BlueST Protocol

BlueST Protocol over Bluetooth Low Energy

Version: 0.16

Date: July 08, 2016

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- As from Bluetooth 4.0 (LE) stack specification the sensor board exposes its functionalities and communicates with the host through structured services and characteristics

- BlueST compliant boards are actually acting as a **GATT server** while BlueST master (e.g. mobile app) is acting as a **GATT client**

- Each data characteristic can be notified with **different timings** (setting the respective register and therefore subsampling the application timer) and can be read asynchronously.

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Advertising format

- Bluetooth LE AD structure (max size 31 bytes):

AD Field Name	AD Type	AD Len	Record size
TX_POWER_LEVEL	0x0A	2	3
COMPLETE_NAME	0x09	Max 10/16 *	11/17 *
MANUF_SPECIFIC	0xFF	13/7 *	14/8 *
FLAGS	0x01	2	3

According to the Bluetooth 4.0 Core Specification Vol.3 Part C, the 0xFF identifies Vendor Specific information.

(*)   If the public device address is not set in the MANUF_SPECIFIC field, then the COMPLETE_NAME can be maximum 16 bytes

- AD structures

  - TX_POWER_LEVEL advertising item

Octets LSB	0	1	2
Name	Len	Type	-100 a + 20 dBm
Value	0x02	0x0A	0xXX

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Advertising format

- **MANUF_SPECIFIC** advertising item

Octets LSB	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Name	Len	Type	Ver	Dev ID	Group A Features		Group B Features		Company assigned			Company id (proposal)		
Value	0x0D	0xFF	0x01	0xXX	0xXXXX		0xXXXX		0xXXXXXX			0x2680E1		
									Public device address (48 bits) (optional)					

- Group A Features map

N	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Bit	RFU	Audio ADPCM Sync	Switch	SOURCE Location	Audio ADPCM	MicLevel	Prox	Lux	ACC	GYRO	MAG	PRESS	HUM	TEMP	BATT	TEMP2

- Group B Features map

N	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Bit	RFU	RFU	RFU	RFU	RFU	Acc Event	~~Free Fall~~	Sensor Fusion Compact	Sensor Fusion	RFU	RFU	Activity Recognition	Carry Position Recognition	Proximity Gesture Recognition	Mems Gesture Recognition	Pedo meter

- Device ID enum:

ID	HW
0x20	*General Purpose available*
0x40	*Device in Sleeping (Low Power)*

ID	HW
0x00	Generic
0x01	WeSU
0x02	Sensor tile
0x03	blueCoin
0x02 – 0x7F	*RFU*
0x80 – 0xFF	*Nucleo Map (TBD)*

Note:
- If GPA or GPB bits are set then the General Purpose Characteristics have to define
- The msb in the Device Id enum is used to indicate a Nucleo based system

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Services/Characteristics

Groups	Service	Char	Max Size	Mode	UUID	Note
Data	Features				0x0000 0000 0001	
		Group A 16 single features	n/a	r/n	0xXXXX 0000 0001	TS + Value, 0xXXXX only one bit, (e.g. Accelerometer bit 7 => 0x00800001-)
		Group B 16 single features	n/a	r/n	0x0000 XXXX 0001	TS + Value, Only one bit
	General Purpose				0x0000 0000 0003	Have to use the characteristic descriptor to configure the data Unit, Name, Type (Size), Format (Precision)
		GP XXXX XXXX	n/a	r/n	0xXXXX XXXX 0003	TS + Value[s]
Debug	Debug				0x0000 0000 000E	
		Term	n/a	r/w/n	0x0000 0001 000E	This characteristic is used for debug purpose as a hyper-terminal like connection (Stdio)
		StdErr	n/a	r/n	0x0000 0002 000E	This characteristic is used for debug purpose as an output only terminal in order for the BLE device to send textual info on errors (StdErr)
Standard	«Battery»				0x180F	Bluetooth.org / Assigned number / Services https://developer.bluetooth.org/gatt/services/Pages/ServicesHome.aspx
		«Battery Level»	1	r/n	0x2A19	Bluetooth.org / Assigned number / Characteristics https://developer.bluetooth.org/gatt/characteristics/Pages/CharacteristicsHome.aspx
Config	Control		64		0x0000 0000 000F	
		Registers access			0x0000 0001 000F	
		Feature Command	64	w/n	0x0000 0002 000F	

Note
BLUETOOTH SPECIFICATION Version 4.2 [Vol 3, Part B] 2.5.1 UUID
Service UUID -11e1-9ab4-0002a5d5c51b
Char UUID -11e1-ac36-0002a5d5c51b
All Data char contains TS [2 bytes] (first field)
TS is timestamp (uint16) relative to the board and valid for all features

HW single feature packet 1/2

All packets start with a uint16 timestamp (TS)

- ## Generic packet format

Octets LSB	0	1	2	3	…	N
Name	TS		Payload:Value[s]			
Value	0xXXXX		0xXXXXXXXX			

Accelerometer payload: *mg, signed int16*
Gyroscope payload: *dps, signed int16*
Magnetometer payload: *mGa, signed int16*

Octets LSB	0	1	2	3	4	5
Name	X		Y		Z	
Value	0xXXXX		0xXXXX		0xXXXX	

Pressure payload: *mbar, signed int32, multiply by 100*

Octets LSB	0	1	2	3
Name	Pressure Value			
Value	0xXXXXXXXX			

Battery payload:
- *Battery level: 0.1%, signed int16 (multiply by 10)*
- *Battery Voltage: mV, signed int 16*
- *Avarage current: mA, signed int16*
- *Power Mng Status: enum, unsigned int8*

Octets LSB	0	1	2	3	4	5	6
Name	Battery level		Battery Voltage		Average current		Power Mng Status
Value							

<0	Battery IN USE
>> 0	Charging
~0	power cable plugged (not charging)

The same of PWRMNG_STATUS session register

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Services/Characteristics

HW single feature packet 2/2

Lux payload: *lux, unsigned int16*

Octets LSB	0	1
Name	Lux	
Value	0xXXXX	

Proximity payload: *mm, unsigned int16*

Octets LSB	0	1
Name	Distance	
Value	0xXXXX	

Temperature payload: Celsius**,** *multiply by 10*

Octets LSB	0	1
Name	Value	
Value	0xXXXX	

Humidity payload: *% multiply by 10*

Octets LSB	0	1
Name	Value	
Value	0xXXXX	

Mic Level payload: *db,N x unsigned int8*

Octets LSB	0	N
Name	mic1	micN
Value	0xXX	0xXX

Source location payload: *degree (0,360), unsigned int16*

Octets LSB	0	1
Name	Value	
Value	0xXXXX	

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Audio feature packet

Audio packets do not start with a timestamp

Audio ADPCM payload: ADPCM samples, 20-byte length array

Octets LSB	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Name	Value																			
Value	0xXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX																			

Audio ADPCM Sync payload:
ADPCM index, int16 – ADPCM predsample, int32

Octets LSB	0	1	2	3	4	5
Name	ADPCM Index		ADPCM Predsample			
Value	0xXXXX		0xXXXXXXXX			

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Services/Characteristics

Aggregate feature packet

To optimize the data throughput you can aggregate multiple feature in a single characteristic. The UUID will be the OR of the UUID of the single features.

The features data must follow the feature mask order.

- Example: Motion packet: Accelerometer+Gyroscope+Magnetometer
  - Accelerometer: 0x00800000
  - Gyroscope: 0x00400000
  - Magnetometer: 0x00200000

  Motion packet: 0x00E00000

Octets LSB	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Name	TS		Accelerometer						Gyroscope						Magnetometer					
			X		Y		Z		X		Y		Z		X		Y		Z	
Value	0xXXXX		0xXXXX		0xXXXX		0xXXXX		0xXXXX		0xXXXX		0xXXXX		0xXXXX		0xXXXX		0xXXXX	

Accelerometer payload: *mg, signed int16*
Gyroscope payload: *dps, signed int16*
Magnetometer payload: *mGa, signed int16*

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SW single feature packet 1/3

All packets start with a uint16 timestamp (TS)

- **Generic packet format**

Octets LSB	0	1	2	3	…	N
Name	TS		Payload:Value[s]			
Value	0xXXXX		0xXXXXXXXX			

Sensor fusion payload: *4x float (IEEE 754 single)*

Octets LSB	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Name	TS		q_i				q_j				q_k				q_s			
Value	0xXXXX		0xXXXXXXXX				0xXXXXXXXX				0xXXXXXXXX				0xXXXXXXXX			
			Vector coefficients												Scalar coefficient (optional)			

IEEE 754 single
Reference: AN4044
(Using floating-point unit (FPU) with STM32F405/07xx and STM32F415/417xx microcontrollers)
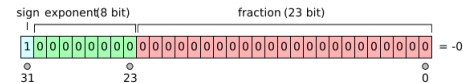
If it has only 3 fields (q_i,q_j,q_k) the vector coefficients shall be normalized

Sensor fusion Compact payload: *3x3 short*

Octets LSB	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Name	TS		q_i1		q_j1		q_k1		q_i2		q_j2		q_k2		q_i3		q_j3		q_k3	
Value	0xXXXX		0xXXXX		0xXXXX		0xXXXX		0xXXXX		0xXXXX		0xXXXX		0xXXXX		0xXXXX		0xXXXX	

3 normalized quaternion, multiply by a factor of 10000

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SW single feature packet 2/3

Free fall payload: 1 byte, its needed if we use it in an aggregated way, 1 = free fall event, 0 = no free fall event

~~Deprecated use Acceleration event~~

Octets LSB	0
Name	Value
Value	0 or 1

Activity recognition payload: 1 byte

Octets LSB	0
Name	Value
Value	0..6

Actovity type	
0x00	No activity (no enough data for decide)
0x01	Stationary
0x02	Walking
0x03	Fast walking
0x04	jogging
0x05	Biking
0x06	driving

Carry Position recognition payload: 1 byte

Octets LSB	0
Name	Value
Value	0..6

Carry Position type	
0x00	Unknown
0x01	On desk
0x02	In hand
0x03	Near head
0x04	Shirt pocket
0x05	Trousers pocket
0x06	Arm swing

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Services/Characteristics

SW single feature packet 2/3

Proximity Gesture Recognition pyload: 1 byte

Octets LSB	0
Name	Value
Value	0..3

Gesture type	
0x00	Unknown
0x01	Tap
0x02	Left
0x03	Right

Mems Gesture Recognition pyload: 1 byte

Octets LSB	0
Name	Value
Value	0..3

Gesture type	
0x00	Unknown
0x01	Pick up
0x02	Glance
0x03	Wake up

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Acceleration Event payload: 1 byte if event! =pedometer

Octets LSB	0
Name	Value
Value	0..256

Acceleration Event payload: 2byte if pedometer is enabled, unsigned int16

Octets LSB	0	1
Name	#steps	
Value	0xXXXX	

Command Type	Value
f = free fall	
s = single tap	
d = double tap	
w = wake ups	0 = Disable 1 = Enable
t = tilt	
o = orientation	
p = pedometer	

Gesture type	
0x00	No Event
0x01	ORIENTATION_TOP_RIGHT
0x02	ORIENTATION_BOTTOM_RIGHT
0x03	ORIENTATION_BOTTOM_LEFT
0x04	ORIENTATION_TOP_LEFT
0x05	ORIENTATION_UP
0x06	ORIENTATION_DOWN
0x08	Tilt
0x10	Free fall
0x20	Single tap
0x40	Double tap
0x80	Wake up
0x100	Pedometer

The feature use the configuration service for enable/disable the event notification. the device will replay the new event status

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Pedomiter: uint32 for the # steps + uint16 for the frquency (step/min)

Octets LSB	0	1	2	3	4	5
Name	# Steps				Freq	
Value	0xXXXXXXXX				0xXXXX	

Switch: *binary map, 8 bit: 0=off, 1=on*

Octets LSB	0
Name	Status
Value	0xXX

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- The remote feature format is used when the ble node is forwarding data from other nodes.
  - For example when you connect with central node in a star network.

- The feature data format will be:

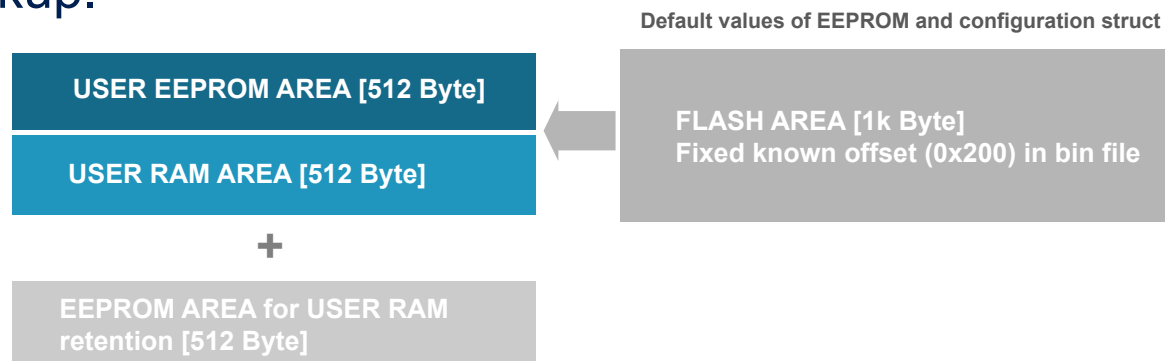| Byte	0	1	2	3	4	…
Name	Node ID		Remote node Timestamp		Feature data	

- The first 2 bytes are used for understand the node that produce the data, the next bytes will follow the normal feature data format.

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Services/Characteristics

Debug

- The package doesn't contains a timestap

- If the package doesn't end with a '\0' the message will finish in the next package

- Max package size is 20 bytes

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Registers

Introduction

It is a set of control registers (16 bits) for hardware configuration and runtime operation. Its default configuration is stored in FLASH memory. At runtime it is divided in RAM and EEPROM area. RAM area can be stored in additional EEPROM space for ultra low power strategies or as user backup.

Default values of EEPROM and configuration struct

USER EEPROM AREA [512 Byte]

USER RAM AREA [512 Byte]

FLASH AREA [1k Byte]
Fixed known offset (0x200) in bin file

+

EEPROM AREA for USER RAM retention [512 Byte]

The access at this memory area is regulated through write and read operations in the Memory Access characteristic and through notification events

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Classification

- Registers classification

  - Persistent registers are stored in EEPROM, data is preserved in case of power loss (battery discharge or failure)

  - Session registers are stored in RAM, data is preserved as long as the system is supplied (battery or external power)

  - Both persistent and session registers are classified as:

    - Mandatory
    - Optional generic
    - Optional specific

  - If optional (generic or specific) registers are not implemented by the BLE device, an ERROR_NOT_IMPLEMENTED error must be set when trying read or write operations on those registers

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Config

- ## Registers access

Octets LSB	0	1	2	3	4	5	…	64
Name	CTRL	ADDR	ERR	LEN		Payload		

- ## CTRL field

N	7	6	5	4	3	2	1	0
	Pending	*Mode*	*Type*	*Error*	*Ack*	*RFU*	*RFU*	*RFU*
1	Exec op	Persistent	Write	Error	Ack required	-	-	-
0	No op	Session	Read	No error	No ack	-	-	-

- ADDR: register address (0x00 – 0xFF)
- ERR: error code (0x00, no ERROR – 0x01-0xFF specific error code)
- LEN: register number (len * 2 = payload size in byte)

More info in «Registers» section

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Errors

- Errors
  - Error codes (TBC)

Name	Error code	Session
NO_ERROR_CODE	0x00	No error
ERROR_LENGHT	0x01	Max payload length is 16 (TBC)
ERROR_WRONG_FORMAT	0x02	Incorrect payload data format
ERROR_NOT_IMPLEMENTED	0x03	Register not implemented (optional)
ERROR_ACTION_NOT_ALLOWED	0x04	Action not allowed
ERROR_REG_IS_READ_ONLY	0x05	Read only register
ERROR_NOT_ALLOWED	0x06	Ctrl field mask is not allowed

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Mandatory

Mandatory (0x00 – 0x1F)	Access Mode	Reg size (2 bytes)	Address	Unit	Type / Note
FW_VER	R	2	0x00 – 0x01	-	X.Y.build
LED_CONFIG	R/W	1	0x02	-	Bit map
BLE_LOC_NAME	R/W	8	0x03 – 0x0A	-	String (first char must be 0x09)
BLE_PUB_ADDR	R/W	8	0x0B – 0x12	-	6 bytes BLE pub add 2 bytesRFU
Reserved for future use	-	13	0x13 – 0x1F		

Led map	
0x00	Internally managed
0x11	User set on
0x12	User set off

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Persistent registers

Optional (generic)

Optional	Access Mode	Reg size (2 bytes)	Address	Unit	Type / Note
RADIO_TXPWR_CONFIG	R/W	1	0x20	-	
TIMER_FREQ	R/W	1	0x21	Hz	uint16
PWR_MODE_CONFIG	R/W	1	0x22	-	Bit map
HW_FEATURES_MAP	R/W	1	0x23	-	Bit map*
HW_FEATURES_CTRLS	R/W	16	0x24 – 0x33	-	uint16[]
SW_FEATURES_MAP	R/W	1	0x34	-	Bit map*
SW_FEATURES_CTRLS	R/W	16	0x35 – 0x44	-	uint16[]
BLE_DEBUG_CONFIG	R/W	1	0x45	-	
USB_DEBUG_CONFIG	R/W	1	0x46	-	
CALIBRATION_HW	R	1	0x47	-	Bit mask as HW features
CALIBRATION_SW	R	1	0x48	-	Bit mask as SW features

Power mode	
0x00	Full run
-	Low power

Octets LSB	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Name	Sub sampling								Output channel sel							
Value	0x0000								RAM	*RFU*	*RFU*	*RFU*	USB	BLE	USART	*RFU*

* See the feature map in the advertising packet

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Persistent registers

Optional (specific)

Optional	Access Mode	Reg size (2 bytes)	Address	Addr Legacy	Unit	Type / Note
TIMER_CONTROL	R	1	TBD	0x13	-	Bit map SW (MCU) HW (MEMS)
USB_BRIDGE_REG	R/W	1	TBD	0x1E	-	Bit map
USB_PWR_DISC_REG	R/W	1	TBD	0x1F	-	Bit map
CHARGER_DISABLE_REG	R/W	1	TBD	0x21	-	Bit map
USB_CONNECT_REG	R/W	1	TBD	0x22	-	Bit map
AUTOSLEEP_TIME_REG	R/W	1	TBD	0x23	seconds	
AUTOSLEEP_THS_REG	R/W	1	TBD	-		
EEREG_STRUCT_BLE_USE_RANDOM_ADDRESS_REG	R/W	1	TBD	0x24	-	Bit map
USB_WAKEUP_DISABLE_REG	R/W	1	TBD	0x25	-	Bit map
GG_PWRDOWN_MODE_REG	R/W	1	TBD	0x26	-	Bit map

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Mandatory

Mandatory (0x00 – 0x1F)	Access Mode	Reg size (2 bytes)	Address	Unit	Type / Note
FW_VER	R	2	0x00 – 0x01	-	X.Y.build
LED_CONFIG	R/W	1	0x02	-	Bit map
BATTERY_LEVEL	R	1	0x03	.1%	uint16
BATTERY_VOLT	R	2	0x04 – 0x05	mV	float32
CURRENT	R	2	0x06 – 0x07	uA	Float32
PWRMNG_STATUS	R	1	0x08	-	enum
Reserved for future use	-	23	0x09 – 0x1F	-	-

As the corresponding persistent registers

Power manager status	
0x00	Low Battery (threshold defined by the user)
0x01	Discharging
0x02	Plugged_Not_Charging
0x03	Charging
0xFF	Generic Error

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Optional (generic)

Optional	Access Mode	Reg size (2 bytes)	Address	Unit	Type / Note
Reserved	-	1	0x20	-	-
TIMER_FREQ	R/W	1	0x21	Hz	uint16
PWR_MODE_CONFIG	R/W	1	0x22	-	Bit map
HW_FEATURES_MAP	R/W	1	0x23	-	Bit map
HW_FEATURES_CTRLS	R/W	16	0x24 – 0x33	-	uint16[]
SW_FEATURES_MAP	R/W	1	0x34	-	Bit map
SW_FEATURES_CTRLS	R/W	16	0x35 – 0x44	-	uint16[]
BLE_DEBUG_CONFIG	R/W	1	0x45	-	
USB_DEBUG_CONFIG	R/W	1	0x46	-	

As the corresponding persistent registers

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Optional (specific)

Optional	Access Mode	Reg size (2 bytes)	Address	Unit	Type / Note
LED_BLINKING_MODE	R/W	1	TBD	-	enum
AHRS_COUNT	R	2	TBD	-	

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Optional command

Optional	Access Mode	Reg size (2 bytes)	Address	Unit	Type / Note
DFU_REBOOT	W	1	0xF0	-	enum
CALIBRATION_HW	RW	1	0xF1	-	Bit mask as HW features
CALIBRATION_HW_STATUS	R	1	0xF2		Enum
CALIBRATION_SW	RW	1	0xF3	-	Bit mask as SW features,
CALIBRATION_SW_STATUS	R	1	0xF4		Enum

DFU Reboot enum	
0	Application Mode
1	USB DFU
2	OTA BLE DFU
3-255	Reserved

Calibratrion XX Status enum	
0	Uncalibrated
1-99	% calibration on going
100	Calibration complete
101-255	Calibration error specific

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Services/Characteristics

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Feature Configuration

- A single characteristics for set the initial condition/start a calibration process of a feature -> change all the "calibration" string with "initialization"

- Characteristics uuid: 0x0000 0002 000F -11e1-ac36-0002a5d5c51b

- It is accessible in Write/Notify.

- Write package: [destination, type, data]

Octets LSB	0	1	2	3	4	5..19
Name	Feature Mask				Request Type	Data*
Value	0xXXXX XXXX				0xXX	0xXXXX

- Response Package [time, destination, type, data]

Octets LSB	0	1	2	3	4	5	6	7..19
Name	Time stamp		Feature Mask				Request Type	Data*
Value	0xXXXX XXXX		0xXXXX XXXX				0xXX	0xXXXX

*The data and the request type is feature depended, and will be parser by the feature class

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Services/Characteristics

Initialization

- **Mems Sensor fusion Initialization**
    - Start Package Data: not needed
    - Status Package Data: 1 byte, 0 not calibrated 100 calibrated
    - Stop Package Data: 1 byte: -1 error or 0-100 calibration goodness
    - When the calibration end it send a status package

Request Type	
Start Initialization	0x00
Stop Initialization	0x01
Get status	0xFF

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Feature Mask	Feature
0x40000000	Audio ADPCM Sync
0x20000000	Switch
0x10000000	DirectionOfArrival
0x08000000	Audio ADPCM
0x04000000	MicLevel
0x02000000	Proximity
0x01000000	Luminosity
0x00800000	Acceleration
0x00400000	Gyroscope
0x00200000	Magnetometer
0x00100000	Pressure
0x00080000	Humidity

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Feature Maskcc	Feature
0x00040000	Temperature
0x00020000	Battery
0x00010000	Temperature
0x00000400	AccelerationEvent
0x00000200	FreeFall
0x00000100	MemsSensorFusionCompact
0x00000080	MemsSensorFusion
0x00000010	Activity
0x00000008	CarryPosition
0x00000004	ProximityGesture
0x00000002	MemsGesture

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Nucleo Characteristics 3/3

Feature Mask	Feature
0x00E00000	Acc+Mag+Gyro
0x001D0000	Pressure+Humidity+Temp1+Temp2

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