Telit wireless solutions

V33 CLDR Software User Guide

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Making machines talk.

APPLICABILITY TABLE

PRODUCT
SL869-ADR

SW Version
1.0.2-CLDR-4.7.5

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Contents

1. Introduction

1.1. Scope

The purpose of this document is to describe the Automotive Dead-reckoning (DR) extensions to the standard serial communications interface between any module in the V33 CLDR GNSS product family and a Host Processor. All non-DR message information can be found in the V33 Software User Guide and V33 Software Authorized User Guide listed in the Reference section below.

1.2. Audience

This document is intended only for distribution to Telit employees and to Automotive DR GNSS module customers who have signed a Non-Disclosure Agreement (NDA) with Telit Wireless. It can be used by potential automotive DR customers who are evaluating a module in the V33 CLDR product family, as well as by customers who are developing application software for their Host Processor in a device that incorporates the module.

1.3. Contact Information, Support

For general contact, technical support, to report documentation errors and to order manuals, contact Telit Technical Support Center (TTSC) at:

TS-EMEA@telit.com
TS-NORTHAMERICA@telit.com
TS-LATINAMERICA@telit.com
TS-APAC@telit.com

Alternatively, use:

http://www.telit.com/en/products/technical-support-center/contact.php

For detailed information about where you can buy the Telit modules or for recommendations on accessories and components visit:

http://www.telit.com

To register for product news and announcements or for product questions contact Telit Technical Support Center (TTSC).

Our aim is to make this guide as helpful as possible. Keep us informed of your comments and suggestions for improvements.

Telit appreciates feedback from the users of our information.

1.4. Document Organization

This document contains the following chapters:

Chapter 1: “Introduction” provides a scope for this document, target audience, contact and support information, and text conventions.

Chapter 2: “Overview” gives an overview of the V33 CLDR module family and introduces the serial communications interface.

Chapter 3: “DR Commands” describes in detail each of the DR related commands.

Chapter 4: “DR Messages” describes in detail each of the DR related messages.

Chapter 5: “Document History” provides a list of the changes made to this User Guide.

1.5. Text Conventions

Danger – This information MUST be followed or catastrophic equipment failure or bodily injury may occur.

Caution or Warning – Alerts the user to important points about integrating the module, if these points are not followed, the module and end user equipment may fail or malfunction.

Tip or Information – Provides advice and suggestions that may be useful when integrating the module.

All dates are in ISO 8601 format, i.e. YYYY-MM-DD.

1.6. Related Documents

1. V33 Software User Guide, 1VV0301317
2. V33 Software Authorized User Guide, 1VV0301319

2. Overview

Automotive DR modules are GNSS receiver modules that are intended for use in automotive dead-reckoning (DR) applications. The firmware within the DR module includes an automotive DR feature set that allows the module to continue to provide periodic estimates of position and velocity after satellite-based navigational fixes have been lost. Thus for example the DR module can continue to update vehicle position inside traffic tunnels or underneath large parking structures. These position and velocity estimates are based upon previously known navigational solutions obtained via the GNSS system, which are then propagated using information provided by external sensors.

The V33 CLDR module family employs a “classical” approach to automotive DR. This means that, in order to perform dead-reckoned positioning, it uses heading information from a gyroscope, speed information from an odometer, and an indication of forward or reverse vehicle movement.

2.1. Communication Interface

The serial communication interface between the receiver module and the Host processor is based on the NMEA-0183 protocol standard specified by the National Marine Electronics Association (NMEA). More information regarding the NMEA protocol and its use by the Telit GNSS module family can be found in Section 2 of the Software User Guides listed as References 1 and 2 in the Introduction above.

Serial communication with the CLDR module is conducted only over the UART port. V33 CLDR modules do not support a USB interface. The default port settings are:

115200 Baud

Eight data bits

No parity bits

One stop bit

Information regarding automotive DR operation, including data from the external sensors, is output within a set proprietary NMEA DR messages, which is described in Section 3.

2.2. Sensors

The CLDR module firmware requires the following sensor inputs in order for the automotive DR feature to function:

- Three-axis MEMS digital gyroscope
- Three-axis MEMS digital accelerometer
- Odometer (wheel tick) pulse train
- Forward/Reverse input signal

The gyroscope and accelerometer are integrated into a single MEMS device called an Inertial Measurement Unit (IMU), which is included within the V33 CLDR module. The odometer and forward/reverse signals are provided to the module from external sources. Sensor inputs are sampled by the firmware at a rate of 15Hz.

More information regarding these sensor inputs can be found in the Product User Guide for a given module within the V33 CLDR product family.

2.2.1. Gyroscope

The digital gyroscope provides heading information to the DR firmware. Digital readings from the gyro are calibrated by the firmware using GNSS navigational fixes so that they can be interpreted correctly.

2.2.2. Accelerometer

The digital accelerometer provides information regarding the gravity vector relative to the orientation of the module, which in turn is used to determine the tilt of the gyro due to installation orientation or to slope of the terrain. The tilt of the gyro must also be known in order for its digital readings to be interpreted correctly.

2.2.3. Odometer

A discrete odometer or wheel tick pulse train input signal is used to provide speed information to the DR firmware. The scale factor of the pulse train as it relates to vehicle speed is calibrated by the firmware using GNSS navigational fixes so that pulse count and frequency can be correctly converted to speed.

2.2.4. Forward/Reverse

A discrete input signal is required to provide an indication as to whether the vehicle is moving in the forward or reverse direction. By default a logical high on this signal is interpreted as reverse movement.

2.2.5. Sensor Calibration

Calibration of sensor data is performed automatically by the DR firmware. The calibration process must be completed in order for the automotive DR feature to operate correctly and provide good position and velocity updates when GNSS navigation is lost. Status information regarding the calibration process is provided in the $PSTMCAL message described later in this document.

2.3. Installation Orientation

Modules in the V33 CLDR product family are able to accommodate any installation orientation within the vehicle, provided that the installation is fixed and does not experience any displacement or rotation.

The DR firmware supports installation orientations in two phases. Firstly, the firmware can be configured to use a sensor reference frame that is oriented orthogonally to the vehicle reference frame in some way. Thus a module mounted on its side or mounted upside down can be supported. By factory default, the firmware assumes that the module is mounted flat and upright with no tilt, and that it is oriented as described in the EVK User Guide for the specific module.

Secondly, any mismatch between the gyro and vehicle reference frames (tilt) can be estimated by the firmware. Or if known, the tilt angles can be set using $PSTMSETPAR commands. The tilt is comprised of two installation angles; pitch, and roll. Each of these installation angles can have values of up to 45 degrees.

Configuration of alternative orientations is described in the referenced Automotive DR Configuration Application Note (Reference 3).

3. DR Commands

The table below lists the commands used for managing the Automotive DR feature. These commands are echoed by the V33 CLDR module back to the Host after the command is executed.

Command ID	Description
PSTMSETPAR	Set a configuration parameter
$PSTMNVMITEMINV	Invalidate stored DR data in non-volatile memory,

3.1. PSTMSETPAR

This command is used to set or modify a system parameter in the module configuration data, and it is introduced in the V33 Software Authorized User Guide. It can be used to configure certain parameters related to the Automotive DR feature as shown below.

It is important to note that after parameter values have been changed, the $PSTMSAVEPAR command must be sent in order to store the updated values in flash. Once the values are stored in flash, the V33 CLDR module must be given a system reset command or a power cycle in order for the new values to take effect.

3.1.1. Default Odometer Scale

The default odometer scale factor is used as an initial value for the scale factor prior to being calibrated. The factory default is 0.4 meters per pulse. The default value can be changed using the command:

```
$PSTMSETPAR,1656,<value><cr><lf>
```

where `value` is the odometer scale factor in meters per pulse, multiplied by 100000, in hexadecimal.

Example:

Set the default odometer scale factor to 0.5 meters/pulse.

```
$PSTMSETPAR,1656,C350
```

3.1.2. Installation Angles

The default installation pitch and roll (tilt) and yaw angles of the gyro are set to 0 degrees at the factory, i.e. there is no misalignment between the sensor and vehicle reference frames (see section 2.3). In cases where the installation angles are non-zero, the angles can be configured manually if their values are known. The installation angles can be configured using the command:

`$PSTMSETPAR,1668,<mask><cr><lf>`

where `mask` specifies each of the installation angles and is formatted as shown in the table below.

Bits	Values	Description
b0 .. b8	0 to 45, 315 to 359 degrees, expressed in hexadecimal	Installation (mounting) gyro yaw angle.
b9 .. b17	0 to 45, 315 to 359 degrees, expressed in hexadecimal	Installation (mounting) gyro roll angle.
b18 .. b26	0 to 45, 315 to 359 degrees, expressed in hexadecimal	Installation (mounting) gyro pitch angle.
b27.. b31	0	Reserved

Note that installation angles are always specified as positive numbers, thus for example -30 degrees is specified as 330 degrees.

Example:

Set the default installation pitch angle to -30 degrees and leave roll and yaw at 0. In this case the sensor is tilted forward and down 30 degrees.

`$PSTMSETPAR,1668,5280000`

Example:

In addition to the -30 degree pitch angle, set the default installation yaw angle to -45 degrees. In this case the sensor is rotated counter-clockwise 45 degrees when viewed from above, then tilted forward and down 30 degrees.

`$PSTMSETPAR,1668,528002D`

Note: In modules where an accelerometer is present, pitch and roll angles that have been set manually will be overridden by the auto-tilt algorithm.

3.1.3. Sensor Frame Orientation

The default sensor frames are configured to reflect that the gyro and accelerometer are mounted horizontally flat and upright as per the EVK User Guide for the given specific module. The firmware can be configured for alternative orientations that are orthogonal to the vehicle frame, for example if the gyro is mounted vertically on one side. The default sensor frame orientation can be changed using the command:

```
$PSTMSETPAR,1669,<value><cr><lf>
```

where `value` is a descriptor relating the sensor frames of the gyro and accelerometer to the vehicle reference frame. Descriptors for specific orientations can be found in EVK User Guide for the given specific module. For descriptors not found in the EVK User Guide, please contact Technical Support.

Example:

Set the sensor frame orientation for an SL869-ADR module that is rotated 180 degrees around a vertical axis from the default orientation shown in the SL869 EVK User Guide.

```
$PSTMSETPAR,1669,801E3FE3
```

3.1.4. Output Message Enable

The DR messages output by the module are controlled by a bitmap parameter containing assigned bits which are used to enable and disable individual messages. DR messages can be enabled or disabled using the command

```
$PSTMSETPAR,1228,<mask><mode><cr><lf>
```

where `mask` is a value representing the bit assignment(s) for the message or messages to be controlled. The message will be enabled if `mode` is 1, or it will be disabled if `mode` is 2.

The table below lists the bit masks for DR messages supported by modules in the V33 CLDR product family.

Message	Default	Mask
PSTMDRCAL	On	0x800000
PSTMDRGPS	On	0x1000000
PSTMDRDEBUG [1]	Off	0x2000000
PSTMDRSTEP [1]	Off	0x2000000
PSTMDRUPD [1]	Off	0x2000000
PSTMDRTUNNEL [1]	Off	0x2000000
PSTMDRSTATE	On	0x4000000

Message	Default	Mask
PSTM3DGYRO [2]	On	0x10000000
PSTM3DACC [2]	On	0x10000000
PSTMDRAHRS	On	0x20000000

Note 1: This group of messages controlled by a common bit.

Note 2: This pair of messages controlled by a common bit.

Example:

Disable output of the PSTM3DGYRO and PSTM3DACC messages:

```
$PSTMSETPAR,1228,10000000,2
```

3.2. PSTMNVMITEMINV

This command can be used to clear the automotive dead-reckoning data stored in non-volatile memory. It is intended to be used only under special circumstances, such as testing, or when there has been a change in the way the module has been installed. More specifically, it is intended to be used to clear DR data in cases where the automotive DR function is to be re-calibrated. The command is:

```
$PSTMNVMITEMINV,80,1<cr><lf>
```

Once the command has been sent, the V33 CLDR module must be given a system reset command or a power cycle in order for the DR data to be cleared.

Use this command with caution. Once it is sent, all calibration data will be lost, and the module DR feature will have to be re-calibrated.

4. DR Messages

The table below summarizes the messages that are related to the automotive DR feature and are output by modules in the V33 CLDR product family. These messages are available to authorized users of these modules.

Most messages are output once per second. Messages that are not output at one Hz are noted in the subsections below.

Message ID	Description
$PSTM3DGYRO	Three-axis gyroscope and odometer data
$PSTM3DACC	Three-axis accelerometer data
$PSTMDRSTATE	DR Kalman state variables
$PSTMDRGPS	GNSS solution data
$PSTMDRDEBUG	Delta values between GNSS solution and DR Kalman state
$PSTMDRSTEP	Integrated values and averages of DR sensor data
$PSTMDRUPD	Delta values between previous and updated DR Kalman state
$PSTMDRTUNNEL	Calculated DR metrics from last GNSS outage
$PSTMDRCAL	Sensor calibration status
$PSTMDRAHRS	Gyroscope installation angles

4.1. $PSTM3DGYRO

This periodic output message reports the raw MEMS three-axis gyroscope angular rate data, as well as the odometer count and reverse indicator. It is output at the DR sensor sampling rate, which is 15Hz.Note that this message will not be output if the DR module is unable to communicate with the MEMS gyroscope.

Format:

```
$PSTM3DGYRO,<CpuTime>,<RawX>,<RawY>,<RawZ>,<Odometer>,
<Reverse>*<checksum><cr><lf>
```

Parameter	Format	Description
CpuTime	Decimal, 10 digits	32-bit time tag
RawX	Decimal, 5 digits	Raw signed 16-bit X-axis angular rate
RawY	Decimal, 5 digits	Raw signed 16-bit Y-axis angular rate
RawZ	Decimal, 5 digits	Raw signed 16-bit Z-axis angular rate
Odometer	Decimal, 5 digits	Unsigned 16-bit odometer count
Reverse	One digit	0 = forward, 1 = reverse

4.2. $PSTM3DACC

This periodic output message reports the raw acceleration data from the three-axis MEMS accelerometer. The message is output at the DR sensor sampling rate, which is 15Hz. Note that this message will not be output if the DR module is unable to communicate with the MEMS accelerometer.

Format:

```
$PSTM3DACC,<CpuTime>,<RawX>,<RawY>,<RawZ>*<checksum><cr><lf>
```

Parameter	Format	Description
CpuTime	Decimal, 10 digits	32-bit time tag
RawX	Decimal, 5 digits	Raw signed 16 bit X-axis acceleration
RawY	Decimal, 5 digits	Raw signed 16 bit Y-axis acceleration
RawZ	Decimal, 5 digits	Raw signed 16 bit Z-axis acceleration

4.3. $PSTMDRSTATE

This message reports the values of the Automotive DR Kalman filter state variables.

Format:

```
$PSTMDRSTATE,<CpuTime>,<Lat>,<Lon>,<Heading>,<Speed>,
<GyroOffset>,<GyroGain>,<OdoScale>,<GyroOvsT>,<AccOffset>,
<Alt>*<checksum><cr><lf>
```

Parameter	Format	Description
CpuTime	Decimal, 10 digits	32-bit time tag
Lat	Double, 5 significant digits	DR latitude in degrees
Lon	Double, 5 significant digits	DR longitude in degrees
Heading	Double, 5 significant digits	DR heading in degrees, -180 to +180
Speed	Double, 5 significant digits	DR speed in meters/second
GyroOffset	Double, 4 significant digits	Gyroscope offset in volts
GyroGain	Double, 4 significant digits	Gyroscope gain in (Radians/s)/Volt
OdoScale	Double, 5 significant digits	Odometer scale factor in meters/pulse
GyroOvsT	Double, 6 significant digits	Gyroscope offset versus temperature coefficient in Volt/^{0}C
AccOffset	Double, 6 significant digits	Accelerometer offset in g's
Alt	Double, 1 significant digit	DR altitude in meters, relative to WGS-84

4.4. $PSTMDRGPS

This message reports the non-augmented GNSS solution data and GNSS fix quality metrics.

Format:

```
$PSTMDRGPS,<Lat>,<Lon>,<Vn>,<Ve>,<Pdop>,<Hdop>,<Vdop>,
<PosRes>,<VelRes>,<Vv>,<Alt>*<checksum><cr><lf>
```

Parameter	Format	Description
Lat	Double, 9 significant digits	GNSS latitude degrees
Lon	Double, 9 significant digits	GNSS longitude degrees
Vn	Double, 5 significant digits	Velocity north vector component, in meters/second
Ve	Double, 5 significant digits	Velocity east vector component, in meters/second
Pdop	Double, 5 significant digits	Position dilution of precision
Hdop	Double, 5 significant digits	Horizontal dilution of precision
Vdop	Double, 5 significant digits	Vertical dilution of precision
PosRes	Double, 5 significant digits	RMS position residual in meters
VelRes	Double, 5 significant digits	RMS velocity residual in meters/second
Vv	Double, 5 significant digits	Velocity vertical vector component, in meters/second
Alt	Double, 1 significant digit	GNSS altitude in meters

4.5. $PSTMDRDEBUG

This message reports the difference in values between certain key corresponding GNSS Kalman solution variables and Automotive DR Kalman state variables.

Format:

```
$PSTMDRDEBUG,<LatError>,<LonError>,<HdgError>,<SpdError>,
<HgtError>,<VvError>*<checksum><cr><lf>
```

Parameter	Format	Description
LatError	Double, 1 significant digit	Latitude error meters
LonError	Double, 1 significant digit	Longitude error meters
HdgError	Double, 1 significant digit	Heading error in degrees
SpdError	Double, 1 significant digit	Horizontal speed error in meters/second
AltError	Double, 1 significant digit	Altitude error in meters
VvError	Double, 1 significant digit	Vertical velocity error in meters/second

4.6. $PSTMDRSTEP

This message reports integrated values and averages of sampled DR sensor data between the two previous consecutive GNSS fixes that occurred over the last one second. This is useful for debugging purposes in assessing whether the odometer count is incremented as expected, whether the number of samples is as expected, whether the sample delta times add up to approximately one second, and whether the average gyro voltage is reasonable.

Format:

```
$PSTMDRSTEP,<Samples>,<GyroAvg>,<GyroNoise>,<TotalOdoStep>,
<DeltaOdoCount>,<DeltaCpuTime>,<DeltaCpuTime2>,<ValidOdo>
*<checksum><cr><lf>
```

Parameter	Format	Description
Samples	Decimal, 2 digits	Number of samples. Should be 15 when sampling at 15Hz.
GyroAvg	Double, 5 significant digits	Average gyro yaw rate voltage over the last second
GyroNoise	Double, 5 significant digits	Gyro voltage variation
TotalOdoStep	Decimal, 5 digits	Total sum of the odometer increments obtained from samples between GNSS fixes [1]
DeltaOdoCount	Decimal, 5 digits	Difference between final odo count value before latest GNSS fix and initial odo count value before previous GNSS fix [1]
DeltaCpuTime	Double, 3 significant digits	Cumulative sum of the CPU time stamp increments between all samples taken between the last two GNSS fixes [2]
DeltaCpuTime2	Double, 3 significant digits	Time in seconds between the first and last DR sample CPU time stamps taken between the last two GNSS fixes [2]
OdoValid	Boolean	0 = invalid odometer 1 = valid odometer [3]

Notes 1 and 2: These two fields should have the same value. If not, it indicates an issue with DR functionality.

Note 3: The odometer is considered valid as long as there are no large discontinuities in the odometer samples.

4.7. $PSTMDRUPD

This message reports the difference in the DR Kalman state variables that were a result of the DR Kalman filter update that was calculated the previous second.

Format:

```
$PSTMDRUPD,<Lat>,<Lon>,<Heading>,<GyroGain>,<GyroOffset>,
<OdoScale>,<GyroOvsT>,<AccOffset>,<Alt>*<checksum><cr><lf>
```

Parameter	Format	Description
Lat	Double, 5 significant digits	Latitude difference in decimal degrees
Lon	Double, 5 significant digits	Longitude difference in decimal degrees
Heading	Double, 4 significant digits	Heading difference in degrees, ranging from -180 to +180
GyroGain	Double, 4 significant digits	Gyro gain difference in (radians/s)/millivolt
GyroOffset	Double, 4 significant digits	Gyro offset difference in millivolts
OdoScale	Double, 4 significant digits	Odometer scale factor difference in millimeters/pulse
GyroOvsT	Double, 6 significant digits	Change in coefficient of gyro offset vs temperature in volts/^{0}C
AccOffset	Double, 6 significant digits	Accelerometer offset difference in g's
Alt	Double, 1 significant digit	Altitude difference in meters

4.8. $PSTMDRTUNNEL

This message reports various DR metrics calculated during the last GNSS outage. It is not output periodically, but rather it is output each time that the DR feature has determined that there has been a GNSS outage, i.e. the vehicle has travelled through a tunnel. Note that these metrics may be approximate due to the conditions by which the algorithm determines tunnel start and stop not being absolute.

Format:

```
$PSTMDRTUNNEL,<Exit>,<Duration>,<Length>,<HdgError>,
<YawRateError>,<CalError>,<PosError>,<PosErrorRatio>,
<NoiseError>*<checksum><cr><lf>
```

Parameter	Format	Description
Exit	boolean	1 indicates that a tunnel was exited.
Duration	Decimal, 5 digits	Number of seconds estimated to have been traveling in a tunnel.
Length	Double, 4 significant digits	Approximated tunnel length in meters
HdgError	Double, 4 significant digits	Approximated heading error at tunnel exit in degrees
YawRateError	Double, 4 significant digits	Approximated yaw rate error at tunnel exit in degrees/second
CalError	Double, 4 significant digits	Approximated gyro gain error at tunnel exit in millivolts
PosError	Double, 4 significant digits	Approximated position error at tunnel exit in meters
PosErrorRatio	Double, 4 significant digits	Approximated position error at tunnel exit as a percent of approximated tunnel length
NoiseError	Double, 4 significant digits	Calculated gyro noise error in degrees

4.9. $PSTMDRAHRS

This message reports the gyro pitch angle (degrees), gyro yaw angle (degrees), and gyro roll angle (degrees). Reported yaw angle is always zero.

Format:

```
$PSTMDRAHRS,<Pitch>,<Roll>,<Yaw>,<Slope>,<Accuracy>,<Reserved>
*<checksum><cr><lf>
```

Parameter	Format	Description
Pitch	ddd.dd	Sensor frame pitch angle relative to vehicle frame in degrees
Roll	ddd.dd	Sensor frame roll angle relative to vehicle frame in degrees
Yaw	ddd.dd	Sensor fame yaw angle relative to vehicle frame in degrees
Slope	ddd.dd	Estimated slope of tilt
Accuracy	ddd.dd	Estimated slope accuracy
Reserved		Reserved field

4.10. $PSTMDRCAL

This message reports the calibration status of the gyroscope and odometer sensor inputs.

Format:

```
$PSTMDRCAL,<DrCalibrated>,<OdoCalibrated>,<GainCalibrated>,
<OffsetCalibrated>,<Reserved>*<checksum><cr><lf>
```

Parameter	Format	Description
DrCalibrated	boolean	1 = DR is fully calibrated 0 = DR is not yet calibrated
OdoCalibrated	boolean	1 = Odometer scale factor is calibrated 0 = Odometer scale factor is not calibrated
GainCalibrated	boolean	1 = gyro gain is calibrated 0 = gyro gain is not calibrated
OffsetCalibrated	boolean	1 = gyro offset is calibrated 0 = gyro offset is not calibrated
Reserved		Reserved field
GyroValid	boolean	1 = gyro data communication is valid 0 = gyro data communication is faulty
AccValid	boolean	1 = accelerometer data communication is valid 0 = accelerometer data communication is faulty

5. Document History

Revision	Date	Changes
0	2016-10-31	First issue