



MTLT335 SERIES USER MANUAL

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WARNING

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Table of Contents

1	Introduction	5
1.1	Manual Overview	5
1.2	Overview of the MTLT335 Dynamic Inclination and 6 DOF IMU Sensor	6
2	Interface	8
2.1	Electrical Interface.....	8
2.1.1	Connector and Mating Connector	8
2.1.2	Power Input and Power Input Ground.....	9
2.1.3	CAN Serial Interface.....	9
2.1.4	RS232 Serial Data Interface	9
2.1.5	Alternative Functions of RS232 pins	9
2.2	Mechanical Interface	11
2.2.1	Recommended Mounting	11
3	Theory of Operation	13
3.1	Sensor fault detection	16
3.2	MTLT335 Series Default Coordinate System	16
3.2.1	Axis Orientation Settings	18
3.3	Digital Filter	18
3.3.1	Acceleration Filter Settings	18
3.3.2	Rate Sensor Filter Settings	18
4	Safety Features	20
4.1	ISO 13849 Compliance	20
4.2	SAE J1939-76 E2E Protection	20
5	CAN Port Interface Definition.....	22
5.1	SAE J1939	22
5.1.1	ECU's Address.....	23
5.1.2	Address Claim.....	23
5.1.3	Baud Rate	24
5.1.4	Get Commands.....	25
5.1.5	Set Commands	41
5.1.6	Data Packets.....	56
5.1.7	Diagnostic Messages DM1.....	64
5.2	DBC File.....	66

6	RS-232 Port Interface Definition.....	67
6.1	General Settings.....	67
6.2	Number Formats.....	67
6.3	Packet Format.....	68
6.3.1	Packet Header.....	68
6.3.2	Packet Type.....	68
6.3.3	Payload Length.....	69
6.3.4	Payload.....	69
6.3.5	16-bit CRC-CCITT	69
6.3.6	Messaging Overview.....	70
7	MTLT335 Standard RS232 Port Commands and Messages	71
7.1	Link Test.....	71
7.1.1	Ping Command.....	71
7.1.2	Ping Response	71
7.1.3	Echo Command.....	71
7.1.4	Echo Response	71
7.2	Interactive Commands.....	72
7.2.1	Get Packet Request	72
7.2.2	System Reset Command.....	72
7.2.3	System Reset Response.....	72
7.2.4	Error Response	72
7.3	Output Packets (Polled).....	73
7.3.1	Identification Data Packet	73
7.3.2	Version Data Packet.....	73
7.3.3	Test (Detailed BIT and Status) Packet	74
7.4	RS232 Output Packets (Polled or Continuous)	74
7.4.1	Angle Data Packet 2 (Default MTLT335 Data).....	74
7.4.2	Scaled Sensor Data.....	75
8	MTLT335 Advanced RS232 Port Commands.....	77
8.1	Configuration Fields.....	77
8.2	Continuous Packet Type Field.....	78
8.3	EKF and DATA Digital Filter Settings	78
8.4	Orientation Field.....	79

8.5	Unit Behavior Switches	80
8.6	Commands to Program Configuration Using RS232 Port.....	80
8.6.1	Write Fields Command	80
8.6.2	Set Fields Command	81
8.7	Read Fields Command	82
8.8	Read Fields Response.....	83
8.9	Get Fields Command.....	83
8.10	Get Fields Response.....	84
9	Bootloader	85
9.1	Firmware Upgrade.....	85
9.2	Firmware Upgrade Using RS232 Interface	85
9.2.1	Commands used for FW upgrade via RS232 Interface	85
10	Customer Service.....	86
10.1	Contact Directory.....	86
10.2	Return Procedure	86
10.2.1	Authorization.....	86
10.2.2	Identification and Protection	87
10.2.3	Sealing the Container	87
10.2.4	Marking.....	87
	Appendix A: 16-bit CRC Implementation Sample Code.....	88
	Appendix B: Function Instance (Detecting location on wire harness).....	89
	Appendix C: Installation and Operation of NAV-VIEW over RS232.....	91
	Appendix D: Response to ECU ID request example	100
	Appendix E: Response to SW Version request.....	102
	Appendix F: FOM and BIT Examples	104
	Appendix G: Advanced RS232 Port BIT.....	105
	Appendix H: RS232 Sample Packet Decoding.....	106

About this Manual

The following annotations have been used to provide additional information.

NOTE

Note provides additional information about the topic.

EXAMPLE

Examples are given throughout the manual to help the reader understand the terminology.

IMPORTANT

This symbol defines items that have significant meaning to the user

WARNING

The user should pay particular attention to this symbol. It means there is a chance that physical harm could happen to either the person or the equipment.

The following paragraph heading formatting is used in this manual:

1 Heading 1

1.1 Heading 2

1.1.1 Heading 3

1.1.1.1 Heading 4

Normal

1 Introduction

1.1 Manual Overview

This manual provides a comprehensive introduction to ACEINNA's MTLT335 Series Dynamic Inclination and Acceleration Sensing Family of products. As the functionality of the different products within the family are identical (only the performance specs are different), for simplicity all references will be to the MTLT335. For users wishing to get started quickly, please refer to the two-page Best Practices Guide available online at www.aceinna.com. Table 1 highlights the content in each section and suggests how to use this manual.

Table 1. Manual Content

Manual Section	Who Should Read?
Section 1: Overview	All customers should read sections 1 and 1.2.
Section 2: Interface	Customers designing the electrical and mechanical interface to the MTLT335 series products should read Section 2.
Section 3: Theory of Operation	All customers should read Section 3.
Section 4 - 5: Safety Features and CAN Port Interface	Customers designing the software interface to the MTLT335 series products CAN Port should review Section 4 and 5
Section 6 - 8: RS232 Port Interface	Customers designing the software interface to the MTLT335 series products RS232 Port should review Sections 6 - 8
Section 9: Bootloader	Customers upgrading firmware should review Section 9.
Section 10: Warranty and Support	Customers who need the support information should review Section 10.

1.2 Overview of the MTLT335 Dynamic Inclination and 6 DOF IMU Sensor

This manual introduces the use of ACEINNA's MTLT335 Series Dynamic Inclination and Acceleration Sensing products listed in Table 2. This manual is intended to be used as a detailed technical reference and operating guide. ACEINNA's MTLT335 Series products combine the latest in high-performance commercial MEMS (Micro-electromechanical Systems) sensors and digital signal processing techniques to provide a small, rugged and cost-effective solution for accurately sensing pitch and roll in dynamic applications.

Table 2. MTLT335 Series Feature Description

Product	Features
MTLT335	Pitch, Roll, 3D ± 8 g acceleration, 3D ± 400 deg/s Bias Corrected Rate

The MTLT335 Series is based on ACEINNA's fourth generation of MEMS-based Inertial Systems, building on over a decade of field experience, and encompassing thousands of deployed units and millions of operational hours in a wide range of land, marine, airborne, and instrumentation applications.

At the core of the MTLT335 Series is a rugged 6-DOF (Degrees of Freedom) MEMS inertial sensor cluster that is also used in such products as IMU383 and OpenIMU330BI. The 6-DOF MEMS inertial sensor cluster includes three axes of MEMS angular rate sensing and three axes of MEMS linear acceleration sensing. These sensors are based on rugged, field proven silicon micromachining technology. Each sensor within the cluster is individually factory calibrated for temperature and non-linearity effects during ACEINNA's manufacturing and test process using automated thermal chambers and precision rate tables.

Coupled to the 6-DOF MEMS inertial sensor cluster is a high-performance microprocessor that utilizes the inertial sensor measurements to accurately compute attitude (pitch and roll). The attitude algorithm utilizes a multi-state Extended Kalman Filter (EKF) to correct for drift errors and estimate sensor bias values.

The differentiating feature of the MTLT335 Series is the trio of redundant 6-DOF MEMS sensor clusters. This redundancy has two direct benefits:

- 1) Combining multiple sensors reading improves the noise characteristics of the output signal
- 2) Using more than one sensor enables the unit to operate through a single sensor-chip failure by detecting and voting out the failed part. Failures include stuck or railed readings as well as sustained inconsistency between the three sensor sets.

Another unique feature of the MTLT335 Series is the extensive field configurability of the units. This field configurability allows the MTLT335 Series of Inertial Systems to satisfy a wide range of applications and performance requirements with a single mass-produced hardware platform. Parameters that can be configured include baud rate, low pass filter settings (acceleration and rate sensors) packet type, update rate, and defining of custom orientation.

The MTLT335 firmware is designed to be field upgradable so units in the field can be upgraded to take advantage of new features or algorithm improvements that may be available in future firmware revision releases.

The MTLT335 Series is available in a packaged cast metal housing or in a lightweight, rugged, IP69K sealed plastic enclosure with nickel plated brass mounting bushings designed for cost-sensitive commercial applications requiring a robust solution that can be exposed to the elements. Mounting configuration is the same for both versions. The MTLT335 can be configured to output data over a CAN Port and / or a RS232 serial port. The MTLT335 RS232 output data port is supported by ACEINNA's NAV-VIEW 3.X, a powerful PC-based operating tool that provides complete field configuration, diagnostics, charting of sensor performance, and data logging with playback.

2 Interface

2.1 Electrical Interface

2.1.1 Connector and Mating Connector

The MTLT335 connector is an AMPSEAL16 6-pos defined in Figure 1

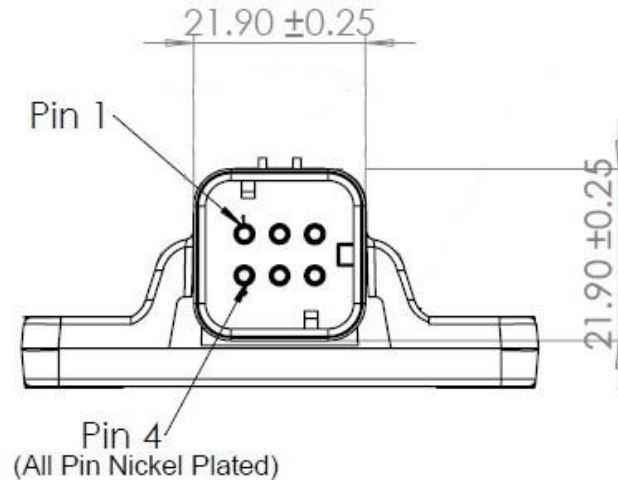


Figure 1 MTLT335 Interface Connector

The mating connector is: TE Connectivity 776531-1 or equivalent, which is currently listed at the following web address: <http://www.te.com/usa-en/product-776531-1.html>



The definitions of connector pins are in Table 3.

Table 3. MTLT335 Interface Connector Pin Definition

Pin	Signal
1	CAN H
2	CAN L
3	Ground
4	RS232 RX / PPS in / Function Instance
5	RS232 TX / Function Instance
6	Power

2.1.2 Power Input and Power Input Ground

Power is applied to the MTLT335 on pin 6, and ground is Pin 3; The MTLT335 accepts an unregulated 9 to 32 VDC input. It is reverse polarity and ESD protected internally. It is designed to be compatible with 12 V and 24 V power environments of Heavy Equipment and Passenger Vehicle power systems.

2.1.3 CAN Serial Interface

The MTLT335 is equipped with a CAN 2.0 electrical interface and is compliant to the SAE J1939 protocol standard.

Baud Rate: The default CAN baud rate setting is 250kb/s. The MTLT335 can support up to 1000kb/s baud rate. The CAN baud rate can be changed and permanently saved by the user using the RS232 port and NAV-VIEW 3.x SW running on a PC or unit can be configured in Auto Baud detection mode. See the section 5.1.3.2 and 5.1.5.7.

CAN Address: The default CAN address is 0x80. The MTLT335 has address claiming capability. In the event there is a conflict with another module on the bus with the same address, it will attempt to claim a new address and save it in non-volatile memory. The CAN address can also be changed and permanently saved by the user by from the CAN bus or using the RS232 port and NAV-VIEW 3.x SW running on a PC. See the section 5.1.5.7.

2.1.4 RS232 Serial Data Interface

The default baud rate of RS232 interface is 115200bps. MTLT335 also supports 38400, 57600, 230400 bps baud rates. User can choose desired baud rate and permanently save it in non-volatile memory through NAV-VIEW.

The RS-232 standard defines the voltage levels that correspond to logical one and logical zero levels for the data transmission and the control signal lines. Valid signals are either in the range of +3 to +15 volts or the range -3 to -15 volts with respect to the "Common Ground" (GND) pin.

A "3-wire" RS-232 connection consisting only of transmit data, receive data, and ground, is used.

2.1.5 Alternative Functions of RS232 pins

2.1.5.1 Function Instance

RS232 RX and TX pins have alternative uses if CAN is the primary interface and the RS232 port is not needed. The Rx and Tx pins can be used to detect location on a wiring harness when multiple instances of the MTLT335D are installed on the same bus. See Appendix B for more information.

2.1.5.2 Synchronization In

The RS232 Rx pin can also be used to synchronize the MTLT335D data collection and processing cycle to a 1 PPS input. MTLT335D synchronizes to rising edge of external 1PPS GPS signal.

The 1PPS signal should be connected to the pin 4 (RS232 RX) of MTLT335D 6-pin connector.

The signal must maintain 0.0-0.2 V zero logic and 3.0 - 5.0 V high logic.

The active (high) level of 1PPS signal pulse should be from 10 ms to 600 ms.

Period of 1PPS signal must be within 10 ms of the internal system 1 second timing.

To enable synchronization to 1PPS signal, 1 needs to be written into factory configuration parameter 0x68. See Table 94 in section 8.1.

In case valid input message on serial port is detected – PPS synchronization is automatically disabled

2.2 Mechanical Interface

The MTLT335D mechanical interfaces are defined by the outline drawings in Figure 2.

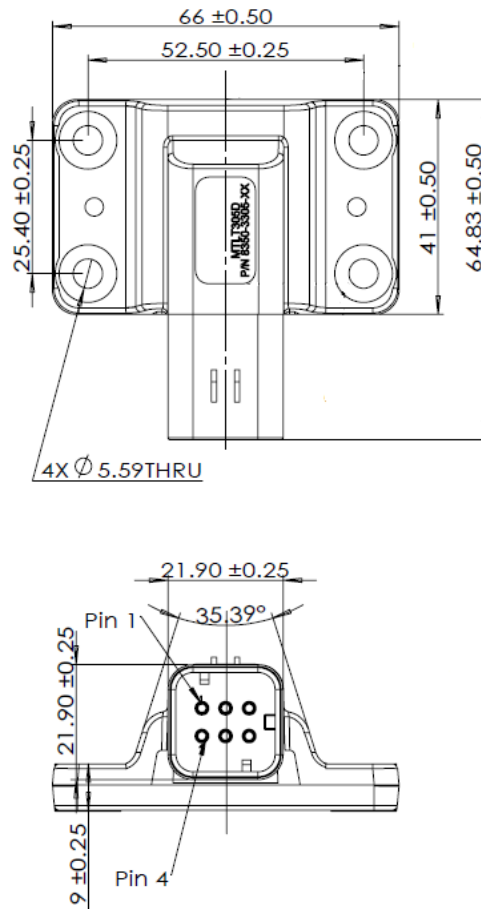


Figure 2 MTLT335D Outline Drawing

Mating Connector: TE Connectivity 776531-1 or equivalent. See Figure 1.

2.2.1 Recommended Mounting

2.2.1.1 Hardware and Torque

Use 4 - M5 Alloy Steel Socket Head Screws to secure the MTLT335.

It is recommended to use standard M5 washer with outer diameter of 10mm, lock washer and Loctite 242 thread lock.

The washer outer diameter must NOT be larger than the outer diameter of the bushing (11mm).

MTLT335D/M –Torque the screws to 5.0 N-m (44.25 inch-pounds).

2.2.1.2 Mounting Surface

Flatness of the mounting surface of 0 ± 0.5 mm is required.

3 Theory of Operation

The MTLT335 Series are a family of dynamic inclination and acceleration sensors. They provide dynamic pitch and roll, 3D linear acceleration, and 3D estimated rate measurement data (Pitch and Roll rates are bias corrected, Yaw is not).

Figure 3 shows the MTLT335 Series hardware block diagram. At the core of the MTLT335 Series is a rugged 6-DOF (Degrees of Freedom) MEMS inertial sensor cluster that is common across all members of the MTLT335 Series. The 6-DOF MEMS inertial sensor cluster includes three axes of MEMS angular rate sensing and three axes of MEMS linear acceleration sensing. These sensors are based on rugged, field proven silicon micromachining technology. Each sensor within the cluster is individually factory calibrated using ACEINNA's automated manufacturing process. Sensor errors compensated for are temperature bias, scale factor, non-linearity and misalignment effects using a proprietary algorithm from data collected during manufacturing. Accelerometer and rate gyro sensor bias shifts over temperature (-40°C to $+85^{\circ}\text{C}$) are compensated and verified using calibrated thermal chambers and precision rate tables.

The acceleration sensors have a full-scale range (FSR) of $\pm 78 \text{ ms}^{-2}$, and the rate sensors have a FSR of 400 degrees/s. The large FSR ensures that the sensors are not over-ranged in the application. Both the acceleration and rate sensors are over sampled at 1000 Hz, and digitally processed through a 3rd order configurable low-pass filter (LPF). The acceleration and rate sensors' LPFs can be set independently. The default setting for the rate data is 25 Hz and the default setting for the acceleration data is 5 Hz. Over sampling and LPF combined together eliminate higher frequency vibration and impulse energy providing greater accuracy in high-vibration environments.

The filtered data is then corrected for temperature related errors and non-linearity by ACEINNA's proprietary compensation algorithm using data collected during ACEINNA's calibration process.

This dataset is used to generate the dynamic roll and pitch estimation and are stabilized by the using the accelerometers as a long-term gravity reference. Internally, the algorithm solves for roll and pitch at a 200 Hz rate, enabling the MTLT335 to continuously maintain the dynamic roll and pitch data as well as the 3D linear acceleration and 3D estimated rate data. The Yaw estimation (RS232 only) is a free integrating yaw angle measurement that is not stabilized by a magnetometer or compass heading. As shown in the software block diagram Figure 4, after the Sensor Calibration block, the temperature corrected, and filtered data are passed into Integration to Orientation block. The Integration to Orientation block integrates body frame sensed angular rate to orientation at a fixed 200 times per second within the MTLT335 Series products. For improved accuracy and to avoid singularities when dealing with the Euler angles, a quaternion formulation is used in the algorithm to provide attitude propagation.

As also shown in the software block diagram, the Integration to Orientation block receives drift corrections from the Extended Kalman Filter (EKF) or Drift Correction Module. In general, rate sensors and accelerometers suffer from bias drift, misalignment errors, acceleration errors (g-sensitivity), nonlinearity (square terms), and scale factor errors. The largest error in the orientation propagation is associated with the rate sensor bias terms. The EKF module provides an on-the-fly calibration for drift errors, including the rate sensor bias, by providing corrections to the Integration to Orientation block and a characterization of the gyro bias state. In the MTLT335, the

internally computed gravity reference vector provides a reference measurement for the EKF when the MTLT335 is in quasi-static motion to correct roll and pitch angle drift and to estimate the X and Y gyro rate bias. Because the gravity vector has no horizontal component, the EKF has no ability to estimate either the yaw angle error or the Z gyro rate bias. The MTLT335 adaptively tunes the EKF feedback in order to best balance the bias estimation and attitude correction with distortion free performance during dynamics when the object is accelerating either linearly (speed changes) or centripetally (false gravity forces from turns). Because centripetal and other dynamic accelerations are often associated with yaw rate, the MTLT335 maintains a low-passed filtered yaw rate signal and compares it to the turnSwitch threshold field (user adjustable). When the user platform to which the MTLT335 is attached exceeds the turnSwitch threshold yaw rate, the MTLT335 lowers the feedback gains from the accelerometers to allow the attitude estimate to coast through the dynamic situation with primary reliance on angular rate sensors. This situation is indicated by the softwareStatus turnSwitch status flag. Using the turn switch maintains better attitude accuracy during short-term dynamic situations, but care must be taken to ensure that the duty cycle of the turn switch generally stays below 10% during the vehicle mission. A high turn switch duty cycle does not allow the system to apply enough rate sensor bias correction and could allow the attitude estimate to become unstable.

The MTLT335 algorithm has two major phases of operation. The first phase of operation is the initialization phase. During the initialization phase, the MTLT335 is expected to be stationary or quasi-static in order to get a good initial estimation of the roll and pitch angles, and X, Y rate sensor bias. The initialization phase lasts less than 2 seconds, and the initialization phase can be monitored in the softwareStatus BIT transmitted by default in each RS232 measurement packet. After the initialization phase, the MTLT335 operates in the dynamic mode to continuously estimate and correct for roll and pitch errors, as well as to estimate X and Y rate sensor bias.

If a user wants to reset the algorithm or re-enter the initialization phase, sending the algorithm reset command, 'AR', will force the algorithm into the reset phase.

The MTLT335 outputs digital measurement data over the CAN or RS232 port at a selectable fixed rate (100, 50, 25, 20, 10, 5 or 2 Hz) or on as requested basis.

In addition to the configurable baud rate, packet rate, axis orientation, and sensor low-pass filter settings, the MTLT335 provides additional advanced settings, which are selectable for tailoring the MTLT335 to a specific application requirement. Currently there are 2 major modes of operation. Mode 0 is for normal general purpose applications such as passenger or other vehicles. Mode 1 is for Excavator and other applications where the chassis, boom, stick, arm or bucket can rotate in place. In this mode, the gyro is used to detect motion to better track pitch and roll angles during rotational movement and minimize effects of centripetal acceleration.

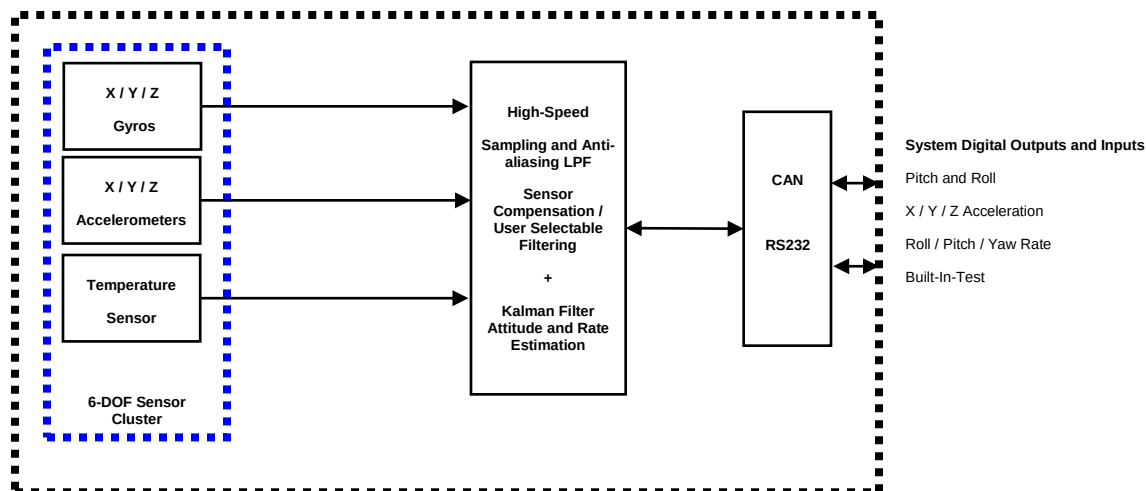


Figure 3 MTLT335 Series Hardware Block Diagram

Figure 4 shows the software block diagram. As shown in the software block diagram, the MTLT335 Series has a unit setting and profile block which configures the algorithm to user and application specific needs. This feature is one of the more powerful features in the MTLT335 Series architecture as it allows the MTLT335 Series to work in a wide range of commercial applications by settings different modes of operation for the MTLT335 Series.

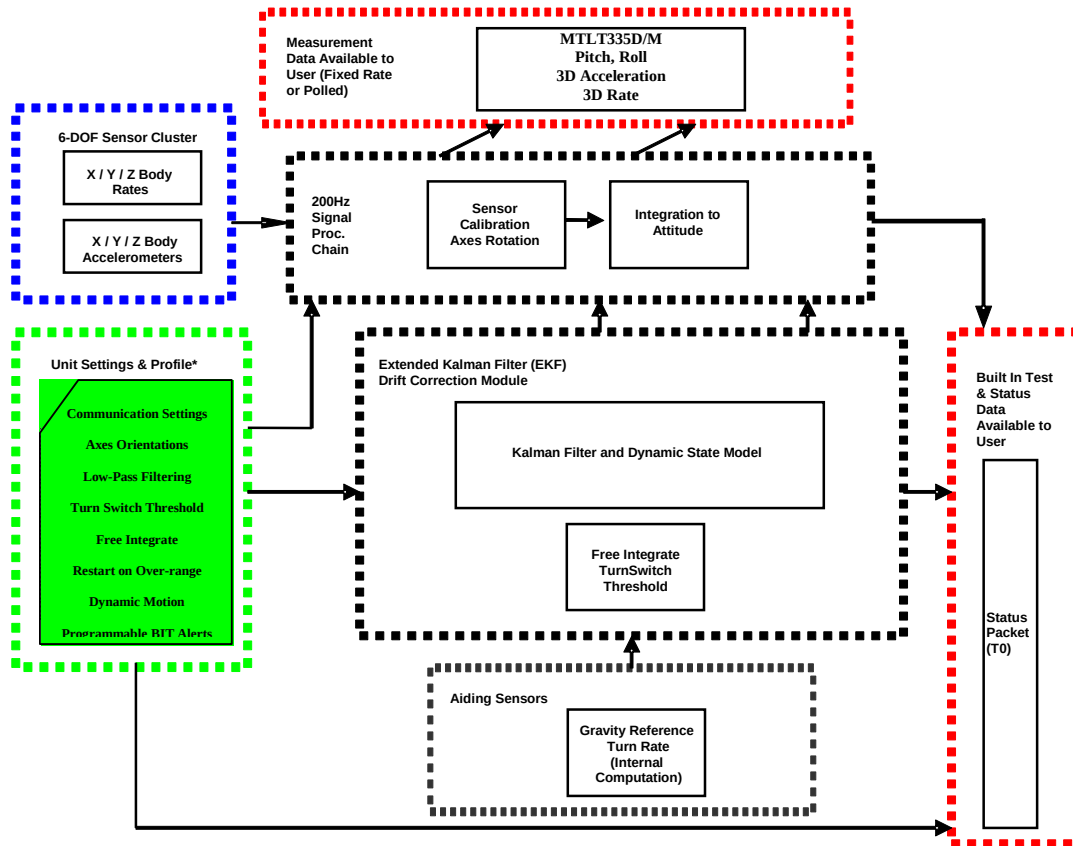


Figure 4 MTLT335 Series Software Block Diagram

The common aiding sensor for the drift correction for the attitude (i.e., roll and pitch only) is a 3-axis accelerometer. This is the default configuration for the MTLT335 products.

3.1 Sensor fault detection

New for the MTLT335 is the incorporation of triple-redundant accelerometer and gyro sensor clusters, which is the basis for a built-in sensor fault detection mechanism. The fault detection routine incorporated into the firmware continually monitors the output of the three sensor chips. If the average of any one of the three sensors disagrees significantly from the other two for 3 Fault Tolerant Time Intervals (FTTI), it is deemed faulty, and removed from the solution. The MTLT335 will continue to work normally using the remaining sensors. The fault detection logic is reset on the next power cycle, including all three sensors in the solution until/unless it is judged faulty again. The Fault Tolerant Time Interval (FTTI) for such a failure is set to 500 msec, however the actual detection time could be changed if needed. Contact the factory for more information.

3.2 MTLT335 Series Default Coordinate System

The MTLT335 Series Inertial System default coordinate systems are shown in Figure 5. As with many elements of the MTLT335 Series, the coordinate system is configurable with either NAV-VIEW or by sending the appropriate serial commands over the CAN or RS232 port. These

configurable elements are known as **Advanced Settings**. This section of the manual describes the default coordinate system settings of the MTLT335 Series when it leaves the factory

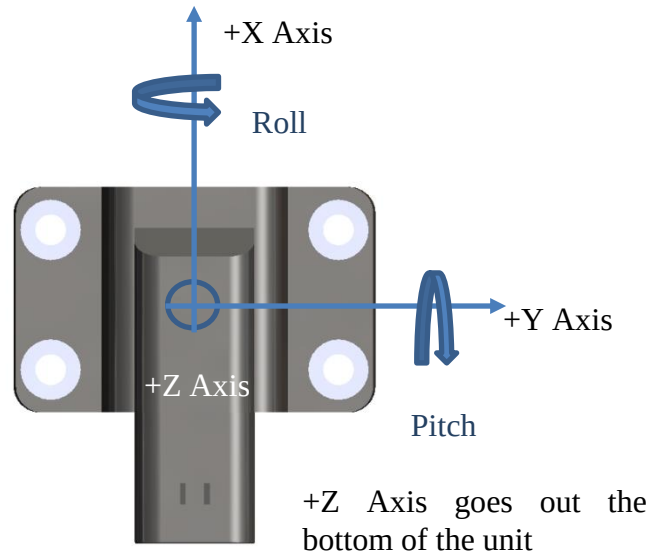


Figure 5. MTLT335 Default Coordinate Frame

The axes form an orthogonal SAE right-handed coordinate system. Acceleration is positive when it is oriented towards the positive side of the coordinate axis. For example, with a MTLT335 Series product sitting on a level table, it will measure zero g along the x and y-axes and -1 g along the z-axis. Normal Force acceleration is directed upward, and thus will be defined as negative for the MTLT335 Series z-axis.

The angular rate sensors are aligned with these same axes. The rate sensors measure angular rotation rate around a given axis. The rate measurements are labeled by the appropriate axis. The direction of a positive rotation is defined by the right-hand rule. With the thumb of your right hand pointing along the axis in a positive direction, your fingers curl around in the positive rotation direction. For example, if the MTLT335 Series product is sitting on a level surface and you rotate it clockwise on that surface, this will be a positive rotation around the z-axis. The x and y-axis rate sensors would measure zero angular rates, and the z-axis sensor would measure a positive angular rate.

Pitch is defined positive for a positive rotation around the y-axis (pitch up). Roll is defined as positive for a positive rotation around the x-axis (roll right). Yaw is defined as positive for a positive rotation around the z-axis (turn right).

“The angles are defined as standard Euler angles using a 3-2-1 system. To rotate from the earth-level frame to the body frame, yaw first, then pitch, and then roll.

3.2.1 Axis Orientation Settings

The MTLT335 gives users the ability to set the axes orientation by selecting which axis aligns with the base axes as well as the sign. The only constraint is the axes must conform to a right-hand definition. The available settings are described in Section 8.4. The specific selections are provided in Table 97. The default setting is (+Ux, +Uy, +Uz).

Refer to CAN Protocol Section 0 for instructions on changing the orientation for your application over the CAN bus.

Refer to RS232 Protocol Section 8.4 for instructions on changing the orientation for your application over the RS232 Port.

3.3 Digital Filter

The MTLT335 contains two sets of configurable low pass filters. One set of acceleration and rate filters is for data presented to the EKF for attitude estimations. The other completely independent set is applied to the data to be output on the CAN bus and the RS232 port. The Filters are 3rd order Butterworth filters that can be set to 50, 40, 25, 20, 10, and 5 Hz cutoff frequencies or turned off.

EKF filter defaults for acceleration and rate sensors are 5 and 25 Hz respectively.

Output data filter defaults for acceleration and rate sensors are both 25 Hz.

3.3.1 Acceleration Filter Settings

Decreasing the EKF accelerometer filter cutoff frequency will reduce transmission of the acceleration noise to the algorithm and enable the system to better estimate roll and pitch angles (as well as rate-sensor bias) under noisy idle-conditions (such as vibration caused by engine noise). The filter will not have a large effect on the estimate of the roll and pitch angles during motion, as the role of the accelerometer is reduced during motion and angles are estimated by integrating the rate-sensor signal. Default factory configuration is 5Hz.

Refer to CAN Protocol Section 5.1.5.5 for instructions on changing the acceleration sensor filter for your application over the CAN bus.

Refer to RS232 Protocol Section 8.3 for instructions on changing the acceleration sensor filter for your application over the RS232 Port.

3.3.2 Rate Sensor Filter Settings

Decreasing the EKF rate-sensor filter cutoff frequency will reduce transmission of the vibrational noise to the algorithm and enable the system to generate less noisy roll and pitch angle estimates under noisy conditions (such as vibration caused by engine noise). However, very low cutoff frequency settings can increase lag in the signal, which may affect system performance. Settings must be made based on system requirements. Default Factory setting and firmware default are 25Hz.

Refer to CAN Protocol Section 5.1.5.5 for instructions on changing the rate sensor filter setting for your application over the CAN bus.

Refer to RS232 Protocol Section 8.3 for instructions on changing the rate sensor filter for your application over the RS232Port

◀ **NOTE on Filter Settings**

Why change the filter settings? Generally, there is no reason to change the low-pass filter settings on the MTLT335 Series Inertial Systems. However, when a MTLT335 Series product is installed in an environment with a lot of vibration, it can be helpful to reduce the vibration-based signal energy and noise prior to further processing on the signal. Installing the MTLT335 in the target environment and reviewing the data with NAV-VIEW can be helpful to determine if changing the filter settings would be helpful. Although the filter settings can be helpful in reducing vibration-based noise in the signal, low pass filter settings (e.g., <10Hz) also reduce the bandwidth of the signal, i.e., can wash out the signals containing the dynamics of a target. Treat the filter settings with caution.

4 Safety Features

4.1 ISO 13849 Compliance

MTLT335 has been designed in compliance with the standard ISO13849. The design incorporates the following safety features:

- Upon startup the MTLT335 performs extensive self-diagnostics. If during self-diagnostics there are serious problems detected with the sensors, the unit will cease sending out sensors data and set corresponding bits in the status register. Also, it will periodically send out a diagnostic message (see PGN 65362). Other diagnostic messages are available on demand (see 5.1.4.7, 5.1.4.8 and 5.1.4.9). In case of severe hardware failures, the unit will disconnect itself from the CAN bus to prevent compromising of system data traffic.
- The MTLT335 constantly monitors its vital configuration/calibration data and will notify master unit of failures by setting corresponding bits in status registers and/or sending diagnostics message PGN 65362. In the event that calibration tables for specific sensors are compromised, the unit will block data from these sensors from participating in the solution.
- The MTLT335 incorporates triple redundant sensors and constantly monitors validity of sensors data using proprietary fault detection mechanism. Upon detection of a fault in one sensor, the MTLT335 will automatically exclude the faulty sensor from the main data processing/presentation stream but will still perform within specifications. If just one of three sensors remains healthy – unit will continue its work but will indicate performance degradation in the data packets. In case when unit detects that data from all sensors is compromised – unit will cease to transmit data and will be sending out periodic diagnostic messages. Contact the factory for more information about fault detection mechanism and its configuration
- The MTLT335 hardware is designed such that it will be automatically disconnected from CAN bus when it's internal core or power supply are compromised.
- The MTLT335 will report degradation of its health – power over consumption, power supply failure, temperature of sensors is outside of sensor temperature calibration range, or unexpected delays in data processing by setting bits in status registers and sending out diagnostics messages.
- Upon restart, the MTLT335 will report the cause of the restart event by setting specific bits in status registers and/or sending out diagnostic message.

4.2 SAE J1939-76 E2E Protection

MTLT335 has the capability to enable SAE J1939-76 Functional Safety Communications Protocol for broadcast data messages. To enable, set bit 6 of the second byte of the Unit Behavior word to 1 and issue a save configuration and reset command. See section 5.1.5.7 for more information on setting and clearing bits in the Unit Behavior word.

When enabled all broadcast data messages will be preceded by a Safety Header Message (SHM) PGN 3584. The SHM data field contains the sequence number, the CRC of the data in the Safety Data Message (SDM), and the inverted 29-bit identifier of the SDM excluding the three Priority bits. Please refer to SAE J1939-76 for full definition of the Functional Safety Communications Protocol.

5 CAN Port Interface Definition

The CAN interface of MTLT supports the CAN protocol version 2.0B. It has been designed to manage high rates of incoming messages efficiently and meets the priority requirements for transmit message.

MTLT335 supports baud rates of 250kbps, 500Kbps, and 1Mbps, and supports automatic baud rate detection (see section 5.1.3.2).

5.1 SAE J1939

The MTLT335 supports CAN's higher layer protocol, SAEJ1939, managing the communication within network. J1939 is a set of standards defined by SAE. The physical layer (J1939/11) describes the electrical interface to the bus. The data link layer (J1939/21) describes the rules for constructing a message, accessing the bus, and detecting transmission errors. The application layer (J1939/71 and J1939/73) defines the specific data contained within each message sent across the network.

J1939 uses the 29-bit identifier defined within the CAN 2.0B protocol shown in Table 4.

Table 4. Structure of a 29-bit identifier

Priority	Reserved	Data Page	PDU Format	PDU Specific	Source Address
3 bits	1 bit	1bit	8 bits	8 bits	8 bits

The first three bits of the identifier are used for controlling a message's priority during the arbitration process. A value of zero has the highest priority. Higher priority values are typically given to high-speed control messages.

The next bit of the identifier is reserved for the future use and should be set to zero for transmitted message.

The next bit of the identifier is the data page selector.

The PDU format determines whether the message can be transmitted with a destination address or if the message is always transmitted as a broadcast message.

The interpretation of the PDU specific field changes based on the PF value:

- If the PF is between 0 and 239, the message is addressable, and the PS field contains a destination address
- If the PF is between 240 and 255, the message can only be broadcast. The PS field contains a Group Extension.

The term Parameter Group Number (PGN) is used to refer to the value of the Reserve bit, DP, PF, and PS fields combined into a single 18-bit value.

The last 8 bits of the identifier contain the address of the device transmitting the message.

5.1.1 ECU's Address

Each device on the network will be associated with one address. The device address defines a specific communications source or destination for messages. The default CAN address for the MTLT335 is 0x80 (128).

The allowed range of unit addresses on the CAN bus is from 128 to 247.

Address 255 is reserved as a global address for broadcast and address 254 is reserved as the “null address” used by devices that have not yet claimed an address or failed to claim an address.

It's possible to assign arbitrary unit address from serial interface as well as from CAN bus.

5.1.2 Address Claim

In general, most ECU addresses on the CAN bus are pre-assigned and used immediately upon power up. In order to permit J1939 to accommodate future devices and functions, a procedure has been specified for dynamically assigning addresses. This procedure is defined according to J1939. Each device must announce its own address.

In the case of the MTLT335, the device will announce its address once upon initialization and retain it unless/until another unit with the same address challenges it. The format of the Address Claim message is defined by J1939, and described below:

Table 5. MTLT335D Address Claim Message

Priority	PGN	PF	PS	SA	Payload
6	60928	238	DA	128*	8 bytes

* By default, the MTLT335 will claim the address 128 (0x80), and this address can be re-programmed using the “Unit Behavior” command.

The Address Claim message payload contains 8 bytes as described in the Table below. This payload can be considered as 64-bit unsigned integer representing the ECU Name. In case of a conflict, the device which has the smaller value of this integer wins the conflict, and the device which lost the competition will switch to the next higher available address and repeat the address claim process.

The MTLT335 will also send out address claim message if another node on the network explicitly requests it.

Table 6. MTLT335 Address Claim Payload

Bits	Contents	Value
63	Arbitrary Address	1
62:60	Industry Group	0
59:56	Vehicle System Instance	0
55:49	System Bits	0

Bits	Contents	Value
48	Reserved	0
47:40	Function Bits	145
39:35	Function Instance	Variable. Refer to Appendix B
34:32	ECU Bits	0
31:21	Manufacturer code	823
20:0	ID bits	Unit SN – least significant bits

The MTLT335 firmware supports dynamic address conflict resolution. If the device address is already used by another ECU on the same network, the device will attempt to claim another address. The device transmits the address claim message once on startup, and thereafter only in case of an address conflict.

Refer to Appendix B for information about using the function instance bits to detect a unit's location on the wiring harness. This can be useful in systems with more than one IMU on the CAN bus.

5.1.3 Baud Rate

5.1.3.1 Manual Baud Rate Configuration

The J1939 network is intended to be a single, linear, shielded twisted pair of wires running around the vehicle to each ECU. The default data rate of J1939 is 250Kbps. A typical message containing 8 bytes is 128 bits long, which in time is approximately 500 microseconds. MTLT335 also supports lower speed, 125Kbps and higher speeds, 500Kbps and 1000Kbps.

The baud rate of MTLT is configurable through the RS232 interface using NAV-VIEW.

5.1.3.2 Auto Baud Detection

Auto baud detection supports 250kb/s, 500kb/s and 1000kb/s. The MTLT335 is configured at the factory for a baud rate of 250kbps. This value is stored in non-volatile memory. When power is applied (or any time the power is cycled), the unit will select a starting baud rate, which will be the last baud rate stored in non-volatile memory and will put itself into Silent Baud Discovery Mode.

In this mode, the unit will listen silently, without transmitting or asserting the Acknowledge bit, and uses an automated error counter mechanism incorporated into its CAN peripheral controller. It checks the error counter at 10ms intervals. At each 10ms interval, the unit checks both the error counter, and the CAN FIFO buffer for a valid 29-bit message identifier. One of three cases can occur:

1. If there is a valid 29-bit message identifier, and the error counter is at zero, the unit will lock to the current baud rate.
2. If the error counter crosses a programmable threshold (default = 20 counts), or if the error counter increases for three sequential 10ms periods, then the unit will switch to the next supported baud rate, clear the message FIFO buffer, and continue monitoring at this new baud rate.

- Otherwise, the unit will continue monitoring at 10ms intervals, at the current baud rate, until case 1 or case 2 occurs.

❖ NOTE

An 11-bit standard frame message will not be considered valid while the unit is in Silent Baud Discovery Mode.

The list of supported baud rates is 250kbps, 500kbps, and 1Mbps, and the MTLT335 will cycle indefinitely in that order, beginning with the last value stored in non-volatile memory, until the baud rate is successfully detected.

In normal operation (after Baud Discovery Mode has ended), the unit will maintain a counter which keeps a running count of CAN errors. Each time it detects an RX error, it increments the error counter by +1. Each time it detects a TX error, it increments the error counter by +8; each time it successfully transmits or receives an error free message, it decrements the error counter by 1. If the error counter reaches 255, the unit will go to the “bus off” state and enter silent Baud Discovery Mode (as described above).

5.1.4 Get Commands

Get commands are used for another ECUs on the network to collect the corresponding message from MTLT335. All of the commands are formed by a Request message of SAEJ1939-21 PGN number 60159. The format of the request message payload provided in Table 7.

Table 7. The format of request message payload

Byte 0	Byte 1	Byte 2
Requested PGN (LSB)	Requested PGN	Requested PGN (MSB)

❖ NOTE

In the previous generation MTLT305, Byte 0 and Byte 2 were reversed. This has been corrected in the MTLT335, but there is a configuration bit available to make it backward compatible with the MTLT305 (See Unit Behavior Settings).

❖ NOTE

Payload of all responses for Get commands are padded to 8 bytes to make messages look uniform on the bus.

5.1.4.1 Software Identification

There are two different possible response to a request for Software ID and ECU ID depending upon the setting of the Bit 5 of the first byte of the Unit Behavior. See Section 5.1.5.7, Table 50. Bit 5 of the first byte of the Unit Behavior setting changes both the ECU ID and the SW ID responses. With default setting (not enabled) the unit will respond to firmware version request PGN 65242 by sending back a set of transport protocol packets containing ASCII presentation of

unit application and bootloader versions. Control sequence for retrieval of firmware version is found in Appendix E.

When bit 5 in first byte of unit behavior word is set, the Short Software ID response is returned. The Short Software ID response payload is shown in Table 8.

Table 8. Format of the Short Software ID Response

Byte	Description	Value	Comment
0	SW Version MAJOR (MSB)	0x30	(0) In ASCII form
1	SW Version MAJOR (LSB)	0x36	(6) In ASCII form
2		0x2E	(.) Dot
3	SW Version MINOR (MSB)	0x30	(0) In ASCII form
4	SW Version MINOR (LSB)	0x36	(6) In ASCII form
5		0x2E	(.) Dot
6	SW Version BUILD (MSB)	0x30	(0) In ASCII form
7	SW Version BUILD (LSB)	0x30	(0) In ASCII form

Note: Values in table above provided for FW version 06.06.00

5.1.4.2 Rate of periodic data packets

Upon receiving a request for parameter with PGN 65365 (current rate value of periodic packets) from another ECU on the network, MTLT335 responds with a packet, containing a 2-byte payload. Table 9 shows the format of the response.

Table 9. The format of packet rate divider response packet

Priority	PGN	PF	PS	SA	Payload
6	65365	255	85		2 bytes

The payload consists of the address of requesting unit and current rate value of periodic packets in MTLT335. See Table 10.

Table 10. Packet rate response payload

Byte 0	Byte 1
Destination Address	Packet rate (see Table 41)

5.1.4.3 Periodic Data Packets Control Settings

Upon receiving request for parameter with PGN 65366 (periodic data packets control) from another ECU on the network MTLT335 responds with a packet, containing 4-byte payload. Table 11 shows the format of the response.

Table 11. The format of data packet types response packet

Priority	PGN	PF	PS	SA	Payload
6	65366	255	86		4 bytes

The response payload consists of address of requesting unit and bitmasks which represents currently enabled periodic packet types and priorities of these packets See Table 12.

Table 12. Packet types response payload

Byte 0	Byte 1	Byte 2	Byte 3
Destination Address	Packet types (LSB) (see Table 43)	Packet types (MSB) (see Table 43)	Priorities for ACCS/ARI/SSI messages (see Table 44)

It is also possible to request a specific data packet from MTLT335. The request payload should contain PGN of the specific data packet (see 5.1.6)

5.1.4.4 Digital Filters

Upon receiving a request for parameter with PGN 65367 (digital filter settings) from another ECU on the network, MTLT335 responds with a packet, containing a 5-byte payload. Table 13 and Table 14 shows the format of the response.

Table 13. The format of digital filters response packet

Priority	PGN	PF	PS	SA	Payload
6	65367	255	87		5 bytes

The response payload consists of address of requesting unit and currently active filters for accelerometers and rate sensors data. See Table 14.

Table 14. Active digital filters response payload

Byte	Description	Default Setting (Hz)
0	Destination Address (Address of unit responding)	
1	EKF - Rate filter cutoff frequency	25
2	EKF – Acceleration cutoff frequency	5
3	Output data – Rate filter cutoff frequency	25
4	Output data – Acceleration filter cutoff frequency	25

5.1.4.5 Axis Orientation

Upon receiving a request for parameter with PGN 65368 (Axis orientation settings) from another ECU on the network, MTLT335 responds with a packet, containing a 3-byte payload. Table 15 shows the format of the response.

Table 15. The format of unit orientation response packet

Priority	PGN	PF	PS	SA	Payload
6	65368	255	88		3 bytes

The response payload consists of address of requesting unit and current unit orientation settings. See Table 16.

Table 16. Unit orientation response payload

Byte 0	Byte 1	Byte 2
Destination Address	Orientation (MSB) See Section 5.1.5.6	Orientation (LSB) See Section 5.1.5.6

See section 5.1.5.6 for values and settings.

5.1.4.6 ECU's ID

There are two different possible response to a request for ECU ID and Software ID depending upon the setting of the bit 5 of the first byte of the Unit Behavior. See Section 5.1.5.7, Table 51. The Unit Behavior setting changes both the ECU ID and the SW ID responses. With default setting (not enabled) unit will respond to ECU ID request PGN 64965 by sending back a set of transport protocol (TP) packets containing ASCII presentation of unit part number and serial number. Protocol for retrieval of ECU ID is provided in Appendix D.

When bit 5 of first byte of unit behavior word is set, the Short ECU ID response is provided. Short ECU ID response payload is shown in Table 17.

Table 17. Format of the Short ECU ID response

Byte	Description	Value	Comment
3:0	Full unit Serial number	Serial number	In little Endian format (byte 0 – LSB, byte 3 - MSB)
4	MFG Code (LSB)	7	
5	MFG Code (MID)	3	
6	MFG Code (MSB)	3	
7	RESERVED	0	

5.1.4.7 Master BIT status word

Upon receiving a request for parameter with PGN 65364 (master BIT status request) from another ECU on the network, the MTLT335 responds with a packet with a 4-bytes payload. Table 18 shows the format of the Master BIT response packet.

Table 18. The format of Master Bit response packet

Priority	PGN	PF	PS	SA	Payload
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6	65364	255	84		4 Bytes
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Table 19 shows the content and definition of the bits in the Master BIT status response payload.

Table 19. Master BIT response payload

Bit	Description	Value	Solution
0	MasterFail	0 = normal; 1 = fatal error has occurred.	Check Master BIT payload bits 1-15 for information on failure type.
1	HW Error	0 = normal; 1 = any of the Failure bit in Hardware BIT status are set (see Table 23) OR Over temperature bits persists for more than 5 minutes.	Reset or power cycle can be tried to recover unit. If not recovered after power cycle the unit should be replaced.
2	SW Error	0 = normal; 1 = any of the Error bit in Software BIT is set (see Table 21).	Reset or power cycle can be tried to recover unit. If not recovered after power cycle the unit should be replaced.
3	Configuration Error	0 = normal; 1 = incorrect configuration parameters detected during initialization or periodic self-test.	Unit needs to be reset by command or power cycled. If state persists after power cycle – unit considered to be damaged and needs to be replaced.
4	Calibration Error	0 = normal; 1 = calibration data for all three sensor chips are corrupted (see Table 23)	Unit needs to be reset by command or power cycled. If state persists after power cycle – unit considered to be damaged and needs to be replaced.
5	Accelerometer Quality Degradation	0 = normal; 1 = accel sensor disagreement bit is set (see Table 21), OR Data Processing delay exceeds 5ms for more than 10 consecutive cycles, OR only one active sensor remaining OR Over Range OR Disagreement bit is set in SW BIT Status	Unit may still work normally. To recover from this condition unit needs to be reset by command or power cycled.
6	Rate Sensor Quality Degradation	0 = normal; 1 = rate sensor disagreement bit is set (see Table 21), OR Data Processing delay exceeds 5ms for more than 10 consecutive cycles, OR only one active sensor remaining OR Over Range OR Disagreement bit is set in SW BIT Status	Unit may still work normally. To recover from this condition unit needs to be reset by command or power cycled.
7	Forced Restart	0 = normal; 1 = forced restart (restart caused by watchdog, brownout or transmit queue congestions)	Check SW BIT[22:24] for cause of restart

Bit	Description	Value	Solution
8	Application CRC Error	0 = normal; 1 = Application CRC error detected	Will be sent from Bootloader periodically with interval of 1 second
9	Tx Overflow Error	0 = normal; 1 = Tx Overflow occurred 10 consecutive cycles	This bit resets when overflow condition is cleared OR the unit will restart automatically when this error persists for more than 20 seconds.
10	Reserved	Reserved (FCF)	
11	Reserved	Reserved (TST 50)	
12:15	Reserved	Reserved	
16:31	Application CRC	Contains application CRC value for reference	

NOTE

Master BIT status word will be also periodically broadcasted on the CAN bus in case if unit triggered fatal internal error (right upon occurrence and every second after that). Bus master then can send request for additional status information.

5.1.4.8 Software BIT status

Upon receiving a request for parameter with PGN 65363 (Software BIT status request) from another ECU on the network, the MTLT335 will respond with a packet with 4-bytes payload. Table 20 shows the format of the Software BIT status response packet.

Table 20. The format of Software BIT status response

Priority	PGN	PF	PS	SA	Payload
6	65363	255	83		4 Bytes

NOTE

The PS value for this command can be changed using the command “Bank of PS numbers” PS Bank 0.

Table 21 shows the content and definition of the packet.

Table 21. Software BIT status payload fields

Bit	Description	Value	Solution
0	Stack Overflow Error	0=normal; 1= stack is 95% full	
1	Algorithm Error	0=normal, 1=error (initialization took more than 5 seconds).	

Bit	Description	Value	Solution
2	Initialization Status	0=normal; 1= Algorithm is in the initialization stage and unit is not ready. Bit will be cleared after initialization is complete (~2s).	
3	Reserved		
4:6	Accelerometer Over Range Status	0=normal; 1= Indicates an over range event, (acceleration exceeds 7.95g). It is cleared when condition is removed. This condition will set SW Error flag in Master BIT status if Sensor Over Range persists more than 20 ms.	Algorithm can be reset using command which can be sent over CAN bus (PGN 65360) or by power cycling unit. If condition persists when system is not moving, after power cycle, the unit is considered faulty and should be replaced.
7:9	Rate Sensor Over Range Status	0=normal; 1= Indicates an over range event, (rotation exceeding 410 dps). It is cleared when condition is removed. EKF will converge to correct solution or Algorithm can be reset. The SW will set SW Error flag in Master BIT status if Sensor Over Range persists more than 20 mS.	Algorithm can be reset using command which can be sent over CAN bus (PGN 65360) or by power cycling unit. If condition persists when system is not moving, after power cycle, the unit is considered faulty and should be replaced.
10	Configuration Error	0=normal, 1=incorrect configuration parameters detected during initialization or periodic self-test.	Unit needs to be reset or power cycled. If state persists after power cycle – unit considered to be faulty and needs to be replaced.
11	Calibration Data Status - Chip 0	0=normal, 1= non-recoverable error of unit calibration data for sensor chip 0 (bad CRC) detected during initialization or periodic self-test. In this case unit will automatically exclude affected sensor from the solution	Unit needs to be reset or power cycled. If state persists after power cycle, and degradation of unit performance is also detected – unit considered to be damaged and needs to be replaced.
12	Calibration Data Status - Chip 1	0=normal, 1= non-recoverable error of unit calibration data for sensor chip 1 (bad CRC) detected during initialization or periodic self-test. In this case unit will automatically exclude affected sensor from the solution	Unit needs to be reset or power cycled. If state persists after power cycle, and degradation of unit performance is also detected – unit considered to be damaged and needs to be replaced.

Bit	Description	Value	Solution
13	Calibration Data Status - Chip 2	0=normal, 1= non-recoverable error of unit calibration data for sensor chip 2 (bad CRC) detected during initialization or periodic self-test. In this case unit will automatically exclude affected sensor from the solution	Unit needs to be reset or power cycled. If state persists after power cycle, and degradation of unit performance is also detected - unit considered to be damaged and needs to be replaced.
14	Accelerometer Sensor 0 Status	0= normal; 1 = accelerometer sensor 0 is voted out due to detected HW or SW fault.	Unit may still work normally until degradation of performance detected. To recover from this condition unit needs to be reset or power cycled.
15	Accelerometer Sensor 1 Status	0= normal; 1 = accelerometer sensor 1 is voted out due to detected HW or SW fault.	Unit may still work normally until degradation of performance detected. To recover from this condition unit needs to be reset or power cycled.
16	Accelerometer Sensor 2 Status	0= normal; 1 = accelerometer sensor 2 is voted out due to detected HW or SW fault	Unit may still work normally until degradation of performance detected. To recover from this condition unit needs to be reset or power cycled.
17	Rate Sensor 0 Status	0= normal; 1 = rate sensor 0 is voted out due to detected HW or SW fault	Unit may still work normally until degradation of performance detected. To recover from this condition unit needs to be reset or power cycled.
18	Rate Sensor 1 Status	0= normal; 1 = rate sensor 1 is voted out due to detected HW or SW fault	Unit may still work normally until degradation of performance detected. To recover from this condition unit needs to be reset or power cycled.
19	Rate Sensor 2 Status	0= normal; 1 = rate sensor 2 is voted out due to detected HW or SW fault	Unit may still work normally until degradation of performance detected. To recover from this condition unit needs to be reset or power cycled.
20	Accel Sensor Disagreement Error	0= normal; 1 = one of the accelerometer sensors was removed from solution due to detected HW or SW fault AND remaining two accelerometer sensors have disagreement.	The fault detection state is reset by power cycling, and the error state may be cleared if the fault was caused by a temporary environmental condition. If condition persists after power cycling, unit is faulty.

Bit	Description	Value	Solution
21	Rate Sensor Disagreement Error	0= normal; 1 = one of the rate sensors is voted out due to detected HW or SW fault AND remaining two accelerometer sensors have disagreement.	The fault detection state is reset by power cycling, and the error state may be cleared if the fault was caused by a temporary environmental condition. If condition persists after power cycling, unit is faulty.
22:24	Last Reset Status	000 = Power-On reset 001 = Software (self-reset) 010 = Reserved 011 = Undefined low supply glitch 100 = Watchdog reset 101 = Brown-out reset 110 = Transmit queue congestion Reset bit in Master BIT status will be set when cause of last reset is Watchdog or Brown-out reset	
25	Data Processing Over Run Status	0 = no overrun 1 = Data Processing Delay exceeded 5ms. SW Error bit and Accel/Rate Sensor Quality Degradation bits will be set in Master BIT status when Over Run persist for more than 10 data processing cycles.	
26	Turn Switch Status	0=off, 1=yaw rate greater than Turn Switch threshold	
27	Algorithm Mode Status	0 = low gain mode, 1 = high gain mode	
28	Transmit queue overflow Error	0=normal, 1 = Unit transmit queue overflow occurred due do the errors or CAN bus congestion. If this condition persists more than 10 cycles, Tx Overflow Error bit is set in Master BIT Status.	This bit resets when overflow condition is cleared

5.1.4.9 HW BIT status

Upon receiving a request for parameter with PGN 65362 (HW BIT status request) from another ECU on the network, the MTLT335 responds with a packet with 2-bytes status message.

Table 22 shows the format of unit HW status response message.

Table 23 shows the contents and definition of unit status response payload.

Table 22. The format of HW BIT status message

Priority	PGN	PF	PS	SA	Payload
6	65362	255	82		2 bytes

NOTE

The PS value for this command can be changed using the “Bank 0” command.

Table 23. Hardware BIT status payload fields

Bit	Description	Value	Solution
0	Power consumption Error	0 = normal 1 = unit consumes excessive amount of power for more than 1 minute.	Check power supply
1	External power supply Error	0 = normal 1 = external power supply voltage is not within specified thresholds for more than 1 minute.	Check power supply
2	Internal power supply Error	0 = normal 1 = Overvoltage or under voltage on internal power supply for more than 1 minute.	Check power supply
3	Over Temperature Environment	0 = normal 1 = MCU temperature exceeds allowed limit Set HW Error in Master BIT Status when temp is 5 deg. over the max temp limit or 5 deg. below min temp limit, for more than 5 minutes.	Cool down the unit
4	Over Temperature Chip 0	0 = normal 1 = Chip 0 temperature exceeds allowed limit. Set HW Error in Master BIT Status when temp is 5 deg. over the max temp limit or 5 deg. below min temp limit, for more than 5 minutes., on all three sensors.	

Bit	Description	Value	Solution
5	Over Temperature Chip 1	0 = normal 1 = Chip 1 temperature exceeds allowed limit. Set HW Error in Master BIT Status when temp is 5 deg. over the max temp limit or 5 deg. below min temp limit, for more than 5 minutes., on all three sensors.	
6	Over Temperature Chip 2	0 = normal 1 = Chip 2 temperature exceeds allowed limit. Set HW Error in Master BIT Status when temp is 5 deg. over the max temp limit or 5 deg. below min temp limit, for more than 5 minutes, on all three sensors.	
7	Sensor Communication Status Chip 0	0 = normal, 1 = communication with sensor chip 0 failed on startup or during runtime self-test. Causes exclusion of the sensor chip from the solution.	Unit needs to be reset by command or power cycled. If state persists after power cycle – unit considered to be damaged and needs to be replaced.
8	Sensor Communication Status Chip 1	0 = normal 1 = communication with sensor chip 1 failed on startup or during runtime self-test. Causes exclusion of the sensor chip from the solution.	Unit needs to be reset by command or power cycled. If state persists after power cycle – unit considered to be damaged and needs to be replaced.
9	Sensor Communication Status Chip 2	0 = normal 1 = communication with sensor chips 2 failed on startup or during runtime self-test. Causes exclusion of the sensor chip from the solution.	Unit needs to be reset by command or power cycled. If state persists after power cycle, unit considered to be damaged and needs to be replaced.
10 : 15	Reserved	Reserved	

5.1.4.10 Unit behavior

Upon receiving a request for parameter with PGN 65369 (current unit behavior configuration) from another ECU on the network, the MTLT335 responds with a packet, containing 2-byte payload. **Table 24** shows the format of the response.

Table 24. The format of unit behavior response packet

Priority	PGN	PF	PS	SA	Payload
6	65369	255	89		2 bytes

NOTE

The PS value for this command can be changed using the “Bank 1” command in case of PGN conflict.

The response payload consists of the address of requesting unit (Byte 0) and the current unit behavior bitmask. When value of specific bit equal to 1 it means that corresponding option is enabled. See **Table 25**.

Table 25. The format of the unit behavior response payload

Byte	Bit	Description	FW Default	As shipped
0	7:0	Destination Address (address of responding unit)	0x80	0x80
1	0	Enable Suppress DM1 Message when there is no fault	1	0
	1	Reserved (DM)	1	1
	2	Use raw rates (not bias corrected by EKF) in ARI message	0	1
	3	Change sequence of ARI and ACCS messages from X, Y, Z (like MTLT305) to Y, X, Z (J1939) in all ARI and ACCS messages	1	1
	4	Enable Auto Baud detection mode	1	1
	5	Enable short format for ECU ID and SW Version responses	0	0
	6	Use North West Up (NWU) acceleration Frame (0 = NED)	1	1
	7	Use unfiltered acceleration as input to Linear Acceleration detection in Extended Kalman Filter	1	1
2	0	Use raw rates (not bias corrected by EKF) to predict acceleration in the Extended Kalman Filter	0	0
	1	Swap byte - Swap Byte 2 and Byte 0 in a GET Message Request payload for backward compatibility with MTLT305, see Section 5.1.4	0	0
	2	Mode of operation. 00 = general purpose; 01 = Excavator mode (default = 01, Excavator mode)	1	1
	3		0	0
	4	Reserved (EFC)	0	0
	5	Enable Averaging at ODR	1	1
	6	Enable E2E protection for data messages	0	0
	7	Enable VG algorithm (Attitude estimation)	1	1

5.1.4.11 In System Alignment

The MTLT335D responds to a J1939 request PGN 65378 (In-System alignment control) packet with a message containing an 8-byte payload. Table 26 shows the format of this In-System Alignment Control response.

Table 27 shows the format of in-system alignment control response.

Table 26. The format of in-system alignment control response

Priority	PGN	PF	PS	SA	Payload
6	65378	255	92		8 bytes

Table 27. In-system alignment control command payload

Byte	Description	Value	Address of destination
0	Destination address	DA	Address of destination device.
1	Order of adjustment	0 - NONE 1 - XYZ 2 - YZX 3 - ZXY 4 - XZY 5 - ZYX 6 - YXZ 7 - ZXZ 8 - XYX 9 - YZY 10 - ZYZ 11 - XZX 12 - YXY 13 - 15 N/A	
2	Euler angle of first axis of rotation	LSB	-64 to 64.51 degrees. 0.002 deg/bit Offset = -64 degrees
3	Euler angle of first axis of rotation	MSB	
4	Euler angle of second axis of rotation	LSB	-64 to 64.51 degrees. 0.002 deg/bit Offset = -64 degrees
5	Euler angle of second axis of rotation	MSB	
6	Euler angle of third axis of rotation	LSB	-64 to 64.51 degrees. 0.002 deg/bit Offset = -64 degrees
7	Euler angle of third axis of rotation	MSB	

NOTE

The MTLT335D has an advanced feature for calculating and correcting for device pitch and yaw mounting error of boom, arm and bucket mounted devices in excavator applications or other applications where rotation is in the plane parallel to gravity and the x axis is orthogonal to the plane. It requires the user to issue an Auto In-System Alignment (Auto ISA) CAN command and then move the boom up and down at greater than 5 degrees per second for greater than 1 second in each direction. The unit will then calculate the misalignment to the plane of rotation. Details of the Auto-ISA function can be found in ACEINNA application note [AN MTLT335D Automatic In-system Alignment Function](#). Please contact ACEINNA for a copy of this application note.

5.1.4.12 Algorithm Control

The MTLT335D responds to a J1939 request PGN 65371 (Algorithm control) packet with a message containing an 8-byte payload. Table 28 shows the format of this Algorithm Control response.

Table 28. The format of the algorithm control response packet

Priority	PGN	PF	PS	SA	Payload
6	65371	255	91		8 bytes

Table 29. The format of the Algorithm control response payload

Byte	Description	Value	Comment
0	Address of Unit	Destination Address	
1	Turn Switch Threshold		Value in deg/s From 1 to 255 Default = 6 dps (No effect in excavator mode)
2	Reserved		
3	Reserved		
4	Limit for accelerometer switch delay	LSB	Value in milliseconds From 10 to 10000 Default = 2000 mS Not used in Excavator Mode
5	Limit for accelerometer switch delay	MSB	
6	Coefficient of reduced Q	LSB	Scale 0.0001 per lsb From 0.0001 to 1
7	Coefficient of reduced Q	MSB	

5.1.4.13 Wheel Speed or Acceleration Aiding Signal Configuration

The MTLT335D responds to a J1939 request PGN 65375 (Wheel Speed or acceleration Aiding Signal Configuration) packet with a message containing an 8-byte payload. Table 30 shows the format of this Aiding Signal Configuration response.

Table 30. The format of the Aiding Signal Configuration response packet

Priority	PGN	PF	PS	SA	Payload
6	65375	255	95		8 bytes

Table 31. The format of the Aiding Signal Configuration response payload

Byte	Description	Comment
0	Address of Unit	
1	Signal Source	Configured Aiding Signal Source. 0 = No aiding signal used 1 = using Odometer 2 = using vehicle accelerations signal.
2	PF value of Aiding Message	Configured Odometer or Vehicle Accelerations data message PF value
3	PS value of Aiding Message	Configured Odometer or Vehicle Accelerations data message PS value
4	Message Rate	Configured Aiding Message rate (in Hz)
5	Driving Direction Data Message PF value	Configured Driving Direction message PF Value
6	Driving Direction Data Message PS value	Configured Driving Direction message PS Value
7	Orientation Switches	Bit 0: IMU Mount Location: 0 = IMU does not experience rotation relative to chassis, such as mounted to a truck's chassis 1 = IMU can experience rotation relative to tracks, such as mounted to body of excavator Bit 1: Reserved (set to "0") Bit 2: Aiding Signal Acceleration Direction 0 = +X Axis acceleration point to vehicle forward. 1 = -X Axis acceleration point to vehicle forward.

5.1.4.14 Aiding Signal Lever Arm Configuration

Refer to section 5.1.5.11 for a more complete description of the Lever Arm. The MTLT335D responds to a J1939 request PGN 65376 (Aiding Signal Lever Arm Configuration) packet with a message containing a 7-byte payload. Table 32 shows the format of this Aiding Signal Configuration response.

Table 32. The format of the Aiding Signal Lever Arm Configuration response packet

Priority	PGN	PF	PS	SA	Payload
6	65376	255	96		7 bytes

Table 33. The format of the Aiding Signal Configuration response payload

Byte	Description	Value	Definition	Comment
0	Address of Unit		Destination Address	NA
1	LeverArmX	LSB	Reads back the current LeverArm value in units of mm, in offset binary format (see section 5.1.5.11)	Millimeter Range = [-32000, 32000] Offset value = -32000
2		MSB		
3	LeverArmY	LSB		
4		MSB		
5	LeverArmZ	LSB		
6		MSB		

As an example, for given byte values of “MSB” and “LSB”, the Actual Lever Arm (in units of mm) is $MSB * 256 + LSB - 32,000$.

5.1.4.15 DM1 Message Configuration

The MTLT335D responds to a J1939 request PGN 65370 (DM1 message configuration) packet with a message containing 8-byte payload. Table 34 shows the format of the response.

Table 34. DM1 Configuration response message format

Priority	PGN	PF	PS	SA	Payload
6	65370	255	90		8 bytes

Table 35. Response Payload Content

Byte	Bits	Parameter name	Default Values
0	DA	Destination address	
1	2-1	Protect Lamp Status	00
	4-3	Amber Warning Lamp Status	01
	6-5	Red Stop Lamp Status	00
	8-7	Malfunction Indicator Lamp Status	00
2	2-1	Flash Protect Lamp	11
	4-3	Flash Amber Warning Lamp	11
	6-5	Flash Red Stop Lamp	11
	8-7	Flash Malfunction Indicator Lamp	11
3	8-1	SPN, 8 least significant bits of SPN	0xB3
4	8-1	SPN, second byte of SPN (most significant at bit 8)	0xF4
5	3-1	SPN, 3 most significant bits (most significant at bit 8)	0x07
6		FMI for DTC1	0x0C

Byte	Bits	Parameter name	Default Values
7		FMI for DTC2	0x0E

5.1.5 Set Commands

Set commands are used for other ECUs to configure the MTLT335 on the network. All the commands are broadcast messages with a destination address. The receivers will decode the payload and decide to ignore the message meant for another ECU.

5.1.5.1 Configuration Save

The command is issued by an ECU on the network to the destination unit who is requested to save the current configuration in RAM to EEPROM. The receiver will send a response back and notify the sender that the save command has been executed successfully or not. If Request field equals 2 unit will reset itself after sending back the response. It is recommended to normally set the Request field = 2.

Table 36 shows the format of the save configuration command. **Table 37** is the description of save configuration command and response payload.

Table 36. The Format of Save Configuration

Priority	PGN	PF	PS	SA	Payload
6	65361	255	81		3 bytes

Table 37. Save Configuration Command / Response Payload

Byte	Description	Value
0	Save Mode	0 = No reset after Save 2 = Reset after save 1 = Response message
1	Address of target or responding unit	Address of target or responding unit
2	Success or failure indicator	0 = failure, 1 = success

5.1.5.2 Algorithm Reset

The algorithm reset command is issued by an ECU on the network to the destination unit which is requested to its reset algorithm. The receiver will send a response back and notify the sender that the re-initialization of algorithm has been executed successfully or not. If Request field equals 2 unit will reset itself after sending back the response. Table 38 shows the format of the algorithm reset command.

Table 38. The format of algorithm reset command

Priority	PGN	PF	PS	SA	Payload
6	65360	255	80		3 bytes

The description of the algorithm reset data field is shown in Table 39.

Table 39. Algorithm Reset Command / Response Payload

Byte	Description	Value
0	Reset Mode	0 = Reset Algorithm Only 2 = Complete Device Reset 1 = Response message
1	Address of target or responding unit	Address of target or responding unit
2	Success or failure indicator	0 = failure, 1 = success

5.1.5.3 Packet Rate Divider

The MTLT335 broadcasts several types of data packet, as defined in Table 43. The default ODR of data packets is 100Hz. The Packet rate divider command is used to change the ODR setting. The 1st byte of the payload is the destination address, and the 2nd byte of the payload sets the new ODR. Table 40 shows the format of packet rate divider command. The values of packet rate divider are defined in Table 41.

Table 40. The format of packet rate divider command

Priority	PGN	PF	PS	SA	Payload
6	65365	255	85		2 bytes

Table 41. Packet Rate Divider Field Definition

Byte Value	Packet broadcasting rate
0	Quiet mode
1	100Hz (default)
2	50Hz
4	25Hz
5	20Hz
10	10Hz
20	5Hz
25	4Hz
50	2Hz

5.1.5.4 Data Packets Control settings

User can configure the combination of output packets and priority of those output packets. MTLT335's data packet type and default priorities of these data packets follows SAEJ1939-DA Table SPNs & PGN.

Users can choose any combination of output packets from the following data packets - slope sensor information 2 (PGN 61481), angular rate information (PGN 61482) acceleration sensors (PGN 61485), high resolution acceleration sensors (PGN 65389), high resolution rate sensors (PGN 65387), slope sensor information (PGN 61459).

The 1st byte of the payload is the destination address. 2nd byte of the payload describes the packet type to be set. 3rd payload byte is reserved, any value written to the payload byte 3 will be ignored. 4th byte of the payload contains bitmask of priorities which can be assigned to specific packet type. 5th byte contains bitmask which enables change of the priority of specific packet. Table 42 shows the format of data packet type command.

Table 42. The format of Data Packet Type command

Priority	PGN	PF	PS	SA	Payload
6	65366	255	86		5 bytes

The 2nd byte is a bitmask and used to select which data messages are to be transmitted. To select specific message type set specific bit to 1. Any combination of messages can be selected for transmission. See Table 43.

Table 43. Data Packet Type Field Definition (2nd byte)

Bit Number	Selected Data Packet Type
0	SSI2
1	Angular Rate
2	Acceleration
3	HR Angular Rate
4	HR Acceleration
5	SSI

The 4th byte is a bitmask and used to select priority of specific message types.

The 5th byte is a bitmask and used to enable change of priority of specific message types. Priority can be changed for any or all messages at the same time.

Table 44. Priority of Data Packets (4th byte)

Bit Number	Bit fields assignment
1:0	Angular Rate & HR Angular Rate Packets Priority (0 - 3) ¹
3:2	Acceleration & HR Acceleration Packets Priority (0 - 3) ¹
5:4	SSI & SSI2 Packets Priority (0 - 3) ¹
7:6	Reserved

Table 45. Priority Change enable mask (5th byte)

Bit Number	Bit fields assignment
1:0	Enable of changing Angular Rate & HR Angular Rate Packets Priority (11 – enable, other – disable)
3:2	Enable of changing Acceleration & HR Acceleration Packets Priority (11 – enable, other – disable)
5:4	Enable of changing SSI & SSI2 Packets Priority (11 – enable, other – disable)
7:6	Reserved

5.1.5.5 Digital Filter

The MTLT335 contains two sets of configurable 3rd order low pass filters. The first set of acceleration and rate filters is for data presented to the EKF for attitude estimations and on RS232 bus. The other completely independent set is applied to the data to be output on the CAN and RS232 bus. The supported frequencies settings are: 5, 10, 20, 25, 40, and 50 Hz and off. The frequencies are changed by the command issued by another ECU on the network. Setting a value of 0 turns the filter off. Turning the filters off is not recommended.

Table 46 and **Table 47** show the format of digital filter setting command.

Valid values for bytes 1 – 4 are: 5, 10, 20, 25, 40, 50 and 0 (off).

Table 46. The format of digital filter change command

Priority	PGN	PF	PS	SA	Payload
6	65367	255	87		5 bytes

Table 47. Active digital filters Command payload

Byte	Description	Default Setting (Hz)
0	Destination Address	
1	EKF - Rate filter cutoff frequency	25
2	EKF – Acceleration cutoff frequency	5

¹ Priority of both the data packets will be changed when these bits are configured

Byte	Description	Default Setting (Hz)
3	Output data – Rate filter cutoff frequency	25
4	Output data – Acceleration filter cutoff frequency	25

If configuration is lost or corrupted, firmware will use default filter settings.

5.1.5.6 Orientation

Users may change the coordinate system of MTLT335 via the command issued by another ECU on the network. The default factory axis setting for the MTLT335 orientation field is logical positive axes (X, Y, Z) = physical device axes (+Ux, +Uy, +Uz) which defines the connector pointing to the opposite of +X direction and +Z direction going out the bottom of the unit.

The 1st byte of payload is the destination address and the next 2 bytes (MSB first) define the orientation to be applied. Table 48. shows the format of unit orientation control command. Table 49 shows the possible orientation settings.

Table 48. The format of the unit orientation command

Priority	PGN	PF	PS	SA	Payload
6	65368	255	88		3 bytes

Table 49. Possible values of the orientation

Orientation Field Value	X Axis	Y Axis	Z Axis
0x0000 (Default)	+Ux	+Uy	+Uz
0x0009	-Ux	-Uy	+Uz
0x0023	-Uy	+Ux	+Uz
0x002A	+Uy	-Ux	+Uz
0x0041	-Ux	+Uy	-Uz
0x0048	+Ux	-Uy	-Uz
0x0062	+Uy	+Ux	-Uz
0x006B	-Uy	-Ux	-Uz
0x0085	-Uz	+Uy	+Ux
0x008C	+Uz	-Uy	+Ux
0x0092	+Uy	+Uz	+Ux
0x009B	-Uy	-Uz	+Ux
0x00C4	+Uz	+Uy	-Ux
0x00CD	-Uz	-Uy	-Ux
0x00D3	-Uy	+Uz	-Ux
0x00DA	+Uy	-Uz	-Ux
0x0111	-Ux	+Uz	+Uy
0x0118	+Ux	-Uz	+Uy
0x0124	+Uz	+Ux	+Uy
0x012D	-Uz	-Ux	+Uy

Orientation Field Value	X Axis	Y Axis	Z Axis
0x0150	+U _x	+U _z	-U _y
0x0159	-U _x	-U _z	-U _y
0x0165	-U _z	+U _x	-U _y
0x016C	+U _z	-U _x	-U _y

5.1.5.7 Unit behavior

The user can choose any combination of MTLT335 behaviors. Table 50 shows the format of unit behavior command.

Table 50. The format of Unit Behavior command

Priority	PGN	PF	PS	SA	Payload
6	65369	255	89		6 bytes

The first payload byte is destination address.

The next 4 payload bytes are used to enable/disable specific unit behavior settings. To enable a specific behavior, the corresponding bit in byte 1 or 2 should be set to 1. To disable a specific behavior, the corresponding bit in byte 3 or 4 should be set to 1. The “disable” bits will override any “enable” bits if sent in the same message. This method allows individual behaviors to be turned on or off, without the need to “remember” the other settings (a zero in any bit location will leave that setting unchanged). Unit behavior settings can be permanently saved using the “Configuration Save” command (PGN 65361). The Unit Behavior payload is described in Table 51.

Table 51. Unit behavior payload

Byte	Bit	Description
0	7:0	Destination Address (address of responding unit)
Enable Behavior Bit Mask (bytes 1 and 2)		
1	0	Enable Suppress DM1 Message when there is no fault
	1	Reserved (DM)
	2	Use raw rates (not bias corrected by EKF) in ARI message
	3	Change sequence of ARI and ACCS messages from X, Y, Z (like MTLT305) to Y, X, Z (J1939) in all ARI and ACCS messages
	4	Enable Auto Baud detection mode
	5	Enable short format for ECU ID and SW Version responses
	6	Use North West Up (NWU) acceleration Frame (0 = NED)
	7	Use unfiltered acceleration as input to Linear Acceleration detection in Extended Kalman Filter
2	0	Use raw rates (not bias corrected by EKF) to predict acceleration in extended Kalman Filter

Byte	Bit	Description
	1	Swap byte - Swap Byte 2 and Byte 0 in a GET Message Request payload for backward compatibility with MTLT305, see Section 5.1.4
	2	Mode of operation. 00 = general purpose; 01 = Excavator mode (default = 01, Excavator mode)
	3	
	4	Reserved (EFC)
	5	Enable Averaging at ODR
	6	Enable E2E protection for data messages
	7	Enable VG algorithm (Attitude estimation)
Disable Behavior Bit Mask (Bytes 3 and 4)		
3	0	Disable Suppress DM1 Message when there is no fault
	1	Reserved (DM)
	2	Disable use raw rates (not bias corrected by EKF) in ARI message
	3	Disable change sequence of ARI and ACCS messages from X, Y, Z (like MTLT305) to Y, X, Z (J1939) in all ARI and ACCS messages
	4	Disable Auto Baud detection mode
	5	Disable short format for ECU ID and SW Version responses
	6	Disable Use North West Up (NWU) acceleration Frame
	7	Disable use unfiltered acceleration as input to Linear Acceleration detection in Extended Kalman Filter
4	0	Disable use raw rates (not bias corrected by EKF) to predict acceleration in extended Kalman Filter
	1	Disable Swap byte - Swap Byte 2 and Byte 0 in a GET Message Request payload for backward compatibility with MTLT305, see Section 5.1.4
	2	Clear Modes of operation bits.
	3	
	4	Reserved (EFC)
	5	Disable Averaging at ODR
	6	Disable E2E protection for data messages
	7	Disable VG algorithm (Attitude estimation)
5	7:0	New Unit address assignment (valid address from 128 to 247). Will become active after save with reset command issued to device.

5.1.5.8 Algorithm Control

The user can adjust certain algorithm parameters which can improve MTLT335D performance. Table 52 shows the format of the algorithm control command.

Table 52 Format of the Algorithm command

Priority	PGN	PF	PS	SA	Payload
6	65371	255	91		8 bytes

Table 53. Algorithm control command payload

Byte	Description	Value	Comment
0	Address of Unit	Destination Address	
1	Turn Switch Threshold		GP mode only Value in deg/s From 1 to 255 Default = 6 dps
2	Reserved	Reserved	
3	Reserved	Reserved	
4	Limit for accelerometer switch delay	LSB	GP Mode only Value in milliseconds From 10 to 10000 Default 2000 mS
5	Limit for accelerometer switch delay	MSB	
6	Coefficient of reduced Q	LSB	Scale 0.0001 per lsb From 0.0001 to 1 (Default 0.001)
7	Coefficient of reduced Q	MSB	

NOTE

Coefficient of reduced Q should not be adjusted without first consulting with ACEINNA

5.1.5.9 In-System Alignment

The user can finely adjust virtual alignment of the unit which was already installed on carrier for up to ± 64 degrees in along each axis.

Table 54 shows the format of in-system alignment control command.

Table 54. The format of in-system alignment control command

Priority	PGN	PF	PS	SA	Payload
6	65378	255	98		8 bytes

Table 55. In-system alignment control command payload

Byte	Description	Value	Comment
0	Address of Unit	Destination Address	Address of destination device.

Byte	Description	Value	Comment
1	Order of adjustment	0 - NONE 1 - XYZ 2 - YZX 3 - ZXY 4 - XZY 5 - ZYX 6 - YXZ 7 - ZXZ 8 - XYX 9 - YZY 10 - ZYZ 11 - XZX 12 - YXY 13 - 15 N/A	
2	Euler angle of first axis of rotation	LSB	-64 to 64.51 degrees. 0.002 deg/bit Offset = -64 degrees
3	Euler angle of first axis of rotation	MSB	
4	Euler angle of second axis of rotation	LSB	-64 to 64.51 degrees. 0.002 deg/bit Offset = -64 degrees
5	Euler angle of second axis of rotation	MSB	
6	Euler angle of third axis of rotation	LSB	-64 to 64.51 degrees. 0.002 deg/bit Offset = -64 degrees
7	Euler angle of third axis of rotation	MSB	

NOTE

Settings programmed by this command are applied only after “Configuration Save” command with Reset, or “Configuration Save” command followed by reset, or power cycle.

NOTE

The MTLT335D has an advanced feature for calculating and correcting for device pitch and yaw mounting error of boom, arm and bucket mounted devices in excavator applications or other applications where rotation is in the plane parallel to gravity and the x axis is orthogonal to the plane. It requires the user to issue an Auto In-System Alignment (Auto ISA) CAN command and then move the boom up and down at greater than 5 degrees per second for greater than 1 second in each direction. The unit will then calculate the misalignment to the plane of rotation. Details of the Auto-ISA function can be found in ACEINNA application note [AN MTLT335D Automatic In-system Alignment Function](#). Please contact ACEINNA for a copy of this application note.

5.1.5.10 Wheel Speed Aiding Signal Configuration

If a wheel speed or acceleration signal is available on the CAN bus, the user can improve MTLT335 algorithm performance by configuring Aiding Signal information. The aiding signal is configured using two different Set Commands, the first of which is shown in the Table below. The algorithm can accept different CAN messages, including PGN65215, PGN65265, and PGN61445. Contact the factory for availability of alternative messages.

This command indicates the type of aiding signal used (if any), along with the PF and PS values of aiding signal, and the message rate of this aiding signal. If the aiding signal is unsigned (e.g. PGN65215 and PGN65265), user also should indicate the PF and PS values of vehicle driving direction signal (e.g. PGN61445), so that unit can recognize the vehicle driving in a forward or reverse direction. If the aiding signal is signed, user does not need to indicate PF and PS values of vehicle driving direction signal. Note that the IMU must be mounted with the physical X axis oriented toward the front of the vehicle, Y axis oriented toward the right, and Z axis oriented down, or if mounted differently, should be configured so that the logical X, Y, and Z axes are configured as above. If vehicle accelerations (signal source is 2) is implemented, the IMU is expecting the acceleration data to be defined in a North-West-Up orientation per the J1939 standard, and the data will be converted internally to the IMU NED frame. Note there is a configuration bit (Bit 2 of Byte 7 in the algorithm control payload) to indicate whether the Vehicle X axis acceleration aiding signal is oriented toward the front or rear of the vehicle.

Table 56. The format of Wheel Speed Aiding Signal Configuration command

Priority	PGN	PF	PS	SA	Payload
6	65375	255	95		8 bytes

Table 57. Wheel speed Aiding Signal command payload

Byte	Description	Comment
0	Address of Unit	
1	Aiding Signal Source	Indicates if the aiding signal is odometer or vehicle accelerations or neither. 0 = No aiding signal used. 1 = Use Odometer or WSS for aiding 2 = Use vehicle accelerations signal for aiding.
2	PF value of Aiding Message	PF Value of the message that has Odometer or Vehicle Accelerations data
3	PS value of Aiding Message	PS Value of the message that has Odometer or Vehicle Accelerations data
4	Message Rate	Message rate (in Hz) of Odometer or Vehicle Accelerations.
5	Driving Direction Data Message PF value	PF Value of the message that has Driving Direction data (if needed)
6	Driving Direction Data Message PS value	PS Value of the message that has Driving Direction data (if needed)

Byte	Description	Comment
7	Configuration Switches	Bit 0: IMU Mount Location: 0 = IMU does not experience rotation relative to chassis, such as mounted to a truck's chassis 1 = IMU can experience rotation relative to tracks, such as mounted to body of excavator Bit 1: Reserved (set to "0") Bit 2: Aiding Signal Acceleration Direction 0 = +X Axis acceleration point to vehicle forward. 1 = -X Axis acceleration point to vehicle forward.

5.1.5.11 Aiding Signal Lever Arm Configuration

There are two different Lever Arm definitions that may be applied, depending on the application. The first case deals with a vehicle application where the IMU does not experience rotation relative to the vehicle chassis, and where there is an independent measure of linear acceleration available on the CAN bus, which can be used to aid the Kalman Filter's estimates of pitch and roll angles. The second case is intended for an application where there are significant angular rates around an axis with known geometry (for example, the base of an excavator which pivots in the yaw axis, and where the IMU is mounted some known distance from the center of rotation). In both cases the lever arm is configured by PGN65376 shown below, but the definition of the lever arm is different for the two cases.

Case 1: IMU does not experience rotation relative to chassis:

For best performance, if an aiding signal is used, the lever arm of the aiding signal should be configured. This lever arm is defined as the X, Y, Z position of the effective location of the aiding sensor, with respect to the IMU location, as measured in the logical IMU frame. Note the logical IMU frame defines the X, Y, and Z axes as configured by the orientation setting (if different from the physical IMU frame). The purpose of this lever arm is to account for differences in velocity and acceleration at different points in the vehicle, caused by angular rates around the X, Y, and Z axes. The illustration below shows how the lever arm would be measured for an aiding signal at point P (lever arm values would be [x1, y1, -z1], measured in millimeters). Note the values can be either positive or negative. Table 58, Table 59 and Table 60 below show the format of the Aiding Signal Lever Arm Configuration command. This case would be indicated by Byte 1 of the Aiding Signal Configuration Command payload = "1" or "2", and Bit 0 of Byte 7 = "0".

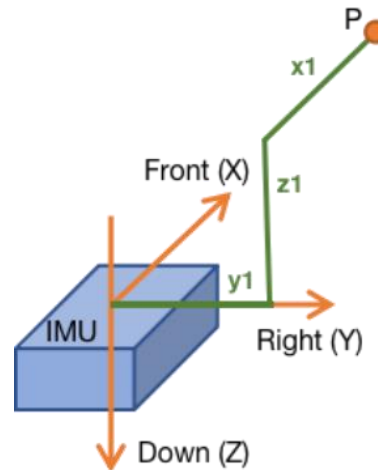


Figure 6. Case 1 Lever Arm Diagram

Table 58. The format of Aiding Signal Lever Arm Configuration command

Priority	PGN	PF	PS	SA	Payload
6	65376	255	96		7 bytes

Table 59. Lever Arm command payload (Case 1)

Byte	Description	Value	Definition	Comment
0	Address of Unit		Destination Address	NA
1	LeverArmX	LSB	LeverArm = X, Y, Z position of the odometer or acceleration aiding signal w.r.t. IMU reference point D (see figure at end of this section) in logical IMU frame in units of millimeters, expressed in offset binary format.	Millimeter Range = [-32000, 32000] Offset value = -32000. Default value in mm is [0, 0, 0], which is indicated by LeverArm values of [32000, 32000, 32000]
2		MSB		
3	LeverArmY	LSB		
4		MSB		
5	LeverArmZ	LSB		
6		MSB		

As an example, if the desired value for LeverArmX is 1000mm, then the two-byte value loaded into bytes 1 and 2 should represent the binary number 33,000. The value for LeverArmX (in mm) = $256 \times \text{MSB} + \text{LSB} - 32,000$.

Case 2: IMU can experience rotation relative to tracks:

In some applications, there may be significant angular rates (which can be internally sensed by the IMU). In these applications, the lever arm indicates the location of the axis of rotation with respect to the IMU. The illustration below shows how the lever arm would be measured for axis of rotation for excavator's body (lever arm values would be $[x1, y1, 0]$, measured in millimeters). Note the values can be either positive or negative. The Table below indicates the definition of the Lever

Arm command payload in this case, which would be indicated by Byte 1 of the Aiding Signal Configuration Command payload = “1” or “2”, and Bit 0 of Byte 7 = “1”. Note, in case 2, the CAN aiding signal is only used to determine whether the vehicle is stationary or moving.

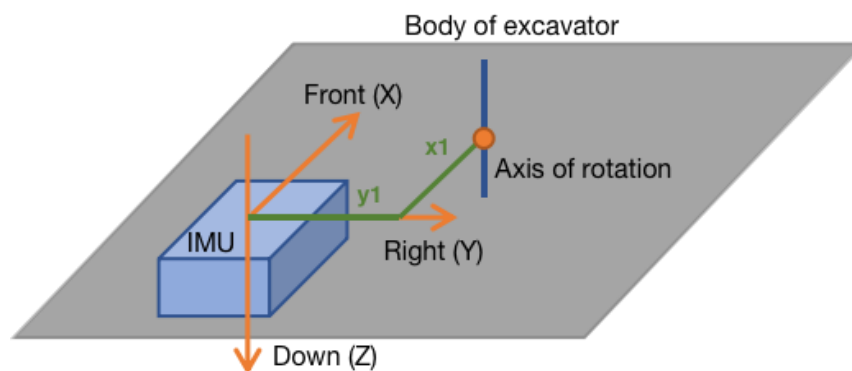


Figure 7. Case 2 Lever Arm Diagram

Table 60. Lever Arm command payload (Case 2)

Byte	Description	Value	Definition	Comment
0	Address of Unit		Destination Address	NA
1	LeverArmX	LSB	LeverArm = X, Y, Z position of the axis of rotation with respect to the IMU Reference Point D (see figure below), in units millimeters, expressed in offset binary format.	Millimeter Range = [-32000, 32000] Offset value = -32000 Default in mm is [0, 0, 0], which is indicated by LeverArm values of [32000, 32000, 32000]
2		MSB		
3	LeverArmY	LSB		
4		MSB		
5	LeverArmZ	LSB		
6		MSB		

As an example, if the desired value for LeverArmX is 1000mm, then the two-byte value loaded into bytes 1 and 2 should represent the binary number 33,000. The value for LeverArmX (in mm) = $256 \times \text{MSB} + \text{LSB} - 32,000$.

The following figure shows the location of the Lever Arm reference point (D), which is the center point on the bottom of the unit:

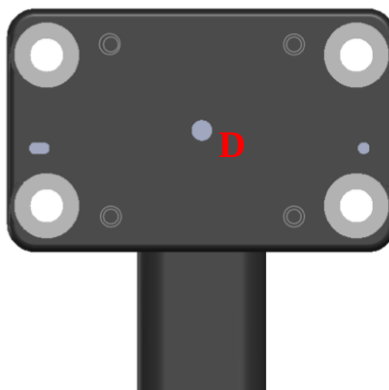


Figure 8. Origin Point for Lever Arm Measurement

5.1.5.12 DM1 Message Configuration

The IMU can send out DM1 diagnostic messages in case of failures. This message allows to configure specific fields of DM1 messages.

Table 61. DM1 Configuration response message format

Priority	PGN	PF	PS	SA	Payload
6	65370	255	90		8 bytes

Table 62. DM1 Configuration payload detail

Byte	Bits	Parameter name	Default Values
1	DA	Destination address	
2	2-1	Protect Lamp Status	00
	4-3	Amber Warning Lamp Status	01
	6-5	Red Stop Lamp Status	00
	8-7	Malfunction Indicator Lamp Status	00
3	2-1	Flash Protect Lamp	11
	4-3	Flash Amber Warning Lamp	11
	6-5	Flash Red Stop Lamp	11
	8-7	Flash Malfunction Indicator Lamp	11
4	8-1	SPN, 8 least significant bits of SPN	0xB3
5	8-1	SPN, second byte of SPN (most significant at bit 8)	0xF4
6	3-1	SPN, 3 most significant bits (most significant at bit 8)	0x07
7		FMI for DTC1	0x0C
8		FMI for DTC2	0x0E

Note: the DM1 messages can be enabled and disabled. To disable message for specific DTC set FMI value to 0xFF.

5.1.5.13 Bank of PS numbers

Users may change the default PS numbers of proprietary MTLT335 PGNs if the pre-configured values have already been used in their system. PS numbers can be re-assigned anywhere in the

range from 0x40 to 0x6C (64 to 108). The three commands below are issued by user's ECU and sent to the MTLT335 in order to change the corresponding PS values. Table 63, Table 64 and Table 65 shows the format of these three commands. The MTLT335 will decode these incoming packets and switch the default PS numbers to the values assigned by users. The new PS numbers will take effect immediately and can be permanently saved. Note that PF numbers for all proprietary PGNs have value 255.

Table 63. The format of PS Bank0 command

Priority	PGN	PF	PS	SA	Payload
6	65520	255	240		8 bytes

Table 64. The format of PS Bank1 command

Priority	PGN	PF	PS	SA	Payload
6	65521	255	241		8 bytes

Table 65. The format of PS Bank2 command

Priority	PGN	PF	PS	SA	Payload
6	65522	255	242		8 bytes

The Bank0, Bank1 and Bank2 payloads each contain 8 bytes, where each byte value represents the newly assigned PS number for the corresponding Get or Set command. See **Table 66** and **Table 67** for a description of which byte corresponds with which command. Note if a byte value of zero is detected, that particular field will be ignored (the PS number is not changed).

Table 66. Bank0 Command Payload

Byte	Default PS	Command / Function associated with corresponding Byte
0	N/A	Destination Address
1	80	Algorithm Reset
2	81	Save Configuration
3	82	HW BIT Status
4	83	SW BIT Status
5	84	Master BIT Status
6	107	HR Angular Rate
7	109	HR Acceleration

Table 67. Bank1 Command Payload

Byte	Default PS	Command / Function associated with corresponding Byte
0	N/A	Destination Address
1	85	Packet Rate Divider
2	86	Packet Type(s)
3	87	Digital Filter
4	88	Orientation
5	89	Unit Behavior
6	91	Algorithm Control
7		Reserved

Table 68. Bank2 Command Payload

Byte	Default PS	Command / Function associated with corresponding Byte
0	N/A	Destination Address
1	95	Aiding Signal Configuration
2	96	Aiding Signal LeverArm Configuration
3	90	DM1 Message Configuration
4 – 7		Reserved

5.1.6 Data Packets

The MTLT335 can be configured to periodically output any combination of six different data packets. These packets are slope sensor information and slope sensor information 2, angular rate and acceleration sensor defined by SAEJ1939-DA, and custom high-resolution acceleration and angular rate packets.

Device temperature information is also available but it is not supported as a broadcast message. Get command is used to read temperature information on demand. See section 5.1.6.7

5.1.6.1 Slope Sensor Information 2

The payload contains 8 bytes in little-endian mode and follows the definition of SLOT 294 and SAEad11 found in SAEJ1939-DA. The first 24-bits is the pitch value and the next 24-bits is the roll value. See the Tables below for details about the format and payload of the message.

Table 69. The format of SSI2 packet

Priority	PGN	PF	PS	SA	Payload
3	61481	240	41		8 bytes

Table 70. Payload of the SSI2 packet

Bytes	Parameter name	Units	Scaling	Data Range	Offset
1-3	Pitch Angle (Extended Range)	°	1/32768 °/Bit	-250 to 252	-250
4-6	Roll Angle (Extended Range)	°	1/32768 °/Bit	-250 to 252	-250
7.1, 2	Pitch Angle Compensation	-	00=On		
7.3, 4	Pitch Angle FOM	-	00=Fully Functional, 01=Degraded, 10=Error, 11=N/A. See Table 71		
7.5, 6	Roll Angle Compensation	-	00=On		
7.7, 8	Roll Angle Figure of FOM	-	00=Fully Functional, 01=Degraded, 10=Error, 11=N/A. See Table 71		
8	Roll and Pitch Latency	ms	0.5 ms/Bit	0 to 125	0

Table 71. SSI2 FOM Definition

Value	Conditions	Action
00	All Conditions are normal	No Action Required
01	Degraded for one or more of the following. a. Turn switch threshold exceeded for more than 50 seconds b. Disagreement BIT is set SW BIT status. At least one sensor has failed, and there is disagreement between the remaining two. c. Rate > 410 dps for 20 ms d. Only one sensor participates in solution e. Data processing timings compromised	Momentary indication can be ignored For Persistent indication: a. Read Master, HW, SW BIT to get more information on cause of condition. b. Try Reset or power cycle to clear condition c. Replace device if condition persists and does not clear after reset or power cycle
10	The Output is in error due to any of the following conditions a. Algorithm is initializing – Clears once algorithm has initialized. You will see this at power on. b. Algorithm is in error state: initialization did not complete or overflow of pitch/roll values c. Rate Sensor > 495 dps	Momentary indication can be ignored For Persistent indication: a. Read Master, HW, SW BIT to get more information on cause of condition. b. Try Algorithm Reset or power cycle to clear condition c. Replace device if condition persists and does not clear
11	This value is not used	

5.1.6.2 Slope Sensor Information

The payload contains 8 bytes in little-endian mode and follows up the definition of message with PGN 61459 found in SAEJ1939-DA. The first 16-bit is the pitch angle value, next 16 bit is roll angle value and following 16 bit is pitch rate value. See the Tables below for a description of the format and payload of the SSI message.

Table 72. The format of SSI packet

Priority	PGN	PF	PS	SA	Payload
3	61459	240	19		8 bytes

Table 73. Payload of the SSI Packet

Bytes	Parameter name	Units	Scaling	Data Range	Offset
1 – 2	Pitch Angle	°	0.002	-64 to 64.51	-64
3 – 4	Roll Angle	°	0.002	-64 to 64.51	-64
5 - 6	Pitch Rate	°/s	0.002	-64 to 64.51	-64
7.1,2	Pitch Angle FOM	-	00=Fully Functional, 01=Degraded, 10=Error, 11=N/A. See Table 71		
7.3,4	Roll Angle FOM	-	00=Fully Functional, 01=Degraded, 10=Error, 11=N/A. See Table 71		
7.5,6	Pitch Rate FOM	-	00=Fully Functional, 01=Degraded, 10=Error, 11=N/A. See Table 76		
7.7,8	Pitch and Roll Comp	-	00=On, 01=Off, 10=Error, 11=N/A		
8	Roll and Pitch Latency	ms/bit	0.5ms/bit	0 to 125	0

5.1.6.3 Angular Rate

The payload contains 8 bytes in little-endian mode and follows the definition of SLOT 288 and SAEva03 found in SAEJ1939-DA. Each of 16 bits is sequentially allocated to the angular velocity in Y, X, and Z per the J1939 standard. See the Tables below for a description of the message format and payload.

Table 74. The format of angular rate packet

Priority	PGN	PF	PS	SA	Payload
3	61482	240	42		8 bytes

Table 75. ARI Payload Description

Bytes	Parameter name	Units	Scaling	Data Range	Offset
1 – 2	Pitch Angular Rate	°/s	1/128 °/s/Bit	-250 to 250.99	-250
3 – 4	Roll Angular Rate	°/s	1/128 °/s/Bit	-250 to 250.99	-250
5 - 6	Yaw Angular Rate	°/s	1/128 °/s/Bit	-250 to 250.99	-250

Bytes	Parameter name	Units	Scaling	Data Range	Offset
7.1, 2	Pitch Rate FOM (Extended Range)	-	00=Fully Functional, 01=Degraded, 10=Error, 11=N/A. See Table 76		
7.3, 4	Roll Rate FOM (Extended Range)	-	00=Fully Functional, 01=Degraded, 10=Error, 11=N/A. See Table 76		
7.5, 6	Yaw Rate FOM (Extended Range)	-	00=Fully Functional, 01=Degraded, 10=Error, 11=N/A. See Table 76		
8	Angular Rate Measurement Latency	ms	0.5 ms/Bit	0 to 125	0

NOTE

By default, the Angular rate packet is arranged in the sequence Pitch, Roll, and Yaw rates, as specified by the J1939 standard. This is different from the previous generation MTLT335, which defines the message sequence as Roll, Pitch, and Yaw rate. It's possible to switch the sequence of X and Y in the message for backward compatibility (See Unit Behavior Settings).

NOTE

It is possible to configure the Angular rate packet to provide either raw or corrected (for bias) angular rates. See Unit Behavior settings for more information.

Table 76. ARI FOM Definition

Value	Conditions	Action
00	All Conditions are normal	No Action Required
01	Degraded for one or more of the following. a. Disagreement BIT is set SW BIT status. At least one sensor has failed, and there is disagreement between the remaining two. b. $ \text{Rate} > 250 \text{ deg/s}$ c. Only one sensor participates in solution d. Data processing timings compromised	Momentary indication can be ignored For persistent indication: a. Read Master, HW, SW BIT to get more information on cause of condition. b. Try Reset or power cycle to clear condition c. Replace MTLT335D if condition persists and does not clear

Value	Conditions	Action
10	The Output is in error due to one or both of the following condition a. Persistent Over Range b. All rate sensor failed c. Value exceeds CAN message range	Momentary indication can be ignored For persistent indication: a. Read Master, HW, SW BIT to get more information on cause of condition. b. Try Reset or power cycle to clear condition c. Replace MTLT335D if condition persists and does not clear
11	This Value is not used	

See **Appendix F**: FOM and BIT Examples for more information

5.1.6.4 High Resolution Angular Rate

The payload contains 8 bytes in little-endian mode. Rate Sensors data transmitted in 19-bit words sequentially allocated to the angular velocity, Y, X and Z. For each, the range is within -250 to 250.992 deg/s and the resolution is 1/1024 deg/s/bit, with an offset of -250 degrees/second. Table 77 shows the format of angular rate message.

Table 77. The format of High-Resolution angular rate packet

Priority	PGN	PF	PS	SA	Payload
3	65387	255	107		8 bytes

Table 78. HR Angular Rate Payload Description

Bits	Parameter name	Units	Scaling	Data Range	Offset
0 - 18	Pitch Angular Rate	°/s	1/1024 °/s/Bit	-250 to 250.99	-250
19 - 37	Roll Angular Rate	°/s	1/1024 °/s/Bit	-250 to 250.99	-250
38 - 56	Yaw Angular Rate	°/s	1/1024 °/s/Bit	-250 to 250.99	-250
57 - 58	Pitch Rate FOM (Extended Range)	-	00=Fully Functional, 01=Degraded, 10=Error, 11=N/A		
59 - 60	Roll Rate FOM (Extended Range)	-	00=Fully Functional, 01=Degraded, 10=Error, 11=N/A		
61 - 62	Yaw Rate FOM (Extended Range)	-	00=Fully Functional, 01=Degraded, 10=Error, 11=N/A		
63	Reserved				

NOTE

By default, the Angular rate packet is arranged in the sequence Pitch, Roll, and Yaw rates, as specified by the J1939 standard. This is different from the previous generation MTLT305D, which defines the message sequence as Roll, Pitch, and Yaw rate. It's possible to switch the sequence of X and Y in the message for backward compatibility (See Unit Behavior Settings).

NOTE

It's possible to configure the Angular rate packet to provide either raw or corrected (for bias) angular rates. See Unit Behavior settings for more information.

5.1.6.5 Acceleration Sensor

The payload contains 8 bytes in little-endian mode, and follows the definition of SLOT 303 and SAEad11 found in SAEJ1939-DA. Each of 16 bits is sequentially allocated to the acceleration in Y, X and Z. See the Tables below for details of the message format and payload.

Table 79. The format of acceleration sensor packet

Priority	PGN	PF	PS	SA	Payload
2	61485	240	45		8 bytes

Table 80. ACCS Payload Description

Bytes	Parameter name	Units	Scaling	Data Range	Offset
1 - 2	Acceleration Y axis	m/s ²	0.01 m/s ² /Bit	-320 to 322.55	-320
3 - 4	Acceleration X axis	m/s ²	0.01 m/s ² /Bit	-320 to 322.55	-320
5 - 6	Acceleration Z axis	m/s ²	0.01 m/s ² /Bit	-320 to 322.55	-320
7.1, 2	Lateral Acceleration FOM	-	00=Fully Functional, 01=Degraded, 10=Error, 11=N/A. See Table 81		

Bytes	Parameter name	Units	Scaling	Data Range	Offset
7.3, 4	Longitudinal Acceleration FOM	-	00=Fully Functional, 01=Degraded, 10=Error, 11=N/A See Table 81		
7.5, 6	Vertical Acceleration FOM	-	00=Fully Functional, 01=Degraded, 10=Error, 11=N/A See Table 81		
7.7, 8	Support Var Tx rep Accel	-	10=20ms Transmission Rate Supported, 11=only 10ms Transmission Rate Supported.		

NOTE

By default, the Acceleration packet is arranged in the sequence Y, X, and Z, and in the North-West-Up orientation, as specified by the J1939 standard. This is different from the previous generation OpenIMU335RI, which defines the message sequence as X, Y, and Z, and North-East-Down orientation. For backward compatibility, it's possible to switch the sequence of X and Y in the message, and also to switch to NED orientation (See Unit Behavior Settings).

Table 81. ACCS FOM Definition

Value	Conditions	Action
00	All Conditions are normal	No Action Required
01	Degraded for one or more of the following. a. Disagreement BIT is set SW BIT status. At least one sensor has failed, and there is disagreement between the remaining two. b. Acceleration > 7.9g for 20 ms c. Only one sensor participates in solution d. Data processing timings compromised	Momentary indication can be ignored For persistent indication: a. Read Master, HW, SW BIT to get more information on cause of condition. b. Try Reset or power cycle to clear condition c. Replace OpenIMU335RI if condition persists and does not clear
10	The Output is in error due to one or both of the following condition a. Persistent Over Range b. All acceleration sensor failed	Momentary indication can be ignored For persistent indication: a. Read Master, HW, SW BIT to get more information on cause of condition. b. Try Reset or power cycle to clear condition c. Replace OpenIMU335RI if condition persists and does not clear
11	This Value is not used	

5.1.6.6 High Resolution Acceleration Sensor data

The payload contains 8 bytes in little-endian mode. Each of 16 bits is sequentially allocated to the acceleration in Y, X, and Z, and in the NWU orientation. As with the ACCS message, it's possible to change both the sequence of X and Y, and also change to NED orientation (See Unit Behavior Settings). See the Tables below for more details on the format and payload for this message.

Table 82. The format of HR acceleration sensor packet

Priority	PGN	PF	PS	SA	Payload
2	65389	255	109		8 bytes

Table 83. HR Acceleration Payload Description

Bits	Parameter name	Units	Scaling	Data Range	Offset
0 –18	Acceleration Y axis	m/s ²	0.00125 m/s ² /Bit	-320 to 322.55	-320
19 –37	Acceleration X axis	m/s ²	0.00125 m/s ² /Bit	-320 to 322.55	-320
38 -56	Acceleration Z axis	m/s ²	0.00125 m/s ² /Bit	-320 to 322.55	-320
57, 58	Lateral Acceleration FOM	-	00=Fully Functional, 01=Degraded, 10=Error, 11=N/A		
59, 60	Longitudinal Acceleration FOM	-	00=Fully Functional, 01=Degraded, 10=Error, 11=N/A		
61,62	Vertical Acceleration FOM	-	00=Fully Functional, 01=Degraded, 10=Error, 11=N/A		
63	Support Var Tx rep Accel	-	1=20ms Transmission Rate Supported, 0=only 10ms Transmission Rate Supported.		

5.1.6.7 Unit Temperature

Unit temperature is not available as a broadcast message. It is obtained using a get command. Upon receiving a request for parameter with PGN 65373 (unit temperature) from another ECU on the network, MTLT335 responds with a packet, containing a 2-byte payload. The payload contains 2 bytes in little-endian mode and follows the definition of SLOT 358 and SAEtp04. See Table 84 and Table 85 for a description of the message format and payload. This message will be returned to the use upon request.

Table 84. Format of Unit Temperature Response Packet

Priority	PGN	PF	PS	SA	Payload
6	65373	255	93		2 bytes

Table 85. Scaling of Unit temperature payload (SLOT 358)

Bytes	Parameter name	Units	Scaling	Data Range	Offset
1 – 2	Unit Temperature	°C	1/128 °C/Bit	-273 to 228.992 °C	-273 °C

5.1.7 Diagnostic Messages DM1

MTLT335D sends DM1 message with 1 second interval to indicate its health. Transmission occurs while external supply is greater than 7.3 V. In case of failures, message will contain DTC to indicate the problem. The format of messages is defined in SAEJ1939-73. Two DTC are defined:

DTC 1: Failure indication which requires restart of unit:

This message will be sent out if unit detects the following critical errors:

Critical HW Error:

- Supply current over limit (~2x nominal) for > 1 min
- External or Internal power supply voltage out of range for > 1 min
- MCU temperature 5C over limit for > 5 min
- All three sensors over temperature limit by 5C for > 5mins

Critical SW Error:

- Stack overflow (>95% full)
- Algorithm error - when Algorithm is not initialized five seconds after startup.
- Data processing delay exceeds 5ms for more than 10 cycles (50ms)
- TX queue overflow for more than 10 cycles (50ms)

Fatal Error:

- Calibration CRC Error (for all three sensors)
- Internal SPI Communication Error (with all three sensors) for > 10 cycles (50ms)
- Configuration CRC Error

DTC 2: Failure indication which requires reprogramming unit:

This message will be sent out if unit detected the following critical errors:

- Application CRC Error

5.1.7.1 DM1 Message Format

This message has default SPN 521395 use FMI values 12 and 14. But SPN and FMI values can be configured. The format of DM1 messages provided below:

Table 86. The format of DM1 packet

Priority	PGN	PF	PS	SA	Payload
6	65226	254	202		8 bytes

Table 87. DM1 messages payload (default)

Byte	Bits	Parameter name	Values DTC 1	Values DTC2
1	2-1	Protect Lamp Status	00	00
	4-3	Amber Warning Lamp Status	01	01
	6-5	Red Stop Lamp Status	00	00
	8-7	Malfunction Indicator Lamp Status	00	00

Byte	Bits	Parameter name	Values DTC 1	Values DTC2
2	2-1	Flash Protect Lamp	11	11
	4-3	Flash Amber Warning Lamp	11	11
	6-5	Flash Red Stop Lamp	11	11
	8-7	Flash Malfunction Indicator Lamp	11	11
3	8-1	SPN least significant byte	0xB3	0xB3
4	8-1	SPN middle byte	0xF4	0xF4
5	8-6	SPN 3 most significant bits	0x7	0x7
	5-1	FMI	0x0C	0x0E
6	7-1	Occurrence Count	0	0
	8	SPN Conversion Method		
7		Reserved	0xFF	0xFF
8		Reserved	0xFF	0xFF

NOTE

Transmission of DM1 message when there is no failure or DTC can be disabled using bit 0 of the Unit Behavior switches. See section 5.1.5.7

NOTE

The DM1 messages can be enabled and disabled. To disable the message for specific DTC set the corresponding FMI value to 0xFF.

5.1.7.2 DTC Reset

The user can decide to reset/clear an active DTC condition. It can be done by sending the DM11 message to unit. DM11 message has the following format:

Table 88. The format of DTC Reset Packet

Priority	PGN	PF	PS	SA	Payload
6	65235	254	211		0 bytes

Upon reception of this message unit will clear active DTC and send back positive acknowledgement with the following format:

Table 89. The format of DTC Reset Response

Priority	PGN	PF	PS	SA	Payload
6	59392	232	255		8 bytes

Table 90 Acknowledgement message payload

Byte	Parameter name	Value DTC 1
1	Control byte	0
2	Group function value	0
3	Reserved	0xFF
4	Reserved	0xFF
5	Reserved	0xFF
6	DM11 PGN (LSB)	0xD3
7	DM11 PGN (2nd byte)	0xFE
8	DM11 PGN (MSB)	0x00

5.2 DBC File

A DBC file is a proprietary but common descriptor database file that is used to describes the CAN network and message decoding. DBC files are created and administered with either the CANdb editor or the CANdb++ editor available from Vector.

The format of DBC file follows the definition of Vector DBC Standard. The link is https://vector.com/vi_candb_en.html

A simplified description of DBC file is available on <https://github.com/stefanhoelzl/CANpy/tree/master/docs>. However, users must contact Vector if the full syntax of DBC file is desired.

A DBC file supporting ACEINNA MTLT335D is available for download from ACEINNA website from the MTLT335D Product page.

6 RS-232 Port Interface Definition

The MTLT335D supports a common packet structure that includes both command or input data packets (data sent to the MTLT335D) and measurement output or response packet formats (data sent from the MTLT335D). This section of the manual explains these packet formats as well as the supported commands. [Navigation studio](#) also features a number of tools that can help a user understand the packet types available and the information contained within the packets. This section of the manual assumes that the user is familiar with ANSI C programming language and data type conventions.

6.1 General Settings

The serial port settings are RS232 with 1 start bit, 8 data bits, no parity bit, 1 stop bit, and no flow control. Standard baud rates supported are 38400, 57600, 115200, 230400. Default is 115200.

NOTE

The boot loader used to update firmware always uses 57600 baud rate.

Common definitions include:

- A word is defined to be 2 bytes or 16 bits.
- All communications to and from the unit are packets that start with a single word alternating bit preamble 0x5555. This is the ASCII string “UU”.
- All multiple byte values are transmitted Big Endian (Most Significant Byte First).
- All communication packets end with a single word CRC (2 bytes). CRC's are calculated on all packet bytes excluding the preamble and CRC itself. Input packets with incorrect CRC's will be ignored.
- Each complete communication packet must be transmitted to the MTLT335 Series inertial system within a 4 second period.

6.2 Number Formats

Number Format Conventions include:

- 0x as a prefix to hexadecimal values
- single quotes (‘’) to delimit ASCII characters
- no prefix or delimiters to specify decimal values.

Table 91. Number Formats

Descriptor	Description	Size (bytes)	Comment	Range
U1	Unsigned Char	1		0 to 255

Descriptor	Description	Size (bytes)	Comment	Range
U2	Unsigned Short	2		0 to 65535
U4	Unsigned Int	4		0 to $2^{32}-1$
I2	Signed Short	2	2' s Complement	-2^{15} to $2^{15}-1$
I2*	Signed Short	2	Shifted 2' s Complement	Shifted to specified range
I4	Signed Int	4	2' s Complement	-2^{31} to $2^{31}-1$
F4	Floating Point	4	IEEE754 Single Precision	$-1*2^{127}$ to 2^{127}
D	Double	8	IEEE-754 Double Precision	2.23^{-308} to 1.80^{308}
SN	String	N	ASCII	

6.3 Packet Format

All of the Input and Output packets, except the Ping command, conform to the following structure:

0x5555	<2-byte packet type (U2)>	<payload byte-length (U1)>	<variable length payload>	<2-byte CRC (U2)>
--------	---------------------------	----------------------------	---------------------------	-------------------

To Ping a MTLT335 Series unit, type the ASCII string 'UUPK'. If properly connected, the MTLT335 Series unit will respond with 'PK'. All other communications with the MTLT335 Series unit require the 2-byte CRC. (Note: A MTLT335 Series unit will also respond to a ping command using the full packet formation with payload 0 and correctly calculated CRC. Example: 0x5555504B009ef4).

6.3.1 Packet Header

The packet header is always the bit pattern 0x5555.

6.3.2 Packet Type

The packet type is always two bytes long in unsigned short integer format. Most input and output packet types can be interpreted as a pair of ASCII characters. As a semantic aid consider the following single character acronyms:

P = packet

F = fields

Refers to Fields which are settings or data contained in the unit

E = EEPROM

Refers to factory data stored in EEPROM

R = read

Reads default non-volatile fields

G = get

Gets current volatile fields or settings

W = write

Writes default non-volatile fields. These fields are stored in non-volatile memory and determine the unit's behavior on power up. Modifying default fields take effect on the next power up and thereafter.

S = set

Sets current volatile fields or settings. Modifying current fields will take effect immediately by modifying internal RAM and are lost on a power cycle

6.3.3 Payload Length

The payload length is always a one-byte unsigned character with a range of 0-255. The payload length byte is the length (in bytes) of the *<variable length payload>* portion of the packet only and does not include the CRC.

6.3.4 Payload

The payload is of variable length based on the packet type.

6.3.5 16-bit CRC-CCITT

Packets end with a 16-bit CRC-CCITT calculated on the entire packet excluding the 0x5555 header and the CRC field itself. A discussion of the 16-bit CRC-CCITT and sample code for implementing the computation of the CRC is included at the end of this document. This 16-bit CRC standard is maintained by the International Telecommunication Union (ITU). The highlights are:

Width = 16 bits

Polynomial 0x1021

Initial value = 0xFFFF

No XOR performed on the final value.

See Appendix A for sample code that implements the 16-bit CRC algorithm.

6.3.6 Messaging Overview

Table 92 summarizes the messages available by MTLT335 Series model. Packet types are assigned mostly using the ASCII mnemonics defined above and are indicated in the summary Table 92 and in the detailed sections for each command. The payload byte-length is often related to other data elements in the packet as defined in the table below. The referenced variables are defined in the detailed sections following. Output messages are sent from the MTLT335 Series inertial system to the user system as a result of a poll request or a continuous packet output setting. Input messages are sent from the user system to the MTLT335 Series inertial system and will result in an associated Reply Message or NAK message. Not that both Input message and its reply message typically have the same **<2-byte packet type (U2)>**.

Table 92. Message Table

ASCII Mnemonic	<2-byte packet type (U2)>	<payload byte-length (U1)>	Description	Type
Link Test				
PK	0x504B	0	Ping Command and Response	Input/Reply Message
CH	0x4348	N	Echo Command and Response	Input/Reply Message
Interactive Commands				
GP	0x4750	2	Get Packet Request	Input Message
AR	0x4152	0	Algorithm Reset	Input/Reply Message
NAK	0x1515	2	Error Response	Reply Message
Output Messages: Status & Other, (Polled Only)				
ID	0x4944	5+N	Identification Data	Output Message
VR	0x5652	5	Version Data	Output Message
T0	0x5430	28	Test 0 (Detailed BIT and Status)	Output Message
Output Messages: Measurement Data (Continuous or Polled)				
A2	0x4132	30	Angle 2 Data	Output Message
S1	0x5331		Scaled Sensors <u>Data</u>	Output Message
Advanced Commands				
WF	0x5746	numFields*4+1	Write Fields Request	Input Message
WF	0x5746	numFields*2+1	Write Fields Response	Reply Message
SF	0x5346	numFields*4+1	Set Fields Request	Input Message
SF	0x5346	numFields*2+1	Set Fields Response	Reply Message
RF	0x5246	numFields*2+1	Read Fields Request	Input Message
RF	0x5246	numFields*4+1	Read Fields Response	Reply Message
GF	0x4746	numFields*2+1	Get Fields Request	Input Message
GF	0x4746	numFields*4+1	Get Fields Response	Reply Message

7 MTLT335 Standard RS232 Port Commands and Messages

7.1 Link Test

7.1.1 Ping Command

Ping ('PK' = 0x504B)			
Preamble	Packet Type	Length	Termination
0x5555	0x504B	0x00	<CRC (U2)>

The ping command has no payload. Sending the ping command will cause the unit to send a ping response.

7.1.2 Ping Response

Ping ('PK' = 0x504B)			
Preamble	Packet Type	Length	Termination
0x5555	0x504B	0x00	<CRC (U2)>

The unit will send this packet in response to a ping command.

7.1.3 Echo Command

Echo ('CH' = 0x4348)				
Preamble	Packet Type	Length	Payload	Termination
0x5555	0x4348	N	<echo payload>	<CRC (U2)>

The echo command allows testing and verification of the communication link. The unit will respond with an echo response containing the *echo data*. The *echo data* is N bytes long.

7.1.4 Echo Response

Echo Payload Contents					
Byte Offset	Name	Format	Scaling	Units	Description
0	echoData0	U1	-	-	First byte of echo data
1	echoData1	U1	-	-	Second byte of echo data
...	...	U1	-	-	Echo data
N-2	echoData...	U1	-	-	Second to last byte of echo data
N-1	echoData...	U1	-	-	Last byte of echo data

7.2 Interactive Commands

Interactive commands are used to interactively request data from the MTLT335 Series, and to calibrate or reset the MTLT335 Series.

7.2.1 Get Packet Request

Get Packet ('GP' = 0x4750)				
Preamble	Packet Type	Length	Payload	Termination
0x5555	0x4750	0x02	<GP payload>	<CRC (U2)>

This command allows the user to poll for both measurement packets and special purpose output packets including 'T0', 'VR', and 'ID'.

GP Payload Contents			
Byte Offset	Name	Format	Description
0	requestedPacketType	U2	The requested packet type

Refer to the sections below for Packet Definitions sent in response to the 'GP' command

7.2.2 System Reset Command

Algorithm Reset ('SR' = 0x5352)				
Preamble	Packet Type	Length	Payload	Termination
0x5555	0x5352	0x00	-	<CRC (U2)>

This command resets unit. The unit will respond with a system reset response.

7.2.3 System Reset Response

Algorithm Reset ('SR' = 0x5352)			
Preamble	Packet Type	Length	Termination
0x5555	0x5352	0x00	<CRC (U2)>

The unit will send this packet in response to an algorithm reset command.

7.2.4 Error Response

Error Response (ASCII NAK, NAK = 0x1515)				
Preamble	Packet Type	Length	Payload	Termination
0x5555	0x1515	0x02	<NAK payload>	<CRC (U2)>

The unit will send this packet in place of a normal response to a *failedInputPacketType* request if it could not be completed successfully.

NAK Payload Contents			
Byte Offset	Name	Format	Description
0	failedInputPacketType	U2	the failed request

7.3 Output Packets (Polled)

The following packet formats are special informational packets which can be requested using the 'GP' command.

7.3.1 Identification Data Packet

Identification Data (‘ID’ = 0x4944)					
Preamble	Packet Type	Length	Payload		Termination
0x5555	0x4944	5+N	<ID payload>		<CRC (U2)>
This packet contains the unit <i>serialNumber</i> and <i>modelString</i> . The model string is terminated with 0x00. The model string contains the programmed versionString (8-bit Ascii values) followed by the firmware part number string delimited by a whitespace. ID Payload Contents					
Byte Offset	Name	Format	Scaling	Units	Description
0	serialNumber	U4	-	-	Unit serial number
4	modelString	SN	-	-	Unit Version String
4+N	0x00	U1	-	-	Zero Delimiter

7.3.2 Version Data Packet

Version Data ('VR' = 0x5652)				
Preamble	Packet Type	Length	Payload	Termination
0x5555	0x5652	5	<VR payload>	<CRC (U2)>

This packet contains firmware version information. *majorVersion* changes may introduce serious incompatibilities. *minorVersion* changes may add or modify functionality but maintain backward compatibility with previous minor versions. *patch* level changes reflect bug fixes and internal modifications with little effect on the user. The build *stage* is one of the following: 0=release candidate, 1=development, 2=alpha, 3=beta. The *buildNumber* is incremented with each engineering firmware build. The *buildNumber* and *stage* for released firmware are both zero. The final beta candidate is v.w.x.3.y, which is then changed to v.w.x.0.1 to create the first release candidate. The last release candidate is v.w.x.0.z, which is then changed to v.w.x.0.0 for release.

VR Payload Contents			
Byte Offset	Name	Format	Description
0	majorVersion	U1	Major firmware version

VR Payload Contents			
Byte Offset	Name	Format	Description
1	minorVersion	U1	Minor firmware version
2	patch	U1	Patch level
3	stage	-	Development Stage (0=release candidate, 1=development, 2=alpha, 3=beta)
4	buildNumber	U1	Build number

7.3.3 Test (Detailed BIT and Status) Packet

Test ('TS' = 0x5430)				
Preamble	Packet Type	Length	Payload	Termination
0x5555	0x5430	0x06	<TS payload>	<CRC (U2)>

This packet contains detailed BIT and status information. The full BIT Status details are described in Appendix G.

Table 93. T0 Payload Contents

TS Payload Contents			
Byte Offset	Name	Format	Description
0	Master BIT status	U2	Master BIT and Status Field
2	Hardware BIT status	U2	Hardware BIT status register
4	Software BIT Status	U4	Software BIT Status register
8 : 27	Reserved	NA	NA

7.4 RS232 Output Packets (Polled or Continuous)

7.4.1 Angle Data Packet 2 (Default MTLT335 Data)

Angle Data ('A2' = 0x4132)				
Preamble	Packet Type	Length	Payload	Termination
0x5555	0x4132	0x1E	<A2 payload>	<CRC (U2)>

This packet contains angle data and selected sensor data scaled in most cases to a signed 2^{16} 's complement number. Data involving angular measurements include the factor π in the scaling and can be interpreted in either radians or degrees.

Angles: scaled to a range of $[-\pi, +\pi]$ or $[-180 \text{ deg to } +180 \text{ deg}]$.

Angular rates: scaled to range of $3.5 * [-\pi, +\pi]$ or $[-630 \text{ deg/sec to } +630 \text{ deg/sec}]$

Accelerometers: scaled to a range of $[-10, +10] \text{ g}$

Temperature: scaled to a range of $[-100, +100] \text{ }^{\circ}\text{C}$

A2 Payload Contents					
Byte Offset	Name	Format	Scaling	Units	Description
0	rollAngle	I2	$2\pi/2^{16}$ [360° /2 ¹⁶]	Radians [°]	Roll angle
2	pitchAngle	I2	$2\pi/2^{16}$ [360° /2 ¹⁶]	Radians [°]	Pitch angle
4	yawAngleTrue	I2	$2\pi/2^{16}$ [360° /2 ¹⁶]	Radians [°]	Yaw angle (free)
6	xRateCorrected	I2	$7\pi/2^{16}$ [1260° /2 ¹⁶]	rad/s [° /sec]	X angular rate corrected
8	yRateCorrected	I2	$7\pi/2^{16}$ [1260° /2 ¹⁶]	rad/s [° /sec]	Y angular rate corrected
10	zRateCorrected	I2	$7\pi/2^{16}$ [1260° /2 ¹⁶]	rad/s [° /sec]	Z angular rate corrected
12	xAccel	I2	$20/2^{16}$	G	X accelerometer
14	yAccel	I2	$20/2^{16}$	G	Y accelerometer
16	zAccel	I2	$20/2^{16}$	G	Z accelerometer
18	xRateTemp	I2	$200/2^{16}$	deg. C	X rate temperature
20	yRateTemp	I2	$200/2^{16}$	deg. C	Y rate temperature
22	zRateTemp	I2	$200/2^{16}$	deg. C	Z rate temperature
24	timeITOW	U4	1	ms	Not Implemented DMU ITOW (sync to GPS)
28	BITstatus	U2	-	-	Master BIT and Status

7.4.2 Scaled Sensor Data

Scaled sensor data ('S1' = 0x5331)				
Preamble	Packet Type	Length	Payload	Termination
0x5555	0x5331	0x18	<S1 payload>	<CRC (U2)>

This packet contains scaled sensor data. Data involving angular measurements include the factor π in the scaling and can be interpreted in either radians or degrees. Note the timer value can be used for synchronization and computation of Delta T. It may appear in NAV-VIEW log files under another column heading.

Angular rates: scaled to range of $3.5 \cdot [-\pi, +\pi]$ or $[-630 \text{ deg/sec to } +630 \text{ deg/sec}]$

Accelerometers: scaled to a range of $[-10, +10]g$

Temperature: scaled to a range of $[-100, +100]^\circ\text{C}$

S1 payload contents					
Byte Offset	Name	Format	Scaling	Units	Description
0	xAccel	I2	$20/2^{16}$	g	X accelerometer
2	yAccel	I2	$20/2^{16}$	g	Y accelerometer
4	zAccel	I2	$20/2^{16}$	g	Z accelerometer
6	xRate	I2	$7\pi/2^{16}$ [1260°/2 ¹⁶]	rad/s [°/sec]	X angular rate
8	yRate	I2	$7\pi/2^{16}$ [1260°/2 ¹⁶]	rad/s [°/sec]	Y angular rate
10	zRate	I2	$7\pi/2^{16}$ [1260°/2 ¹⁶]	rad/s [°/sec]	Z angular rate
12	xRateTemp	I2	$200/2^{16}$	deg. C	X rate temperature
14	yRateTemp	I2	$200/2^{16}$	deg. C	Y rate temperature
16	zRateTemp	I2	$200/2^{16}$	deg. C	Z rate temperature
18	boardTemp	I2	$200/2^{16}$	deg. C	CPU board temperature
20	timer	U2	15.259022	uS	Free running fast counter 1s= 65535, captured at sampling
22	BITstatus	U2	-	-	Master BIT and Status

8 MTLT335 Advanced RS232 Port Commands

8.1 Configuration Fields

Configuration fields determine various behaviors of the unit that can be modified by the user e.g. settings like baud rate, packet output. Advanced commands allow users to programmatically change the MTLT335 Series settings. This section of the manual documents all of the settings and options contained under the Unit Configuration tab within NAV-VIEW. Using these advanced commands, a user's system can change or modify the settings without the need for NAVrate and type, algorithm type, etc. These fields are stored in EEPROM and loaded on power up. These fields can be read from the EEPROM using the 'RF' command. These fields can be written to the EEPROM affecting the default power up behavior using the 'WF' command. The current value of these fields (which may be different from the value stored in the EEPROM) can also be accessed using the 'GF' command. All of these fields can also be modified immediately for the duration of the current power cycle using the 'SF' command. The unit will always power up in the configuration stored in the EEPROM. Configuration fields can only be set or written with valid data from Table below.

Table 94. Configuration Fields

<i>configuration fields</i>	<i>field ID</i>	<i>Valid Values</i>	<i>description</i>
Packet rate divider	0x0001	0 (default), 1, 2, 5, 10, 20, 25, 50, 200	quiet (default), 100Hz, 50Hz, 20Hz, 10Hz, 5Hz, 4Hz, 2Hz, 200 Hz
Unit BAUD rate	0x0002	3, 5(default), 6	57600, 115200(default), 230400
Continuous packet type	0x0003	Any output packet type S1, A2(default)	Actual FW default is S1. Units are configured prior to shipment to output A2. If configuration is lost during FW upgrade process, unit will default to S1 packet.
EKF Accelerometer Filter Setting	0x0005	5 or (8035-18749) 10 or (4018-8034) 20 or (2411-4017) 25 or (1741-2410) 40 or (1205-1740) 50 or (1-1204) 0 = [Unfiltered]	Sets low pass cutoff for accelerometers. Cutoff Frequency choices are 5 (default), 10, 20, 25, 40, and 50 Hz. Setting value 0 disables the filter. Note in range (1-1000), any valid LPF value (2, 10, 20, 25, or 40) will override 50 Hz setting. These values are exceptions in the (1 – 1000) range.
EKF Gyro Filter Setting	0x0006	5 or (8035-18749) 10 or (4018-8034) 20 or (2411-4017) 25 or (1741-2410) 40 or (1205-1740) 50 or (1-1204) 0 = [Unfiltered]	Sets low pass cutoff for rate sensors. Cutoff Frequency choices are 5, 10, 20, 25 (default), 40, and 50 Hz. Setting value 0 disables the filter. Note in range (1-1000), any valid LPF value (2, 10, 20, 25, or 40) will override 50 Hz setting. These values are exceptions in the (1 – 1000) range.

<i>configuration fields</i>	<i>field ID</i>	<i>Valid Values</i>	<i>description</i>
Orientation	0x0007	See below	Determine forward, rightward, and downward facing sides
Ecu Address	0x0032	128 - 247	Default 128
Ecu Baudrate	0x0033	0 - 500K 1 - 250K 2 - 125K 3 - 1000K	Default 500K; Autobaud enabled and unit will sync to any of these rates.
DATA Accelerometer Filter Setting (for CAN bus)	0x005A	5 or (8035-18749) 10 or (4018-8034) 20 or (2411-4017) 25 or (1741-2410) 40 or (1205-1740) 50 or (1-1204) 0 = [Unfiltered]	Sets low pass cutoff for accelerometers. Cutoff Frequency choices are 25 (default), 10, 20, 25, 40, and 50 Hz. Setting value 0 disables the filter. Note in range (1-1000), any valid LPF value (2, 10, 20, 25, or 40) will override 50 Hz setting. These values are exceptions in the (1 – 1000) range.
DATA Gyro Filter Setting (for CAN bus)	0x005B	5 or (8035-18749) 10 or (4018-8034) 20 or (2411-4017) 25 or (1741-2410) 40 or (1205-1740) 50 or (1-1204) 0 = [Unfiltered]	Sets low pass cutoff for rate sensors. Cutoff Frequency choices are 5, 10, 20, 25 (default), 40, and 50 Hz. Setting value 0 disables the filter. Note in range (1-1000), any valid LPF value (2, 10, 20, 25, or 40) will override 50 Hz setting. These values are exceptions in the (1 – 1000) range.
Unit Behavior Switch	0x0064	See Table 51	This field is the same as byte 1 and 2 of Table 51
Synchronization In	0x0068	0 – Disable 1 – Enable PPS in	Default = 0

Note: BAUD rate SF and WF has no immediate effect. A new BAUD rate will be applied after IMU restart.

8.2 Continuous Packet Type Field

This is the packet type that is being continually output. The supported packet depends on the model number. Please refer to Section 7.4 for a complete list of the available packet types.

8.3 EKF and DATA Digital Filter Settings

These four fields set the digital low pass filter cutoff frequencies for data to be used in attitude estimation (EKF) and separately for data to be output over the CAN bus and serial port (See Table 95).

Table 95. Digital Filter Settings

Field	Filter Setting
0x0006	EKF FilterGyro

Field	Filter Setting
0x0005	EKF FilterAccel
0x005B	DATA FilterGyro
0x005A	DATA FilterAccel

8.4 Orientation Field

This field defines the rotation from the factory physical to user logical axis sets. This rotation is relative to the default factory orientation for the MTLT335 family model. The default factory axis setting for the MTLT335 orientation field is logical positive axes (X, Y, Z) = physical device axes (+Ux, +Uy, +Uz) which defines the connector pointing to the opposite of +X direction and +Z direction going out the bottom of the unit. See Figure 5.

Table 96. MTLT335 Orientation Definitions

Description	Bits	Meaning
X Axis Sign	0	0 = positive, 1 = negative
X Axis	1:2	0 = Ux, 1 = Uy, 2 = Uz, 3 = N/A
Y Axis Sign	3	0 = positive, 1 = negative
Y Axis	4:5	0 = Uy, 1 = Uz, 2 = Ux, 3 = N/A
Z Axis Sign	6	0 = positive, 1 = negative
Z Axis	7:8	0 = Uz, 1 = Ux, 2 = Uy, 3 = N/A
Reserved	9:15	N/A

There are 24 possible orientation configurations (See Table 97). Setting/Writing the field to anything else generates a NAK and has no effect.

Table 97. MTLT335 Orientation Fields

Orientation Field Value	X Axis	Y Axis	Z Axis
0x0000 (default)	+Ux	+Uy	+Uz
0x0009	-Ux	-Uy	+Uz
0x0023	-Uy	+Ux	+Uz
0x002A	+Uy	-Ux	+Uz
0x0041	-Ux	+Uy	-Uz
0x0048	+Ux	-Uy	-Uz
0x0062	+Uy	+Ux	-Uz
0x006B	-Uy	-Ux	-Uz
0x0085	-Uz	+Uy	+Ux
0x008C	+Uz	-Uy	+Ux
0x0092	+Uy	+Uz	+Ux
0x009B	-Uy	-Uz	+Ux
0x00C4	+Uz	+Uy	-Ux
0x00CD	-Uz	-Uy	-Ux
0x00D3	-Uy	+Uz	-Ux
0x00DA	+Uy	-Uz	-Ux
0x0111	-Ux	+Uz	+Uy

Orientation Field Value	X Axis	Y Axis	Z Axis
0x0118	+U _x	-U _z	+U _y
0x0124	+U _z	+U _x	+U _y
0x012D	-U _z	-U _x	+U _y
0x0150	+U _x	+U _z	-U _y
0x0159	-U _x	-U _z	-U _y
0x0165	-U _z	+U _x	-U _y
0x016C	+U _z	-U _x	-U _y

8.5 Unit Behavior Switches

This field allows configuration of the unit behavior switches detailed in bytes 1 and 2 of Table 51.

8.6 Commands to Program Configuration Using RS232 Port

8.6.1 Write Fields Command

Write Fields ('WF' = 0x5746)				
Preamble	Packet Type	Length	Payload	Termination
0x5555	0x5746	1+numFields*4	<WF payload>	<CRC (U2)>

This command allows the user to write default power-up configuration fields to the EEPROM. Writing the default configuration will not take effect until the unit is power cycled. *NumFields* is the number of words to be written. The *field0*, *field1*, etc. are the field

IDs that will be written with the *field0Data*, *field1Data*, etc., respectively. The unit will not write to calibration or algorithm fields. If at least one field is successfully written, the unit will respond with a write fields response containing the field IDs of the successfully written fields. If any field is unable to be written, the unit will respond with an error response. Note that both a write fields and an error response may be received as a result of a write fields command. Attempts to write a field with an invalid value is one way to generate an error response. A table of field IDs and valid field values is available in Section 8.1.

WF Payload Contents					
Byte Offset	Name	Format	Scaling	Units	Description
0	numFields	U1	-	-	The number of fields to write
1	field0	U2	-	-	The first field ID to write
3	field0Data	U2	-	-	The first field ID's data to write
5	field1	U2	-	-	The second field ID to write
7	field1Data	U2	-	-	The second field ID's data
...	...	U2	-	-	...
numFields*4 -3	field...	U2	-	-	The last field ID to write

WF Payload Contents					
numFields*4 -1	field... Data	U2	-	-	The last field ID's data to write

Write Fields Response

Write Fields ('WF' = 0x5746)				
Preamble	Packet Type	Length	Payload	Termination
0x5555	0x5746	1+numFields*2	<WF payload>	<CRC (U2)>

The unit will send this packet in response to a write fields command if the command has completed without errors.

WF Payload Contents					
Byte Offset	Name	Format	Scaling	Units	Description
0	numFields	U1	-	-	The number of fields written
1	field0	U2	-	-	The first field ID written
3	field1	U2	-	-	The second field ID written
...	...	U2	-	-	More field IDs written
numFields*2 - 1	Field...	U2	-	-	The last field ID written

8.6.2 Set Fields Command

Set Fields ('SF' = 0x5346)				
Preamble	Packet Type	Length	Payload	Termination
0x5555	0x5346	1+numFields*4	<SF payload>	<CRC (U2)>

This command allows the user to set the unit's current configuration (SF) fields immediately which will then be lost on power down. *NumFields* is the number of words to be set. The *field0*, *field1*, etc. are the field IDs that will be written with the *field0Data*, *field1Data*, etc., respectively. This command can be used to set configuration fields. The unit will not set calibration or algorithm fields. If at least one field is successfully set, the unit will respond with a set fields response containing the field IDs of the successfully set fields. If any field is unable to be set, the unit will respond with an error response. Note that both a set fields and an error response may be received as a result of one set fields command. Attempts to set a field with an invalid value is one way to generate an error response. A table of field IDs and valid field values is available in Section 8.1.

SF Payload Contents					
Byte Offset	Name	Format	Scaling	Units	Description
0	numFields	U1	-	-	The number of fields to set

1	field0	U2	-	-	The first field ID to set
3	field0Data	U2	-	-	The first field ID' s data to set
5	field1	U2	-	-	The second field ID to set
7	field1Data	U2	-	-	The second field ID' s data to set
...	...	U2	-	-	...
numFields*4 -3	field...	U2	-	-	The last field ID to set
numFields*4 -1	field... Data	U2	-	-	The last field ID' s data to set

Set Fields Response

Set Fields ('SF' = 0x5346)				
Preamble	Packet Type	Length	Payload	Termination
0x5555	0x5346	1+numFields*2	<SF payload>	<CRC (U2)>

The unit will send this packet in response to a set fields command if the command has completed without errors.

SF Payload Contents			
Byte Offset	Name	Format	Description
0	numFields	U1	The number of fields to set
1	field0	U2	The first field ID to set
3	field1	U2	The second field ID to set
...	...	U2	More field IDs to set
numFields*2 - 1	Field...	U2	The last field ID to set

8.7 Read Fields Command

Read Fields ('RF' = 0x5246)				
Preamble	Packet Type	Length	Payload	Termination
0x5555	0x5246	1+numFields*2	<RF payload>	<CRC (U2)>

This command allows the user to read the default power-up configuration fields from the EEPROM. *NumFields* is the number of fields to read. The *field0*, *field1*, etc. are the field IDs to read. RF may be used to read configuration and calibration fields from the EEPROM. If at least one field is successfully read, the unit will respond with a read fields response containing the field IDs and data from the successfully read fields. If any field is unable to be read, the unit will respond with an error response. Note that both read field and error response may be received as a result of a read fields command.

RF Payload Contents			
Byte Offset	Name	Format	Description
0	numFields	U1	The number of fields to read
1	field0	U2	The first field ID to read
3	field1	U2	The second field ID to read
...	...	U2	More field IDs to read
numFields*2 - 1	Field...	U2	The last field ID to read

8.8 Read Fields Response

Read Fields ('RF' = 0x5246)				
Preamble	Packet Type	Length	Payload	Termination
0x5555	0x5246	1+numFields*4	<RF payload>	<CRC (U2)>

The unit will send this packet in response to a read field request if the command has completed without errors.

RF Payload Contents					
Byte Offset	Name	Format	Scaling	Units	Description
0	numFields	U1	-	-	The number of fields read
1	field0	U2	-	-	The first field ID read
3	field0Data	U2	-	-	The first field ID' s data read
5	field1	U2	-	-	The second field ID read
7	field1Data	U2	-	-	The second field ID' s data read
...	...	U2	-	-	...
numFields*4 -3	field...	U2	-	-	The last field ID read
numFields*4 -1	field...Data	U2	-	-	The last field ID' s data read

8.9 Get Fields Command

Get Fields ('GF' = 0x4746)				
Preamble	Packet Type	Length	Payload	Termination
0x5555	0x4746	1+numFields*2	<GF Data>	<CRC (U2)>

This command allows the user to get the unit's current configuration fields. *NumFields* is the number of fields to get. The *field0*, *field1*, etc. are the field IDs to get. GF may be used to get configuration, calibration, and algorithm fields from RAM. Multiple algorithm fields will not necessarily be from the same algorithm iteration. If at least one field is successfully collected, the unit will respond with a get fields response with data containing the field IDs of the successfully received fields. If any field is unable to be received, the unit will respond with an error response.

Note that both a get fields and an error response may be received as the result of a get fields command.

GF Payload Contents					
Byte Offset	Name	Format	Scaling	Units	Description
0	numFields	U1	-	-	The number of fields to get
1	field0	U2	-	-	The first field ID to get
3	field1	U2	-	-	The second field ID to get
...	...	U2	-	-	More field IDs to get
numFields*2 - 1	Field...	U2	-	-	The last field ID to get

8.10 Get Fields Response

Get Fields ('GF' = 0x4746)				
Preamble	Packet Type	Length	Payload	Termination
0x5555	0x4746	1+numFields*4	<GF Data>	<CRC (U2)>

The unit will send this packet in response to a get fields request if the command has completed without errors.

GF Payload Contents					
Byte Offset	Name	Format	Scaling	Units	Description
0	numFields	U1	-	-	The number of fields retrieved
1	field0	U2	-	-	The first field ID retrieved
3	field0Data	U2	-	-	The first field ID' s data retrieved
5	field1	U2	-	-	The second field ID retrieved
7	field1Data	U2	-	-	The second field ID' s data
...	...	U2	-	-	...
numFields*4 -3	field...	U2	-	-	The last field ID retrieved
numFields*4 -1	field...Data	U2	-	-	The last field ID' s data retrieved

9 Bootloader

9.1 Firmware Upgrade

MTLT335/OpenIMU335 units have a built-in bootloader. Firmware can be upgraded over RS232 interface or over CAN bus interface.

Firmware upgrade over RS232 interface described in section 9.2.

Firmware upgrade over CAN bus interface described in the document "Upgrading FW on Aceinna IMUs over CAN bus"

9.2 Firmware Upgrade Using RS232 Interface

Nav-View Graphical User interface provides a convenient platform for upgrading FW in the MTLT335D. Refer to Appendix C.

Alternatively a user can initiate firmware upgrade procedure on RS232 interface at any time by sending 'JI' or "JB" command (see below command's format) to application program. This command forces the unit enter Bootloader mode. The unit will communicate at 57.6Kbps baud rate regardless of the original baud rate the unit is configured to. The Bootloader always communicates at 57.6Kbps until the firmware upgrade is complete.

As an additional device recovery option immediately after powering up, every MTLT33xD will enter a recovery window of 200ms prior to application start. During this 200mS window, the user can send 'JI' command at 57.6Kbps to the Bootloader in order to force the unit to remain in Bootloader mode.

Once the device enters Bootloader mode via the 'JI' command either during recovery window or from normal operation, a user can send a sequence 'WA' commands to write a complete application image into the device's FLASH.

After loading the entire firmware image with successive 'WA' commands, a 'JA' command is sent to instruct the unit to exit Bootloader mode and begin application execution. At this point, the device will return to its original baud rate.

Optionally, the system can be reboot by cycling power to restart the system.

Use the commands detailed in Sections 9.2.1 for upgrading to a new firmware version.

9.2.1 Commands used for FW upgrade via RS232 Interface

Firmware upgrade is performed by a Write APP command through RS232 port, through Windows GUI, NAV-View, or a python program. See Appendix C for information on using Nav-View to update device firmware.

10 Customer Service

As an ACEINNA customer you have access to product support services, which include:

- Single-point return service
- Web-based support service
- Same day troubleshooting assistance
- Worldwide ACEINNA representation
- Onsite and factory training available
- Preventative maintenance and repair programs
- Installation assistance available

10.1 Contact Directory

Email: techsupport@aceinna.com

<http://www.aceinna.com/support/index.cfm>

10.2 Return Procedure

10.2.1 Authorization

Before returning any equipment, please contact ACEINNA to obtain a Returned Material Authorization number (RMA).

Be ready to provide the following information when requesting a RMA:

- Name
- Address
- Telephone, Fax, Email
- Equipment Model Number
- Equipment Serial Number
- Installation Date
- Failure Date
- Fault Description
- Will it connect to NAV-VIEW 3.X?

10.2.2 Identification and Protection

If the equipment is to be shipped to ACEINNA for service or repair, please attach a tag TO THE EQUIPMENT, as well as the shipping container(s), identifying the owner. Also indicate the service or repair required, the problems encountered, and other information considered valuable to the service facility such as the list of information provided to request the RMA number.

Place the equipment in the original shipping container(s), making sure there is adequate packing around all sides of the equipment. If the original shipping containers were discarded, use heavy boxes with adequate padding and protection.

10.2.3 Sealing the Container

Seal the shipping container(s) with heavy tape or metal bands strong enough to handle the weight of the equipment and the container.

10.2.4 Marking

Please write the words, “FRAGILE, DELICATE INSTRUMENT” in several places on the outside of the shipping container(s). In all correspondence, please refer to the equipment by the model number, the serial number, and the RMA number.

10.3 Warranty

The ACEINNA product warranty is one year from date of shipment.

Appendix A: 16-bit CRC Implementation Sample Code

```
uint16_t CalculateCRC (uint8_t *buf, uint16_t length)
{
    uint16_t crc = 0x1D0F;

    for (int i=0; i < length; i++) {
        crc ^= buf[i] << 8;
        for (int j=0; j<8; j++) {
            if (crc & 0x8000) {
                crc = (crc << 1) ^ 0x1021;
            }
            else {
                crc = crc << 1;
            }
        }
    }
    return ((crc << 8) & 0xFF00) | ((crc >> 8) & 0xFF);
}
```

Appendix B: Function Instance (Detecting location on wire harness)

The MTLT335/OpenIMU335 includes a feature for detecting the installation location on a bus which includes more than one IMU module. The feature uses the state of RS-232 pins to populate the “Function Instance” Field (bits 35:39) in the address claim payload, according to the definition in the Table below:

Table 1: Definition of Function Instance Field based on RS-232 pin states

Function Instance Field (Bits 35:39 of “Name”)	State of RS-232 RX pin (pin 4)
00000	Pin 4 (RX) = open or GND*
00001	Pin 4 = VDD or above 2 Volts
00010	Pin 4 (RX) shorted to Pin 5 (TX)
00011	1kHz clock
00100	2kHz clock
00101	3kHz clock
00110	4kHz clock
00111	5kHz clock
11111	Invalid frequency detected

* Pin 4 has an internal pull-down resistor

In order for a valid frequency signal to be detected, the unit must receive at least 2 cycles of the given frequency during a window in time starting 50ms after valid power supply and ending 200ms after valid power supply. The accuracy of the frequency must be within 5% to be considered valid.

By reading the “Function Instance” field (bits 35:39 of the address claim payload), the main ECU can associate an installation location with a specific device SA. This allows uploading onto IMU a specific configuration, or even a different firmware version, based on the installation location.

When power is first applied, the unit will enter boot mode, and (if automatic baud rate detection is enabled) silent baud discovery mode. In parallel, the unit is detecting the state of the RS-232 pins. During the configuration detection period (which spans the time from 50ms to 200ms after POR), the unit is looking for a valid frequency. As soon as a valid frequency is detected, the detection process is terminated. If no frequency is detected by the time the 200ms period has expired, the unit will attempt to send a message from the TX pin to the RX pin; if it is unsuccessful, the last state of the RX pin (low or high) will be used to determine the configuration. If a frequency is detected that is not valid, the Function Instance bits will be populated with “11111”, indicating an invalid configuration. After 200ms (from valid power supply) has passed, and provided a valid baud rate has been detected, the unit will issue an address claim message, with the Function Instance field populated based on the detected state of the RS-232 pins. If a valid application has been detected, the unit will exit from boot mode and control will be passed to main application. If no valid application has been detected, the unit will remain in boot mode until a valid application has been uploaded. If an INVALID application is detected (application not recognized, or has

invalid CRC detected), the unit will remain in boot mode, and will also indicate this error by periodically transmitting the Master BIT (PGN65364), with the appropriate bits set (see description of PGN65364).

❖ NOTE

Using the function instance to detect wire harness location is a dual use of the RS-232 pins. This typically does not present any issues in the end application, where CAN J1939 is the primary communication method. However, there is also an RS-232 bootloader available. If 1) an RS-232 Boot command is received during the 200ms power up sequence or 2) application received command to enter BOOT mode from RS232 port, control will be passed to the RS232 Bootloader, and the location detection function will be aborted (case 1) or not performed (case 2).

Appendix C: Installation and Operation of NAV-VIEW over RS232

NAV-VIEW has been designed to allow users to control all aspects of the MTLT335 Series operation including data recording, configuration and data transfer. For proper use with the MTLT335 family version 3.5.6 or higher of NAV-VIEW is required.

NAV-VIEW Computer Requirements

The following are minimum requirements for the installation of the NAV-VIEW Software:

- CPU: Pentium-class (1.5GHz minimum)
- RAM Memory: 500MB minimum, 1GB+ recommended
- Hard Drive Free Memory: 20MB
- Operating System: Windows 7, 8 and 10
- Properly installed Microsoft .NET 2.0 or higher

Install NAV-VIEW

Download Nav-View from ACEINNA Website. To install NAV-VIEW onto your computer:

1. Extract files to local folder.
2. Locate the “NAV-VIEW” folder. Double click on the “setup.exe” file.
3. Follow the setup wizard instructions. You will install NAV-VIEW and .NET 2.0 framework.

Connections

The MTLT3 Series Inertial Systems products can be purchased with a with a 6-pin Ampseal 16 to 6 Position connector to flying lead cable. In order to connect to NAV-VIEW, the cable can be attached to a standard DB9 connector.

1. Connect the blue wire (Ampseal pin 4 - RS232-RX) to the host system RS232 TX pin.
2. Connect the white wire (Ampseal pin 5 - RS232-TX) to the host system RS232 RX pin.
3. Connect the black wire (Ampseal pin 3 - GND) to host system and power supply ground.
4. Connect the red wire (Ampseal pin 6 - Power) to power supply positive, 9 - 32 VDC.

◀ NOTE

Allow at least 1 seconds after power up for the MTLT3 Series product for initialization. The MTLT3 Series needs to be held motionless during this period.

Setting up NAV-VIEW

With the MTLT335 Series product powered up and connected to your PC serial port, open the NAV-VIEW software application.

1. NAV-VIEW should automatically detect the MTLT335 Series product and display the serial number and firmware version if it is connected.
2. If NAV-VIEW does not connect, check that you have the correct COM port selected. You will find this under the “Setup” menu. Select the appropriate COM port and allow the unit to automatically match the baud rate by leaving the “Auto: match baud rate” selection marked.
3. If the status indicator at the bottom is green and states, **Unit Connected**, you’re ready to go. If the status indicator doesn’t say connected and is red, check the connections between the MTLT335 Series product and the computer, check the power supply, and verify that the COM port is not occupied by another device.
4. Under the “View” menu you have several choices of data presentation. Graph display is the default setting and will provide a real time graph of all the MTLT335 Series data. The remaining choices will be discussed in the following pages.

Data Recording

NAV-VIEW allows the user to log data to a text file (.txt) using the simple interface at the top of the screen. Customers can now tailor the type of data, rate of logging and can even establish predetermined recording lengths.

To begin logging data follow the steps below (See Figure 6):

1. Locate the  icon at the top of the page or select “Log to File” from the “File” drop down menu.
2. The following menu will appear.

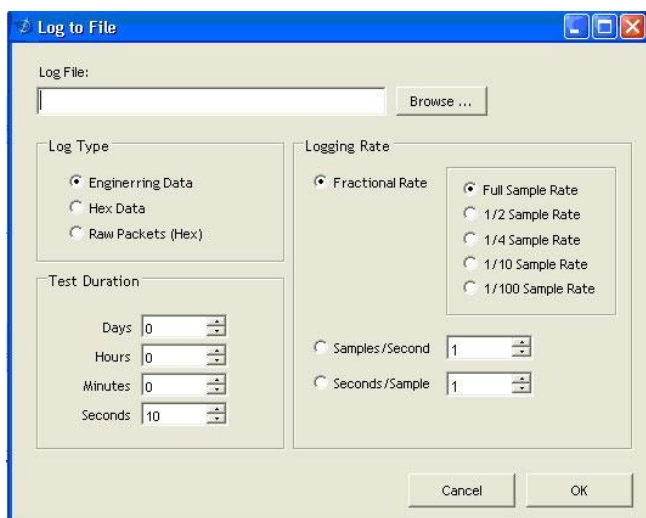


Figure 9 Log to File Dialog Screen

3. Select the “Browse” box to enter the file name and location that you wish to save your data to.

4. Select the type of data you wish to record. “Engineering Data” records the converted values provided from the system in engineering units, “Hex Data” provides the raw hex values separated into columns displaying the value, and the “Raw Packets” will simply record the raw hex strings as they are sent from the unit.
5. Users can also select a predetermined “Test Duration” from the menu. Using the arrows, simply select the duration of your data recording.
6. Logging Rate can also be adjusted using the features on the right side of the menu.
7. Once you have completed the customization of your data recording, you will be returned to the main screen where you can start the recording process using the  button at the top of the page or select “Start Logging” from the “File” menu. Stopping the data recording can be accomplished using the  button and the recording can also be paused using the  button.

Data Playback

In addition to data recording, NAV-VIEW allows the user to replay saved data that has been stored in a log file.

1. To playback data, select “Playback Mode” from the “Data Source” drop down menu at the



2. Selecting Playback mode will open a text prompt which will allow users to specify the location of the file they wish to play back. All three file formats are supported (Engineering, Hex, and Raw) for playback. In addition, each time recording is stopped/started a new section is created. These sections can be individually played back by using the drop down menu and associated VCR controls.
3. Once the file is selected, users can utilize the VCR style controls at the top of the page to start, stop, and pause the playback of the data.
4. NAV-VIEW also provides users with the ability to alter the start time for data playback.

Using the  slide bar at the top of the page users can adjust the starting time.

Raw Data Console

NAV-VIEW offers some unique debugging tools that may assist programmers in the development process. One such tool is the Raw Data Console. From the “View” drop down menu, simply select the “Raw Data Console”. This console provides users with a simple display of the packets that have been transmitted to the unit (Tx) and the messages received (Rx). An example is provided in Figure 7.

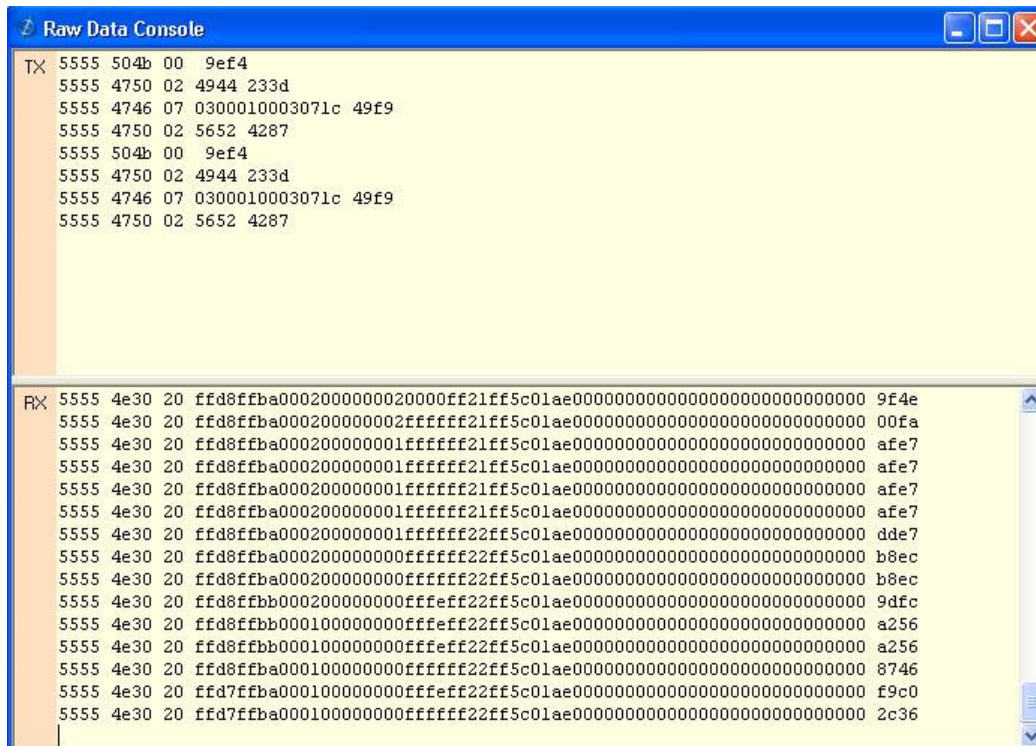


Figure 10 Raw Data Console

Packet Statistics View

Packet statistics can be obtained from the “View” menu by selecting the “Packet Statistics” option (See Figure 11). This view simply provides the user with a short list of vital statistics (including Packet Rate, CRC Failures, and overall Elapsed Time) that are calculated over a one second window. This tool should be used to gather information regarding the overall health of the user configuration. Incorrectly configured communication settings can result in a large number of CRC Failures and poor data transfer.

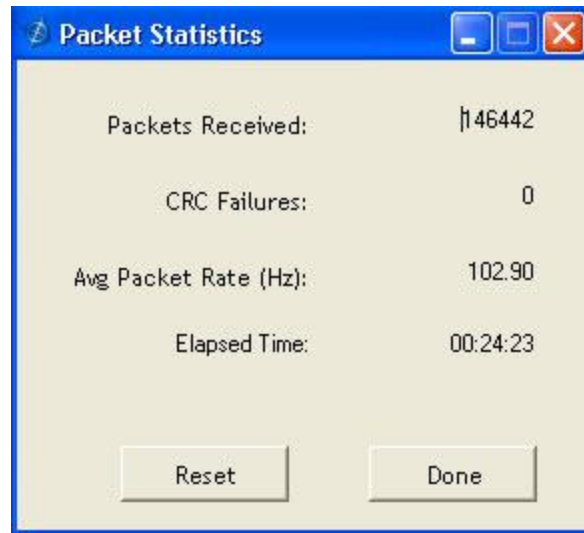


Figure 11 Packet Statistics

CAN configuration

MTLT's address is configurable through NAV-VIEW, or automatically assigned by address claiming protocol if the existing address is conflict with another ECU on the same network. See below Figure 12.

Click Menu Configuration, then select Unit Configuration and click the tab, CAN Parameter. Choose the address' value, then click the button Set Values.

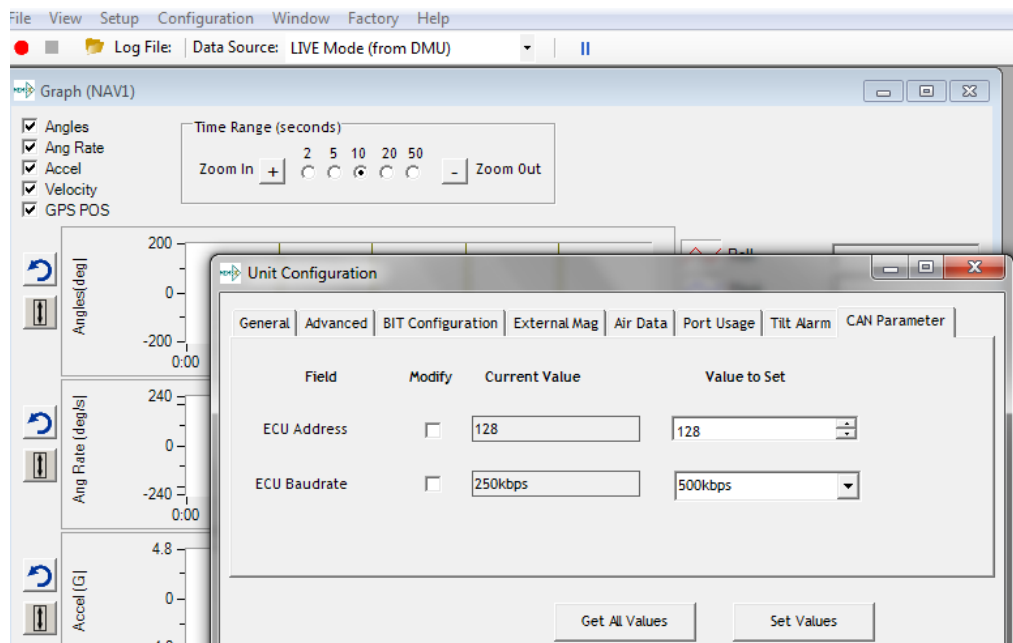


Figure 12 Unit Configuration

Firmware Upgrade

Step 1, select Firmware upgrade from configuration menu.

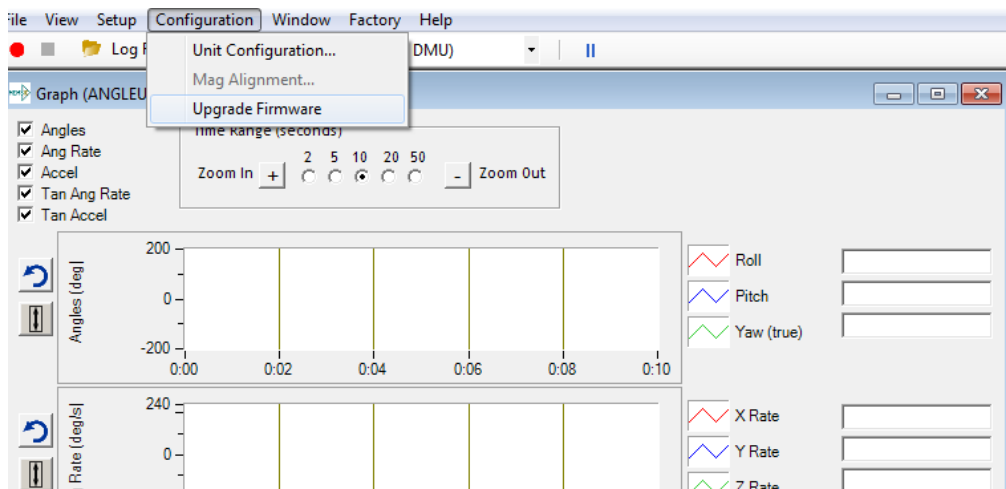


Figure 10 Firmware Upgrade 1

Step 2, On pop-up window, select a new version binary file by clicking SELECT button, then click Upgrade button.

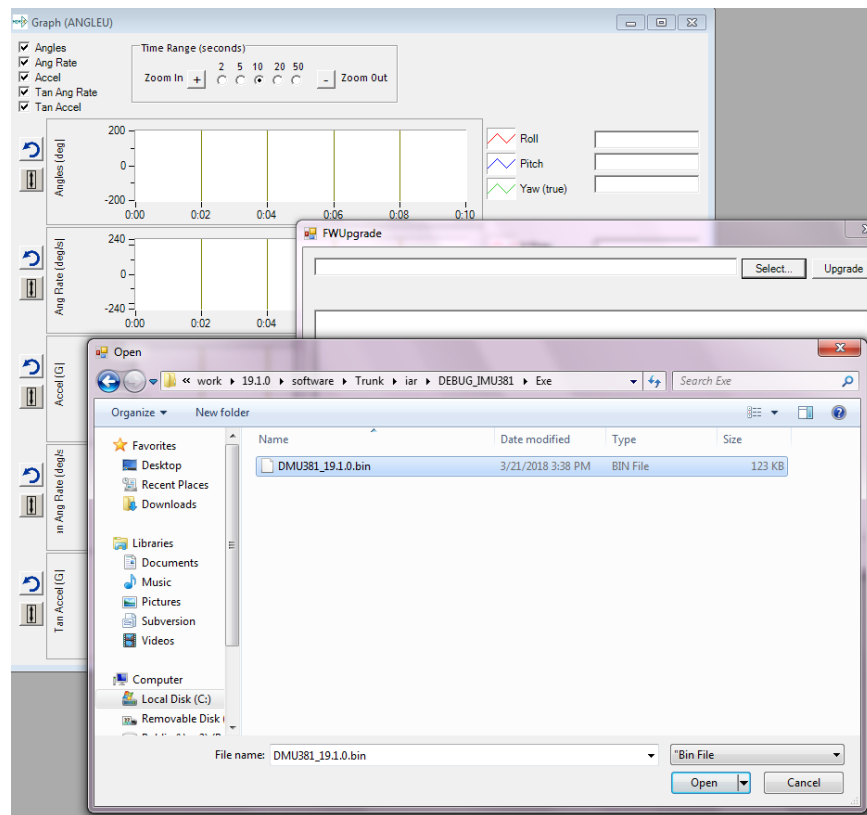


Figure 11 Firmware Upgrade 2

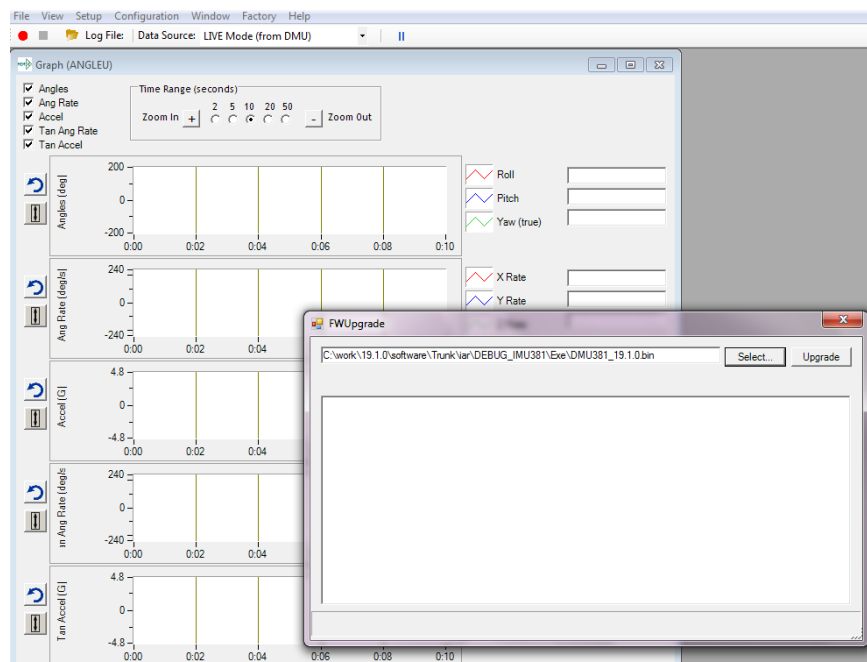
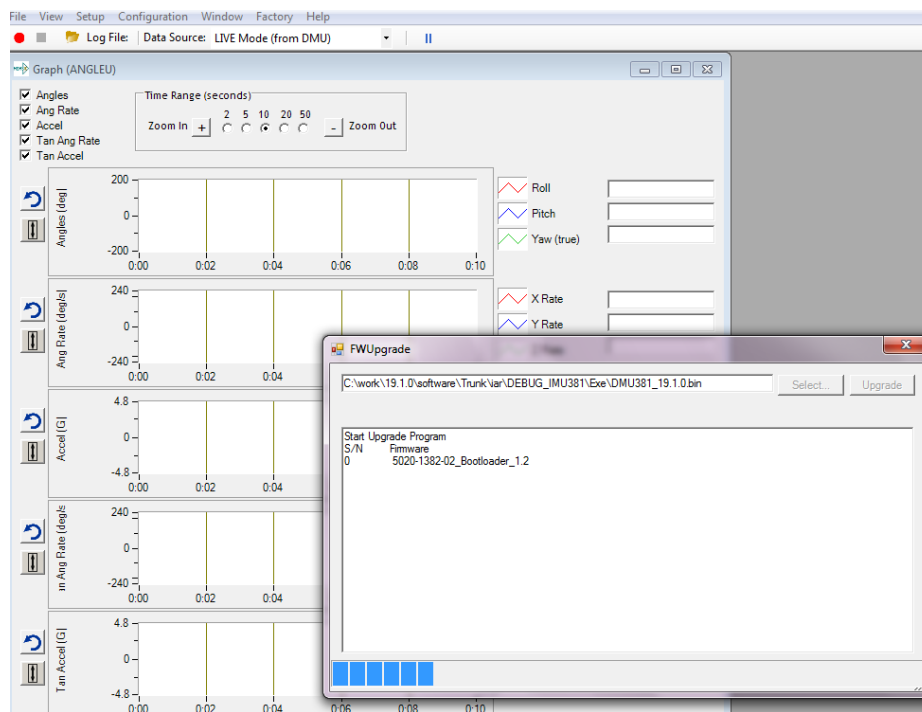


Figure 12 Firmware Upgrade 3

Step 3, wait for the process ongoing until a successful or failure message pops up.

**Figure 12 Firmware Upgrade 4**

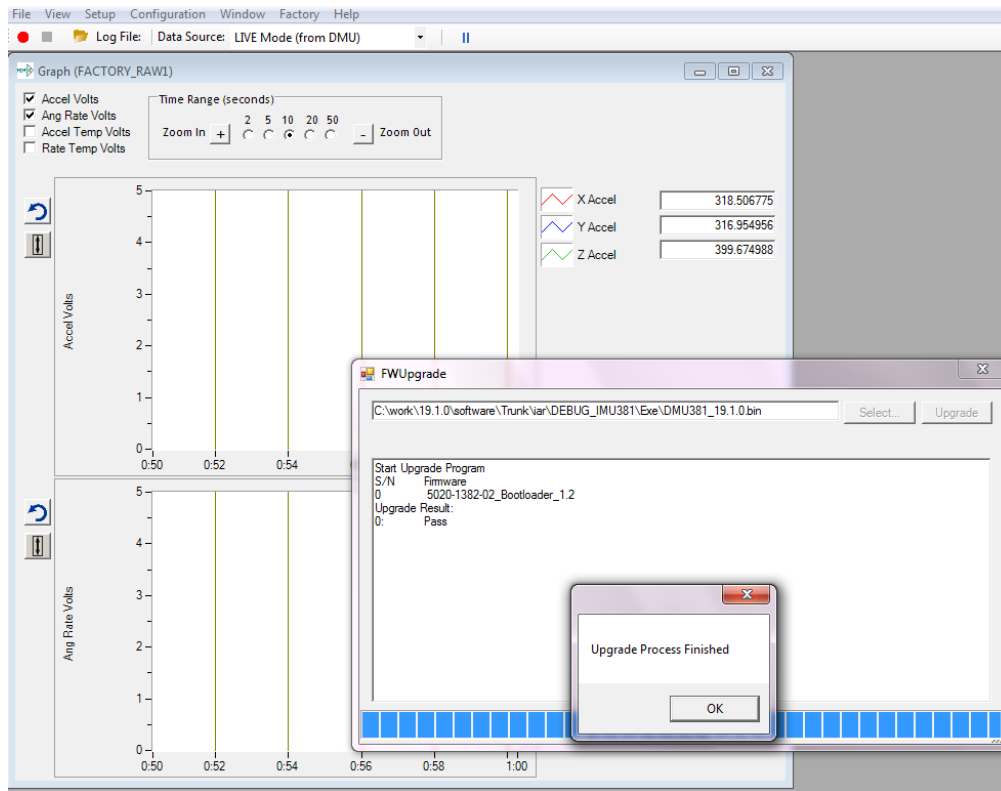


Figure 13 Firmware Upgrade 5

Appendix D: Response to ECU ID request example

1. ECU ID provides information on the ECU Model number, part number and serial number in ASCII form. For example:

MTLT335D,3327-01*2043604055* (28 bytes)

Where: MTLT335D – Model name
 3327-01 – Part number
 2043604055 – Unit Serial number

2. User send to IMU Get PGN 64965 message with the following payload in the Get PGN request.

Byte0	Byte1	Byte2
0xC5	0xFD	0x00

3. IMU responds with Transport Control Protocol (TP) RTS message (PGN 60416) with the following payload.

Byte	Value	Comment
0	0x10	RTS
1:2	0x001A	Total Response Size in Bytes
3	4	Total Number Of TP data packets to transfer ECU ID
4	4	Maximum Number Of TP data packets to be transferred
5	0xC5	PGN (LSB)
6	0xFD	PGN (MID)
7	0x00	PGN (MSB)

4. User responds to IMU with TP CTS message (PGN 60416) with the following payload:

Byte	Value	Comment
0	0x11	CTS
1	4	Total Number Of TP data packets to receive
2	1	Number of first packet
4:5		Reserved
5	0xC5	PGN (LSB)
6	0xFD	PGN (MID)
7	0x00	PGN (MSB)

5. Unit responds with back with the set of 4 TP data message:

```
1CEBAB80 01 4D 54 4C 54 33 33 35 ... MTLT335
1CEBAB80 02 44 2C 33 33 32 37 2D ... D,3327-
1CEBAB80 03 30 31 2A 32 30 34 33 ... 01*2043
1CEBAB80 04 36 30 34 30 35 35 2A ... 604055*
```

First byte in every packet is TP data packet number.

6. User responds to IMU with TP ACK message (PGN 60416) with next payload:

Byte	Value	Comment
0	0x13	ACK
1:2	0x001A	Total received message size (in Bytes)
3	4	Total Number Of TP data packets to received
4	4	Reserved
5	0xC5	PGN (LSB)
6	0xFD	PGN (MID)
7	0x00	PGN (MSB)

Appendix E: Response to SW Version request

- SW Version provides information on the bootloader and firmware version in ASCII form. For example:

BB0001,1.0.14#AP0101,6.06#* (27 bytes)

Where: BB0001,1.0.14 – Bootloader Version 01.0.14,

AP0101,6.06 – Application Version 06.06

- User send to IMU Get PGN 65242 message with the following payload in the Get PGN request.

Byte0	Byte1	Byte2
0xDA	0xFE	0x00

- IMU responds with TP RTS message (PGN 60416) with next payload

Byte	Value	Comment
0	0x10	RTS
1:2	0x001B	Total Response Size in Bytes
3	0x04	Total number of TP data packets to transfer ECU ID
4	0x04	Maximum Number Of TP data packets to be transferred
5	0xDA	PGN (LSB)
6	0xFE	PGN (MID)
7	0x00	PGN (MSB)

- User responds to IMU with TP CTS message (PGN 60416) with next payload:

Byte	Value	Comment
0	0x11	CTS
1	4	Total number of TP data packets to ready to receive
2	1	Number of first packet
4:5	0	Reserved
5	0xDA	PGN (LSB)
6	0xFE	PGN (MID)
7	0x00	PGN (MSB)

- Unit responds with back with the set of TP data message. Actual number of TP messages depends upon the boot loader and FW version. Here is an example:

1CEBAA80 Rx 8 01 42 42 30 30 30 31 2CBB0001,
 1CEBAA80 Rx 8 02 31 2E 30 2E 31 34 231.0.14#
 1CEBAA80 Rx 8 03 41 50 30 31 30 31 2CAP0101,
 1CEBAA80 Rx 8 04 36 2E 30 36 23 2A FF6.06#*ÿ
 First byte in every packet is TP data packet number.

5. User responds to IMU with TP ACK message (PGN 60416) with next payload:

Byte	Value	Comment
0	0x13	ACK
2:1	0x001B	Total received message size (in Bytes)
3	0x04	Total Number Of TP data packets to received
4	0x04	Reserved
5	0xDA	PGN (LSB)
6	0xFE	PGN (MID)
7	0x00	PGN (MSB)

Appendix F: FOM and BIT Examples

Below are some scenarios that can help guide users with using FOM and Built In Test (BIT).

Scenarios

- 1) During operation rate sensor (1) disagrees with the sensor (0) and sensor (2)
 - Master BIT [2] is set to 1 indicating there is a SW BIT set.
 - SW BIT [18] is set to 1 indicating that rate sensor (1) is excluded from the solution
 - FOM remains 00. MTLT335 continues to function normally excluding data from rate sensor (1) from the solution.
 - ACTION: No action required. If condition persists device can be replaced during regular machine service event.
- 2) Sensor (0) fails at startup self-test.
 - Master BIT [1] is set to 1 indicating there is a HW issue.
 - HW BIT [7] is set to 1 indicating sensor (0) failed
 - SW BIT [14] is set to 1 indicating acceleration data from sensor (0) is excluded from the solution
 - SW BIT [17] is set to 1 indicating rate data from sensor (0) is excluded from the solution
 - FOM remains 00. MTLT335 continues to function normally excluding failed sensor from the solution.
 - ACTION: No action required. If condition persists device can be replaced during regular machine service event.
- 3) Sensor (0) fails Self-test at startup AND during operation X, Y, or Z acceleration of the two remaining sensors are in found to be in disagreement.
 - Master BIT [1] is set to 1 indicating there is a HW issue
 - Master BIT [2] is set to 1 indicating a SW BIT error was detected
 - Master BIT [5] is set to 1 indicating the acceleration sensor is the problem
 - HW BIT [7] is set to 1 indicating acceleration sensor (0) failed
 - SW BIT [14] is set to 1 indicating acceleration data from sensor (0) is excluded from the solution
 - SW BIT [17] is set to 1 indicating rate from sensor (0) is excluded from the solution
 - SW BIT [20] is set to 1 indicating that the two remaining acceleration sensors are in disagreement
 - ACCS FOM of the X, Y or Z is set to 01 indicating degradation in acceleration output of that channel
 - ACTION: Stop using device for machine input. Reset or Power cycle device to try and clear condition. If condition persists replace device.
- 4) Algorithm Fails to complete initialization
 - Master BIT [2] is set to 1 indicating there is a SW BIT error
 - SW BIT [1] is set to 1 indicating the algorithm initialization took longer than 5 second
 - SW BIT [2] is set to 1 indicating the algorithm is still in the initialization state and unit is not ready
 - SSI2 FOM is set to 10 indicating there is an error.
 - ACTION: Stop using device for machine input. Reset or Power cycle device to try and clear condition. If condition persists replace device.

Appendix G: Advanced RS232 Port BIT

Built In Test (BIT) and Status Words

Master BIT Status Word

The Master BIT Status word is the global indication of health and status of the MTLT335 Series product. It contains the same information and has the same structure as Master BIT Status word which can be requested over CAN bus. Please refer to p. 5.1.4.7. Master status word is appended to every periodic data packet (A1, S1)

Software BIT Status Word

The Software BIT Status word contains the same information and has the same structure as Software BIT Status word which can be requested over CAN bus. Software status word can be requested via serial port as a part of T0 message. Please refer to p. 5.1.4.8.

Hardware BIT Status Word

The Hardware BIT Status word contains the same information and has the same structure as Hardware BIT Status word which can be requested over CAN bus. Hardware status word can be requested via serial port as a part of T0 message. Please refer to p. 5.1.4.9.

Appendix H: RS232 Sample Packet Decoding

