

## Operating Instructions for the **TMS9000 Torque Measurement**

*Rev D: Nov. 2006*

**008-0688-00**

## Intended Use

Rotating torque sensors are intended for use between a power source and its load. They may be used to measure the power output of a drive (such as an electric motor or gasoline engine)

and a suitable load. They are also used to measure the torque required to operate a given load.

## Operating Principles

### Torque Sensor

Lebow Torque Sensors are designed structures that perform in a predictable and repeatable manner when a torque is applied. This torque is translated into a signal voltage by the resistance change of strain gages, which are attached to the torque sensor structure. The change in resistance indicates the degree of deformation, and in turn, the torque on the structure.

The strain gages are connected in a 4 arm Wheatstone Bridge configuration which acts as an adding and subtracting electrical network and allows compensation for temperature effects as well as cancellation of signals caused by extraneous loading.

When the torque sensor is rotating, a means must be provided to transfer an excitation voltage to the rotational element from a stationary surface, and also to transfer the torque signal from the rotational element back to the stationary surface. This is accomplished through the use of digital telemetry.

### Principle of Telemetry

The digital telemetry system consists of a receiver-transmitter module, a caliper-style

coupling module, and a signal processing module.

The receiver-transmitter module is an integral part of the torque sensor and is connected to the strain gauges and to the epoxy glass annular printed circuit board that contains the rotating antenna system. Within the receiver-transmitter module, the sensor signals are amplified, digitized, and are then used to modulate the radio frequency carrier wave that is detected by the antenna after being transmitted across the air gap by the caliper coupling module. That same carrier wave is rectified to provide power to drive the strain gauges and the electronic components in the module, which is managed by a miniature microprocessor.

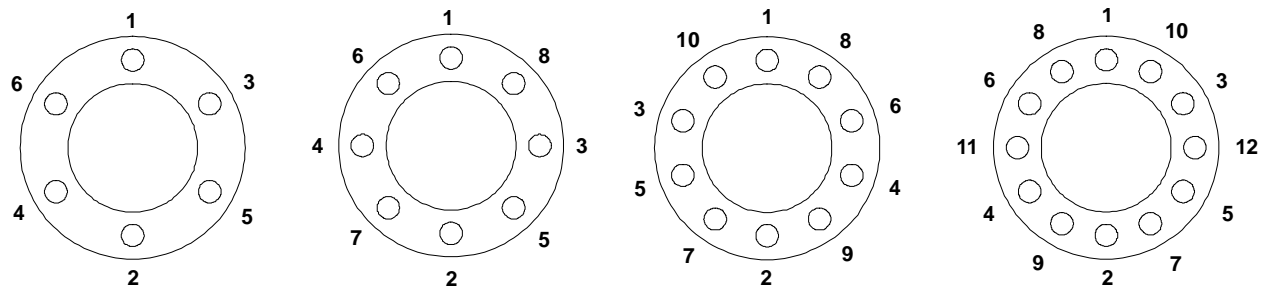
The caliper coupling module connects to the signal processing module via a simple co-axial cable. The detector circuitry in the signal processing module recovers the digital measurement data from the torque sensor and passes it to the second microprocessor for scaling and linearizing.

The third microprocessor provides the drive to the two analog outputs, as well as the standard digital interfaces and the optional digital interface modules. Extensive facilities are provided in software for setup and configuration of the complete system.

## Bolting Information

Tighten all bolts, in incremental steps, to the bolt manufacturers rated torque specification. Use the respective sequence illustration shown

below depending on the number of bolts the sensor requires. This bolting sequence applies to both bolt circles of the torque sensor.



## Installation and Set-up

### Torque Sensor

The TMS 9000 series torque sensors may be operated horizontally, vertically, or any angle in between provided the load is applied through the loading axis.

All torque sensors in this series have bolt patterns that mate directly to standard industrial couplings. When mounted, one of the flanges should be mated to a good quality double flex coupling or a driveshaft arrangement that incorporates universal joints at each end. This is designed to compensate for angular and parallel misalignment.

Avoid applications that place extraneous loads on the torque sensor.

### Caliper Coupling Module

The caliper coupling module must be firmly mounted to a non-rotating support structure. It must be aligned with the epoxy glass annular printed circuit board antenna so that the air gap between the caliper and the antenna is approximately equal on both sides. Care should be taken to avoid any items touching one another, and consideration should be given to the effects of vibration as well as the free play in any driveshaft sliding joints.

To assist in the process of aligning the caliper and the antenna, a simple plastic alignment tool is provided with each system. The tool is used to hold the required clearance between the caliper and the antenna while the caliper fixing bolts are being tightened, and then is removed before the sensor is rotated.

The tolerances for end-float (axial) are +/- 4.5mm (+/- 3/16") and for run-out (radial) are +/- 1.0mm (+/- 1/16"). For installations where run-out cannot be controlled within the specified tolerance, the secondary coupling position can be used. This is achieved by placing the edge of the caliper in close proximity to the edge of the antenna. In this position, the run-out tolerance can be at least doubled, at the expense of a reduced signal to noise ratio caused by the higher incidence of data drop outs. The axial

tolerance is limited by the distance between the caliper sections.

The caliper can also be mounted such that only one side is in proximity to the antenna, if the mounting arrangement does not allow for placing of the antenna between the two sides of the caliper.

Successful positioning of the caliper can be confirmed by the presence of the ROTOR ACTIVE light on the signal processing module.

The length of the RF cable connection between the caliper coupling module and the signal processing module is critical to system performance (due to reflections and standing waves). When using RG58 50-ohm cable, the length must be maintained at 13.9 metres (45'6" feet) or a multiple thereof. When using Belden 89907 cable, length must be maintained at 17.6 metres (57 feet) or a multiple thereof. For cable runs of less than 0.6 metre (2 feet), the cable that is provided with the unit can be cut to the required length. Otherwise, simply coil up any excess length.

### Signal Processing Module

The receiver is mounted remotely with the coaxial cable being the only connection between it and the caliper coupling module. The receiver has holes provided for permanent mounting. Request the appropriate certified drawing from Lebow before making fixtures.

When deciding where to locate the signal processing module, consideration should be given to the type of output that will be used. If the analog voltage or current output is to be used, then the signal processing module should be mounted in an area of low electrical noise and the connection between the module and the data acquisition equipment should be as short as possible and should be made up from double screened twisted pair cable. If the frequency output or the digital output is to be used, then the signal processing module can be mounted in the electrically noisy area provided that good quality dual screened twisted pair cables are used.

## Electrical Connections

The signal processing module features two-part plug and socket connectors and the connection details are shown in Figure 2.

All cable connections should pass through the cable glands, which when properly assembled, provide adequate sealing to allow the module to

be operated in NEMA4 or IP65 environmental conditions (occasional water splash). The RF connection is made via the standard BNC connector, and IP65 rated cable assemblies can be supplied upon request.

Figure 2

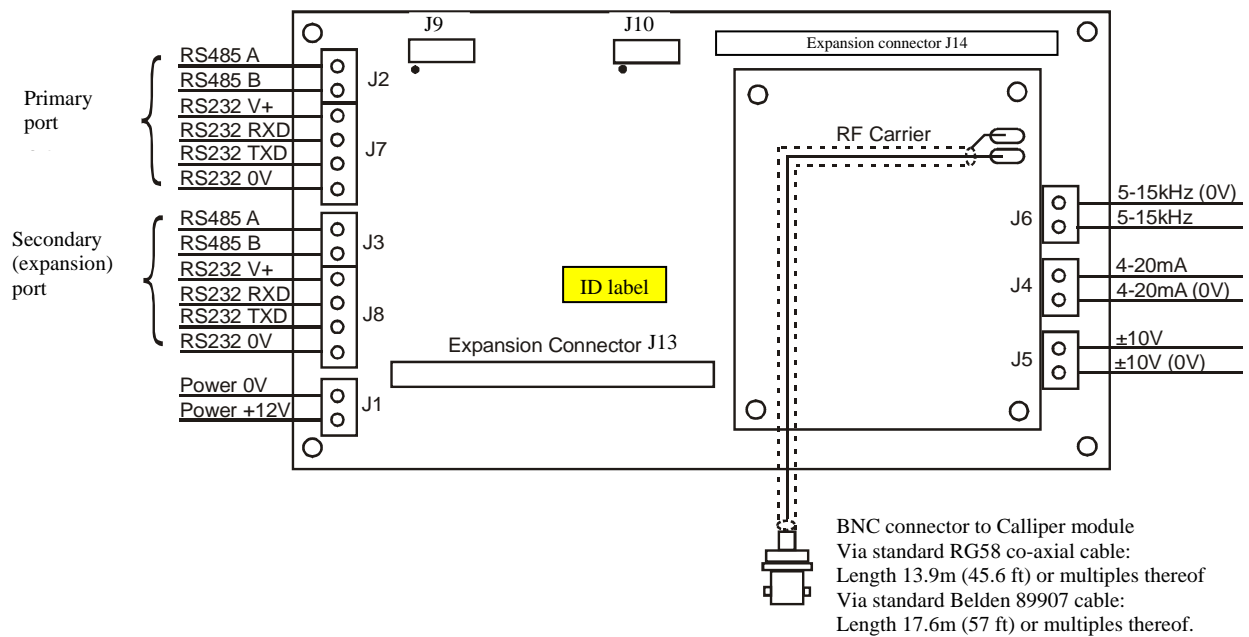


TABLE 1: Connector and Jumper Functions

Connector	Function
J1	DC Power 12 V
J2	Primary RS485 port
J3	Secondary RS485 port
J4	Current loop output
J5	Voltage output
J6	Frequency output
J7	Primary RS232 port <b>NOTE - THIS IS THE DEFAULT COMMUNICATIONS PORT</b>
J8	Secondary RS232 port
J9	Factory use only
J10	Factory use only
J11	
J12	
J13	Expansion port
J14	Memory expansion port
JP1	Primary RS232/RS485 default select
JP2	Secondary RS232/RS485 default select
JP3	
JP4	

## Command Set

Below is the list of parameters supported by the TMS 9000 (corresponding to firmware version v1.38) :

Parameter Name	Description	Data Type										
#A	Mode reporting access used by TMS Toolkit software to extract parameter information from the device.	Read only										
#AnOutHigh	Sets or returns the value in engineering units applied to the input that will give 100% (maximum positive full scale) output on the analog outputs. To invert the output polarity, enter the required negative full scale output value.	Read/write										
#AnOutLow	Sets or returns the value in engineering units applied to the input that will give 0% (minimum negative full scale) output on the analog outputs. To invert the output polarity, enter the required positive full scale output value.	Read/write										
AuxBaud	Not yet supported.	Read/write										
AuxOPType	Not yet supported.	Read/write										
BaudRate	Not yet supported.	Read only										
*CalCnts1- *CalCnts9	Internal calibration data. This is read only via TMS Toolkit and is viewable only in "CAL" level access. These parameters are exposed to enable the saving and loading of calibration data only.	Read only										
#CalPoints	Sets the number of calibration points in use. Value must be between 2 and 9. Any change in #CalPoints should be followed by a #CalReset command to clear the previous unwanted calibration data from the memories.  <b>NOTE</b> – all calibration data and all analog output setting data will be cleared by #CalReset. It is recommended to save the parameter list before invoking #CalReset.	Read/write										
#CalReset	Resets all calibration information. When the reset command is issued, all calibration data and all settings of the analog outputs (#AnOutHigh and #AnOutLow) are cleared so no reliable output will be available until all of the calibration points specified by the #CalPoints parameter and the required values of #AnOutHigh and #AnOutLow have been entered.  <b>NOTE</b> – all calibration data and all analog output setting data will be cleared by #CalReset. It is recommended to save the parameter list before invoking #CalReset.	Command										
#CalValue1 to #CalValue9	These values are written in engineering units when the appropriate load is applied. Each of the nine parameters can be written at any time. See Calibration section later in this document. <b>NOTE</b> – the values entered <b>MUST</b> be in ascending order, starting with #CalValue1 (negative values count as lower than positive values). The number of calibration points entered must be equal to the number of calibration points activated by #CalPoints.  <b>NOTE</b> – the existing calibration data is overwritten by any new input of #CalValue1-9. It is recommended to save the parameter list before entering new values.	Read/write										
#Counts	Returns the raw A-D counts value derived from the ADC on the rotating sensor.	Read only										
ErrFlag	The ErrFlag parameter will indicate any errors that have occurred by returning a numeric value that is comprised of binary values representing the various error states. i.e. the binary values for each error are added together to produce the ErrFlag value. The error states are not retained between power cycles.  <table border="0"> <thead> <tr> <th>Decimal Value</th> <th>Error Description</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>No error.</td> </tr> <tr> <td>1</td> <td>Power cycled.</td> </tr> <tr> <td>2</td> <td>Output clamped.</td> </tr> <tr> <td>4</td> <td>Watchdog reset.</td> </tr> </tbody> </table> Once the errors have been read they can be reset using the RstErrFlag command.	Decimal Value	Error Description	0	No error.	1	Power cycled.	2	Output clamped.	4	Watchdog reset.	Read only
Decimal Value	Error Description											
0	No error.											
1	Power cycled.											
2	Output clamped.											
4	Watchdog reset.											
#FastMode	Used to initiate raw throughput of data without scaling or filtering. Set this parameter to 1 to enable fast mode. This setting is volatile so the device will revert to normal mode after the next Reset or the next power-up. Set to zero to disable fast mode. When in fast mode, the internal raw A-D counts results are fed directly to the analog output (voltage or current) without any scaling or filtering, giving a data throughput rate of 8.8 kHz (when FiltLevel=1). <b>NOTE</b> - the frequency output is not supported in fast mode. The fast mode can be scaled in the user's data acquisition system by using the shunt cal facility, and is intended to be used for dynamic measurements only.	Read/write										

<b>FiltLevel</b>	Used to set the threshold of operation of the digital filter. Values are set as parts per 10000, meaning that to set a threshold of 10% of the sensor rated capacity, then <b>FiltLevel</b> =1000 For a % step change in input, which is greater than ( <b>FiltLevel</b> / 10000 * 100%), the new input value will be passed immediately to the output. For a step change in input, which is below the threshold set by <b>FiltLevel</b> , the output is filtered according to the setting of <b>FiltSteps</b> .  <b>NOTE</b> – when <b>FiltLevel</b> is set to 0 or 1, digital filtering is disabled. Factory default value is 100, representing a threshold of 1% of sensor rated capacity (refer to the factory calibration data sheet or the rating plate attached to the sensor to confirm the rated capacity)	Read/write
<b>FiltSteps</b>	Used to set the response time of the digital filter. Used in conjunction with <b>FiltLevel</b> to control the digital filtering behavior. Value range is 1 through 1000. Filtering takes the form of an RC equivalent where a change in input value, which is greater than the threshold set by <b>FiltLevel</b> , causes the output value to be incremented in the number of steps set by <b>FiltSteps</b> . The filter refresh rate is 1200 Hz. Factory default setting is 10, which in conjunction with the factory default setting of <b>FiltLevel</b> =100 provides for an output increment in the form of (x/2, x/3, x/4, x/5, x/6 ... x/10) where x=step change in input of more than (( <b>FiltLevel</b> /10000)*rated capacity). Given the filter update rate of 1200 Hz, the settling time to 63% final value will be 8.3 ms (Update rate divided by <b>FiltSteps</b> ) and to 1% final value will be 41.7 ms (Update rate divided by <b>FiltSteps</b> x 5). The settling time to 0.1% final value will be 58.3 ms (Update rate divided by <b>FiltSteps</b> x 7).	Read/write
<b>#M</b>	Mode reporting access used by TMS Toolkit software to extract parameter information from the device.	Read only
<b>Model</b>	Returns the model name (TMS)	Read only string
<b>OpType</b>	Sets or returns the currently selected analog output where 0=current; 1=voltage; 2=frequency 10 kHz; 3=frequency 60 kHz, 4=current and frequency 10 kHz, 5=voltage and frequency 10 kHz, 6=current and frequency 60 kHz, 7=voltage and frequency 60 kHz.	Read/write
<b>ParaCnt</b>	Returns the number of parameters in the device.	Read
<b>Paraltem</b>	Set to the index number of the required parameter.	Write
<b>ParaList</b>	Returns the information on the parameter indexed by <b>Paraltem</b> . Format: ' <b>index,paramname,type</b> ' a string.  The value of <i>type</i> indicates the parameter's properties by the addition of the following numerical values:  1        Readable 2        Writeable 4        Command 32       String 64       Numeric 128      Boolean  Example: ' <b>1,MODEL,33</b> ' In the above example where <i>type</i> = 33 the parameter <i>MODEL</i> is a readable string.	Read string
<b>Percent</b>	Returns the value of the applied torque in percentage terms (0-100) where this range is the selected range over which the analog outputs work and is set by <b>#AnOutLow</b> and <b>#AnOutHigh</b> .	Read only
<b>Reset</b>	<b>Reset</b> command to restart device and to implement parameter changes that require a reset.	Command
<b>RstErrFlag</b>	Reset all error flags.	Command
<b>SysZero</b>	Allows manual setting of the current <b>Value</b> or querying of the current zero offset being applied. The returned value is the amount of zero offset being applied to the true <b>Value</b> . To zero the system, this parameter should be set in engineering units to the value read when the system is supposed to be displaying zero. The action of <b>SysZero</b> may be limited by <b>#ZeroLimit</b> as described above, in which case the flag <b>ZeroOK</b> will be set to 0. Note that when any calibration parameter ( <b>#CalValue1-9</b> , <b>#CalReset</b> ) is changed, the value of <b>SysZero</b> is set to 0 and any zero offset is cancelled. This function, when used with <b>#ZeroLimit</b> , allows the current <b>Value</b> to be offset to any desired level (remember to consider the dynamic loading range of the sensor itself when applying large offsets)	Read/write



# TMS 9000 Torque Measurement System

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<b>Units</b>	Text memo field in which the name of the engineering units used for calibration can be stored for recall later. Note that when reading some characters via a 7-segment display (TMS Toolkit uses a virtual 7-segment display), some characters such as M will not display correctly.	Read/Write
<b>Value</b>	Returns the value of the applied torque in calibrated engineering units.	Read only
<b>Version</b>	Returns the software version	Read only
<b>ZeroNow</b>	Sets the current <b>Value</b> to zero unless limited by <b>#ZeroLimit</b> as described above. The action performed by <b>ZeroNow</b> is to clear any previous zero offset then compare the true <b>Value</b> to <b>#ZeroLimit</b> , then, to the extent allowable by <b>#ZeroLimit</b> , write the true <b>Value</b> to <b>SysZero</b> , resulting in a new current <b>Value</b> of zero	Command
<b>ZeroOK</b>	Returns indication of 1 if the previous <b>ZeroNow</b> command was successful in setting the current <b>Value</b> to zero and returns 0 if the action was limited by <b>#ZeroLimit</b> .	Read only
<b>#ZeroLimit</b>	The limit in engineering units at which the <b>ZeroNow</b> command will be allowed to operate, relative to the computed <b>Value</b> at zero load that was stored during the calibration process. Therefore <b>#ZeroLimit</b> represents the maximum allowable difference between the "calibration" zero and the "current" zero. If the <b>ZeroNow</b> command is issued when the current <b>Value</b> is greater than <b>#ZeroLimit</b> , then the current <b>Value</b> will be moved to the extent allowed by <b>#ZeroLimit</b> and the flag <b>ZeroOK</b> will be set to 0. Factory setting is 50% of the calibrated range. Note that <b>#ZeroLimit</b> is a bipolar setting, so it will be applied to both directions (+ and -) around the calibration zero value.	Read/Write
<b>*ZeroPVal</b>	Internal system zero data. This is read only via TMS Toolkit and is viewable only in "CAL" level access. This parameter is exposed to enable the saving and loading of calibration and zero data.	Read only

## System Calibration

The TMS 9000 features nine-point linearization and all calibration is achieved using the following parameters:

#CalSteps  
#CalReset  
#CalValue1  
#CalValue2  
#CalValue3  
#CalValue4  
#CalValue5  
#CalValue6  
#CalValue7  
#CalValue8  
#CalValue9

The minimum number of calibration points is 2. Calibration points can be created in any order provided that the values they contain are in ascending order starting with #CalValue1. Therefore, the lowest or the most negative (counter-clockwise) calibration point should be designated as #CalValue1.

The number of calibration points that are in use is set by the parameter "#CalPoints". Any change to the value of #CalPoints should be followed by the issuance of a "#CalReset" command, to clear the old calibration values from the EEPROM memories.

Calibration is achieved by applying known loads at each of the calibration points that are selected for use and then writing the engineering units value to the appropriate #CalValue<sub>x</sub> parameter.

The analog outs are precalibrated in the factory, so calibration of the input to the required output range is automatic and is dependent on the values entered for the parameters

#AnOutHigh  
#AnOutLow

#AnOutHigh and #AnOutLow are written-to using the engineering units value at which the analog outputs are required to give the maximum and minimum outputs.

Available analog outputs are :

Voltage range is -10 to +10 volts.  
Current output range is 4 to 20 mA.  
Frequency range is 5 kHz to 15 kHz or alternatively, 40 kHz to 80 kHz

Calibration Example:

To calibrate from -100 to +100 Nm in five steps of -100, -50, 0, +50 and +100 Nm:

- Set #CalSteps=5
- #CalReset
- Apply -100 Nm and set #CalValue1=-100,
- Apply -50 Nm and set #CalValue2=-50
- Apply 0 Nm and set #CalValue3=0
- Apply +50 Nm and set #CalValue4=50
- Apply 100 Nm and set #CalValue5=100
  
- To obtain a frequency output of 5 kHz at 10 Nm and 15 kHz at 80 Nm then the parameters would be #AnOutLow=10 and #AnOutHigh=80.

The device will then be fully calibrated.

Note that for best results and to conform to accepted calibration practice, the unit under test should be exercised three times at the full load in the direction of loading prior to the setting of calibration points. This is especially important when calibrating in both the clockwise and the counterclockwise directions. Please contact the factory for a detailed description of calibration practice and procedure.

If an alternative analog output is selected at a later date, or if different settings are chosen for the #AnOutHigh/Low parameters later, it is not necessary to repeat the loading calibration because all analog outputs are digitally driven.

## Troubleshooting

Problem	Possible Solutions
<p>“Power On” light is not showing</p>	<p>Check that 12VDC is being applied to the correct terminals (J1) and at the correct polarity.</p> <p>In certain cases, for example where the caliper coupling module has been left in direct contact with a metal surface for some time, the internal thermal protection circuit may have activated. To reset this condition, remove power and wait ten minutes before restoring power.</p>
<p>“Rotor Active” light is not showing</p>	<p>Check that the RF cable is in good condition and is of the correct length (look for damage to the outer sheath that may indicate that the cable has been crushed at some time).</p> <p>Check that the caliper coupling module has been correctly positioned in close proximity to the rotating antenna. Use the positioning guide that was supplied with the system to confirm the position. Move the caliper coupling module to try and achieve coupling in an alternative position.</p> <p>Check that there are no metal parts (flanges, covers, etc), within one and a half inches (40mm) of the caliper coupling surfaces.</p> <p>Check that the power supply is actually 12 VDC when the caliper coupling module is in the appropriate position (some power supplies have built-in protection circuits that cause a reduction in supply voltage when current demands increase).</p>
<p>Shunt calibration does not operate</p>	<p>Check that the “Rotor Active” light is showing, prior to using the shunt calibration function.</p> <p>Check that the RF cable is in good condition and is of the correct length (look for damage to the outer sheath that may indicate that the cable has been crushed at some time).</p> <p>Check that the caliper coupling module has been correctly positioned in close proximity to the rotating antenna. Use the positioning guide that was supplied with the system to confirm the position. Move the caliper coupling module to try and achieve coupling and shunt cal functionality in an alternative position.</p> <p>Check that there are no metal parts (flanges, covers, etc), within one and a half inches (40mm) of the caliper coupling surfaces.</p> <p>Check that the power supply is actually 12 VDC when the caliper coupling module is in the appropriate position (some power supplies have built-in protection circuits that cause a reduction in supply voltage when current demands increase).</p>
<p>Cannot communicate.</p>	<p>Check all wiring.</p> <p>If using the RS232 port, check that the Rx pin of the host computer is connected to the Tx pin of the TMS 9000 and vice versa.</p> <p>Check that the communications cable being used is of high quality or try a shorter length of cable (RS232 is sensitive to cable length and grounding issues, especially when used with laptop computers where grounding is uncertain).</p>

<p>Cannot communicate.</p>	<p>Check that the correct serial port is selected in the software or TMS Toolkit. When using Windows, the serial port in use can be found by using the CONTROL PANEL, SYSTEM, HARDWARE, DEVICE MANAGER, COM ports functions. On older desktop PC's, the COM1 port is already in use for the mouse, so a different COM port should be selected. If using a USB to Serial adapter, Windows assigns the COM port designations dynamically so they may change whenever the system is rebooted. The serial port settings are automatically modified by TMS Toolkit so there is no need to change any of the settings in Windows. The baud rate setting in TMS Toolkit should always be 38400 because that is the default baud rate of the TMS 9000. The "TMS ID" should be left blank because TMS Toolkit will search the connected port for any TMS device and will commence the communication automatically if present. Refer to the TMS Toolkit User Manual for more information</p>
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## Conversion Table

Imperial-Metric conversion

Foot-pounds	inch-pounds	Nm
1	12	1.35575
2	24	2.7115
3	36	4.0673
4	48	5.4230
5	60	6.7788
6	72	8.1345
7	84	9.4903
8	96	10.846
9	108	12.202
10	120	13.558
20	240	27.115
30	360	40.673
40	480	54.230
50	600	67.788
60	720	81.345
70	840	94.903
80	960	108.46
90	1080	122.02
100	1200	135.58
200	2400	271.15
300	3600	406.73
400	4800	542.30
500	6000	677.88
600	7200	813.45
700	8400	949.03
800	9600	1084.6
900	10800	1220.2
1000	12000	1355.8
2000	24000	2711.5
3000	36000	4067.3
4000	48000	5423.0
5000	60000	6778.8
6000	72000	8134.5
7000	84000	9490.3
8000	96000	10846
9000	108000	12202
10000	120000	13558
20000	240000	27115
30000	360000	40673
40000	480000	54230
50000	600000	67788
60000	720000	81345
70000	840000	94903
80000	960000	108460
90000	1080000	122018
100000	1200000	135575

Metric-Imperial conversion

Nm	inch-pounds	foot-pounds
1	8.85119	0.73760
2	17.702	1.4752
3	26.554	2.2128
4	35.405	2.9504
5	44.256	3.6880
6	53.107	4.4256
7	61.958	5.1632
8	70.810	5.9008
9	79.661	6.6384
10	88.512	7.3760
20	177.02	14.752
30	265.54	22.128
40	354.05	29.504
50	442.56	36.880
60	531.07	44.256
70	619.58	51.632
80	708.10	59.008
90	796.61	66.384
100	885.12	73.760
200	1770.2	147.52
300	2655.4	221.28
400	3540.5	295.04
500	4425.6	368.80
600	5310.7	442.56
700	6195.8	516.32
800	7081.0	590.08
900	7966.1	663.84
1000	8851.2	737.60
2000	17702	1475.2
3000	26554	2212.8
4000	35405	2950.4
5000	44256	3688.0
6000	53107	4425.6
7000	61958	5163.2
8000	70810	5900.8
9000	79661	6638.4
10000	88512	7376.0
20000	177024	14752
30000	265536	22128
40000	354048	29504
50000	442559	36880
60000	531071	44256
70000	619583	51632
80000	708095	59008
90000	796607	66384
100000	885119	73760

## Specifications - Electronics

**Power supply** 12 V DC +/- 10%, 0.75A  
9W maximum

**Protection** Reverse polarity connection or fault condition will trip the internal thermal fuse (self-resetting)

**Analog output signals:**

- 4-20 mA (zero torque = 12 mA)
- +/- 10 VDC (zero torque = 0 V)
- 10 kHz +/- 5 kHz (zero torque = 10 kHz)
- 60 kHz +/- 20 kHz (zero torque = 60 kHz)

**Output drive capability:**

- 4-20 mA 500 Ohms max
- +/- 10 VDC 2 k Ohms min
- Frequency 4.0 V p-p into 100 k Ohms min load 1k Ohms

**Digital resolution:**

- Normal mode 16-bit ( 0.01 %FS)
- Hi-res mode 19-bit (0.001 %FS)

RF carrier frequency 6.78 MHz

**Accuracy:**

- Electronics 0.002% FS typical
- Sensor 0.050% FS typical
- System refer to system calibration data sheet

**Temperature Range:**

- Operating -40 to +85 C (-40 to 185 F)
- Compensated -10 to +50 C (14 to 122 F)
- Zero temp stability <0.0025 %FS/C
- Gain temp stability <0.001 %FS/C

**Frequency response:**

- Input sampling rate 17,656 samples/sec
- Anti-aliasing filter (fixed) 4.1 kHz
- Telemetry update rate 8.828 kHz
- Fast mode data throughput rate 8.828 kHz
- Normal mode data throughput rate 1.104 kHz
- Analog output bandwidth (max) 3 kHz @ -3 db
- Group delay (typical, normal mode) 2.5 ms
- Group delay (typical, fast mode) 1.2 ms

**Digital filtering:**

FIR mode 0.1 through 1000 Hz  
IIR mode recursive algorithm

**Cable length:**

Using RG58 cable 13.9 meters (45'6") or multiples thereof (max. 10x standard)  
  
Using Belden 89907 cable 17.6 meters (57'1") or multiples thereof

**Enclosure rating:** NEMA-4, IP65

**EMC immunity:** 10V/m (30MHz-1GHz)

## Shunt Calibration

An electrical signal equivalent to that produced by a known load can be obtained by activating the shunt calibration function. The shunt calibration function is built in to the sensor itself, and it is therefore necessary for the Rotor Active light to be showing before the function can be operated. By design, the caliper coupling module is more sensitive to receiving data than it is to transmitting data, therefore it may be necessary to adjust the caliper coupling module position to ensure good two-way communications, prior to using the shunt cal function.

The shunt calibration function is achieved by connecting a high-precision resistor of known value, in parallel (shunt) with one arm of the strain gage Wheatstone bridge. The connection is made by a solid state switch, under the control of the microprocessor on the rotating sensor, when commanded by the remote Signal Processing Module. This switch can be activated via the pushbutton on the face of the signal processing module. The shunt calibration value is determined during factory calibration of the torque sensor.

The shunt calibration function is a very useful aid when setting up the system or when fault finding. In applications where it is not possible nor practicable to perform dead weight system calibration, the shunt calibration function can be used as an alternative, at the cost of some loss of calibration accuracy. To provide for this eventuality, the shunt calibration value is factory-set to represent between 50% and 95% of full scale, and is achieved by using high grade resistors that exhibit very low thermal sensitivity.

## Storage and Recalibration

This torque measurement system may be stored for an indefinite period in a dry place at room temperature. Recalibration should follow your normal instrumentation certification schedule.

## APPENDIX

### SUPPLEMENTARY INFORMATION RELEVANT TO YOUR USER MANUAL TMS 9000 TORQUE MEASUREMENT SYSTEM.

**Appendix A** – Supplement for TMS 9000 SPM Square Wave Output Option

**Appendix B** – Supplement for TMS 9000 SPM Remote Shunt Cal Option

**Appendix C** – Supplement for TMS 9000 SPM Digital Filter Settings

**Appendix D** – Supplement for TMS 9000 FASTMODE Operation



## APPENDIX A

### Manual Supplement for TMS9000 SPM Square Wave Output Option

This supplement provides information on the operation and specifications of the TMS9000 SPM with the Square Wave Output Option, P/N 064-LW37040.

#### Overview

The Square Wave Output Option is a plug-in module for the SPM that converts the sine-wave analog frequency output of the SPM to a square wave that is compatible with most RS-422 and RS-485 type inputs to data acquisition systems and frequency/pulse counters. The frequency of the square wave is equal to the frequency of the standard sine wave output. The square wave output is available in three formats: positive phase (TTL level), differential (+/- 5 VDC), and negative phase (TTL level, 180 degrees out of phase compared to positive phase).

#### Setup

The Square Wave Output Option is installed and tested at the factory. A two-pin green mating connector and 120 ohm termination resistor is provided with the SPM to connect between the output option board and the customer supplied data acquisition system (DAQ), counter or other device. The following steps describe the process of connecting the SPM option board to the DAQ or counter.

1. Be sure AC/DC power supply module is not connected to a power source.
2. Place the SPM on a flat workbench or table, preferably with an ESD-safe mat or cover to dissipate electrostatic voltages. Wear an ESD-safe grounded wrist strap while working inside the SPM box.
3. Carefully remove the four screws of the SPM cover and slowly lift the cover off the SPM. Take care not to damage the ribbon and ground wires connected to the inside of the cover.
4. The square wave option module is installed just to the right of J3 and J8 on the main circuit board. A twisted pair jumper cable connects between J6 of the main board (frequency output) and the J1 (frequency input) on the option board.
5. Determine the desired output type. On the option board, the negative phase output is J2, differential output is J4, and positive phase is J5. The ground (common) point is on the left side of the output connectors J2 and J5.
6. Route the wires from the DAQ system through the conduit hole labeled "frequency" to the desired output connector on the option board. Twisted pair 2-conductor shielded wire is recommended for best performance. Strip off about ¼" of insulation from the wire and tin the ends with solder. Loosen the screws on the connector and slide the wires into the connector next to the resistor leads. Remember, the ground (or common) wire must be attached to the left side of the connector.
7. Re-attach the SPM cover and tighten the cover screws.
8. Continue with system installation as described in the TMS9000 user manual.

## **APPENDIX B**

### **Manual Supplement for TMS9000 SPM Remote Shunt Cal Option**

This supplement provides information on the operation and specifications of the TMS9000 SPM with the Remote Shunt Cal Option, P/N 064-LW37039.

#### **Overview**

The TMS9000 SPM with Remote Shunt Cal option allows the user to remotely activate and deactivate the shunt cal mode via an external switch and cable.

#### **Setup**

The Remote Shunt Cal option is installed and tested at the factory. A six-pin circular connector is mounted to the front panel of the SPM box as a connection point for the remote shunt cal switch. A mating connector (023-LW181-034) is provided so the user can attach a cable between the SPM and the customer supplied switch.

1. Connect a two-conductor cable between the remote switch and the mating connector. Solder one conductor to pin A of the mating connector and the other conductor to pin B. Attach the strain relief to the connector.
2. Attach the mating connector to the six pin connector on the SPM.
3. After setting up the sensor and caliper module, power on the SPM and verify the Power LED and the Rotor Active LED is lit on the top of the SPM. Turn on the remote shunt cal switch and verify the Shunt Cal Mode LED is lit on the top of the SPM. Turn off the remote shunt cal switch and verify the Shunt Cal Mode LED turns off.
4. Setup of the Remote Shunt Cal Option is complete.

## APPENDIX C

### Manual Supplement for TMS9000 SPM Digital Filter Settings

This supplement provides information on the operation and specifications of the TMS9000 SPM with the Digital Filter Settings, as they relate to v1.38 software.

#### Intended Use

This supplement is intended for the purpose of describing the function and operation of the digital filtering algorithms that are included in the TMS 9000 version 1.38 firmware. It should be used in conjunction with the TMS 9000 User

Manual and the TMS Toolkit User Manual, both of which are supplied with a TMS 9000 Torque Measuring System.

#### Filter Operation General Description

The digital filter algorithm in the v1.30 and later firmware versions of the TMS 9000 is basically a recursive filter that behaves like an “RC” circuit.

It has two user settings, the first being a “level” set by the parameter **FiltLevel**, and the second being a filter “weight”, set by the parameter **FiltSteps**.

The “level” works as a threshold, above which the filter is reset to allow a fast response to a event that exceeded the threshold. This is useful in the case when well-damped steady state data is required, but when significant fast transients and disturbances should not be filtered out.

The “weight” of the filter is set by increasing the number of filter steps, which in turn increases

the time constant of the RC filter, increasing the damping effect.

The settings of any of the TMS 9000 parameters can be changed at any time via the RS232 communications link. Changing parameters while the system is running will take effect immediately, and in the case of filter setting changes, will become effective as soon as the filter flushes through.

The TMS Toolkit software, supplied with the TMS 9000 system, simplifies the task of changing settings, although any character-based communications software could be used instead (e.g. HyperTerminal).

#### Filter Operation Detailed Description

Consider the input signal as being  $V_i$  and the output signal being  $V_o$ .

In a steady state situation,  $V_o$  will equal  $V_i$ .

When  $V_i$  changes, the extent of the change is compared with the threshold, which is set as a proportion of the full scale sensitivity, by the parameter **FiltLevel**.

If the change exceeds the threshold, then the new input value is passed immediately to the output, thereby resetting the filter.

If the change does not exceed the threshold, then the output value  $V_o$  is updated by a fractional amount of the new value  $V_i$  until the output value equals the input value again. The number of steps set by **FiltSteps** determines the number of fractional steps that are taken to increment the output value, according to the following series :

**1 / 2, 1 / 3, 1 / 4, 1 / 5 ....etc**

The output characteristic is therefore exponential and behaves in a predictable manner.

To determine the settling time of the filter (the time taken to reach the  $V_o = V_i$  condition), it is necessary to know both the filter update rate and the number of fractional steps. The filter update rate is fixed at 1000 Hz in the firmware v1.30 and above, although other filter update rates can be made available upon request to the factory.

The cut-off point (in Hz) is given by the expression

$$\text{Frequency (-3dB)} = (\text{update rate}/\text{number of steps})/6.3$$

The table below provides a quick reference to determine the filter characteristic

Note that this filter operates only when the change in the input is below the threshold set by **FiltLevel**.

## Filter Settling Time

The time required for the output to settle following a step change in input level is given by the following table.

% of Final Value	Time to Settle
63 %	Filter Update rate * FiltSteps
99 %	Filter Update rate * FiltSteps * <b>5</b>
99.9 %	Filter Update rate * FiltSteps * <b>7</b>

Where the Update Rate is the period in seconds (1/f), fixed at 0.001s for firmware v1.30 and above

**AND**

Where the change in input signal magnitude is below the threshold set by **FiltLevel**.

## Example

There follows an example of typical filter settings as applicable to a standard production TMS 9000 torque measuring system.

Consider a sensor with a 1000Nm full scale torque measuring range.  
Consider a test running at steady state torque of 550 Nm.

Consider **FiltLevel** set at 1000. The unit of measure for **FiltLevel** approximates to 0.01%FS (where FS is the full scale of the sensor), therefore a **FiltLevel** of 1000 sets a threshold of change of 10% of FS which in this example is 100 Nm, above which the filter is reset and the output value becomes equal to the input value again. Note that the threshold is with respect to the current value, and not with respect to zero torque. Therefore, if the torque is fluctuating within a band of less than 100 Nm, the filter performance will be determined by **FiltSteps** alone.

In the case where torsional vibrations and spikes may be present in the input signal, then the threshold set by **FiltLevel** should be raised so that the filter is not being reset by events which are not of interest. A safe value to use when setting up is 5000, which corresponds to 50% of FS, then reduce the threshold later if required.

Now consider an input change of 0.1 Nm, which is below the threshold and therefore subjected to filtering. The difference between the input and the output is 0.1 Nm so this is the change that will be used by the filter comparator.

If the **FiltSteps** parameter is set to 10, then the output of the TMS 9000 will be incremented towards the input in 10 steps, as follows :

**1 / 2(0.1 Nm), 1 / 3(0.1 Nm), 1 / 4(0.1 Nm), 1 / 5(0.1 Nm), .... 1 / 9(0.1 Nm), 1 / 10(0.1 Nm)**

The filter update rate being 1000 Hz gives an update period of  $1/1000=0.001$  seconds, therefore the filter will settle to 63% of its final value in 0.01 seconds (being  $0.001 * \mathbf{FiltSteps}$ ).

Using the formula described in the table above, it can be seen that the filter will settle to within 99.9% of its final value in 0.07 seconds (being  $0.001 * \mathbf{FiltSteps} * 7$ )

## Quick Look Up Table

Desired Settling Time to 99.9% of Final Value (seconds)	Equivalent to Cut-Off Frequency of (Hz)	FiltSteps setting required
7 s	0.16 Hz	1000
3.5 s	0.32 Hz	500
1.4 s	0.79 Hz	200
0.7 s	1.59 Hz	100
0.35 s	3.17 Hz	50
0.14s	7.94 Hz	20
0.07 s	15.87 Hz	10
0.035 s	31.75 Hz	5
0.014 s	79.37 Hz	2
0.007 s	158.73 Hz	1

**NOTE :** The setting of **FiltLevel** is of great importance when adjusting the filter settings. Unexpected torsional spikes and vibration noise can cause the frequent resetting of the filter. If in doubt, increase **FiltLevel** (range 1 through 100000)

When **FiltLevel=1**, the filter is bypassed and the torque value is delivered to the output processor at a rate of 2207 Hz, thereby providing a 3dB cut-off of 350 Hz

When **FastMode=1**, the scaling and linearizing algorithms are bypassed and the raw ADC count value is delivered to the output processor at a rate of 8828 Hz, thereby providing a 3 dB cut-off of 1400 Hz.

## Reference and Equations

To calculate the setting of **FiltSteps** required for a particular 3dB cut-off frequency, use

$$\text{FiltSteps} = \text{Update rate} / (\text{Frequency} * 6.3)$$

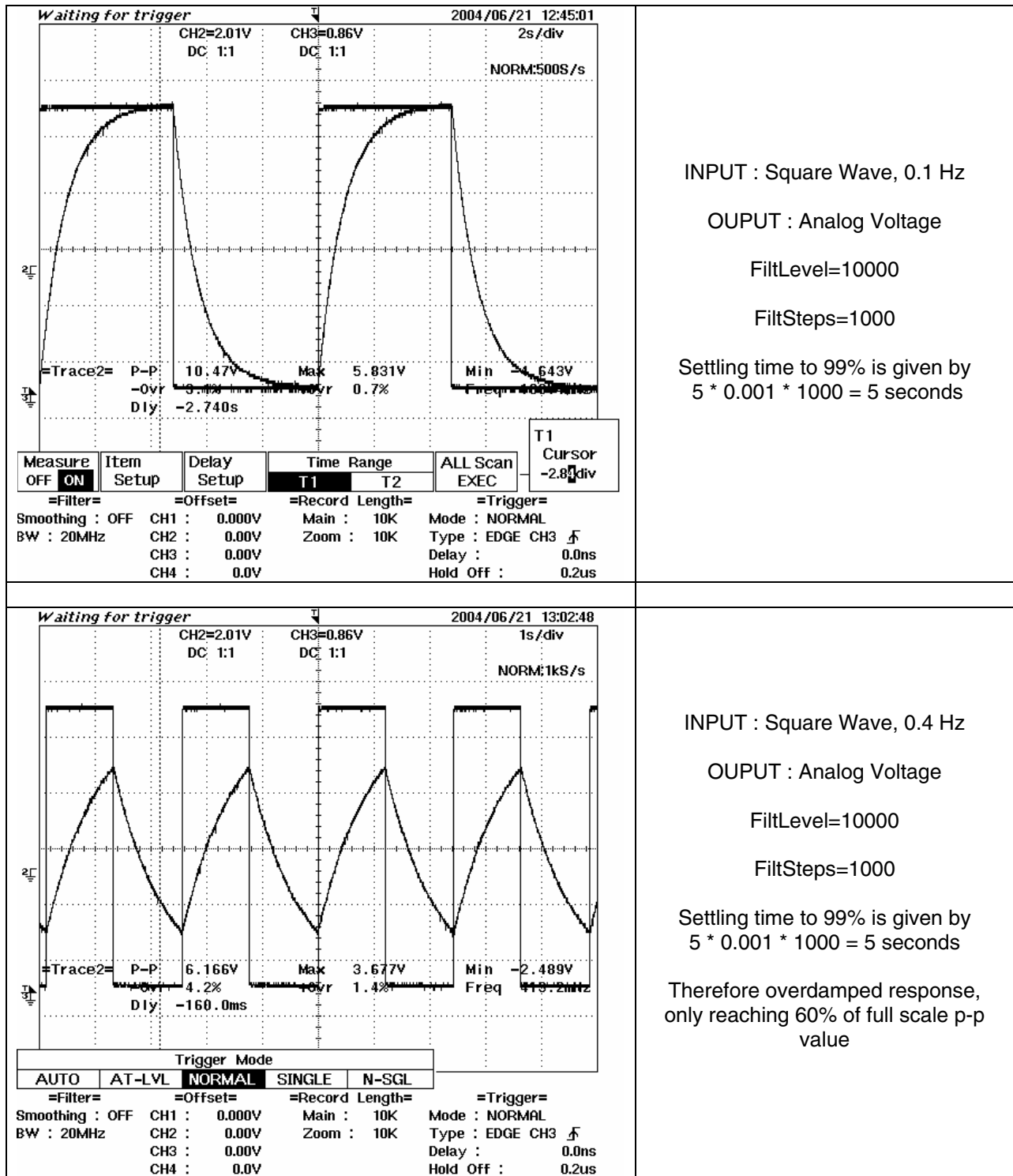
To calculate the 3dB cut-off frequency for a particular setting of **FiltSteps**, use

$$\text{Frequency} = (\text{Update rate} / \text{FiltSteps}) / 6.3$$

**NOTE:** the 3 dB point is also known as the half power point and occurs when the output voltage is equal to 71% of the input or output power is 50% of the input power.

$$\begin{aligned} \text{dB}_{\text{volt}} &= 20 \text{ Log}_{10} \left( \frac{V_{\text{out}}}{V_{\text{in}}} \right) \\ \text{dB}_{\text{pwr}} &= 10 \text{ Log}_{10} \left( \frac{P_{\text{out}}}{P_{\text{in}}} \right) \end{aligned}$$

## Sample Charts



INPUT : Square Wave, 0.1 Hz

OUPUT : Analog Voltage

FiltLevel=10000

FiltSteps=1000

Settling time to 99% is given by  
 $5 * 0.001 * 1000 = 5$  seconds

INPUT : Square Wave, 0.4 Hz

OUPUT : Analog Voltage

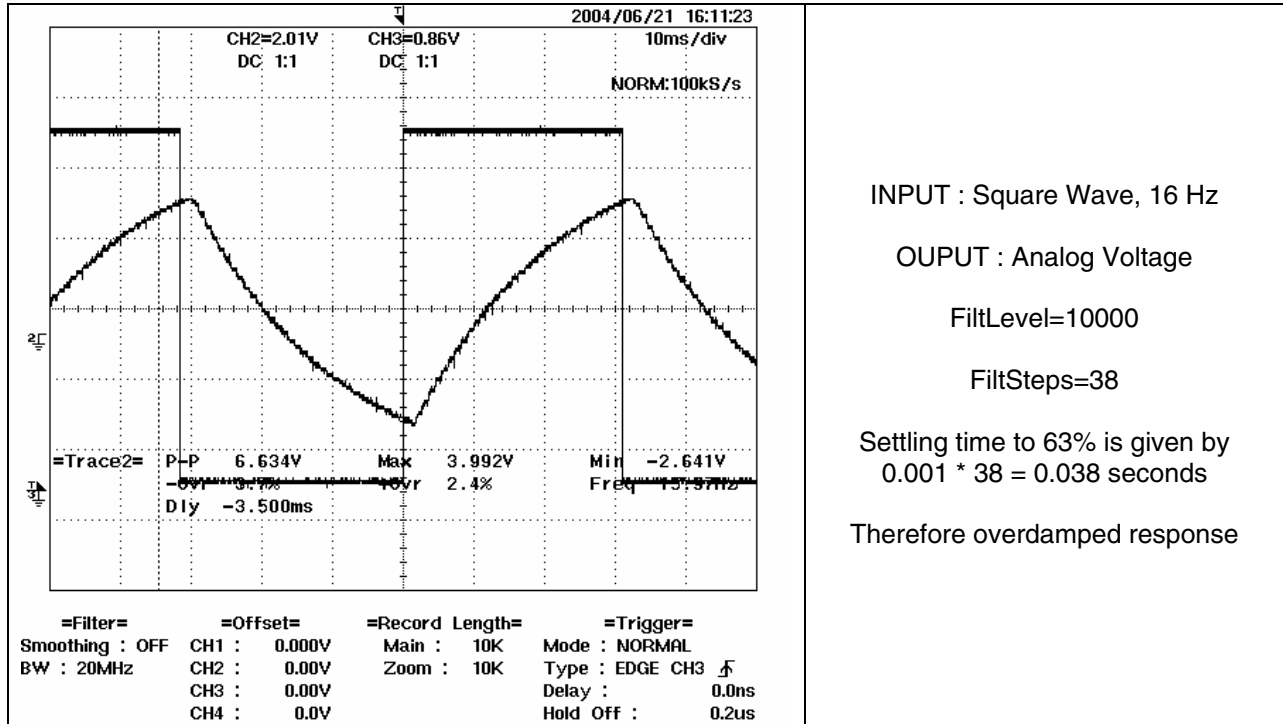
FiltLevel=10000

FiltSteps=1000

Settling time to 99% is given by  
 $5 * 0.001 * 1000 = 5$  seconds

Therefore overdamped response,  
only reaching 60% of full scale p-p  
value

## Sample Charts





## **APPENDIX D**

### **Manual Supplement for TMS9000 SPM FASTMODE Operation and Settings**

This supplement provides information related to v1.30 firmware and above.

### **Intended Use**

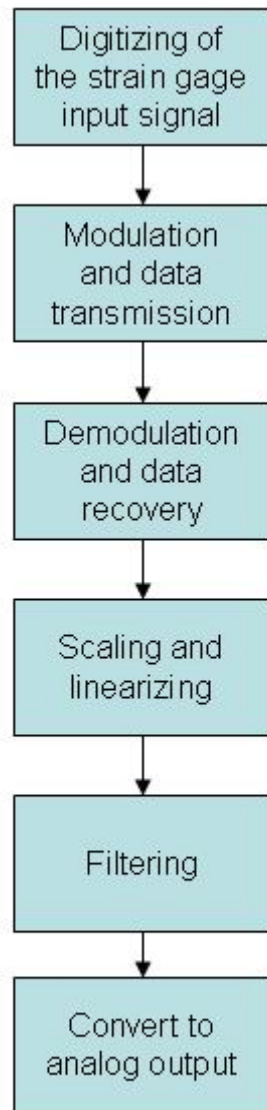
This supplement is intended for the purpose of describing the function and operation of the FASTMODE feature that is included in the TMS 9000 version 1.30 firmware and above. It should be used in conjunction with the TMS 9000 User

Manual and the TMS Toolkit User Manual, both of which are supplied with a TMS 9000 Torque Measuring System

## FASTMODE Operation General Description

The flow of data in the TMS 9000 is subjected to various forms of processing as it passes from input to output.

This process is best described by use of a flow chart as follows :



### Normal mode

The data is transmitted from the rotor at the maximum data rate but the rate has to be slowed down for linearizing and scaling due to

the amount of processing required – the TMS 9000 features independent scaling of the input and output, using floating point values for convenience of the user, and the linearizing routine can use up to 9 data points (user selectable), so a significant amount of processor power is consumed during these floating point calculations.

The next process is digital filtering, using a parameter driven recursive algorithm that performs output smoothing but also provides a separate parameter that controls a filter bypass in the event of a significant change in input being required to be reflected through to the output without delay.

The filtered data is then converted to the required analog output format or formats (the TMS 9000 can drive the voltage or current loop output at the same time as providing a frequency output) using the output scaling parameters that are independent from the input calibration.

The rate at which the microprocessor can perform the separate linearizing and scaling calculations is the limiting factor in determining the available bandwidth of the TMS 9000.

To provide a faster response for users that want to analyze the dynamic data, a FASTMODE is provided, and in this mode, the data is “piped” directly from the rotor to the analog voltage output.

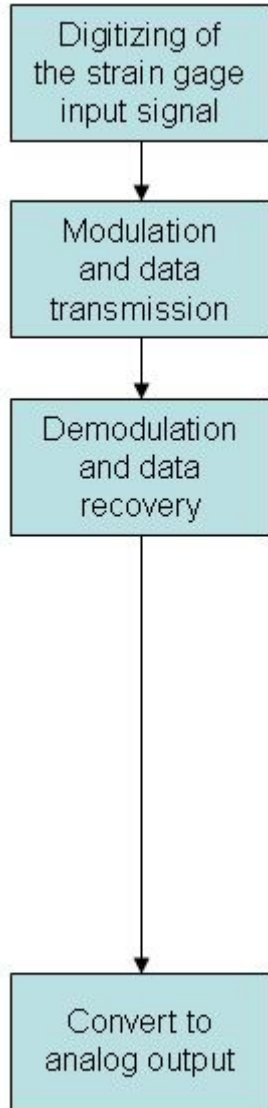
The benefit of this mode is that the analog voltage output is updated at the maximum data rate, which is eight times faster than the normal mode rate.

The penalty of using fastmode is that the scaling and linearizing stages are bypassed, so the relationship between input and output becomes fixed, and the only way to calibrate the output against the input is to calculate the expected change in output value (by reference to the calibration data stored in the TMS 9000), or perform a physical system calibration or to use the SHUNT CAL feature.

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The following diagram shows the change in data flow when using FASTMODE.



**FAST mode**

Because of the significant change in output characteristics that takes place when FASTMODE is selected, it is implemented as a VOLATILE setting, therefore recycling the power or performing a soft reset will return the TMS 9000 to NORMAL mode.

As an indication to the user that FASTMODE is in operation, the ROTOR ACTIVE light on the lid of the TMS 9000 Signal processing Modules (SPM) is de-activated.

## FASTMODE Operation Detailed Description

The strain gage input value is digitized at a rate of 17,656 samples per second with 24-bit resolution, but this amount of data is in excess of the capacity of the telemetry link, so it is reduced by the simple averaging of every pair of A-D results at the rotor electronics module. The data that is transmitted across the telemetry gap consists of 8,828 results per second at a resolution of 16-bit, and it is this data that is then piped directly to the analog voltage output whenever FASTMODE is turned on.

The analog voltage output channel is a 16-bit digital-to-analog converter with a bandwidth of greater than 3 kHz, therefore the expected analog output voltage for a full scale torque measurement can be calculated by reference to the calibration data tables held in the TMS 9000.

Assuming that the factory calibrated (or user re-calibrated) data tables can be accessed using the CAL user mode of the TMS Toolkit, the

output calibration can be determined using this theoretical method, an example of which will be given later.

When the TMS Toolkit is not available, the user will need to perform a physical system calibration by placing a known torque on the sensor and measuring the change in the analog output voltage.

In cases where the shunt calibration value is known, the change in output due to shunt calibration can be measured and the result extrapolated to give a full scale equivalent. Note that this result will need to be adjusted when the shunt cal scaling feature has been used (#SCSCALE is something other than 1). An example of calculating the analog output voltage by using shunt cal and the #SCSCALE parameter is also given later.

## Normal mode and FASTMODE data update rates

The table below provides a quick reference to the data rates available in either of two available modes.

Mode	Data rate
NORMAL	When FILTSTEPS>1, data rate is 1104 results per second
NORMAL	When FILTSTEPS=1, data rate is 2207 results per second
FASTMODE	8828 results per second

Note that the analog voltage output channel should be only channel is use for any data rate above 1104 results per second. Therefore OPTYPE should be set to 1.

Note that any traffic on the RS-232 port caused by TMS Toolkit or any other communications package will disrupt the flow of data due to the interrupts that are generated by the external software.

## Examples

The following examples assume that either the TMS Toolkit is available and running in CAL user mode, or that a hard copy of the parameters list is available and is valid.

### **Example 1 – Theoretical determination of analog output value**

The relationship between torque and digital counts can be determined by reference to the parameters held in the TMS 9000. When in FASTMODE, the digital counts received from the rotor are simply piped through to the analog voltage output channel, so the counts values can be used to determine the expected analog output values (actual values may vary within the calibration accuracy of the analog output channel, usually within 0.1%FS).

Consider a sensor with a 2000Nm full scale torque measuring range

Calibration values most likely to have been used will be (approximately) -2000, 0 and +2000 Nm

The actual values used may have been adjusted to take account of local gravity and buoyancy and can be seen from the parameters **#CALVALUE1**, 2 and 3

Make a note of the actual values used and compare them to the values of **#CALCNTS1**, 2 and 3

The **#CALCNTSx** values store the digital counts values that were output by the rotor for the load conditions given by the relevant **#CALVALUEx**

The analog voltage output channel is 16-bit and it will generate an output of -10V when it is driven by a counts value of 0, and will generate an output of +10V when driven by a COUNTS value of 65535. Therefore each count generates 0.0003052V starting from a base of -10V.

The analog voltage output will be generated in direct relationship to the statement above. Therefore, using the following data, the analog voltage output will be:

**#CALVALUE1=-1998.699      #CALCNTS1=21553**

**Therefore at a load of -1998.699 Nm, the analog Voltage will be  $(21553 \times 0.0003052) - 10V = -3.422V$**

**#CALVALUE2=0.000000      #CALCNTS2=32700**

**Therefore at a load of 0 Nm, the analog Voltage will be  $(32700 \times 0.0003052) - 10V = -0.020V$**

**#CALVALUE3=1998.500      #CALCNTS3=43842**

**Therefore at a load of +1998.500 Nm, the analog Voltage will be  $(43842 \times 0.0003052) - 10V = +3.381V$**

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## Example 2 - Using the SHUNT CALIBRATION feature

The shunt cal feature operates by switching-in a high precision shunt resistor across one of the arms of the strain gage bridge on the rotor. The change in output that occurs due to this shunting is repeatable and is often used as a means of calibration. During factory calibration, the apparent change in torque output due to shunt cal will have been recorded, and this value can be used to re-calibrate the analog voltage output when in FASTMODE.

Consider a sensor with a 2250 Lbf.in measuring range. The factory calibration certificate will include the changes due to shunt cal as a list of effects such as follows :

Shunt Calibration							at Analog Output Settings		
		Lbf.in	V	mA	Hz (10)	Hz (60)	High	Low	Units
Shunt Cal	Gross	1692.2	7.553	18.025	13761	75043	2250	-2250	Lbf.in
	Zero	0.0	0.031	12.008	10000	60000			
	Nett	1692.2	7.522	6.017	3761	15043			
	%	75.21%	75.24%	75.21%	75.22%	75.22%			

Note - Hz(10) denotes 10 kHz range (10 kHz +/- 5 kHz), Hz(60) denotes 60 kHz range (60 kHz +/- 20 kHz)

When in FASTMODE, the shunt cal values for voltage, current and frequency are invalid because the scaling module is bypassed, so the only piece of information that remains valid and that we need to use from this data table is the apparent change in **TORQUE** due to shunt cal, and in the case of this example, it is **1692.2 Lbf.in**

It follows that the change in analog voltage output when in FASTMODE will represent 1692.2 Lbf.in

The exception to this case will be when a value has been set for #SCSCALE. This parameter allows the effect of shunt cal to be varied, according to the value set. The default is 1 and any other value acts as a multiplier – but only when the scaling module is operating.

For FASTMODE operation, the scaling module is bypassed so the effect of shunt cal will be the original effect, as manufactured, and may be significantly different from the calibration certificate value.

To compensate for any value of #SCSCALE, calculate as follows :

Certificated change in torque due to shunt cal is 1692.2 Lbf.in

Value set for #SCSCALE is 1.5

Actual change due to shunt cal is  $1692.2/1.5 = 1128.13$  Lbf.in

If #SCSCALE is 1, then no calculation is necessary.

## Analog Output characteristics

The analog output channel is specified for a bandwidth of 3 kHz so there is no output filtering that follows the digital-to-analog converter (DAC). This can lead to a “staircasing” effect when the DAC is being updated at a relatively slow rate such as 1104Hz.

For users that do not require wide bandwidth, this staircasing will not be a problem and can be eliminated from the measurement by applying a suitable sampling rate at the data acquisition end. Typically, a sampling rate of one quarter of the TMS 9000 DAC update rate (or less) would be sufficient to solve this problem.

For applications where the fidelity of the output waveform is of prime importance, the solution to staircasing is to add a filter network across the analog voltage output terminals. Such networks are available from Lebow in a range of cut-off frequencies and with various filtering characteristics.

When using FASTMODE, the DAC is being updated at a rate of 8828 Hz therefore staircasing is reduced as a result of the much faster update rate.



## WARNING

### MISUSE OF DOCUMENTATION

- The information presented in this product sheet is for reference only. Do not use this document as product installation guide.
- Complete installation, operation, and maintenance information is provided in the instructions supplied with each product.

**Failure to comply with these instructions could result in death or serious injury.**



## WARNING

### PERSONAL INJURY

DO NOT USE these products as safety or emergency stop devices or in any other application where failure of the product could result in personal injury.

**Failure to comply with these instructions could result in death or serious injury.**

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