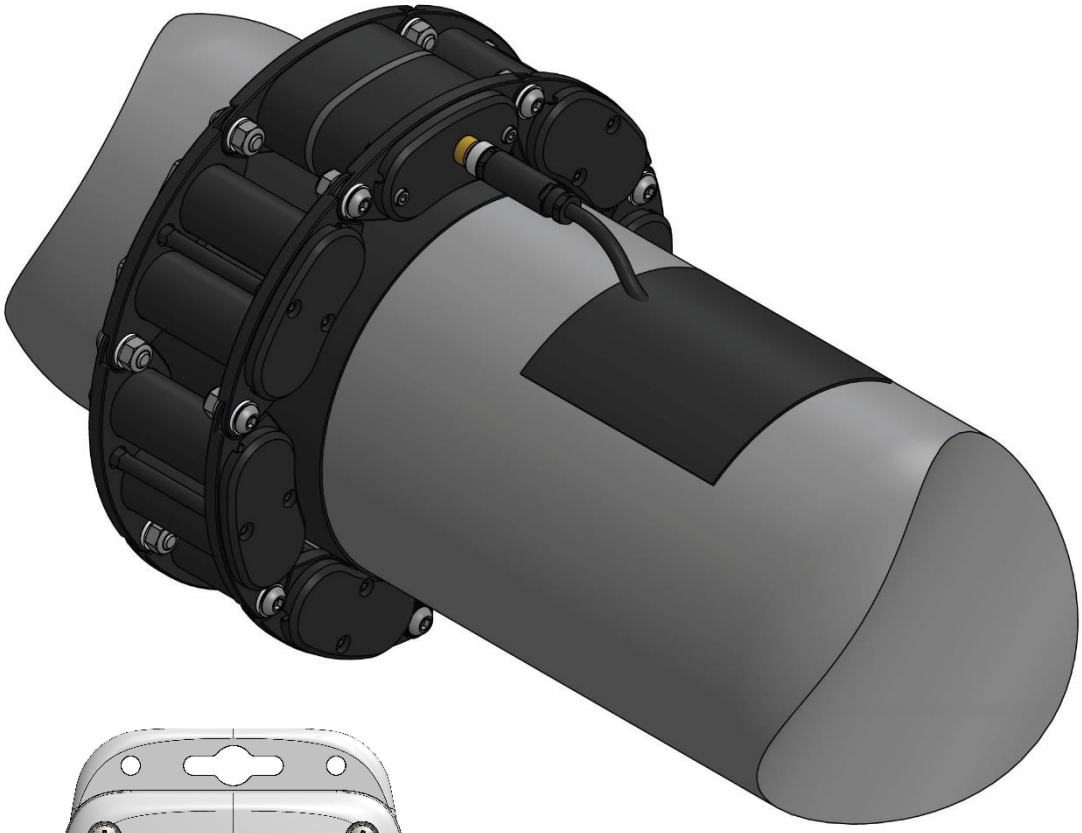
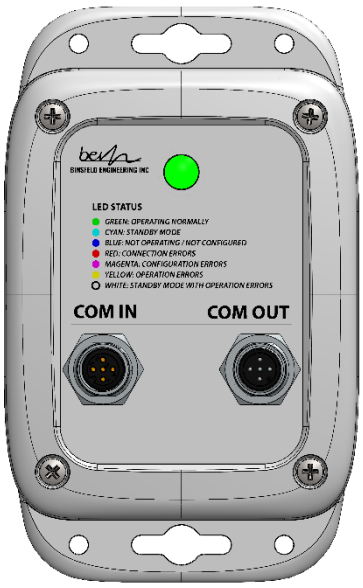
TorqueTrak TS User Manual 866-700-9-4

TorqueTrak TS User Manual





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1 INTRODUCTION

This document describes the TTTS mechanical shaft power meter. The TTTS combines a strain-gage based TTTS Collar with a gyro rpm sensor to provide an all-in-one power measurement system.

1.1 FUNCTION DESCRIPTION

1.1.1 Torque Measurement

The TTTS is a strain gage transmitter. It is made to measure torque on rotating shafts using a 350 ohm torque pattern strain gage. The TTTS calculates torque using shaft deformation signal from the strain gage according to the following equations:

$$\varepsilon\ (inches/inch) = \frac{GV}{2^{30} * GF}$$

$$Torque\ (N.m) = \frac{\varepsilon * \pi * E * (OD^4 - ID^4)}{16 * 10^3 * OD * (1 + v)}$$

where

ε = strain (inches/inch)
GV = Gage Value read from sensor (from -2^{23} to $2^{23}-1$)
GF = gage factor
E = Shaft material modulus of elasticity (MPa or N/mm2)
ID = Shaft inner diameter (mm)
OD = Shaft outer diameter (mm)
v = Shaft material Poisson ratio
N.m = Newton-meters

1.1.2 RPM Measurement

The TTTS has the unique capability to measure revolution speed using a high-speed gyro, eliminating the need for a fixed rpm pick up sensor.

The embedded Gyro sensor can measure up to 3000 RPM.

1.1.3 Power Calculation

The TTTS calculates Power from Torque and RPM using the following equation:

$$Power\ (Watts) = \frac{Torque(N.m) * RPM * \pi}{30}$$

1.1.4 AVERAGING

A strongly fluctuating torque causes the display to vary accordingly and renders the torque and power difficult to interpret by the operator. The averaging function smoothes the data by performing an average over several measured values.

2 TTTS SPECIFICATIONS

2.1 TTTS RECEIVER DIMENSIONS

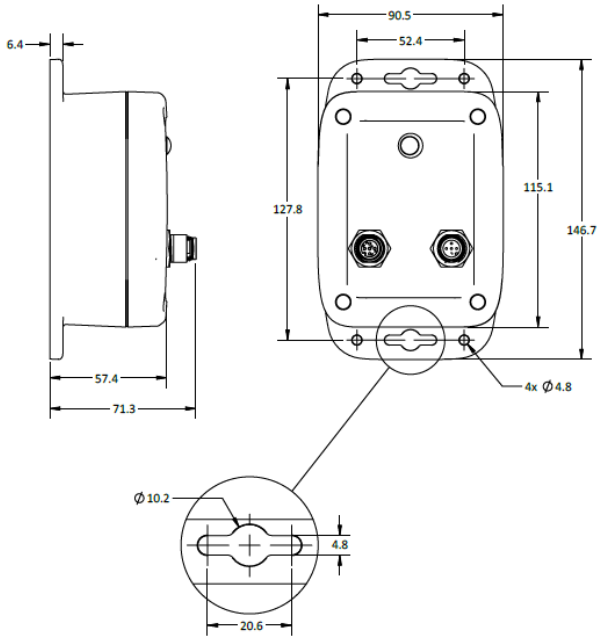


Figure 1 – TTTS Receiver Dimensions (mm)

2.2 TTTS COLLAR DIMENSIONS

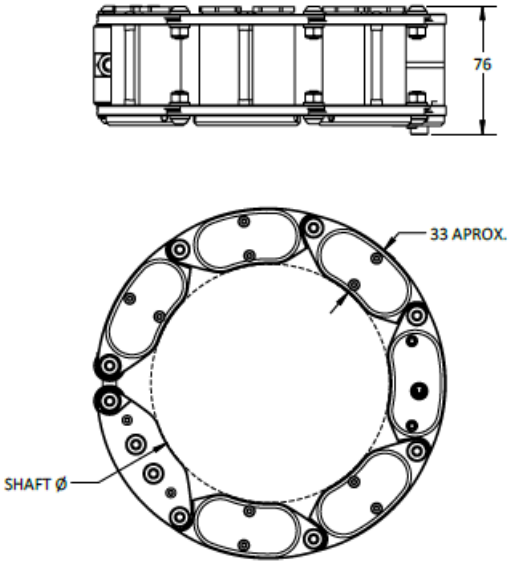


Figure 2 - TTTS Collar Dimensions (mm)

2.3 TTTS RECEIVER SPECIFICATIONS

Table 1 – TTTS Receiver Specifications

Description	Data
Input Voltage	9-36 VDC
Current Consumption	40 mA max
Electrical Isolation	500V
Storage Temperature	-35°C to 85°C
Operating Temperature	-35°C to 70°C
Humidity	10% to 90% non-condensing
Vibration	5 – 50 Hz @ 20 mm/s +/- 1.0g max
Degree of Protection	IP 66
Wireless Communication	Wireless connection to one TTTS Collar

2.4 TTTS SENSOR LINK SPECIFICATIONS

Table 2 – TTTS Sensor Link Specifications

Description	Data
Electrical Consumption	<1mA @ 3.6V
Batteries	3.6VLiSoCl2 (lowest self-discharge)
Strain Gage	350 ohm torque pattern, welded or bonded
Autonomy	2 years on 10x 3.6AH, 3.6V batteries
ADC Resolution	24 bits
Torque Accuracy	± 0.1%
RPM Accuracy	± 1%
Maximum RPM	3000 rpm
Degree of Protection	IP 66

2.5 COMMUNICATION PROTOCOL

The TTTS Receiver module communication protocol is Modbus RTU over RS-485. Up to 32 modules can be connected on the same Modbus line.

Table 3 - Modbus Protocol Description

Description	Data
Interface Type	RS-485
Baud Rate	9600/19200/38400/57600/115200
Protocol	Modbus RTU
Serial Settings	8N1

2.6 CABLE TYPE

Table 4 - Recommended Cable Type

Description	Data
Conductors	2 power wires + 1 twisted communication pair + 1 drain (shield) wire
Recommended Cable	Belden 1502SB
Communication Pair Impedance	120 Ω
Connector	M12
Recommended Connectors	Phoenix Contact 1424670 (Male) Phoenix Contact 1424672 (Female)

2.7 PINOUT

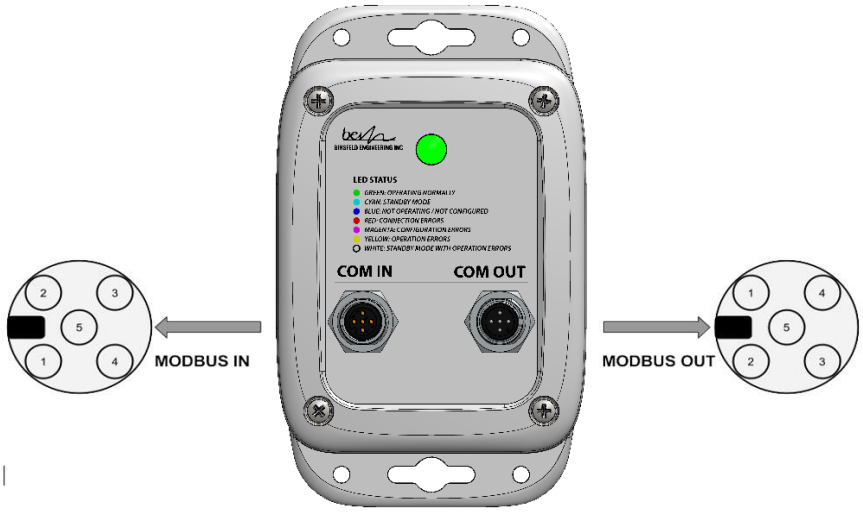


Figure 3 – TTTS Receiver Pinout

Table 5 – TTTS Receiver Pinout

Description	Pin number
Shield	1
9-36 VDC	2
0 VDC	3
RS-485 A+	4
RS-485 B-	5

3 WORKING WITH THE SYSTEM

3.1 COMMUNICATION

The TTTS Receiver module use a powered bus architecture and connectorized cables to reduce the amount of electrical connections.

Up to 16 TTTS Receivers can be connected in chain using the powered bus.

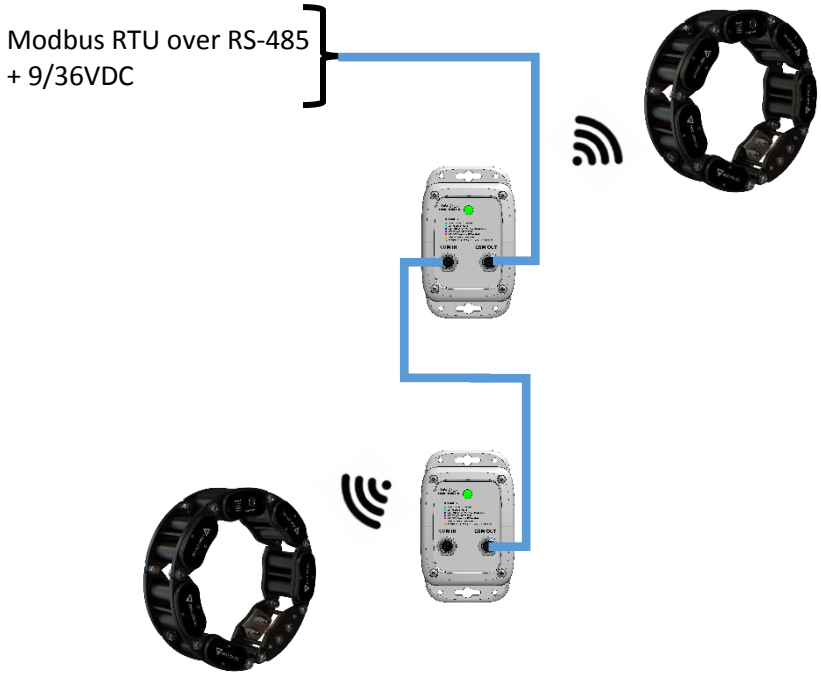


Figure 4 – Wiring principle

3.1.1 MODBUS ADDRESS SELECTION

The TTTS Receiver module Modbus address is selected using the 2 digits selector found on the circuit board. For example, to select address 27 set the X10 selector to 2 and the X1 selector to 7.

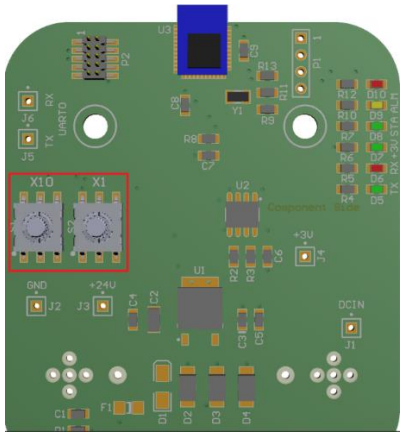


Figure 5 – TTTS Receiver Modbus Address Selection

3.2 TTTS COLLAR

The TTTS Collar is made to be installed on rotating shafts. It contains the following elements:

- Strain gage transducer
- Gyro RPM sensor
- Wireless radio module
- Batteries

The TTTS chain link architecture makes it scalable for various shaft diameter. The TTTS Collar electronics are highly optimized for multi-year operation between battery changes.

Figure 6 - TTTS Collar

3.2.1 TTTS TRANSMITTER LINKS

3.2.1.1 TTTS SENSOR LINK

The TTTS Sensor Link contains the strain gage transducer, the gyro and communicates with the TTTS Receiver

It also contains a soldering pad for connection to the strain gage. The soldering pad is accessible after removing the cover panel.

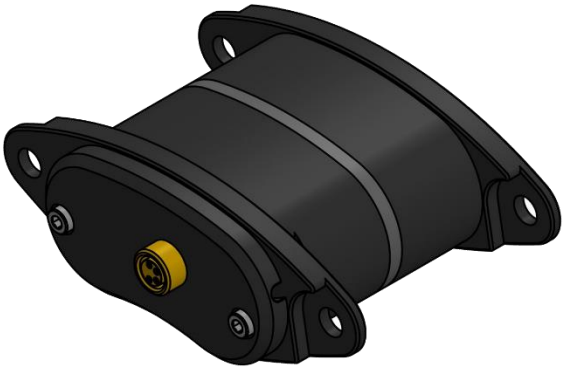


Figure 7 - TTTS Sensor Link

3.2.1.2 BATTERY LINK

Each battery link contains two $LiSOCL_2$ 3.6V batteries and reverse battery protection.

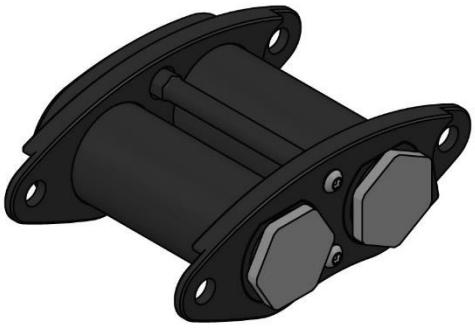


Figure 8 - Battery Link

3.2.1.3 TIE KIT

The tie links are used to attach the TTTS Transmitter to the shaft.

Figure 9 - Tie Kit

3.2.1.4 EXTENSION LINKS

The extension links are used to extend the collar diameter for shaft diameters above 150mm.

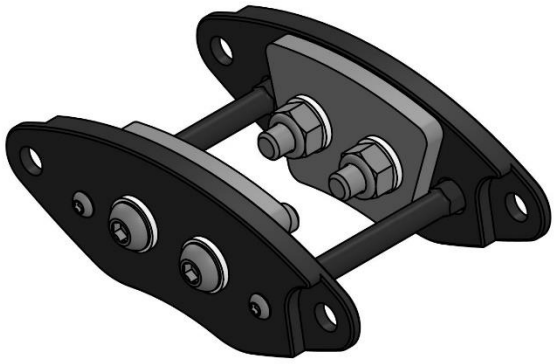


Figure 10 - Extension Link

3.3 INSTALLATION

3.3.1 INSTALLING THE TTTS COLLAR ON THE SHAFT

The following steps describe installation of the TTTS Collar on a rotating shaft

1. Locate an area with at lest 250 mm of free horizontal space on the shaft

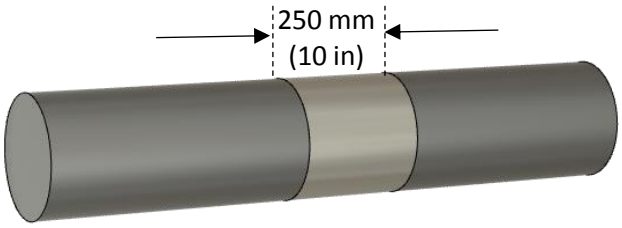


Figure 11 - Installation Area

2. Identify the strain gage installation location

3. Install the strain gage. See the following link for more details. https://binsfeld.com/support/torquetrak-support/torquetrak-support-strain-gage-installation/

4. Remove the TTTS Collar from its packaging and lay the TTTS on the shaft.
   Wrap the collar around the shaft and attach the tie kit loosely

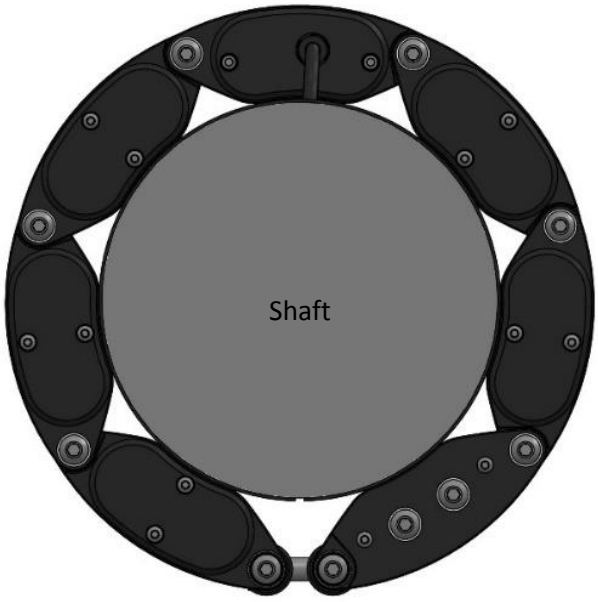


Figure 12 - TTTS Collar Loosely Attached

5. Rotate the TTTS Collar so the sensor link is aligned with the strain gage.

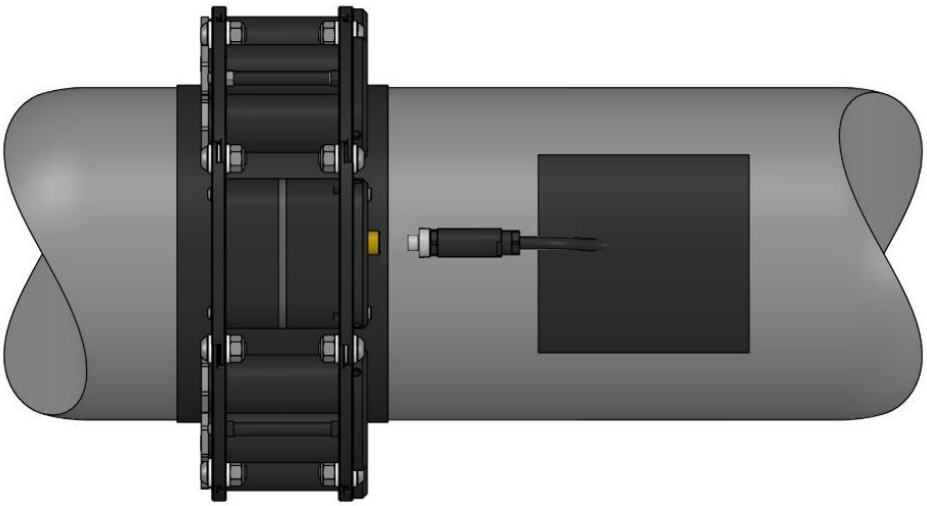


Figure 13 - Positioning the TTTS Collar

6. Tighten the TTTS Tie kit to a final torque of 25N-m on the M8 bolts using a ball nose hex drive to avoid damaging the TTTS surface.

Figure 14 - Tie Kit Tightening

~~7. and the pivot boats~~

~~8.~~7. Tighten all the pivot bolts around the collar to a final torque of 12N-m.

Figure 15 - Pivot Bolts Tightening

~~9.~~8. Connect the strain gage connector to the sensor link.

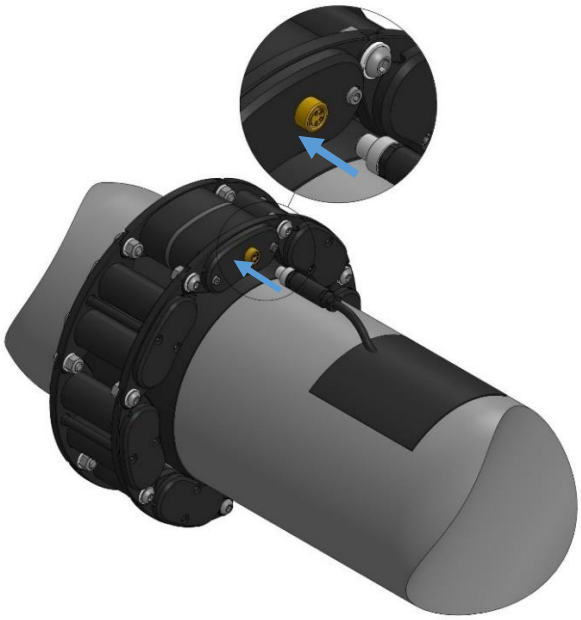


Figure 16 – Connection of the Strain Gage

3.3.2 CONNECTING THE TTTS RECEIVER

The following steps describe the steps required to verify the connection between the TTTS Receiver and the TTTS Collars.

1. Install the TTTS Receiver within 15m line-of-sight or closer to the TTTS Collar. The signal strength must be greater than -80dBm (usually between -40dBm and -70dBm). See Table 13.
   Please note that any metal parts close to the TTTS will affect the signal. So, the receiver might have to be closer from the collar to get a strong signal.
2. Connect the TTTS Receiver using the recommended cable as described in Table 4.

   To communicate with the device, use RS-485, 8N1, Modbus RTU commands Read Holding Registers (0x03) and Write Multiple Registers (0x10).

   The default baud rate is 38400 bps.

   If the baud rate is unknown, write a given baud rate in the baud rate configuration register at each possible baud rate, then communicate normally at given baud rate.
   Example to set 38400 baud rate to the device at address 1:

   01 10 0030 04 00009600 9f1b
   01: Device address 1
   10: Write Multiple Register function code
   0030: Baudrate Configuration Register start
   04: Number of bytes to write (baud rate is 32 bits / 4 bytes)
   00009600: Baudrate Configuration Register Data to Write
   9F1B: Modbus CRC-16 checksum (Recompute for each unique Modbus request)

   Write the previous command at each baud rate (9600,19200,38400, 57600 and 115200) to set device address 1 to baud rate 38400.

   To test data acquisition through Modbus communication from the TTTS Receiver, query the TTTS Receiver by reading the data registers.

   Example:
   To read data from the TTTS Collar, read 12 registers starting from address 0x80

   The read command should be formatted as :

   01 03 0080 000C 4427

   Where:
   01: TTTS Receiver Modbus Address
   03: Modbus command Read Holding Registers
   0080: 0x80 Starting address
   000C: 0x000C-> 12 Registers to read
   4427: CRC-16 (Cyclic redundancy check)

The answer from the TTTS Receiver should be formatted as follows:

01 03 18 00000000 0007815F 0000021F 0004448C 00033B57 0B01 FFBF F23F

01: TTTS Receiver Modbus Address
03: Modbus command Read Holding Registers
18: Byte count: 24 bytes -> 12 x 16-bit registers
00000000: 32 bits alarm
0007815F: Torque: 4 918.71 Nm
0000021F: Shaft speed: 54.3 RPM
0004448C: Power: 27 969.2 W
00033B57: Gage voltage: 211799
0B01: Battery voltage: 2.817 V
FFBF: Receive Signal Power: -65 dBm
F23F: CRC 16

3. Setup communication with TTTS Collar

   Note: Leave MAC Address registers blank for unused

   Write TTTS Collar MAC Address to registers starting 0x32 (3 Bytes).
   Ex: 0x12AB F54A 7DE3

4. Verify communication with the linked TTTS collars:
   Write 0xFFFFFFFF to register 0xC4 clear all alarms
   a. Wait **5** seconds.
   b. Read Register 0x80 :TTTS Collar Alarms Register.
   c. Apply Mask 0x00008000 to display Alarm 16 Status “TTTS Collar Connection Alarm Register”.
   d. If Communication is OK, Alarm 16 value is 0.

3.3.3 SETTING UP THE TORQUE CALCULATION

To calculate torque from the strain gage voltage reading, TTTS needs the torque calculation parameters to be entered in the Modbus registers (see table 11):

Example: Setting the torque calculation parameters in TTTS Collar

- Shaft inside diameter: 50.5 mm
- Shaft outside diameter: 125.0 mm
- Shaft material Poisson ratio: 0.3 (for steel)
- Gage factor: 2.16
- Shaft material modulus of elasticity: 206 800 MPa (for steel)

a. Write the TTTS Collar: Shaft inside diameter(mm) to register 0x40
The register 0x40 has a x10 multiplier, the value to enter is 50.5 * 10 = 505 (U16)

Example command: **01100040000101F901DB**
Where :

01: 0x01 TTTS Receiver Modbus Address
10: 0x10 Write Multiple Registers Operation
0040: 0x40 Starting Address
0001: 1 Register to write
01F9: 505 in HEX
01DB: CRC-16 (Cyclic redundancy check)

b. Write the TTTS Collar: Shaft outside diameter(mm)to register 0x41
The register 0x4D has a x10 multiplier, the value to enter is 125.0 * 10 = 1250 (U16)

c. Write the TTTS Collar: Shaft material Poisson ratio to register 0x42
The register 0x4E has a x1000 multiplier, the value to enter is 0.3 *1000 = 300 (U16)

d. Write the TTTS Collar: Gage factor to register 0x43
The register 0x4F has a x1000 multiplier, the value to enter is 2.16 *1000 = 2160 (U16)

e. Write the TTTS Collar: Shaft material elastic modulus (MPa or N/mm^2) to register 0x44
The register 0x4F has a x1 multiplier, the value to enter is 216800 (U32)

Example command: **01 10 0044 0002 0003 27D0 7BAA**
Where :

01: 0x01 TTTS Receiver Modbus Address
10: 0x10 Write Multiple Registers Operation
0044: 0x44 Starting Address
0002: 2 Registers to write
0003: 206800 is 0x000327D0 in Hex, 0003 is the MSB
27D0: 206800 LSB
7BAA: CRC-16 (Cyclic redundancy check)

Note: It is a good practice to read the values after the write operation to make sure that the value has been written properly.

3.4 REPLACING BATTERIES

It is recommended to replace battery every 2 years when using sleep function of the TTTS or 1 year when the system is continuously sampling the strain gage.

To replace batteries:

1. Remove the hexagonal battery caps and remove **ALL** the old batteries. Remove all batteries before installing new ones and ensure that ALL replacement batteries are new.
2. Install the first battery and install the hexagonal cap. Repeat for all batteries.
3. Open the cover of the transmitter link, then press the button for at least 10 seconds.

3.5 SOFTWARE SETTINGS

3.5.1 AVERAGING

In many applications, such as thermal engines, the torque reading varies significantly. Each explosion is a piston creates a torque peak, which leads to high frequency and high amplitude variations in the torque reading. To attenuate the variations, the TTTS performs averaging by acquiring torque 4 times per second.

If required, additional averaging can be applied to further reduce variations. However, while the averaging reduces the amplitude of the random variations, it also reduces the response time of the TTTS.

The following table describes the effect of averaging on the response time. The response time is defined as the time required to reach 99.9% of a step variation.

For 0 or 1, there is no filtering. The acquisition period 0.25s is the reaction time.
From 2 to 16 a moving average is used. The reaction time is samples*0.25s
From 17+, an exponential filter is used. The reaction time can be extrapolated with the table below.

Table 6 - Reaction Time vs Averaging

Averaging	Reaction time
0 or 1	0.25 s
2	0.5 s
16	4 s
17	0.8 s
30	2.5 s
50	4.8 s
100	10.6 s
200	22.2 s
500	56.7 s

3.5.2 BATTERY VOLTAGE

TTTS is powered by 3.6V $LiSoCL_2$ Batteries. These batteries have a low self-discharge and a high energy density. The battery voltage is expected to stay stable until approximately 5% of the battery capacity is left. When the voltage starts to drop, it is recommended to plan battery change within a month.

The battery voltage register is included in the commonly read data registers.

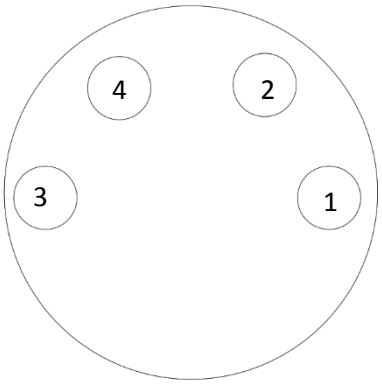
4 SENSORS DETAILS

4.1 STRAIN GAGE

4.1.1 GAGE MICROSTRAIN RANGE

(With a 2.000 Gage Factor)
Gage Strain Maximum Range: ±3900 με
Gage Strain Resolution: 0.00047 με

Strain Gage Connector			
TS Terminal	**Description**	**Connector Cable Color**	**Ribbon Cable Color**
1	Sen+ (Sense Positive)	Brown	Green
2	Sen- (Sense Negative)	White	White
3	Exc+ (Excitation Positive)	Blue	Red
4	Exc- (Excitation Negative)	Black	Black



TS Strain Gage Connector

5 MODBUS REGISTERS LIST

This section describes the Modbus Registers.

Address: Modbus address of the beginning of the register

Type: Type of data contained in the register.

Size: The Modbus registers are all 16-bits. The size describes the number of 16 bits registers to read for a particular parameter. For example, TTTS Collar serial number is a 32-bit registers, therefore the size is 2 (2x16 bits). All registers access (16, 32 or 64 bits) are big endian way.

Table 7 – 32-Bits Register Example

Serial_Number U32 (32-bit data beginning at address 0x00)	
0x0098A761	
Serial number HI(16 bits data at 0x00)	**Serial number LO(16 bits data at 0x01)**
0x0098	**0xA761**

Mult: Modbus registers on the TTTS Receiver cannot contain floating point data. When decimals are needed, a multiplier is used. For example, the torque has 2 decimals (Mult. = 100). When the parameter is read from the TTTS Receiver, it must be divided by 100.

The same logic applies when writing to the TTTS Receiver. For example, to write a shaft inside diameter value of 200.1 mm, the value 2001 (200.1 x Mult. 10) should be written to the register.

Table 8 – Data Types

Type	**Signedness**	**Bits length**	**Register Length**	**Minimum Value**		**Maximum Value**	
				Hex	**Decimal**	**Hex**	**Decimal**
U16	Unsigned	16	1	0x0	0	0xFFFF	65535
I16	Signed	16	1	0x8000	-32768	0x7FFF	32767
U32	Unsigned	32	2	0x0	0	0xFFFFFFFF	4294967295
I32	Signed	32	2	0x80000000	-2147483648	0x7FFFFFFF	2147483647
U48	Unsigned	48	3	0x0	0	0xFFFFFFFFFFFF	281474976710655

Table 9 - Protected Values (Read only)

Name	Description	Addr.	Type	Mult.	Value Range	Typical
Serial_Number	TTTS Receiver Serial Number	0x00	U32	1	0030000001 :0039999999	0030000001
Device_ID	Customer serial number	0x02	U32	1	N/A	1
Boot_Count	Number of device boot	0x04	U16	1	N/A	1
Software Version	Software Version	0x05	U16	100	1.00:655.35	1.00
Hardware Version	Hardware Version	0x06	U16	100	1.00:655.35	1.00

Table 10 – TTTS Receiver Alarm Register (Read only)

Description	Addr.	Type	Size	Mult.	Value Range	Typical
32 bits alarm register*	0x14	U32	2	1	N/A	0

*Use TTTS Receiver alarm clear register to clear alarms

Table 11 - Communication Registers

Name	Addr.	Type	Mult.	Value Range	Typical
Serial Modbus baud rate	0x30	U32	1	9600, 19200, 38400, 57600, 115200	38400
TTTS Collar: MAC address	0x32	U48	1	N/A	0xF8F0050123451

Table 12 – TTTS Collar Configuration Registers

Name	Addr.	Type	Mult.	Value Range	Typical
TTTS Collar: Shaft inside diameter (mm)	0x40	U16	10	N/A	50.0
TTTS Collar: Shaft outside diameter (mm)	0x41	U16	10	N/A	0.0
TTTS Collar: Shaft material Poisson ratio	0x42	U16	1000	N/A	0.300
TTTS Collar: Gage factor	0x43	U16	1000	N/A	2.000
TTTS Collar: Shaft material elastic modulus (MPa or N/mm^2)	0x44	U32	1	N/A	206000
TTTS Collar: Number of filtering samples	0x46	U16	1	N/A	100
TTTS Collar: Low battery alarm voltage (V)	0x47	U16	1000	N/A	3.450
TTTS Collar: Gage voltage at rest	0x48	I32	1	N/A	1000
TTTS Collar: Shaft speed at rest (RPM)	0x4A	I16	10	N/A	1.0
TTTS Collar: Shaft speed sleep threshold for sleep (RPM)	0x4B	I16	10	N/A	5.0

Table 13 – TTTS Collar Data Registers

Name	Addr.	Type	Mult.	Value Range	Typical
TTTS Collar: 32 bits alarm	0x80	U32	1	N/A	0
TTTS Collar: Torque (in Nm)	0x82	I32	100	N/A	20000.00
TTTS Collar: Shaft speed (RPM)	0x84	I32	10	N/A	100.0
TTTS Collar: Power (W)	0x86	I32	10	N/A	2000000.0
TTTS Collar: Gage voltage	0x88	U32	1	N/A	300000
TTTS Collar: Battery voltage (V)	0x8A	U16	1000	N/A	3.000
TTTS Collar: Receive signal power (dBm)	0x8B	I16	1	N/A	-50

Table 14 – Receiver Alarm Clear Registers (Write Only)

Name	Description	Addr.	Type	Mult.	Value Range	Typical
Alarm Clear	To clear an alarm from register 0x14, write the associated mask value.	0xC4	U32	1	N/A	0xFFFFFFFF

Table 15 – TTTS Collar Alarm Clear Registers (Write Only)

Name	Description	Addr.	Type	Mult.	Value Range	Typical
TTTS Collar: Alarm Clear	To clear an alarm from register 0x80, write the associated mask value.	0xC6	U32	1	N/A	0xFFFFFFFF

5.1 MODBUS LINE SUPERVISOR

The TTTS comes equipped with an automatic software Modbus line supervisor. Since the Modbus line can be shared with other devices, this can sometimes be problematic when those devices do not respect the standard Modbus timing and implementation. So, the supervisor has been implemented to monitor the Modbus line for faulty devices and restore the communication when needed. When this process is triggered, the TTTS can take a few seconds (~30 seconds) to restore the communication during which it won't respond.

6 ALARMS DESCRIPTION

The following alarms list describes alarms for both TTTS Receiver and TTTS Collar.

Alarm 1 to 24 (mask 0xFF000000) are alarms to a specific TTTS Collar. Alarms 25 to 32 (mask 0x00FFFFFF) are alarms related to the receiver.

Table 16 – Alarms Register layout

Alarm register name	Addr.	Alarms layout
TTTS Receiver Alarms	0x14	0xUUWWWWWW
TTTS Collar Alarms	0x80	0xUUWWWWWW

UU are alarms specific to receiver
WWWWWW are alarms specific to TTTS Collar
Note: Registers 0x14 and 0x80 are duplicate in prevision for future developments

UU part for TTTS Receiver are duplicated in each TTTS Collar alarms (duplicated information). VVVVVV is an aggregate of all TTTS Collars Alarms.

Table 17 – Alarms Clear Register content layout

Alarm register name	Addr.	Alarms Clear layout
TTTS Receiver Alarms	0xC4	0xMMQQQQQQ
TTTS Collar Alarms	0xC6	0xMMQQQQQQ

Any MM clear alarms specific to receiver (all UU in all alarms)
QQQQQQ clear alarms specific to TTTS Collar (WWWWWW)
Note: Registers 0xC4 and 0xC6 are duplicate in prevision for future developments

Table 18 – TTTS Receiver Alarms Definition (Address 0x14)

Name	Alarm #	Mask
Alarm 1 - TTTS Collar: Gauge Disconnected	1	0x00000001
Alarm 3 - TTTS Collar: Unsupported Configuration	3	0x00000004
Alarm 5 - TTTS Collar: Battery Low	5	0x00000010
Alarm 12 - TTTS Collar: Shaft Speed Sleep warning	12	0x00000800
Alarm 13 - TTTS Collar: Acquisition Not Ready warning	13	0x00001000
Alarm 15 – TTTS Collar: Disconnection Error	15	0x00004000
Alarm 16 – TTTS Collar: Connection Error	16	0x00008000
Alarm 17 – TTTS Collar: Configuration Read Error	17	0x00010000
Alarm 18 – TTTS Collar: Configuration Write Error	18	0x00020000
Alarm 19 – TTTS Collar: Calibration Error	19	0x00040000
Alarm 20 – TTTS Collar: Acquisition Error	20	0x00080000
Alarm 21 – TTTS Collar: Unexpected Communication Error	21	0x00100000
Alarm 22 – TTTS Collar: Synchronization Error	22	0x00200000
Alarm 23 – TTTS Collar: Acquisition Timeout	23	0x00400000
Alarm 24 – TTTS Collar: Unexpected Disconnection Error	24	0x00800000
Alarm 25 – TTTS Receiver: Unsolicited Communication Error	25	0x01000000
Alarm 26 – TTTS Receiver: Non-Unique MAC Address Error	26	0x02000000
Alarm 27 – TTTS Receiver: Internal Error	27	0x04000000
Alarm 28 – TTTS Receiver: Internal Error	28	0x08000000
Alarm 32 - TTTS Receiver: Device has rebooted	32	0x80000000

Table 19 – TTTS Collars Alarms Definition (Address 0x80)

Name	Alarm #	Mask
Alarm 1 - TTTS Collar: Gauge Disconnected	1	0x00000001
Alarm 3 – TTTS Collar X: Unsupported Configuration	3	0x00000004
Alarm 5 - TTTS Collar X: Battery Low	5	0x00000010
Alarm 12 - TTTS Collar X: Shaft Speed Sleep warning	12	0x00000800
Alarm 13 - TTTS Collar X: Acquisition Not Ready warning	13	0x00001000
Alarm 15 – TTTS Collar X: Disconnection Error	15	0x00004000
Alarm 16 – TTTS Collar X: Connection Error	16	0x00008000
Alarm 17 – TTTS Collar X: Configuration Read Error	17	0x00010000
Alarm 18 – TTTS Collar X: Configuration Write Error	18	0x00020000
Alarm 19 – TTTS Collar X: Calibration Error	19	0x00040000
Alarm 20 – TTTS Collar X: Acquisition Error	20	0x00080000
Alarm 21 – TTTS Collar X: Unexpected Communication Error	21	0x00100000
Alarm 22 – TTTS Collar X: Synchronization Error	22	0x00200000
Alarm 23 – TTTS Collar X: Acquisition Timeout	23	0x00400000
Alarm 24 – TTTS Collar X: Unexpected Disconnection Error	24	0x00800000
Alarm 25 – TTTS Receiver: Unsolicited Communication Error	25	0x01000000
Alarm 26 – TTTS Receiver: Non-Unique MAC Address Error	26	0x02000000
Alarm 27 – TTTS Receiver: Internal Error	27	0x04000000
Alarm 28 – TTTS Receiver: Internal Error	28	0x08000000
Alarm 32 - TTTS Receiver: Device has rebooted	32	0x80000000

Note: X is for number 1 to 4 for TTTS Collar numbering

Alarms details

Alarm 1:
Detail: Strain Gauge is disconnected or incorrectly connected to collar. Torque, power, and gage voltage values are not reliable.
Correction: Connect Strain Gauge Connector to TTTS Collar (See section **Error! Reference source not found.**, REF _Ref94778156 \h * MERGEFORMAT **Error! Reference source not found.**, step **Error! Reference source not found.**, **Error! Reference source not found.**) Contact strain gage vendor for support for damaged wiring on the strain gage.

Alarm 3: Factory use only: undocumented registers with invalid settings has been written. Write back zeros to written registers to clear alarm condition and clear alarms.

Alarm 5: The battery voltage is equal or lesser than configured “Low battery alarm voltage” for given TTTS Collar. Plan for battery change (or decrease “Low battery alarm voltage”: not recommended)

Alarm 13: TTTS Collar is getting prepared for acquisition and no timeout or error occurred so far.

Alarm 12: The given TTTS Collar shaft speed is below “shaft speed at rest”. The TTTS Collar is sleeping. The last data values can be read, but no actual data acquisition is done (shaft speed is sampled one time per second to check for wake condition, but this data cannot be read).

Alarm 21: Communication from a configured TTTS Collar, but not the expected one scheduled by the base station. It can happen when there is wireless interference and multiple TTTS Collars connected.

Alarm 22: Communication from a configured TTTS Collar, but the type of communication is expected giving the configuration state of the TTTS Collar. It can happen when there is wireless interference and multiple TTTS Collars connected.

Alarm 25: Received communication from a wireless device, but not a configured TTTS Collar. It happens mostly when an TTTS Collar address is removed, but the disconnection is not done correctly.

Alarm 26-27: Internal errors related to non-volatile memory issues. Should never happens. Factory use only.

7 TROUBLESHOOTING

7.1 MODBUS COMMUNICATION WITH TTTS RECEIVER

Trouble	Probable cause	Solution
TTTS Receiver not responding to Modbus Commands	Device not powered Device defective	Open TTTS Receiver Cover Verify power LED Verify status LED flashing at 1 Hz
	Incorrect RS-485 cabling	Confirm that RX LED is flashing on the TTTS Receiver when receiving Modbus Commands.
	Incorrect modbus address selected (RX LED Flashes but no TX)	Adjust the X1 and X10 knobs on the TTTS Receiver board to match the Modbus Commands.
	End of line resistor not installed	Install the M12 end of line resistor at the end of the last TTTS Receiver on the Modbus line.
	Incorrect Baud Rate (RX LED Flashes but no TX)	Set send the "Set Modbus baud rate" command from Table 11 at 9600, 19200, 38400, 57600 and 115200 or until TTTS Receiver properly responds.
	Incorrect Modbus command format	See section 0 Modbus Registers List

7.2 COMMUNICATION BETWEEN TTTS RECEIVER AND TTTS SENSOR LINK

Trouble	Probable cause	Solution
No Communication between TTTS Receiver and TTTS Sensor Link Red Light on TTTS Receiver indicates no communication with TTTS Collar	Low Battery	Replace batteries
	Wrong Mac address configuration	Note Mac Address behind the strain gage cover on the TTTS Sensor Link and update the corresponding **TTTS Collar: MAC address** (See Table 11).
	Low radio signal/interference	Install the TTTS Receiver closer to the TTTS Collar. The distance between the TTTS Collar and the TTTS Receiver must be no more than 15 meters and the signal strength must be greater than -80dBm (see Table 13).
	Sensor link not started.	Open the sensor link and press the button for more than 10 seconds.
	Sensor link not disconnected with previous receiver before trying to pair with a new receiver.	Open the sensor link and press the button for more than 10 seconds.