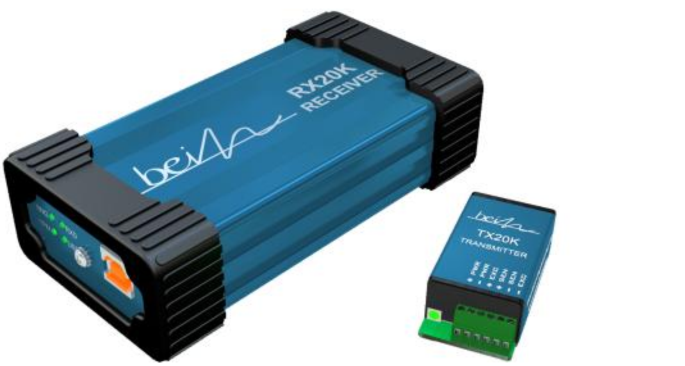
BINSFELD ENGINEERING INC.

Torque Trak 20K
Torque Telemetry System



User's Guide

869610-9

Contents

1 System Overview

The TorqueTrak 20K Torque Telemetry System utilizes proven digital RF technology to transmit a single data signal (most typically from a strain gage) a distance of 10 feet (3 meters) or more depending on the environment. Up to 16 systems can operate simultaneously on independent channels.

TX20K Transmitter:

The TorqueTrak 20K is a robust, precision strain measurement instrument ideal for short-term data collection and diagnostic testing. It is designed to withstand harsh field conditions with ease-of-use in mind. A standard TorqueTrak 20K Torque Telemetry System includes the following items:

- TX20K Transmitter
- RX20K Receiver
- Receiver Antenna Element
- Receiver Antenna Magnetic Base with 13-ft Cable
- 6-ft USB 2.0 A-male to B-male Shielded Cable
- 10-ft 4-Conductor Ribbon Cable
- BS900 Bridge Simulator
- Narrow Blade Screwdriver
- 9V Battery Connectors (2)
- 9V Lithium Battery
- 1 Roll of 1" Fiberglass Reinforced Strapping Tape
- Butyl Rubber Sheet
- Teflon Film kit
- Printable TT20K User's documentation
- TT20K Equipment Case
- Calibration Certificate
- TT20K Configuration and Monitor PC software

1.1 TX20K Transmitter

- High signal-to-noise ratio for excellent resolution
- Low temperature coefficient for accuracy from -40 to 85°C
- Wide power supply input range from 6 to 20VDC
- Power Standby mode to extend battery life
- Two on-board shunt calibration values
- Status Indicator light to assist in troubleshooting
- Circuit fully encapsulated
- Two different transmit modes; Block, and Stream.
- Remotely configurable sample rate, signal bandwidth, baud rate, RF channel, transmit power, and input signal range.
- Two on-board shunt calibration values.
- Status Indicator light to assist in troubleshooting.
- Circuit fully encapsulated.

1.2 RX20K Receiver

- Compact 30 x 63 x 125 mm (1.2" x 2.5" x 5") size.
- USB powered (PC or USB charger)
- Digital USB serial data and analog voltage output signals
- Stable 1.2KHz analog output frequency response
- Configurable RF channel settings
- Seven unique simulated transmitter inputs
- Configure from PC over USB connection
- Standalone operation without PC using analog output
- Four external status LEDs.
- Analog output configurable for 0-5V, 0-10V, ±3V, ±5V, ±10V.
- Configurable analog output offset, scale, and polarity.

- Configurable input for optional speed sensor.
- Simple Configuration and Monitor PC software included as well as serial protocol information for digital interface to data acquisition systems.

2 Features and Controls

The TT20K is a dynamic torque measurement system designed for temporary installations. The TX20K Transmitter is mounted on the rotating shaft along with a strain gage(s) and battery. The RX20K Receiver is connected to the USB port of a PC. The TX20K and RX20K communicate with one another using RF transceivers built into each. The strain gage (torque) signal and status information is transmitted off the shaft by the TX20K and received by the RX20K and then sent on to the PC. Operational configuration information is sent from the PC, though the RX20K to the TX20K on the shaft.

The TT20K system is compact yet powerful. Configuration and monitoring is intuitive using the included PC software. Incorporation into data acquisition systems can be accomplished using the serial digital data available through the USB connection or the standard analog output.

The RF transceivers in the TX20K and RX20K are user selected to operate any of 16 different frequencies below. This allows up to 16 TT20K systems to simultaneously operate in fairly close proximity. These RF frequencies are different than those of the TT10K system. So TT20K and TT10K systems can also operate in close proximity without interference.

Table 1, TT20K RF Channels

CH	Freq (MHz)	CH	Freq (MHz)	CH	Freq (MHz)	CH	Freq (MHz)
1	903.37	5	909.37	9	915.37	13	921.37
2	904.87	6	910.87	10	916.87	14	922.87
3	906.37	7	912.37	11	918.37	15	924.37
4	907.87	8	913.87	12	919.87	16	925.87

The TX20K RF transmission power level is user adjustable. There are four different levels that can be chosen depending on the specific application. A higher RF power level will allow for more reliable transmissions over longer distances or in noisy RF environments. The lower RF power levels will increase battery life longevity.

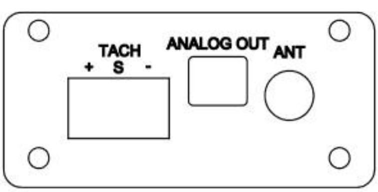
The RX20K always operates at maximum allowable RF power level since it is not battery operated.

2.1 RX20K Receiver

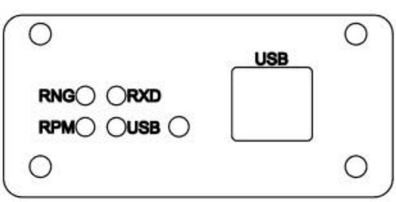
The Receiver module had no display or control buttons. Configuration is done through the USB connection with a PC using the included Configuration and Monitor software. See the Configuration and Monitor software User's Guide for information regarding program operation and use. Once the Receiver module has been configured, it is possible to use it as a standalone system with power through the USB connector and the optional analog output expansion board.

2.1.1 Connections

One end of the receiver features a SMA reverse polarity antenna connector and a 5.08mm pitch 3 position plug receptacle for the optional speed sensor input. With the standard analog output expansion board, a 3.81mm pitch 2 position plug receptacle provides the analog output signal.



The opposite end has a high insertion force USB type B receptacle for power and serial communication. Near the USB connector are four green indicator LEDs.



2.1.2 LED Indicators

Starting with the upper left LED and moving clockwise, the indicators are RNG, RXD Data, USB Data, and RPM.

During power-up initialization or after a system reset, the normal LED pattern has both USB Data and RPM LEDs OFF while RNG and RXD Data LEDs alternate being ON. The power-up initialization lasts for about 5 seconds followed by all LEDs being on solid for about 1 second then all turn OFF before beginning normal operation.

If a bootloader checksum error is detected during initialization, the RXD Data LED turns ON alone and remains ON (not recoverable).

If a program checksum error is detected during initialization, the RPM LED turns ON alone and remains ON (not recoverable).

2.1.2.1 Range (RNG) LED

The Range LED is ON solid green when torque values are being received from the TX20K and are within range. If no torque values are being received, the Range LED is OFF. If torque error value(s) are received, the Range LED flashes at a rate of 2Hz. If errors are received intermittently, the Range LED is retriggered OFF for a least one 250msec period.

Table 2, Signal Sample Error Values

Torque sample value	**Description**	**Indication**
±20000	Valid signal sample value range	Samples between these values (inclusive) are valid signal measurements
+20001	TX20K input differential mode over-range	The input signal is out-of-range. Increase Range setting, check gage and wiring
-20001	TX20K input differential mode under-range	
+20002	TX20K input common mode over-range	+Vsen of the bridge is not near midscale of Vexc. Check gage and wiring
-20002	TX20K input common mode under-range	
+20005	TX20K internal analog zero is over-range	Internal circuit fault
-20005	TX20K internal analog zero is under-range	
+20010	TX20K Vpwr is over-range	Circuit damage could occur. Check Vpwr (battery) voltage.
-20010	TX20K Vpwr is under-range	Circuit may not function properly. Check Vpwr (battery) voltage.

Note: Larger error values have higher priority when two or more errors occur at the same time.

2.1.2.2 RF Receive Data (RXD) LED

The green RXD Data LED is retriggered ON for 20msec when a byte is received by the RF transceiver of the RX20K. If the 20msec ON duration expires before another byte is received, the RXD Data LED switches OFF until another byte is received.

2.1.2.3 USB Data LED

The green USB Data LED turns ON at the start of a USB Data transmission from the RX20K to the host PC. The LED remains ON for 20msec after the transmission completes and then turns OFF unless another transmission begins before the 20msec OFF delay expires.

2.1.2.4 RPM LED

The green RPM LED is triggered ON every time the leading edge of a speed pulse is detected. After a 20msec duration the RPM LED switches OFF again unless another speed pulse extends the ON time another 20msec.

2.2 TX20 Transmitter

The TX20K transmitter is encased in a small, rugged, potted plastic housing with a six position screw terminal block for external connections. It also features a single green Status Indicator LED next to its terminal block.

2.2.1 External Connections

A small six position terminal block provides external connections for power and strain gauge connections. Because of their small size the screw terminals can be damaged if too much force is applied. Always use an appropriately sized small screwdriver and do not over-tighten.

Starting next to the LED indicator the connections are:

+ Transmitter Power
- Transmitter Power
+ Bridge Excitation
+ Bridge Sense
- Bridge Sense
- Bridge Excitation

2.2.2 LED Indicator

The TX20K has one green indicator LED that is ON solid when it is operating in any mode other than Standby with no problems detected. In Standby mode the LED is OFF to conserve battery power.

2.2.2.1 Input Signal Out of Range

When the input (strain gage) signal is detected to be out of range, the indicator LED flashes five times per second (5Hz).

2.2.2.2 Low Battery Indication

Below approximately 6.0V the TX20K will flash once per second (1Hz mostly on) its LED indicator and set the Low Battery Warning transmitter status flag. This indicates a low battery that should be replaced soon. The TX20K will continue to transmit accurate signal samples until the battery voltage is below about 4.5V. At this point the LED will flash once per second (1Hz mostly off), the Low Battery Fault transmitter status flag will be set and the transmitted samples will have a value of -20010.

2.2.3 Measurement Ranges

The internal amplifier of the TX20K has seven configurable range settings of 0.2, 0.5, 1, 2, 5, 10, and 20mV/V.

TX20K bridge excitation voltage is 3.0V. The unitless full scale digital output value for all ranges is ±20,000.

The TX20K has seven user selectable input range settings from ±0.2 to ±20mV/V. The table below shows just the positive side. The transmitted signal sample has a maximum range of ±20000. This gives the output resolutions listed below for each range.

Table 3, Input Ranges

Input Range mV/V[1]	**Input Range µe**[2]	**Output Resolution µe/lsb**[2]	**Output Resolution µV/V/lsb**	**Output Shunt1**[3] **100µV/V**	**Output Shunt2**[3] **1mV/V**
0.2	100	0.005	0.010	10000	over-range
0.5	250	0.0125	0.025	4000	over-range
1	500	0.025	0.050	2000	20000[4]
2	1000	0.05	0.10	1000	10000
5	2500	0.125	0.25	400	4000
10	5000	0.25	0.5	200	2000
20	10000	0.5	1	100	1000

[1] These are the absolute maximum input values (±). If the expected input levels are close to these, the next larger input range should be selected. This will give some overhead for the signal span and gage offset.

[2] Microstrain with a Gage factor = 2.00.
lsb = least significant bit of the output (transmitted) sample value.

[3] The shunt values shown are for a 350Ω gage

[4] This shunt value is right at full scale and could cause an over-range condition

2.2.4 Internal Shunt Resistors

There are two internal shunt resistors for calibration that can be enabled and disabled individually by the RX20K.

Shunt 1 is 875KΩ, 0.1%, 10ppm to produce Vout = 100µV/V with a 350Ω bridge.

Shunt 2 is 87370Ω, 0.1%, 10ppm to produce Vout = 1mV/V with a 350Ω bridge.

2.2.5 Operating Modes

2.2.5.1 Block Mode

In Block mode torque measurements are buffered and transmitted to the RX20K in blocks of 100 samples at regular intervals. Immediately after each block is transmitted, the TX20K switches its transceiver to receive configuration commands from the RX20K. If a command is received before the next block needs to be sent, it is executed. If no command is received, the next sample block is transmitted at the scheduled interval. The TX20K always operates in this mode when it powers up.

Because samples are buffered at the transmitter in block mode, they are delayed by between one and two block intervals before reaching the USB port of the PC.

Table 4, Block mode baud/sample rates

Baud Rate	**Sample Rate**	**Block Interval**
250Kbps	5000sps	20msec
250Kbps	500sps	200msec
250Kbps	50sps	2 seconds

2.2.5.2 Stream Mode

In Steam Mode the transmitter streams torque measurements individually and continuously at a rate of 5000 samples per second. Samples reach the analog output with low latency. This is the highest speed, lowest latency operating mode for the TT20K. This makes it very useful for accurately synchronizing the torque signal to other events or signals.

Since the TX20K is constantly transmitting torque samples, it does not have enough time to switch its transceiver to receive commands from the RX20K. Therefore, the operational mode of the TX20K cannot be changed while it is in Stream Mode. However, the user can specify how long the TX20K will be in Stream Mode. This time can be from 1 to 4095 minutes (2 days, 20 hours, 15 minutes) or indefinite, which is when the battery dies or power is cycled. When Stream Mode time expires, the TX20K reverts back to Block Mode operation at 250Kbaud/5000sps. Cycling TX20K power takes it out of Stream Mode and back into Block Mode operation.

In Stream mode, samples are also buffered and transmitted serially through the USB connection in 100 sample blocks just like block mode.

2.2.5.3 Standby Mode

This is the TX20K low power, sleep mode. It is used to conserve battery power between test sessions. No torque or status data is transmitted while in Standby Mode. The TX20K wakes from this mode every 15 seconds to see if the RX20K is sending Wake commands. If not, the TX20K goes back to sleep. If the TX20K receives a Wake command from the RX20K, it will wake and operate at same Block Mode baud/sample rate as when it was put to sleep. Resetting power of the TX20K will take it out of Standby Mode and back into Block Mode operation.

2.2.6 Signal Accuracy

Below are the TX20K's maximum signal errors at 25˚C along with the temperature coefficients for each range setting.

Table 5, TX20K signal accuracy

Input Range mV/V	**Zero Error % Full Scale**	**Scale Error % Reading**	**Zero TC ppm/°C**	**Scale TC ppm/°C**
0.2	0.02	0.25	50	30
0.5	0.02	0.25	30	25
1	0.15	0.20	25	20
2	0.15	0.20	20	20
5	0.15	0.20	20	20
10	0.15	0.20	20	20
20	0.15	0.20	20	20

2.2.7 Signal to Noise Ratio

Below are the TX20K's typical Signal to Noise Ratios at the different range settings and sample rates.

Table 6, TX20K signal to noise ratios

Input Range mV/V	**50sps (dB)**	**500sps (dB)**	**5000sps (dB)**
0.2	68	58	49
0.5	75	66	57
1	81	72	62
2	84	76	66
5	86	79	70
10	86	79	70
20	86	79	70

2.2.8 RF Power Level

The TX20K RF transmission power level is user adjustable. There are four different levels that can be chosen depending on the specific application. A higher RF power level will allow for more reliable transmissions over longer distances or in noisy RF environments. The lower RF power levels will increase battery life longevity.

2.2.9 Power Supply Voltage Measurement

The TX20K measures and transmits its power supply voltage. The tolerance of this measurement is +/-2%. The voltage is internally limited to approximately 15V.

2.2.10 Power Consumption

The following table shows typical power supply current draw for the stream mode.

Table 7, TX20K current draw, stream mode, 250K baud, 5000 sps

Power Supply (Vdc)	Power supply current draw (mA) at the four RF power levels			
	1	2	3	4
6.0	33	36	39	43
8.0	26	28	30	33
12.0	21	22	24	26
20.0	19	20	21	22

2.2.11 Battery Life

Below are typical battery life times for the different operating modes of the TX20K. The 2 batteries listed are an Ultralife 9V Lithium battery and a standard 9V Alkaline battery. The battery capacities used for the calculations are 1200mAh for the lithium and 550mAh for the alkaline. These values are with a 350Ω gage connected and at and RF Power level of 1. Actual battery life times can vary depending on battery type, age, charge state, RF power level, gage resistance and operating environment.

Table 8, TX20K battery life

Mode	**Baud**	**Sample Rate**	**RF Power Level**	**Average Current (mA)**	**Lithium Battery (hours)**	**Alkaline Battery (hours)**
Stream	250K	5000	1	28	43	20
Block	250K	5000	1	26	46	21
Block	250K	500	1	21	57	26
Block	250K	50	1	21	57	26
Standby	250K	5000	1	0.36	3300	1500

3 Product Safety

WARNING!

PERSONAL INJURY

DO NOT USE this product as a safety or emergency stop device or in any application where failure of the product could result in personal injury.

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

The user assumes all risk and liability for the installation and operation of this equipment. Each application presents its own hazards. Typically, certain system components are strapped to a rotating shaft. If sufficient care is not taken to properly secure these components or accessories connected to them, they can be flung from the shaft, causing damage to the components or to property or persons in the vicinity. Use more than enough tape: 10 or more wraps is not too much.

A shield or guard is recommended in applications where something or someone could come in contact with the rotating parts of the system.

Keep clear of the machinery while the shaft is rotating.

4 Installation

The TorqueTrak 20K System is designed for ease of use. The procedure for a typical setup on a shaft for obtaining torque measurements is detailed in the *Field Testing* section below.

It is recommended that the user bench test the instrument to become familiar with the various operational features prior to conducting tests in the field. The BS900 Bridge Simulator and 9V Battery Connector have been provided for this purpose. See section 4.2 *Bench Testing* for details.

4.1 Field Testing

Although the settings of the TX20K can be changed during operation of the system, it is best to determine the appropriate Transmitter Gain setting for a given application prior to installation. Refer to Appendix B for the relevant calculations.

1. Attach sensor or strain gage to the shaft (or other surface) where the desired strain will be measured. Refer to Appendix C for instructions on strain gage application.
2. Secure TX20K and fresh battery to shaft using fiberglass reinforced strapping tape. Do not cover TX20K Status Indicator. Alternatively, hose clamps, machined collars, or other mounting devices may be used but avoid excessive compression.

   CAUTION: Be certain all components are fixed firmly to moving surfaces. The fiberglass reinforced strapping tape should be wrapped around at least 10 times (5 times in each direction) to secure the components to the shaft. The open end of the tape should follow shaft rotation. For extra protection, glue the end of the tape down. When finished with your testing, cut the tape and remove the components. Avoid the risk of being struck by an improperly secured object flung from the machine by standing clear during operation!

   NOTE 1: This method of securing the transmitter and battery holder is for **temporary use only**. For long term use this tape should be examined frequently for the effects of environmental influences (e.g.: excessive oils) or extreme conditions (e.g.: rapid starts/stops, high temperatures). Replace tape as required following the notes in the “CAUTION” previously listed.

   NOTE 2: If the shaft is small (≤1” or 25 mm), balance might be an issue. In this case, mount the TX20K and battery 180° from each other on the shaft. The battery weighs nearly the same as the TX20K.
3. Connect the positive battery terminal to **+PWR** on TX20K and the negative battery terminal to **-PWR** on TX20K. The Status Indicator light should blink several times and then come on solid.

Secure to shaft.

NOTE: If testing will not begin for some time, put the TX20K in Standby mode to save battery life. The Status Indicator light will turn off. A fresh battery will last for several days in this mode.

4. Cut an appropriate length of 4-conductor ribbon cable (as short as practical to avoid unwanted electrical noise) and strip and tin ends. Solder to gage per Appendix C or gage manufacturer's specification and make appropriate connections to the TX20K terminals. Secure loose cable to shaft.

5. Connect Receiver Antenna to **Antenna** connector on the rear panel of the RX20K Receiver. Position magnetic-mount antenna with element installed near the TX20K, typically within 10 feet (3 meters).

6. Use a USB A male to B male cable to connect the RX20K to a computer for power and communications. The TT20K Configuration and Monitoring LabVIEW program must already be installed on the computer as explained in the 818006-9 TT20K Configuration and Monitoring User's Guide.

   NOTE: If the RX20K was previously configured and only the analog output (no serial data) is being used, any USB power source with a minimum of 250mA output capability can be used to power the RX20K.

7. If the TX20K and RX20K are not already communicating, use the Configuration and Monitoring program to establish communications between them. Verify adequate signal strength. If possible, rotate the TX20K through complete range of motion to verify strong signal reception in all orientations.

8. Use the Configuration and Monitoring program to set up other parameters as necessary for the desired operation. All parameters previously configured, should have been automatically saved to non-volatile memory and should not require reconfiguration. Configuration and Monitoring program operation is detailed in document 818006-9.

9. The system is now operational.

4.2 Bench Testing

1. Connect Receiver Antenna to **Antenna** connector on the rear panel of the RX20K Receiver. Position magnetic-mount antenna with element installed near the TX20K, typically within 10 feet (3 meters).
2. Use a USB A male to B male cable to connect the RX20K to a computer for power and communications. The TT20K Configuration and Monitoring LabVIEW program must already be installed on the computer as explained in the 818006-9 TT20K Configuration and Monitoring User's Guide.

   NOTE: If the RX20K was previously configured and only the analog output (no serial data) is being used, any USB power source with a minimum of 250mA output capability can be used to power the RX20K.
3. Attach 9V Battery Connector to TX20K Transmitter (red to **+PWR**, black to **–PWR**). Attach BS900 Bridge Simulator to the TX20K terminals **+/- EXC** and **+/- SEN** to coincide with pins on BS900. Clip 9V battery to connector.
4. If the TX20K and RX20K are not already communicating, use the Configuration and Monitoring program to establish communications between them. Verify adequate signal strength.

5 Communications Protocol

5.1 General USB Host to RX20K Communications

The RX20K uses a FTDI chips FT230XS USB interface. PC software drivers are available on the FTDI chips web site http://www.ftdichip.com/FTDrivers.htm. The Binsfeld Engineering TT20K Configuration/Monitoring LabVIEW program requires the FTDI VCP driver for the operating system used (typically Windows 32bit).

Serial communications settings are 1M baud, 8 bits, odd parity, 1 stop bit, RTS/CTS flow control.

5.2 RX20K to USB Host Block Messages

Table 9 - RX20K to USB Host Block Message Format

byte index	**byte variable, all variables start with `USBmsg2host.name.`**	**Description**
0	hdr.stx	header start char, always 0x55
1	hdr.len	# of bytes following this byte in the USB msg to the host (always even and ≥ 52). # of header bytes is fixed at 44 (not counting stx and len). # of sample bytes is normally 200 (100 16 bit samples) but could be some other even #. # of TX status bytes is fixed at 8 and are always the last 8 bytes in the message. So len is normally 44 + 200 + 8 = 252.

byte index	byte variable, all variables start with **`USBmsg2host.name.`**	Description
2	hdr.RXstat (LB)	low byte of the RX20K status word b0 - NoTxData, no data rcvd from TX b1 - TxDataErr, error in data rcvd from TX b2 - CmdAck, valid cmd rcvd from USB host b3 - CmdNak, invalid cmd rcvd from USB host b4 - EcomErr, frame, parity, or checksum error in data received from the USB host b5 – Speed input disabled (sensor pwr is off) b6 – not used b7 - MultXmit, set for multiple transmitter operation; separate transmitters for each RF channel (separate xmit params for each)
3	hdr.RXstat (HB)	high byte of the RX20K status word b8 – WakeInPrg, Wake-up sequence in progress b14:b9 not used b15 – TestMode, RX20 is in test mode operation

byte index	byte variable, all variables start with **USBmsg2host.name.**	Description
4	hdr.RFcomm	RF data baud/sps; 0x77: 250K, 5000sps 0x74: 250K, 500sps (default) 0x71: 250K, 50sps
5	hdr.RFchan	RF data channel index (ch# - 1), values 0x00 thru 0x0F
6	hdr.RxRFpwr	RX RF xmit power setting, values 0x00 thru 0x0F
7	hdr.RxRFlevData	RF xcvr receive signal strength while good data is being received.
8	hdr.RxRFlevQt	RF xcrv receive signal strength while the transmitter is OFF (quiet or background noise signal strength).
9	hdr.RxErrRate	# of blocks received with errors in a sample of 100 blocks.
10	hdr.unused1	Unused byte
11	hdr.unused2	Unused byte
12	hdr.rpm (LB)	low byte of Speed period value (shifted 12MHz)
13	hdr.rpm (HB)	high byte of Speed period value (shifted 12MHz)
14	hdr.rpmRel (LB)	low byte of block start to Speed input -edge time

byte index	byte variable, all variables start with **USBmsg2host.name.**	Description
15	hdr.rpmRel (HB)	high byte of block start to Speed input -edge time
16	hdr.spdShift	Timer #right bit shift for Speed and Sync values. The upper nibble is the #bit shift for Sync. The lower nibble is the #bit shift for Speed.
17	hdr.seqID	8 bit running value that increments every msg.
18	hdr.opMode	Block = 0, Stream = 1, Standby = 2
19	hdr.inSrc	RX input source 0 - transmitter (default) 1 - forced output value = +1/4FS 2 - forced output value = +1/2FS 3 - forced output value = +FS 4 - forced output value = 0 5 - forced output value = -1/4FS 6 - forced output value = -1/2FS 7 - forced output value = -FS

byte index	byte variable, all variables start with **USBmsg2host.name.**	Description
20	hdr.exp[0]	Expansion board type: 0x7f = none b7 – update expansion board configuration, flag This flag is used internally and always displays as '0'. See separate expansion board parameter tables for details of hdr.exp[0] through hdr.exp[7]
21	hdr.exp[1]	Expansion board configuration bits that control hardware options. Changing this bytes triggers expansion board hardware configuration to change.
	...	Expansion board parameters
27	hdr.exp[7]	Last expansion board parameter
28	hdr.rfu[0]	reserved future use, not presently used
	...	reserved future use, not presently used
41	hdr.rfu[13]	reserved future use, not presently used
42	hdr.Debug0 (LB)	low byte of Debug0
43	hdr.Debug0 (HB)	high byte of Debug0
44	hdr.Debug1 (LB)	low byte of Debug1

byte index	byte variable, all variables start with **USBmsg2host.name.**	Description
45	hdr.Debug1 (HB)	high byte of Debug1
46	samp[0] (LB)	sample 0 low byte
47	samp[0] (HB)	sample 0 high byte (signed 16 bit)
48	samp[1] (LB)	sample 1 low byte
49	samp[1] (HB)	sample 1 high byte
hdr.len - 10	samp[n-1] (LB)	sample n-1 low byte
hdr.len - 9	samp[n-1] (HB)	sample n-1 high byte
hdr.len - 8	samp[n] (LB)	sample n low byte
hdr.len - 7	samp[n] (HB)	sample n high byte
hdr.len - 6	TXstat.Vpwr	TX power supply level
hdr.len - 5	TXstat.VpwrFlags	TX Vpwr status flags: b4:b0 - unused b5 - Vpwr too low flag b6 - Vpwr getting low, replace battery flag b7 - Vpwr too high flag
hdr.len - 4	TXstat.Range	TX range value setting: b2:b0 - range value b7:b3 - unused

byte index	byte variable, all variables start with **USBmsg2host.name.**	Description
hdr.len - 3	TXstat.Shunt	b0 is shunt1 status b1 is shunt2 status 0 = Off, 1 = On b7:b2 - unused
hdr.len - 2	TXstat.RFpwr	b3:b0 = Transmitter RF TX power level setting b7:b4 - unused
hdr.len - 1	TXstat.Misc	b0 – bad/unknown command or parameter received b1 – CalErr, error during auto calibration process b2 – CalDflt, non-volatile memory error, using default calibration values b3 – CfgDflt, non-volatile memory error, using default configuration parameters b7:b4 – unused
hdr.len	TXstat.SPS	b3:b0 – sample rate code 1 = 50 samples/sec 4 = 500 samples/sec 7 = 5000 samples/sec b7:b4 – low nibble of Streaming minutes remaining value
hdr.len + 1	TXstat.Stream	High 8 bits of Streaming minutes remaining value.

Table 10: Analog Output Expansion Board hdr.exp[ ] parameters

hdr.exp[] byte index	name inside program	description
[0]	mEXtype	b7 – update expansion board configuration flag. Always write to this index after all other necessary indexes have been written. When b7 of index 0 is written as a '1', it triggers the RX20K to process the data in the 8 expansion configuration bytes. 0x00 = analog output; write to 0x80 last to trigger config
[1]	mAOcfg	AO configuration bits: b7:b4 – unused b3 – reverse output polarity b2:b0 - analog output voltage: 0b000 - ±10V 0b001 - 0 to 10V 0b010 - ±5V 0b011 - 0 to 5V 0b100 - ±3V
[2]	mAOoffLB	signed offset value normalized for the 0.2mV/V range, low byte
[3]	mAOoffHB	signed offset value normalized for the 0.2mV/V range, high byte
[4]	mAOscale	unsigned scale factor, fixed point between b6 and b5

Note: When there is no transmitter data available, all samp[ ] data is absent from the message and all TXstat bytes are 0x00. It is allowable for the number of samples contained in a message to be any value from 0 to 100. Normally, only values of 0 or 100 are used.

5.3 USB Host to RX20K Commands

Table 11 - USB host to RX20K Command Format.

Command Description	byte0 cmd code	byte1	byte2	byte3 chksum
Read checksums byte 1 – 0x00 Forces bootloader checksum to be output in block header bytes Debug0 and program checksum to be output in Debug1 byte 2 not used (0x00) byte 1 – 0x01 Cancel pending save of non-volatile parameters (used during TX scan) byte 2 not used (0x00)	0x40			chksum

Command Description	**byte0 cmd code**	**byte1**	**byte2**	**byte3 chksum**
Expansion board configuration byte 1 - Expansion board parameter index byte 2 - Expansion board parameter value byte 1 - Index [0] is always the Expansion board type with a byte 2 value: 0xff = no expansion board 0x80 = analog output Valid index values are 0 through 7. Writing a value for index 0 with bit 7 of byte 2 set triggers updating the expansion board configuration. Always write to all other necessary indexes before triggering an update of expansion board configuration. See tables of expansion board specific parameters for index values and corresponding byte 2 parameters.	0x50			chksum

Command Description	**byte0 cmd code**	**byte1**	**byte2**	**byte3 chksum**
Speed input configuration byte1 – Speed input configuration b7:b4 - #bits to right shift sync timer value. b3:b0 - #bits to right shift speed timer value. Speed timer measures the period between negative speed input edges. Sync timer measures the time from the start of the previous block message to the first negative speed input edge.	0x60		0x00	chksum
Receiver RF transmit power control byte1 - RF power level to set (0 to 14)	0x61		0x00	chksum
Receiver RF channel control byte 1 – RF channel to set (0 to 15) value = RF channel (1 to 16) – 1, add 128 to value for multiple transmitters (in other words, set bit 7 of byte 1)	0x62		0x00	chksum

Command Description	**byte0 cmd code**	**byte1**	**byte2**	**byte3 chksum**

Receiver Input Source control
byte 1 - Input source value (0 to 7)
 	
`0 - transmitter (default)`
`1 - forced output value = +1/4FS`
`2 - forced output value = +1/2FS`
`3 - forced output value = +FS`
`4 - forced output value = 0`
`5 - forced output value = -1/4FS`
`6 - forced output value = -1/2FS`
`7 - forced output value = -FS`
	0x65		0x00	chksum

Command Description	**byte0 cmd code**	**byte1**	**byte2**	**byte3 chksum**

Receiver RF communications
 	
byte1 – Operational mode
Block = 0, Stream = 1, Standby = 2
 	
byte2 – Block and Standby Mode byte2 is same as System RF communications (both RX and TX) below (cmd code 0x9a)
 	
`value     baud`
`samples/sec`
`0 (0x71)  250K  50`
`1 (0x74)  250K  500 (default)`
`2 (0x77)  250K  5000`
 	
If already in standby, sending the standby command with the same byte2 value starts the wake process. Sending the standby command with a new byte2 value updates the baud/sps that will be used but does not start the wake process.
 	
If the standby wake process is active, sending the standby command with any byte2 value cancels the active process.
 	
byte2 - Stream Mode: ignored
	0x6a			chksum

Command Description	**byte0 cmd code**	**byte1**	**byte2**	**byte3 chksum**
System control: byte1 - RFU byte2 1 = Reset TT20K Transmitter 2 = Reset TT20K System	0x90	0x00		chksum
System RF channel control byte 1 – RF channel value to set (0 to 15) value = RF channel (1 to 16) - 1	0x92		0x00	chksum

Command Description	byte0 cmd code	byte1	byte2	byte3 chksum

System RF communications (both RX and TX)
 	
byte1 – Low nibble:
Operational mode
Block = 0, Stream = 1, Standby = 2
 	
byte1 upper nibble – Stream mode:
Duration value most significant 4 bits.
Block: set to 0
Standby: set to 0xF
 	
byte2 – Block mode:
`value baud samples/sec`
`0 (0x71) 250K 50`
`1 (0x74) 250K 500 (dflt)`
`2 (0x77) 250K 5000`
 	
byte2 – Stream mode:
Streaming duration value low 8 bits. A duration value of 0 means continue until power loss. Once in Stream mode, no commands are accepted until the duration expires or transmitter power is cycled. The baud rate is always 250K and sample rate is 5000. At the termination of Stream mode the transmitter enters Block mode 25K baud and 500 sps. Stream mode is designed to drive optional analog output circuitry but it also continues to transmit digital data in block format over the USB connection.
 	
byte2 – Standby mode:
`0xFF = enter Standby mode`
	0x9a			chksum

Command Description	**byte0 cmd code**	**byte1**	**byte2**	**byte3 chksum**
Transmitter shunt and range control byte1 bits, shunt control b7:b2, not used b1 – shunt 2, 0 = OFF, 1 = ON b0 – shunt 1, 0 = OFF, 1 = ON byte2, transmitter range value (mV/V * 1ue) 1 = 0.2 2 = 0.5 3 = 1 4 = 2 5 = 5 6 = 10 7 = 20	0xa0			chksum
Transmitter RF power control byte 1 – RF power level to set (0 to 15)	0xa1		0x00	chksum

Notes:

The chksum value is the low byte of the sum of byte0, 1, and 2.

The CmdAck and CmdNak bits in `USBmsg2host.name.hdr.RXstat` serve as an acknowledgement to USB host messages sent to the RX20K.

The baud rate, sample rate and transmitter range parameters are saved in non-volatile memory and retained through power loss.

Appendix A: System Specifications

Description of system specifications.

TX20K Transmitter Specifications

Power input	6.0 ~ 20VDC
Current draw	See section 2.2.10
Antenna	Internal
Operating temperature range	-40 to +85°C (Ultralife 9V lithium battery -40 to +60°C)
Size	26w x 16h x 52 lg mm (1.03"w x 0.64"h x 2.03"lg)
Weight	35g
G force	3000Gs
Operating Frequencies	902 ~ 928MHz band see RF channels in Table 1
Excitation voltage	3.0V, Precision reference: 0.1%, 20ppm/°C
Excitation current	12.5mA (max)
Gage resistance	240Ω (min)

RX20K Receiver Specifications

Power input	USB powered (5VDC @ 60mA main board only)
Antenna input connection	SMA
Operating temperature range	-40 to +75°C
Size	70w x 37h x 134lg mm (2.76"w x 1.46"h x 5.28"lg)
Weight	230g
Operating Frequencies	902 ~ 928MHz band see RF channels in Table 1
Digital Output connection	USB 2.0 Full Speed compatible, type B receptacle, using FTDI FT230X USB to UART IC @ 1Mbaud, 8 data bits, odd parity, 1 stop bit, RTS/CTS hardware flow control

Serial Output Digital communication protocol	See paragraph 5 above.
Speed sensor power	4.2V @ up to18mA. Current draw for the speed sensor adds to the system USB 5V current draw.
Speed sensor signal input	10K ohm pull-up to 3.3V. Maximum input freq 10KHz
Speed sensor example	Spectec 0158M-2-2-2-1-5. There are many variations. www.spectecsensors.com
Analog output board power	Powered by the RX20K main board from USB 5V. Adds approximately 70mA plus maximum output load current.
Analog output ranges	±3, ±5, ±10, 0 to 5, 0 to 10V
Analog output impedance	325 ohms
Analog output offset adjustment range	Half of full scale output.
Analog output scale adjustment range	8 bit fixed point value with 2 bit integer word length. 0.015625 to 3.984375

Appendix B: Calibration Calculations

The equations in this Appendix define the relationship between the input signal to the TX20K Transmitter (typically from a strain gage) and the Full Scale output voltage of the TorqueTrak 20K System. The calculations are based on parameters of the device being measured (e.g. shaft diameter), sensor parameters (e.g. gage factor) and Transmitter Gain setting.

Section B1 is specific to torque measurements on round shafts (full bridge, 4 active arms).

Section B2 applies to axial strain (tension/compression) measurements on round shafts (full bridge, 2.6 active arms).

Section B3 is for use with a single grid (1/4 bridge).

1 με is distortion of the shaft surface 1 x 10^{-6} in/in. For more technical information regarding the relationship between shear strain and torque, see the excellent technical article TN-512 published by Vishay.

Torque on Round Shafts

Step 1: Calculate Full Scale Torque, T_{FS} (ft-lb)

The Full Scale Torque corresponds to a system output of 10 V. For a solid steel shaft, use the calculator on our website at www.binsfeld.com or use the simplified equation below:

$$\frac{(1510.38 \times 10^3 \text{ ft-lb/in}^3)(D_o^3)}{(GF)(G_{XMT})} = T_{FS} \text{ (ft-lb)}$$

For all other shafts use the more general equation:

$$\frac{(V_{FS})(\pi)(E)(4)(D_o^4 - D_i^4)}{(TX_{const})(GF)(N)(16)(1+\nu)(G_{XMT})(D_o)(12)} = T_{FS} \text{ (ft-lb)}$$

For metric applications with D_o and D_i in millimeters and T_{FS} in N-m, the general equation is:

$$\frac{(V_{FS})(\pi)(E)(4)(D_o^4 - D_i^4)}{(TX_{const})(GF)(N)(16000)(1+\nu)(G_{XMT})(D_o)} = T_{FS} \text{ (N-m)}$$

Where E= 206.8×10^3 N/mm^2

Legend of Terms	
D_i	Shaft Inner Diameter (in) (zero for solid shafts)
D_o	Shaft Outer Diameter (in)
E	Modulus of Elasticity (30×10^6 PSI steel)
GF	Gage Factor (specified on strain gage package)
G_{XMT}	Telemetry Transmitter Gain (user configurable, typical is 4000 for ±500 microstrain range)
N	Number of Active Gages (4 for torque)
T_{FS}	Full Scale Torque (ft-lb)

TX_{const}	Transmitter constant = 2.5V
V_{FS}	Full Scale Output of System = 10 volts
ν	Poisson's Ratio (0.30 for steel)

For example, given a solid steel shaft with:

D_O (shaft Outer Diameter, measured) = 3.000 inches

GF (Gage Factor from gage package) = 2.08

G_{XMT} (TX10K Gain setting) = 4000

$$T_{FS} = \frac{(1510.38 \times 10^3 \text{ ft-lb/in}^3)(3.000 \text{ in})^3}{(2.08)\ (4000)} = 4{,}901 \text{ ft-lb}$$

so 10 V output from the RX20K indicates 4,901 ft-lb of torque or 490.1 ft-lb/volt.

Step 2: *Scale the Full Scale Output*

If desired, the Full Scale voltage output of the TX20K can be scaled so that it corresponds to a convenient torque value, e.g. 100 ft-lb /volt. As stated earlier, the System Gain can be adjusted from ¼ to 4 times the Transmitter Gain. The equation below defines the Scale Factor (Z):

$$Z = \frac{T_{FS}}{T_{REF}}$$

Legend of Terms	
Z	Scale Factor (0.25 to 4.0)
T_{FS}	Full Scale Torque (ft-lb)
T_{REF}	Reference Full Scale Torque (ft-lb)

In the example from Step 1 above, Full Scale Torque (T_{FS}) has been calculated to be 4,901 ft-lb. It may be convenient to scale the output so that 10 V indicates 5,000 ft-lb (1 V = 500.0 ft-lb). First, calculate the Scale Factor (Z):

$$\frac{4{,}901 \text{ ft-lb}}{5{,}000 \text{ ft-lb}} = Z = 0.9802$$

Next, multiply the Scale Factor times the Transmitter Gain setting to find the System Gain setting.

$$4000 \times 0.9802 = 3920$$

Scroll to the Gain parameter screen on the RX20K and set the System Gain to 3920. In summary:

Before adjusting full scale output:

4,901 ft-lb = 10.000 V (490.1 ft-lb/volt)

After adjusting full scale output:

5,000 ft-lb = 10.000 V (500.0 ft-lb/volt)

Step 3: Calibrate the Output

There are two ways to perform a calibration of the installation: a deadweight calibration or shunt calibration.

Deadweight Calibration

The most precise method is to perform a deadweight calibration. This involves suspending a known mass a known horizontal distance from the center of the shaft. This is not always practical but does take into account all possible deviation in the system (actual material properties versus data sheet, shaft geometry, gage imbalance, etc.) With the known moment applied, adjust the System Gain until the output is the same as the calculated torque value.

Using the parameters outlined in the previous example, a deadweight is applied to the gaged 3-inch shaft that corresponds to 500 ft-lb of torque. The System Gain would be adjusted until the output was equal to 1 volt. NOTE: It is recommended that in order to be meaningful, the deadweight should create a torque load close to those expected during testing. At a minimum, they should represent at least 10% of the range.

Shunt Calibration

The more common method is to perform a shunt calibration. This method takes into account deviations in the setup from the strain gage to the transmitter, but unlike a deadweight calibration, none of the deviations in the physical parameters.

The easiest way to conduct a shunt calibration is by enabling one of the reference shunt resistors on-board the TX20K. An internal precision resistor is placed in parallel with one arm of the bridge to simulate a precise strain value. As stated earlier, Reference 1 simulates 100 microstrain (µe) and Reference 2 simulates 500 µe when using a 350Ω strain gage with a Gage Factor of 2.0. Alternatively, precision resistors can be placed in parallel with one arm of the bridge to simulate a torque load. The Tech Info section on our website (www.binsfeld.com) has a helpful Torque Strain Calculator to assist in determining the strain a given resistor value simulates. The equation relating strain and shunt resistance is shown below:

$$R_C = \frac{R_G}{(N)(GF)(\varepsilon)}$$

Legend of Terms	
R_C	Shunt Calibration Resistance (kΩ)
R_G	Gage Resistance (Ω)
N	Number of Active Gages
GF	Gage Factor
ε	Strain (µe)

In the example from Steps 1 & 2, the Full Scale Torque is 4,901 ft-lb and the RX20K output has been scaled so that 10 V corresponds to a torque load of 5,000 ft-lb by setting the System Gain to 3920. This was determined by multiplying the Transmitter Gain of 4000 (±500 µe range) by the Scale Factor (Z) that was calculated to be 0.9802.

First, determine what the system output should be when applying the shunt resistance. In this case, Reference 1 (100 µe) is a good choice (20% of Full Scale). To calculate the calibrated output of the system, use the equation below:

$$V_S = \left(\frac{\varepsilon_S}{\varepsilon_{FS}} \right) (Z)(V_{FS})$$

Legend of Terms	
V_S	Voltage Output with Shunt Applied (V)
ε_S	Strain Simulated by Shunt (µe, GF = 2.0)
ε_{FS}	Full Scale Strain (µe, GF = 2.0)
Z	Scale Factor (one if no scaling)
V_{FS}	Full Scale Voltage Output (V) (10V)

In this example, with Reference 1 applied, the calibrated Voltage Output would be calculated as follows:

$$\left(\frac{100\ \mu e}{500\ \mu e} \right) (0.9802)\ (10\ V) = V_S = 1.9604\ V$$

Adjust the System Gain setting until the output matches this value. The adjustment is typically small (<0.5%). The system is now ready to measure torque with the desired output scaling.

NOTE: When the Gage Factor is not 2.0, the actual Full Scale Strain and Simulated Strain values are affected proportionately. In the example above with a Gage Factor of 2.08, Full Scale Strain is technically 480.7µe, not 500. However, the Simulated Strain is likewise affected (Ref 1 becomes 96.14µe, not 100). The ratio of Simulated Strain to Full Scale Strain remains constant (20%) and the calculation above remains valid.

Also, if the gage resistance is not 350Ω, the Reference 1 & 2 Simulated Strain values are not 100 and 500 µe, respectively. Use our online calculator or the equation on page 33 to calculate the simulated strain in this instance (use GF = 2.0).

Appendix C: Strain Gage Installation

View BEI's online Strain Gage Installation Training videos at
www.binsfeld.com/torquetrak/torquetrak-revolution/training-videos.html

(Also refer to instruction bulletin B-127-12 provided with GAK-2-200 Strain Gage Application Kit from Vishay Measurements Group, Inc., Raleigh, NC, 919-365-3800, www.measurementsgroup.com.)

PREPARING THE SURFACE

1. A 3-inch square area will be used for gaging. Scrape off any paint or other coatings and inspect shaft for oil residue. If necessary, use a degreasing solution or isopropyl alcohol to remove.
2. Rough sand the gaging area with 220 grit paper. Finish the sanding procedure by wetting the gaging area with M-Prep Conditioner A and the wetted surface with 400 grit paper provided. Rinse by squirting with M-Prep Conditioner A. Wipe the area dry with tissue taking care to wipe in only one direction. Each time you wipe use a clean area of the tissue to eliminate contamination.
3. Rinse shaft this time by squirting with M-Prep Neutralizer 5A. Wipe the gaging area dry with a clean tissue, wiping in only one direction and using clean area of tissue with each wipe. Do not allow any solution to dry on the surface as this may leave a contaminating film which can reduce bonding. Surface is now prepared for bonding.

MARKING THE SHAFT FOR GAGE ALIGNMENT

4. The gage needs to be perpendicular to the shaft axis. In general, this can be accomplished by eye since misalignment of less than 4 degrees will not generate significant errors. For higher precision, we recommend two methods for marking the shaft:
   a. Use a machinist square and permanent marker or scribe for perpendicular and parallel lines; or
   b. Cut a strip of graph paper greater than the circumference of the shaft. Tape it to the shaft while lining up the edges. Mark desired gage position with a scribe or permanent marker.

PREPARING THE GAGE FOR MOUNTING

5. Using tweezers, remove one gage from its package. Using the plastic gage box as a clean surface, place the gage on it, bonding side down. Take a 6” piece of PCT-2M Mylar Tape and place it on the gage and terminal, centered. Slowly lift the tape at a shallow angle. You should now have the gage attached to the tape.

POSITIONING THE GAGE

6. Using the small triangles located on the four sides of the gage, place the taped gage on the shaft, perpendicular with the shaft axis, aligned with your guide marks. If it appears to be misaligned, lift one end of tape at a shallow angle until the assembly is free to realign. Keep one end of the tape firmly anchored. Repositioning can be done as the PCT-2M tape will retain its mastic when removed and therefore not contaminate the gaging area.

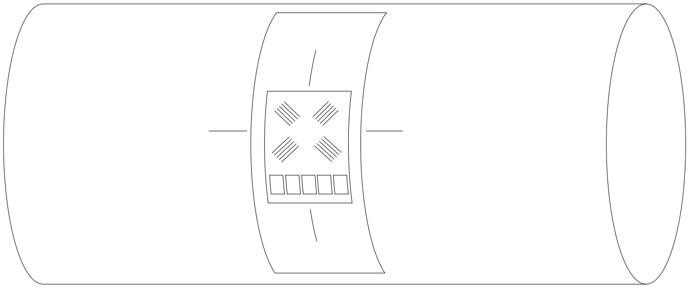


Figure 1, Strain gage mounting

POSITIONING THE GAGE ON THE SHAFT

7. Gage should now be positioned. Once again, lift the gage end of the tape at a shallow angle to the surface until the gage is free of the surface. Continue pulling the tape until you are approximately 1/8” – 1/4” beyond gage. Turn the leading edge of the tape under and press it down, leaving the bonding surface of the gage exposed.
8. Apply a very thin, uniform coat of M-Bond 200-Catalyst to the bonding surface of the gage. This will accelerate the bonding

when glue is applied. Very little catalyst is needed. Lift the brush cap out and wipe excess on lip of bottle. Use just enough catalyst to wet gage surface. Before proceeding, allow catalyst to dry at least one minute under normal ambient conditions of + 75°F and 30-65% relative humidity.

NOTE: The next three steps must be completed in sequence within 3 – 5 seconds. Read through instructions before proceeding so there will be no delays.

Have Ready:
M-Bond (Cyanoacrylate) Adhesive
2” – 5” piece of teflon tape
Tissues

MOUNTING THE GAGE

9. Lift the leading edge of the tape and apply a thin bead of adhesive at the gage end where the tape meets the shaft. Adhesive should be of thin consistency to allow even spreading. Extend the line of glue outside the gage installation area.
10. Holding the tape taut, slowly and firmly press with a single wiping stroke over the tape using a teflon strip (to protect your thumb from the adhesive) and a tissue (to absorb excess adhesive that squeezes out from under the tape). This will bring the gage back down over the alignment marks on the gaging area. This forces the glue line to move up and across the gage area. A very thin, uniform layer of adhesive is desired for optimum bond performance.
11. Immediately, using your thumb, apply firm pressure to the taped gage by rolling your thumb over the gage area. Hold the pressure for at least one minute. In low humidity conditions (below 30%) or if ambient temperature is below + 70° F, pressure application time may have to be extended to several minutes.
12. Leave the mylar tape on an additional five minutes to allow total drying then slowly peel the tape back directly over itself, holding it close to the shaft while peeling. This will prevent damage to the gages. It is not necessary to remove the tape immediately after installation. It offers some protection for the gaged surface and may be left until wiring the gage.

WIRING THE GAGE

13. Tin each solder pad with a solder dot. (It is helpful to polish the solder tabs, e.g. with a fiberglass scratch brush or mild abrasive, before soldering.) Trim and tin the ends of the 4-conductor ribbon wire. Solder the lead wires to the gage by placing the tinned lead onto the solder dot and pressing it down with the hot soldering iron. Note: For single-stamp torque gages, a short jumper is required between solder pads 2 and 4 as shown in the diagram on the next page
14. Use the rosin solvent to clean excess solder rosin from the gage after wiring. Brush the gage pads with the solvent and dab with a clean tissue.
15. Paint the gage area (including the solder pads) with M-Coat A polyurethane and allow to air dry 15 minutes. This protects the gage from moisture and dirt. To further protect the gage, apply M-Coat J protective coating for protection against moisture, fluids and mechanical damage.

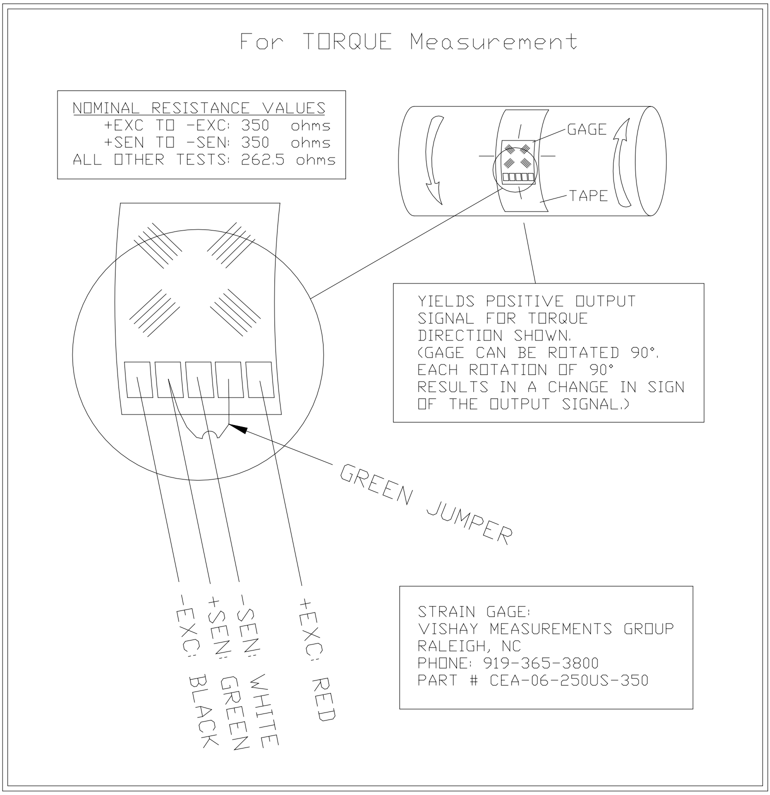
16. 

Figure 2, Strain gage wiring

Warranty and Service Information

Limited Warranty

Binsfeld Engineering Inc. warrants that its products will be free from defective material and workmanship for a period of one year from the date of delivery to the original purchaser and that its products will conform to specifications and standards published by Binsfeld Engineering Inc. Upon evaluation by Binsfeld Engineering Inc., any product found to be defective will be replaced or repaired at the sole discretion of Binsfeld Engineering Inc. Our warranty is limited to the foregoing, and does not apply to fuses, paint, or any equipment, which in Binsfeld Engineering's sole opinion has been subject to misuse, alteration, or abnormal conditions of operation or handling.

This warranty is exclusive and in lieu of all other warranties, expressed or implied, including but not limited to any implied warranty of merchantability or fitness for a particular purpose or use. Binsfeld Engineering Inc. will not be liable for any special, indirect, incidental or consequential damages or loss, whether in contract, tort, or otherwise.

NOTE (USA only): Some states do not allow limitation of implied warranties, or the exclusion of incidental or consequential damages so the above limitations or exclusions may not apply to you. This warranty gives you specific legal rights and you may have other rights which vary from state to state.

For service please contact Binsfeld Engineering Inc.:

4571 W. MacFarlane Road
Maple City, MI 49664
Phone: (+1) 231-334-4383
Fax: (+1) 231-334-4903
Internet: www.binsfeld.com
Email: sales@binsfeld.com

FCC Rules Part 15: Computing Devices

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

In order to maintain compliance with FCC regulations, shielded cables must be used with this equipment. Operation with non-approved equipment or unshielded cables is likely to result in interference to radio and TV reception.

The user is cautioned that changes and modifications made to the equipment without the express approval of the manufacturer could void the user's authority to operate this equipment.

This device complies with Part 15 of the FCC rules.
Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference that may cause undesired operation of the device.