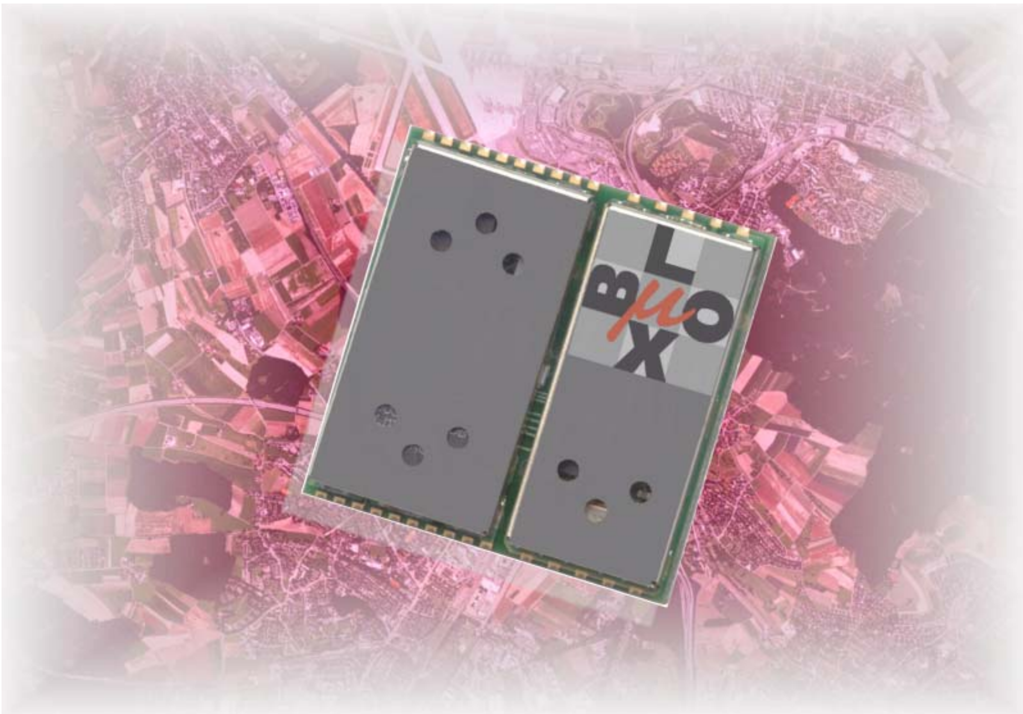
TIM

LOW POWER MODES

APPLICATION NOTE

RELEASED



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CONTENTS

1 OVERVIEW

The TIM GPS receiver from u-blox provides three different operating modes:

- Continuous Mode
- TricklePower™ Mode (abbreviated as TPM)
- Push-To-Fix™ Mode (abbreviated as P2F)

The last two modes are low power modes.

1.1 Continuous Mode

In this mode the GPS receiver is always fully powered and computes one navigation solution per second.

1.2 TricklePower™ Mode

In this mode the GPS receiver is switched on and off periodically with a specified *Interval*. A *DutyCycle* or *OnTime* can be specified. During the *OnTime* the GPS receiver acquires GPS Signal and computes a navigation solution. During the *OffTime* the GPS receiver is in a low power consumption state waiting for the next *Interval* to wake up.

When the GPS receiver needs special data from one or more satellites (ephemeris, almanac) it temporarily switches to "*Full Power*" state and when completed switches back to *TricklePower*™ state.

1.3 Push-To-Fix™ Mode

In this mode the GPS receiver is almost always in a low power consumption state. If a position fix is requested (by “pushing” reset) the receiver starts in "*Full Power On*" state, acquires GPS signal and computes a navigation solution, then immediately returns to the low power consumption state.

Every *PushToFixPeriod* seconds the GPS receiver temporarily switches to "*Full Power On*" state to collect and update satellite data (ephemeris, almanac) and, when completed, switches back to low power consumption state.

1.4 Boundary Condition

Best performance is achieved with backup battery or permanent power supply in order to retain last position, ephemeris, almanac and time information.

2 CHOOSING A OPERATING STRATEGY

Requirements	**Solution**
• Maximum accuracy	Only *Continuous Mode* can satisfy this requirement
• Periodic position fixes • Power consumption is of minor concern	*Continuous Mode*. It is possible to adjust the message rate of the serial output messages.
• Periodic position fixes (1 Hz to 0.1 Hz) • Periodic serial output (1 Hz to 0.1 Hz) • Minimal power consumption	*TricklePower™ Mode* Set *Interval* anywhere between 1 s to 10 s
• Periodic serial output (10 s to 100 s) • Minimal power consumption	*TricklePower™ Mode* Set *Interval* to 10 s and output message rate on serial port for instance to 60 s.
• Periodic position fixes (100 s to 7200 s) • Minimal power consumption	*Push-To-Fix™ Mode* Set period to the desired update rate.
• Position fix required upon demand • 'Time to first fix' must not exceed 8s. • Minimal power consumption.	*Push-To-Fix™ Mode* Toggling the reset signal requests a position fix. The reset line must be at logic zero for at least 1 µs. Remark: The GPS receivers is going to wake up automatically to update ephemeris data whenever necessary.
• Position fix required upon demand • 'Time to first fix' may exceed 30 seconds. • Minimal power consumption • External micro controller is available	Let the external micro controller turn on or off the power to the GPS receiver. Use *Continuous Mode* while the GPS receiver is turned on. Note: Connect a backup battery to VBAT for an improved 'time to first fix'.
• Periodic position fixes • Minimal power consumption • GPS system with low sensitivity (e.g. poor antenna quality)	Good antenna quality is prerequisite for good GPS performance. Low sensitivity should therefore not be a major concern in most of the applications. If however a design still has a low sensitivity, *TricklePower™ Mode* should be avoided and *Push-To-Fix™ Mode* with an update rate of 10s used instead.

Table 2-1: Choosing the optimal operating strategy

3 TRICKLEPOWER™ MODE

The *TricklePower™ Mode* of the u-blox GPS receiver allows saving a lot of power while maintaining good position accuracy. This is possible by tracking satellites only a few milliseconds (typically 200ms), computing a navigation solution and then waiting in a Low Power Sleep state for the next cycle begin (typically at intervals of a few seconds).

This low power mode is best suited when low power consumption is an issue and a regular update rate of 1 second or less frequently is needed.

Let's now take a more in-depth look at the functionality of *TricklePower™ Mode*.

Assuming we are starting up with *TricklePower™ Mode* already set up we will observe the following:

Initially, the receiver is in a "*Full Power On*" state where it tries to find satellites. Once it has found the satellites it will wait until all ephemeris data of each satellite is received, then if the real time clock (RTC) accuracy is good enough it will switch to the "*TricklePower™ On*" state. Note: if not enough satellite can be found or if RTC accuracy can't be reached within a timeout of *MaxAcqTime*, the receiver will go to a "*Full Power Sleep*" state where it will stay for *MaxOffTime*, and then it will retry the satellite acquisition or RTC calibration.

In "*Full Power On*" state, the RTC will be calibrated to the GPS time. The time needed for calibration depends on the temperature (self heat-up) effects of the RTC crystal.

If the receiver reached the "*TricklePower™ On*" state then it will normally just track satellites for *OnTime*, compute a navigation solution, output it and then enter a "*Full Power Sleep*" state that will last until the beginning of the next TricklePower™ cycle. The cycle duration can be set by the *Interval* or *DutyCycle* parameter. Every 10 minutes the receiver will test if the ephemeris of some satellite needs to be updated (older than 2 hours or a new satellite has been found in the last 10 min); if ephemeris update is needed a switch to "*Full Power On*" state is made (when ephemeris update is complete it will automatically return to "*TricklePower™ On*" state). A switch to "*Full Power On*" state can also occur when the RTC accuracy is too bad. The last reason for a switch to "*Full Power On*" state is a loss of satellite signals (obstructed sky view); if the sky view remains obstructed for more than about 20 seconds a switch to "*Full Power On*" state is forced.

Two approaches exist to configure *TricklePower™ Mode*:

- Set *OnTime*, *Interval*, *MaxAcqTime*, *MaxOffTime*, and enabling *PowerCycling* during a firmware upgrade. This method has the advantage that you only need to do it once, then after each power-on the receiver will have the desired settings and automatically start in *TricklePower™ Mode*.
- Use NMEA $PSRF107 or SiRF® binary message I.D. 151 to configure *OnTime* and *DutyCycle*, and SiRF® binary message I.D. 167 to configure *MaxAcqTime* and *MaxOffTime* if needed. Since message-based configuration is stored in volatile memory, these messages need to be sent to the GPS receiver after every power on (cold start).

For detailed information on messages, please refer to the Protocol Specification [2].

3.1 TricklePower™ State Diagram

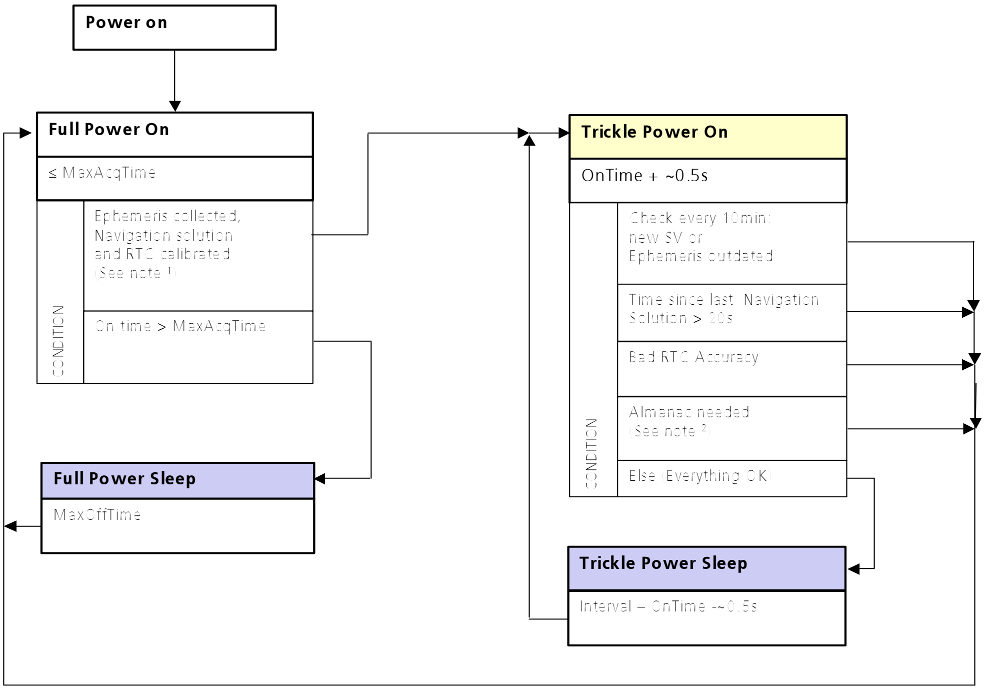

Figure 3-1: TPM State Diagram

[1] Collecting ephemeris normally takes 18 seconds (receiving 3 subframes @ 6 seconds). After a power-up, the receiver will collect the ephemris of all visible satellites, which usually take a few dozen seconds.

[2] Almanac is received subframe by subframe.

Color coding: White relates to "Full Power", light shade to "TricklePower™ On", and dark shade to sleeping state (RF and CPU off).

TPM Parameter	***Default Value***	***Remark***
MaxAcqTime	120 [s]	This is the maximum time the GPS receiver remains in *Countinuous Mode* (to search for satellites after ostructed sky view). Must be at least 1 s.
MaxOffTime	30 [s]	This is the maximum time the GPS receiver remains in "*Full Power Sleep*" state after having tried to acquire satellites for *MaxAcqTime*. Must be between 1 s and 1800 s (30 min).
OnTime	200 [ms]	This is the time the GPS receiver acquires data. Must be multiple of 100 ms and should not exceed 500 ms.
Interval	2 [s]	This is the interval between TricklePower™ cycles. Must be at least 1 s. Recommended maximum: 10 s.
DutyCycle	10 %	This parameter is only needed when setting *TricklePower™ Mode* with the u-blox tool u-Center. It affects the parameter *Interval* (it defines the ratio between *OnTime* and *Interval*). *DutyCycle* = (*OnTime / Interval*)*100

Table 3-1: TPM Parameters

3.2 TricklePower™ Stages

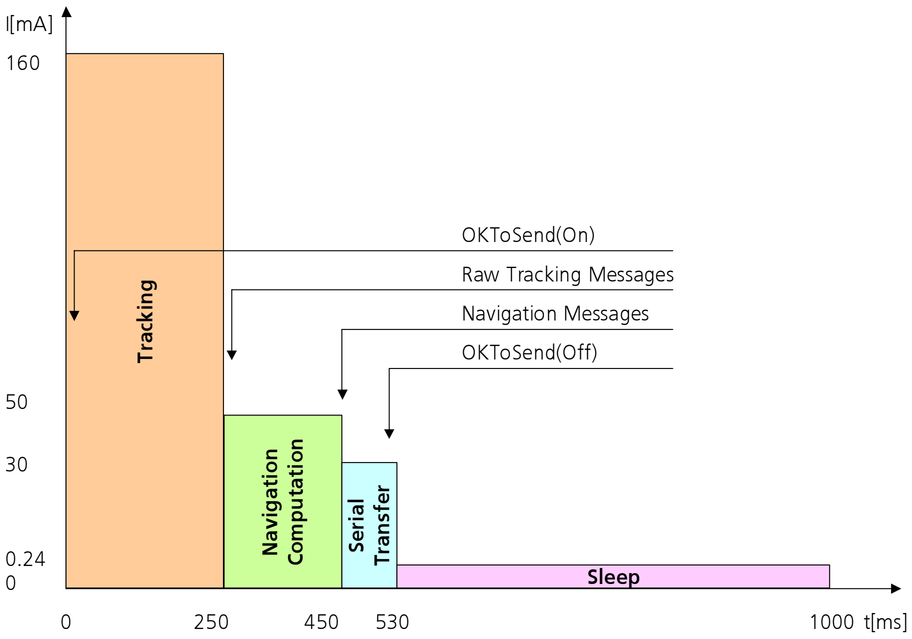

Figure 3-2: TPM Stages

Tracking: RF chip is powered (TIM pin 20: VCC_RF = high), RF section is active (TIM pin 9: RF_ON = high). CPU is idle for most of the time. This stage duration can be controlled by the *On Time* parameter; note that the effective duration of this stage is OnTime+50ms.

Typical current consumption: 160mA (at 3.3 V).

Navigation Computation: RF chip is powered (TIM pin 20: VCC_RF = high), but RF section is deactivated (TIM pin 9: RF_ON = low); RF chip is only used as a clock generator for the CPU. The CPU is running 100% and calculating navigation solution for the data acquired in the previous stage. This stage typically completes in 200ms.

Typical current consumption: 50mA (at 3.3 V).

Serial Transfer: RF chip is powered (TIM pin 20: VCC_RF = high), but RF section is deactivated (TIM pin 9: RF_ON = low); RF Chip is only used as a clock generator for the CPU. CPU is not doing very much in this stage (IDLE most of the time). In this stage the computed navigation solution computed in the previous stage is transferred to a host over a serial port. The duration of this stage may vary depending on the selected protocol, amount of active messages and baud rate.

Typical current consumption: 30mA (at 3.3 V).

Sleep: RF chip is *not* powered at all (TIM pin 20: VCC_RF = low and pin 9: RF_ON = low). CPU is powered but has no clock. In this stage the GPS receiver waits until it is time to do the next position acquisition and computation. The duration of this stage is *Interval* minus the duration of all other stages.

Typical current consumption: 240uA (at 3.3 V)

3.3 Power Consumption Calculations

Mean current consumption:

$(I_{tracking} * T_{tracking} + I_{nav} * T_{nav} + I_{serial} * T_{serial} + I_{sleep} * T_{sleep})$ / *Interval*

Where:

$I_{tracking}$ = 160 mA

I_{nav} = 50 mA

I_{serial} = 30 mA

I_{sleep} = 240 µA

$T_{tracking}$ = *OnTime* + 50 ms

T_{nav} = 200 ms

T_{serial} = *PayLoad* / (*BaudRate*/10)

T_{sleep} = *Interval* – (*OnTime* + 50 ms) – 200 ms - *PayLoad* / (*BaudRate*/10)

Payload = Length of all messages transmitted in bytes

BaudRate = Transmission rate in Kbit/s

For a more visual and practical way of computing power consumption, u-blox provides a Microsoft® Excel® sheet called "TIM TricklePower™ Calculator" ([4], GPS.G2-X-02004.xls). This file can be downloaded from the u-blox website.

3.4 Serial Transfer and On/Off Signaling

During the four stages described in section 3.2 some serial transfer also takes place outside the "Serial Transfer" stage.

Let's take a look at what is sent and at what time:

1. At the beginning of the *Tracking* stage the *OKToSend(On)* message is sent. Depending on the selected protocol, this is SiRF® binary message I.D. 18 or NMEA-formatted proprietary message $PSRF150. See the protocol specification [2] for details. This is useful for a host PC to synchronize its requests to the GPS receiver so that they are sent when the receiver is ON. Note that sending this message does not waste time since it is done in background while acquiring GPS signals.
2. At the beginning of the navigation computation stage the raw tracking message (SiRF® binary message I.D. 28. Info: message I.D. 5 is obsolete. See protocol specification [2] for details) is sent out. Note that sending this message does not waste time since it is done in background while computing navigation.
3. During Serial Transfer stage the result of navigation computation is sent out. Note that this is indeed a time wasting operation since there is nothing else sensible that has to be done; if possible try to minimize the amount of messages and maximize the baud rate to reduce duration of this stage and therefore power consumption.
4. The last message that is sent at the end of the Serial Transfer stage is the *OKToSend(Off)*.

3.5 Recommended TPM Settings

We recommend use an *Interval* of maximum 10 seconds. An *OnTime* of 200ms works fine, but bigger values provide improved navigation results. However, it's not recommended to use *OnTime* values above 500ms.

Intervals [s]	*OnTime [ms]*	*Duty cycle [%]*	*Average Current[1)] [mA]*
1	200ms	20%	55 *2)*
2	200ms	10%	28 *2)*
5	200ms	4%	12 *2)*
10	200ms	2%	6 *2)*

Table 3-3: Recommended TPM Settings

1) NMEA protocol, RMC message @ 9600 Baud on port A and RTCM @ 9600 Baud on port B.

2) Good visibility provided. In case of obscured visibility (i.e. indoors), the avarge current consumption depends entirely on the settings for *MaxAcqTime* and *MaxOffTime.*

3.6 Impact on Positioning Accuracy

The *TricklePower™ Mode* parameters (*OnTime* and *Interval*) have an impact on positioning accuracy. This is due to following aspects:

1. A bigger time *Interval*, particular when moving, will deliver fewer position fixes at lower accuracy. Since the Kalman filter algorithm uses an approximate approach to calculate the navigation solution where taking into account the previous position fixes, an expanded time period with spread position fixes will lead to a less accurate approximation.
2. A bigger *OnTime* allows more time to track satellites and possibly find new satellites, having a positive impact on positioning accuracy. Satellites with C/No less than 35 dBHz cannot be tracked. In a design with good antenna performance, this is only a minor concern.

The following figures illustrate the different qualities of *TricklePower™ Mode* behavior at different intervals. A vehicle approaches a roundabout with diameter of ca 20 meters, drives one complete circle, and returns on the same road.

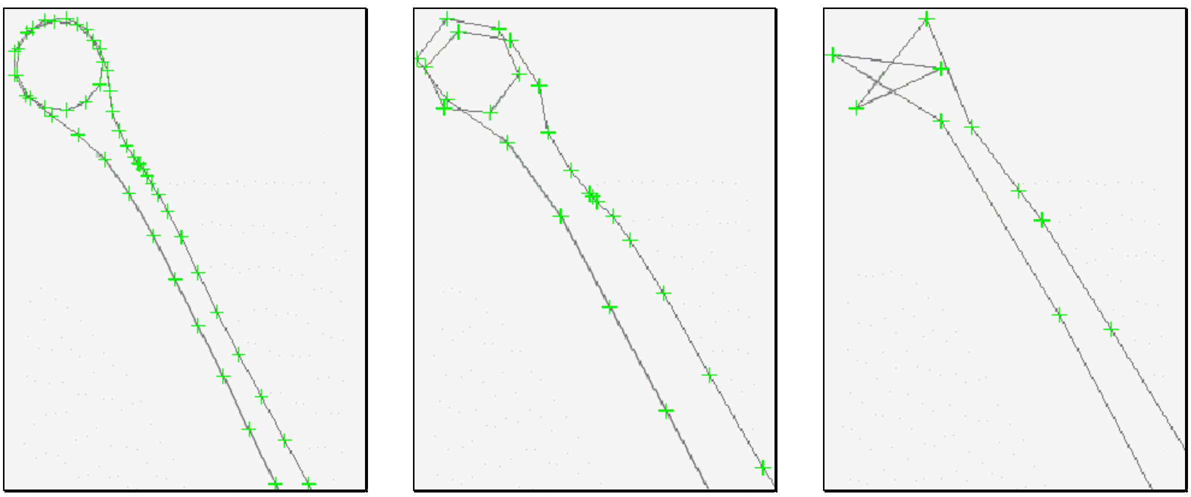

Figure 3-3: Position at *Continuous Mode* (left), *TricklePower™ Modes* 200ms, 2s (center) and 200ms / 5s (right)

3.7 Message Output Rates

Various messages, such as (but not limited to) SiRF® binary message I.D. 2 or NMEA $GPGGA, containing navigation information, are transmitted at configurable time intervals like 1 second or an integral multiple of it. The output rate can be configured with messages (NMEA $PSRF103 or SiRF® binary message I.D: 166) or user parameters. Details are summarized in the Protocol Specification [2].

In *TricklePower™ Mode*, the effective output rate is the product of the message rate and the *Interval*. For example, if the output rate for a particular message is set to 5, and the *Interval* equals 4, then the effective output rate is 20 seconds.

3.8 Active Antenna Considerations

If firmware is configured to use an Active Antenna, then the DC offset on the GPS antenna cable used to power the active antenna is switched on and off. It is switched on at the beginning of a TricklePower™ cycle and switched off just before going in the Sleep stage.

This configuration is only possible if the active antenna supervisor circuit described in the TIM data sheet is implemented. See [1] for details.

3.9 TricklePower™ Operation in DGPS Mode

When in TricklePower™ mode, differential corrections can only be received when TIM is in 'on' mode. It might therefore be necessary to buffer the data externally.

4 PUSH-TO-FIX™ MODE

Push-to-Fix™ *Mode* is an alternative low-power mode supported by the u-blox GPS receiver. To save power this mode tracks satellites, computes navigation solution and outputs it only upon a user request. This low power mode is best suited for applications that don't need a fix periodically but only upon request.

Let's now take a more in-depth look at the functionality of *Push-To-Fix*™ *Mode*:

Assuming we are starting up with *Push-To-Fix*™ *Mode* already set up we will observe the following:

Initially, the receiver is in a "*Full Power On*" state where it tries to find satellites. Once it has found the satellites it will wait until all ephemeris data of each satellite is received, then if the real time clock (RTC) accuracy is good enough it will go to sleep for *PushToFixPeriod*. Note: if not enough satellite can be found or if RTC accuracy can't be reached within a timeout of *MaxAcqTime*, the receiver will also enter "*Full Power Sleep*" state where it will stay for *PushToFixPeriod*, and then it will retry the satellite acquisition or RTC calibration.

Upon a user request (reset signal asserted) or after *PushToFixPeriod* the receiver will return to the "*Full Power On*" state where it will output position fixes (while running in "*Full Power On*" *state), do*wnload ephemeris or recalibrate RTC if necessary then return to sleep for another *PushToFixPeriod*.

Typically the GPS receiver stays in "*Full Power On*" state of *Push-To-Fix*™ *Mode*:

- First power on: ~1 minute at good visibility, maximum time ruled by *MaxAcqTime*
- When PushToFixPeriod time has elapsed, state "*Full Power On*" is entered to continue satellite acquisition.
- User request: 2 seconds (if no ephemeris or RTC recalibration needed)

Two approaches exist to configure *Push-To-Fix*™ *Mode*:

- Set *PushToFixPeriod*, *MaxAcqTime*, and enabling *PowerCycling* and *PushToFix* during a firmware upgrade. This method has the advantage that you only need to do it once, then after each power-on the receiver will have the desired settings and automatically start in *Push-To-Fix*™ *Mode*.
- Use NMEA $PSRF107 or SiRF® binary message I.D. 151 to activate *PushToFix*™ mode. To Set *PushToFixPeriod* and *MaxAcqTime* you have to use message I.D: 167 (only available in SiRF® protocol). Since message-based configuration is stored in volatile memory, these messages need to be sent to the GPS receiver after every power on (cold start).

For detailed information on messages, please refer to the Protocol Specification [2].

4.1 Push-To-Fix™ State Diagram

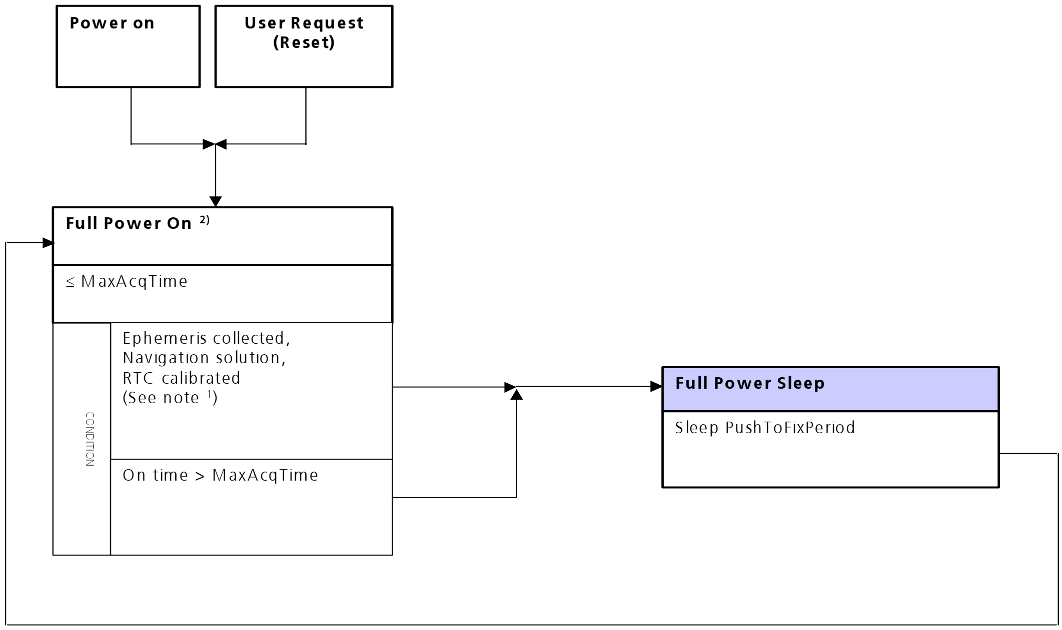

Figure 4-1: P2F State Diagram

[1] Collecting ephemeris takes normally 18 seconds (receiving 3 subframes @ 6 seconds). 42 seconds may be needed after a power-up.

[2] The almanac is automatically collected in 'Full Power On' state.

Color coding: White relates to 'Full Power' and dark shade to sleeping state (RF and CPU off).

P2F Parameter	***Default Value***	***Remark***
MaxAcqTime	120 [s]	This is the maximum of time the GPS receiver remains in *Countiuous Mode* (to search for satellites after obstructed sky view). Must be at least 1 s.
PushToFixPeriod	1800 [s]	This is the maximum time the GPS receiver remains in "*Full Power Sleep*" state. Range: 10 … 7200 s.

Table 4-1: P2F Parameters

4.2 Push-To-Fix™ Stages

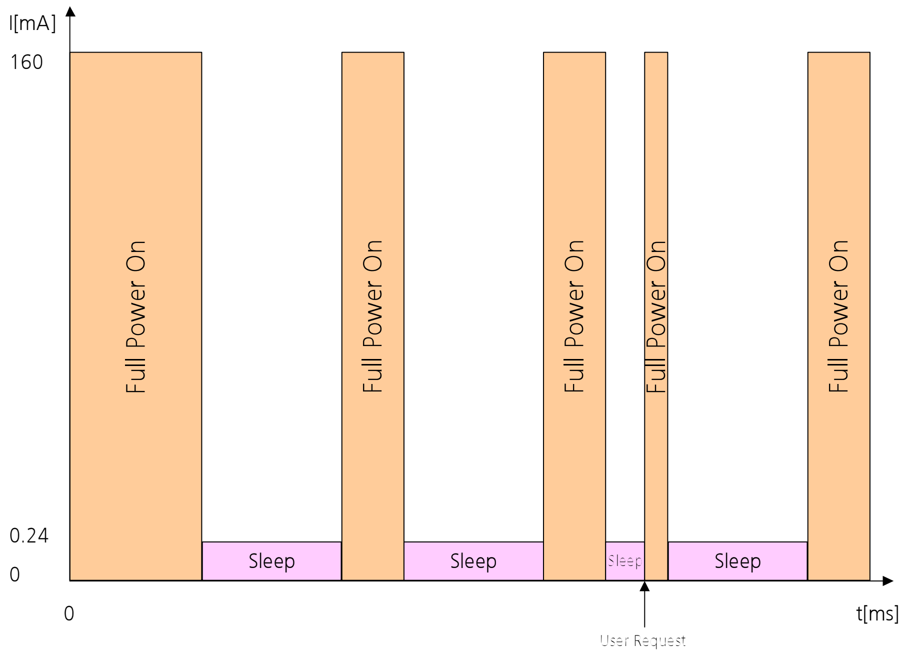

Figure 4-2: P2F Stages

4.3 Power Consumption Calculations

Mean Current Consumption:

$(I_{continuous} * T_{continuous} + I_{sleep} * T_{sleep})$ / (PushToFixPeriod + 42 seconds)

Where:

$I_{continuous}$ = 160 mA

I_{sleep} = 240 uA

$T_{continuous}$ = 42 s (when updating ephemeris)

T_{sleep} = *PushToFixPeriod*

4.4 Serial Transfer and On/Off Signaling

During Push-To-Fix™ operation all serial transfer is done as in "*Full Power On*" state except for the OKToSend signaling.

OKToSend(On) message is sent just after entering a "*Full Power On*" state and *OKToSend(Off)* message is sent just before entering the Sleep state. Depending on the selected protocol, this is SiRF® binary message I.D. 18 or NMEA-formatted proprietary message $PSRF150. See the protocol specification [2] for details.

4.5 Active Antenna Considerations

If firmware is configured to use an active antenna, then the DC offset on the GPS antenna cable used to power the active antenna is switched on and off. It is switched on while in "*Full Power On*" state of *Push-To-Fix™ Mode* and switched off just before going in the "*Full Power Sleep*" state.

This configuration is only possible if the active antenna supervisor circuit described in the TIM data sheet is implemented. See [1] for details.

A APPLICATION EXAMPLES

1. Emergency Call Enabled Mobile Phone

Requirement: Very fast position fix needed at sporadic events since time may be very critical.

Best Solution: *Push-To-Fix™ Mode*

Discussion: One could consider *TricklePower™ Mode* instead, but it keeps the mobile phone more active than actually needed, provides lots of position information, which is no longer valuable and consumes too much power.

2. Handheld Tracking Device

Requirement: Periodic position updates at a low power consumption.

Best Solution: *TricklePower™ mode*

Discussion: In *TricklePower™ mode,* there exists a trade off between battery life and fast reacquisiton in case of obscured visibility. If the tracking device is brought from obscured to good visibility and a position fix should be obtained as fast as possible, *MaxOffTime* should be kept at a minimum. If however a long battery lifetime is more important, *MaxOffTime* should significantly be increased.

3. Animal Tracking

Requirement: Periodic position updates at an ultra low power consumption.

Best Solution: For accurate route pattern recording, several position fixes per minutes are necessary. *TricklePower™ mode* fits best since it provides periodic position fixes and keeps power consumption low.

Discussion: Study of slow moving mammals may require fewer position fixes. In this case, *Push-To-Fix™ Mode* with a user defined *PushToFixPeriod* will be better suited.

4. Navigation in a Motor Vehicle

Requirement: Accurate position fixes at the highest possible update rate.

Best Solution: *Continuous Mode*. Power consumption is no issue here since a vehicle battery delivers plenty of power. This mode gives best GPS performance.

B RELATED DOCUMENTS

[1] TIM GPS Receiver Macro Component – Data Sheet, GPS.G2-MS2-01001

[2] TIM GPS Receiver - Protocol Specification - Application Note, GPS.G2-X-01003

[3] TIM Firmware Update Utility - User's Manual, GPS.G2-SW-02004

[4] TIM Evaluation Kit - User's Guide, GPS-EK-01001

[5] The GPS Dictionary, GPS-X-00001

[6] TricklePower™ Calculator (Spreadsheet file), GPS.G2-X-02004

All these documents are available on our homepage (http://www.u-blox.com).

C GLOSSARY

Please refer to the *GPS Dictionary*, [5].

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