TorqueTrak TPM2
Torque and Power Monitoring System

User’s Guide

866600-9_E

Contents

This document is subject to change without prior notification.

1 System Overview

The TorqueTrak Torque and Power Monitoring System Generation 2 (*TPM2*) is a rugged precision instrument designed for applications where ongoing measurement of torque and/or power on a rotating shaft is required.

System Features include:

- Digital design inherently immune to electrical noise.
- Non-contact inductive power and data transfer eliminates wear surfaces for long life without signal degradation.
- Installation does not require shaft modification or machine disassembly.
- Built-in shunt system calibration.

New features:

- Single turn transmitter and stationary ring with a minimum number of connections and high reliability.
- Fully encapsulated electronics for high reliability.
- Eight user selectable input ranges from 0.25 to 32 mV/V (125 to 16000 microstrain with gage factor of 2.0).
- RS-422 serial communications from stationary interface for long distance error free data transmission to system monitoring and display equipment.
- 15 bit signed strain value, 16 bit signed speed value, and 24 bits of status information contained in every data sample.
- Four dual color LEDs on stationary interface for system status and error indication in addition to status information contained in the RS-422 serial communications data.

1.1 System Components

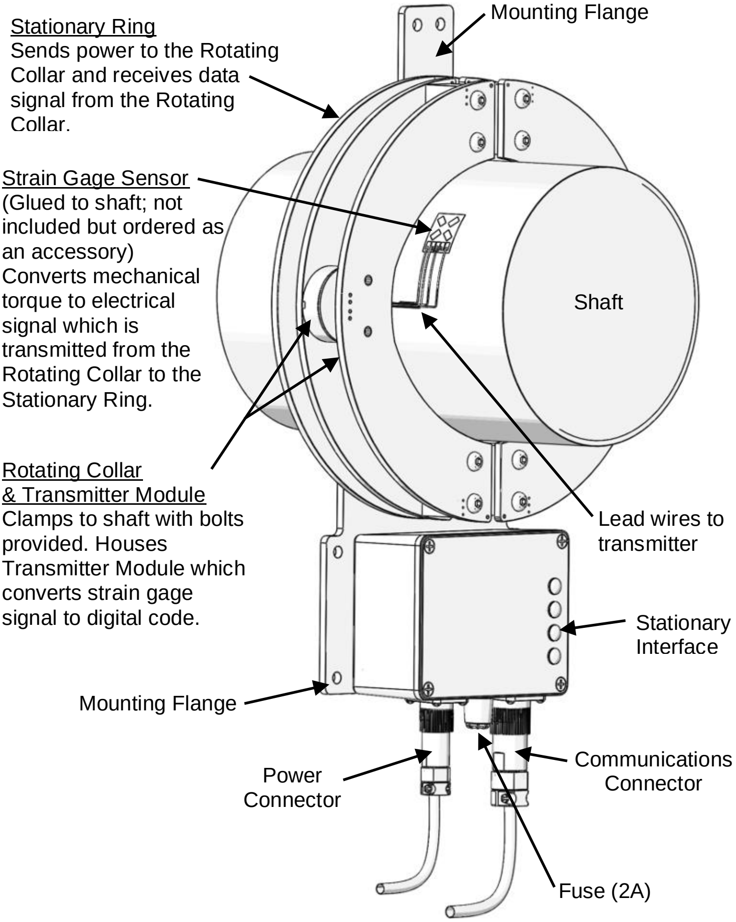


Figure 1 - System Components

Refer to TPM2 Specifications in Appendix A: TPM2 Specifications

1.1.1 Rotating Collar Assembly

The transmitter is part of the rotating collar assembly mounted on the shaft near the strain gage. The transmitter supplies power to the gage, measures and digitizes the gage signals, and transmits the digitized signals to the stationary interface. The transmitter is powered inductively from the stationary ring.

1.1.2 Stationary Interface

The stationary interface generates power for, and receives data from the transmitter. The stationary interface then communicates the data to a connected host device through a dedicated bi-directional RS-422 interface.

2 Installation

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 end user is responsible for the proper installation and operation of this device. Improper installation or operation could result in damage, injury or death.

Certain environments could cause damage or degradation to the components of the system resulting in mechanical failure.

The TPM2 system must be sealed by the installer for operation in wet/harsh environments.

Mechanical failure could cause parts to detach from the shaft and fly off at high speeds. These flying parts could cause equipment damage, bodily injury and possibly death. Keep equipment and personnel away from areas where parts flung from the shaft could enter.

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

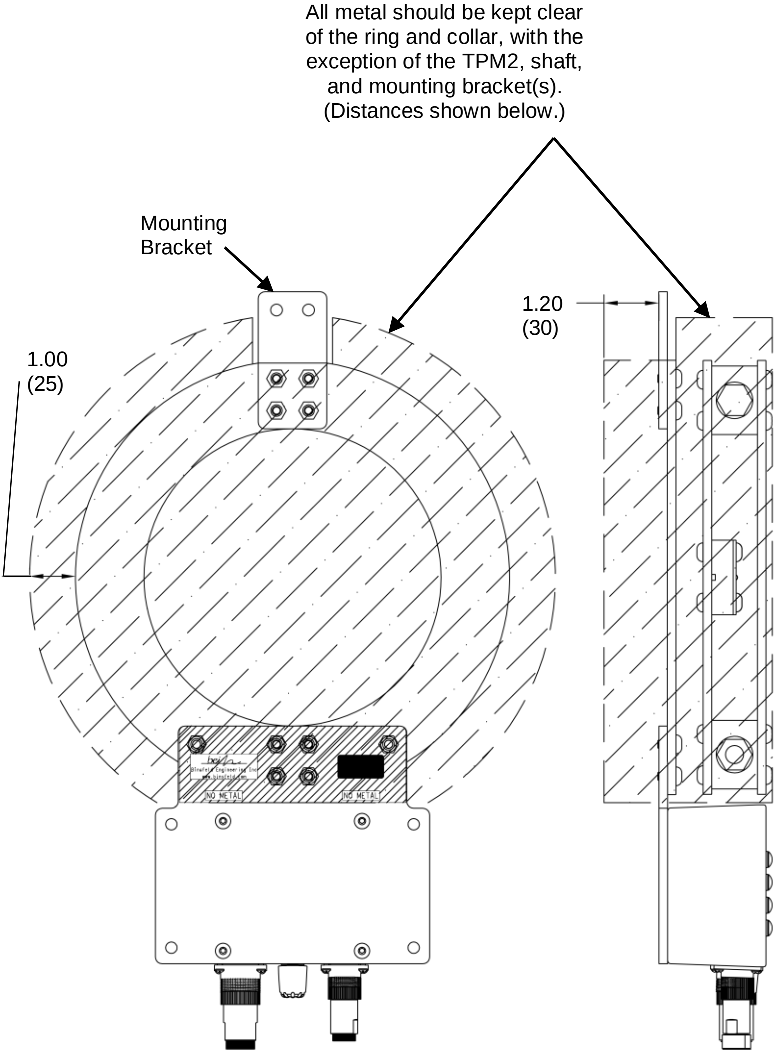


Figure 2 - Metal Interference Area

Make sure there is proper rotor-stator spacing before rotating the shaft.

Make sure the TPM2 is properly installed and clear of all obstructions before rotating the shaft.

Keep clear of the machinery while the shaft is rotating.

Each TPM2 is custom made to fit a certain shaft size range. Therefore the shaft diameter must be specified at time of order. Do not try to adapt the TPM2 to a shaft size outside its intended range of operation.

2.1 Rotating Collar Installation

If there is any damage to the rotating collar (gouges, chips, cuts, cracks, etc.) IMMEDIATELY DISCONTINUE USE, remove from the shaft and contact BEI for a replacement.

The Rotating Collar must be installed on a smooth, clean area of the shaft.

DO NOT operate the rotating collar at rotational speeds exceeding specifications listed in Appendix “F”.

DO NOT mount the rotating collar directly over the strain gage.

DO NOT substitute mounting hardware. Use only the supplied mounting hardware for installation. Contact BEI for replacement mounting hardware.

DO NOT remove the Counter-Weight/Magnet or loosen its screws.

Use the supplied thread lubricant as indicated.

Use Threadlocker (Loctite 242) supplied as indicated.

Should removal of the transmitter be necessary, reinstall with #242 Loctite applied to the threads of M-6 screws.

Install the rotating collar assembly with the ring surface on which the transmitter is mounted, nearest to the stationary ring.

Apply anti-seize compound to the threads of all M-10 collar bolts prior to assembly.

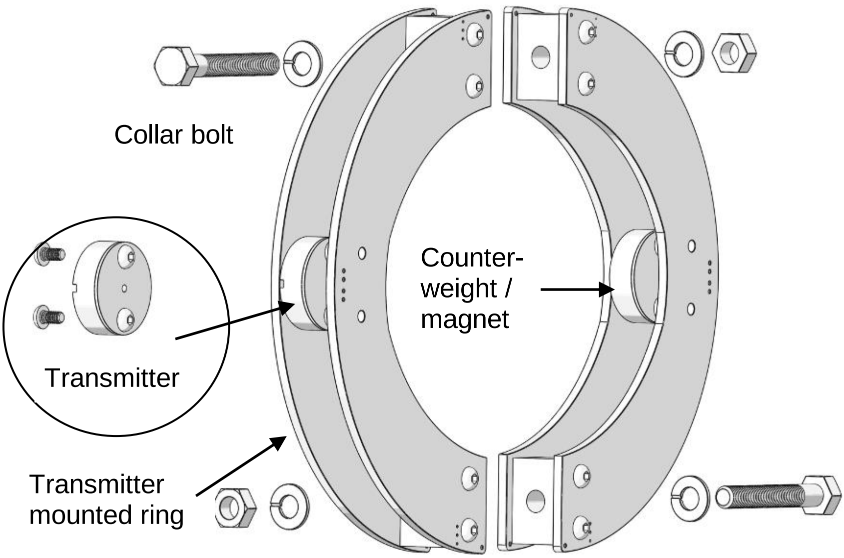


Figure 3 - Rotating Collar Installation

Alternately tighten the collar bolts, keeping the gaps between the rotating collar sections equal, until specified bolt torque is reached.

Table 1: Torque Specifications

Description	**Type**	**N-m**	**ft-lbs**	**in-lbs**
Collar bolts	M10 -1.5 class 10.9	20	15	180
Transmitter screws	M5-0.8 class 10.9	6.2	4.6	55
Stator Coil PCB	M6	3.6	2.7	32

Make sure the rotating collar is mounted squarely on the shaft and does not wobble.

The rotating collar bolts and transmitter mounting screws must be tightened for proper system operation since power for the Transmitter is conducted through these fasteners.

Make sure there is proper rotor-stator spacing before rotating the shaft.

2.2 Stationary Ring and Stationary Interface Installation

The TPM2 enclosure is only sealed when the mating connectors/cables are attached.

> In other words: Do not expose to adverse conditions (liquids) if connectors/cables are disconnected.

The TPM2 stationary interface requires a custom fabricated mount to hold it securely in place. Refer to Appendix D: Dimensions, for mounting flange dimensions necessary to create a custom mounting bracket. Figure 2 provides information about rotor-to-stator spacing guidelines and a metal interference area that should be kept clear of all other metal.

Generally it is a good idea to mount the stationary interface with the cable connections pointing down to minimize the exposure of the connectors to contaminants, but axially rotated orientations are acceptable as dictated by available space and other application specific considerations. The mounting should secure the stationary interface and power ring as rigidly as possible.

2.2.1 Stationary Interface Connections

2.2.1.1 Power Connection

The TPM2 comes with a standard 10ft (3m)[1] power cable terminated at one end with a rugged metal sealed circular 3 pin connector. The other end is un-terminated and must be connected by the end user to a 24VDC regulated power supply (a range from 10 to 30VDC is acceptable) with a maximum current of 2 amps and typical operating current of 0.5 amps. Actual operating current depends on the power supply voltage (lower voltages require more current), and the efficiency of the inductive power transfer to the rotating collar.

The power is fused at the TPM2 Stationary interface with a 5_x_20mm 2 amp fast blow fuse. The standard supplied power cable is 16awg shielded twisted pair with a resistance of 4.2mΩ/ft. Be sure to take into account the resistance and added voltage drop of any additional wire connected between the power supply and the TPM2 (for instance between an intermediate junction box and a control cabinet).

The three pin TPM2 power connector has the following pinout and color code:

Table 2: Stationary Interface Power Cable

Pin#	Wire Color	Signal Description
1	RED	+24VDC (10 to 30VDC is acceptable), 15 watt max, 10 watt typical
2	BLK	Power Supply common
3	CLR	TPM2 chassis (connected to aluminum enclosure)

The internal power supply of the TPM2 is isolated from its aluminum enclosure so for safety and to reduce electrical noise, the CLR conductor in the power cable should be terminated to chassis ground (cabinet, frame or earth ground) at the user terminated end.

[1] Contact Binsfeld Engineering for other cable lengths.

2.2.1.2 Communications Connection

The TPM2 comes with a standard 10ft (3m) communications cable terminated at one end with a rugged metal sealed circular 7 pin connector. The other end must be field terminated by the end user.

Communication distances of over 1000ft (300m) are possible with proper cabling and installation. Slower baud rates generally allow for the longest possible cable lengths. When long cable lengths are required, use the lowest baud rate possible for the desired sampling rate.

The recommended RS-422 interface for connecting a PC USB port to the TPM2 communications connector is the model USOPTL4-LS isolated, locked S/N converter from B&B Electronics; http://www.bb-elec.com.

Any RS-422 interface should work but may not work with the standard BEI TPM2 Configuration and Monitoring software. Be aware that the baud rate must be set high enough to support the desired output sample rate. Please see the TPM2 Communications Specification document for detailed information.

DIP switch settings for the USOPTL4-LS (back side):

1 - RS-422
2 - Echo ON or OFF, does not matter
3 - 4 Wire
4 - 4 Wire

The 7 pin TPM2 communications connector has the following pinout and color code:

Table 3: Stationary Interface Communications Cable

Pin#	Wire Color	Signal Description
1	BLU/WHT	RX+, connect to USOPTL4-LS TDB+
2	WHT/BLU	RX-, connect to USOPTL4-LS TDA-
3		common
4	CLR	common, connect to USOPTL4-LS GND
5		common
6	WHT/ORN	TX-, connect to USOPTL4-LS RDA-
7	ORN/WHT	TX+, connect to USOPTL4-LS RDB+

NOTE: Wire colors specified in the format XXX/ZZZ have a primary color of XXX and a stripe color of ZZZ.

2.2.2 Stationary Ring Installation

After securely mounting the stationary interface to its bracket, assemble and mount the stationary ring around the shaft. Mount the ring on top of the surface of the stationary interface mounting flange labeled “FRONT” with the surface of the ring that is labeled “FRONT” also facing to the front. Mount the ring splice tabs in the same plane as the mounting flange (on the back side of the ring). When the “FRONT” label on the mounting flange and the “FRONT” label on all the ring pieces and splice tabs can be read from the same side, it is mounted correctly. Tighten all ring assembly screws as specified in Table 1.

3 System Operation and LED Descriptions

3.1 Stationary Interface

Figure 4 - Stationary Interface Faceplate

3.1.1 Startup Operation

Immediately after power-up, internal operation is tested. If the test fails, only the red *Torque LED* is turned ON solid and remains so until power is removed.

If the test passes, the red *Torque LED* flashes at a rate of 5Hz for 1/2 second. The green *Rotor LED* flashes opposite the red *Torque LED*. The internal firmware of the Stationary Interface can be updated if special programming messages are received during this time period.

If no programming messages are detected, normal operation continues starting with a test of the indicator LEDs. First, all red LEDs are turned ON for 1 second then turned OFF. Next, all green LEDs are turned ON for 1 second and then turned OFF. After the LED test, normal LED operation commences.

3.1.2 Normal Operation

Following Startup, the Inductive Interface varies inductive power from high to low seeking to establish communications with the rotor. The green *Stator LED* flashes with a frequency of 2.34Hz and a duty cycle (ON time relative to OFF time) that is proportional to the power level. The greater the ratio of the ON to OFF duration of the green *Stator LED*, the higher the inductive power.

The *Rotor LED* becomes solid green to indicate that the rotor power supply voltage is within its target range. At that point the *Stator LED* stops indicating the inductive power level and begins indicating stator power and connected device communications status.

3.1.3 Stator LED

The *Stator LED* has two modes during normal operation. Typically it operates as an indicator for the status of Stator main regulated voltage, main regulator over current, power amplifier over temperature, and connected device communications. It also indicates the output power level while it varies to produce the required transmitter voltage level. When the *Rotor LED* is flashing, the stator is adjusting and indicating the output power level.

The *Stator LED is solid green* when stator power supply voltage is in range, the power supply current is under the over current threshold, the power amplifier is below the over temperature threshold, and no communications errors exist with the connected device. The acceptable stator power supply range is 10 to 30 volts DC.

Auto baud rate detection of the RS-422 connection is a feature of the TPM2. Requirements are defined in the TPM2 Communications Specification that allow the TPM2 to properly and accurately determine the baud rate being used. While operating in Auto Baud Rate Detection mode, the *Stator LED flashes green with a 50% duty cycle at 5Hz*.

The *Stator LED will change to red* while power supply voltage, power supply over current, power amplifier over temperature, or communications errors exist. Communications errors are UART errors like framing, parity, checksum, and buffer overrun. As soon as the error condition clears, the LED returns to solid green.

Power supply over current errors begin to appear when an over current condition is sensed for more than 2 seconds. When over current errors are detected the *Stator LED is red*. If the error condition lasts for more than 3 seconds, an over current fault is triggered and inductive power for the transmitter is shut OFF for 7 seconds, during which the *Stator LED remains red*. After the 7 second OFF period expires, inductive power is re-enabled and adjusted. If over current is detected again, the cycle repeats.

Power amplifier over temperature errors begin to appear whenever the sensed amplifier section temperature exceeds the over temperature threshold. While over temperature errors exist, the *Stator LED is red*. If the condition remains for more than 1 second, an over temperature fault is triggered and the inductive power is shut OFF. The inductive power is held OFF and the *Stator LED remains red* until the temperature is sensed to cool below a lower threshold temperature. Cooling could take several seconds or minutes depending on the ambient temperature around the instrument. When the power amplifier section has cooled, it is re-enabled.

3.1.4 Rotor LED

The function of the Rotor LED is to indicate the health of the inductive link between the rotor and the stator regarding power transfer and communications. It does not indicate the status of rotor measurement problems. Rotor measurement problems like signal over range are indicated in the status bits of the RS-422 data from the stator to a connected device or host.

The *Rotor LED is solid green* when rotor power supply voltage and communications are OK.

The *Rotor LED flashes (red or green)* when rotor power supply voltage is not within the normal operating window.

The *Rotor LED is red* when rotor communication errors are detected.

The *Rotor LED is off* when rotor communications are lost for 16 consecutive 4800Hz sample times.

3.1.5 Torque LED

The *Torque LED is solid green* when the rotor is communicating and the differential and common mode inputs are within range.

The *Torque LED is red* when the differential or common mode inputs are not within range.

The *Torque LED is off* when rotor communications are lost.

3.1.6 Speed LED

The *Speed LED flashes green for 200msec* for every magnet pulse detected when the pulse frequency is low. The *Speed LED flashes green for 20msec* for every magnet pulse detected when the pulse frequency is high. The low pulse frequency threshold is approximately 1.75Hz when frequency is increasing from below 0.88Hz. The low frequency threshold is approximately 0.88Hz when frequency is decreasing from above 1.75Hz.

If the duration of speed pulses becomes too short or pulse frequency is erratic, the *Speed LED flashes red* (not green).

3.2 Transmitter LED Operation

When the single green Transmitter LED is ON solid, all is OK with the transmitter.

One quick Transmitter LED pulse (about 0.1 second every 1.7 seconds) indicates transmitter voltage is detected to be outside of the normal operating range.

Two quick Transmitter LED pulses (each pulse 0.1 second duration, separated by 0.3 seconds of OFF time, repeated every 1.7 seconds) indicates the transmitter is having problems saving configuration values in memory.

A 50% duty cycle 1.2Hz flashing rate indicates that the transmitter input signal is out of range, either common mode or differential mode.

A 50% duty cycle 4.7Hz flashing rate indicates that the transmitter input reference signal is out of range.

If the Transmitter LED is OFF, the transmitter voltage is very low.

4 Communications Protocol

Bi-directional RS-422 communications are supported with the connected device but are not required. The TPM2 does not expect any data to be received from the connected device so no communications errors are declared if there is nothing connected to the RS-422 connector. In simple systems the connected device could just monitor the data sent from the TPM2 but bi-directional communications are required to configure parameters such as gain, baud rate and sample rate.

4.1 Data Byte Format

Each transmitted or received byte consists of: 1 start bit, 8 data bits, 1 parity bit (optional), 1 stop bit (minimum). The 8 data bits are transmitted least significant bit first.

5 TPM2 Stationary Interface Transmitted Data

5.1 Message Format

The TPM2 streams out samples at the selected sample rate. Each sample consists of 8 bytes as follows:

Table 4: TPM2 Stationary Interface sample transmit data

Byte	**Description**
0	Strain Gage Value (low byte)
1	Strain Gage Value (high byte)
2	Shaft Speed Value (low byte)
3	Shaft Speed Value (high byte)
4	Status Info (byte 0)
5	Status Info (byte 1)
6	Status Info (byte 2)
7	Checksum byte

5.1.1 Strain Gage Value

The combined low byte and high byte of the Strain Gage Value form a 16 bit signed integer that is used to calculate the torque strain using the equation:

$$\epsilon = (Val_{out} * 15729) / (G_{xmtr} * GF * 7864.32)$$

ϵ = strain (in units of μstrain)
Val_{out} = TPM2 output Strain Gage Value
G_{xmtr} = user selectable transmitter gain (see Table 3)
GF = gauge factor
(15729 / 7864.32) is a system derived constant

The Torque Strain value, along with the shaft parameters, allow the monitoring device to calculate the actual shaft torque in force times distance units (Newton-meters, ft-lbs, etc.) using the equation:

$$T = (\epsilon * \pi * E * (OD^4 - ID^4)) / (K_T * OD * (1 + v))$$

T = torque (N-m or ft-lbs)
ϵ = strain, (in units of μstrain)
E = modulus of elasticity of the shaft material (N/mm^2 or Mpsi)
OD = outside diameter (mm or inches)
ID = inside diameter (mm or inches)
v = Poisson's ratio of the shaft material
K_T = torque units dependent constant (for N-m, $K_T = 1.6 \times 10^{10}$: for ft-lbs, K_T = 192)

The sign of the Strain Gage Value indicates the relative torque force direction.

From the torque, the power can be calculated using the equation:

$$P = (T * 2\pi * \omega) / K_p$$

P = power
T= torque
2π is radians/revolution
ω = rotational speed (RPM)
K_p = torque units dependent power constant

Table 5: Power Constant values (K_p)

Power units	Torque units	K_p
watts	N-M	60

hp	ft-lbs	33000
hp	in-lbs	2750

5.1.2 Shaft Speed Value

The combined low byte and high byte of the Shaft Speed Value forms a 16 bit signed integer. This binary integer value is in either revolutions per minute (RPM) or hundredths of revolutions per minute (RPM x 100). The resolution of the Shaft Speed Value is indicated by the RPM_RES bit in status byte 0.

The sign of the Shaft Speed value indicates the relative direction of rotation. When looking at the front of the TPM2 Stator, a positive value indicates clockwise rotation and negative indicates counter-clockwise rotation. A zero Shaft Speed Value indicates that the shaft is turning slower than the minimum shaft speed value or has stopped.

The Shaft Speed Value is measured once per shaft revolution. This new value is transmitted with the next sample and the RPM_NEW status flag is set to indicate a new shaft speed measurement. This same value is transmitted on subsequent samples, until the shaft completes another rotation and a new speed is measured.

5.1.2.1 Shaft Power Calculation

The actual shaft power can be calculated using the measured Strain Gage Value, the shaft parameters and the measured Shaft Speed Value.

5.1.3 Status Information

The status information bytes are grouped bit flags that indicate the operating status of the TPM2. The flags are active high; bits set to ‘1’ indicate the condition exists and bits cleared to ‘0’ indicate the condition does not exist. Below is a description of each bit (flag).

5.1.3.1 Status Info byte 0 (Stator Status and Error flags)

Bit Name/Description

0 RPM_NEW

1 = Shaft Speed value in this sample was just measured

0 = Shaft Speed value in this sample is old, a hold from the last sample measured

1 RPM_ERR

1 = An error was detected in the RPM measurement. Check rotor-stator alignment and spacing

0 = No RPM measurement errors detected.

2 RPM_RES

1 = The Shaft Speed value's resolution is 1/100 RPM, set when the shaft speed falls below approximately 53 RPM.

0 = The Shaft Speed value's resolution is 1 RPM, cleared when the shaft speed rises above approximately 105 RPM.

3 ECOM_ACK

1 = A command has been received OK. This is an acknowledgment that the TPM2 received one or more commands since the last sample was sent. It is set in the sample following reception of the command(s), after which it is cleared.

0 = No command received since last sample sent.

4 ECOM_ERR

1 = An error was detected in external communication link from the Connected Device. Possible errors: Transmit buffer overrun, received data parity error, received data framing error, incorrect received message checksum detected.

0 = No external communication errors detected

5 STAT_PWR_ERR

1 = The Stator main regulated power supply voltage is too high or low, or an over current error exists.

0 = No Stator main regulated power supply problems are detected.

6 II_AMP_TEMP_WRN

1 = The II power amplifier temperature is at or nearing thermal shutdown.

0 = The II power amplifier temperature is OK.

7 STAT_TEST_MODE

1 = Stator in test mode.

0 = Stator in normal mode.

5.1.3.2 Status Info byte 1 (Rotor Error Flags)

0 TRQ_HLD_ERR

1 = The Torque value in this sample is a hold from the last good sample received from the Transmitter

0 = The Torque value is new

1 TRQ_RNG_ERR

1 = The Torque value in this sample is out of range

0 = The Torque value is not out of range

2 GAGE_DIFF_ERR

1 = Gage differential mode input of the transmitter is out of range. This error will also give a TRQ_RNG_ERR

0 = Gage differential mode input of the transmitter is in range

3 GAGE_COM_ERR

1 = Gage common mode input of the transmitter is out of range. This error will also give a TRQ_RNG_ERR

0 = Gage common mode input of the transmitter is in range

4 ROT_PWR_LO_ERR

1 = The Rotor power supply voltage is too low.

0 = The Rotor power supply voltage is not low.

5 ROT_DATA_ERR

1 = An error has been detected receiving data from the Rotor (Transmitter)

0 = Rotor data is being received OK

6 ROT_DATA_GONE

1 = There is no Rotor (Transmitter) Data being received without error

0 = Rotor data is being received

7 RFU

Not currently used

5.1.3.3 Status Info byte 2 (Rotor Status)

0 GAIN0

1 GAIN1

2 GAIN2

Table 6: TPM2 Transmitter Gain settings

GAIN2	GAIN1	GAIN0	GAIN Factor	Strain Range Full Scale (µϵ)	[1]Input Voltage Range Full Scale (mV/V)	Strain Gage Value Full Scale
0	0	0	1	±16000	±32.000	±16000
0	0	1	2	±8000	±16.000	±16000
0	1	0	4	±4000	±8.000	±16000
0	1	1	8	±2000	±4.000	±16000
1	0	0	16	±1000	±2.000	±16000
1	0	1	32	±500	±1.000	±16000
1	1	0	64	±250	±0.500	±16000
1	1	1	128	±125	±0.250	±16000

[1] Gage Factor = 2.0

3 Shunt 1 is ON

1 = Shunt 1 (200uV/V) is ON.

0 = Shunt 1 is OFF

4 Shunt 2 is ON

1 = Shunt 2 (1000uV/V) is ON.

0 = Shunt 2 is OFF

5 RFU

Not currently used

6 RFU

Not currently used

7 RFU

Not currently used

5.1.4 Checksum

The checksum byte is simply the low byte of the sum of the 7 other bytes in the sample.

6 TPM2 Stationary Interface Commands (Received Data)

Commands are sent to the TPM2 for set up and control of TPM2 operation.

6.1 Command Format

Commands consist of 4 byte blocks.

Table 7: Stationary Interface command message format

Byte	Description
0	Command code
1	Command data byte1
2	Command data byte2
3	Checksum byte

6.1.1 Command bytes

Command code, Command data byte1, Command data byte2

The first byte is the command byte. It is a single byte value The first three bytes identify the command and command data.

6.1.2 Checksum

The checksum (chksum) byte is simply the low byte of the sum of the three command bytes.

Table 8: Stationary Interface commands

Command Description	byte0 cmd code	byte1	byte2	byte3 chksum
Establish communications (auto baud detect) Send the entire message at the desired baud rate repeatedly. If possible, insert a byte of dead time between messages to allow the TPM2 to properly frame the message. If it is not possible to create this transmission timing, send the message repeatedly with zero or no more than a few bits of dead time between messages for a minimum of 10msec (at least two messages at low baud rates, whichever is longer). Then stop transmitting for at least 8 byte times. Keep repeating the sequence until an auto baud response data (55 01 02 03 FE E8 C4 05) is received back from the TPM2 indicating success. Dead time greater than 120msec terminates auto	0x55	0x08	0xef	chksum

Command Description	byte0 cmd code	byte1	byte2	byte3 chksum
baud detection whether it is successful or not. If auto baud detection is unsuccessful, the TPM2 will revert to its last known good settings. When auto baud detection is successful, the TPM2 will continue to transmit the auto baud response data once every 90msec until it detects receive dead time of more than 120msec. After detecting sufficient receive dead time, normal data transmission is resumed.				
Configure communications byte1 bits b7, b6 – parity 00 = none (default) 01 = even 10 = odd b5 – stop bits 0 = 1 stop bit (default) 1 = 2 stop bits b4 downto b0 - baud rate code value 0 = 460.8K 1 = 230.4K 2 = 115.2K (default) 3 = 57.6K 4 = 28.8K 5 = 14.4K 6 = 9600 7 = 4800 8 = 2400 9 = 1200	0x8a			chksum

Command Description	byte0 cmd code	byte1	byte2	byte3 chksum
byte2, TX sample rate value: 0 = 4800 samples/sec 1 = 2400 2 = 1200 (default) 3 = 600 4 = 300 5 = 150 6 = 75 7 = 37.5 8 = 18.75 9 = 9.375 **Note: the baud rate code value in byte1must be <= the sample rate value in byte2 because the baud rate limits the possible sample rates.**				
System control: byte1 - RFU byte2 1 = Reset TPM2 Transmitter 2 = Reset TPM2 System 0x80 = Disable Auto Baud detection. Auto Baud detection is active by default at power-up or system reset.	0x90	0x00		chksum

Command Description	byte0 cmd code	byte1	byte2	byte3 chksum
Transmitter control byte1 bits, shunt control b7 downto b2, RFU b1 – shunt 2, 0 = OFF, 1 = ON b0 – shunt 1, 0 = OFF, 1 = ON byte2, transmitter gain value 0 = gain of 1 (default) 1 = gain of 2 2 = gain of 4 3 = gain of 8 4 = gain of 16 5 = gain of 32 6 = gain of 64 7 = gain of 128	0xa0			chksum
Speed input configuration byte1 – zero speed RPM threshold value (0 to 250). Value of 0 sets the threshold to its minimum which is approximately = 0.4RPM / PPR. Default value is 60RPM. byte2 – pulses per revolution (PPR) value (1 to 254). Value of 0 means speed input not used. Default value is 1.	0x60			chksum

Notes:

The ECOM_ACK bit in sample data status byte 0 serves as an acknowledgement to messages sent to the TPM2.

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

The effects of Transmitter Control Commands are delayed due to internal communications between the Transmitter and the TPM2. Transmitter control commands that modify either the gain or shunts require approximately 2.5 seconds to take effect. A command that modifies both gain and shunts at the same time requires 4 seconds.

Appendix A: TPM2 Specifications

Transmitter (mounted inside rotating collar)

Sensor Input:	Full Bridge strain gage (4 active arms, 350Ω standard; up to 1000 Ω acceptable.)
Bridge Excitation:	3.0 VDC, Regulated 25mA max.
Linearity:	0.05% Full Scale

DC Specifications:

Table 9: Transmitter Input Range Specifications

Nominal Input Range (mV/V)	**32**	**16**	**8**	**4**	**2**	**1**	**0.5**	**0.25**
Strain[1] max PFS (µЄ)	16000	8000	4000	2000	1000	500	250	125
Offset Error max (%FS)	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Gain Error max (%)	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Offset TC max (%FS/°C)	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.010
Gain TC max (%/°C)	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.010

FS - Full Scale, PFS – Positive Full Scale,
TC – Temperature Coefficient

[1] Strain using gage factor = 2.0

AC Specifications:

Table 10: Typical Signal Bandwidth and Delay

Sample Rate (samples/second)	Bandwidth[1] (Hz)	Delay[2] (ms)
9.375	3	1700
18.75	6	850
37.5	12	420
75	25	210
150	50	104
300	100	50
600	200	25
1200	380	11
2400	740	4.3
4800	1000	1

[1] Bandwidth is the frequency at which the signal is -3dB (70.8%) relative to the DC (0Hz) level.

[2] Signal delay is measured from analog (gage) input of the transmitter to the end of the sample transmission out of the communication link.

These values are valid for all input range (gain) settings.

Table 11: Typical Signal To Noise Ratio (dB)

	Input Range							
Sampling Rate (SPS)	1	2	3	4	5	6	7	8
9.375	>100	>100	>100	>100	>100	94	81	73
18.75	>100	>100	>100	>100	>100	88	79	70
37.5	>100	>100	>100	>100	94	84	76	68
75	>100	>100	>100	>100	88	82	73	66
150	>100	>100	>100	98	85	79	71	64
300	96	96	96	92	82	76	69	62
600	89	89	89	84	79	74	66	60
1200	82	82	81	80	76	71	64	58
2400	76	76	76	76	73	68	62	56
4800	73	73	73	72	70	66	60	54

Signal to Noise Ratio (in dB) is calculated as follows:

S/N = 20 * $\log_{10}$ (Nominal Signal Range / Residual Noise Level)

Transmitter Connections:

Power Connection: Through Collar mounting bolts and Transmitter mounting screws

Sensor Input: Full (Wheatstone) bridge (120Ωmin)

Sensor Excitation: 3.0Vdc (25mA max)

Sensor Connection: Solder pads or included cable

+Exc: positive excitation voltage to the sensor (red)

+Sen: positive sense voltage from the sensor (green)

-Sen: negative sense voltage from the sensor (white)

-Exc: negative excitation voltage to the sensor (black)

Table 12: Stationary Interface General Specifications

Input Power	10-30Vdc; 15W max, 10W nom
Communication	RS-422 full duplex, point-to-point serial interface
External Connections (included)	Harsh environment sealed circular connectors with 10ft (3m) cables and discrete wire termination at the user end (standard). Contact BEI for other lengths or custom end terminations.
PC software (included)	For device configuration and simple monitoring of output data. Not intended to replace data acquisition system.

Table 13: TPM2 General System Specifications

Torque signal resolution	15 bits, 1 unit in 32,768
Torque signal sampling rate	4800Hz (max)
Shaft speed signal resolution	33.91nsec
Shaft speed signal sampling rate	1 per revolution
Operating temperature	-40° to +70°C, 0 to 90% non-condensing humidity

Specifications are subject to change without notice.

Appendix B: Troubleshooting

There are multiple features built into the TPM2 system to aid in troubleshooting. There are four bi-color status LED's on the Stationary Interface. There are also 24 status bits in the serial data transmitted from the Stationary Interface.

Generally the first step in troubleshooting is to observe (if possible) all LED's on the Stationary Interface.

There should always be at least one LED ON or flashing in some way. If all Stationary Interface LED's are OFF, it may not be receiving power:

1. Check the power source and wiring to the TPM2.
2. Check the TPM2 power fuse (5 x 20mm 2 amp fast blow).

If at least one Stationary Interface LED is ON or flashing, observe (if possible) the transmitter LED on the rotating collar. The transmitter LED operation is detailed in paragraph 3.2 of this document.

If the transmitter LED is always OFF, then the transmitter power is too low for operation:

3. Check that the stationary ring is mounted correctly with the proper surface facing the rotating collar as specified in the installation instructions.
4. Check that the rotating collar is mounted with the proper surface facing the stationary ring as specified in the installation instructions.
5. Check that the spacing between the stationary ring and the rotating collar is as specified in the installation instructions.
6. Check that all bolts in the rotating collar are tight, including the bolts that secure the transmitter.
7. Check that all bolts holding the stationary ring together are tight.

If the Transmitter and/or Stationary Interface LED's are flashing in some manner, refer to section 3 of this manual to determine the operational status.

In addition to the status LED's, the TPM2 RS-422 data contains status information. Please refer to the TPM2 Communications Specification document for detailed information.

Appendix C: Strain Gage Installation

View BEI's online Strain Gage Installation Training videos at:

Training Videos

(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.

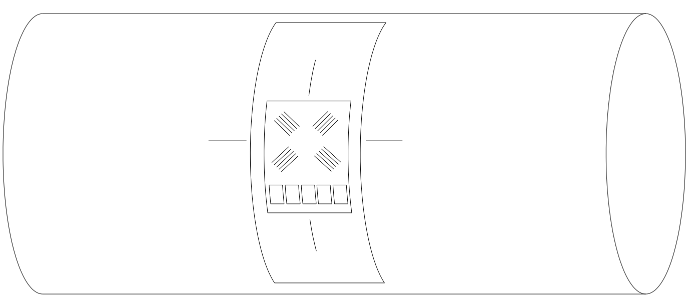


Figure 5 - Strain Gage Mounting

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.

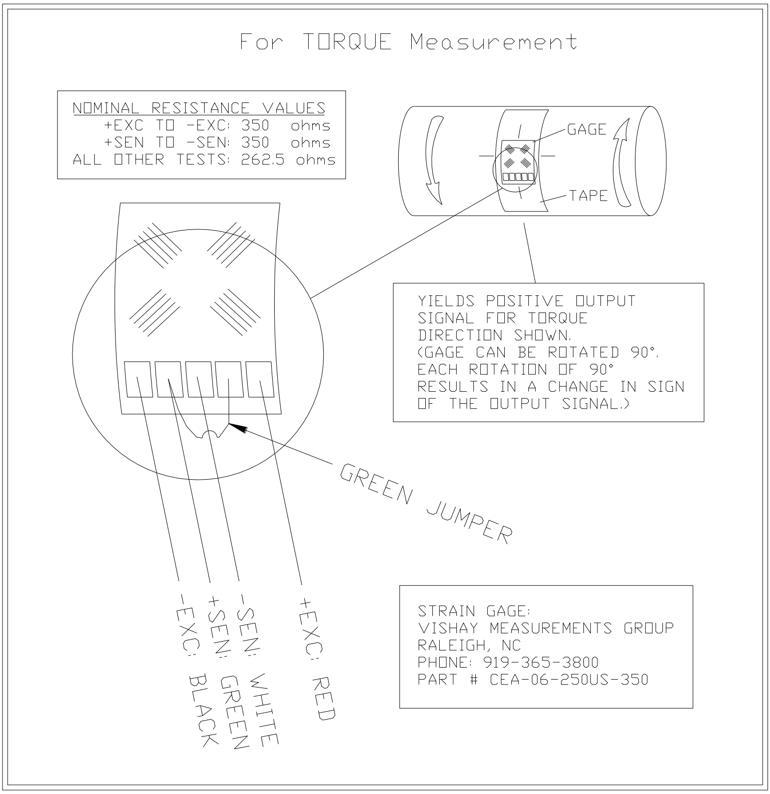


Figure 6 - Strain Gage Wiring

Appendix D: Dimensions

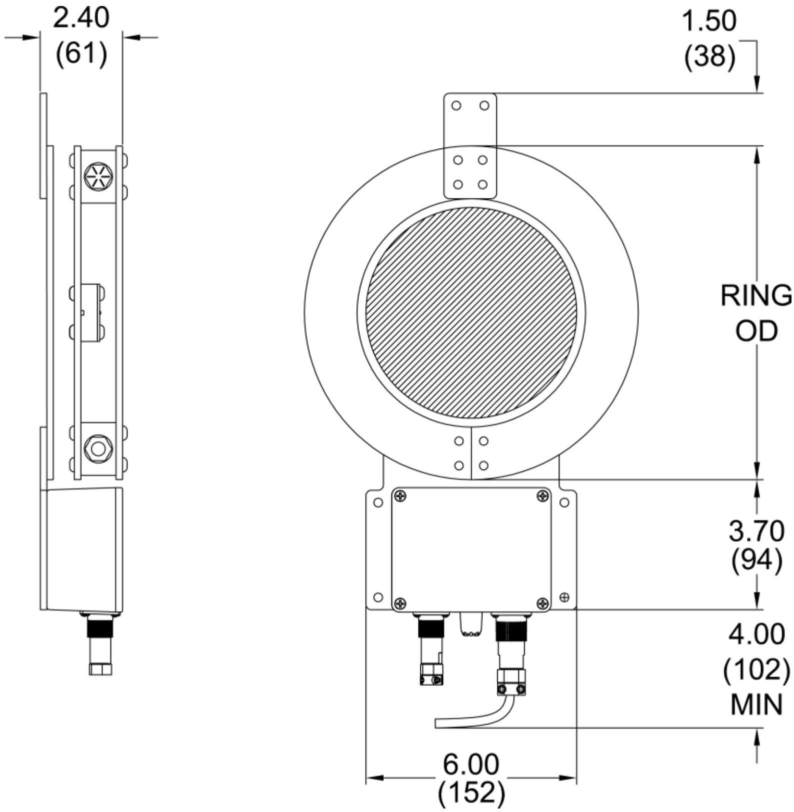


Figure 7 - General Dimensions

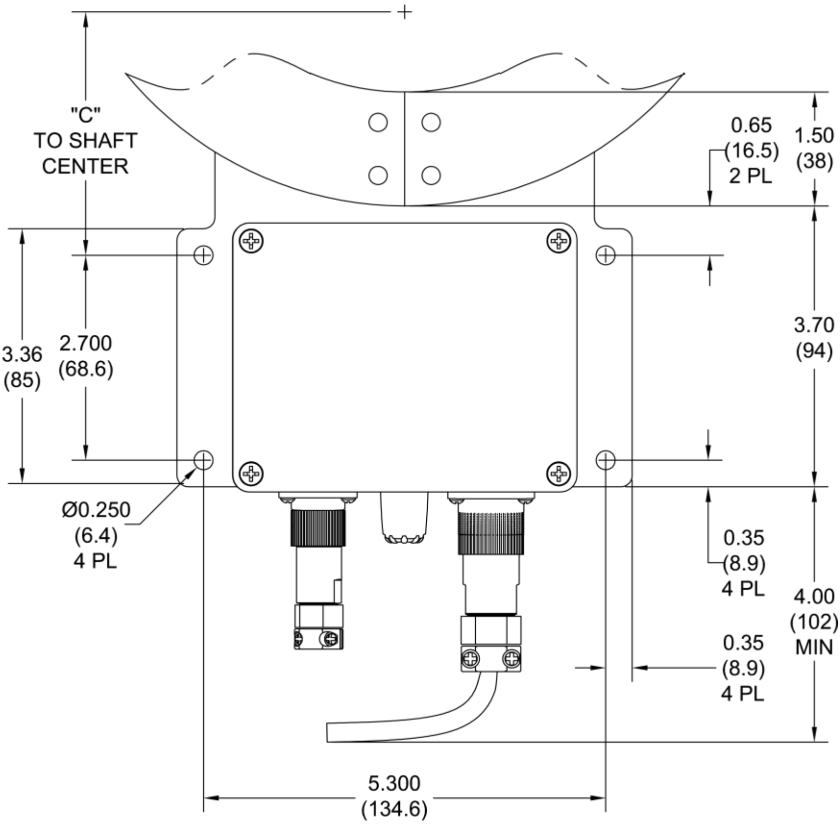


Figure 8 - Stationary Interface Mounting Dimensions

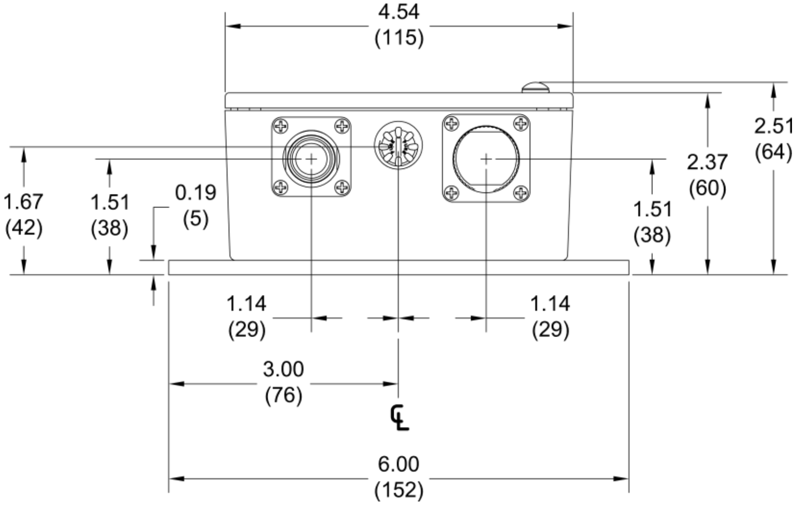


Figure 9 - Stationary Interface Bottom Dimensions

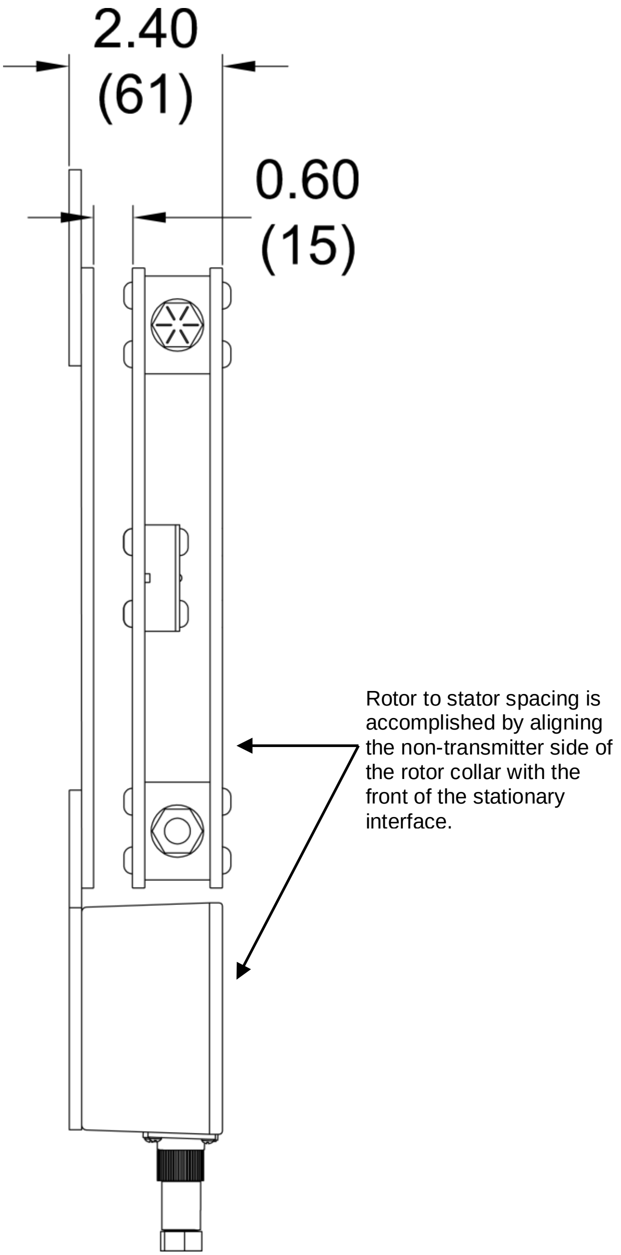
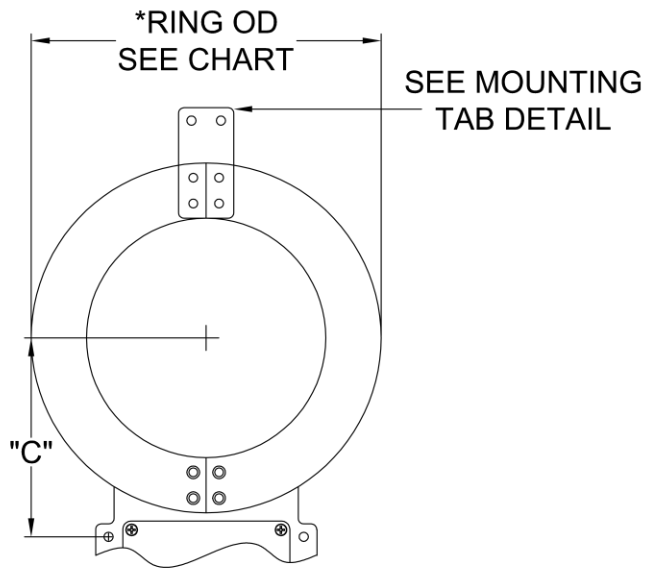
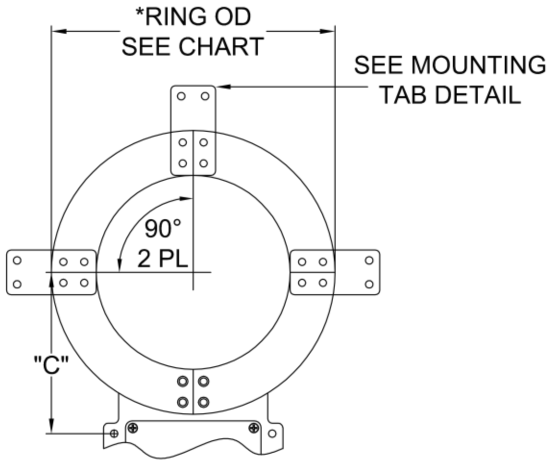


Figure 10 - Collar Spacing



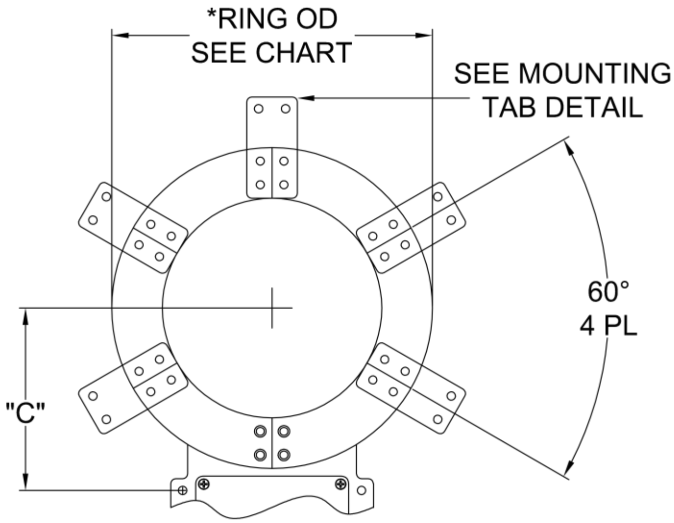
SHAFT SIZES 0.75-6.00 (20-152)			
SHAFT OD MIN	SHAFT OD MAX	*RING OD	"C"
0.75 (19)	1.50 (38)	5.00 (127)	3.15 (80)
1.50 (38)	2.00 (51)	5.50 (140)	3.40 (86)
2.00 (51)	4.00 (102)	7.50 (191)	4.40 (112)
4.00 (102)	6.00 (152)	9.50 (241)	5.40 (137)
*RING AND ROTOR OD ARE NOMINALLY SAME SIZE			

Figure 11 - 0.75" to 6" Shaft Diameter Dimensions



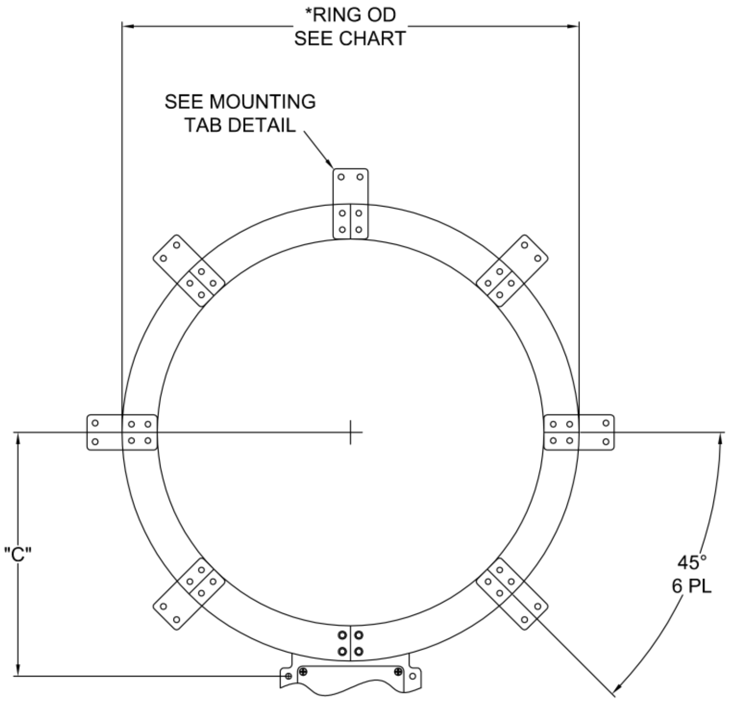
SHAFT SIZES 6.00-24.00 (152-610)			
SHAFT OD MIN	SHAFT OD MAX	*RING OD	"C"
6.00 (152)	8.00 (203)	11.50 (292)	6.40 (163)
8.00 (203)	10.00 (254)	13.50 (343)	7.40 (188)
10.00 (254)	12.00 (305)	15.50 (394)	8.40 (213)
12.00 (305)	14.00 (356)	17.50 (445)	9.40 (239)
14.00 (356)	16.00 (406)	19.50 (495)	10.40 (264)
16.00 (406)	18.00 (457)	21.50 (546)	11.40 (290)
18.00 (457)	20.00 (508)	23.50 (597)	12.40 (315)
20.00 (508)	22.00 (559)	25.50 (648)	13.40 (340)
22.00 (559)	24.00 (610)	27.50 (699)	14.40 (366)
*RING AND ROTOR OD ARE NOMINALLY SAME SIZE			

Figure 12 - 6" to 24" Shaft Diameter Dimensions



SHAFT SIZES 24.00-40.00 (610-1016)			
SHAFT OD MIN	SHAFT OD MAX	*RING OD	"C"
24.00 (610)	28.00 (711)	31.50 (800)	16.40 (417)
28.00 (711)	32.00 (813)	35.50 (902)	18.40 (467)
32.00 (813)	36.00 (914)	39.50 (1003)	20.40 (518)
36.0 (914)	40.00 (1016)	43.50 (1105)	22.40 (569)
*RING AND ROTOR OD ARE NOMINALLY SAME SIZE			

Figure 13 - 24" to 40" Shaft Diameter Dimensions



SHAFT SIZES 40.00-48.00 (1016-1219)			
SHAFT OD MIN	SHAFT OD MAX	*RING OD	"C"
40.00 (1016)	44.00 (1118)	47.50 (1207)	24.40 (620)
44.00 (1118)	48.00 (1219)	51.50 (1308)	26.40 (671)
*RING AND ROTOR OD ARE NOMINALLY SAME SIZE			

Figure 14 - 40" to 48" Shaft Diameter Dimensions

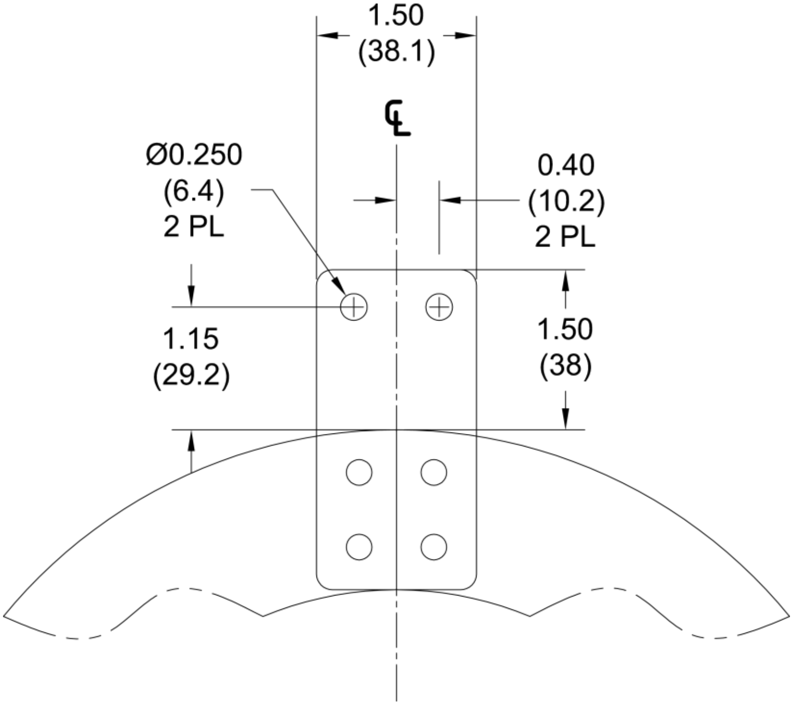


Figure 15 - Stationary Ring Mounting Tab Dimensions

Appendix E: Maximum Shaft Speeds

Table 9: Rotating Collar OD and Max Recommended RPM

Collar Outside Diameter		[1]Maximum safe RPM
(inches)	(mm)	
5	127	9100
5.5	139	8500
7.5	190	6900
9.5	241	5900
11.5	292	4300
13.5	342	3800
15.5	393	3400
17.5	444	3100
19.5	495	2800
21.5	546	2300
23.5	596	2200
25.5	647	2100
27.5	698	1900
31.5	800	1500
35.5	901	1400
39.5	1003	1300
43.5	1104	1200
47.5	1206	1000
51.5	1308	1000

[1]Valid only if rotating collar is properly installed with mounting bolts tightened to specified torque values.

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.

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