

PATTern
Sets the trigger event to a serial pattern. To define the pattern, use `TRIGger:A:SPI:PATTern`.
For a complete configuration of the pattern mode, you also have to set `TRIGger:A:SPI:PLENgth` and `TRIGger:A:SPI:POFFset`.

*RST: BSTart

TRIGger:A:SPI:PATTern <DataPattern>

Defines the bit pattern as trigger condition. The pattern length is adjusted to the number of bits defined in the pattern.

Parameters:

<DataPattern> String with max. 32 characters (4 byte + 8 bit) . Characters 0, 1 and X are allowed.

Example: `TRIG:A:SPI:PATT "0011XXXX0110"`
Sets a 12bit pattern.

TRIGger:A:SPI:PLENgth <PatternLength>

Returns the number of bits in the previously defined bit pattern (TRIGger:A:SPI:PATTern). The command can also be used to shorten a previously defined bit pattern.

Parameters:

<PatternLength> Range: 1 to 32
Increment: 1
*RST: 4

Example:
```
TRIG:A:SPI:PATT "0011XXXX0110"
TRIG:A:SPI:PLEN?
12
TRIG:A:SPI:PLEN 4
TRIG:A:SPI:PATT?
"0011"
```

TRIGger:A:SPI:POFFset <PatternBitOffset>

Sets the number of bits before the first bit of the pattern.

Parameters:

<PatternBitOffset> Number of ignored bits

Range: 0 to 4095
Increment: 1
*RST: 0

10.10.2.4 SPI and SSPI - Decode Results

In all BUS<b>:SPI... and BUS<b>:SSPI... commands, the suffix <b> selects the bus.

BUS<b>:SPI:FCOunt?

Returns the number of decoded frames.

Suffix:

<b> 1 | 2

Return values:

<FrameCount> Total number of decoded frames.

Usage: Query only

BUS<b>:SPI:FRAME<n>:STATus?

Returns the overall state of the specified frame.

Suffix:

<b> 1 | 2

<n> *
Selects the frame.

Return values:

<Status> OK | INCFirst | INCLast | INSufficient

INCFirst
First frame is incomplete

INCLast
Last frame is incomplete

Usage: Query only

BUS<b>:SPI:FRAME<n>:STARt?

Returns the start time of the specified frame.

Suffix:

<b> 1 | 2

<n> *

Return values:

<StartTime> Range: depends on sample rate, record length, and time base
Increment: depends on the time base
Default unit: s

Usage: Query only

BUS<b>:SPI:FRAME<n>:STOP?

Returns the end time of the specified frame.

Suffix:

<b> 1 | 2

<n> *
Selects the frame.

Return values:

<StopTime>	Range:	depends on sample rate, record length, and time base
	Increment:	depends on the time base
	Default unit:	s

Usage: Query only

BUS<b>:SPI:FRAME<n>:DATA:MOSI?

Returns the data words of the specified frame of the MOSI line.

Suffix:

<b> 1 | 2

<n> *
Selects the frame.

Return values:

<DataMosi> List of decimal values of data bytes

Example:
```
BUS:SPI:FRAM3:DATA:MOSI?
-> 94,177,171,60,242,219,100,0
```

Usage: Query only

BUS<b>:SPI:FRAME<n>:DATA:MISO?

Returns the data words of the specified frame of the MISO line.

Suffix:

<b> 1 | 2

<n> *
Selects the frame.

Return values:

<DataMiso> List of decimal values of data bytes

Example:
```
BUS:SPI:FRAM3:DATA:MISO?
-> 94,177,171,60,242,219,100,0
```

Usage: Query only

BUS<b>:SPI:FRAME<n>:WCOunt?

Returns the number of words in the specified frame.

Suffix:

<b> 1 | 2

<n> *
Selects the frame.

Return values:

<WordCount> Number of words

Usage: Query only

BUS<b>:SPI:FRAME<n>:WORD<o>:STARt?

Returns the start time of the specified data word.

Suffix:

<b>	1 | 2
<n>	* Selects the frame.
<o>	* Selects the word number.

Return values:

<StartTime>
Range: depends on sample rate, record length, and time base
Increment: depends on the time base
Default unit: s

Usage: Query only

BUS<b>:SPI:FRAME<n>:WORD<o>:STOP?

Returns the end time of the specified data word.

Suffix:

<b>	1 | 2
<n>	* Selects the frame.
<o>	* Selects the word number.

Return values:

<StopTime>
Range: depends on sample rate, record length, and time base
Increment: depends on the time base
Default unit: s

Usage: Query only

BUS<b>:SPI:FRAME<n>:WORD<o>:MOSI?

Returns the data value of the specified word on the MOSI line.

Use this command if only one line is defined.

Suffix:

<b> 1 | 2

<n>	*
	Selects the frame (1...n)
<o>	*
	Selects the word number (1...o)

Return values:

<Data>	Decimal value of the data word

Usage: Query only

BUS<b>:SPI:FRAME<n>:WORD<o>:MISO?

Returns the data value of the specified word on the optional MISO line.

Suffix:

<b>	1 | 2
<n>	*
	Selects the frame (1...n)
<o>	*
	Selects the word number (1...o)

Return values:

<Data>	Decimal value of the data word

Usage: Query only

10.10.3 I²C

The Inter-Integrated Circuit is a simple, low-bandwidth, low-speed protocol used for communication between on-board devices, for example, in LCD and LED drivers, RAM, EEPROM, and others.

10.10.3.1 I²C - Configuration (Option R&S RTB-K1)

Start the bus configuration with the threshold setting. Use one of the following commands:

- `CHANnel<m>:THReshold:FINDlevel` on page 179
- `CHANnel<m>:THReshold` on page 178

In all `BUS<b>:I2C...` commands, the suffix <b> selects the bus.

BUS<b>:I2C:CLOCk:SOURce <Source>

Sets the input channel to which the clock line is connected.

Suffix:

<b> 1 | 2

Parameters:

<Source> CH1 | CH2 | CH3 | CH4 | D0..D15

CH3 and CH4 are only available with 4-channel R&S RTB2000 oscilloscopes.

*RST: CH1

BUS<b>:I2C:DATA:SOURce <Source>

Sets the input channel to which the data line is connected.

Suffix:

<b> 1 | 2

Parameters:

<Source> CH1 | CH2 | CH3 | CH4 | D0..D15

CH3 and CH4 are only available with 4-channel R&S RTB2000 oscilloscopes.

*RST: CH1

10.10.3.2 I²C - Trigger

To configure the protocol trigger, make sure to set first:

- `TRIGger:A:TYPE` to `BUS`
- `TRIGger:A:SOURce` to `SBUS1 | SBUS2`

TRIGger:A:I2C:MODE <Mode>

Specifies the trigger mode for I²C.

Parameters:

<Mode> STARt | RESTart | STOP | MACKnowledge | PATTern

STARt
Start of the message. The start condition is a falling slope on SDA while SCL is high.

RESTart
Restarted message. The restart is a repeated start condition.

STOP
End of the message. The stop condition is a rising slope on SDA while SCL is high.

MACKnowledge
Missing acknowledge. If the transfer failed, at the moment of the acknowledge bit the SCL and the SDA lines are both on high level.

PATTern
Triggers on a set of trigger conditions: read or write access of the master, to an address, or/and to a bit pattern in the message.
For a complete configuration of the pattern mode, you have to set:
`TRIGger:A:I2C:ACCess` (read/write access), and
`TRIGger:A:I2C:AMODe` and `TRIGger:A:I2C:ADDRess` (address), and/or
`TRIGger:A:I2C:POFFset` and `TRIGger:A:I2C:PLENgth` and `TRIGger:A:I2C:PATTern` (pattern)

*RST: STARt

TRIGger:A:I2C:ACCess <Access>

Toggles the trigger condition between Read and Write access of the master.

Parameters:

<Access> READ | WRITe

*RST: READ

TRIGger:A:I2C:AMODe <AdrMode>

Sets the lenght of the slave address.

Parameters:

<AdrMode> NORMal | EXTended

NORMal: 7 bit address
EXTended: 10 bit address

*RST: NORMal

TRIGger:A:I2C:ADDRess <AddressString>

Sets the address of the slave device. The address can have 7 bits or 10 bits.

Parameters:

<AddressString> String with max. 7 or 10 characters, depending on the address length. Characters 0, 1, and X are allowed, but X cannot be assigned to a specified bit. If at least one X occurs in the address, the complete address is set to X.

Example:
```
TRIG:A:I2C:AMOD NORM
TRIG:A:I2C:ADDR "1011"
TRIG:A:I2C:ADDR?
```
Return value (7bit address): `"0001011"`

Example:
```
TRIG:A:I2C:AMOD EXT
TRIG:A:I2C:ADDR "10X1"
TRIG:A:I2C:ADDR?
```
Return value (10bit address): `"XXXXXXXXXX"`

TRIGger:A:I2C:PATTern <DataPattern>

Defines the bit pattern as trigger condition. Make sure that the correct pattern length has been defined before with `TRIGger:A:I2C:PLENgth`.

Parameters:

<DataPattern> String with max. 24 characters (3 byte * 8 bit). Characters 0, 1, and X are allowed. X can be assigned to a specified bit. If you define a pattern shorter than the pattern length, the missing LSB are filled with X. If you define a pattern longer than the pattern length, the pattern string is not valid

Example:
```
TRIG:A:I2C:PLEN 2
TRIG:A:I2C:PATT "10X10000XXXX1111"
TRIG:A:I2C:PATT?
```
Return value (2 bytes): `"10X10000XXXX1111"`

Example:
```
TRIG:A:I2C:PLEN 1
TRIG:A:I2C:PATT "110"
TRIG:A:I2C:PATT?
```
Return value (1 byte): `"110XXXXX"`

TRIGger:A:I2C:PLENgth <PatternLength>

Defines how many bytes are considered in the trigger condition. To set the pattern for these bytes, use `TRIGger:A:I2C:PATTern`.

Parameters:

<PatternLength> Number of bytes

Range: 1 to 3
Increment: 1
*RST: 1

TRIGger:A:I2C:POFFset <PatternByteOffset>

Sets the number of bytes before the first byte of interest, relating to the end of the address bytes.

Parameters:

<PatternByteOffset> Number of ignored bytes

Range: 0 to 4095
Increment: 1
*RST: 0

10.10.3.3 I²C - Decode Results

In all `BUS<b>:I2C...` commands, the suffix <b> selects the bus.

BUS<b>:I2C:FCOunt?

Returns the number of received frames.

Suffix:

<b> 1 | 2

Return values:

<FrameCount> Total number of decoded frames.

Usage: Query only

BUS<b>:I2C:FRAMe<n>:DATA?

Returns the data words of the specified frame.

Suffix:

<b> 1 | 2

<n> *
Selects the frame.

Return values:

<DataWords> Comma-separated list of decimal values of the data bytes.

Example: `BUS:I2C:FRAM2:DATA?`
returns four data bytes:
`-> 69,158,174,161`

Usage: Query only

BUS<b>:I2C:FRAMe<n>:STATus?

Returns the overall state of the frame.

Suffix:

<b> 1 | 2

<n> *
Selects the frame.

Return values:

<State> INComplete | OK | UNEXpstop | INSufficient | ADDifferent

INComplete
The frame is not completely contained in the acquisition.

Usage: Query only

BUS<b>:I2C:FRAMe<n>:STARt?

Returns the start time of the specified frame.

Suffix:

<b> 1 | 2

<n> *
Selects the frame.

Return values:

<StartTime> Range: depends on sample rate, record length, and time base
Increment: depends on the time base
Default unit: s

Usage: Query only

BUS<b>:I2C:FRAMe<n>:STOP?

Returns the end time of the specified frame.

Suffix:

<b> 1 | 2

<n> *
Selects the frame.

Return values:

<EndTime> Range: depends on sample rate, record length, and time base
Increment: depends on the time base
Default unit: s

Usage: Query only

BUS<b>:I2C:FRAMe<n>:AACCess?

Returns the address acknowledge bit value for the indicated frame.

Suffix:

<b> 1 | 2

<n> *
Selects the frame.

Return values:

<Acknowledge> INComplete | ACK | NACK | EITHer

Usage: Query only

BUS<b>:I2C:FRAMe<n>:ACCess?

Returns the transfer direction - read or write access from master to slave.

Suffix:

<b> 1 | 2

<n> *
Selects the frame.

Return values:

<Access> INComplete | READ | WRITE | EITHer | UNDF

INComplete
The frame is not completely contained in the acquisition.

UNDF
Access is not defined.

Usage: Query only

BUS<b>:I2C:FRAMe<n>:ACOMplete?

Returns the state of the address.

Suffix:

<b> 1 | 2

<n> *
Selects the frame.

Return values:
<AddressComplete> ON | OFF

ON
Address was received completely.

Usage: Query only

BUS<b>:I2C:FRAMe<n>:ADBStart?

Returns the start time of the address acknowledge bit.

Suffix:
<b> 1 | 2

<n> *
Selects the frame.

Return values:
<AckStartTime> Range: depends on sample rate, record length, and time base
Increment: depends on the time base
Default unit: s

Usage: Query only

BUS<b>:I2C:FRAMe<n>:ADDRess?

Returns the decimal address value of the indicated frame **including** the R/W bit.

Suffix:
<b> 1 | 2

<n> *
Selects the frame.

Return values:
<AddressValue> Decimal value

Range: 0 to 2047
Increment: 1

Usage: Query only

BUS<b>:I2C:FRAMe<n>:ADEVice?

Returns the decimal address value of the indicated frame **without** R/W bit.

Suffix:
<b> 1 | 2

<n> *
Selects the frame.

Return values:

<SlaveAddress>	Decimal value Range: 0 to 1023 Increment: 1

Usage: Query only

BUS<b>:I2C:FRAMe<n>:AMODe?

Returns the address length.

Suffix:

<b>	1 | 2
<n>	* Selects the frame.

Return values:

<AddressMode>	BIT7 | BIT10

Usage: Query only

BUS<b>:I2C:FRAMe<n>:ASTart?

Returns the start time of the address for the indicated frame.

Suffix:

<b>	1 | 2
<n>	* Selects the frame.

Return values:

<StartTime>	Range: depends on sample rate, record length, and time base Increment: depends on the time base Default unit: s

Usage: Query only

BUS<b>:I2C:FRAMe<n>:BCOunt?

Returns the number of data bytes in the specified frame.

Suffix:

<b>	1 | 2
<n>	* Selects the frame.

Return values:

<ByteCount im Frame>	Number of words (bytes)

Example: `BUS:I2C:FRAM2:BCO?`
`-> 4`

Usage: Query only

BUS<b>:I2C:FRAMe<n>:BYTE<o>:ACCess?

Returns the acknowledge bit value of the specified data byte.

Suffix:

<b>	1 | 2
<n>	* Selects the frame.
<o>	* Selects the byte number.

Return values:

<Acknowledge>	INComplete | ACK | NACK | EITHer

Usage: Query only

BUS<b>:I2C:FRAMe<n>:BYTE<o>:ACKStart?

Returns the start time of the acknowledge bit of the specified byte.

Suffix:

<b>	1 | 2
<n>	* Selects the frame.
<o>	* Selects the byte number.

Return values:

<AckStartTime>	Range:	depends on sample rate, record length, and time base
	Increment:	depends on the time base
	Default unit:	s

Usage: Query only

BUS<b>:I2C:FRAMe<n>:BYTE<o>:COMPlete?

Returns the state of the byte.

Suffix:

<b>	1 | 2
<n>	* Selects the frame.

<o> *
Selects the byte number.

Return values:
<ByteComplete> ON | OFF
ON
Data byte was received completely.

Usage: Query only

BUS<b>:I2C:FRAMe<n>:BYTE<o>:STARt?

Returns the start time of the specified data byte.

Suffix:
<b> 1 | 2

<n> *
Selects the frame.

<o> *
Selects the byte number.

Return values:
<StartTime> Range: depends on sample rate, record length, and time base
Increment: depends on the time base
Default unit: s

Usage: Query only

BUS<b>:I2C:FRAMe<n>:BYTE<o>:VALue?

Returns the decimal value of the specified byte.

Suffix:
<b> 1 | 2

<n> *
Selects the frame.

<o> *
Selects the byte number.

Return values:
<ByteValue> Decimal value
Range: 0 to 255
Increment: 1

Example:
```
BUS:I2C:FRAM2:BYTE2:VAL?
-> 158
```

Usage: Query only

10.10.4 UART (Option R&S RTB-K2)

The Universal Asynchronous Receiver/Transmitter (UART) converts a word of data into serial data, and vice versa.

10.10.4.1 UART - Configuration

Start the bus configuration with the threshold setting. Use one of the following commands:

- `CHANnel<m>:THReshold:FINDlevel` on page 179
- `CHANnel<m>:THReshold` on page 178

In all `BUS<b>:UART...` commands, the suffix <b> selects the bus.

BUS<b>:UART:RX:SOURce <Source>
BUS<b>:UART:TX:SOURce <Source>
BUS<b>:UART:DATA:SOURce <Source>

Selects the input channel of the data line.

Suffix:

<b>	1 | 2

Parameters:

<Source>	CH1 | CH2 | CH3 | CH4 | D0..D15 CH3 and CH4 are only available with 4-channel R&S RTB2000 oscilloscopes. *RST: CH1

BUS<b>:UART:POLarity <IdleState>

Defines the logic levels of the bus. The idle state corresponds to a logic 1, and the start bit to a logic 0.

Alternative command for `BUS<b>:UART:DATA:POLarity`

Suffix:

<b> 1 | 2

Parameters:

<IdleState> IDLLow | IDLHigh

IDLLow: idle low, low = 1
IDLHigh: idle high, high = 1

*RST: IDLH

BUS<b>:UART:DATA:POLarity <Polarity>

Defines if the transmitted data on the bus is high (high = 1) or low (low = 1) active.

Alternative command for `BUS<b>:UART:POLarity` .

Suffix:

<b> 1 | 2

Parameters:

<Polarity> POSitive | NEGative

POSitive = high active
NEGative = low active

*RST: POS

BUS<b>:UART:SSIZe <SymbolSize>

Sets the number of data bits in a message.

Suffix:

<b> 1 | 2

Parameters:

<SymbolSize> Range: 5 to 9
Increment: 1
*RST: 8
Default unit: Bit

BUS<b>:UART:PARity <Parity>

Defines the optional parity bit that is used for error detection.

Suffix:

<b> 1..2
Selects the bus.
Note: SPI/SSPI and UART protocols occupy two bus lines.

Parameters:

<Parity> ODD | EVEN | NONE

*RST: NONE

BUS<b>:UART:SBIT <StopBitNumber>

Sets the stop bits.

Suffix:

<b>	1..2 Selects the bus. Note: SPI/SSPI and UART protocols occupy two bus lines.

Parameters:

<StopBitNumber>	B1 | B1_5 | B2 1 stop bit, 1.5 stop bits or 2 stop bits are possible. *RST: B1

BUS<b>:UART:BAUDrate <Baudrate>

Sets the number of transmitted bits per second.

Suffix:

<b>	1 | 2

Parameters:

<Baudrate>	Range: 100 to 78.1E6 Increment: 100 *RST: 115200 Default unit: Bit

BUS<b>:UART:BITime <BurstIdleTime>

Sets the minimal time between two data frames (packets), that is, between the last stop bit and the start bit of the next frame.

Suffix:

<b>	1 | 2

Parameters:

<BurstIdleTime>	Range: Range depends on the bus configuration, mainly on bit rate and symbol size. Default unit: s

10.10.4.2 UART - Trigger

To configure the protocol trigger, make sure to set first:

- `TRIGger:A:TYPE` to `BUS`
- `TRIGger:A:SOURce` to `SBUS1 | SBUS2`

TRIGger:A:UART:MODE <Mode>

Specifies the trigger mode for UART/RS-232 interfaces.

Parameters:

<Mode> BSTart | SBIT | NTHSymbol | SYMBol | PATTern | PRERror | FERRor | BREak

BSTart
Burst start. Sets the trigger to the begin of a data frame. The frame start is the first start bit after the idle time.

SBIT
Start bit. The start bit is the first low bit after a stop bit.

NTHSymbol
Sets the trigger to the n-th symbol of a burst.

SYMBol
Triggers if a pattern occurs in a symbol at any position in a burst.

PATTern
Triggers on a serial pattern at a defined position in the burst.
To define the pattern, use `TRIGger:A:UART:PLENgth` and `TRIGger:A:UART:PATTern`.
To define the position, use `TRIGger:A:UART:POFFset`.
See also: "Pattern" on page 141.

PRERror
Parity Error: Triggers if a bit error occured in transmission.

FERRor
Triggers on frame error.

BREak
Triggers if a start bit is not followed by a stop bit within a defined time. During the break the stop bits are at low state.

*RST: SBIT

TRIGger:A:UART:PATTern <DataPattern>

Defines the bit pattern as trigger condition.

Parameters:

<DataPattern> Binary pattern with max. 32 bit. Characters 0, 1, and X are allowed.

*RST: 1 = "00000001"

TRIGger:A:UART:PLENgth <PatternLength>

Defines how many symbols build up the serial pattern.

Parameters:

<PatternLength> Number of symbols

Range: 1 to 4
Increment: 1
*RST: 1

TRIGger:A:UART:POFFset <PatternByteOffset>

Sets the number of symbols before the first symbol of the pattern.

Parameters:

<PatternByteOffset> Number of ignored symbols

Range: 0 to 4095
Increment: 1
*RST: 0

10.10.4.3 UART - Decode Results

In all `BUS<b>:UART...` commands, the suffix <b> selects the bus.

BUS<b>:UART:FCOunt?
BUS<b>:UART:RX:FCOunt?
BUS<b>:UART:TX:FCOunt?

Return the number of decoded frames on the data line.

Suffix:

<b> 1 | 2

Return values:
<FrameCount> Total number of decoded frames.

Usage: Query only

BUS<b>:UART:FRAMe<n>:WCOunt?
BUS<b>:UART:RX:FRAMe<n>:WCOunt?
BUS<b>:UART:TX:FRAMe<n>:WCOunt?

Returns the number of symbols in the specified frame.

Suffix:
<b> 1 | 2

<n> *
Selects the frame.

<o> *

Return values:
<WordCount> Number of words (symbols, characters)

Usage: Query only

BUS<b>:UART:FRAMe<n>:WORD<o>:STATe?
BUS<b>:UART:RX:FRAMe<n>:WORD<o>:STATe?
BUS<b>:UART:TX:FRAMe<n>:WORD<o>:STATe?

Returns the status of the specified symbol (word).

Suffix:
<b> 1 | 2

<n> *
Selects the frame.

<o> *
Selects the word number.

Return values:
<Status> OK | FRSTart | FRENd | FRMError | STERror | SPERror | PRERror | INSufficient | BREak

`OK`: the frame is valid.
`FRSTart`: frame start not found
`FRENd`: frame end not found
`FRMError`: error in frame
`STERror`: start error, no start bit found.
`SPERror`: stop error, no stop condition found.
`PRERror`: parity error, which indicates a transmission error.
`INSufficient`: the frame is not completely contained in the acquisition. The acquired part of the frame is valid.
`BREak`: break condition found. A start bit is not followed by a stop bit, and the data line remains at logic 0 for longer than a UART word.

Usage: Query only

BUS<b>:UART:FRAMe<n>:WORD<o>:STARt?
BUS<b>:UART:RX:FRAMe<n>:WORD<o>:STARt?
BUS<b>:UART:TX:FRAMe<n>:WORD<o>:STARt?

Returns the start time of the specified symbol (word).

Suffix:

<b> 1 | 2

<n> *
Selects the frame.

<o> *
Selects the word number.

Return values:

<StartTime> Range: depends on sample rate, record length, and time base
Increment: depends on the time base
Default unit: s

Usage: Query only

BUS<b>:UART:FRAMe<n>:WORD<o>:STOP?
BUS<b>:UART:RX:FRAMe<n>:WORD<o>:STOP?
BUS<b>:UART:TX:FRAMe<n>:WORD<o>:STOP?

Returns the end time of the specified symbol (word).

Suffix:

<b> 1 | 2

<n> *
Selects the frame.

<o> *
Selects the word number.

Return values:

<StopTime> Range: depends on sample rate, record length, and time base
Increment: depends on the time base
Default unit: s

Usage: Query only

BUS<b>:UART:RX:FRAMe<n>:WORD<o>:VALue?
BUS<b>:UART:TX:FRAMe<n>:WORD<o>:VALue?

Return the value of the specified symbol (word) on the Rx line and Tx line, respectively.

Suffix:

<b>	1..2 Selects the bus. Note: SPI/SSPI and UART protocols occupy two bus lines.
<n>	* Selects the frame.
<o>	* Selects the word number.

Return values:

<Value>	Range: 0 to 511 Increment: 1

Usage: Query only

BUS<b>:UART:FRAMe<n>:WORD<o>:VALue?
BUS<b>:UART:FRAMe<n>:WORD<o>:RXValue?
BUS<b>:UART:FRAMe<n>:WORD<o>:TXValue?

Suffix:

<p>	1..2
<n>	*
<o>	*

Return values:
<TxValue>

Usage: Query only

10.10.5 CAN

CAN is the Controller Area Network, a bus system used within automotive network architecture.

10.10.5.1 CAN - Configuration

Start the bus configuration with the threshold setting. Use one of the following commands:

- `CHANnel<m>:THReshold:FINDlevel` on page 179
- `CHANnel<m>:THReshold` on page 178

In all `BUS<b>:CAN...` commands, the suffix <b> selects the bus.

BUS<b>:CAN:DATA:SOURce <Source>

Sets the source of the data line. All channel waveforms can be used.

Suffix:

<b>	1 | 2

Parameters:

<Source>	CH1 | CH2 | CH3 | CH4 | D0..D15 Logic channels D0..D15 are available if MSO option R&S RTB-B1 is installed. *RST: CH1

BUS<b>:CAN:TYPE <SignalType>

Selects the CAN-High or CAN-Low line. CAN uses both lines for differential signal transmission.

If you measure with a differential probe, connect the probe to both CAN-H and CAN-L lines, and set the type CANH.

If you use a single-ended probe, connect the probe to either CAN_L or CAN_H, and select the type accordingly.

Suffix:

<b>	1 | 2

Parameters:

<SignalType>	CANH | CANL *RST: CANH

BUS<b>:CAN:SAMPlepoint <SamplePoint>

Sets the position of the sample point within the bit in percent of the nominal bit time.

See also: "Sample Point" on page 145.

Suffix:

<b>	1 | 2

Parameters:

<SamplePoint>	Range: 10 to 90 Increment: 1 *RST: 50 Default unit: %

BUS<b>:CAN:BITRate <BitRate>

Sets the number of transmitted bits per second.

Suffix:

<b>	1 | 2

Parameters:

<BitRate>	Range: 100 to 5,04E06 Increment: Depends on the bit rate value *RST: 50E03 Default unit: Bit/s

10.10.5.2 CAN - Trigger

To configure the protocol trigger, make sure to set first:

- `TRIGger:A:TYPE` to `BUS`
- `TRIGger:A:SOURce` to `SBUS1 | SBUS2`

TRIGger:A:CAN:TYPE <TriggerType>

Specifies the trigger mode for CAN.

Parameters:

<TriggerType> STOFrame | EOFrame | ID | IDDT | FTYPe | ERRCondition

STOFrame
Start of frame

EOFrame
End of frame

ID
Sets the trigger to a specific message "Identifier" or an "Identifier" range.
Specify the identifier with TRIGger:A:CAN:ITYPe, TRIGger:A:CAN:ICONdition and TRIGger:A:CAN:IDENtifier.

IDDT
Sets the trigger to a combination of "Identifier and Data" condition. The instrument triggers at the end of the last byte of the specified data pattern.
Specify the "Identifier" (see ID), and the "Data" with TRIGger:A:CAN:DLC, TRIGger:A:CAN:DCONdition and TRIGger:A:CAN:DATA.

FTYPe
Triggers on a specified "Frame".
Specify the frame type with TRIGger:A:CAN:FTYPe.

ERRCondition
Identifies various errors in the frame.
Specify the "Error" with TRIGger:A:CAN:ACKerror, TRIGger:A:CAN:BITSterror, TRIGger:A:CAN:CRCerror and TRIGger:A:CAN:FORMerror.

*RST: STOF

TRIGger:A:CAN:FTYPe <FrameType>

Specifies the frame type to be triggered on if TRIGger:A:CAN:TYPE is set to FTYPe.

Parameters:

<FrameType> DATA | REMote | ERRor | OVERload | ANY

*RST: ERR

TRIGger:A:CAN:ITYPe <IdentifierType>

Selects the length of the identifier: 11 bit for CAN base frames, or 29 bits for CAN extended frames.

The command is relevant if TRIGger:A:CAN:TYPE is set to ID, IDDT, or FTYPe (data and remote frames).

Parameters:

<IdentifierType> B11 | B29 | ANY

ANY: use if the identifier length is not relevant. Not available for trigger type ID.

*RST: B11

TRIGger:A:CAN:ICONdition <IdentifierCondition>

Sets the comparison condition: If the pattern contains at least one X (don't care), you can trigger on values equal or not equal to the specified value. If the pattern contains only 0 and 1, you can also trigger on a range greater than or lower than the specified value.

The command is relevant, if TRIGger:A:CAN:TYPE is set to ID or IDDT.

Parameters:

<IdentifierCondition> EQUual | NEQual | GTHan | LTHan

*RST: EQ

TRIGger:A:CAN:IDENtifier <Identifier>

Defines the identifier pattern. The pattern length is defined with TRIGger:A:CAN:ITYPe.

The command is relevant if TRIGger:A:CAN:TYPE is set to ID or IDDT.

Parameters:

<Identifier> String containing binary pattern with 11 bit or 29 bit. Characters 0, 1, and X are allowed.

TRIGger:A:CAN:DCONdition <DataCondition>

Sets the comparison condition for data: If the pattern contains at least one X (don't care), you can trigger on values equal or not equal to the specified value. If the pattern contains only 0 and 1, you can also trigger on a range greater than or lower than the specified value.

The command is relevant if TRIGger:A:CAN:TYPE is set to IDDT.

Parameters:

<DataCondition> EQUal | NEQual | GTHan | LTHan

*RST: EQ

TRIGger:A:CAN:DLC <DataLength>

Defines the length of the data pattern - the number of bytes in the pattern.

The command is relevant if TRIGger:A:CAN:TYPE is set to IDDT.

Parameters:

<DataLength>	Range: 0 to 8 Increment: 1 *RST: 1 Default unit: Byte

---

TRIGger:A:CAN:DATA <Data>

Defines the data pattern. The number of bytes in the data pattern is defined with `TRIGger:A:CAN:DLC`.

The command is relevant if `TRIGger:A:CAN:TYPE` is set to `IDDT`.

Parameters:

<Data>	String containing binary pattern with max. 64 bit. Characters 0, 1, and X are allowed. Make sure to enter complete bytes.

TRIGger:A:CAN:ACKerror <AcknowledgeError>

Triggers on acknowledgement errors. An acknowledgement error occurs when the transmitter does not receive an acknowledgment - a dominant bit during the Ack Slot.

The command is relevant if `TRIGger:A:CAN:TYPE` is set to `ERRCondition`.

Parameters:

<AcknowledgeError>	ON | OFF *RST: OFF

TRIGger:A:CAN:BITSterror <BitStuffingError>

Triggers on bit stuffing errors.

See also: "Stuff Bit" on page 148.

The command is relevant if `TRIGger:A:CAN:TYPE` is set to `ERRCondition`.

Parameters:

<BitStuffingError>	ON | OFF *RST: ON

TRIGger:A:CAN:CRCerror <CRCerror>

Triggers on errors in the Cyclic Redundancy Check.

The command is relevant if `TRIGger:A:CAN:TYPE` is set to `ERRCondition`.

Parameters:

<CRCerror>	ON | OFF *RST: OFF

TRIGger:A:CAN:FORMerror <FormError>

Triggers on form errors. A form error occurs when a fixed-form bit field contains one or more illegal bits.

The command is relevant if `TRIGger:A:CAN:TYPE` is set to `ERRCondition`.

Parameters:

<FormError> ON | OFF

*RST: OFF

10.10.5.3 CAN - Decode Results

In all `BUS<b>:CAN...` commands, the suffix <b> selects the bus.

BUS<b>:CAN:FCOunt?

Returns the number of received frames.

Suffix:

<b> 1 | 2

Return values:

<FrameCount> Total number of decoded frames.

Usage: Query only

BUS<b>:CAN:FRAMe<n>:TYPE?

Returns the type of the specified frame.

Suffix:

<b>	1 | 2
<n>	* Selects the frame (1...n).

Return values:

<FrameType>	DATA | REMote | ERR | OVLD Data, remote, error or overload frame

Usage: Query only

BUS<b>:CAN:FRAMe<n>:STATus?

Returns the overall state of the specified frame.

Suffix:

<b>	1 | 2
<n>	* Selects the frame (1...n).

Return values:

<FrameStatus>	OK | BTST | CRCD | ACKD | CRC | EOFD | NOACk | INSufficient OK: frame is valid. BTST: bit stuffing error occured CRCD: wrong CRC delimiter occured ACKD: Wrong ACK delimiter occured CRC: cyclic redundancy check failed EOFD: wrong end of frame NOACk: acknowlegde is missing INSufficient: frame is not completely contained in the acquisition. The acquired part of the frame is valid.

Usage: Query only

BUS<b>:CAN:FRAMe<n>:STARt?

Returns the start time of the specified frame.

Suffix:

<b>	1 | 2
<n>	* Selects the frame (1...n).

Return values:

<StartTime>	Default unit: s

Usage: Query only

BUS<b>:CAN:FRAMe<n>:STOP?

Returns the end time of the specified frame.

Suffix:

<b>	1 | 2
<n>	* Selects the frame (1...n).

Return values:

<StopTime>	Default unit: s

Usage: Query only

BUS<b>:CAN:FRAMe<n>:DATA?

Returns the data words of the specified frame.

Suffix:

<b>	1 | 2
<n>	* Selects the frame (1...n).

Return values:

<FrameData>	Comma-separated list of decimal values of the data bytes.

Usage: Query only

BUS<b>:CAN:FRAMe<n>:ACKState?

Returns the state of the acknowledge field.

Suffix:

<b>	1 | 2
<n>	* Selects the frame (1...n).

Return values:

<AcknowledgeState>	OK | UNDF UNDF: Undefined

Usage: Query only

BUS<b>:CAN:FRAMe<n>:ACKValue?

Returns the value of the acknowledge field.

Suffix:

<b>	1 | 2
<n>	* Selects the frame (1...n).

Return values:
<AcknowledgeValue> Decimal value

Usage: Query only

BUS<b>:CAN:FRAMe<n>:CSSTate?

Returns the state of the checksum.

Suffix:

<b> 1 | 2

<n> *
Selects the frame (1...n).

Return values:

<ChecksumState> OK | UNDF
UNDF: Undefined

Usage: Query only

BUS<b>:CAN:FRAMe<n>:CSValue?

Returns the checksum value.

Suffix:

<b> 1 | 2

<n> *
Selects the frame (1...n).

Return values:

<ChecksumValue> Decimal value

Usage: Query only

BUS<b>:CAN:FRAMe<n>:DLCState?

Returns the state of the data length code.

Suffix:

<b> 1 | 2

<n> *
Selects the frame (1...n).

Return values:

<DLCState> OK | UNDF
UNDF: Undefined

Usage: Query only

BUS<b>:CAN:FRAMe<n>:DLCValue?

Returns the number of data bytes in the specified frame.

Suffix:

<b>	1 | 2
<n>	* Selects the frame (1...n).

Return values:

<DLCValue>	Non-negative integer

Usage: Query only

BUS<b>:CAN:FRAMe<n>:IDSTate?

Returns the state of the identifier.

Suffix:

<b>	1 | 2
<n>	* Selects the frame (1...n).

Return values:

<IdentifierState>	OK | UNDF UNDF: Undefined

Usage: Query only

BUS<b>:CAN:FRAMe<n>:IDTYpe?

Returns the length of the identifier: 11 bits for CAN base frames, 29 bits for CAN extended frames.

Suffix:

<b>	1 | 2
<n>	* Selects the frame (1...n).

Return values:

<IdentifierType>	ANY | B11 | B29

Usage: Query only

BUS<b>:CAN:FRAMe<n>:IDValue?

Returns the identifier of the specified frame.

Suffix:

<b>	1 | 2

<n> *
Selects the frame (1...n).

Return values:
<IdentifierValue> Decimal value

Usage: Query only

BUS<b>:CAN:FRAMe<n>:BSEPosition?

Returns the position of the bit stuffing error in the specified frame (if available).

Suffix:
<b> 1 | 2

<n> *
Selects the frame (1...n).

Return values:
<ErrorPosition> *RST: 0
Default unit: s

Usage: Query only

BUS<b>:CAN:FRAMe<n>:BCOunt?

Returns the number of data bytes in the specified frame.

Suffix:
<b> 1 | 2

<n> *
Selects the frame (1...n).

Return values:
<ByteCount> Number of words (bytes)

Usage: Query only

BUS<b>:CAN:FRAMe<n>:BYTE<o>:STATe?

Returns the state of the specified data byte.

Suffix:
<b> 1 | 2

<n> *
Selects the frame (1...n).

<o> *
Selects the byte number (1...m).

Return values:
<ByteStatus> OK | UNDF
UNDF: Undefined

Usage: Query only

BUS<b>:CAN:FRAMe<n>:BYTE<o>:VALue?

Returns the decimal value of the specified byte.

Suffix:

<b> 1 | 2

<n> *
Selects the frame (1...n).

<o> *
Selects the byte number (1...m).

Return values:

<ByteValue> Decimal value

Usage: Query only

10.10.5.4 CAN - Search

SEARch:PROTocol:CAN:CONDition <SearchCondition>

Sets the event or combination of events to be searched for. Depending on the selected event, further settings are required.

Parameters:

<SearchCondition> FRAMe | ERRor | IDENtifier | IDData | IDERror

FRAMe
Search for a frame type. Set the frame type with SEARch:PROTocol:CAN:FRAMe.

ERRor
Search for errors of one or more error types. Set the error types with SEARch:PROTocol:CAN:ACKerror, SEARch:PROTocol:CAN:BITSterror, SEARch:PROTocol:CAN:CRCerror and SEARch:PROTocol:CAN:FORMerror.

IDENtifier
Search for identifier.
Specifiy the identifier with SEARch:PROTocol:CAN:FTYPe, SEARch:PROTocol:CAN:ITYPe, SEARch:PROTocol:CAN:ICONdition and SEARch:PROTocol:CAN:IDENtifier.

IDData
Search for identifier and data.
Set the identifier (see IDENtifier) and the data with SEARch:PROTocol:CAN:DLENgth, SEARch:PROTocol:CAN:DCONdition and SEARch:PROTocol:CAN:DATA.

IDERror
Search for errors that occur with a specified identifier.
Set the identifier (see IDENtifier) and the errors to be found (see ERRor)

*RST: FRAM

SEARch:PROTocol:CAN:FRAMe <Frame>

Selects the frame type to be searched for.

The command is relevant if SEARch:PROTocol:CAN:CONDition is set to FRAMe.

Parameters:

<Frame> SOF | EOF | OVERload | ERRor | DTA11 | DTA29 | REM11 | REM29

SOF: start of frame
EOF: end of frame
OVERload: overload frame
ERRor: error frame
DTA11: data frame with 11bit identifier
DTA29: data frame with 29bit identifier
REM11: remote frame with 11bit identifier
REM29: remote frame with 29bit identifier

*RST: SOF

SEARch:PROTocol:CAN:ACKerror <AcknowledgeError>

Searches for acknowledgement errors. An acknowledgement error occurs when the transmitter does not receive an acknowledgment - a dominant bit during the Ack Slot.

The command is relevant if `SEARch:PROTocol:CAN:CONDition` is set to `ERRor` or `IDERror`.

Parameters:

<AcknowledgeError> ON | OFF
*RST: OFF

SEARch:PROTocol:CAN:BITSterror <BitStuffingError>

Searches for bit stuffing errors.

See also: "Stuff Bit" on page 148.

The command is relevant if `SEARch:PROTocol:CAN:CONDition` is set to `ERRor` or `IDERror`.

Parameters:

<BitStuffingError> ON | OFF
*RST: OFF

SEARch:PROTocol:CAN:CRCerror <CRCerror>

Searches for errors in the Cyclic Redundancy Check.

The command is relevant if `SEARch:PROTocol:CAN:CONDition` is set to `ERRor` or `IDERror`.

Parameters:

<CRCerror> ON | OFF
*RST: OFF

SEARch:PROTocol:CAN:FORMerror <FormError>

Searches for form errors. A form error occurs when a fixed-form bit field contains one or more illegal bits.

The command is relevant if `SEARch:PROTocol:CAN:CONDition` is set to `ERRor` or `IDERror`.

Parameters:

<FormError> ON | OFF
*RST: OFF

SEARch:PROTocol:CAN:FTYPe <FrameType>

Specifies the frame type to be searched for if SEARch:PROTocol:CAN:CONDition is set to IDENtifier.

Parameters:

<FrameType> DATA | REMote | ANY

SEARch:PROTocol:CAN:ITYPe <IdType>

Selects the length of the identifier: 11 bit for CAN base frames, or 29 bits for CAN extended frames.

The command is relevant if SEARch:PROTocol:CAN:CONDition is set to IDENtifier, IDData, or IDERror.

Parameters:

<IdType> B11 | B29

*RST: B11

SEARch:PROTocol:CAN:ICONdition <IdCondition>

Sets the comparison condition for the identifier: If the pattern contains at least one X (don't care), you can trigger on values equal or not equal to the specified value. If the pattern contains only 0 and 1, you can also trigger on a range greater than or lower than the specified value.

The command is relevant if SEARch:PROTocol:CAN:CONDition is set to IDENtifier, IDData, or IDERror.

Parameters:

<IdCondition> EQUal | NEQual | GTHan | LTHan

*RST: EQU

SEARch:PROTocol:CAN:IDENtifier <Identifier>

Defines the identifier pattern. The pattern length is defined with SEARch:PROTocol:CAN:ITYPe.

The command is relevant if SEARch:PROTocol:CAN:CONDition is set to IDENtifier, IDData, or IDERror.

Parameters:

<Identifier> String containing binary pattern with max. 29 bit. Characters 0, 1, and X are allowed.

SEARch:PROTocol:CAN:DLENgth <DataLength>

Defines the length of the data pattern - the number of bytes in the pattern.

The command is relevant if SEARch:PROTocol:CAN:CONDition is set to IDData.

Parameters:

<DataLength>	Range: 0 to 8 Increment: 1 *RST: 1 Default unit: Byte

SEARch:PROTocol:CAN:DCONdition <DataCondition>

Sets the comparison condition for data: If the pattern contains at least one X (don't care), you can trigger on values equal or not equal to the specified value. If the pattern contains only 0 and 1, you can also trigger on a range greater than or lower than the specified value.

The command is relevant if `SEARch:PROTocol:CAN:CONDition` is set to `IDData`.

Parameters:

<DataCondition>	EQUal | NEQual | GTHan | LTHan *RST: EQU

SEARch:PROTocol:CAN:DATA <Data>

Defines the data pattern. The pattern length is defined with `SEARch:PROTocol:CAN:DLENgth`.

The command is relevant if `SEARch:PROTocol:CAN:CONDition` is set to `IDData`.

Parameters:

<Data>	String containing binary pattern with max. 64 bit. Characters 0, 1, and X are allowed. Make sure to enter complete bytes.

10.10.6 LIN (Option R&S RTB-K3)

The Local Interconnect Network (LIN) is a simple, low-cost bus system used within automotive network architectures.

Note: SPI/SSPI and UART protocols occupy two bus lines (bus 1 and 2 or bus 3 and 4). If one of these buses is configured, the number of buses (suffix <b>) is reduced. Bus 2 and/or bus 4 is not available.

10.10.6.1 LIN - Configuration

Start the bus configuration with the threshold setting. Use one of the following commands:

- `CHANnel<m>:THReshold:FINDlevel` on page 179

- `CHANnel<m>:THReshold` on page 178

In all `BUS<b>:LIN...` commands, the suffix <b> selects the bus.

BUS<b>:LIN:DATA:SOURce <Source>

Sets the source of the data line. All channel waveforms can be used.

Suffix:

<b> 1 | 2

Parameters:

<Source> CH1 | CH2 | CH3 | CH4 | D0..D15

*RST: CH1

BUS<b>:LIN:POLarity <Polarity>

Defines the idle state of the bus. The idle state is the recessive state and corresponds to a logic 1.

Suffix:

<b> 1 | 2

Parameters:

<Polarity> IDLHigh | IDLLow

IDLHigh: Low active, negative polarity
IDLLow: High active, positive polarity

*RST: IDLL

BUS<b>:LIN:STANdard <Standard>

Selects the version of the LIN standard that is used in the DUT. The setting mainly defines the checksum version used during decoding.

The most common version is LIN 2.x. For mixed networks, or if the standard is unknown, set the LIN standard to AUTO.

Suffix:

<b> 1 | 2

Parameters:

<Standard> V1X | V2X | J2602 | AUTO

*RST: V1X

BUS<b>:LIN:BITRate <BitRate>

Sets the number of transmitted bits per second.

Suffix:

<b> 1 | 2

Parameters:

<BitRate> *RST: 9,6E03
Default unit: Bit/s

10.10.6.2 LIN - Trigger

To configure the protocol trigger, make sure to set first:

- `TRIGger:A:TYPE` to `BUS`
- `TRIGger:A:SOURce` to `SBUS1 | SBUS2`

TRIGger:A:LIN:TYPE <TriggerType>

Specifies the trigger mode for LIN.

Parameters:

<TriggerType> SYNC | WKFRame | ID | IDDT | ERRCondition

SYNC
Start of frame, triggers on the stop bit of the sync field.

WKFRame
Triggers after a wakeup frame.

ID
Sets the trigger to a specific identifier or an identifier range.
Set the identifier with `TRIGger:A:LIN:ICONdition` and `TRIGger:A:LIN:IDENtifier`.

IDDT
Set the identifier (see ID) and the data with `TRIGger:A:LIN:DLENgth`, `TRIGger:A:LIN:DCONdition` and `TRIGger:A:LIN:DATA`.

ERRCondition
Identifies various errors in the frame. You can select one or more error types as trigger condition.
Select the error types with `TRIGger:A:LIN:CHKSerror`, `TRIGger:A:LIN:IPERror` and `TRIGger:A:LIN:SYERror`.

*RST: SYNC

TRIGger:A:LIN:CHKSerror <ChecksumError>

Triggers on a checksum error. The checksum verifies the correct data transmission. It is the last byte of the frame response. The checksum includes not only the data but also the protected identifier (PID).

The command is relevant if `TRIGger:A:LIN:TYPE` is set to `ERRCondition`.

Parameters:

<ChecksumError>	ON | OFF	
	*RST:	ON

TRIGger:A:LIN:IPERror <IdParityError>

Triggers on a parity error. Parity bits are the bits 6 and 7 of the identifier. They verify the correct transmission of the identifier.

The command is relevant if `TRIGger:A:LIN:TYPE` is set to `ERRCondition`.

Parameters:

<IdParityError>	ON | OFF	
	*RST:	OFF

TRIGger:A:LIN:SYERror <SyncError>

Triggers if synchronization caused an error.

The command is relevant if `TRIGger:A:LIN:TYPE` is set to `ERRCondition`.

Parameters:

<SyncError>	ON | OFF	
	*RST:	OFF

TRIGger:A:LIN:ICONdition <IdentifierCondition>

Sets the comparison condition for the identifier: If the pattern contains at least one X (don't care), you can trigger on values equal or not equal to the specified value. If the pattern contains only 0 and 1, you can also trigger on a range greater than or lower than the specified value.

The command is relevant if `TRIGger:A:LIN:TYPE` is set to `ID` or `IDDT`.

Parameters:

<IdentifierCondition>	EQUal | NEQual | GTHan | LTHan	
	*RST:	EQ

TRIGger:A:LIN:IDENtifier <Identifier>

Defines the identifier pattern.

The command is relevant if `TRIGger:A:LIN:TYPE` is set to `ID` or `IDDT`.

Parameters:

<Identifier> String containing binary pattern. Characters 0, 1, and X are allowed. Enter the 6 bit identifier without parity bits, not the protected identifier.

TRIGger:A:LIN:DATA <Data>

Defines the data pattern. The number of bytes in the data pattern is defined with `TRIGger:A:LIN:DLENgth`.

The command is relevant if `TRIGger:A:LIN:TYPE` is set to `IDDT`.

Parameters:

<Data> String containing binary pattern with max. 64 bit. Characters 0, 1, and X are allowed. Make sure to enter complete bytes.

TRIGger:A:LIN:DCONdition <DataCondition>

Sets the comparison condition for data: If the pattern contains at least one X (don't care), you can trigger on values equal or not equal to the specified value. If the pattern contains only 0 and 1, you can also trigger on a range greater than or lower than the specified value.

The command is relevant if `TRIGger:A:LIN:TYPE` is set to `IDDT`.

Parameters:

<DataCondition> EQUal | NEQual | GTHan | LTHan

*RST: EQ

TRIGger:A:LIN:DLENgth <DataLength>

Defines the length of the data pattern - the number of bytes in the pattern.

The command is relevant if `TRIGger:A:LIN:TYPE` is set to `IDDT`.

Parameters:

<DataLength> Range: 1 to 8
Increment: 1
*RST: 1
Default unit: Byte

10.10.6.3 LIN - Decode Results

In all `BUS<b>:LIN...` commands, the suffix <b> selects the bus.

BUS<b>:LIN:FCOunt?

Returns the number of received frames of the active LIN bus.

Suffix:

<b> 1 | 2

Return values:

<FrameCount> Total number of decoded frames.

Usage: Query only

BUS<b>:LIN:FRAMe<n>:DATA?

Returns the data bytes of the specified frame.

Suffix:

<b> 1 | 2

<n> *
Selects the frame (1...n).

Return values:

<FrameData> Comma-separated list of decimal values of the data bytes.

Usage: Query only

BUS<b>:LIN:FRAMe<n>:STATus?

Returns the overall state of the specified frame.

Suffix:

<b> 1 | 2

<n> *
Selects the frame (1...n).

Return values:

<FrameStatus> OK | UART | CHCKsum | PRERror | SYERror | WAKeup | INSufficient | ERR | LENer

Usage: Query only

BUS<b>:LIN:FRAMe<n>:STARt?

Returns the start time of the specified frame.

Suffix:

<b>	1 | 2
<n>	* Selects the frame (1...n).

Return values:

<StartTime>
Range: depends on sample rate, record length, and time base
Increment: depends on the time base
Default unit: s

Usage: Query only

BUS<b>:LIN:FRAMe<n>:STOP?

Returns the end time of the specified frame.

Suffix:

<b>	1 | 2
<n>	* Selects the frame (1...n).

Return values:

<StopTime>
Range: depends on sample rate, record length, and time base
Increment: depends on the time base
Default unit: s

Usage: Query only

BUS<b>:LIN:FRAMe<n>:CSSTate?

Returns the checksum state of the specified frame.

Suffix:

<b>	1 | 2
<n>	* Selects the frame (1...n).

Return values:

<ChecksumState>
OK | ERR | UNDF

ERR: error
UNDF: undefined

Usage: Query only

BUS<b>:LIN:FRAMe<n>:CSValue?

Returns the checksum value.

Suffix:

<b> 1 | 2

<n> *
Selects the frame (1...n).

Return values:

<ChecksumValue> Decimal value

Usage: Query only

BUS<b>:LIN:FRAMe<n>:IDPValue?

Returns the parity value.

Suffix:

<b> 1 | 2

<n> *
Selects the frame (1...n).

Return values:

<IdentifierParityValue> Decimal value

Usage: Query only

BUS<b>:LIN:FRAMe<n>:IDSTate?

Returns the identifier state of the selected frame.

Suffix:

<b> 1 | 2

<n> *
Selects the frame (1...n).

Return values:

<IdentifierState> OK | PRERror | UVAL | INSufficient

PRERror: parity error
UVAL: unexpected value
INSufficient: the frame is not completely contained in the acquisition. The decoded part of the frame is valid.

Usage: Query only

BUS<b>:LIN:FRAMe<n>:IDValue?

Returns the identifier value (address)

Suffix:

<b> 1 | 2

<n> *
Selects the frame (1...n).

Return values:
<IdentifierValue> Decimal value

Usage: Query only

BUS<b>:LIN:FRAMe<n>:SYSTate?

Returns the state of the sync field for the specified frame.

Suffix:
<b> 1 | 2

<n> *
Selects the frame (1...n).

Return values:
<SyncFieldState> OK | ERR | UNDF
ERR: error
UNDF: undefined

Usage: Query only

BUS<b>:LIN:FRAMe<n>:SYValue?

Returns the value of the synchronization field.

Suffix:
<b> 1 | 2

<n> *
Selects the frame (1...n).

Return values:
<SyncFieldValue> Decimal value

Usage: Query only

BUS<b>:LIN:FRAMe<n>:VERSion?

Returns the version of the LIN standard for the specified frame.

Suffix:
<b> 1 | 2

<n> *
Selects the frame (1...n).

Return values:
<FrameVersion> V1X | V2X | UNK
UNK: Unknown

Usage: Query only

BUS<b>:LIN:FRAMe<n>:BCOunt?

Returns the number of data bytes in the specified frame.

Suffix:

<b>	1 | 2
<n>	* Selects the frame (1...n).

Return values:

<ByteCount>	Number of words (bytes)

Usage: Query only

BUS<b>:LIN:FRAMe<n>:BYTE<o>:STATe?

Returns the state of the specified data byte.

Suffix:

<b>	1 | 2
<n>	* Selects the frame (1...n).
<o>	* Selects the byte number (1...o).

Return values:

<ByteStatus>	OK | INS | UART **INS** Insufficient, the byte is not completely contained in the acquisition. **UART** At least one UART error occured. LIN uses UART words without parity bit.

Usage: Query only

BUS<b>:LIN:FRAMe<n>:BYTE<o>:VALue?

Returns the decimal value of the specified byte.

Suffix:

<b>	1 | 2
<n>	* Selects the frame (1...n).
<o>	* Selects the byte number (1...o).

Return values:

<ByteValue>	Decimal value

Usage: Query only

10.10.6.4 LIN - Search

SEARch:PROTocol:LIN:CONDition <SearchCondition>

Sets the event or combination of events to be searched for. Depending on the selected event, further settings are required.

Parameters:

<SearchCondition> FRAMe | ERRor | IDENtifier | IDData | IDERror

FRAMe
Search for a frame type.
Set the frame type with `SEARch:PROTocol:LIN:FRAMe`.

ERRor
Search for errors of one or more error types.
Set the error types with`SEARch:PROTocol:LIN:CHKSerror` , `SEARch:PROTocol:LIN:IPERror` and `SEARch:PROTocol:LIN:SYERror`.

IDENtifier
Search for identifier.
Specifiy the identifier with `SEARch:PROTocol:LIN:ICONdition` and `SEARch:PROTocol:LIN:IDENtifier`.

IDData
Search for identifier and data.
Set the identifier (see IDENtifier) and the data with `SEARch:PROTocol:LIN:DLENgth`, `SEARch:PROTocol:LIN:DCONdition` and `SEARch:PROTocol:LIN:DATA`.

IDERror
Search for errors that occur with a specified identifier. Set the identifier (see IDENtifier) and the errors to be found (see ERRor).

*RST: FRAM

SEARch:PROTocol:LIN:FRAMe <Frame>

Selects the frame type to be searched for.

The command is relevant if `SEARch:PROTocol:LIN:CONDition` is set to `FRAMe`.

Parameters:

<Frame> SOF | WAKeup

SOF: start of frame
WAKeup: Wakeup frame

*RST: SOF

SEARch:PROTocol:LIN:IPERror <IdParityError>

Searches for parity errors.

The command is relevant if `SEARch:PROTocol:LIN:CONDition` is set to `ERRor` or `IDERror`.

Parameters:

<IdParityError> ON | OFF

*RST: OFF

SEARch:PROTocol:LIN:CHKSerror <ChecksumError>

Searches for checksum errors.

The command is relevant if `SEARch:PROTocol:LIN:CONDition` is set to `ERRor` or `IDERror`.

Parameters:

<ChecksumError> ON | OFF

*RST: OFF

SEARch:PROTocol:LIN:SYERror <SyncError>

Searches for synchronization errors.

The command is relevant if `SEARch:PROTocol:LIN:CONDition` is set to `ERRor` or `IDERror`.

Parameters:

<SyncError> ON | OFF

*RST: OFF

SEARch:PROTocol:LIN:ICONdition <IdCondition>

Sets the comparison condition for the identifier: If the pattern contains at least one X (don't care), you can trigger on values equal or not equal to the specified value. If the pattern contains only 0 and 1, you can also trigger on a range greater than or lower than the specified value.

The command is relevant if SEARch:PROTocol:LIN:CONDition is set to IDENtifier, IDData or IDERror.

Parameters:

<IdCondition> EQUal | NEQual | GTHan | LTHan

*RST: EQU

SEARch:PROTocol:LIN:IDENtifier <Identifier>

Defines the identifier pattern.

The command is relevant if SEARch:PROTocol:LIN:CONDition is set to IDENtifier, IDData or IDERror.

Parameters:

<Identifier> String containing binary pattern. Characters 0, 1, and X are allowed. Enter the 6 bit identifier without parity bits, not the protected identifier.

SEARch:PROTocol:LIN:DLENgth <DataLength>

Defines the length of the data pattern - the number of bytes in the pattern.

The command is relevant if SEARch:PROTocol:LIN:CONDition is set to IDData.

Parameters:

<DataLength> Range: 1 to 8
Increment: 1
*RST: 1
Default unit: Byte

SEARch:PROTocol:LIN:DCONdition <DataCondition>

Sets the comparison condition for data: If the pattern contains at least one X (don't care), you can trigger on values equal or not equal to the specified value. If the pattern contains only 0 and 1, you can also trigger on a range greater than or lower than the specified value.

The command is relevant if SEARch:PROTocol:LIN:CONDition is set to IDData.

Parameters:

<DataCondition> EQUal | NEQual | GTHan | LTHan

*RST: EQU

SEARch:PROTocol:LIN:DATA <Data>

Defines the data pattern. The pattern length is defined with `SEARch:PROTocol:LIN:DLENgth`.

The command is relevant if `SEARch:PROTocol:LIN:CONDition` is set to `IDData`.

Parameters:

<Data> String containing binary pattern with max. 64 bit. Characters 0, 1, and X are allowed. Make sure to enter complete bytes.

10.11 Signal Generation (Option R&S RTB-B6)

10.11.1 Function Generator

WGENerator:FUNCtion <Function>

Selects the function to be generated.

Parameters:

<Function>	DC | SINusoid | SQUare | PULSe | TRIangle | RAMP | SINC | ARBitrary | EXPonential

WGENerator:VOLTage <Amplitude>

Defines the amplitude value (peak-to-peak value) of the selected generator function.

Parameters:

<Amplitude> Numeric value

Range: 6.0000E-02 to 6.00000E+00
*RST: 5.0000E-01
Default unit: Vpp

WGENerator:VOLTage:OFFSet <Offset>

Sets the DC offset of the selected generator function.

Parameters:

<Offset> Numeric value

Range: -3.00000E+00 to 3.00000E+00
*RST: 0.00E+00
Default unit: V

WGENerator:FREQuency <Frequency>

Defines the frequency value of the selected generator function.

Parameters:

<Frequency> Numeric value depending on the selected generator function

Range: 1.000E-01 to 5.000000000E+4 (sine / square)
1.000E-01 to 1.000000000E+4 (pulse / triangle / ramp)
*RST: 1.00000000E+3

WGENerator:FUNCtion:PULSe:DCYCle <DutyCycle>

Defines the duty cycle value of the generator function pulse.

Parameters:

<DutyCycle> Numeric value

Range: 1.000E+01 to 9.000E+01
*RST: 2.500E+01
Default unit: %

WGENerator:FUNCtion:PULSe:ETIMe <EdgeTime>

Sets the pulse edge time.

Parameters:

<EdgeTime>

WGENerator:FUNCtion:RAMP:POLarity <Polarity>

Sets the polarity of the generator function ramp.

Parameters:

<Polarity> POSitive | NEGative

*RST: NEG

WGENerator:ARBitrary:SOURce <Source>

Selects the input channel for an arbitrary function to be generated.

Parameters:

<Source> CH1 | CH2 | CH3 | CH4

*RST: CH1

WGENerator:ARBitrary:UPDate

Loads the waveform from the selected signal source (`WGENerator:ARBitrary:SOURce`).

Usage: Event

WGENerator:ARBitrary[:FILE]:NAME <FilePath>

Sets the file path and the file for an arbitrary waveform to be loaded.

Parameters:

<FilePath> string

*RST: "

WGENerator:ARBitrary[:FILE]:OPEN

Loads the arbitrary waveform, that is selected with the `WGENerator:ARBitrary[:FILE]:NAME` command.

Usage: Event

WGENerator:MODulation[:ENABLE] <Enable>

Activates or deactivates modulation of the function generator output. To define the modulation function, see `WGENerator:MODulation:FUNCtion`.

Parameters:
<Enable> ON | OFF

WGENerator:MODulation:FUNCtion <ModulationFunction>

Selects a function for the modulation.

Parameters:
<ModulationFunction>SINusiod | SQUare | TRIangle | RAMP

WGENerator:MODulation:TYPE <ModulationType>

Sets the modulation type, which defines how the carrier signal is modified.

Parameters:
<ModulationType> AM | FM | ASK | FSK

AM
Amplitude modulation. The amplitude of the carrier signal is varied according to the modulation signal.

FM
Frequency modulation. The frequency of the carrier signal is varied according to the modulation signal.

ASK
Amplitude shift keying (ASK) modulation. The amplitude switches between 100% and the `WGENerator:MODulation:ASK:DEPTh` amplitude with a defined modulating `WGENerator:MODulation:ASK:FREQuency`.

FSK
Frequency shift keying (FSK) modulation. The signal frequency switches between the carrier frequency and the `WGENerator:MODulation:FSK:HFREquency` at a `WGENerator:MODulation:FSK:RATE`.

WGENerator:MODulation:AM:FREQuency <Frequency>

Sets the frequency of the modulating waveform for AM modulation.

Parameters:
<Frequency>

WGENerator:MODulation:AM:DEPTh <ModulationDepth>

Sets the modulation depth, the percentage of the amplitude range that is used for AM modulation.

Parameters:
<ModulationDepth>

WGENerator:MODulation:FM:FREQuency <Frequency>

Sets the frequency of the modulating waveform for FM modulation.

Parameters:
<Frequency>

WGENerator:MODulation:FM:DEViation <Deviation>

Sets the frequency deviation, the maximum difference between the FM modulated signal and the carrier signal.

Parameters:
<Deviation>

WGENerator:MODulation:ASK:FREQuency <Frequency>

Sets the frequency of the modulating waveform for ASK modulation.

Parameters:
<Frequency>

WGENerator:MODulation:ASK:DEPTh <ModulationDepth>

Sets the modulation depth, the percentage of the amplitude range that is used for ASK modulation.

Parameters:
<ModulationDepth>

WGENerator:MODulation:FSK:HFREquency <HoppingFrequency>

Sets the second frequency of the FSK-modulated signal.

Parameters:
<HoppingFrequency>

WGENerator:MODulation:FSK:RATE <Rate>

Sets the rate at which signal switches between the carrier frequency and the hopping frequency.

Parameters:
<Rate>

WGENerator:NOISe:ABSolute <AbsoluteNoise>

Parameters:
<AbsoluteNoise>

WGENerator:NOISe:RELative <RelativeNoise>

Parameters:
<RelativeNoise>

WGENerator:OUTPut:DESTination <Destination>

Sets the output connector for the function generator waveform.

Parameters:

<Destination>	BNC | P3

WGENerator:OUTPut:LOAD <Load>

Select the user load, the load of the DUT at its connection. You can select either a "50Ω" or a "High-Z" (high input impedance) load.

Parameters:

<Load>	HIGHz | R50

WGENerator:OUTPut[:ENABle] <OutputEnable>

Enables the function generator and outputs the waveform.

Parameters:

<OutputEnable>	ON | OFF

WGENerator:SWEep:FEND <StopFrequency>

Sets the stop frequency of the sweep signal.

Parameters:
<StopFrequency>

WGENerator:SWEep:FSTart <StartFrequency>

Sets the start frequency of the sweep signal.

Parameters:
<StartFrequency>

WGENerator:SWEep:TIME <SweepTime>

Sets the duration of the sweep.

Parameters:
<SweepTime>

WGENerator:SWEep:TYPE <SweepType>

Sets the type of the sweep, a linear or logarithmic change of the frequency.

Parameters:
<SweepType> LINear | LOGarithmic

WGENerator:SWEep[:ENABle] <SweepEnable>

Enables or disables sweeping.

Parameters:
<SweepEnable> ON | OFF

10.11.2 Pattern Generator

PGENerator:FUNCtion <PatternFunction>

Selects the pattern generator function.

Parameters:

<PatternFunction> SQUarewave | COUNter | ARBitrary | SPI | I2C | UART | CAN | LIN | MANual

SQUarewave
Square wave function (e.g. for manual probe compensation).

COUNter
Definition of a 4-bit wide counter pattern.

ARBitrary
Definition of a 4-bit wide and 2048 samples deep pattern.

SPI
SPI BUS signals for measurements without measurement object. Data rate 100 kBit/s, 250 kBit/s or 1 MBit/s.

I2C
I^2C BUS signals for measurements without measurement object. Data rate 100 kBit/s, 400 kBit/s, 1 MBit/s or 3.4 MBit/s.

UART
UART BUS signals for measurements without measurement object. Data rate 9600 Bit/s, 115.2 kBit/s and 1 MBit/s.

CAN
CAN BUS signals for measurements without measurement object up to 50 MBit/s.

LIN
LIN BUS signals for measurements without measurement object up to 50 MBit/s.

MANual
Manual pattern mode.

PGENerator:PATTern:STATe <State>

Activates or deactivates the pattern.

Parameters:

<State> ON | OFF

Range: OFF

PGENerator:PATTern:STIMe <SampleTime>

Defines the sample time of the pattern generator function.

Parameters:

<SampleTime> Numeric value

Range: 2.000E-08 to 4.200E+01
*RST: 2.000E-08
Default unit: s

PGENerator:PATTern:PERiod <PatternPeriod>

Defines the period of the pattern generator function.

Parameters:

<PatternPeriod> Numeric value (Period = Pattern length * Bit time)

Range: MIN 1 Sample * 20ns = 20ns to MAX 2048 Samples * 42s = 10416s (approx. 2.89h)
*RST: 2.000E-06
Default unit: s

PGENerator:PATTern:FREQuency <PatternFrequency>

Defines the frequency (period) value of the pattern generator function.

Parameters:

<PatternFrequency> Numeric value

Default unit: Hz

PGENerator:PATTern:ITIMe <IdleTime>

Defines the idle time of the pattern generator function. The idle time can be only defined with activated BURST function.

Parameters:

<IdleTime> Numeric value

Range: 2.000E-08 to 4.200000000000E+01
*RST: 2.5000000000E-01
Default unit: s

PGENerator:PATTern:BURSt:STATe <BurstState>

Turns the BURST function on or off.

Parameters:

<BurstState> ON | OFF

*RST: OFF

PGENerator:PATTern:BURSt:NCYCle <PatternCycles>

Defines the BURST pattern cycles. The cycles can be only defined with activated BURST function.

Parameters:

<PatternCycles> Numeric value

Range: 1 to 4096
*RST: 1

PGENerator:PATTern:TRIGger:MODE <TriggerMode>

Defines the arbitrary trigger mode of the pattern generator function.

Parameters:
<TriggerMode> CONTinuous | SINGle

CONTinuous
The CONT function (continuous trigger) issues the pattern continuously.

SINGle
If the SING setting is activated, the pattern is issued manually.

*RST: CONT

PGENerator:PATTern:TRIGger:SINGle

Manual output of a pattern (single trigger).

Usage: Event

PGENerator:PATTern:TRIGger:EXTern:SLOPe

Defines the slope of the external arbitrary pattern trigger.

Parameters:
<ExternSlope> POSitive | NEGative | EITHer

POSitive
Rising edge (rise).

NEGative
Falling edge (fall).

EITHer
Rising as well as the falling edge (both).

*RST: POSitive

PGENerator:PATTern:ARBitrary:DATA[:SET] <ArbitraryData>

Defines the arbitrary pattern.

Parameters:
<ArbitraryData> List of Values

Example: PGEN:PATT:ARB:DATA 0,1,1,1,2,0,3,1,4,0

PGENerator:PATTern:ARBitrary:DATA:APPend <AppendData>

Defines the arbitrary pattern.

Setting parameters:
<AppendData> List of Values

Example: PGEN:PATT:ARB:DATA:APP 4
From index = n, the oscilloscope appends a 4 in HEX to the pattern.

Usage: Setting only

PGENerator:PATTern:ARBitrary:DATA:APPend:BOR <AppendData>

From index = n, data will be integrated in existing pattern via OR combination.

Setting parameters:
<AppendData> List of Values

Usage: Setting only

PGENerator:PATTern:ARBitrary:DATA:APPend:BAND <AppendData>

From index = n, data will be integrated in existing pattern via AND combination.

Setting parameters:
<AppendData> List of Values

Usage: Setting only

PGENerator:PATTern:ARBitrary:DATA:APPend:INDex <AppendIndex>

Defines the index of the arbitrary pattern.

Parameters:
<AppendIndex> Numeric value

Example: PGEN:PATT:ARB:DATA:APP:IND 5
PGEN:PATT:ARB:DATA:APP 4
From index = n, a pattern length of 6 will be defined with last high bit 4.

PGENerator:PATTern:ARBitrary:DATA:LENGth <PatternLength>

Defines the arbitrary pattern length.

Parameters:
<PatternLength> Numeric value

Range: 1 to 2048
*RST: 1

PGENerator:PATTern:COUNter:FREQuency <Period>

Defines the frequency value of the pattern generator counter function. The user frequency always refers to the switching of the pattern condition. This results in square waveforms for individual pins.

Pin	Frequency
S0	f/2
S1	f/4
S2	f/8
S3	f/16

Parameters:
<Period> Numeric value

Range: 2.380952425301E-02 to 2.500000000000E+07
*RST: 1.000000000000E+05
Default unit: Hz

PGENerator:PATTern:COUNter:DIRection <CountDirection>

Sets the pattern generator counter direction.

Parameters:
<CountDirection> UPWard | DOWNward

*RST: UPW

PGENerator:PATTern:SQUarewave:POLarity <Polarity>

Defines the polarity of the pattern generator square wave function.

Parameters:
<Polarity> NORMal | INVerted

*RST: NORM

PGENerator:PATTern:SQUarewave:DCYCle <DutyCycle>

Sets the duty cycle of the square wave function.

Parameters:
<DutyCycle> Numeric value

Range: 1.00E+00 to 9.900E+01
*RST: 5.000E+01
Default unit: %

Example: PGEN:PATT:SQU:DCYC 20
Sets the duty cycle of the square wave function to 20%.

PGENerator:MANual:STATe<s> <State>

Selects the pins S0 to S3 manually and sets their states to high (H) or low (L).

Suffix:

<s> 0..3
Pins S0 to S3

Parameters:

<State> ON | OFF

ON
Pin state is set to high (H).

OFF
Pin state is set to low (L).

*RST: OFF

Example: PGEN:MAN:STAT2 ON
Sets the state of pin S2 to high (H).

11 Maintenance

The instrument does not need a periodic maintenance. Only the cleaning of the instrument is essential.

To protect the front panel and to transport the instrument to another workplace safely and easily, several accessories are provided. The type designations and order numbers are listed in the data sheet.

In case of instrument damage, contact the nearest Rohde & Schwarz service center. A list of all service centers is available on www.services.rohde-schwarz.com.

The addresses of Rohde & Schwarz support centers can be found at www.customer-support.rohde-schwarz.com.

11.1 Cleaning

The outside of the instrument can be cleaned sufficiently using a soft, lint-free dust cloth. Make sure that the fan openings are not obstructed.

⚠ WARNING

Shock hazard

Before cleaning the instrument, make sure that the instrument is switched off and disconnected from all power supplies.

NOTICE

Instrument damage caused by cleaning agents

Cleaning agents contain substances that may damage the instrument. For example, cleaning agents that contain a solvent may damage the front panel labeling, plastic parts, or the display.

Never use cleaning agents such as solvents (thinners, acetone, etc), acids, bases, or other substances.

The outside of the instrument can be cleaned sufficiently using a soft, lint-free dust cloth.

NOTICE

Risk of instrument damage due to obstructed fans

If the instrument is operated in dusty areas, the fans may become obstructed by dust or other particles in the process of time. Make sure to check and, if necessary, clean the fans regularly to ensure they operate properly at all times. If the instrument is run with obstructed fans for a longer period, it may become overheated which may cause damage.

11.2 Storing and Packing

The storage temperature range of the instrument is given in the data sheet. If the instrument is to be stored for a longer period of time, it must be protected against dust.

Repack the instrument as it was originally packed when transporting or shipping. The two protective foam plastic parts prevent the control elements and connectors from being damaged. The antistatic packing foil avoids any undesired electrostatic charging to occur.

If you do not use the original packaging, use a sturdy cardboard box of suitable size and provide for sufficient padding to prevent the instrument from slipping inside the package. Wrap antistatic packing foil around the instrument to protect it from electrostatic charging.

11.3 Replacing the Fuses

The instrument is protected by a fuse. You can find it on the rear panel between the main power switch and AC power supply.

Type of fuse: Size 5x20 mm, 250V~, T2.5H (slow-blow), IEC60127-2/5

WARNING

Shock hazard

Before replacing a fuse, make sure that the instrument is switched off and disconnected from all power supplies. Always use fuses supplied by Rohde & Schwarz as spare parts, or fuses of the same type and rating.

1. Pull the fuse holder out of its slot on the rear panel.
2. Exchange the fuse.
3. Insert the fuse holder carefully back in its slot until it latches.

11.4 Data Security

If you have to send the instrument to the service, or if the instrument is used in a secured environment, consider the document "Instrument Security Procedures" that is available on the R&S RTB2000 internet web page.

You can delete all current instrument configuration data and user data with "Setup" menu > "Secure Erase".

Annex

A SCPI Command Structure

SCPI commands consist of a header and, in most cases, one or more parameters. The header and the parameters are separated by a "white space" (ASCII code 0 to 9, 11 to 32 decimal, e.g. blank). The headers may consist of several mnemonics (keywords). Queries are formed by appending a question mark directly to the header.

The commands can be either device-specific or device-independent (common commands). Common and device-specific commands differ in their syntax.

A.1 Syntax for Common Commands

Common (= device-independent) commands consist of a header preceded by an asterisk (*), and possibly one or more parameters.

Table A-1: Examples of common commands

*RST	RESET	Resets the instrument.
*ESE	EVENT STATUS ENABLE	Sets the bits of the event status enable registers.
*ESR?	EVENT STATUS QUERY	Queries the contents of the event status register.
*IDN?	IDENTIFICATION QUERY	Queries the instrument identification string.

A.2 Syntax for Device-Specific Commands

Not all commands used in the following examples are necessarily implemented in the instrument. For demonstration purposes only, assume the existence of the following commands for this section:

- `DISPlay[:WINDow<1...4>]:MAXimize <Boolean>`
- `FORMat:READings:DATA <type>[,<length>]`
- `HCOPy:DEVice:COLor <Boolean>`
- `HCOPy:DEVice:CMAP:COLor:RGB <red>,<green>,<blue>`
- `HCOPy[:IMMediate]`
- `HCOPy:ITEM:ALL`
- `HCOPy:ITEM:LABel <string>`
- `HCOPy:PAGE:DIMensions:QUADrant[<N>]`
- `HCOPy:PAGE:ORIentation LANDscape | PORTrait`
- `HCOPy:PAGE:SCALe <numeric value>`
- `MMEMory:COPY <file_source>,<file_destination>`
- `SENSE:BANDwidth|BWIDth[:RESolution] <numeric_value>`
- `SENSe:FREQuency:STOP <numeric value>`
- `SENSe:LIST:FREQuency <numeric_value>{,<numeric_value>}`

A.2.1 Long and short form

The mnemonics feature a long form and a short form. The short form is marked by upper case letters, the long form corresponds to the complete word. Either the short form or the long form can be entered; other abbreviations are not permitted.

Example:

`HCOPy:DEVice:COLor ON` is equivalent to `HCOP:DEV:COL ON`.

Case-insensitivity

Upper case and lower case notation only serves to distinguish the two forms in the manual, the instrument itself is case-insensitive.

A.2.2 Numeric Suffixes

If a command can be applied to multiple instances of an object, e.g. specific channels or sources, the required instances can be specified by a suffix added to the command. Numeric suffixes are indicated by angular brackets (<1...4>, <n>, <i>) and are replaced by a single value in the command. Entries without a suffix are interpreted as having the suffix 1.

Example:

Definition: `HCOPy:PAGE:DIMensions:QUADrant[<N>]`

Command: `HCOP:PAGE:DIM:QUAD2`

This command refers to the quadrant 2.

Different numbering in remote control

For remote control, the suffix may differ from the number of the corresponding selection used in manual operation. SCPI prescribes that suffix counting starts with 1. Suffix 1 is the default state and used when no specific suffix is specified.

Some standards define a fixed numbering, starting with 0. If the numbering differs in manual operation and remote control, it is indicated for the corresponding command.

A.2.3 Optional Mnemonics

Some command systems permit certain mnemonics to be inserted into the header or omitted. These mnemonics are marked by square brackets in the description. The instrument must recognize the long command to comply with the SCPI standard. Some commands are considerably shortened by these optional mnemonics.

Example:

Definition: `HCOPy[:IMMediate]`

Command: `HCOP:IMM` is equivalent to `HCOP`

Optional mnemonics with numeric suffixes

Do not omit an optional mnemonic if it includes a numeric suffix that is relevant for the effect of the command.

Example:

Definition:`DISPlay[:WINDow<1...4>]:MAXimize <Boolean>`

Command: `DISP:MAX ON` refers to window 1.

In order to refer to a window other than 1, you must include the optional `WINDow` parameter with the suffix for the required window.

`DISP:WIND2:MAX ON` refers to window 2.

A.3 SCPI Parameters

Many commands are supplemented by a parameter or a list of parameters. The parameters must be separated from the header by a "white space" (ASCII code 0 to 9, 11 to 32 decimal, e.g. blank).

The parameters required for each command and the allowed range of values are specified in the command description.

Allowed parameters are:

A.3.1 Numeric Values

Numeric values can be entered in any form, i.e. with sign, decimal point and exponent. Values exceeding the resolution of the instrument are rounded up or down. The mantissa may comprise up to 255 characters, the exponent must lie inside the value range -32000 to 32000. The exponent is introduced by an "E" or "e". Entry of the exponent alone is not allowed.

Example:

`SENS:FREQ:STOP 1500000` = `SENS:FREQ:STOP 1.5E6`

Units

For physical quantities, the unit can be entered. If the unit is missing, the basic unit is used. Allowed unit prefixes are:

- G (giga)
- MA (mega), MOHM, MHZ
- K (kilo)
- M (milli)
- U (micro)
- N (nano)

Example:

`SENSe:FREQ:STOP 1.5GHz` = `SENSe:FREQ:STOP 1.5E9`

Some settings allow relative values to be stated in percent. According to SCPI, this unit is represented by the `PCT` string.

Example:

`HCOP:PAGE:SCAL 90PCT`

A.3.2 Special Numeric Values

The following mnemonics are special numeric values. In the response to a query, the numeric value is provided.

- **MIN and MAX**: denote the minimum and maximum value.
- **DEF**: denotes a preset value which has been stored in the EPROM. This value conforms to the default setting, as it is called by the *RST command.
- **NAN**: Not A Number (NAN) represents the value 9.91E37. NAN is only sent as a instrument response. This value is not defined. Possible causes are the division of zero by zero, the subtraction of infinite from infinite and the representation of missing values.

Example:

Setting command: `SENSe:LIST:FREQ MAXimum`

Query: `SENS:LIST:FREQ?`

Response: `3.5E9`

Queries for special numeric values

The numeric values associated to `MAXimum/MINimum/DEFault` can be queried by adding the corresponding mnemonic after the quotation mark.

Example: `SENSe:LIST:FREQ? MAXimum`

Returns the maximum numeric value as a result.

A.3.3 Boolean Parameters

Boolean parameters represent two states. The "ON" state (logically true) is represented by "ON" or a numeric value 1. The "OFF" state (logically untrue) is represented by "OFF" or the numeric value 0. The numeric values are provided as the response for a query.

Example:

Setting command: `HCOPy:DEV:COL ON`

Query: `HCOPy:DEV:COL?`

Response: `1`

A.3.4 Text Parameters

Text parameters observe the syntactic rules for mnemonics, i.e. they can be entered using a short or long form. Like any parameter, they have to be separated from the header by a white space. In the response to a query, the short form of the text is provided.

Example:

Setting command: `HCOPy:PAGE:ORIentation LANDscape`

Query: `HCOP:PAGE:ORI?`

Response: `LAND`

A.3.5 Character Strings

Strings must always be entered in quotation marks (' or ").

Example:

`HCOP:ITEM:LABel "Test1"`

`HCOP:ITEM:LABel 'Test1'`

A.3.6 Block Data

Block data is a format which is suitable for the transmission of large amounts of data. For example, a command using a block data parameter has the following structure:

`FORMat:READings:DATA #45168xxxxxxxx`

The ASCII character # introduces the data block. The next number indicates how many of the following digits describe the length of the data block. In the example the 4 following digits indicate the length to be 5168 bytes. The data bytes follow. During the transmission of these data bytes all end or other control signs are ignored until all bytes are transmitted.

#0 specifies a data block of indefinite length. The use of the indefinite format requires a `NL^END` message to terminate the data block. This format is useful when the length of the transmission is not known or if speed or other considerations prevent segmentation of the data into blocks of definite length.

A.4 Overview of Syntax Elements

The following tables provide an overview of the syntax elements and special characters.

Table A-2: Syntax elements

:	The colon separates the mnemonics of a command.
;	The semicolon separates two commands of a command line. It does not alter the path.
,	The comma separates several parameters of a command.
?	The question mark forms a query.

*	The asterisk marks a common command.
' ' "	Quotation marks introduce a string and terminate it (both single and double quotation marks are possible).
#	The hash symbol introduces binary, octal, hexadecimal and block data. ● Binary: #B10110 ● Octal: #O7612 ● Hexa: #HF3A7 ● Block: #21312
	A "white space" (ASCII-Code 0 to 9, 11 to 32 decimal, e.g. blank) separates the header from the parameters.

Table A-3: Special characters

|	**Parameters**
	A vertical stroke in parameter definitions indicates alternative possibilities in the sense of "or". The effect of the command differs, depending on which parameter is used.
	Example:
	Definition:`HCOPy:PAGE:ORIentation LANDscape | PORTrait`
	Command `HCOP:PAGE:ORI LAND` specifies landscape orientation
	Command `HCOP:PAGE:ORI PORT` specifies portrait orientation
	Mnemonics
	A selection of mnemonics with an identical effect exists for several commands. These mnemonics are indicated in the same line; they are separated by a vertical stroke. Only one of these mnemonics needs to be included in the header of the command. The effect of the command is independent of which of the mnemonics is used.
	Example:
	Definition`SENSE:BANDwidth|BWIDth[:RESolution] <numeric_value>`
	The two following commands with identical meaning can be created:
	`SENS:BAND:RES 1`
	`SENS:BWID:RES 1`

[ ]	Mnemonics in square brackets are optional and may be inserted into the header or omitted. Example: `HCOPy[:IMMediate]` `HCOP:IMM` is equivalent to `HCOP`

{ }	Parameters in curly brackets are optional and can be inserted once or several times, or omitted.
	Example: `SENSe:LIST:FREQuency <numeric_value>{,<numeric_value>}`
	The following are valid commands:
	`SENS:LIST:FREQ 10`
	`SENS:LIST:FREQ 10,20`
	`SENS:LIST:FREQ 10,20,30,40`

A.5 Structure of a Command Line

A command line may consist of one or several commands. It is terminated by one of the following:

- <New Line>

- <New Line> with EOI
- EOI together with the last data byte

Several commands in a command line must be separated by a semicolon ";".

Example:

`MMEM:COPY "Test1","MeasurementXY";:HCOP:ITEM ALL`

This command line contains two commands. The first command belongs to the MMEM system, the second command belongs to the HCOP system. If the next command belongs to a different command system, the semicolon is followed by a colon.

Example:

`HCOP:ITEM ALL;:HCOP:IMM`

This command line contains two commands. Both commands are part of the `HCOP` command system, i.e. they have one level in common.

If the successive commands belong to the same system, having one or several levels in common, the command line can be abbreviated. When abbreviating the command line, the second command begins with the level below HCOP. The colon after the semicolon is omitted. The abbreviated form of the command line reads as follows:

`HCOP:ITEM ALL;IMM`

Example:

`HCOP:ITEM ALL`

`HCOP:IMM`

A new command line always begins with the complete path.

A.6 Responses to Queries

A query is defined for each setting command unless explicitly specified otherwise. It is formed by adding a question mark to the associated setting command. According to SCPI, the responses to queries are partly subject to stricter rules than in standard IEEE 488.2.

- The requested parameter is transmitted without a header.
  Example: `HCOP:PAGE:ORI?`, Response: `LAND`
- Maximum values, minimum values and all other quantities that are requested via a special text parameter are returned as numeric values.
  Example: `SENSe:FREQuency:STOP? MAX`, Response: `3.5E9`
- Numeric values are output without a unit. Physical quantities are referred to the basic units or to the units set using the `Unit` command. The response `3.5E9` in the previous example stands for 3.5 GHz.
- Truth values (Boolean values) are returned as `0` (for OFF) and `1` (for ON).
  Example:
  Setting command: `HCOPy:DEV:COL ON`
  Query: `HCOPy:DEV:COL?`

Response: `1`

- Text (character data) is returned in a short form.
  Example:
  Setting command: `HCOPy:PAGE:ORIentation LANDscape`
  Query: `HCOP:PAGE:ORI?`
  Response: `LAND`
- Invalid numerical results
  In some cases, particularly when a result consists of multiple numeric values, invalid values are returned as 9.91E37 (not a number).

B Command Sequence and Synchronization

IEEE 488.2 defines a distinction between overlapped (asynchronous) and sequential commands:

- A sequential command finishes executing before the next command starts executing. Commands that are processed quickly are usually implemented as sequential commands.
- An overlapping or asynchronous command does not automatically finish executing before the next command starts executing. Usually, overlapping commands take longer to process and allow the program to do other tasks while being executed. If overlapping commands must be executed in a defined order, e.g. to avoid wrong measurement results, they must be serviced sequentially. This method is called synchronization between the controller and the instrument.

As a rule, send commands and queries in different program messages, i.e. in separate command lines.

Do not combine queries with commands that affect the queried value in one program message because the response to the query is not predictable.

The following messages always return correct results:

`:CHAN:SCAL 0.01;POS 1`

`:CHAN:SCAL?`

Result: `0.01` (10 mV/div)

Reason: Setting commands within one command line, even though they are implemented as sequential commands, are not necessarily serviced in the order in which they have been received.

For further information, refer to:

- rohde-schwarz.com/rckb: Rohde & Schwarz web page that provides information on instrument drivers and remote control.
- "Automatic Measurement Control - A tutorial on SCPI and IEEE 488.2" from John M. Pieper (R&S order number 0002.3536.00). The book offers detailed information on concepts and definitions of SCPI.

B.1 Preventing Overlapping Execution

To prevent an overlapping execution of commands, one of the commands `*OPC`, `*OPC?` or `*WAI` can be used. All three commands cause a certain action only to be carried out after the hardware has been set. The controller can be forced to wait for the corresponding action to occur.

*Table B-1: Synchronization using *OPC, *OPC? and *WAI*

Com-mand	Action	Programming the controller
*OPC	Sets the Operation Complete bit in the ESR after all previous commands have been executed.	• Setting bit 0 in the ESE • Setting bit 5 in the SRE • Waiting for service request (SRQ)
*OPC?	Stops command processing until 1 is returned. This occurs when all pending operations are completed.	Send *OPC? directly after the command whose processing must be terminated before other commands can be executed.
*WAI	Stops further command processing until all commands sent before *WAI have been executed.	Send *WAI directly after the command whose processing must be terminated before other commands are executed.

Command synchronization using `*WAI` or `*OPC?` is a good choice if the overlapped command takes only little time to process. The two synchronization commands simply block overlapped execution of the command. Append the synchronization command to the overlapping command, for example:

```
SINGle; *OPC?
```

For time consuming overlapped commands, you can allow the controller or the instrument to do other useful work while waiting for command execution. Use one of the following methods:

*OPC with a service request

1. Set the OPC mask bit (bit no. 0) in the ESE: *ESE 1
2. Set bit no. 5 in the SRE: `*SRE 32` to enable ESB service request.
3. Send the overlapped command with `*OPC` .
4. Wait for a service request.

   The service request indicates that the overlapped command has finished.

*OPC? with a service request

1. Set bit no. 4 in the SRE: `*SRE 16` to enable MAV service request.
2. Send the overlapped command with `*OPC?`.
3. Wait for a service request.

   The service request indicates that the overlapped command has finished.

Event status register (ESE)

1. Set the OPC mask bit (bit no. 0) in the ESE: `*ESE 1`
2. Send the overlapped command without `*OPC`, `*OPC?` or `*WAI`.
3. Poll the operation complete state periodically (with a timer) using the sequence: `*OPC; *ESR?`

   A return value (LSB) of 1 indicates that the overlapped command has finished.

List of Commands