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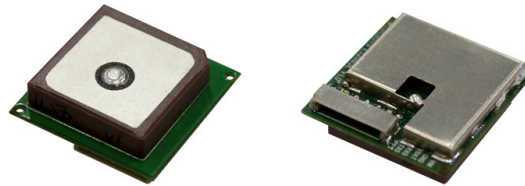| Product name	Description	Version
LS2003E	Standalone GPS smart antenna module	1.1

22 x 22 x 7.5 mm

1   Introduction

LS2003E is a complete standalone GPS smart antenna module, including embedded patch antenna and GPS receiver circuits. The module is powered by MediaTek GPS chip and can acquire a lot of satellites at a time while providing fast time-to-first-fix and low power consumption. Besides, it can provide you with superior sensitivity and performance even in urban canyon and dense foliage environment.

This module supports hybrid ephemeris prediction to achieve faster cold start. One is self-generated ephemeris prediction (called EASY) that is no need of both network assistance and host CPU's intervention. This is valid for up to 3 days and updates automatically from time to time when GPS module is powered on and satellites are available. The other is server-generated ephemeris prediction (called EPO) that gets from an internet server. This is valid for up to 14 days. Both ephemeris predictions are stored in the on-board flash memory and perform a cold start time less than 15 seconds.

It is easy to install without both RF connector and coaxial cable that are needed in a separated GPS active antenna. In other words, reduce the cost and size. Also, speed up the time to market by eliminating R&D efforts on RF matching and stability between separated GPS antenna and module. Furthermore, it can be directly powered by a lithium battery without any external voltage regulars. Therefore, LS2003E of miniature size and brilliant performance is the best choice to be integrated into your slim devices.

2   Features
- MediaTek high sensitivity solution
- Support 66-channel GPS
- Ultra low power consumption
- Fast TTFF at low signal level
- Built-in 12 multi-tone active interference canceller
- Free hybrid ephemeris prediction to achieve faster cold start
- Built-in data logger
- Built-in DC/DC converter to save power
- Allow direct connection with the lithium battery
- Up to 10 Hz update rate
- ±11ns high accuracy time pulse (1PPS)
- Capable of SBAS (WAAS, EGNOS, MSAS, GAGAN)
- Support Japan QZSS
- Indoor and outdoor multi-path detection and compensation
- RoHS compliant

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3　Application

- Personal positioning and navigation
- Automotive navigation
- Marine navigation
- Weather balloon

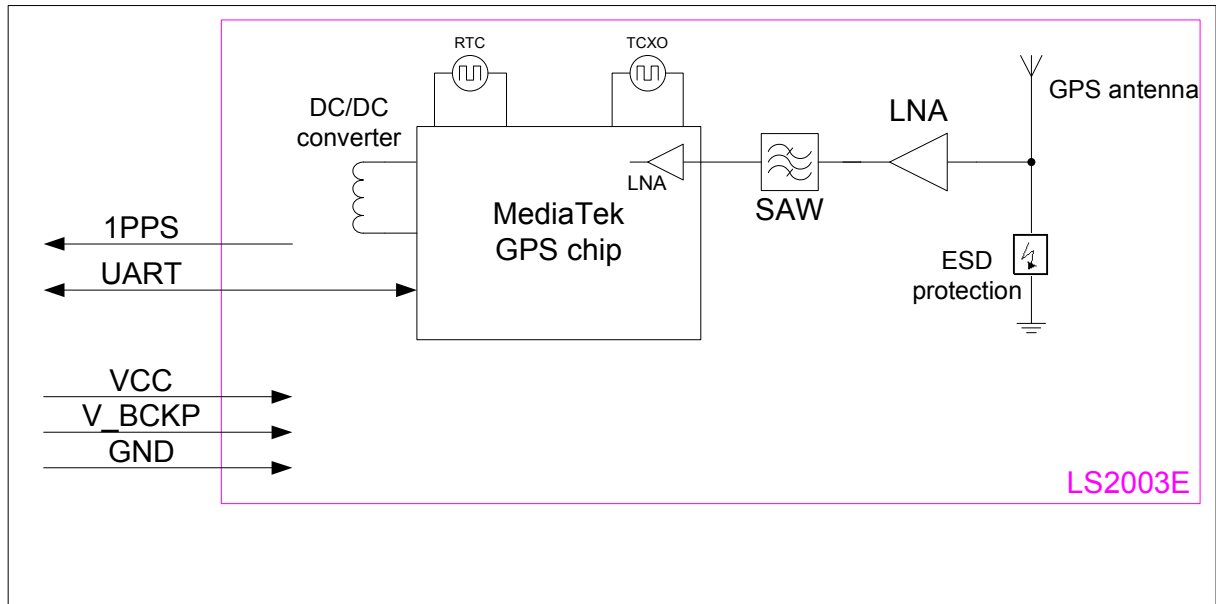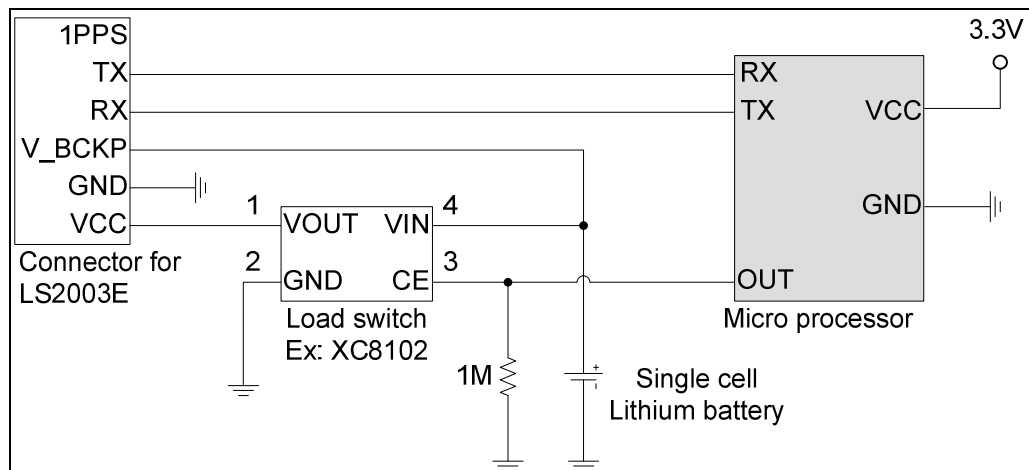Fig 3-1 System block diagram of LS2003E

Fig 3-2 Typical application circuit that directly uses lithium battery to save power.

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4 GPS receiver and antenna

4.1 GPS receiver

Chip	MediaTek MT3339	
Frequency	L1 1575.42MHz, C/A code	
Channels	Support 66 channels (22 Tracking, 66 Acquisition)	
Update rate	1Hz default, up to 10Hz	
Acquisition Time	Hot start (Open Sky)	< 1s (typical)
	Cold Start (Open Sky)	33s (typical) without AGPS
		< 15s (typical) with AGPS (hybrid ephemeris prediction)
Position Accuracy	Autonomous	3m (2D RMS)
	SBAS	2.5m (depends on accuracy of correction data)
Datum	WGS-84 (default)	
Max. Altitude	< 50,000 m	
Max. Velocity	< 515 m/s	
Protocol	NMEA 0183 ver 3.01	9600 bps [1], 8 data bits, no parity, 1 stop bits
		1Hz: GGA, GLL, GSA, GSV, RMC, VTG

Note 1: Both baud rate and output message rate are configurable.

4.2 GPS antenna

Antenna type	Patch antenna (4mm thickness)
Polarization	RHCP
Frequency Range	1575.42MHz ± 1.023MHz [1]
Gain	2 dBic Typ. @zenith [1]
Axial ratio	Max 4.0dB @zenith [1]

Note 1: This value is measured with the evaluation board and must be fine tuned when installed into your device. Please contact LOCOSYS for your antenna tuning.

5 Software interface

5.1 NMEA output message

Table 5.1-1 NMEA output message

NMEA record	Description
GGA	Global positioning system fixed data
GLL	Geographic position - latitude/longitude
GSA	GPS DOP and active satellites
GSV	GPS satellites in view
RMC	Recommended minimum specific GPS data
VTG	Course over ground and ground speed

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● GGA--- Global Positioning System Fixed Data

Table 5.1-2 contains the values for the following example:

$GPGGA,053740.000,2503.6319,N,12136.0099,E,1,08,1.1,63.8,M,15.2,M,,0000*64

Table5.1- 2 GGA Data Format

Name	Example	Units	Description
Message ID	$GPGGA		GGA protocol header
UTC Time	053740.000		hhmmss.sss
Latitude	2503.6319		ddmm.mmmm
N/S indicator	N		N=north or S=south
Longitude	12136.0099		dddmm.mmmm
E/W Indicator	E		E=east or W=west
Position Fix Indicator	1		See Table 5.1-3
Satellites Used	08		Range 0 to 12
HDOP	1.1		Horizontal Dilution of Precision
MSL Altitude	63.8	mters	
Units	M	mters	
Geoid Separation	15.2	mters	
Units	M	mters	
Age of Diff. Corr.		second	Null fields when DGPS is not used
Diff. Ref. Station ID	0000		
Checksum	*64		
<CR> <LF>			End of message termination

Table 5.1-3 Position Fix Indicators

Value	Description
0	Fix not available or invalid
1	GPS SPS Mode, fix valid
2	Differential GPS, SPS Mode, fix valid
3-5	Not supported
6	Dead Reckoning Mode, fix valid

● GLL--- Geographic Position – Latitude/Longitude

Table 5.1-4 contains the values for the following example:

$GPGLL,2503.6319,N,12136.0099,E,053740.000,A,A*52

Table 5.1-4 GLL Data Format

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Name	Example	Units	Description
Message ID	$GPGLL		GLL protocol header
Latitude	2503.6319		ddmm.mmmm
N/S indicator	N		N=north or S=south
Longitude	12136.0099		dddmm.mmmm
E/W indicator	E		E=east or W=west
UTC Time	053740.000		hhmmss.sss
Status	A		A=data valid or V=data not valid
Mode	A		A=autonomous, D=DGPS, E=DR, N=Data not valid, R=Coarse Position, S=Simulator
Checksum	*52		
<CR> <LF>			End of message termination

● **GSA---GPS DOP and Active Satellites**

Table 5.1-5 contains the values for the following example:

$GPGSA,A,3,24,07,17,11,28,08,20,04,,,,,2.0,1.1,1.7*35

Table 5.1-5 GSA Data Format

Name	Example	Units	Description
Message ID	$GPGSA		GSA protocol header
Mode 1	A		See Table 5.1-6
Mode 2	3		See Table 5.1-7
ID of satellite used	24		Sv on Channel 1
ID of satellite used	07		Sv on Channel 2
….			….
ID of satellite used			Sv on Channel 12
PDOP	2.0		Position Dilution of Precision
HDOP	1.1		Horizontal Dilution of Precision
VDOP	1.7		Vertical Dilution of Precision
Checksum	*35		
<CR> <LF>			End of message termination

Table 5.1-6 Mode 1

Value	Description
M	Manual- forced to operate in 2D or 3D mode
A	Automatic-allowed to automatically switch 2D/3D

Table 5.1-7 Mode 2

Value	Description
1	Fix not available

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2	2D
3	3D

● **GSV---GPS Satellites in View**

Table 5.1-8 contains the values for the following example:

$GPGSV,3,1,12,28,81,285,42,24,67,302,46,31,54,354,,20,51,077,46*73

$GPGSV,3,2,12,17,41,328,45,07,32,315,45,04,31,250,40,11,25,046,41*75

$GPGSV,3,3,12,08,22,214,38,27,08,190,16,19,05,092,33,23,04,127,*7B

Table 5.1-8 GSV Data Format

Name	Example	Units	Description
Message ID	$GPGSV		GSV protocol header
Total number of messages[1]	3		Range 1 to 3
Message number[1]	1		Range 1 to 3
Satellites in view	12		
Satellite ID	28		Channel 1 (Range 01 to 196)
Elevation	81	degrees	Channel 1 (Range 00 to 90)
Azimuth	285	degrees	Channel 1 (Range 000 to 359)
SNR (C/No)	42	dB-Hz	Channel 1 (Range 00 to 99, null when not tracking)
Satellite ID	20		Channel 4 (Range 01 to 196)
Elevation	51	degrees	Channel 4 (Range 00 to 90)
Azimuth	077	degrees	Channel 4 (Range 000 to 359)
SNR (C/No)	46	dB-Hz	Channel 4 (Range 00 to 99, null when not tracking)
Checksum	*73		
<CR> <LF>			End of message termination

1. Depending on the number of satellites tracked multiple messages of GSV data may be required.

● **RMC---Recommended Minimum Specific GPS Data**

Table 5.1-9 contains the values for the following example:

$GPRMC,053740.000,A,2503.6319,N,12136.0099,E,2.69,79.65,100106,,,A*53

Table 5.1-9 RMC Data Format

Name	Example	Units	Description
Message ID	$GPRMC		RMC protocol header
UTC Time	053740.000		hhmmss.sss
Status	A		A=data valid or V=data not valid
Latitude	2503.6319		ddmm.mmmm
N/S Indicator	N		N=north or S=south
Longitude	12136.0099		dddmm.mmmm

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E/W Indicator	E		E=east or W=west
Speed over ground	2.69	knots	True
Course over ground	79.65	degrees	
Date	100106		ddmmyy
Magnetic variation		degrees	
Variation sense			E=east or W=west (Not shown)
Mode	A		A=autonomous, D=DGPS, E=DR, N=Data not valid, R=Coarse Position, S=Simulator
Checksum	*53		
<CR> <LF>			End of message termination

● **VTG---Course Over Ground and Ground Speed**

Table 5.1-10 contains the values for the following example:

$GPVTG,79.65,T,,M,2.69,N,5.0,K,A*38

Table 5.1-10 VTG Data Format

Name	Example	Units	Description
Message ID	$GPVTG		VTG protocol header
Course over ground	79.65	degrees	Measured heading
Reference	T		True
Course over ground		degrees	Measured heading
Reference	M		Magnetic
Speed over ground	2.69	knots	Measured speed
Units	N		Knots
Speed over ground	5.0	km/hr	Measured speed
Units	K		Kilometer per hour
Mode	A		A=autonomous, D=DGPS, E=DR, N=Data not valid, R=Coarse Position, S=Simulator
Checksum	*38		
<CR> <LF>			End of message termination

5.2 Proprietary NMEA input message

Please refer to MTK proprietary message.

5.3 Examples to configure the power mode of GPS module

5.3.1 Standby mode

User can issue software command to make GPS module go into standby mode that consumes less than 200uA current. GPS module will be awaked when receiving any byte.

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The following flow chart is an example to make GPS module go into standby mode and then wake up.

```
        ┌───────────┐
        │   Start   │
        └───────────┘
              │
              ▼
   ┌─────────────────────┐
   │ GPS module is powered on │
   │ and in normal operation mode │
   └─────────────────────┘
              │
              ▼
   ┌─────────────────────┐          unsigned char StandbyMode[] = {"$PMTK161,0*28\x0D\x0A"};
   │    Change GPS to    │
   │    standby mode     │
   └─────────────────────┘
              │
              ▼
          ◇─────────◇
         ╱  Wake up   ╲         Yes
        ◇  GPS module  ◇──────────────┐
         ╲            ╱               │
          ◇─────────◇                 ▼
              │            ┌─────────────────────┐
              │ No         │   Issue any byte to  │
              │            │  wake up GPS module  │
              │            └─────────────────────┘
              │                       │    GPS module will return {"$PMTK010,002*2D\x0D\x0A"}
              │◄──────────────────────┘    and start normal operation.
              ▼
        ┌───────────┐
        │    End    │
        └───────────┘
```
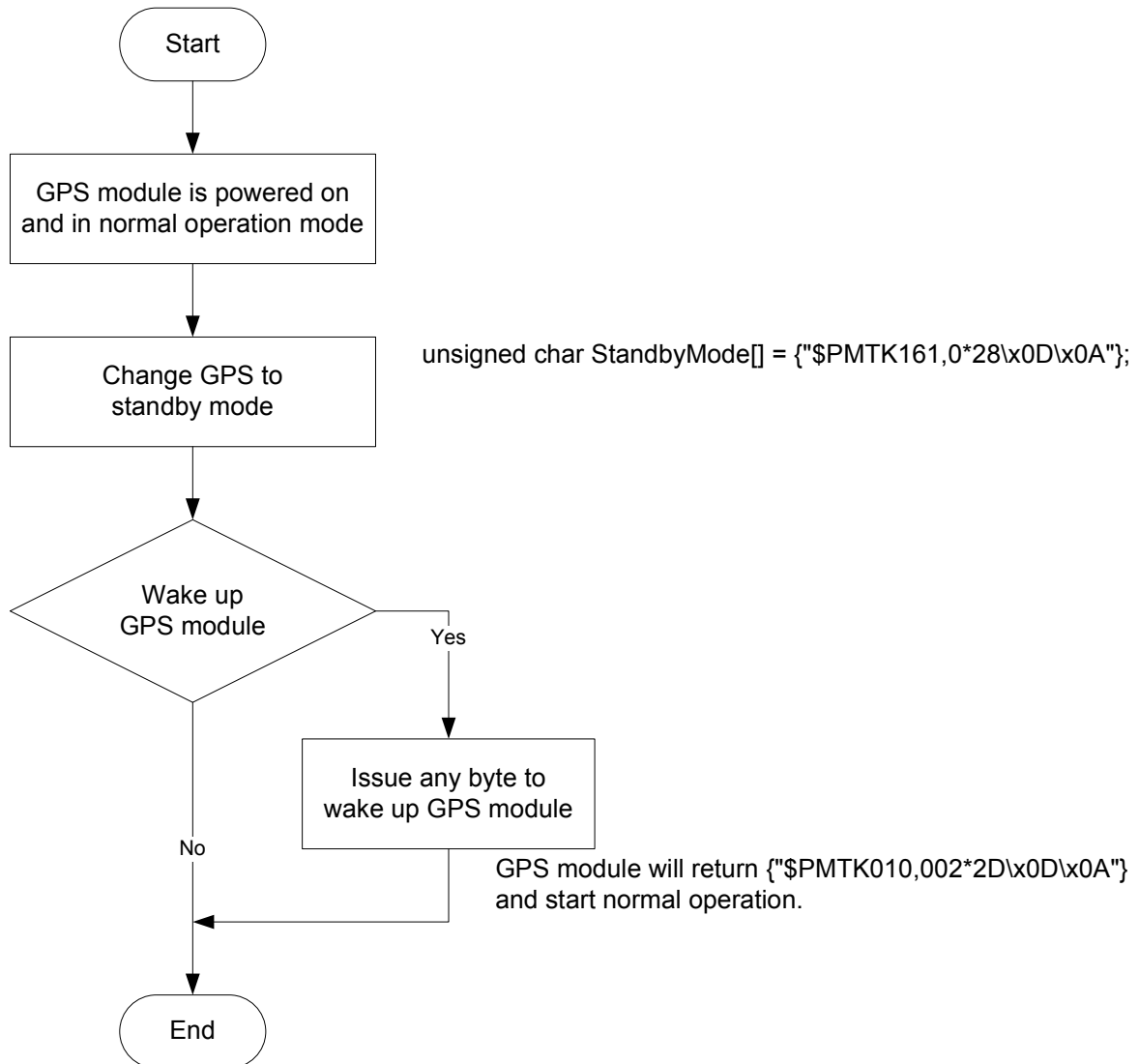
5.3.2 Periodic mode

When GPS module is commanded to periodic mode, it will be in operation and standby periodically. Its status of power consumption is as below chart.

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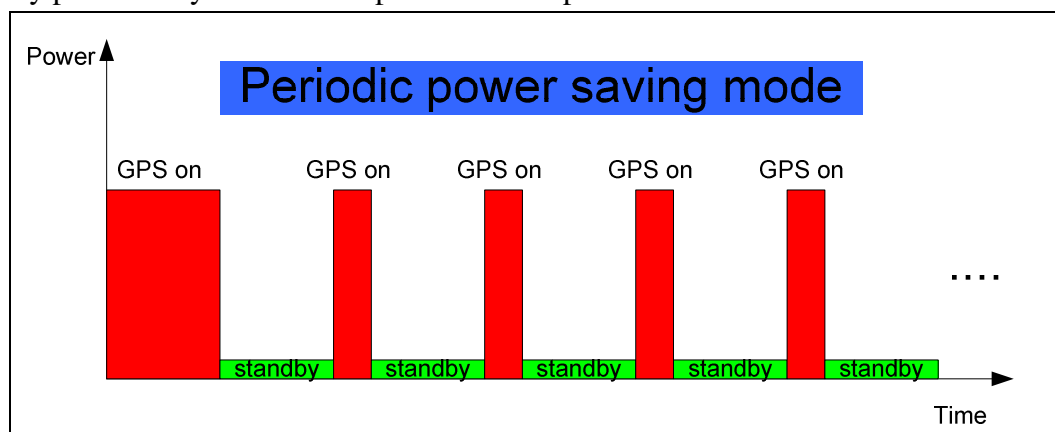
The following flow chart is an example to make GPS module go into periodic mode and then back to normal operation mode.

```
                        ┌─────────┐
                        │  Start  │
                        └─────────┘
                             │
                             ▼
                ┌────────────────────────┐
                │ GPS module is powered on │
                └────────────────────────┘
                             │
                             ▼
```
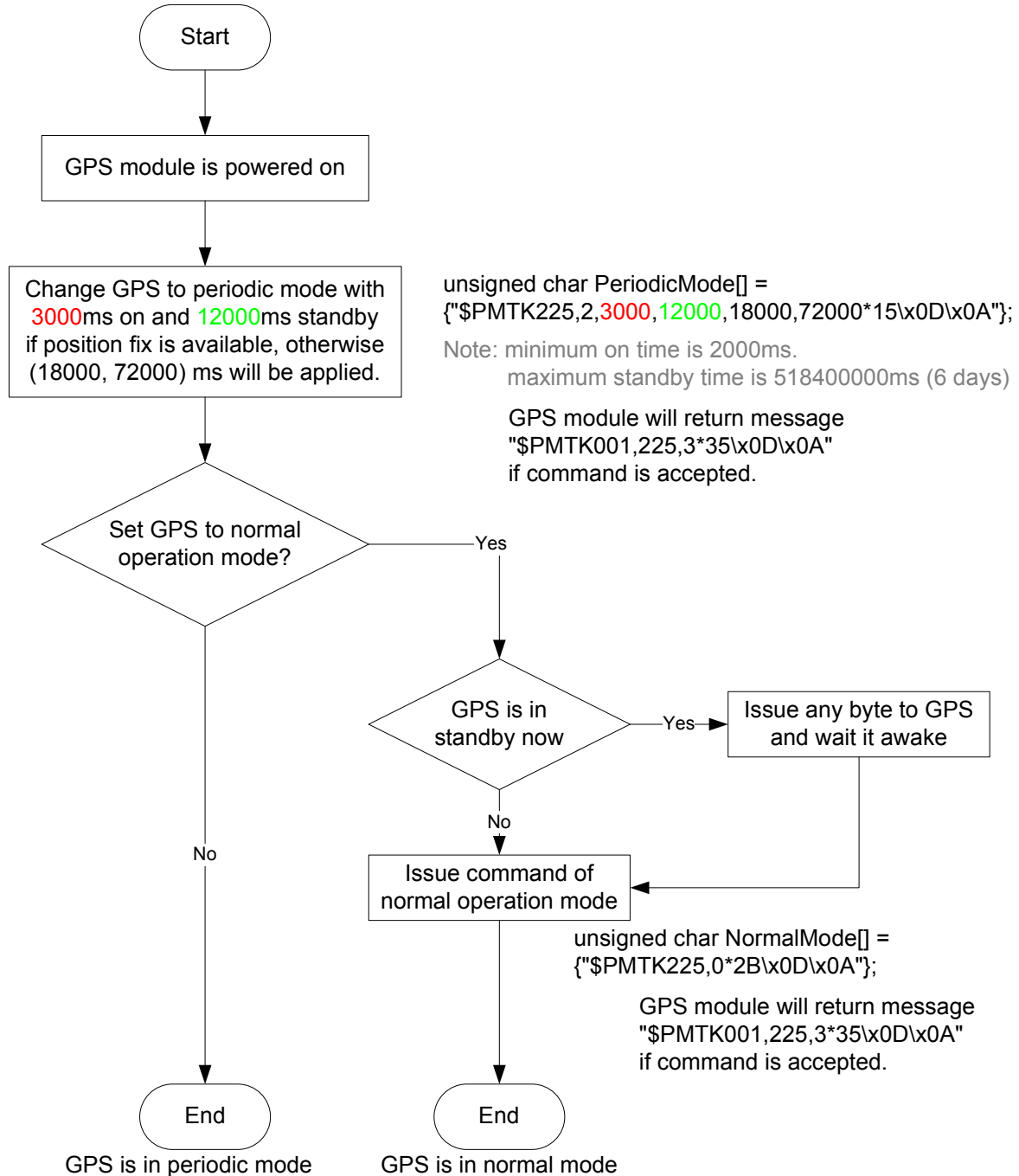
Change GPS to periodic mode with 3000ms on and 12000ms standby if position fix is available, otherwise (18000, 72000) ms will be applied.	unsigned char PeriodicMode[] = {"$PMTK225,2,3000,12000,18000,72000*15\x0D\x0A"};

Note: minimum on time is 2000ms.
　　　maximum standby time is 518400000ms (6 days)

GPS module will return message
"$PMTK001,225,3*35\x0D\x0A"
if command is accepted.

Set GPS to normal operation mode? ──Yes──►

GPS is in standby now ──Yes──► Issue any byte to GPS and wait it awake

No

Issue command of normal operation mode

unsigned char NormalMode[] = {"$PMTK225,0*2B\x0D\x0A"};

GPS module will return message
"$PMTK001,225,3*35\x0D\x0A"
if command is accepted.

No

End — GPS is in periodic mode
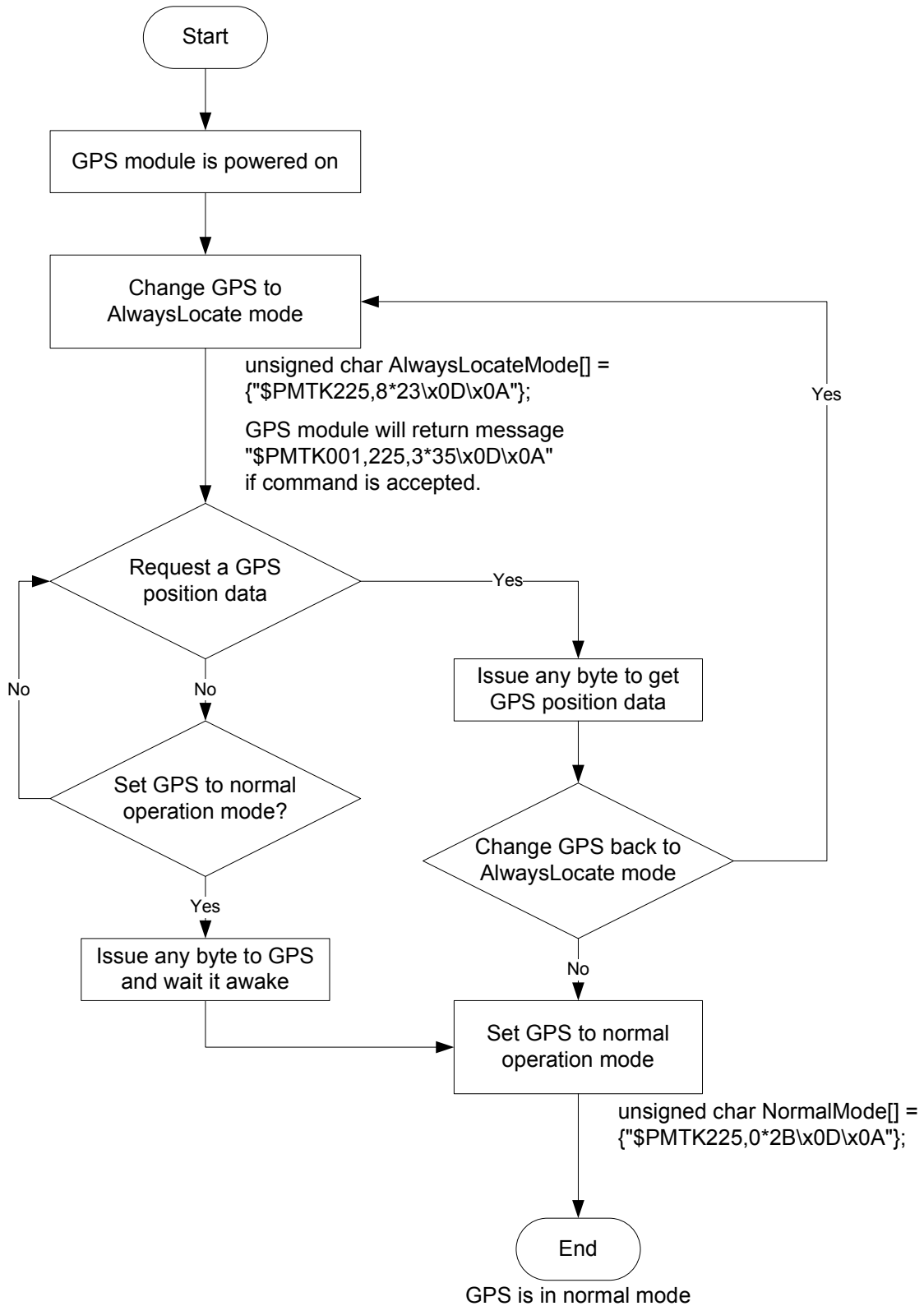
End — GPS is in normal mode

5.3.3 AlwaysLocate™ mode

AlwaysLocate™ is an intelligent controller of periodic mode. Depending on the environment and motion conditions, GPS module can adaptively adjust working/standby time to achieve balance of positioning accuracy and power consumption. In this mode, the host CPU does not need to control GPS module until the host CPU needs the GPS position

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data. The following flow chart is an example to make GPS module go into

AlwaysLocate^{Tm} mode and then back to normal operation mode.

Note: AlwaysLocate^{TM} is a trade mark of MTK.

```
                          ┌─────────┐
                          │  Start  │
                          └────┬────┘
                               │
                  ┌────────────▼────────────┐
                  │ GPS module is powered on │
                  └────────────┬────────────┘
                               │
                  ┌────────────▼────────────┐
                  │      Change GPS to       │◄──────────────────────┐
                  │    AlwaysLocate mode     │                       │
                  └────────────┬────────────┘                       │
                                                                    │
          unsigned char AlwaysLocateMode[] =                      Yes
          {"$PMTK225,8*23\x0D\x0A"};                                │
                                                                    │
          GPS module will return message                            │
          "$PMTK001,225,3*35\x0D\x0A"                               │
          if command is accepted.                                   │
```

unsigned char AlwaysLocateMode[] =
{"$PMTK225,8*23\x0D\x0A"};

GPS module will return message
"$PMTK001,225,3*35\x0D\x0A"
if command is accepted.

Request a GPS position data — Yes → Issue any byte to get GPS position data

No

Set GPS to normal operation mode?

No → Change GPS back to AlwaysLocate mode — Yes

Yes

Issue any byte to GPS and wait it awake

No → Set GPS to normal operation mode

unsigned char NormalMode[] =
{"$PMTK225,0*2B\x0D\x0A"};

End

GPS is in normal mode

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5.4 Data logger

The GPS module has internal flash memory for logging GPS data. The configurations include time interval, distance, speed, logging mode, and … etc. For more information, please contact us.

5.5 Examples to configure the update rate of GPS module

The GPS module supports up to 10Hz update rate that user can configure by issuing software commands. Note that the configurations by software commands are stored in the battery-backed SRAM that is powered through VBACKUP pin. Once it drains out, the default/factory settings will be applied.

Due to the transmitting capacity per second of the current baud rate, GPS module has to be changed to higher baud rate for high update rate of position fix. The user can use the following software commands to change baud rate.

Baud rate	Software command
Factory default	$PMTK251,0*28<CR><LF>
4800	$PMTK251,4800*14<CR><LF>
9600	$PMTK251,9600*17<CR><LF>
19200	$PMTK251,19200*22<CR><LF>
38400	$PMTK251,38400*27<CR><LF>
57600	$PMTK251,57600*2C<CR><LF>
115200	$PMTK251,115200*1F<CR><LF>

Note: <CR> means Carriage Return, i.e. 0x0D in hexadecimal. <LF> means Line Feed, i.e. 0x0A in hexadecimal.

If the user does not want to change baud rate, you can reduce the output NMEA sentences by the following software commands.

NMEA sentence	Software command
Factory default	$PMTK314,-1*04<CR><LF>
Only GLL at 1Hz	$PMTK314,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0*29<CR><LF>
Only RMC at 1Hz	$PMTK314,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0*29<CR><LF>
Only VTG at 1Hz	$PMTK314,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0*29<CR><LF>
Only GGA at 1Hz	$PMTK314,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0*29<CR><LF>
Only GSA at 1Hz	$PMTK314,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0*29<CR><LF>
Only GSV at 1Hz	$PMTK314,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0*29<CR><LF>
Only ZDA at 1Hz	$PMTK314,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0*29<CR><LF>
RMC, GGA, GSA at 1Hz and GSV at	$PMTK314,0,1,0,1,1,5,0,0,0,0,0,0,0,0,0,0,0,0,0*2C<CR><LF>

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0.2Hz	
If the command is correct and executed, GPS module will output message $PMTK001,314,3*36<CR><LF>	

After the GPS module is changed to higher baud rate or reduced NMEA sentence, the user can configure it to high update rate of position fix by the following commands.

Interval of position fix	Software command
Every 100ms (10Hz)[1]	$PMTK220,100*2F<CR><LF>
Every 200ms (5Hz)	$PMTK220,200*2C<CR><LF>
Every 500ms (2Hz)	$PMTK220,500*2B<CR><LF>
Every 1000ms (1Hz)	$PMTK220,1000*1F<CR><LF>
Every 2000ms (0.5Hz)[2]	$PMTK220,2000*1C<CR><LF>
If the command is correct and executed, GPS module will output message $PMTK001,220,3*30<CR><LF>	

Note 1: The minimum interval of position fix is 100ms, i.e. the maximum update rate is 10Hz.

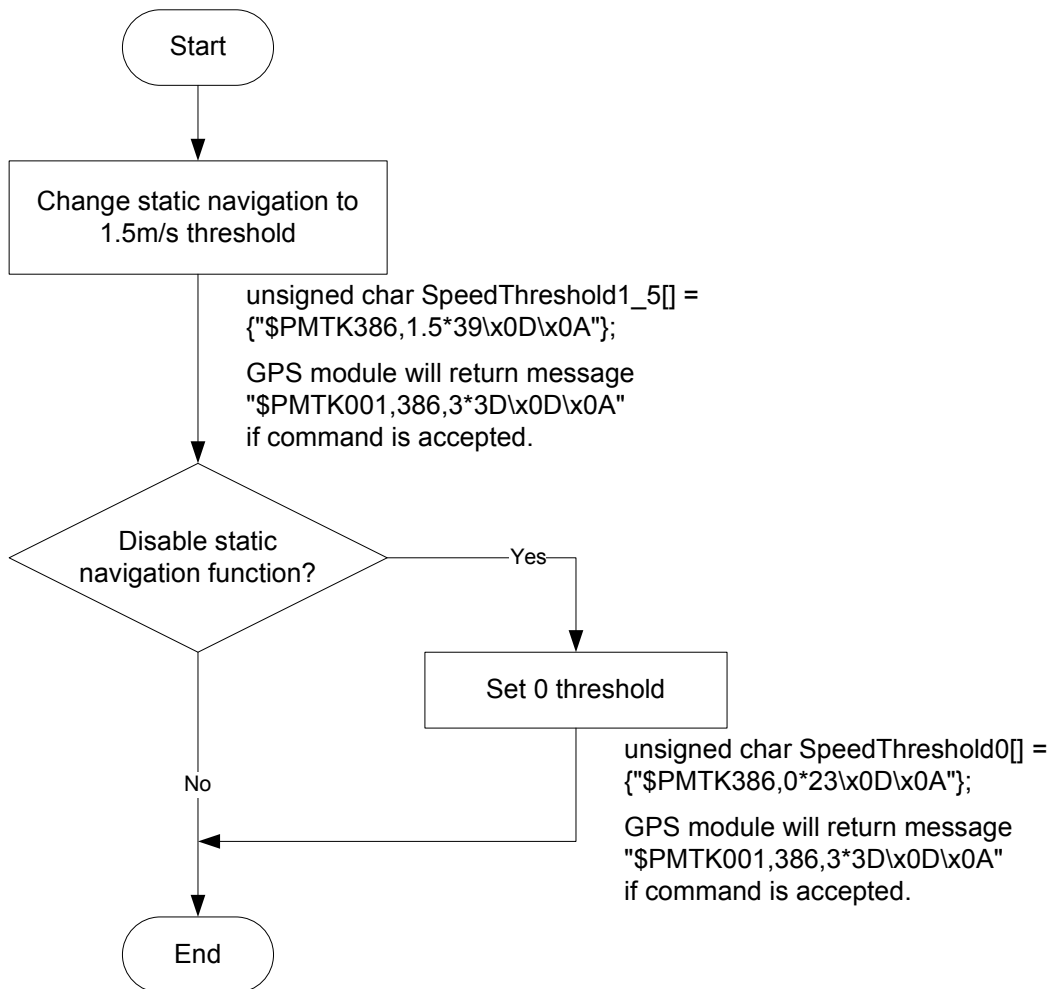Note 2: The current consumption is the same with the update rate of 1Hz.

5.6 Configure the static navigation parameter

The output position of GPS module will keep the same and output speed will be zero if the actual speed is below the threshold of the static navigation parameter. This is useful for different applications. For example, the car stopped at a red light will get stationary GPS position if the threshold is 1.5m/s. It is better to disable this function by setting threshold to 0 for pedestrian navigation.
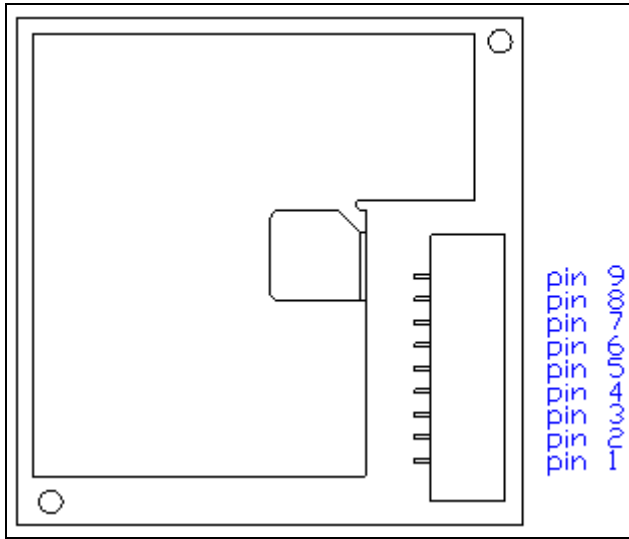
The format of the software command is as below.

$PMTK386,speed threshold*checksum<CR><LF>

The unit of speed threshold is meter per second. The range of speed threshold is from 0.1m/s to 2.0m/s. Value 0 is to disable the function.

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Start

Change static navigation to
1.5m/s threshold

unsigned char SpeedThreshold1_5[] =
{"$PMTK386,1.5*39\x0D\x0A"};

GPS module will return message
"$PMTK001,386,3*3D\x0D\x0A"
if command is accepted.

Disable static
navigation function?

Yes

Set 0 threshold

unsigned char SpeedThreshold0[] =
{"$PMTK386,0*23\x0D\x0A"};

GPS module will return message
"$PMTK001,386,3*3D\x0D\x0A"
if command is accepted.

No

End

6 Pin assignment and descriptions

Pin #	Name	Type	Description
1	NC		Not connect.
2	1PPS	O	Pulse per second (default 100 ms pulse/sec when 3D fix is available)
3	TX	O	Serial data output
4	RX	I	Serial data input
5	NC		Not connect.
6	NC		Not connect.
7	V_BCKP	P	Backup battery supply voltage. **This pin must be powered to enable the module.**
8	GND	P	Ground
9	VCC	P	DC supply voltage

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7 DC & Temperature characteristics

7.1 Absolute maximum ratings

Parameter	Symbol	Ratings	Units
Input Voltage	VCC	4.3	V
Input Backup Battery Voltage	V_BCKP	4.3	V
Operating Temperature Range	Topr	-40 ~ 85	℃
Storage Temperature Range	Tstg	-40 ~ 85	℃

7.2 DC Electrical characteristics

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Units
Input Voltage	VCC		3.0		4.3	V
Input Backup Battery Voltage	V_BCKP		2.0		4.3	V
Supply Current	I_{VCC}	Full operation		17[1]	75[2]	mA
Backup Battery Current	I_{BAT}	VCC = 0		6		uA
High Level Input Voltage	V_{IH}		2.0		3.6	V
Low Level Input Voltage	V_{IL}		-0.3		0.8	V
High Level Input Current	I_{IH}		-1		1	uA
Low Level Input Current	I_{IL}		-1		1	uA
High Level Output Voltage	V_{OH}		2.4		3.3	V
Low Level Output Voltage	V_{OL}				0.4	V
High Level Output Current	I_{OH}			2		mA
Low Level Output Current	I_{OL}			2		mA

Note 1: Measured when position fix (1Hz) is available, input voltage is 3.3V and the function of self-generated ephemeris prediction is inactive. For different input voltage (VCC), the current consumption is as below chart. This is because LS2003E has a built-in DC/DC converter.
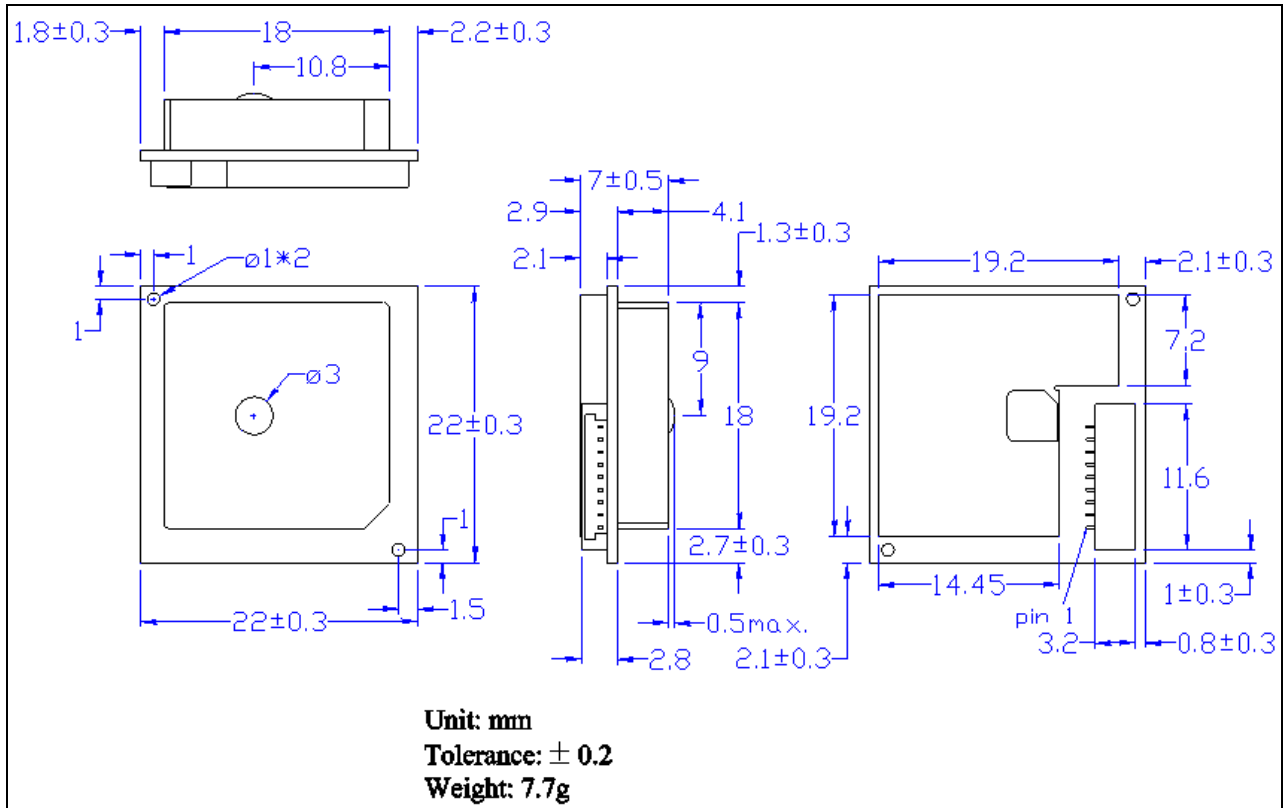
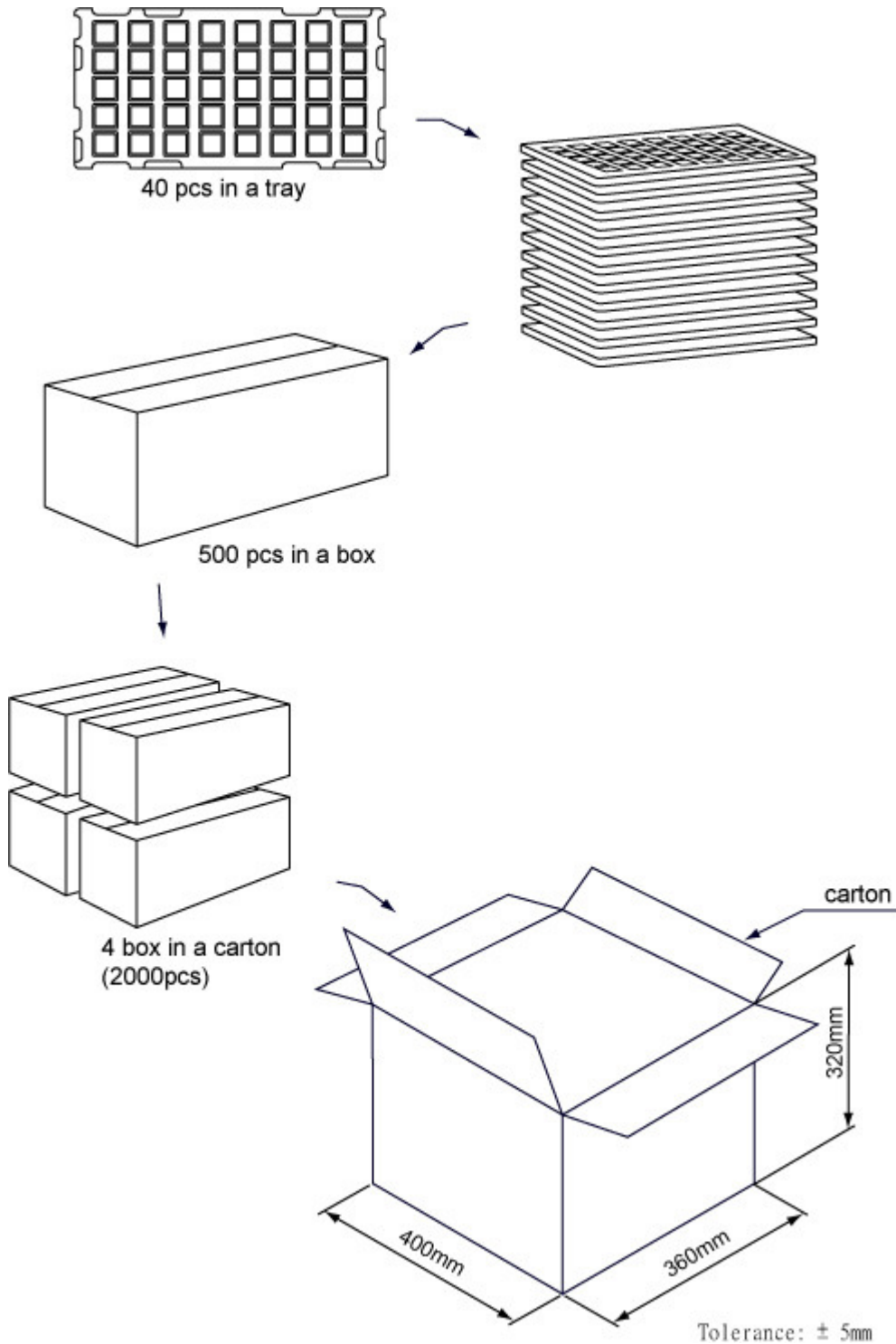Note 2: This happens when downloading AGPS data to LS2003E.

Input voltage (VIN) vs. current (Iss)

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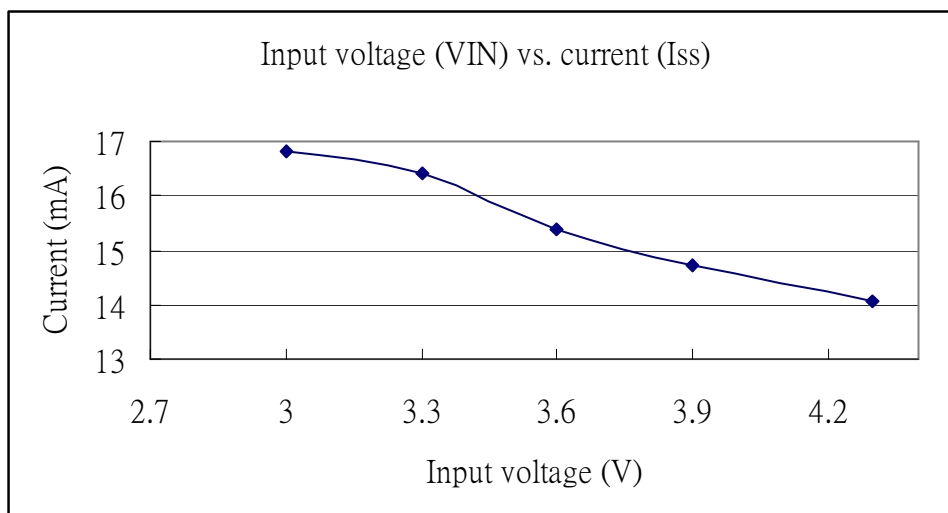
7.3 Temperature characteristics

Parameter	Symbol	Min.	Typ.	Max.	Units
Operating Temperature	Topr	-40	-	85	℃
Storage Temperature	Tstg	-40	25	85	℃

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8   Mechanical specification

Unit: mm
Tolerance: ± 0.2
Weight: 7.7g

The connector's part number is SM09B-SSR-H-TB(LF)(SN) from the company, JST.

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9　Packing information

40 pcs in a tray

500 pcs in a box

4 box in a carton
(2000pcs)

carton

320mm

400mm

360mm

Tolerance: ± 5mm

Document change list

Revision 1.0
- First release on January 21, 2013

Revision 1.1 (March 8, 2013)
- Changed the packing information from 1600pcs to 2000pcs in the section 9