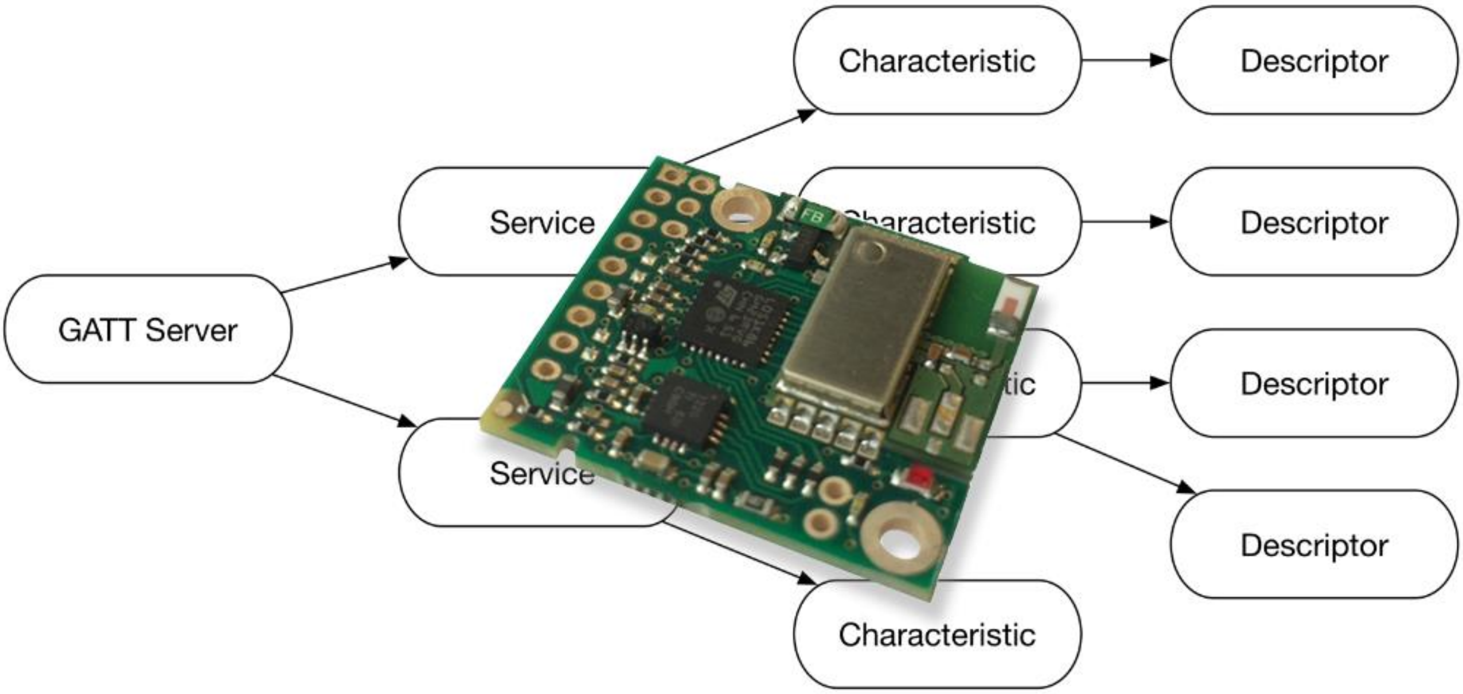
Bluetooth® Telemetry System



BTS Telemetry Technical Manual

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Introduction / Overview

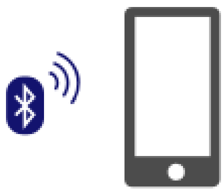
The BTS Bluetooth Telemetry range provides access to quality measurements on a mobile platform such as a phone or tablet. The delivery mechanism is ‘Bluetooth Low Energy’ (Also known as ‘Bluetooth Smart’ or BLE) which utilizes the flexibility and availability of Bluetooth receivers while maintaining the low power requirements of embedded systems. BTS is built upon two complimentary principles of BLE, broadcast advertising data which enables users to deliver the same data to multiple receivers simultaneously and low power connections which can be used in a point to point system. BTS is available in OEM bare board formats or with environmentally sealed enclosure and integrated battery holder.
This manual provides details of data delivery and configuration mechanisms available to system developers intending to implement their own configuration and monitoring application. There are also worked examples for calibration, data delivery and unit conversion.

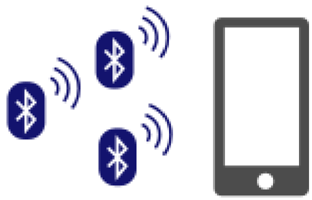
Advertising Operation

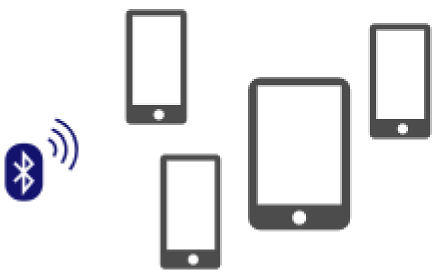
The advertising mode of operation enables BTS modules to broadcast measurement data to multiple locations without retransmission. The advert is a new operational mode within ‘Bluetooth Low Energy’ and facilitates the delivery of data without a connection. This mode of operation is useful in ‘many to many’ and ‘one to many’ use cases.

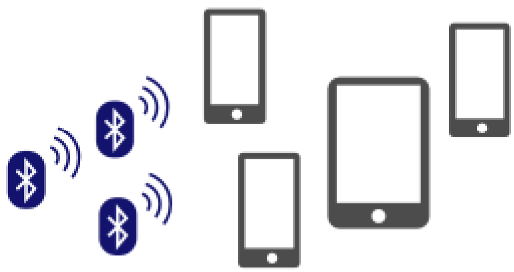
Connected Operation

The connected operational mode enables Bluetooth Low Energy devices to connect directly to the BTS module. A single mobile device can be connected to multiple BTS transmitter modules simultaneously. This mode has a dual purpose as it may be used to monitor data and configure the device. When it is used for the delivery of data the application can register to receive notification updates when the status and engineering unit value changes. This mode of operation is useful in ‘one to one’ and ‘many to one’ use cases.


One to One


Many to One


One to Many


Many to Many

BTS Advert Format

The Bluetooth advert is the primary operating role of this product. The advertising packet is broadcast periodically at a configurable rate. The full list of configurable items will be discussed in the section titled Bluetooth Connected Mode.
The transmission of the advert and the corresponding data is also split into subtopics. The Bluetooth Special Interest Group (SIG) has provided specific details on the format and content of each advert type. The BTS advert is constructed from the connection flags (advert type 0x01), manufacturer specific data (advert type 0xFF) and the device local name (advert type 0x09).
Provision has been made for future developments and extensions of the manufacturer specific data to include other data formats but for the moment only one will be discussed.

The basic format and structure of the BTS advert packet can be observed using a simple BLE scanner. There are many available for android and Apple iOS (A good example is the nRF Connect app).

Local Name

The local name is part of the standard set of data defined by the Bluetooth SIG. The module name that is supplied will depend upon the length of the name given to the product. The length of the name has an impact upon the rest of the data packet and as such should be kept short where possible. The advert is sent with advert type 0x09 as an ASCII character array.
The local name is factory configured to the default value "B24". The name field in the device has a maximum length of eight characters. The advert mechanism will send the full name of the device stored in the EEPROM.

Manufacturer Specific Data

The manufacturer specific data is sent with advert type 0xFF. The current format carries data for a single sensor. The format of this section is shown in Table 1. By default a hash is applied to the data broadcast from the unit and this will be applied to all bytes after the first data tag pair (Shown in bold). An example of decoding the advert is provided later in this section. The measured data is a fixed length parameter in the advert of 4 bytes. This will follow the standard Float format (IEEE 754). N.B The status byte, units, data and the terminating data tag pair are encoded. **N.B The format shown in Table 1 is indicative of the bytes transmitted. Some monitoring applications and APIs do not present the length field to the user.**

Name	Size	Description
Length field	1 byte	Part of the Spec
Advert Type	1 byte	0xFF (Manufacturer Specific Data)
Company ID	2 bytes	0x04C3
Format ID	1 byte	
Data Tag	2 bytes	Module ID
Status	**1 byte**	
Units	**1 byte**	
Data	**4 bytes**	**Floating point data (IEEE 754)**
Data Tag	**2 bytes**	**Used to verify decoding**
Data Tag	**2 bytes**	**Used to verify decoding**

Table 1: BTS Advert Format

Format ID

The format ID uniquely identifies the format of the rest of the packet. This allows for future expansion of the format for other purposes without impacting legacy equipment. This is currently set to 1.

Status

The status byte indicates status using the bit values and is defined in Table 2.

Bit	Name	Description
7	Reserved	Reserved
6	Digital Input	Digital Input Active Flag
5	Batt Low	Low battery warning flag
4	Fast Mode	Unit is currently operating in "Fast" data rate mode.
3	OverRange	Input is out of sensitivity or display range
2	NotGross	A tare value has been applied.
1	Integrity	Sensor integrity Error
0	Shunt Cal	Shunt Cal active

Table 2: Status Byte format.

Units

The units for the module are sent as a single byte. The definition of these groups and values is in Appendix B - Units. This table identifies the group within which a simple translation can be applied and the symbol that should be displayed on the screen. It also includes the conversion factors that may be used to convert within a group.

Data Tag

The Data tag is defined as a 2 byte hexadecimal number. This number is specific to the sensor and configurable in the unit. The default value is assigned in the factory prior to shipping and indicated on the label. The data tag is repeated in the transmission packet in order to facilitate the extraction of the encoded data. Please refer to the Decoding Data with View PIN section.

Data

The data is a fixed length field of four bytes. All data is transmitted as a standard Float format (IEEE 754).

Bluetooth Connected Mode

The BTS profile provides access to services and characteristics used to configure and receive measurements. They are all custom 128-bit Unique ID's. The only generic profiles that will be enabled in the module are the mandatory Generic Access and Generic Attribute profiles. Please refer to documentation supplied by the Bluetooth SIG (Special Interest Group) for a description of the characteristics provided by these services.
All the data carried over Bluetooth is received by the host application as a byte array. The data format on a read is described in Appendix A.

> *It is recommended that all writes to characteristics use the **Write With Response** method rather than **Write With No Response**. This allows time for indexed characteristics to update internally.*

Telemetry Configuration Service

The telemetry Configuration service provides access to general configuration parameters. The characteristics within this service are likely to be required by technicians and installers.
This service is identified by its unique 128-bit ID. This is:
a970fd30-a0e8-11e6-bdf4-0800200c9a66

Data Rate

The data rate defines the period between taking a measurement. The advert broadcast is also linked to this parameter. The data rate is specified in ms as the period between measurements. The value entered may be between 0 and 10000. N.B. Bluetooth does not allow adverts to be broadcast more often than every 80 ms. As such, values between 1 and 79 will be accepted as a value of 80. A value of 0 will stop data acquisition. However it will not stop the advertising profile. The adverts will be broadcast once every 5 seconds with a value of NaN and the status byte will be set to 0xFF (255 decimal).
This characteristic is identified by its unique 128-bit ID. This is:
a970fd31-a0e8-11e6-bdf4-0800200c9a66

Resolution

The number of samples used to produce a measurement is configurable. The resolution that can be achieved is given in Table 3. The number of samples used to obtain a measurement will directly impact upon the battery life of the product as it changes the time required to make a measurement. The measurement time is the time that the Strain Bridge input is being sampled.
If the Data Rate is set to less than 200mS then the Resolution parameter is limited to a maximum of 16.

Resolution Parameter	Bits Noise Free @ 2.5 mV/V	Measurement time	Effect on Battery Life
8 (default)	14.25	20 ms	Maximum
16	15.25	32 ms	75%
32	16	56 ms	50%
48	16.5	80 ms	37%
64	16.75	104ms	30%

Table 3: Resolution Table.

This characteristic is identified by its unique 128-bit ID. This is:
a970fd32-a0e8-11e6-bdf4-0800200c9a66

Battery Threshold

The battery threshold value is a floating point number specified in volts. The default value (2.5 V) is designed for use with a pair of alkaline cells. The minimum operating voltage is 2.3 V. This characteristic is identified by its unique 128-bit ID. This is:
a970fd33-a0e8-11e6-bdf4-0800200c9a66

View PIN

The View PIN is used to encode the broadcast data such that other users are not able to decode and read the values. This is applied on top of the normal encoding and allows the user to hide individual systems. The View PIN is an array of four characters. The full description of the usage of the data in this characteristic is given in the Operation Examples section titled Decoding Data with View PIN.
This characteristic is identified by its unique 128-bit ID. This is:
a970fd34-a0e8-11e6-bdf4-0800200c9a66

Serial Number

The serial number is set in the factory and cannot be changed by the user.
This characteristic is identified by its unique 128-bit ID. This is:
a970fd35-a0e8-11e6-bdf4-0800200c9a66

Data Tag

The data tag is used to identify the transmitter. It is set in the factory and indicated on the label. The parameter is writable and as such may be set to any 32 bit number.
This characteristic is identified by its unique 128-bit ID. This is:
a970fd36-a0e8-11e6-bdf4-0800200c9a66

Battery Value

The battery value contains the latest measurement of the battery voltage. The parameter is a read only float.
This characteristic is identified by its unique 128-bit ID. This is:
a970fd37-a0e8-11e6-bdf4-0800200c9a66

System Zero

The system zero is a floating point value that is stored in non-volatile memory. This value is subtracted from the final value on each measurement. It is stored as a floating point number.

> This value should not be used as a live tare (i.e. for each new measurement). It is designed such that the zero can be applied at the point of installation and stored in non-volatile memory rather than written multiple times per day. There are 100,000 write cycles on the non-volatile memory before it is worn out.

The system zero value will be converted automatically if a unit conversion is made to the module. This will have no effect if the Linearisation Points is zero.
This characteristic is identified by its unique 128-bit ID. This is:
a970fd38-a0e8-11e6-bdf4-0800200c9a66

Configuration Pin

The Configuration PIN controls the access to the device. It must be written to as the first action after connecting to the unit. Until it has verified the value of the Configuration PIN it will always read zero then disconnect the link. Attempting to access any parameter prior to entering a valid Configuration PIN will result in disconnection of the link. The Configuration PIN number is a user settable unsigned 32 bit integer. The default value is 0.
This characteristic is identified by its unique 128-bit ID. This is:
a970fd39-a0e8-11e6-bdf4-0800200c9a66

See Connection Security

Model Name

The model name is a factory set parameter that indicates the type of acquisition module that is present. It is a string of characters that identify the module. Currently there is only one. This is formatted as:
"B24-SSBX-A"

B24 – B24 range
SSB - Strain Sensor Bridge
X -OEM Module
A -Standard Variant

This characteristic is identified by its unique 128-bit ID. This is:
a970fd3a-a0e8-11e6-bdf4-0800200c9a66

Firmware Version

The firmware version is a read only parameter. The value is stored as a float and updated when new firmware is generated.
This characteristic is identified by its unique 128-bit ID. This is:
a970fd3b-a0e8-11e6-bdf4-0800200c9a66

Telemetry Data Service

The telemetry data service is where the main measurements are exposed. The status and data values may be enabled in notification mode. The characteristics within this profile will be used by all users planning to use the device in a connected mode.
This service is identified by its unique 128-bit ID. This is:
a9712440-a0e8-11e6-bdf4-0800200c9a66

Status

The status value is an unsigned integer. The format of the data is the same as in the advert. The full details of the values are shown in Table 2. The application can register to receive notifications ***** from this parameter.
This characteristic is identified by its unique 128-bit ID. This is:
a9712441-a0e8-11e6-bdf4-0800200c9a66

Data Value

The data value is transmitted as a float in IEEE 754 format. The application can register to receive notifications ***** from this parameter.
This characteristic is identified by its unique 128-bit ID. This is:
a9712442-a0e8-11e6-bdf4-0800200c9a66

Data Units

The data units are transmitted as an unsigned integer value. This can be decoded using the lookup table in Appendix B - Units. The format and value is identical to the broadcast advert.
This characteristic is identified by its unique 128-bit ID. This is:
a9712443-a0e8-11e6-bdf4-0800200c9a66

* When registering for notifications from the Status and Data Value characteristics, be aware that the notifications will only occur at the rate of the current Data Rate.

Telemetry Calibration Service

The telemetry calibration profile is used by advanced users to access the linearisation routines and the advanced access to the internal memory. Access to these values is protected by the Calibration PIN.

> Note that even in connected mode the measurements are still only being taken at the Data Rate (Or Fast Rate) so time needs to be given to allow applied inputs to be reflected in the measurements before calculating new gains and offsets.

This service is identified by its unique 128-bit ID. This is:
a970fd30-a0e8-11e6-bdf4-0800200c9a66

Sensitivity Range

The full Scale input sensitivity of the module is selectable. There are four sensitivity ranges available and corresponding input sensitivity is given in Table 4.

Sensitivity Parameter	Full Scale Sensitivity
0 (default)	±6 mV/V
1	±12 mV/V
2	±24 mV/V
3	±48 mV/V

Table 4: Sensitivity ranges

If the input exceeds the full scale sensitivity + 20% then the overrange flag will be set in the Status.This characteristic is identified by its unique 128-bit ID. This is:
a9717261-a0e8-11e6-bdf4-0800200c9a66

Coefficient (@Index)

The coefficient parameter is used to read or write the linearisation points into the unit. The value is stored as a float. The storage method and the values that should be written to each index during calibration are described in the Operation Examples section titled Calibration.
This characteristic is identified by its unique 128-bit ID. This is:
a9717262-a0e8-11e6-bdf4-0800200c9a66

Linearisation Index

The linearisation index parameter indicates the current location that will be written to by the coefficient parameter.
This characteristic is identified by its unique 128-bit ID. This is:
a9717263-a0e8-11e6-bdf4-0800200c9a66

Linearisation Repeat

The linearisation repeat parameter is used to set the size of the table used during calibration. The value of this parameter is currently set to three which indicates a linear calibration. Higher order calibrations (i.e. quadratics) are advanced and not supported or described here.
This characteristic is identified by its unique 128-bit ID. This is:
a9717264-a0e8-11e6-bdf4-0800200c9a66

Linearisation Points

The linearisation point's parameter is used to set the number of calibration points used in the calibration.
This characteristic is identified by its unique 128-bit ID. This is:
a9717265-a0e8-11e6-bdf4-0800200c9a66

Base Value

The base value is the measurement presented in factory calibrated units (i.e. without user calibration). The value is a read only float. Prior to running the calibration this value will match the Engineering unit value.
For the strain module this value is in mV/V terms.
This characteristic is identified by its unique 128-bit ID. This is:
a9717266-a0e8-11e6-bdf4-0800200c9a66

Base Units

This parameter indicates the units that the factory calibrated the unit in. The base unit will correspond to the measurement type. The Strain module will report the base value in mV/V.
This characteristic is identified by its unique 128-bit ID. This is:
a9717267-a0e8-11e6-bdf4-0800200c9a66

Data Gain

The data gain value is used when applying a unit conversion to a calibration. An example of how this is applied is in the Operation Examples section titled

Unit Conversion.
This characteristic is identified by its unique 128-bit ID. This is:
a9717268-a0e8-11e6-bdf4-0800200c9a66

Data Offset

The data offset value is used when applying a unit conversion to a calibration. An example of how this is applied is in the Operation Examples section.
This characteristic is identified by its unique 128-bit ID. This is:
a9717269-a0e8-11e6-bdf4-0800200c9a66

Calibration PIN

The Calibration PIN may be used to protect the calibration of the unit. The connecting app can optionally request a Calibration PIN from the user and access to calibration pages in the app may be restricted if the PINs do not match. The default value is 0.
This characteristic is identified by its unique 128-bit ID. This is:
a971726a-a0e8-11e6-bdf4-0800200c9a66

Calibration Units

This unit should be written with the units corresponding to the calibration. The value written to this parameter should correspond to the unit look up table found in Appendix B - Units.
This characteristic is identified by its unique 128-bit ID. This is:
a971726b-a0e8-11e6-bdf4-0800200c9a66

Advanced Index

The advanced index is used to access the internal memory of the device. This should not normally be required. The address locations that can be used are given in Appendix C - Advanced Parameters.
It is recommended that the Advanced Index be read back after writing to confirm that it has been changed correctly before writing to the Advanced Data characteristic.
This characteristic is identified by its unique 128-bit ID. This is:
a971726c-a0e8-11e6-bdf4-0800200c9a66

Advanced Data

The advanced data parameter is used to read and write to the internal memory of the device that is not exposed through the other characteristics. This should not normally be required. (N.B the format of the data sent should match the destination selected. Failure to do so may lead to unexpected behavior). The address locations that can be used are given in Appendix C - Advanced Parameters.
This characteristic is identified by its unique 128-bit ID. This is:
a971726d-a0e8-11e6-bdf4-0800200c9a66

Connection Security

This Interface Inc. product uses its own method of securing the link prior to allowing access to the data and calibration. BLE stipulates that the initial connection request must occur without the need for security and this is the case for this product. Once the connection is made any attempt to read data will lead to a disconnect request. This is to avoid generic applications halting the delivery of data in the broadcast mode. Furthermore the correct Configuration PIN must be set within 5 seconds of establishing the connection. Otherwise a disconnect command will be issued.

> *Because the module only allows five seconds to write a correct Configuration PIN after initial connection, this can present some difficulties with some hardware and library combinations. The problems can arise when it takes a long time to read back all services and characteristics before writing the Configuration PIN.*
> *Depending on the software library used this may be alleviated by writing to the Configuration PIN as soon as a connection has been made by either using the unique ID for the service and characteristic or by some other repeatable identifier supported by the driver such as a Handle which may be nothing more than the index into the list of characteristics.*

Operation Examples

This section looks at a few of the common operations that will need to be conducted over Bluetooth and details the methodology involved. This encompasses both the connected and advertising mode of operation.

Decoding Data with View PIN

The encoding applied to the data in the Bluetooth advertising packet is very simple but effective. It works on the principle of a shared ASCII View PIN. Each individual character of the View PIN is used to apply an XOR on the corresponding data. This means that the value delivered is difficult to decipher without knowledge of the View PIN. To decode the transmission the same process of XOR is applied. The data tag is repeated twice in an encoded form at the end of the advert and may be used by applications to check that the decoding has been successful.
The advert key is encoded by default with a 10 byte seed. Each byte is used in turn to encode the value that is transmitted.

This Default Seed value is:
`0x5C, 0x6F, 0x2F, 0x41, 0x21, 0x7A, 0x26, 0x45, 0x5C, 0x6F`

The View PIN is repeated in the encoding table. The example below uses a View PIN of ASCII encoded 8742 (The PIN does not need to be numeric. It is entered as a byte array of ASCII characters. 8742 is chosen over the default of 0000 in this example to show how the PIN is repeated).

The example in Table 5 shows how the encryption array is calculated from the View PIN and the Default Seed. The example uses a measured value of 2.54 kg and a data tag of 1234.

Description	**Unencoded Value**	**Encoding array** Seed ▼ PIN ▼	**Encoded Transmission**
Length field – fixed at 16	0x10		0x10
Advert Type	0xFF		0xFF
Company ID – Mantracourt ID	0xC3		0xC3
	0x04		0x04
Format ID	0x01		0x01
Data Tag	0x12		0x12
	0x34		0x34
Status	0x00	0x5C XOR 0x38 = 0x64	0x64
Units – from look up table 'kg'	0x2D	0x6F XOR 0x37 = 0x58	0x75
Data – MSB first	0x40	0x2F XOR 0x34 = 0x1B	0x5B
2.54 → 0x40228F5C	0x22	0x41 XOR 0x32 = 0x73	0x51
	0x8F	0x21 XOR 0x38 = 0x19	0x96
	0x5C	0x7A XOR 0x37 = 0x4D	0x11
Data Tag	0x12	0x26 XOR 0x34 = 0x12	0x00
	0x34	0x45 XOR 0x32 = 0x77	0x43
Data Tag	0x12	0x5C XOR 0x38 = 0x64	0x76
	0x34	0x6F XOR 0x37 = 0x58	0x6C

Table 5: Example of encoding the advert

Connection

The device operates in a general discoverable mode. As such the device is always broadcasting its advert at the set interval and is open to connections. A defensive connection mechanism is employed on the device. This involves disconnecting any device that does not enter the correct value into the Configuration PIN within 5 seconds. The process flow is as follows:

- Scan for devices
- Select required corresponding device MAC address and connect
- Send the Configuration PIN to characteristic a970fd39-a0e8-11e6-bdf4-0800200c9a66 attributed to service a970fd30-a0e8-11e6-bdf4-0800200c9a66.
- Read required aspects and configure as appropriate.
- Disconnect to allow device to resume transmitting advertising packets.

Once connected the app can use the data profile to read data and register for notifications or configure the device and disconnect and use the broadcast adverts.

See Connection Security

Reading Data

When reading from the device the data will be returned in the format stored in the device.

Examples:

Reading the Status characteristic (a9712441-a0e8-11e6-bdf4-0800200c9a66) when there are no errors (zero) will return 1 byte as shown below.

0x00
Data Value = 0 as unsigned integer 8 bit

Reading the View PIN characteristic (a970fd34-a0e8-11e6-bdf4-0800200c9a66) to 1234 as shown below. Note full length of string is always returned and unused characters are padded with NULL character.

0x31	0x32	0x33	0x34	0x00	0x00	0x00	0x00
Data Value = 1234				as string			

Reading the Configuration PIN characteristic (a970fd39-a0e8-11e6-bdf4-0800200c9a66) of 1234 will return 4 bytes as shown below.

0x00	0x00	0x04	0xD2
Data Value = 1234			as unsigned integer 32 bit

Reading the Data Value characteristic in engineering units (a9712442-a0e8-11e6-bdf4-0800200c9a66) when 2.54 mV/V is applied and no calibration will return 4 bytes as shown below.

0x40	0x22	0x8F	0x5C
Data Value = 2.54			as floating point

Writing Data

When writing to the device, the data must be formatted to the native characteristic format defined (See Appendix A).

Examples:

Writing the View PIN characteristic (a970fd34-a0e8-11e6-bdf4-0800200c9a66) to 1234 as shown below. Note following NULL character.

0x31	0x32	0x33	0x34	0x00
Data Value = 1234 as string				

Writing the View PIN characteristic (a970fd34-a0e8-11e6-bdf4-0800200c9a66) to NULL as shown below. Note following NULL character.

0x00
Data Value = NULL as string

Writing the Configuration PIN characteristic (a970fd39-a0e8-11e6-bdf4-0800200c9a66) to 1234 as shown below.

0x00	0x00	0x04	0xD2
Data Value = 1234 as unsigned 32 bit			

Writing the Data Gain characteristic (a9717268-a0e8-11e6-bdf4-0800200c9a66) to 100 as shown below.

0x42	0xC8	0x00	0x00
Data Value = 100 as floating point			

Calibration

The calibration involves setting the gain and offset values in particular regions of operation of the load cell. This can be achieved through table calibration or live calibration.

Procedure	Action	Description
1. Initialisation of parameters	Set the Linearisation Repeat Set the Linearisation Points Set the Sensitivity Range	Should be 3 (default) Set to one for a two point calibration. Set to required range (default 0 → ± 6 mV/V)
2. Take readings – Live Cal **Skip this stage if conducting the table cal.**	Apply low input. Receive input from user for the expected Low Data Value in engineering units. Read and store Low Base Value Apply high input. Read and store High Base Value Receive input from user for the expected High Data Value in engineering units.	
3. Calculate Gain and Offset	Please see example below.	
4. Program coefficients	Set the Calibration Units. Set the Data Units. Set the Data Gain = 1. Set the Data Offset = 0. Set the Linearisation Index to 0. Write the linearisation table terms (values for each cell in the table. Start from top left progressing through each column then on to the next row by incrementing the Linearisation Index).	

The calibration coefficients can be thought of as a table with a number of columns and rows. The number of columns is set by the 'Linearisation Repeat' value and the number of rows is set by the 'Linearisation Points' value. For a two point calibration the table has three columns and one row. The first column holds the base unit value where the calculation becomes valid. The second column holds the gain and the third column holds the offset. There is an extra row in the first column to indicate where the range ends.
This is easier to explain with an example:

Given a table Cal (or the data gathered from a live calibration where 10 pounds weight corresponds to 2.0 mV/V and the 0.0 pound weight gives 0.2 mV/V.
The gain and offset values are:

$$\textbf{Gain} = \frac{\textbf{HighDataValue - LowDataValue}}{\textbf{HighBaseValue - LowBaseValue}}$$

$$= \frac{10 - 0.0}{2.0 - 0.2}$$

$$= 5.56$$

$$\textbf{Offset} = \textbf{Gain x LowBaseValue - LowDataValue}$$

$$= (5.56 \times 0.2) - 0.0$$

$$= 1.11$$

To enter this information into the linearisation table the device needs to know the range within which the calculation is valid (this is a little moot on a two point calibration but is required when extending to a multi-point calibration). With the example given above the table becomes:

Valid from (base units i.e. mV/V)	Gain	Offset
Valid to (base units)		

➔

-6	5.56	1.11
+6		

Table 6: Example of linearisation table

In this example the range of valid values has been chosen to be the full range of the load cell mV/V input with sensitivity range set to 0 (±6 mV/V). In order to write to this table we first set the number of rows and columns required and set the index to zero. The linearisation values in the table are then written in turn starting from the top left and progressing through each column before proceeding to the next row.

Unit Conversion

The unit facilitates a method of unit conversion between Calibration Units and Data Units by writing Data Gain and Data Offset values into the device.

Following on from the calibration example which was calibrated in pounds, this section will apply a conversion to kilograms.

Procedure	Action	Description
Prepare for conversion	Read the Calibration Units.	
Calculate the conversion gain and offset.	See below.	
Write the parameters to the unit.	Write the Data Gain Write the Data Offset Write the Data Units	-From calculation below -**Not normally required (use zero)**. -from look up table

The conversion is calculated based upon the **Ratio** values in the Appendix B table. The first step is to divide by the Calibration Units Ratio and then multiply by the required Data Units Ratio.

$$\textbf{Display Gain} = \frac{\textbf{Data Units Ratio}}{\textbf{Calibration Units Ratio}}$$

$$= \frac{1}{2.204585538}$$

$$= 0.4536$$

After all the parameter values have been written, subsequent transmissions will have been converted to the new unit range. This method may be used to convert between any of the units within the same unit group.

N.B The unit conversion values are held in non-volatile memory and will persist following a power cycle.

System Zero

The system zero may be applied at any point of the commissioning process following the calibration. The value entered into the device incorporates any display unit conversion applied. In order to enable a simpler interface the value read out of the device will be converted to the current Data Units value. The value written into the system zero parameter is subtracted from any subsequent transmission.

To apply a zero to the current measurement, simply write the value of the last measurement into the system zero parameter.

Appendices

Appendix A - Bluetooth UUID Quick Reference

All of the Interface Inc. services and characteristics have a common 96 bit tail and a variable 32 bit identifier.
00000000-a0e8-11e6-bdf4-0800200c9a66
The following table shows the 32 bit identifier used to replace the **00000000** shown above to produce the full 128-bit UUID.

ID	Description	Type	Format	Min	Max
a970fd30	**Configuration Profile**	**Service**	-	-	-
a970fd31	Data Rate	Characteristic	Uint32	0	10000
a970fd32	Resolution	Characteristic	Uint8	0	64
a970fd33	Battery Threshold	Characteristic	Float	2.3	3.5
a970fd34	View PIN	Characteristic	String	4	4 bytes
a970fd35	Serial Number	Characteristic	Uint32	Read Only	
a970fd36	Data Tag	Characteristic	Uint16	0	0xFFFF
a970fd37	Battery Value	Characteristic	Float	Read Only	
a970fd38	System Zero	Characteristic	Float	-FLT_MAX	FLT_MAX[1]
a970fd39	Configuration PIN	Characteristic	Uint32	0	4294967295
a970fd3a	Model Name	Characteristic	String	Read Only	
a970fd3b	Firmware Version	Characteristic	Float	Read Only	
a9712440	**Data Profile**	**Service**	-	-	-
a9712441	Status	Characteristic	Uint8	Read Only	
a9712442	Data Value	Characteristic	Float	Read Only	
a9712443	Data Units	Characteristic	Uint8	0	255
a9717260	**Calibration Profile**	**Service**	-	-	-
a9717261	Sensitivity Range	Characteristic	Uint8	0	3
a9717262	Coefficient (@Index)	Characteristic	Float	-FLT_MAX	FLT_MAX
a9717263	Linearisation Index	Characteristic	Uint8		
a9717264	Linearisation Repeat	Characteristic	Uint8	3	11
a9717265	Linearisation Points	Characteristic	Uint8	0	15
a9717266	Base Value	Characteristic	Float	Read Only	
a9717267	Base Units	Characteristic	Uint8	Read Only	
a9717268	Data Gain	Characteristic	Float	-FLT_MAX	FLT_MAX
a9717269	Data Offset	Characteristic	Float	-FLT_MAX	FLT_MAX
a971726a	Calibration PIN	Characteristic	Uint32	0	4294967295
a971726b	Calibration Units	Characteristic	Uint8	0	255
a971726c	Advanced Index	Characteristic	Uint8	0	255
a971726d	Advanced Data	Characteristic	Byte Array[2]	unknown	

Uint8 - unsigned integer 8 bits
Uint16 - unsigned integer 16 bits
Uint32 - unsigned integer 32 bits
String - character array with length given by Max in the table
Float - float value in IEEE 754 format

[1] FLT_MAX is 3.402823e+38
[2] The format of the advanced data depends on the parameter that the advanced index is pointing to. The data is transferred as a byte array and the format of the parameter being written to is applied.

Appendix B - Units

Number	Hex Value	Group	Unit	Symbol	Ratio
0	0x00	ratio	mV/V	mV/V	1
1	0x01	angle	radians	rad	1
2	0x02	angle	degrees	°	57.30659026
3	0x03	angle	circumference		0.159159637
4	0x04	angle	grade		63.66197711
5	0x05	angle	minutes	'	3437.607425
6	0x06	angle	seconds	“	206264.7982
7	0x07	angle	revolutions	rev	0.159159637
15	0x0F	length	meters	m	1
16	0x10	length	angstrom	Å	10000000000#
17	0x11	length	astronomical unit	AU	6.69E-12
18	0x12	length	centimeters	cm	100
19	0x13	length	chains gunters	ch	0.0497097
20	0x14	length	ell	ell	0.874890639
21	0x15	length	em	em	236.2391
22	0x16	length	fathoms	fm	0.546805453
23	0x17	length	feet	ft	3.280839895
24	0x18	length	furlongs	fur	4.97E-03
25	0x19	length	inches	in	39.37007874
26	0x1A	length	kilometers	km	0.001
27	0x1B	length	league	lea	2.07E-04
28	0x1C	length	leagues	league	0.00018
29	0x1D	length	light years	ly	1.06E-16
30	0x1E	length	lines	ln	472.4424
31	0x1F	length	microns	µ	1000000
32	0x20	length	miles nautical	mi n	5.40E-04
33	0x21	length	miles	mi	6.22E-04
34	0x22	length	millimeters	mm	1000
35	0x23	length	mils	mil	39370.07874
36	0x24	length	nanometers	nm	1000000000
37	0x25	length	parsec	pc	3.24E-17
38	0x26	length	yards	yd	1.093613298
45	0x2D	mass	kilograms	kg	1
46	0x2E	mass	drams	dr av	564.3977876
47	0x2F	mass	grains	gr	15432.7514
48	0x30	mass	grams	g	1000

49	0x31	mass	milligrams	mg	1000000
50	0x32	mass	ounces	oz	35.27395713
51	0x33	mass	pennyweights	pwt	643.0165191
52	0x34	mass	pounds	lb	2.204585538
53	0x35	mass	kilopounds	klb	2.204585538
54	0x36	mass	scruples	s ap	771.63757
55	0x37	mass	slug	slug	6.85E-02
56	0x38	mass	tons long	ton	9.84E-04
57	0x39	mass	tons metric	T	0.001
58	0x3A	mass	tonnes	tonne	0.001
59	0x3B	mass	tons short	sh tn	1.10E-03
65	0x41	force	newtons	N	9.80665
66	0x42	force	kilonewtons	kN	0.00980665
67	0x43	force	millinewtons	mN	9806.65
68	0x44	force	meganewtons	MN	9.80665E-06
69	0x45	force	crinals	crinal	10
70	0x46	force	dynes	dyn	1000000
71	0x47	force	grams force	gf	1000
72	0x48	force	joules per cm	J/cm	0.01
73	0x49	force	kilograms force	kgf	1
74	0x4A	force	kilograms force kp	kp	1
75	0x4B	force	kilograms meter/second²	kg ms²	1
76	0x4C	force	ounces force	ozf	35.27396195
77	0x4D	force	pounds force	lbf	2.204622622
78	0x4E	force	poundals	pdl	70.93163528
79	0x4F	force	tons force long	tonfl	9.84E-04
80	0x50	force	tons force short	tonfs	0.001102311
81	0x51	force	tons force metric	tonfm	0.001
95	0x5F	pressure	bar	bar	1
96	0x60	pressure	atmosphere techn	at	1.019716213
97	0x61	pressure	atmosphere phys	atm	0.986923267
98	0x62	pressure	dyne/cm²	dyncm²	1000000
99	0x63	pressure	foot of water (39°F)	ftH2O	33.45525633
100	0x64	pressure	inch of water (39°F)	inH2O	401.463076
101	0x65	pressure	gigapascal	GPa	0.0001
102	0x66	pressure	hectopascal	hPa	1000
103	0x67	pressure	kg force / cm²	kgfcm²	1.019716213
104	0x68	pressure	kg force / m²	kgf/m²	10197.16213
105	0x69	pressure	microbar	µbar	1000000
106	0x6A	pressure	pascal	Pa	100000
107	0x6B	pressure	newton/m²	N/m²	100000

108	0x6C	pressure	ounce(avdp)/square inch	oz/in²	3215070
109	0x6D	pressure	pounds per square foot	lb/ft²	2088.54
110	0x6E	pressure	pounds per square inch	psi	14.50377439
111	0x6F	pressure	tonne per square cm	T/cm²	0.001019716
120	0x78	speed	meter/sec	m/s	1
121	0x79	speed	centimeters/sec	cm/s	100
122	0x7A	speed	feet/min	ft/min	196.8503937
123	0x7B	speed	feet/sec	ft/s	3.280839895
124	0x7C	speed	kilometers/hr	km/h	3.599712023
125	0x7D	speed	kilometers/min	km/min	0.06
126	0x7E	speed	kilometers/sec	km/s	0.001
127	0x7F	speed	knots	kn	1.942430403
128	0x80	speed	meters/hr	m/h	3600
129	0x81	speed	meters/min	m/min	60
130	0x82	speed	miles/hr	mph	2.237136465
131	0x83	speed	miles/min	mpm	3.73E-02
132	0x84	speed	miles/sec	mps	0.000621
133	0x85	speed	nautical miles/hr	n mph	1.943846
134	0x86	speed	nautical miles/min	n mpm	0.0324
135	0x87	speed	nautical miles/sec	n mps	0.00054
150	0x96	torque	newton meter	N m	1
151	0x97	torque	meter kilogram	m kg	0.101971621
152	0x98	torque	foot pound	ft lbf	0.737562149277266
153	0x99	torque	foot poundal	ft pdl	23.7303604042319
154	0x9A	torque	inch pound	in lbf	8.85074579132716
200	0xC8	arbitrary	counts	counts	1
255	0xFF	Undefined	Undefined		

Appendix C - Advanced Parameters

Index	Access	Format	Min	Max	Parameter
5	Read	FLOAT	0	0	**Peak Value** – Peak Value since last power up.
6	Read	FLOAT	0	0	**Trough Value** – Trough value since last power up
26	Read and Write	FLOAT	-FLT_MAX	+FLT_MAX	**Display Min** – Min Value in display units. Causes an overrange flag to be set in status.
27	Read and Write	FLOAT	-FLT_MAX	+FLT_MAX	**Display Max** – Max Value in display units. Causes an overrange flag to be set in status.
28	Read and Write	FLOAT	-FLT_MAX	+FLT_MAX	**Filter Level** – See Appendix D - Filter
29	Read and Write	UINT32	0	4294967295	**Filter Steps** – See Appendix D - Filter
35	Read and Write	UINT8	0	1	**Linearisation Direction** – Set the linearisation direction as positive or negative. Default is positive
38	Action	NONE	0	0	**Calculate Coefficients** – recalculate the live coefficients. (Is automatically applied at the end of a calibration routine)
39	Read and Write	UINT32	0	1	**Digital Output Function** – Set the digital output to follow the LED with a 1.
40	Read and Write	UINT8	0	0	**Fast Mode** – determines how the device can dynamically switch between the standard Data Rate and the Fast Rate (Below). 0 = Fast Rate disabled. 1 = On connection. Fast Mode entered when device is connected. 2 = On Level. Fast Mode activated when the measured value exceeds the Fast Level. 3 = On Change. Fast Mode entered when the rate of change between two readings exceeds that calculated as the Fast Level over the Data Rate.
41	Read and Write	UINT32	0	0	**Fast Rate** – this is the fast transmission rate entered in milliseconds and is equivalent to the Data Rate. Range is 80 to 10000 milliseconds.
42	Read and Write	UINT32	0	0	**Fast Duration** – This sets how long the Fast Mode will be sustained. This is stated in multiples of the Fast Rate. Example. If **Fast Rate** is set to 100 (0.1S) and **Fast Duration** set to 200 then the device will remain in **Fast Mode** for 0.1 x 200 = 20 seconds.

43	Read and Write	FLOAT	0	0	**Fast Level** – This value is entered in Data Units and will be used depending on the Fast Mode as follows: When Fast Mode = 1: The **Fast Rate** will return to the **Data Rate** after the **Fast Duration** period expires from when the device is disconnected. When Fast Mode = 2: this value when exceeded triggers **Fast Rate r**eturning back to **Data Rate** when the level drops below this value and after the **Fast Duration** period has elapsed. When Fast Mode = 3: this level sets the rate of change level which triggers **Fast Rate** returning back to **Data Rate** when the rate of change drops below this value and after the **Fast Duration** period has elapsed.
189	Action	NONE	0	0	**Restart** module.
192	Action	NONE	0	0	**Shunt Cal On** – Apply 100 k Shunt Cal.
193	Action	NONE	0	0	**Shunt Cal Off** – Remove Shunt Cal
194	Action	NONE	0	0	**Tare** – Apply a local tare to the measurement **(N.B does not persist through power up)**
195	Action	NONE	0	0	**Reset Tare** – Reset Tare value to zero.
196	Action	NONE	0	0	**Reset Peak and Trough**
197	Action	NONE	0	0	**Restore EEPROM Defaults** – Restore all default values. (Calibration would be lost. Factory Cal remains.)

Appendix D – Filter

The filter level and filter steps affect the frequency response of the input which is indicated at the bottom of the page.

The Dynamic filter is basically a recursive filter and therefore behaves like an electronic 'RC' circuit. It has two user settings, a level set in the calibrated engineering units and the maximum number of steps (up to 255).

This filter is very basic and operates at the mV/V level.

Instead of outputting every new value, a fraction of the *difference* between the new input value and the current filtered value is added to the current filtered value to produce the filtering action.

If this difference is less than the value set in the **Filter Level** then the fractional amount added each time is decremented until it reaches the minimum level set by **Filter Steps** i.e. **Filter Steps** is the *limit* of the divisor.

e.g. if **Filter Steps** = 10 the fractional part of the difference between the new value and the current filtered value will be added to the current filtered value.

If a rapidly changing or step input occurs and the difference between the new input value and the current filtered value is greater than the value set in **Filter Level** then the output of the filter will be made equal to the new input reading i.e. the fractional amount of the new reading added to the current reading is reset to 1.
This allows the Filter to respond rapidly to fast moving input signals.

When a step change occurs which does not exceed **Filter Level**, the new filtered value is calculated as follows:

New Filter Output value = Current Filter Output Value + ((Input Value - Current Filter Output Value) / Filter Steps)

The time taken to reach 63% of a step change input (which is less than **Filter Level**) is dependent on the frequency at which values are passed to the dynamic filter, set in **Data Rate**, multiplied by **Filter Steps**.

The table below gives an indication of the response to a step input which is less than **Filter Level**.

% Of Final Value	Time To settle
63%	**Data Rate** * **Filter Steps**
99%	**Data Rate** * **Filter Steps** * 5
99.9%	**Data Rate** * **Filter Steps** * 7

For example, If **Data Rate** is set to 10Hz = 0.1s and **Filter Steps** is set to 10 then the time taken to reach a % of step change value is as follows.

% Of Final Value	Time To settle
63%	0.1 x 10 = 1 seconds
99%	0.1 x 10 x 5 = 5 seconds
99.9%	0.1 x 10 x 7 = 7 seconds

The following table shows the number of updates **'x Filter Steps'** and the **'% Error'** that the **Filtered Output value** will differ from the constant **Input Value**.

x Filter Steps	% Error	x Filter Steps	% Error
1	36.78794412	11	0.00167017
2	13.53352832	12	0.00061442
3	4.97870684	13	0.00022603
4	1.83156389	14	0.00008315
5	0.67379470	15	0.00003059
6	0.24787522	16	0.00001125
7	0.09118820	17	0.00000414
8	0.03354626	18	0.00000152
9	0.01234098	19	0.00000056
10	0.00453999	20	0.00000021

Remember: if the step change in mV/V is greater than the value set in **Filter Level** then:
New Filter Output value = New Input Value i.e. the output jumps to the new input value and the internal working value of **Filter Steps** is reset to 1. This is then incremented each update (set by **Measurement Rate)** until it reaches the user set value of **Filter Steps**.

The filter can be disabled by entering zero for **Filter Steps**.

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Revisions			
Rev.	**Author**	**Description**	**Date**
A-1	WAU	BTS Technical Manual	10/28/2019