MT Low-Level Communication Protocol Documentation

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Revisions

Revision	Date	By	Changes
A	June 3, 2005	SSM	First version
B	July 4, 2005	SSM	Added examples (Xbus class + raw data) Changed maximum sample period Added Miscellaneous Section Added info about SyncIn - offset
C	August 5, 2005	SSM	Update Xbus class example code for Xbus class version 1.1 Added message ReqProductCode / ProductCode
D	September 8, 2005	SSM	Added message Req/Set ExtOutput for analog outputs
E	March 2, 2006	SSM	Changed name Xbus class to MTComm Update incorrect maximum value of SetTransmitDelay
F	September 20, 2006	SSM	Updated Output mode & settings for temperature & auxiliary outputs. Added Req / SetObjectAlignment messages
G	October 30, 2007	PRI	Updated for MTi-G, MTi-G specific messages, XKF Scenario messages
H	April 1, 2008	MMI	Updated regarding firmware version 2.1
I	August 8, 2008	MMI RZA	Textual correction w.r.t. SetOutputSettings table Output format corrections and clarification
J	October 19, 2008	JPM MMI PRI	Added detailed information about the status byte Small textuals changes Added Req / Set ProcessingFlags and SetNoRotation messages
K	May 27, 2009	PRI MHA	Added scenario numbering Added baud rates, StoreXKFstate, 12.20 calculation Changed Raw GPS - > GPS PVT New corporate design

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1 Terms, abbreviations and references

Term	Description
Quaternion	A non-commutative extension of complex numbers

Abbreviation	Description
DOF	Degrees Of Freedom
DSP	Digital Signal Processor
GPS	Global Positioning System
IMU	Inertial Measurement Unit
LLA	Latitude Longitude Altitude
MT	Motion Tracker
MTB	MT Binary Communication Protocol
MTM	MT Manager
PVT	Position, Velocity, Time
SDK	Software Development Kit
UTC	Coordinated Universal Time
WR(-A)	Wireless Receiver
Xbus	Xsens digital data bus system
XKF-3	Xsens Kalman Filter 3 DOF
XKF-6	Xsens Kalman Filter 6 DOF
XML	eXtended Markup Language

Abbreviation	Description
[LLCP]	“MT Low-Level Communication Protocol Documentation.pdf”, document id MT0101P
[MFM]	“Magnetic Field Mapper Documentation.pdf”, document id MT0202P
[MTi_MTx]	“MTi and MTx User Manual and Technical Documentation.pdf”, document id MT0100P
[MTi-G]	“MTi-G User Manual and Technical Documentation.pdf”, document id MT0137P
[XBM]	“XM-B User Manual.pdf”, document id XM0100P “XM-B Technical Documentation.pdf”, document id XM0101P
[MTM]	“MT Manager User Manual.pdf”, document id MT0216P
[SDK]	“MT Software Development Kit Documentation.pdf”, document id MT0200P

2 Introduction

This document describes how to communicate with Xsens' range of miniature MEMS based inertial Motion Trackers; the MTi-G, the MTi and the MTx. These Motion Trackers (or MTs) all use a common binary communication protocol called the "MT Communication Protocol". Knowledge of this protocol is important if you wish to directly communicate to an MT on low-level basis using the RS-232, RS-485 or RS-422 interfaces. The MT communication protocol based message enables the user to change the configuration of the MT-G, MTi and MTx and retrieve the output data.

NOTE: The MTi-G is the most advanced member of the MT family, and some messages are not supported by the MTi and MTx. Also, some specific messages or settings are not relevant and/or supported by the MTi-G. Where a specific type of MT is not supported it is clearly indicated.

The communication protocol used for the MTs is compliant to the **MotionTracker communication protocol**. This document fully documents this standard message based protocol developed by Xsens for use of inertial sensors.

The configuration settings are all user-settable using the communication protocol. Examples are sample frequency, in- and output synchronization, baudrate and output modes. The different output modes enable the user to change the output data to the one that is preferred.

Configuration changes are executed in the so-called "**Config State**". In this state the MT accepts messages that set the output mode or other settings. Whenever the preferred configuration is set the user can set the MT into the "**Measurement State**". In this state the MT starts outputting the data based the current configuration settings. The MT states are discussed in the Section 3.

The messages used in **Config** and **Measurement** state are described in Section 4. In this section the generic format of a message is first explained, next is described how to use the message in general and finally all the messages are described grouped by functionality.

Section 5 lists some examples of how to use the MT binary data communication protocol. Additional information about the MT such as a list of factory default values and table of maximum sample frequencies can be found in section 6.

The last section gives a message reference overview of the MT messages with a short description, see section 7.

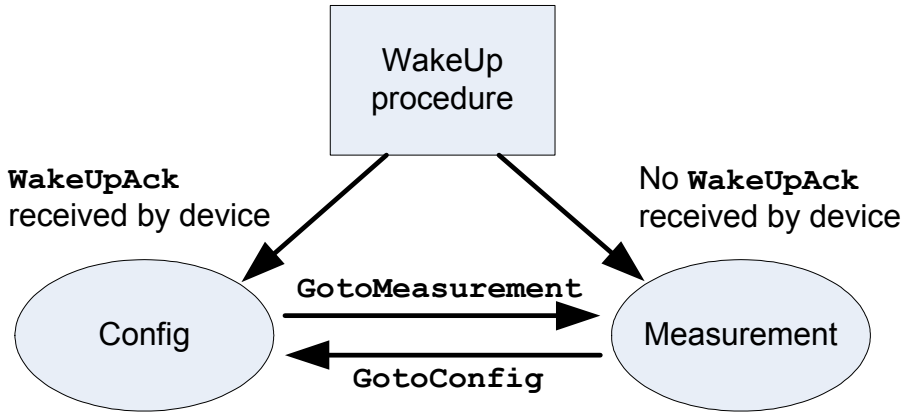
3 States

The MT has two states, i.e. **Config** and **Measurement** state. In the **Config** State various settings can be read and written and in the **Measurement** state the MT will output its data message which contains data dependent on the current configuration.

There are two different ways to enter the Config State or the Measurement State. At power-up the MT starts the WakeUp procedure and it will send the **`WakeUp`** message. If no action is taken the device enters the Measurement State. But if the **`WakeUpAck`** message is sent within 500ms after reception of the **`WakeUp`** message the MT enters the Config State.

Prior to entering the Measurement State, the **`Configuration`** message is always sent to the host[1]. This is the configuration that is read from the internal non-volatile memory and will be used in the Measurement State. The data in the **`Configuration`** message can always be used to determine the output mode and settings.

Another way to enter the Config or Measurement State is to use the **`GoToConfig`** or **`GoToMeasurement`** messages while the other state is active.



3.1 Config State

Config State is used to get and/or set various settings of the MT. Most of the settings will change the configuration which defines the device functionality in Measurement State. Settings that change the configuration are for example the communication baudrate, sample period, output mode, output settings or synchronization properties.

At power-up all settings are read from non-volatile memory. All settings are stored in a format developed by Xsens known as the eMTS (extended Motion Tracker Specification), along with other device specific data such

[1] If the device is set to RAW OutputMode the device will send additional encrypted data to the host after sending the **`Configuration`** message. The encrypted data primarily contains the calibration values of the device. This data is referred to as the eMTS data (extended Motion Tracker Specification data). This data is required to be able to later process the data using Xsens' software to calculate calibrated inertial data values as well as estimating orientation etc.

as calibration parameters. The format is proprietary, but all settings can be manipulated by using the appropriate Set messages.

Settings changed in Config State are immediately stored in the memory and will retain their latest values even if the device is disconnected from power. Some messages have an additional parameter that requires the user to **expressly** specify whether or not the new values should be stored in non-volatile memory. Either way, the setting changes are immediate.

NOTE: There is one exception, namely the baudrate setting. The new setting will **not** be used immediately, it will be used at the next power-cycle or after a soft-reset.

See Section 4 for more information about messages.

3.2 Measurement State

In Measurement State the MT will output its data to the host in a way depending on the configuration settings defined in Config State. A single message, **`MTData`**, is used for all different output modes. It is therefore important that the host knows how the device is configured. The current configuration will determine how the message data must be interpreted. A special message, **`Configuration`**, contains the relevant information which with the data received by the host in Measurement State can be unambiguously interpreted. When logging **`MTData`** messages it is advisable to include the **`Configuration`** message in the data header for future analysis or post-processing.

If the host does not respond to the **`WakeUp`** message at power-up (or after issuing a **`Reset`** message) the MT will automatically enter the Measurement State. Just before entering the state it will send the **`Configuration`** message[2]. The configuration settings are all read from the non-volatile memory and are used during the measurement. The default configuration of the MT is shown in the next table.

Property	Value
Output mode	Orientation output
Output settings	Orientation in quaternion mode Sample counter enabled
Sample frequency	100 Hz
Baudrate	115k2 bps
Output skip factor	0
SyncIn	Disabled
SyncOut	Disabled

Measurement State is normally not used to change any settings. To change settings the device must enter the Config State for which the user must first send the **`GoToConfig`** message.

See Section 4 for more information about messages.

[2] If the output mode is set to un-calibrated raw data an additional message with the calibration parameters (eMTS) is sent after the Configuration message.

4 Messages

4.1 Message structure

The communication with the MT is done by messages which are built according to a standard structure. The message has two structures; one with a standard length and one with extended length. The standard length message has a maximum of 254 data bytes and is used most frequently. In some cases the extended length message needs to be used if the number of data bytes exceeds 254 bytes.

An MTComm message (standard length) contains the following fields:

PREAMBLE	BID	MID	LEN	DATA	CHECKSUM

An MTComm message (extended length) contains these fields:

PREAMBLE	BID	MID	LEN^{ext}	EXT LEN	DATA	CHECKSUM

Field	Field width	Description
Preamble	1 byte	Indicator of start of packet → 250 (0xFA)
BID	1 byte	Bus identifier or Address → 255 (0xFF)
MID	1 byte	Message identifier
LEN	1 byte	For standard length message: Value equals number of bytes in DATA field. Maximum value is 254 (0xFE) For extended length message: Field value is always 255 (0xFF)
EXT LEN	2 bytes	16 bit value representing the number of data bytes for extended length messages. Maximum value is 2048 (0x0800)
DATA (standard length)	0 – 254 bytes	Data bytes (optional)
DATA (extended length)	255 – 2048 bytes	Data bytes
Checksum	1 byte	Checksum of message

Preamble

Every message starts with the preamble. This field always contains the value 250 (=0xFA).

BID or Address

The BID (bus ID address) field is included in the message format to be compatible with the XbusMaster which connects to multiple MotionTrackers**.**

A stand-alone MT (i.e. not connected on an Xbus) has a BID value of 1 (0x01) indicating “first device”. A stand-alone MT device is however also a “master device” on its own bus and it can therefore also be addressed using the BID value 255 (0xFF) indicating a “master device”.

An MT will only acknowledge a message (reply) if it is addressed with a valid BID. An MT will always acknowledge a message with the same BID that has been used to address it. For example, this means that the

same device can be addressed using a BID of 255 (0xFF) as well as 1 (0x01), and it will reply appropriately with the corresponding BID. Note however, that messages generated by the MT itself (i.e. not in acknowledge on a request) will always have a BID of 255 (0xFF). In practice, the only message for which this occurs is the **MTData** message.

Message Identifier (MID)
This message field identifies the kind of message. For a complete listing of all possible messages see section 4.

Length (LEN)
Specifies the number of data bytes in the DATA field for standard length message. If value 255 (=0xFF) is specified the message will be interpreted as an extended message length and the next two bytes are used for the number of bytes in the DATA field. If zero, no DATA field exists.

Extended Length (EXT LEN)
This field is a 16 bit value representing the number of data bytes in the DATA field of an extended length message.

Data (DATA)
This field contains the data bytes and it has a variable length which is specified in the Length or Extended Length field. The interpretation of the data bytes is message specific, i.e. depending on the MID value the meaning of the data bytes is different. The data is always transmitted in big-endian format. See the description of the specific message for more details about the data bytes.

Checksum
This field is used for communication error-detection. If all message bytes excluding the preamble are summed and the lower byte value of the result equals zero, the message is valid and it may be processed. The checksum value of the message should be included in the summation.

4.2 Message usage
Generally, a message with a certain MID value will be replied with a message with a MID value that is increased by one, i.e. the acknowledge message. Depending on the message type the acknowledge message can have a data field (no fixed length) or not. If nothing is specified the data field does not exist. In some cases an error message will be returned (MID = 66 (0x42)). This occurs in case the previous message has invalid parameters, is not valid, or could not be successfully executed. An error message contains an error code in its data field.

Example
Requesting the device ID of an MT:

Sending message:
ReqDID = 0xFA 0xFF 0x00 0x00 0x01 (hexadecimal values)
Receiving message (= Acknowledge):
DeviceID = 0xFA 0xFF 0x01 0x04 HH HL LH LL CS (hexadecimal values)

The requested Device ID is given in the acknowledge message **DeviceID** (here shown as: HH HL LH LL, the checksum is CS). As you can see the MID (Message ID) of the acknowledge message is increased by one in comparison with the sending message **ReqDID**.

Some messages have the same MID and depending on whether or not the message contains the data field the meaning differs. This is the case with all the messages that refer to changeable settings. For example, the MID

of message requesting the output mode (**ReqOutputMode**) is the same as the message that sets the output mode (**SetOutputMode**). The difference between the two messages is that the Length field of **ReqOutputMode** is zero and non-zero for **SetOutputMode**.

Example

Request current output mode:

Sending message:

ReqOutputMode =	0xFA 0xFF 0xD0 0x00 0x31 (hexadecimal values)

Receiving message (= Acknowledge):

ReqOutputModeAck =	0xFA 0xFF 0xD1 0x02 MH ML CS (hexadecimal values)

ReqOutputModeAck contains data which represents the current mode (= MH & ML). CS stands for the checksum value. To change the output mode you must add the new mode in the data field of the sending message:

Set the output mode:

Sending message:

SetOutputMode =	0xFA 0xFF 0xD0 0x02 MH ML CS (hexadecimal values)

Receiving message (= Acknowledge):

SetOutputModeAck =	0xFA 0xFF 0xD1 0x00 0x30 (hexadecimal values)

4.3 Message listing

4.3.1 WakeUp + State messages

WakeUp

MID	62 (0x3E)
DATA	n/a
Direction	To host
Valid in	WakeUp procedure

At power-up or after issuing a reset this message is sent to the host. If the host sends **WakeUpAck** (MID 63 (0x3F)) within 500ms after reception of this message, the MT enters the Config State else Measurement State.

GoToConfig

MID	48 (0x30)
DATA	n/a
Direction	To MT
Valid in	Measurement State and Config State

Switch the active state of the device from Measurement State to Config State. This message can also be used in Config State to confirm that Config State is currently the active state.

GoToMeasurement

MID	16 (0x10)
DATA	n/a
Direction	To MT
Valid in	Config State

Switch the active state of the device from Config State to Measurement State. The current configuration settings are used to start the measurement.

Reset

MID	64 (0x40)
DATA	n/a
Direction	To MT
Valid in	Config State and Measurement State

Sending this message will cause the MT to reset and to activate the WakeUp procedure. An acknowledge message will be sent to confirm reception of the **Reset** message.

4.3.2 Informational messages

ReqDID

MID	0 (0x00)
DATA	n/a
Direction	To MT
Valid in	Config State

Request to send the device identifier (or serial number). MT acknowledges by sending the **DeviceID** message.

DeviceID

MID	1 (0x01)
DATA	IDHH IDHL IDLH IDLL (4 bytes)
Direction	To host
Valid in	Config State

Acknowledge of **ReqDID** message. Data field contains device ID / serial number.

InitMT / InitBus

MID	2 (0x02)
DATA	n/a
Direction	To MT
Valid in	Config State

This message is supported so the host can use the same message for MT as for the XbusMaster. The device will answer with the **InitMTResults** message. For the MT it has the same functionality as **ReqDID**.

InitMTResults / InitBusResults

MID	3 (0x03)
DATA	IDHH IDHL IDLH IDLL (4 bytes)
Direction	To host
Valid in	Config State

Acknowledge of **InitMT** message. Data field contains device ID / serial number and corresponds to the S/N number on the bottom of the device (hexadecimal values).

ReqProductCode

MID	28 (0x1c)
DATA	n/a
Direction	To MT
Valid in	Config State

Request to send the product code. MT acknowledges by sending the **ProductCode** message.

ProductCode

MID	29 (0x1d)
DATA	PRODUCT CODE (max 20 bytes)
Direction	To host
Valid in	Config State

Acknowledge of **ReqProductCode** message. Data field contains the product code string in ASCII format, e.g. MTi-28A33G85.

ReqFWRev

MID	18 (0x12)
DATA	n/a
Direction	To MT
Valid in	Config State

Request to send the firmware revision of the device. MT acknowledges by sending **FirmwareRev** message.

FirmwareRev

MID	19 (0x13)
DATA	MAJOR MINOR REV (3 bytes)
Direction	To host
Valid in	Config State

Acknowledge of **ReqFWRev** message. Data field contains firmware code (major, minor, revision part).

ReqDataLength

MID	10 (0x0a)
DATA	n/a
Direction	To MT
Valid in	Config State

Request the length of the data field of the **MTData** message based on the current configuration. The device acknowledges with the **DataLength** message.

DataLength

MID	11 (0x0b)
DATA	DATALENGTH (2 bytes)
Direction	To host
Valid in	Config State

Acknowledge of **ReqDataLength** message. The data field contains DATALENGTH, an unsigned 16 bits value that is equal to the data length of the **MTData** message send in Measurement State based on the current configuration.

Error

MID	66 (0x42)
DATA	ERRORCODE (1 byte)
Direction	To host
Valid in	Config and Measurement State

Indicate that an error has occurred. Error type is specified in the ERROR field.

ERRORCODE
A one-byte value indicating the type of error. See table.

ERRORCODE	Error description
3 (0x03)	Period sent is not within valid range

4 (0x04)	Message sent is invalid
30 (0x1E)	Timer overflow, this can be caused to high sample frequency or sending to much data to MT during measurement
32 (0x20)	Baudrate sent is not within valid range
33 (0x21)	Parameter sent is invalid or not within range

ReqGPSStatus

MID	166 (0xA6)
DATA	n/a
Direction	To MTi-G
Valid in	Config State

NOTE: Only supported by MTi-G

MTi-G requests status information from the GPS receiver at regular intervals. On request, this data is sent from cache. Also refer to the GPSStatus message below.

GPSStatus

MID	167 (0xA7)
DATA	GPSSTATUS
Direction	To MTi-G
Valid in	Config State

NOTE: Only supported by MTi-G

Acknowledge of the ReqGPSStatus message. The DATA field contains the GPS Satellite Status information of the GPS receiver. The MTi-G requests this information from the GPS receiver at regular intervals. On request, the latest data is sent from cache.

GPSSTATUS

DATA (B)	Description
0	Number of channels in range
Repeat the following block for all channels	
1 + NCH*5	Channel number, range 0..NCH-1 (NCH = number of channels)
2 + NCH*5	Satellite ID
3 + NCH*5	Bitmask, made up of the following values 0x01 = SV is used for navigation 0x02 = Differential correction data is available for this SV 0x04 = Orbit information is available for this SV (ephemeris or Almanach) 0x08 = Orbit information is Ephemeris 0x10 = SV is unhealthy / shall not be used
4 + NCH*5	Signal Quality indicator (range 0..7) 0: This channel is idle 1,2: Channel is searching 3: Signal detected but unusable 4: Code lock on Signal 5,6: Code and Carrier locked 7: Code and Carrier locked, receiving 50bps data
5 + NCH*5	Carrier to Nose Ratio (Signal Strength)

4.3.3 Device-specific messages

ReqBaudrate

MID	24 (0x18)
DATA	n/a
Direction	To MT
Valid in	Config State

Request the baudrate of the device. See **SetBaudrate** for data field description of the received acknowledge.

SetBaudrate

MID	24 (0x18)
DATA	BAUDRATE (1 byte)
Direction	To MT
Valid in	Config State

This message changes the baudrate of the communication interface (RS-232 or RS-422). The new baudrate will be stored in non-volatile memory and will become active after issuing the **Reset** message or power cycle.

BAUDRATE
See table for the different baudrates and the corresponding value of BAUDRATE.

NOTE: The baudrate may limit the sample frequency that can be used for a specific output mode and output setting due to the amount of data that must be transmitted (throughput); please refer to the device specific manuals ([MTi_MTx] and [MTi-G]) for further details.

The default baudrate is 115k2 bps. Baudrate settings 921k6 (0x0A) and 4k8 are only available for firmware versions higher than 2.4.8

Baudrate (bps)	BAUDRATE
921k6	128 (0x80)
921k6 (alternative)	10 (0x0A)
460k8	0 (0x00)
230k4	1 (0x01)
115k2	**2 (0x02)**
57k6	4 (0x04)
38k4	5 (0x05)
28k8	6 (0x06)
19k2	7 (0x07)
14k4	8 (0x08)
9k6	9 (0x09)
4k8	11 (0x0B)

ReqErrorMode

MID	218 (0xDA)
DATA	n/a
Direction	To MT
Valid in	Config State

Request the current error mode - see **SetErrorMode** for information about data field of received acknowledge.

SetErrorMode

MID	218 (0xDA)
DATA	ERRORMODE (2 bytes)
Direction	To MT
Valid in	Config State

Set the error mode to a specific ERRORMODE.

ERRORMODE

The ERRORMODE is an unsigned 16 bit value that defines how the device should deal with errors that are not message-related. The default error mode is that in case the sampling instance is missed the sample counter is increase and no further action is taken (ERRORMODE = 1).

ERRORMODE	Description
0 (0x0000)	Ignore any errors except message handling errors
1 (0x0001)	In case of missing sampling instance: increase sample counter and do NOT send error message
2 (0x0002)	In case of missing sampling instance: increase sample counter and DO send error message
3 (0x0003)	In case of non-message handling error an error message is sent and the device will enter the Config State

ReqLocationID

MID	132 (0x84)
DATA	n/a
Direction	To MT
Valid in	Config State

Request location ID - see **SetLocationID** for information about data field of received acknowledge message.

SetLocationID

MID	132 (0x84)
DATA	LOCID (2 bytes)
Direction	To MT
Valid in	Config State

Set a user-defined value. This value can be used to give the device a location dependant identifier or any arbitrary user value.

LOCID

A 16 bit value having an arbitrary value set by the user. Default value is zero.

RestoreFactoryDef

MID	14 (0x0E)
DATA	n/a
Direction	To MT
Valid in	Config State

If this message is sent to the MT the factory defaults are restored. All settings that have changed will be discarded including object alignments, filter settings, etc. For more information about the default settings values see section 6.1.

ReqTransmitDelay

MID	220 (0xDC)
DATA	n/a
Direction	To MT
Valid in	Config State

Requests the delay value which equals the minimum time between last byte reception and transmission start of acknowledge in RS485 mode.

SetTransmitDelay

MID	220 (0xDC)
DATA	SETTING (2 bytes)
Direction	To MT
Valid in	Config State

An unsigned 16 bit value that defines the number of clock ticks to delay the transmission start after last byte reception. One clock tick is equal to 1 / 29.4912 MHz = 33.9ns. This setting has no effect on RS-232 type MTs.

SETTING	Description
Bit 16-0	Delay value
	Valid value is 590 (20 usec) to 65535 (2.2 msec)

StoreXkfState

MID	138 (0x8A)
DATA	N/A
Direction	To MT
Valid in	Config State

Stores the estimated biases of the physical sensors in the eMTS data of the MT.

4.3.4 Synchronization messages

ReqSyncInSettings

MID	214 (0xD6)
DATA	PARAM (1 byte)
Direction	To MT
Valid in	Config State

Request one of the current SyncIn settings of the device, i.e. mode, skip factor or offset. The requested setting is specified by the PARAM value. See **SetSyncInSettings** for description of the data field of the received acknowledge.

PARAM
PARAM defines which of the SyncIn settings should be returned by the acknowledge message. See following table.

PARAM value	Setting
0 (0x00)	SyncIn mode
1 (0x01)	Skip factor
2 (0x02)	Offset

SetSyncInSettings

MID	214 (0xD6)
DATA	PARAM VALUE (1+N bytes)
Direction	To MT
Valid in	Config State

Set a SyncIn setting defined by the PARAM field with the value specified with the VALUE field. Use SyncIn to synchronize the MT with external hardware. Both the MTi (standard version) and MTx have an input pin that can be connected to other hardware, like a high-precision clock generator. See MTi and MTx User Manual ([MTi_MTx]) for important information about triggering and synchronization.

NOTE: The MTi-G does not support SyncIN. The MTi-G is synced to UTC when a GPS fix is available.

PARAM
The PARAM value (1 byte) indicates which SyncIn setting will be set. The VALUE field, which can be either two or four bytes long, defines the new value of the setting. See table for the different PARAM values.

PARAM value	Setting
0 (0x00)	SyncIn mode
1 (0x01)	Skip factor
2 (0x02)	Offset

VALUE - SyncIn mode

PARAM	VALUE	Description
0		SyncIn mode (2 bytes)
	Bit 1-0	Trigger mode ***NOT valid for MTi-G***
		00 = SyncIn mode disabled (default)
		01 = Rising Edge
		10 = Falling Edge
		11 = Reserved
	Bit 3-2	Trigger type ***NOT valid for MTi-G***
		00 = ADC sampling (incl sending of **`MTData`**)
		01 = Sending of latest output data
	Bit 15-4	Reserved

VALUE – Skip factor

An unsigned 16 bit value that defines how many times the trigger should be skipped before actually trigger the device.

PARAM	VALUE	Description
1		Skip factor (2 bytes)
	Bit 15-0	Skip factor value

VALUE – Offset

By default, the time between a valid trigger and actual sampling of the internal sensors is 20±2us. An additional offset can be set to increase this time. The offset value is an unsigned 32 bit value that defines the number of clock ticks to delay the sampling. One clock tick is equal to 1 / 29.4912 MHz = 33.9ns.

PARAM	VALUE	Description
2		Offset (4 bytes)
	Bit 31-0	Offset value
		Valid value is 0, 264 (0x00000108) and higher

ReqSyncOutSettings

MID	216 (0xD8)
DATA	PARAM (1 byte)
Direction	To MTi
Valid in	Config State

Request one of the current SyncOut settings of the MTi, i.e. SyncOut mode, skip factor, offset or pulse width. The requested setting is specified by the PARAM value. See **SetSyncOutSettings** for description of the data field of the received acknowledge.

PARAM
PARAM defines which of the SyncOut settings should be returned by the acknowledge message. See following table.

PARAM value	Setting
0 (0x00)	SyncOut mode
1 (0x01)	Skip factor
2 (0x02)	Offset
3 (0x03)	Pulse width

SetSyncOutSettings

MID	216 (0xD8)
DATA	PARAM VALUE (1+N bytes)
Direction	To MTi
Valid in	Config State

Set a SyncOut setting defined by the PARAM field with the value specified with the VALUE field. Use SyncOut to synchronize other external hardware with the MTi[3]. Only the standard version of the MTi has an output pin that can be connected to other hardware which can be synchronized with the MTi. See MTi and MTx User Manual ([MTi_MTx]) or MTi-G User Manual ([MTi-G]) for more information about the SyncOut pin.

PARAM
The PARAM value (1 byte) indicates which SyncOut setting will be set. The VALUE field, which can be either two or four bytes long, defines the new value of the setting. See table for the different PARAM values.

PARAM value	Setting
0 (0x00)	SyncOut mode
1 (0x01)	Skip factor
2 (0x02)	Offset
3 (0x03)	Pulse width

[3] Please note that the MTx does not support the SyncOut settings

VALUE - SyncOut mode

See the next table for the description of the SyncOut mode bits.

PARAM	VALUE	Description
0		SyncOut mode (2 bytes)
	Bit 3-0	
		0000 = SyncOut mode disabled (default)
		0001 = Toggle mode
		0010 = Pulse mode
	Bit 4	Polarity
		0 = Negative pulse
		1 = Positive pulse
	Bit 15-5	Reserved

VALUE – Skip factor

An unsigned 16 bit value that defines how many times the internal sampling instance should be skipped before changing the SyncOut pin state. The internal trigger instance is based on the sampling period set by **`SetPeriod`**.

PARAM	VALUE	Description
1		Skip factor (2 bytes)
	Bit 15-0	Skip factor value

VALUE – Offset

An unsigned 32 bit value that defines the number of clock ticks to delay the SyncOut state-change after the internal sampling instance. One clock tick is equal to 1 / 29.4912 MHz = 33.9ns.

PARAM	VALUE	Description
2		Offset (4 bytes)
	Bit 31-0	Offset value
		Valid value is 0, 513 (0x00000201) and higher

VALUE – Pulse width

An unsigned 32 bit value that defines the pulse width when SyncOut mode is set to Pulse mode. The pulse width is specified in ticks and one tick is equal to 1 / 29.4912 MHz = 33.9ns.

PARAM	VALUE	Description
3		Pulse width (4 bytes)
	Bit 31-0	Pulse width value
		Valid value is 0, 1700 (0x000006A4) and higher

4.3.5 Configuration messages

ReqConfiguration

MID	12 (0x0C)
DATA	n/a
Direction	To MT
Valid in	Config State

Request the configuration settings of the device. Can be used for logging purposes - include the **Configuration** message in the log file to store the settings for offline processing of the data.

Configuration

MID	13 (0x0D)
DATA	CONFIGURATION (118 bytes)
Direction	To host
Valid in	Config State

Acknowledge of **ReqConfiguration** message. Data field contains the current configuration of the MT.

CONFIGURATION

The CONFIGURATION data contains the following information. For more information about the different fields check the corresponding message description.

offset (B)	length (B)	field description
0	4	Master device ID
4	2	Sampling period
6	2	Output skip factor
8	2	Syncin settings - Mode
10	2	Syncin settings - Skip Factor
12	4	Syncin settings - Offset
16	8	Date, format YYYYMMDD (can be set by host)
24	8	Time, format HHMMSSHH (can be set by host)
32	32	Reserved (host)
64	32	Reserved (client)
96	2	Number of devices (= 1 (0x0001))
98	4	Device ID (same as master device ID)
102	2	Data length of MTData message
104	2	Output mode
106	4	Output settings
110	8	Reserved

ReqPeriod

MID	4 (0x04)
DATA	n/a
Direction	To MT
Valid in	Config State

Request the current sample period. The MT replies with **ReqPeriodAck**. The data field of this message contains the sample period. For the description of the data field see **SetPeriod**.

SetPeriod

MID	4 (0x04)
DATA	PERIOD (2 bytes)
Direction	To MT
Valid in	Config State

Sets the sampling period of the device used in Measurement State.

PERIOD

PERIOD is an unsigned 16-bit value indicating the length of the period. Resolution is in (1/115200) seconds, i.e. 8.68 us. The following table shows the default, minimum and maximum values.

PERIOD	Value	Sampling period (freq)
Default	1152 (0x0480)	10.0ms (100Hz)
Minimum	225 (0x00E1)	1.95ms (512Hz)
Maximum[4]	1152 (0x0480)	10.0ms (100Hz)

The MT outputs the **MTData** at a rate that is not only depending on the sampling frequency but also on the OutputSkipfactor (see **SetOutputSkipfactor**). Normally this factor is zero and the **MTData** message is sent (1 / sampling period) times per second. A value higher than zero corresponds to how many times the **MTData** message is NOT sent to the host. To calculate how often the **MTData** is sent to the host, use the following formula.

MTData frequency (Hz) = 115200 / (PERIOD * (OutputSkipfactor + 1))

The MT sample frequencies lower than 100Hz are not settable directly. By default, the device uses 100Hz as lowest sampling frequency. However in combination with the OutputSkipfactor (see **SetOutputSkipfactor** message) lower frequencies can be set. For example, if **SetPeriod** is sent with a sampling period of 20ms (50Hz), the device will automatically set the sampling period to 10ms (100Hz) and the OutputSkipfactor to 1. The resulting sampling period is 10ms * (OutputSkipfactor + 1) = 20ms (50Hz). If the sampling period can not be made (OutputSkipfactor is not an integer), an error message will be returned. In this case, choose a lower sampling period with an integer OutputSkipfactor to generate the requested frequency. For example, to have a resulting sampling period of 13.33ms (75Hz) set the sampling period to 6.67ms (150Hz) and the OutputSkipfactor to 1.

[4] The maximum value defined for PERIOD. The actual data output frequency can be set lower than 100Hz in combination with the OutputSkipFactor. See text.

NOTE: The baudrate may limit the sample frequency that can be used for a specific output mode and output setting due to the amount of data that must be transmitted (throughput); please refer to the device specific manuals ([MTi_MTx] and [MTi-G]) for further details.

ReqOutputSkipFactor

MID	212 (0xD4)
DATA	n/a
Direction	To MT
Valid in	Config State

Request how many times the data output is skipped before sending the data in the **MTData** message to host. For information about data field of received acknowledge see **SetOutputSkipFactor**.

SetOutputSkipfactor

MID	212 (0xD4)
DATA	SKIPFACTOR (2 bytes)
Direction	To MT
Valid in	Config State

Set the output skip factor.

SKIPFACTOR
The skip factor is an unsigned 16 bit value and is by default zero. The value represents how many times the data output is skipped (running at the current sampling frequency) before the next **MTData** message is sent. I.e. at sample period of 5.0ms (200Hz) and a skip factor of 4, the measurement is running at 200Hz but the data is sent at a rate of 40Hz (not 50Hz). See also **SetPeriod** for more information about the relationship between the sampling period and output skip factor.

If SKIPFACTOR is set to 65535 (0xFFFF), no data will be sent to the host and **ReqData** can be use to request an **MTData** message at an arbitrary time. This works also if SyncIn mode is enabled.

NOTE: The baudrate may limit the sample frequency that can be used for a specific output mode and output setting due to the amount of data that must be transmitted (throughput); please refer to the device specific manuals ([MTi_MTx] and [MTi-G]) for further details.

SKIPFACTOR	Description
≠ 65535 (0xFFFF)	Skipfactor value
65535 (0xFFFF)	Do not send **MTData** automatically

ReqObjectAlignment

MID	224 (0xE0)
DATA	n/a
Direction	To MT
Valid in	Config State

Request the internally stored object alignment matrix which is set by the **ResetOrientation** message or **SetObjectAlignment** message. For information about data field of received acknowledge see **SetObjectAlignment**.

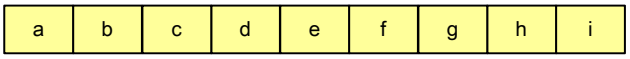
SetObjectAlignment

MID	224 (0xE0)
DATA	MATRIX (9x4 bytes)
Direction	To MT
Valid in	Config State

Set the object alignment matrix.

MATRIX
Is equal to the object alignment matrix which is a 3x3 matrix of which all elements are specified in floats in the order first row then column. See the section about arbitrary alignment in the MTi and MTx User Manual ([MTi_MTx]) or MTi-G User Manual ([MTi-G]) for more information and an example for setting the object alignment to a known orientation.

Correspondence between the data fields and the alignment matrix is shown below.



$$R_{OS} = \begin{bmatrix} a & b & c \\ d & e & f \\ g & h & i \end{bmatrix}$$

ReqOutputMode

MID	208 (0xD0)
DATA	n/a
Direction	To MT
Valid in	Config State

Request the current output mode. See **SetOutputMode** for information about data field of the received acknowledge.

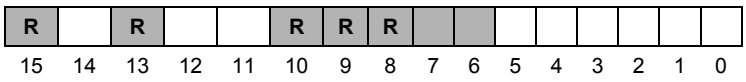
SetOutputMode

MID	208 (0xD0)
DATA	MODE (2 bytes)
Direction	To MT
Valid in	Config State

Sets the output mode of the MT. The settings here, combined with the **SetOutputSettings**, define the content of the DATA field in the **MTData** message. The output mode can be set to various output modes of which most of them can be combined, like for example calibrated sensor data and orientation data. The un-calibrated RAW inertial data output however can not be used together with any of the other outputs, except GPS PVT data. The RAW inertial data and the GPS PVT data messages should often be used together.

NOTE: The baudrate may limit the sample frequency that can be used for a specific output mode and output setting due to the amount of data that must be transmitted (throughput); please refer to the device specific manuals ([MTi_MTx] and [MTi-G]) for further details.

MODE



MODE bits	Output mode
Bit 0	Temperature data
Bit 1	Calibrated data
Bit 2	Orientation data
Bit 3	Auxiliary data
Bit 4	Position data
Bit 5	Velocity data
Bit 11	Status data
Bit 12	GPS PVT data (Position, Velocity, Time and barometric pressure)
Bit 14	RAW inertial data (16-bit ADC values) (Can only be combined with GPS PVT data)

ReqOutputSettings

MID	210 (0xD2)
DATA	n/a
Direction	To MT
Valid in	Config State

Requests the current output settings. See **SetOutputSettings** for information about data field of received acknowledge.

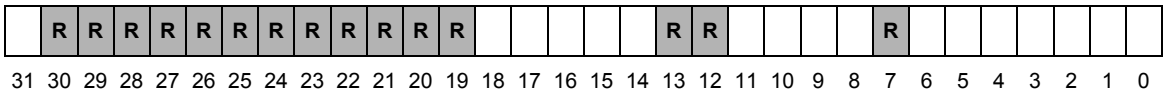
SetOutputSettings

MID	210 (0xD2)
DATA	SETTINGS (4 bytes)
Direction	To MT
Valid in	Config State

Sets the output settings of the MT.

NOTE: The baudrate may limit the sample frequency that can be used for a specific output mode and output setting due to the amount of data that must be transmitted (throughput); please refer to the device specific manuals ([MTi_MTx] and [MTi-G]) for further details.

SETTINGS



SETTINGS bits	Settings
Bit 1-0	Timestamp output
	00 = No timestamp
	01 = Sample Counter
	10 = UTC Time
	11 = Sample Counter + UTC Time
Bit 3-2	Orientation Mode
	00 = Quaternion
	01 = Euler angles
	10 = Matrix
Bit 6-4	Calibration Mode
	Bit 4: 0 = Enable acceleration (XYZ) output
	1 = Disable acceleration (XYZ) output
	Bit 5: 0 = Enable rate of turn (XYZ) output
	1 = Disable rate of turn (XYZ) output
	Bit 6: 0 = Enable magnetometer (XYZ) output
	1 = Disable magnetometer (XYZ) output
Bit 7	Reserved
Bit 9-8	Output Format
	00 = Float output (default)
	01 = Fixed Point Signed 12.20 format
	10 = Fixed Point Signed 16.32 format (High precision mode, 6 bytes)
Bit 11-10	Auxiliary Mode
	Bit 10: 0 = Enable analog in #1 output
	1 = Disable analog in #1 output
	Bit 11: 0 = Enable analog in #2 output
	1 = Disable analog in #2 output
Bit 13-12	Reserved
Bit 16-14	000 = LLA WGS84
Bit 18-17	00 = m/s XYZ
Bit 30-19	Reserved

Bit 31	0 = Use default co-ordinate system (X North, Z up)
	1 = Use X North, Z down “North East Down” (NED) convention for both LTP and MT body fixed coordinate system

Output Format: Float (DEFAULT)
The default format used by the MT is FLOAT. FLOAT is 4 bytes long and corresponds with the single-precision floating-point value as defined in the IEEE 754 standard (= float)

Output Format: Fixed point signed 12.20 format
This is a two’s complement fixed point format. It consists of 12 integer bits and 20 fractional bits.

There are several ways to convert a 12.20 format number to a double precision floating point number. The best way is to place the values into a 32-bit integer. The floating point value can then be computed by casting the value to double precision and dividing by 2^20.

Output Format: Fixed point signed 16.32 format (high precision)
This format consists of a signed 16-bit integer and an unsigned 32 bit integer. The short value is the integral part of the number, while the long value represents the fractional part. Concatenating the two values will effectively yield a 6-byte fixed point number with the radix point after the 16th bit, but note that the 32 fractional bits are sent before the 16 integer bits.

There are several ways to convert a 16.32 format number to a double precision floating point number. The best way is to place the values into a 64-bit integer, where the short value should be sign-extended (the highest bit should be copied into the upper 16 bits of the 64-bit integer), which can often be accomplished by casting to a long value. The floating point value can then be computed by casting the value to double precision and dividing by 2^32.

The high precision format is recommended to avoid quantization in position output (LLA) for the MTi-G when high precision is required for position.

4.3.6 Data-related messages

ReqData

MID	52 (0x34)
DATA	n/a
Direction	To MT
Valid in	Measurement State

This message can be used to ask the MT to send data to the host. Normally, the MT will send the **MTData** message automatically according to the sampling period and output skip factor settings. If however, the OutputSkipFactor is set to 65535 (0xFFFF) the MT will not send the **MTData** except if the user sends **ReqData**.

MTData

MID	50 (0x32)
DATA	DATA (length variable)
Direction	To host
Valid in	Measurement State

This message contains the output data depending on the current OutputMode and OutputSettings. The data field can contain multiple data outputs but the order of outputs is always the same. The following order is used (disabled outputs must be omitted):

1. GPS PVT data
2. Temp
3. Calibrated data output
4. Orientation data output
5. Auxiliary data output
6. Position
7. Velocity
8. Status
9. Sample counter

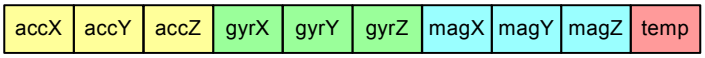
RAW inertial data output can not be used together with any of the other outputs, except GPS PVT data. The RAW inertial data and GPS PVT data should be used together.. The following text explains the data values of each output.

DATA

The data can contain multiple outputs. All the different outputs are described separately here. If not specified otherwise each data value is 4 bytes long and corresponds with the single-precision floating-point value as defined in the IEEE 754 standard (= float).

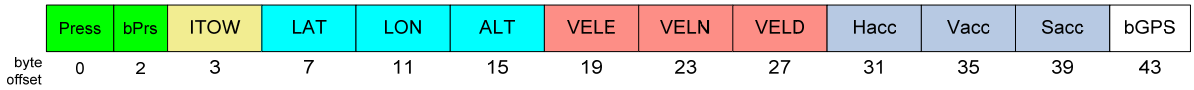
Un-calibrated RAW inertial data output mode (20 bytes)

Contains the un-calibrated raw data output of the accelerations, rate of turn and magnetic field in X, Y and Z axes. These values are equal to the analog-digital converter readings of the internal sensors. The data values are NOT float values but 16 bit unsigned integer values.



GPS PVT data output mode (44 bytes)

When the MTi-G output mode is set to GPS PVT data, the following message structure will be output by the MTi-G. The data message contains pressure sensor and GPS data as described below. The description of each data field is given in the following table.



Description of MTi-G GPS PVT Sensor Data Message Structure

Name	Byte offset	Number format	Scaling	unit	Purpose/Comment
Press	0	U2	2	Pa	Pressure value in Pascals.
bPrs	2	U1	-	-	Pressure sensor status. When the value decreases, new pressure data is available.
ITOW	3	U4	-	ms	GPS Millisecond Time of Week
LAT	7	I4	1e-7	deg	Latitude
LON	11	I4	1e-7	deg	Longitude
ALT	15	I4	-	mm	Altitude/Height above Ellipsoid/Mean Sea Level
VEL_N	19	I4	-	cm/s	NED north velocity
VEL_E	23	I4	-	cm/s	NED east velocity
VEL_D	27	I4	-	cm/s	NED down velocity
Hacc	31	U4	-	mm	Horizontal Accuracy Estimate. Expected error standard deviation.
Vacc	35	U4	-	mm	Vertical Accuracy Estimate. Expected error standard deviation.
Sacc	39	U4	-	cm/s	Speed Accuracy Estimate. Expected error standard deviation.
bGPS	43	U1	-	-	GPS status byte or GPS data age. When the value decreases, new GPS data is available. The value is reset to zero upon receipt of GPS 1PPS pulse. The “data age” of GPS data can be calculated based on elapsed number of samples since the last 1PPS pulse.

U1: Unsigned Char.
U2: Unsigned 16-bit integer
U4: Unsigned 32-bit integer
I2: Two’s complement 16-bit integer.
I4: Two’s complement 32-bit integer.

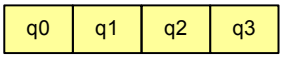
Temperature data output mode (4 bytes)

Contains the internal temperature of the sensor in degrees Celsius (float value).

Calibrated data output mode (36 bytes)

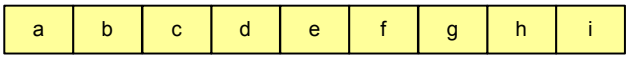
Contains the calibrated data output of the accelerations, rate of turn and magnetic field in X, Y and Z axes in floats.

Orientation data output mode – quaternion (16 bytes)
Contains the q0, q1, q2 and q3 quaternions, in floats, that represent the orientation of the MT.

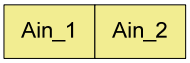


Orientation data output mode – Euler angles (12 bytes)
Contains the three Euler angles, in floats, that represent the orientation of the MT

Orientation data output mode – Matrix (36 bytes)
Contains the rotation matrix (DCM), in floats, that represents the orientation of the MT. See MTi and MTx User Manual ([MTi_MTx]) or MTi-G User Manual ([MTi-G]) for the interpretation of the data values.



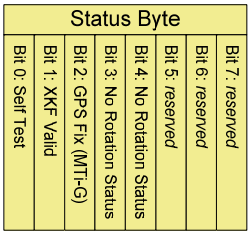
Auxiliary data output mode (4 bytes)
Auxiliary data consists of both analogIN 1 and 2 data. This is the sampled value of the analog input #1 and #2. The data format is two 16 bit unsigned integer value and NOT a float value.



Position data output mode – LLA (12 bytes)
Contains the latitude, longitude and altitude, in floats, that represent the position of the MTi-G.

Velocity data output mode – VelXYZ (12 bytes)
Contains the velocity X, Y and Z, in, that represent the velocity of the MTi-G. Note that velocity in North East Down can be obtained by changing bit 31 in the **`SetOutputSettings`** DATA field.

Status (1 byte)
This byte contains flags that represent the status and estimated validity of the output of the MT. The currently defined flags are summarized below. A flag is set to 1 when the relevant condition is true.



Self Test: This flag indicates if the power-up self test completed successfully.
XKF Valid: This flag indicates if input into the XKF orientation filter is reliable and / or complete. If for example the measurement range of internal sensors is exceeded, orientation output cannot be reliably estimated and the XKF flag will drop to 0. For the MTi-G, the XKF flag will also become invalid if the GPS status remains invalid for an extended period
GPS Fix: This flag indicates if the GPS unit has a proper fix. The flag is only available in MTi-G units.
NoRotation Status (only available for MTi/MTx): This flag indicates the status of the no rotation update procedure in the filter after the `SetNoRotation` message has been sent.
11: Running with no rotation assumption
10: Error: Rotation detected, procedure not started (sticky)
01: Estimation complete, some samples rejected (sticky)
00: Estimation complete, no errors

Sample counter (2 bytes)
The (optional) sample counter is a 16 bit unsigned integer value that is increased for each transmission of the **`MTData`** message. If its maximum value is reached, i.e. 65535 (0xFFFF), it will wrap and start at zero again. See also **`SetErrorMode`** for the relation between the sample counter and the error mode.

UTC Time (12 bytes)
Besides the sample counter, it is also possible to let the data be time stamped by UTC time. This data package is identical to the result of **`ReqUTCTime`**.

The CMT C++ class has an easy to use member function to retrieve the individual **`MTData`** DATA fields[5].

[5] Refer to "MT Software Development Kit Documentation" ([SDK]) documentation for further details.

4.3.7 XKF Filter messages

ReqHeading

MID	130 (0x82)
DATA	n/a
Direction	To MT
Valid in	Config State

Request the current heading setting - see **SetHeading** for information about data field of received acknowledge. SetHeading is available for the MTi and MTx only.

SetHeading

MID	130 (0x82)
DATA	HEADING (4 bytes)
Direction	To MT
Valid in	Config State

Sets the heading with the value specified in data field. SetHeading is available for the MTi and MTx only.

HEADING
HEADING is a single-precision floating-point number (4 bytes). The valid range is specified as [-π, +π]. Default value is zero.

ReqMagneticDeclination

MID	106 (0x6A)
DATA	n/a
Direction	To MT
Valid in	Config State

Request the current magnetic declination setting - see **SetMagneticDeclination** for information about data field of received acknowledge.

Magnetic declination is valid for MTi-G only.

SetMagneticDeclination

MID	106 (0x6A)
DATA	MAGNETICDECLINATION (4 bytes)
Direction	To MT
Valid in	Config State

Sets the magnetic declination with the value specified in data field.

MAGNETICDECLINATION
MAGNETICDECLINATION is a single-precision floating-point number (4 bytes). The valid range is specified as [-π, +π]. Default value is zero.
Magnetic declination is valid for MTi-G only.

ReqAvailableScenarios

MID	98 (0x62)
Direction	To MT
Valid in	Config State

NOTE: For MTi and MTx this is not supported in firmware version 2.0 and lower.

Requests the available Xsens Kalman Filter (XKF) Scenarios from the MTi-G, MTi or MTx.

AvailableScenarios

Contains information about available filter scenarios that are stored on the non-volatile memory of the MTi-G, MTi or MTx.
Data contains the following for all 5 available scenarios. When less than 5 scenarios are available, the remaining scenarios are of type 0.

DATA (B)	Description
TYPE (0 + 22*index)	Scenario type
VERSION (1 + 22*index)	Scenario version
LABEL (2 + 22*index)	Scenario label. The label is NOT 0-terminated and it is padded to 20 bytes with spaces.

ReqCurrentScenario

Direction	To MT
MID	100 (0x64)

Requests the ID of the currently used scenario.

NOTE: For MTi and MTx this is not supported in firmware version 2.0 and lower.

SetCurrentScenario

Direction	To MT
MID	100 (0x64)
DATA	SCENARIO (2 bytes)

Sets the scenario to use. For more information about the various scenarios please refer to the 'XKF Scenarios' sections in the device specific manuals ([MTi_MTx] and [MTi-G]).

NOTE: For MTi and MTx this is not supported in firmware version 2.0 and lower.

SCENARIO	Hardware Type	Description
1	MTi-G	General
2	MTi-G	Automotive
3	MTi-G	Aerospace
4	MTi-MTx	Human
5	MTi-MTx	Human_large_accelerations
6	MTi-MTx	Machine
7	MTi-MTx	Machine_nomagfield

8	MTi-MTx	Marine
9	MTi-G	General_nobaro
10	MTi-G	Aerospace_nobaro
11	MTi-G	Automotive_nobaro
17	MTi-G	Marine

ReqCurrentScenarioAck

Direction	To host
MID	101 (0x65)
DATA	SCENARIO VERSION

Contains the currently used scenario.

NOTE: For MTi and MTx this is not supported in firmware version 2.0 and lower.

DATA (B)	Description
SCENARIO (0)	Scenario type
VERSION (1)	Scenario version

ReqGravityMagnitude

Direction	To MT
MID	102 (0x66)

Requests the magnitude of the gravity that is used in XKF - see **SetGravityMagnitude** for information about data field of received acknowledge.

NOTE: For MTi and MTx this is not supported in firmware version 2.0 and lower.

SetGravityMagnitude

Direction	To MT
MID	102 (0x66)
DATA	GRAVITY (float)

Sets the magnitude of the gravity that is used in XKF.

NOTE: For MTi and MTx this is not supported in firmware version 2.0 and lower.

ReqProcessingFlags

Direction	To MT
MID	32 (0x20)

Requests the processing flags that are used in XKF - see **SetProcessingFlags** for information about data field of received acknowledge.

NOTE: For MTi and MTx this is not supported in firmware version 2.2 and lower.

SetProcessingFlags

Direction	To MT
MID	32 (0x20)
DATA	PROCESSING FLAGS

Sets the processing flags that are used in XKF.

NOTE: For MTi and MTx this is not supported in firmware version 2.2 and lower.

PROCESSING FLAGS bits	Processing Flag
Bit 0	Initialization Gyroscope Bias Estimation On/Off: Automatic 'No Rotation' assumption after filter reset and/or power on) to quickly estimate rate gyroscope bias. Refer to section 3.3 in User Manual. Refer also to the `SetNoRotation` message on page 34. DEFAULT = off
Bit 1	Fixed Gravity On/Off: XKF can either calculate the local gravity from the GPS LatLonAlt or use a fixed gravity set by the `SetGravityMagnitude` message DEFAULT = off

ReqLeverArmGps

Direction	To MT
MID	104 (0x68)

Requests the lever arm of the GPS antenna with respect to the MTi-G in OBJECT coordinates.

NOTE: Only supported by MTi-G.

SetLeverArmGps

Direction	To MT
MID	104 (0x68)
DATA	ARM (3x float)

Sets the lever arm of the GPS antenna with respect to the MTi-G in OBJECT coordinates.

NOTE: Only supported by MTi-G.

ReqLeverArmGpsAck

Direction	To host
MID	105 (0x69)
DATA	ARM (3x float)

DATA Contains the lever arm of the GPS antenna with respect to the MTi-G in OBJECT coordinates.

NOTE: Only supported by MTi-G.

ResetOrientation

MID	164 (0xA4)
DATA	CODE (2 bytes)
Direction	To MT
Valid in	Config State and Measurement State

Reset the orientation. Different resets are supported; see next table. For more information about the different resets see MTi and MTx User Manual ([MTi_MTx]) or MTi-G User Manual ([MTi-G]). To store the new orientation goto Config state and send the **ResetOrientation** message again but now with CODE = 0x0000. If the orientation is not stored the next time, the Measurement State becomes active the reset orientation results are discarded.

CODE
A two-byte value indicating which reset to perform during Measurement State. To store the present settings, enter the Config State and send the same message again with RESET equal to zero.

CODE	Description
0 (0x0000)	Store current settings (only in config mode)
1 (0x0001)	Heading reset *(NOT supported by MTi-G)*
2 (0x0002)	RESERVED
3 (0x0003)	Object reset
4 (0x0004)	Align reset *(NOT supported by MTi-G)*

SetNoRotation

MID	34 (0x22)
DATA	Duration (seconds) (2 bytes)
Direction	To MT
Valid in	Measurement State

Initiates the 'no rotation' update procedure. For more information about the no rotation update procedure see MTi and MTx User Manual ([MTi_MTx]). Note that the acknowledge does not reflect the result of the `SetNoRotation` message. The result of the SetNoRotation message are represented in bits 3 and 4 of the status byte (see `MTdata` / 0x32).

With the `SetProcessingFlags` message, an initial gyroscope bias estimation upon start-up of the MTi / MTx can be activated. Refer to the description of the SetProcessingFlags message for details.

DATA

PARAM	DATA	Description
0	Duration (seconds)	Duration of the 'no rotation' update.

NOTE: Not supported by MTi-G.
NOTE: For MTi and MTx this is not supported in firmware version 2.2 and lower.

ReqUTCTime

Direction	To MT
MID	96 (0x60)

Request UTC Time from sensor

NOTE: Only supported by MTi-G.

UTC Time

Direction	To host
MID	97 (0x61)
DATA	UTCTime (12 bytes)

Contains UTC Time

DATA (B)	Description
0	Nanoseconds of second, range 0 .. 1.000.000.000
4	Year, range 1999 .. 2099
6	Month, range 1..12
7	Day of Month, range 1..31
8	Hour of Day, range 0..23
9	Minute of Hour, range 0..59
10	Seconds of Minute, range 0..59
11	0x01 = Valid Time of Week 0x02 = Valid Week Number 0x04 = Valid UTC (Leap Seconds already known?)

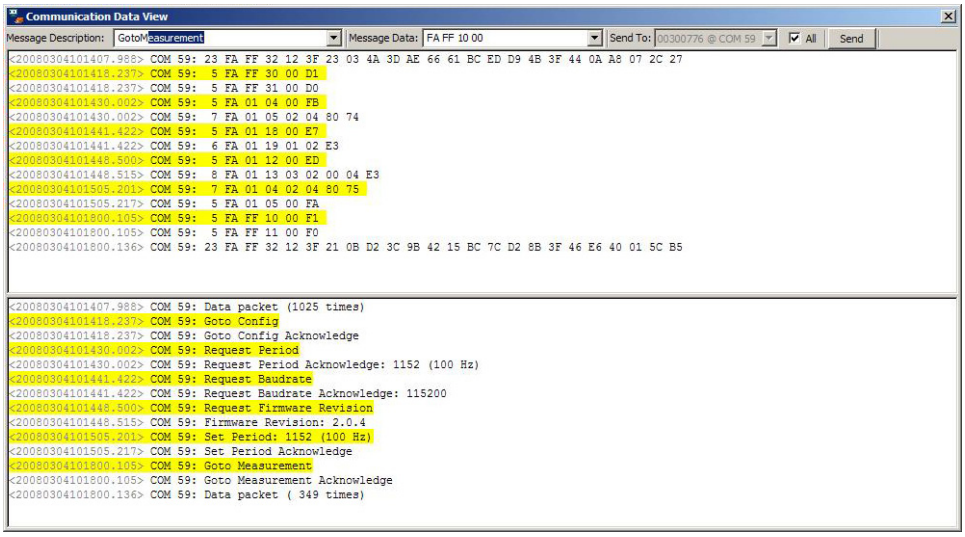
NOTE: Only supported by MTi-G.

5 MT low level communication protocol example

This section shows the communication between the host and MT as data bytes.

NOTE: The MT Manager has a tool emulating a console to view and input raw MT message and view the hexadecimal message flow simultaneously. This is a very convenient tool to get to know the MT communication protocol in detail, and to access all advanced functionality directly. Please refer to the MT Manager User Manual ([MTM]) for more details.

The byte values of the following examples are shown in hexadecimal. Please check if your application has also a hexadecimal view and the capability to send user input entered as hexadecimal strings.



Before you can change any settings, make sure Config is active:

TX: **FA FF 30 00 D1**

Continue receiving data until the following bytes are received:
RX: **FA FF 31 00 D0**

Set the Output mode to calibration + orientation data:

TX: **FA FF D0 02 00 06 29**

The MT acknowledges with
RX: **FA FF D1 00 30**

Set the Output setting to matrix orientation output + sample counter:

TX: **FA FF D2 04 00 00 00 09 22**

The MT acknowledges with
RX: **FA FF D3 00 2E**

Set the sample period to 1 / 120 sec (= 120Hz):

TX: **FA FF 04 02 03 C0 38**

The MT acknowledges with
RX: **FA FF 05 00 FC**

Goto measurement state to start logging data:

TX: **FA FF 10 00 F1**

The MT acknowledges with
RX: **FA FF 11 00 F0**

Start logging data:

The MT sends the **MTData** message which has the following format:
RX: **FA FF 32 4A AccData GyrData MagData MatrixData SC CS**

The **AccData, GyrData, MagData** fields contain 3x 4 bytes that are single-precision float values for the X,Y and Z-axis. **SC** stands for sample counter and is a 2 byte unsigned value and **CS** is the checksum.

6 Miscellaneous

6.1 Default factory settings

The default settings of the MT will set the device in a configuration that calculates and outputs the orientation 100 times per second in quaternions. The **MTData** message will also include a sample counter which can be used to detect missing samples. The data is transmitted at a baudrate of 115k2 bits per second and the synchronization in- and outputs are disabled.

The default settings and the messages to change the specific setting are listed in the following table.

Property	Default value	Message (section nr)
Output mode	Orientation output	**SetOutputMode** (4.3.5)
Output settings	Orientation in quaternion mode Sample counter	**SetOutputSettings** (4.3.5)
Sample frequency	100 Hz	**SetPeriod** (4.3.5)
Baudrate	115k2 bps	**SetBaudrate** (4.3.3)
Output skip factor	0	**SetOutputSkipfactor** (4.3.5)
SyncIn	Disabled	**SetSyncInSettings** (0)
SyncOut	Disabled	**SetSyncOutSettings** (0)
Error mode	1	**SetErrorMode** (4.3.3)

There are two ways to set the MT in this default setting. You can **RestoreFactoryDef** or you can use the individual messages shown in the table to (re)set the settings. Keep in mind that if you use the **RestoreFactoryDef** message the filter / device settings shown in the next table are also reset.

Property	Default value	Message (section nr)
Location	0	**SetLocationID** (4.3.3)
Object alignment	Unity matrix	**ResetOrientation** (4.3.7)
Heading	0	**SetHeading** (4.3.7)
XKF Scenario	1	**SetCurrentScenario** (4.3.7)

6.2 Restore communication

If the MT has been programmed with a baudrate setting that is not compatible with software or is unknown to the user, a 'restore communication' procedure can be applied. This procedure will set a number of settings to its default values including the baudrate. The following settings will be reset.

Property	Default value
Output mode	Orientation output
Output settings	Orientation in quaternion mode Sample counter
Sample frequency	100 Hz
Baudrate	115k2 bps
Output skip factor	0
SyncIn	Disabled
SyncOut	Disabled
Error mode	1

You can either use the MT Manager (see Tools menu) or perform the procedure manually. To restore the settings manually follow the following procedure:

1. Disconnect the MT from the USB-serial converter cable
2. Insert the USB-serial converter cable into a free USB port and open the respective virtual COM port with the following settings: baudrate 115k2, 8 databits, no parity and 2 stopbits
3. Start sending the byte value 222 (0xDE) repeatedly but make sure there is a gap of 0.1 to 0.5 ms between the words (no back-to-back transfer)
4. While sending connect the MT to the USB converter
5. Stop sending when the **`WakeUp`** message is received

All settings shown in the previous table are now reset.

This procedure during MT device WakeUp ensures that communication can always be restored with the device, even if erroneous settings have been programmed by accident.

7 Message Reference Listing

This section gives a quick reference of all the valid messages. For more information about the use of the messages see Section 4.

WakeUp and State messages (Section 4.3.1)

Message	MID	Direction	Description
WakeUp	62 (0x3E)	To host	The device sends this message at power- up or reset
WakeUpAck	63 (0x3F)	To MT	If received within 500ms after WakeUp device enters Config State else Measurement State
GoToConfig	48 (0x30)	To MT	Device enters config state
GoToConfigAck	49 (0x31)	To host	Device acknowledges GoToConfig message
GoToMeasurement	16 (0x10)	To MT	Device enters measurement state
GoToMeasurementAck	17 (0x11)	To host	Device acknowledges GoToMeasurement message
Reset	64 (0x40)	To MT	Reset device
ResetAck	65 (0x41)	To host	Acknowledgement of Reset message

Informational messages (Section 4.3.2)

Message	MID	Direction	Description
ReqDID	0 (0x00)	To MT	Host request device ID of the device
DeviceID	1 (0x01)	To host	Device acknowledges request by sending its ID
InitMT	2 (0x02)	To MT	Request device ID of the device (for compatibility of Xbus Master users)
InitMTResults	3 (0x03)	To host	Same as DeviceID message
ReqProductCode	28 (0x1c)	To MT	Host request product code of the device
ProductCode	29 (0x1d)	To host	Device acknowledges request by sending its product code
ReqFWRev	18 (0x12)	To MT	Host requests firmware revision of device
FirmwareRev	19 (0x13)	To host	Device acknowledges request by sending its firmware revision
ReqDataLength	10 (0x0A)	To MT	Request the number of data bytes in MTData message
DataLength	11 (0x0B)	To host	Contains the number of data bytes of the MTData message
Error	66 (0x42)	To host	Error message
ReqGPSStatus	166 (0xA6)	To MT	Request GPS Status
GPSStatus	167 (0xA7)	To host	Device returns GPS Status

Device-specific messages (Section 4.3.3)

Message	MID	Direction	Description
ReqBaudrate	24 (0x18)	To MT	Requests current baudrate of the serial communication
ReqBaudrateAck	25 (0x19)	To host	Device returns baudrate of serial communication
SetBaudrate	24 (0x18)	To MT	Host sets baudrate of serial communication

SetBaudrateAck	25 (0x19)	To host	Device acknowledges SetBaudrate message
ReqErrorMode	218 (0xDA)	To MT	Request error mode
ReqErrorModeAck	219 (0xDB)	To host	Device returns error mode
SetErrorMode	218 (0xDA)	To MT	Host sets error mode
SetErrorModeAck	219 (0xDB)	To host	Device acknowledges SetErrorMode message
ReqLocationID	132 (0x84)	To MT	Request location ID
ReqLocationIDAck	133 (0x85)	To host	Device returns location ID
SetLocationID	132 (0x84)	To MT	Host sets location ID
SetLocationIDAck	133 (0x85)	To host	Device acknowledges SetLocationID message
RestoreFactoryDef	14 (0x0E)	To MT	Restore factory defaults
RestoreFactoryDefAck	15 (0x0F)	To host	Device acknowledges RestoreFactoryDef message
ReqTransmitDelay	220 (0xDC)	To MT	Requests delay value which equals the minimum time between last byte reception and transmission start of acknowledge in RS485 mode
ReqTransmitDelayAck	221 (0xDD)	To host	Device returns delay value
SetTransmitDelay	220 (0xDC)	To MT	Host sets delay value
SetTransmitDelayAck	221 (0xDD)	To host	Device acknowledges SetTransmitDelay message
StoreXkfState	138 (0x8A)	To host	Stores state of XKF in non-volatile memory of device

Synchronization messages (Section 4.3.4)

Message	MID	Direction	Description
ReqSyncInSettings	214 (0xD6)	To MT	Request a SyncIn setting of the device, i.e. SyncIn mode, skip factor or offset
ReqSyncInSettingsAck	215 (0xD7)	To host	Device returns SyncIn setting
SetSyncInSettings	214 (0xD6)	To MT	Host sets a SyncIn setting
SetSyncInSettingsAck	215 (0xD7)	To host	Device acknowledges SetSyncInSettings message
ReqSyncOutSettings	216 (0xD8)	To MTi	Request a SyncOut setting of the device, i.e. SyncOut mode, skip factor, offset or pulse width
ReqSyncOutSettingsAck	217 (0xD9)	To host	Device returns SyncOut setting
SetSyncOutSettings	216 (0xD8)	To MTi	Host sets a SyncOut setting
SetSyncOutSettingsAck	217 (0xD9)	To host	Device acknowledges SetSyncOutSettings message

Configuration messages (Section 4.3.5)

Message	MID	Direction	Description
ReqConfiguration	12 (0x0C)	To MT	Request the configuration of device. For logging/quick setup purposes
Configuration	13 (0x0D)	To host	Contains the configuration of device
ReqPeriod	4 (0x04)	To MT	Request current sampling period
ReqPeriodAck	5 (0x05)	To host	Device returns sampling period
SetPeriod	4 (0x04)	To MT	Host sets sampling period (10-500Hz)
SetPeriodAck	5 (0x05)	To host	Device acknowledges SetPeriod message
ReqOutputSkipFactor	212 (0xD4)	To MT	Request how many times the data output is skipped before sending a MTData message
ReqOutputSkipFactorAck	213 (0xD5)	To host	Device returns OutputSkipFactor

SetOutputSkipFactor	212 (0xD4)	To MT	Host sets OutputSkipFactor
SetOutputSkipFactorAck	213 (0xD5)	To host	Device acknowledges SetOutputSkipfactor message
ReqObjectAlignment	224 (0xE0)	To MT	Request object alignment matrix
ReqObjectAlignmentAck	225 (0xE1)	To host	Device returns object alignment matrix
SetObjectAlignment	224 (0xE0)	To MT	To set the object alignment matrix
SetObjectAlignmentAck	225 (0xE1)	To host	Device acknowledges SetObjectAlignment message
ReqOutputMode	208 (0xD0)	To MT	Request current output mode
ReqOutputModeAck	209 (0xD1)	To host	Device returns output mode
SetOutputMode	208 (0xD0)	To MT	Host sets output mode
SetOutputModeAck	209 (0xD1)	To host	Device acknowledges SetOutputMode message
ReqOutputSettings	210 (0xD2)	To MT	Request current output settings
ReqOutputSettingsAck	211 (0xD3)	To host	Device returns output settings
SetOutputSettings	210 (0xD2)	To MT	Host sets output settings
SetOutputSettingsAck	211 (0xD3)	To host	Device acknowledges SetOutputSettings message

Data-related messages (Section 4.3.6)

Message	MID	Direction	Description
ReqData	52 (0x34)	To MT	Host requests device to send MTData message
MTData	50 (0x32)	To host	Message with un-calibrated raw data, calibrated data,orientation data or GPS PVT data

XKF Filter messages (Section 4.3.7)

Message	MID	Direction	Description
ReqHeading	130 (0x82)	To MT	Request heading settings
ReqHeadingAck	131 (0x83)	To host	Device returns heading
SetHeading	130 (0x82)	To MT	Host sets output mode
SetHeadingAck	131 (0x83)	To host	Device acknowledges SetHeading message
ResetOrientation	164 (0xA4)	To MT	Resets the orientation
ResetOrientationAck	165 (0xA5)	To host	Device acknowledges ResetOrientation message
ReqUTCTime	96 (0x60)	To MT	Request UTC Time
UTCTime	97 (0x61)	To host	Device return UTC Time
ReqAvailableScenarios	98 (0x62)	To MT	Request available scenarios
AvailableScenarios	99 (0x63)	To host	Device return available scenarios
ReqCurrentScenario	100 (0x64)	To MT	Request current used scenario
ReqCurrentScenarioAck	101 (0x65)	To host	Device return current scenario
SetCurrentScenario	100 (0x64)	To MT	Host set current scenario
SetCurrentScenarioAck	101 (0x65)	To host	Device acknowledges SetCurrentScenario
ReqGravityMagnitude	102 (0x66)	To MT	Request current used gravity magnitude
ReqGravityMagnitudeAck	103 (0x67)	To host	Device returns current gravity magnitude
SetGravityMagnitude	102 (0x66)	To MT	Host set gravity magnitude
SetGravityMagnitudeAck	103 (0x67)	To host	Device acknowledges SetGravityMagnitude
ReqleverArmGPS	104 (0x68)	To MT	Request current used lever arm GPS
ReqleverArmGPSAck	105 (0x69)	To host	Device returns current lever arm GPS
SetleverArmGPS	104 (0x68)	To MT	Host set current lever arm GPS

SetleverArmGPSAck	105 (0x69)	To host	Device acknowledges SetLeverArmGPS
ReqMagneticDeclination	106 (0x6A)	To MT	Request current used magnetic declination
ReqMagneticDeclinationAck	107 (0x6B)	To host	Device returns current magnetic declination
SetMagneticDeclination	106 (0x6A)	To MT	Host set current magnetic declination
SetMagneticDeclinationAck	107 (0x6B)	To host	Device acknowledges SetMagnetic Declination
ReqProcessingFlags	32 (0x20)	To MT	Request filter processing flags
ReqProcessingFlagsAck	33 (0x21)	To host	Device returns processing flags
SetProcessingFlags	32 (0x20)	To MT	Host sets processing flags
SetProcessingFlagsAck	33 (0x21)	To host	Device acknowledges SetProcessing Flags
SetNoRotation	34 (0x22)	To MT	Initiates XKF3 ‘no rotation’ update procedure
SetNoRotationAck	35 (0x23)	To host	Device acknowledges SetNoRotation message