TorqueTrak TPM2 with RS-485 Modbus Installation and Operation Manual

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TorqueTrak TPM2 with RS-485 Modbus Installation and Operation Manual

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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 (for 350Ω strain gage).
- 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 at gage factor of 2.0).
- RS-485 Modbus 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 lights for system status and error indication in addition to status information contained in the RS-485 Modbus serial communications data.

1.1 SYSTEM COMPONENTS

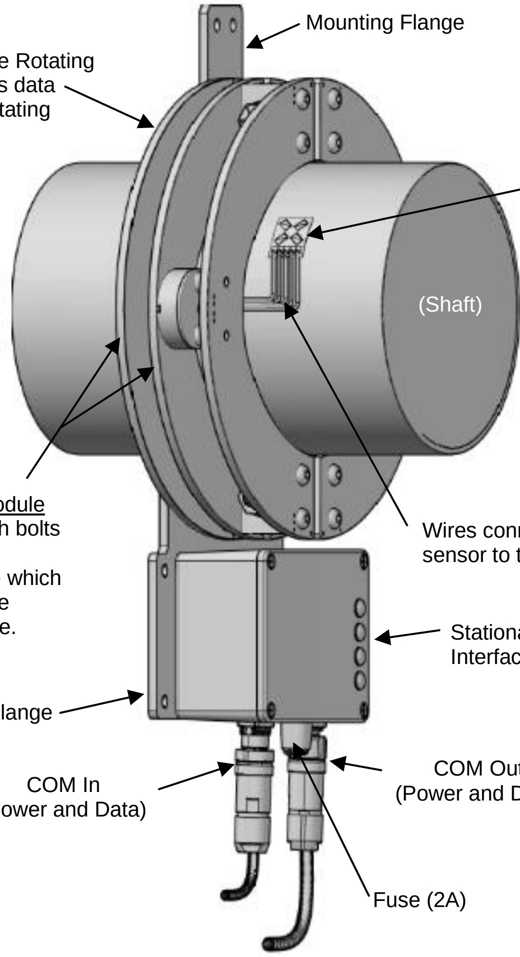

Figure 1: System Components

1.1.1 Rotating Collar Assembly

The transmitter module 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 via the rotating collar.

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 bi-directional RS-485 Modbus 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.

Make sure there is proper spacing between the rotating and stationary components 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 made to fit a specific shaft diameter. Do not try to adapt the TPM2 to fit a different shaft size.

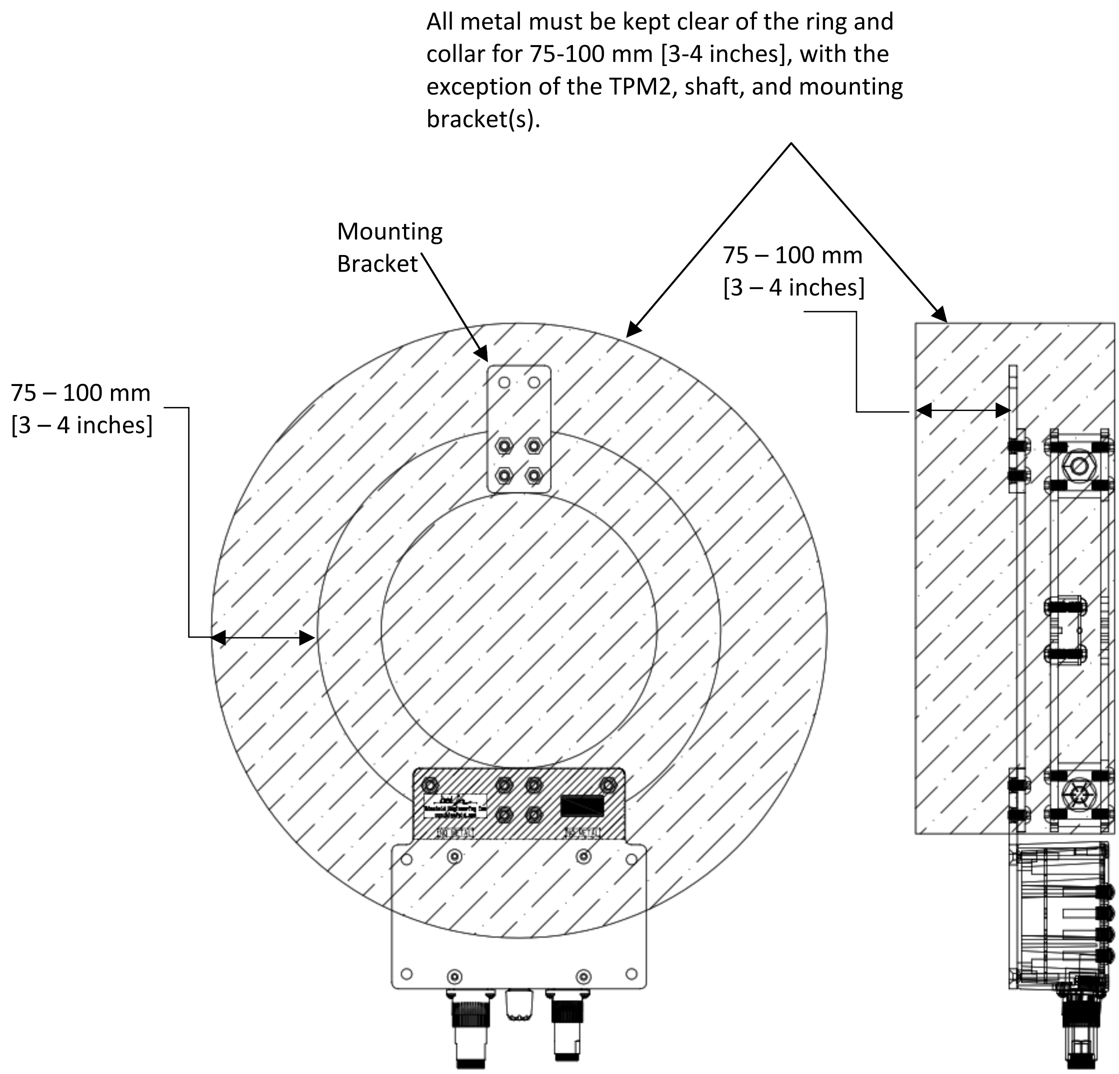

Figure 2: Metal-Free Area (shaded)

2.1 ROTATING COLLAR INSTALLATION

WARNING:
If there is any damage to the rotating collar (gouges, chips, cuts, cracks, etc.) IMMEDIATELY DISCONTINUE USE, remove from the shaft, and contact Binsfeld 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 E.
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 Binsfeld for replacement mounting hardware.
DO NOT remove the Counterweight/Magnet module or loosen its screws.
Use the supplied thread lubricant (anti-seize) as indicated.
Use the supplied Threadlocker (Loctite 242) as indicated.
Should removal of the transmitter be necessary, reinstall with Loctite 242 applied to the threads of M-6 screws.

IMPORTANT: Install the rotating collar assembly with the collar section on which the transmitter and counterweight modules are mounted, nearest to the stationary ring.

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

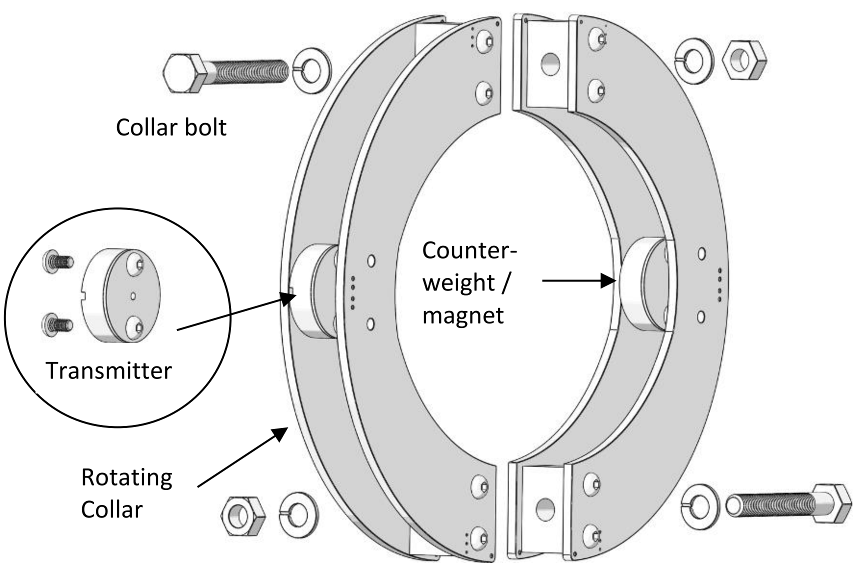

Figure 3: Rotating Collar Installation

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.

IMPORTANT: 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 ring-collar spacing before rotating the shaft.

2.2 STATIONARY RING AND STATIONARY INTERFACE INSTALLATION

Note: The TPM2 enclosure is only sealed (e.g. from liquids, dust) when the mating connectors/cables are attached.

The TPM2 stationary interface requires a fabricated mount to hold it securely in place. Refer to Appendix D for corresponding dimensions to create a mounting bracket. Figure 2 and Appendix D for ring-collar spacing guidelines and a metal-free zone 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 other 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

The TPM2 features two COM connections (COM In and COM Out) so multiple units can be connected in series ("daisy-chained") as needed. For a single system installation, connect the cable to the COM In connector and connect a termination resistor (e.g. Phoenix Contact #15007816, provided) into the COM Out connector.

The communications cable includes power from a 24VDC regulated power supply (a range from 10 to 30VDC is acceptable) with a maximum current of 2amps and typical operating current of 0.5amps. 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 16 AWG 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).

CAUTION: Do not connect or disconnect the COM cable while power is applied or damage due to arcing may occur and damage the connectors.

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

WIRE	CONNECTOR	DESCRIPTION
Shield/Gray	Brown/Red	RS-485 signal GND
Brown/Red	White	+24 VDC
Black	Blue	0 VDC
Blue	Black	RS-485 A+
White	Gray	RS-485 B-

Stationary Interface M12 Connector Wiring

Communication distances of over 300 m [1000 ft] 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-485 interface for connecting a PC USB port to the TPM2 communications connector is the model **BB-USOPTL4-LS isolated, locked S/N converter** from B&B Electronics (Advantech); http://www.bb-elec.com.

Any RS-485 interface should work but may not work with the standard Binsfeld TPM2 Modbus Configuration software (P/N 818007). Please see Section 4 of this document for detailed communications protocol information.

Correct DIP switch settings when using the BB-USOPTL4-LS:

1 - RS-485
2 - Echo OFF
3 - 2 Wire
4 - 2 Wire

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 stationary ring mounting brackets 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 mounting brackets 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

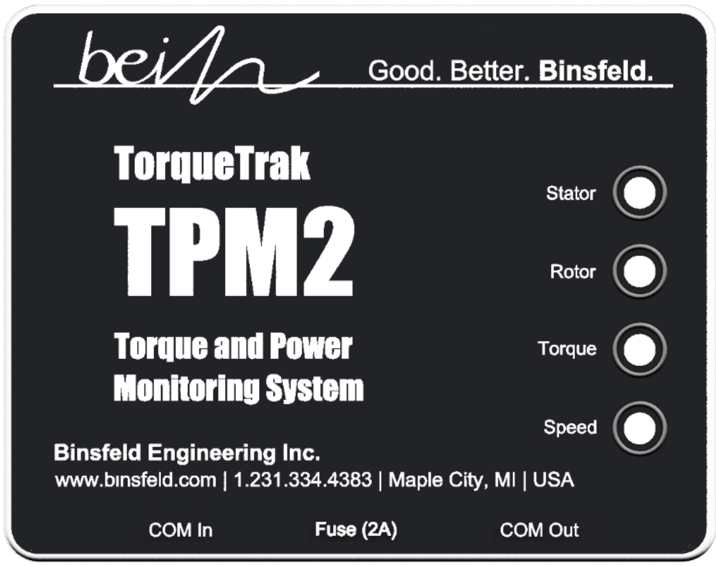

Figure 4: Stationary Interface Front Panel

3.1.1 Startup Operation

Immediately after power-up the system performs a self-test. 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 5 times/second (5Hz) for one-half 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 then turned OFF. After the LED test, normal LED operation commences.

3.1.2 Normal Operation

Following Startup, the Stationary Interface varies inductive power from high to low seeking to establish communications with the transmitter. 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 Stationary Interface 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.

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 RS-485 UART errors such as baud rate, 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, 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 sensed temperature drops below a lower threshold temperature. Cooling could take several seconds or minutes depending on the ambient temperature. When the power amplifier section has cooled sufficiently, 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 overrange are indicated in the status bits of Modbus register data.

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

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 sample times (at 4800Hz).

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).

The *Speed LED* will not flash when the RPM value is below the Zero Speed Threshold (See section 5.2.1 of the TorqueTrak TPM2 Software Manual for more information).

3.2 TRANSMITTER LED OPERATION

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

One quick Transmitter LED pulse (about 0.1 second every 1.7 seconds) indicates transmitter voltage is 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 and likely too low for operation.

4 COMMUNICATIONS PROTOCOL

Bi-directional RS-485 Modbus RTU communications are supported with a Modbus master device but are not required. The TPM2 does not require any data to be received from a master device so no communications errors are declared if there is nothing connected to the RS-485 connector. A Modbus master is required to configure parameters such as gain, baud rate and sample rate. The Modbus ASCII transmission mode is not supported.

Generally, configuration should be required only once during installation. If the default parameters don't need to be changed then configuration during installation may not be required. The default parameter settings are:

Table 2: Default configuration parameters

Modbus slave address	31
Baud rate	115.2K
Parity	none
Stop bits	1
Sample rate (bandwidth)	150 samples/sec (50Hz)
Transmitter gain (sensitivity)	32 (1mV/V)
Zero speed threshold	60 RPM

Binsfeld Engineering TPM2 Modbus Configuration software (P/N 818007) running on a Windows PC can be used for configuration. See TPM2 Modbus Configuration software manual P/N 818007-9 for more information.

4.1 DATA BYTE FORMAT

Each transmitted or received byte consists of 1 start bit, and 8 data bits. Baud rate, parity, and the number of stop bits is configurable. The 8 data bits are ordered least significant bit first.

5 TPM2 MODBUS

5.1 SUPPORTED MODBUS FUNCTIONS AND EXCEPTION CODES

Table 3: Supported Modbus Functions and Exception Codes

Function	Description	Supported Error: Exception Codes
3	Read Holding Register	0x83: 01, 02, 03, 04
4	Read Input Register	0x84: 01, 02, 03, 04
6	Write Single Register	0x86: 01, 02, 03, 04
16	Write Multiple Registers	0x90: 01, 02, 03, 04

5.2 TPM2 MODBUS REGISTER MAPPING

All hexadecimal register addresses with high byte equal to 0 are read only and only support Modbus function codes 3 & 4.

Table 4: TPM2 Modbus Register Map

Address (hex)	Register (decimal)	Access Type	Data Type	Value	Description
0x0000	1	read (input reg)	16 bit unsigned		Product ID
0x0001	2	read (input reg)	16 bit unsigned	0xMMmm	Firmware version: MM is major, mm is minor
0x0002	3	read (input reg)	16 bit unsigned	0xMMmm	Boot version: MM is major, mm is minor
0x0003	4+5	read (input reg)	32 bit signed		TPM2 speed count per revolution, 33.9nsec/count
0x0005	6	read (input reg)	16 bit signed	±16000	TPM2 torque strain value (unitless)
0x0006	7	read (input reg)	16 bit signed		TPM2 rpm value, rpm x 100 at low rpm when status byte0 bit 2 is '1'
0x0007	8	read (input reg)	16 bit unsigned		status byte0_1
0x0008	9	read (input reg)	16 bit unsigned		status byte2_checksum
0x0100	257	r/w (hold reg)	16 bit unsigned	1 to 247 default: 31	Modbus slave address

Address (hex)	**Register** (decimal)	**Access Type**	**Data Type**	**Value**	**Description**
0x0101	258	r/w (hold reg)	16 bit unsigned	0 - 460.8K 1 - 230.4K 2 - 115.2K 3 - 57.6K 4 - 38.4K 5 - 19.2K 6 - 9600 default: 115.2K	Baud rate (EbaudIndex)
0x0102	259	r/w (hold reg)	16 bit unsigned	0 - none 1 - even 2 - odd default: none	Parity
0x0103	260	r/w (hold reg)	16 bit unsigned	0 - 1 stop 1 - 2 stop default: 1 stop bit	Stop bits
0x0104	261	r/w (hold reg)	16 bit unsigned	0 - 4800 (1KHz) 1 - 2400 (740Hz) 2 - 1200 (380Hz) 3 - 600 (200Hz) 4 - 300 (100Hz) 5 - 150 (50Hz) 6 - 75 (25Hz) 7 - 37.5 (12Hz) 8 - 18.75 (6Hz) 9 - 9.375 (3Hz) default: 150 (50Hz)	Sample rate in samples per second (bandwidth) To clarify, a value of 5 configures the sample rate to 150 samples/sec with a signal bandwidth of 50Hz. The Modbus master can read a sample whenever it wants but the TPM2 would update the samples at a rate of 150 samples per second in this case.
0x0105	262	r/w (hold reg)	16 bit unsigned	0 to 3 b15 : b2 RFU b1 – shunt 2, 0 = OFF 1 = ON b0 – shunt 1, 0 = OFF 1 = ON	Transmitter shunt control

Address (hex)	Register (decimal)	Access Type	Data Type	Value	Description
0x0106	263	r/w (hold reg)	16 bit unsigned	0 = gain of 1, 32mV/V 1 = gain of 2, 16mV/V 2 = gain of 4, 8mV/V 3 = gain of 8, 4mV/V 4 = gain of 16, 2mV/V 5 = gain of 32, 1mV/V 6 = gain of 64, 0.5mV/V 7 = gain of 128, 0.25mV/V default, gain of 1, 32mV/V	Transmitter gain control
0x0107	264	r/w (hold reg)	16 bit unsigned	0 to 250 RPM Value of 0 sets the threshold to its minimum which is approx. = 0.4RPM / PPR. Default value is 60RPM.	Zero speed threshold
0x0108	265	r/w (hold reg)	16 bit unsigned	0 - speed disabled	Speed sensor PPR
0x0109	266	r/w (hold reg)	16 bit unsigned	1 - reset transmitter 2 - reset system	System control

5.2.1 Strain Value (Modbus register 6)

The Strain Value is a 16 bit signed integer that is used to calculate the torque strain using the equation:

$\epsilon = (Val_{out} * 2) / (G_{xmtr} * GF)$

ϵ = strain (in units of µstrain)
Val_{out} = TPM2 output Strain Value
G_{xmtr} = user selectable transmitter gain (see Table 6)
GF = gauge factor (from gage manufacturer)

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:

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

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 = shaft outside diameter (mm or inches)
ID = shaft 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:

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

P = power (Watts or horsepower)
T= torque (N-m, in-lbs or ft-lbs)
2π is radians/revolution
ω = rotational speed (RPM)
K_p = torque units dependent power constant (see table)

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

5.2.2 Shaft RPM Value (Modbus register 7)

The Shaft RPM Value is a 16 bit signed integer. This 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 counter-clockwise rotation and negative indicates 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 updated 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 reported on subsequent samples until the shaft completes another rotation and a new speed is measured.

5.2.3 Shaft Speed Count (Modbus registers 4 & 5)

The Shaft Speed Count is a 32 bit signed integer. This value is the number of internal timer ticks counted between the last two speed sensor pulses. There is one timer tick every 33.9×10^{-9} seconds, and one speed sensor pulse per shaft revolution. This is the speed value to use for the most accurate power calculation.

Register 4 is the high word of the 32 bit value and register 5 is the low word.

5.2.3.1 Shaft Power Calculation

The actual shaft power can be calculated using the measured Strain Value, the measured Shaft Speed Count and either the shaft parameters or calibrated torque values.

$\epsilon = (Val_{out} * 2) / (G_{iamp} * GF)$

$\epsilon_k = 2 / (G_{iamp} * GF)$

$\epsilon = Val_{out} * \epsilon_k$

ϵ = strain (in units of μstrain)
Val_{out} = TPM2 output Strain Gage Value
G_{iamp} = user selectable instrumentation amp gain
GF = gauge factor

1.1.1.1.1 Shaft Power Using Shaft Parameters

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

T = torque (N-m or ft-lbs)
E = modulus of elasticity of the shaft material
(N/mm^2 or Mpsi)
OD = shaft outside diameter (mm or inches)
ID = shaft inside diameter (mm or inches)
K_T = torque units dependent constant
(for N-m, $K_T = 16 \times 10^9$: for ft-lbs, $K_T = 192$)
v = Poisson's ratio of the shaft material

$T_k = (2 * \pi * E * (OD^4 - ID^4)) / (G_{iamp} * GF * K_T * OD * (1 + v))$

T_k = torque scale factor (N-m or ft-lbs)

$T = Val_{out} * T_k$

Note: Val_{out}here is the difference between a TPM2 torque value sample and the TPM2 torque value sample at no load (offset value).The offset value must be subtracted out of every torque sample read.

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

P = power (watts or hp)
2π is radians/revolution
ω = rotational speed (RPM)
K_p = units dependent power constant
(for watts, $K_p = 60$: for hp $K_p = 33{,}000$)

$P_k = (T_k * 2\pi * \omega_k) / K_p$

P_k = power scale factor (watts or hp)
ω_k = 1,769,472,000 speed timer counts / minute
K_p = units dependent power constant
(for watts, K_p = 60: for hp K_p = 33,000)

$\omega = \omega_k$ / X tmr cnts

$P = (Val_{out} * P_k) / X$

X = number of timer counts per revolution

Note: Val_{out} here is the difference between a TPM2 torque value sample and the TPM2 torque value sample at no load (offset value). The offset value must be subtracted out of every torque sample read.

5.2.3.1.1 Shaft Power Using Calibrated Torque Values

$T_k = T_{ref}$ / (Val_ref - Val_rest)

T_k = torque scale factor
T_{ref} = reference torque applied
Val_ref = TPM2 torque value for the applied reference torque
Val_rest = TPM2 torque value when no torque is applied.

Torque, power scale factor, and power are calculated using the same equations used with shaft parameters (only T_k is calculated differently).

5.2.4 Status Information

The status information bit flags 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).

5.2.4.1 Status Info byte0_1 (Modbus register 8, Stator and Rotor status flags)

bit 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

bit 1 TRQ_RNG_ERR

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

0 = The Torque value is not out of range

bit 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

bit 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

bit 4 ROT_PWR_LO_ERR

1 = The Rotor power supply voltage is too low.

0 = The Rotor power supply voltage is not low.

bit 5 ROT_DATA_ERR

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

0 = Rotor data is being received OK

bit 6 ROT_DATA_GONE

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

0 = Rotor data is being received

bit 7 RFU

Not currently used

bit 8 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

bit 9 RPM_ERR

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

0 = No RPM measurement errors detected.

bit 10 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.

bit 11 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.

bit 12 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

bit 13 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.

bit 14 II_AMP_TEMP_WRN

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

0 = The II power amplifier temperature is OK.

bit 15 STAT_TEST_MODE

1 = Stator in test mode.

0 = Stator in normal mode.

5.2.4.2 Status Info byte 2(Modbus register 9 high byte, Rotor Status)

bit 8 GAIN0

bit 9 GAIN1

bit 10 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

bit 11 Shunt 1 is ON

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

0 = Shunt 1 is OFF

bit 12 Shunt 2 is ON

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

0 = Shunt 2 is OFF

bit 13 RFU

Not currently used

bit 14 RFU

Not currently used

bit 15 RFU

Not currently used

5.2.5 Checksum (Modbus register 9 low byte)

Bits 7 down to 0 of the low byte of Modbus register 9 are an 8 bit checksum byte that is simply the low byte of the sum of the 7 other bytes in the sample.

5.2.6 Non-Volatile Parameters

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

5.2.7 Transmitter Command Notes

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.

6 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 7: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 8: 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 9: Typical Signal To Noise Ratio (dB)

	Input Range							
Sampling Rate (Samples per second)	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:

$S/N = 20 * \log_{10} (NominalSignalRange / ResidualNoiseLevel)$

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 10: Stationary Interface General Specifications

Input Power	10-30Vdc; 15W max, 10W nom
Communication	Modbus RS-485RTU
External Connections (included)	Harsh environment sealed circular connectors with 10ft (3m) cables and discrete wire termination at the user end (standard). Contact Binsfeld for other lengths or custom end terminations.
PC software (included)	For configuration of Modbus registers.

Table 11: 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.

7 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 LEDs 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 LEDs are flashing in some manner, refer to the section of this manual for that component to determine the operational status.

In addition to the status LEDs, some of the TPM2 Modbus registers hold status information. Please refer to section 5.2.4 of this manual.

If during troubleshooting the collar connections have been loosened, it is recommended to cycle the main power (power off, power on) to reset the system.

8 APPENDIX C: STRAIN GAGE INSTALLATION

View Binsfeld 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.

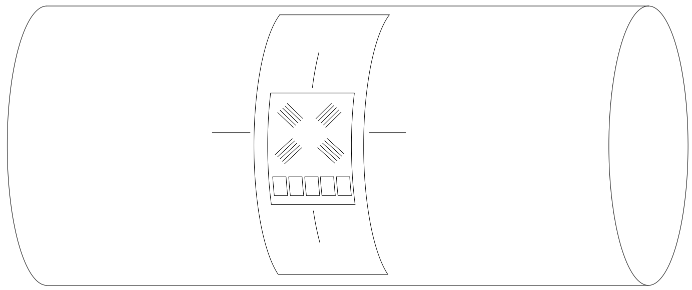

Figure 5: Strain Gage Mounting

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 (or equivalent) (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.

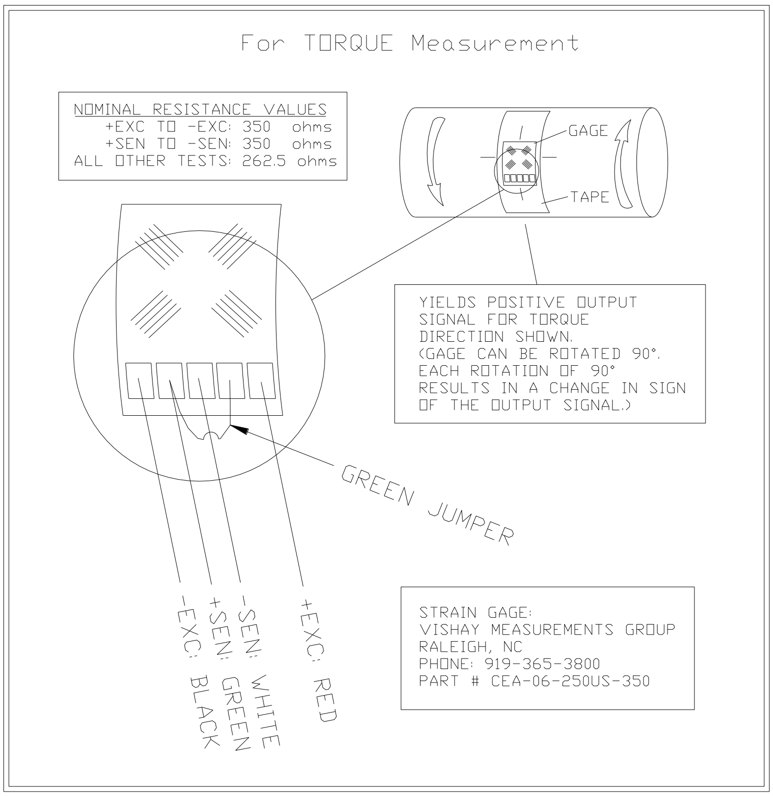

Figure 6: Strain Gage Wiring

9 APPENDIX D: DIMENSIONS

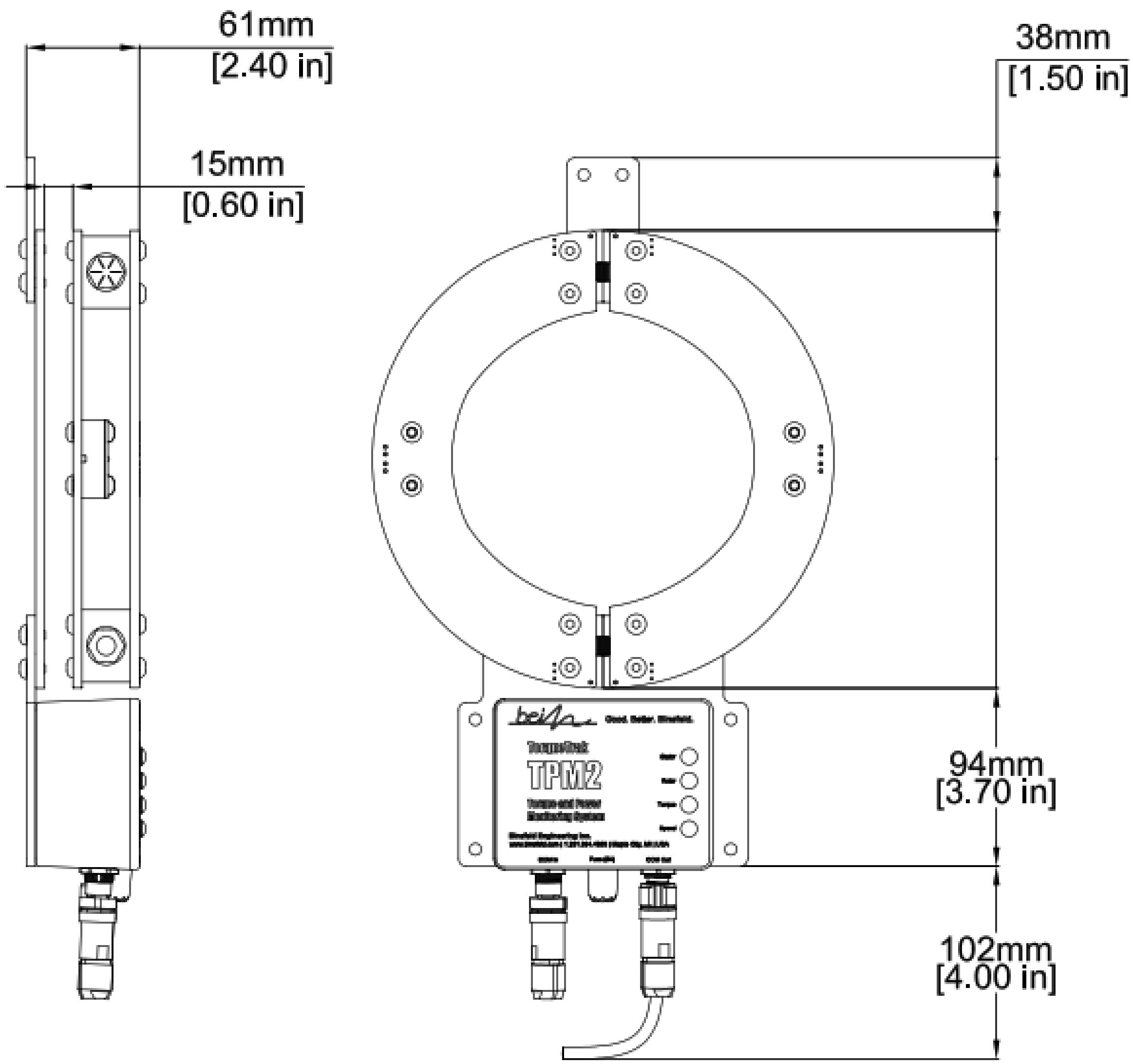

Figure 7: Basic System Dimensions

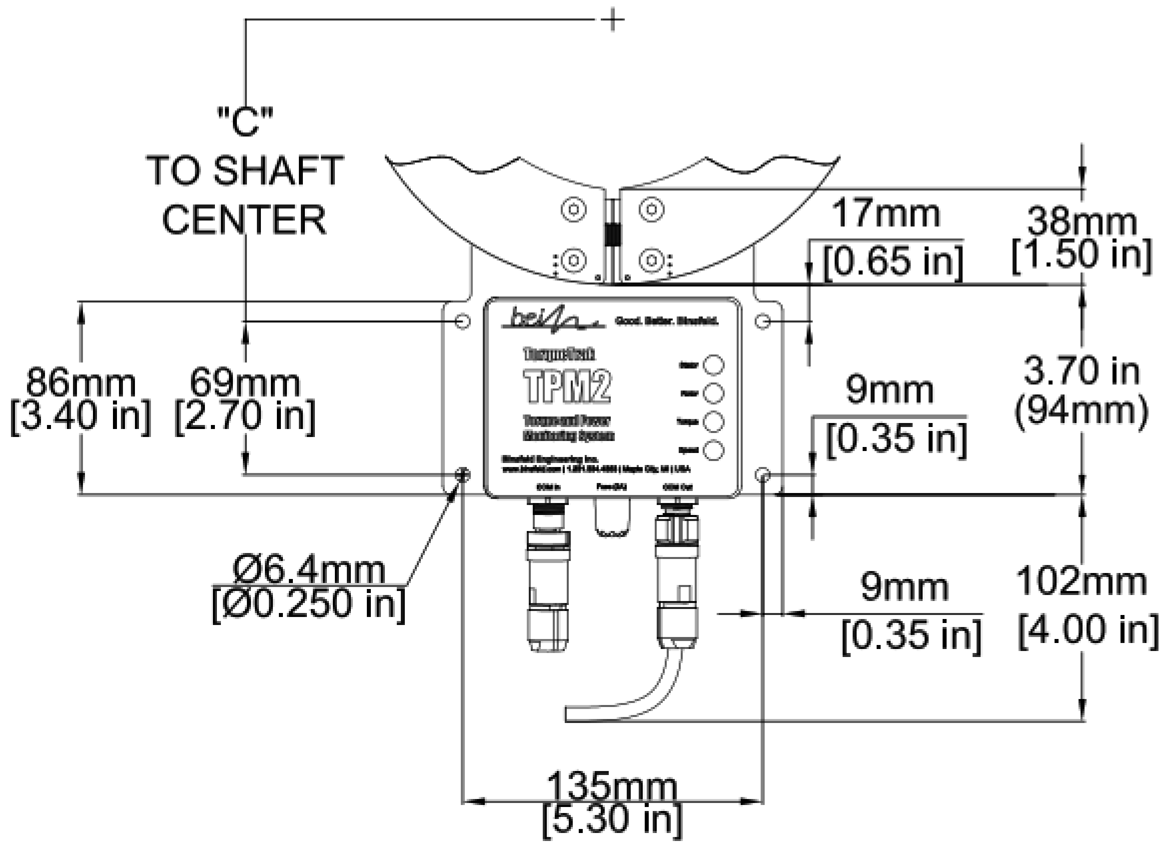

Figure 8: Stationary Interface Mounting Dimensions

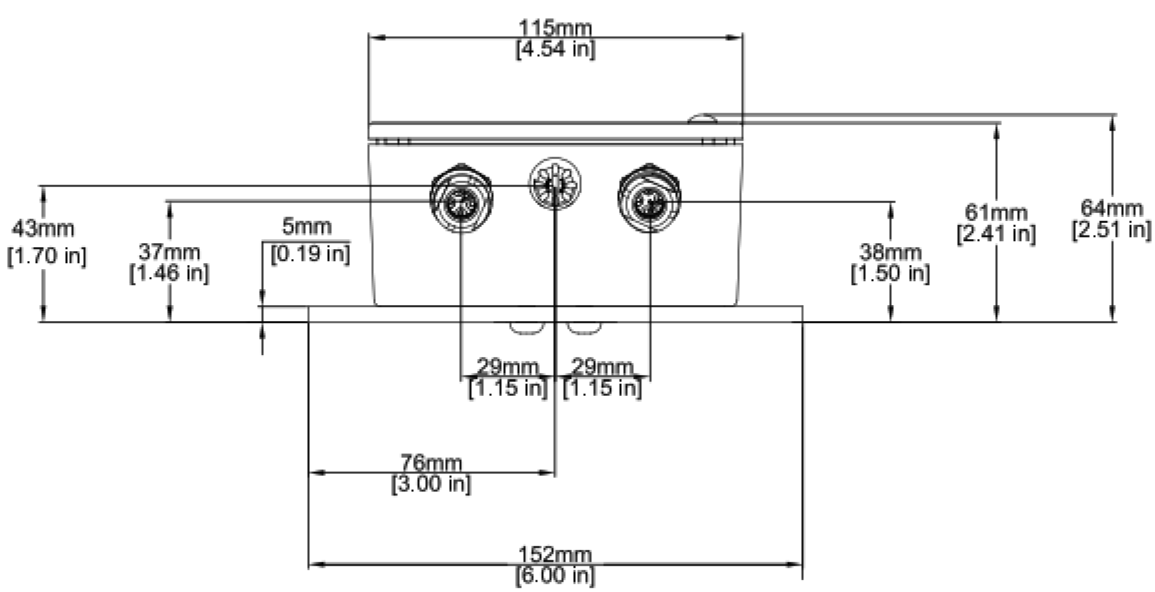

Figure 9: Stationary Interface Bottom Dimensions

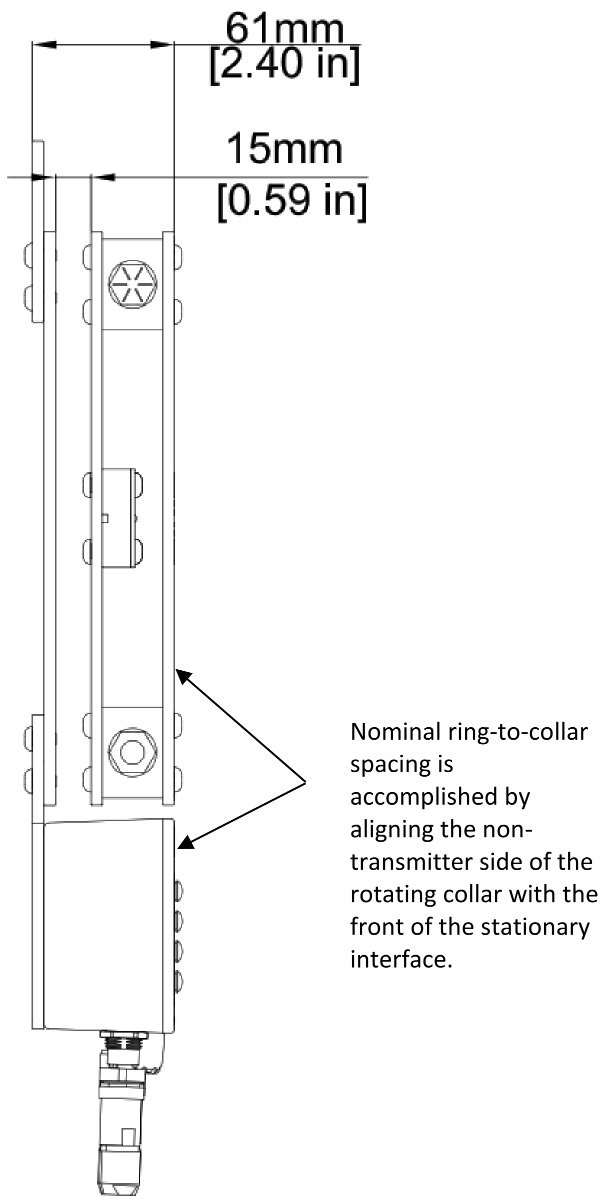

Figure 10: Ring-Collar Spacing using Front Alignment

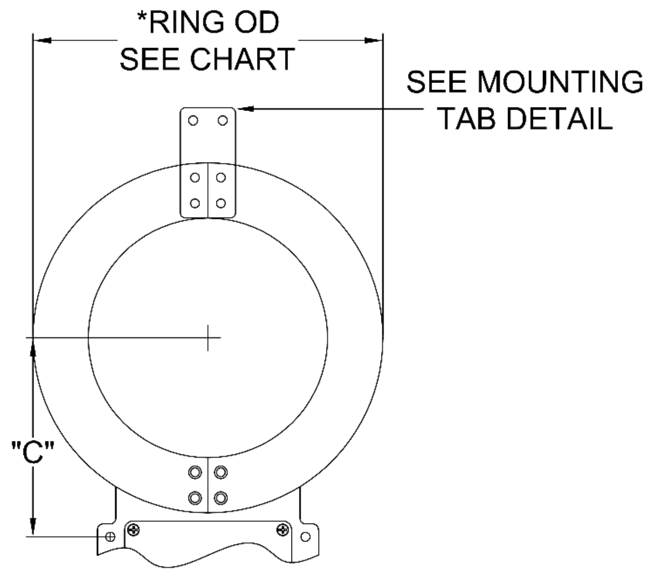

Figure 11: Ring Diameter and Interface Location for 20 to 52 mm [0.75 to 6.00 in] Shafts

SHAFT SIZE 20-152 MM [0.75-6.00 INCHES]			
SHAFT OD MIN	SHAFT OD MAX	*RING OD	"C"
19 mm [0.75 in]	38 mm [1.50 in]	127 mm [5.00 in]	80 mm [3.15 in]
38 mm [1.50 in]	51 mm [2.00 in]	140 mm [5.50 in]	86 mm [3.40 in]
51 mm [2.00 in]	102 mm [4.00 in]	191 mm [7.50 in]	112 mm [4.40 in]
102 mm [4.00 in]	152 mm [6.00 in]	241 mm [9.50 in]	137 mm [5.40 in]
*RING AND COLLAR OD ARE NOMINALLY SAME SIZE			

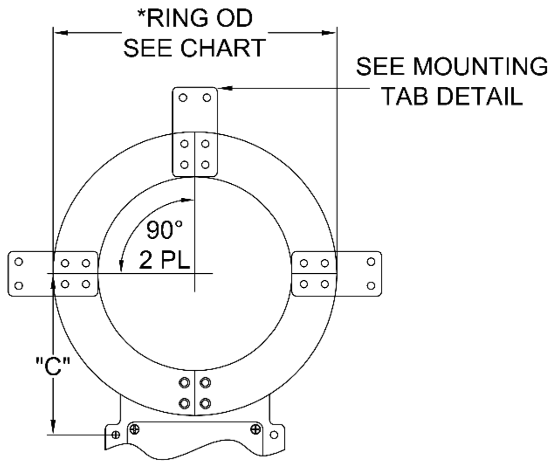

Figure 12: Ring Diameter and Interface Location for 152 to 610 mm [6.00 to 24.00 in] Shafts

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

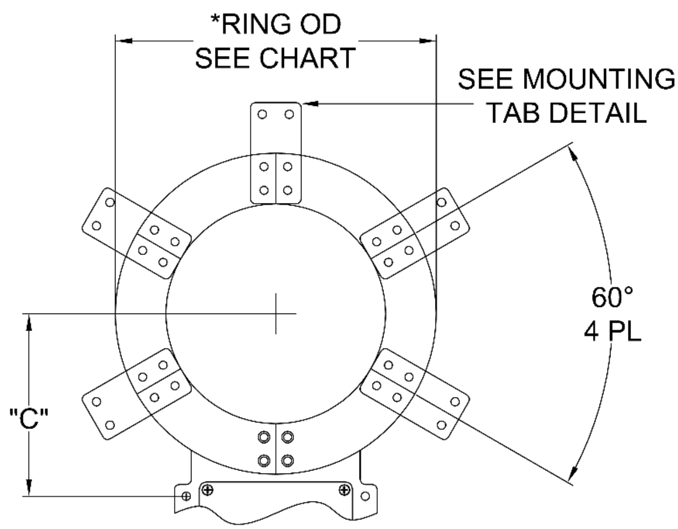

Figure 13: Ring Diameter and Interface Location for 610 to 1016 mm [24.00 to 40.00 in] Shafts

SHAFT SIZE 610-1016 MM [24.00-40.00 INCHES]			
SHAFT OD MIN	SHAFT OD MAX	*RING OD	“C”
610 mm [24.00 in]	711 mm [28.00 in]	800 mm [31.50 in]	417 mm [16.40 in]
711 mm [28.00 in]	813 mm [32.00 in]	902 mm [35.50 in]	467 mm [18.40 in]
813 mm [32.00 in]	914 mm [36.00 in]	1003 mm [39.50 in]	518 mm [20.40 in]
914 mm [36.00 in]	1016 mm [40.00 in]	1105 mm [43.50 in]	569 mm [22.40 in]
*RING AND COLLAR OD ARE NOMINALLY SAME SIZE			

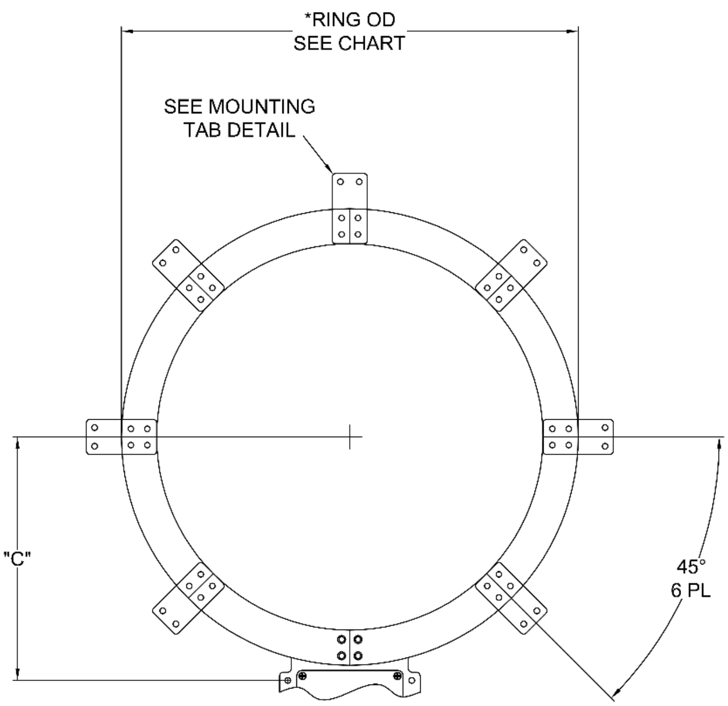

Figure 14: Ring Diameter and Interface Location for 1016 to 1219 mm [40.00 to 48.00 in] Shafts

SHAFT SIZE 1016-1219 MM [40.00-48.00 INCHES]			
SHAFT OD MIN	SHAFT OD MAX	*RING OD	"C"
1016 mm [40.00 in]	1118 mm [44.00 in]	1207 mm [47.50 in]	620 mm [24.40 in]
1118 mm [44.00 in]	1219 mm [48.00 in]	1308 mm [51.50 in]	671 mm [26.40 in]
*RING AND COLLAR OD ARE NOMINALLY SAME SIZE			

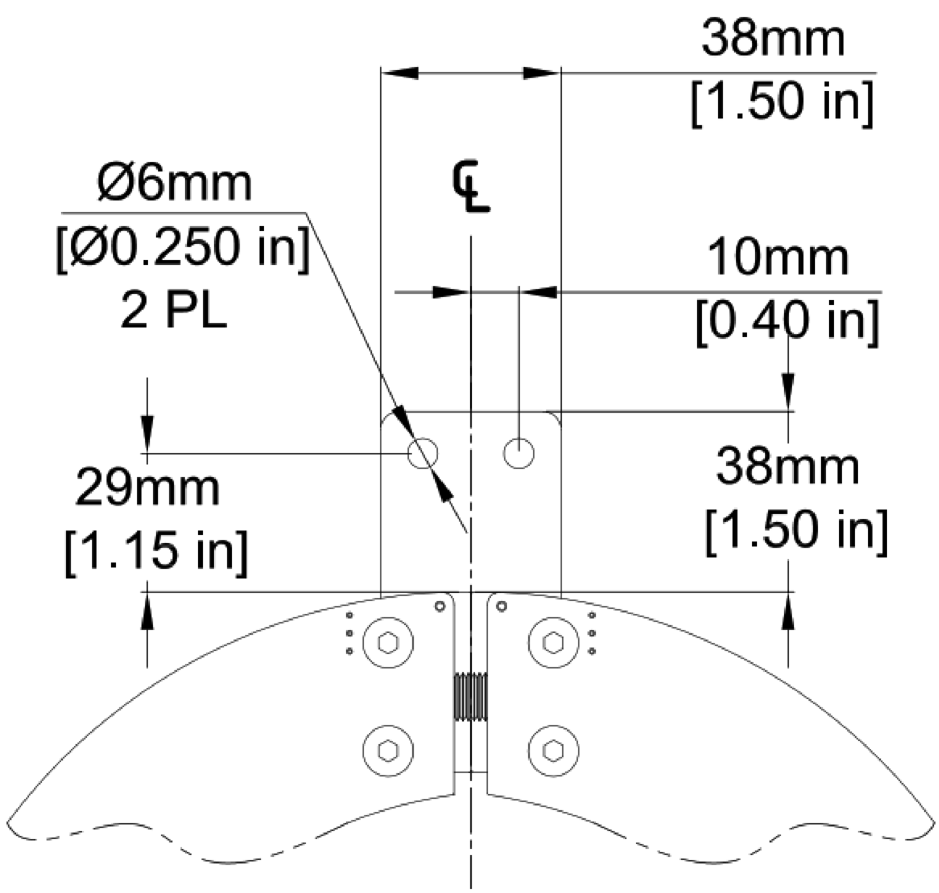

Figure 15: Stationary Ring Mounting Bracket Dimensions

10 APPENDIX E: MAXIMUM SHAFT SPEEDS

Table12: 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.

11 WARRANTY AND SERVICE INFORMATION

ONE YEAR LIMITED WARRANTY

Binsfeld Engineering Inc. warrants solely to the original purchaser of the Products for a period of (1) one year after the date of delivery, the Products to be free from defect in material and workmanship under normal use and will conform to Binsfeld Engineering Inc. published specifications of the Products. Notwithstanding the foregoing, Binsfeld Engineering Inc. retains its right to deviate from published specifications due to latest improvements in function and design of the Product. The foregoing warranty is subject to proper storage, transportation and use of the Products, and does not include defects due to normal wear and tear or deterioration. Upon delivery, Customer shall immediately inspect the Products for conformity and visible defects. Customer shall give Binsfeld Engineering Inc. immediate written notice of any conformities or visible defects regarding the Products and contact Binsfeld Engineering Inc. in writing concerning return or repair, as the case may be.

Binsfeld Engineering Inc.'s sole obligation under this warranty is, upon evaluation by Binsfeld Engineering Inc., and at Binsfeld Engineering Inc. 's option, to repair or correct any defect or to replace or exchange the Product with a copy of the original invoice to Binsfeld Engineering Inc. at its own cost. Any repaired, corrected, replaced or exchanged Products shall be subject to the warranty and limitations set forth. If Binsfeld Engineering Inc. has received notification from Customer, and no defects of the Product could be found, Customer shall bear the costs that Binsfeld Engineering Inc. incurred as a result of notice.

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