JF2 Low Power Modes Application Note

80000NT10062A Rev.4 – 2011-07-20

Making machines talk.

APPLICABILITY TABLE

PRODUCT
JF2

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Contents

1. Introduction

1.1. Scope

This document is intended to give an overview of the low power modes available in JF2 module.

1.2. Audience

This document is intended for customers who are about to develop an application based on Telit JF2 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 (sample):

"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 features of the product.

"Chapter 3: "System Power States" describes in details the characteristics of the different power states.

"Chapter 4: "Power Management Modes" describes in details the power management.

"Chapter 5: "Antenna Performance Considerations" provides some considerations about antennas

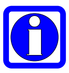
"Chapter 6: "Low Power Input Messages" gives an overview about messages concerning power management.

"Chapter 7: "Document History" provides history of the present document.

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

- JF2 Product Description, 80403ST10103A
- JF2 Hardware User Guide, 1vv0300985
- JF2 EVK User Guide, 1vv0300987

2. Overview

As GPS continues to gain popularity with consumers, it has found its way into more battery-powered devices for which saving power is critical. The SiRFStarIV chipset offers three low power operating modes used by Telit Jupiter GPS modules to provide flexibility in the power versus performance trade-off, which OEMs involved in battery-powered applications must address. These operating modes are controlled using SiRF Binary messages.

Important Note:

All data values provided in this document are approximate and provided for example and illustration only. These are not meant to be specifications or performance guarantee.

2.1. Background

The baseband processor within SiRFStarIV performs GPS tasks such as satellite signal acquisition, tracking and navigation, while the RF front-end provides signal down conversion and clock generation. During the course of GPS operations, not all of these functions need to be fully powered and operating. By controlling the power and clock carefully, power consumption can be managed more efficiently. For this purpose, SiRFStarIV provides power management schemes: TricklePowerTM, Push-To-FixTM, and Micro Power/SiRFAware™.

2.2. Overview

The power management process can be summarized as follows. The receiver starts up in hibernate mode until an ON_OFF signal is sent. The receiver stays in Full Power mode until the user's position is fixed and all relevant information is gathered. It takes about 30 to 40 seconds on average to compute the first position fix and extract other information. The time is shorter in cases with aided or hot starts. When the receiver is ready to carry out normal processing, different sections of hardware can be turned off or un-clocked, depending on the receiver state. After processing is completed, the receiver programs the RTC (Real Time Clock) to wake up at a specified time and then go to sleep by turning off most of the circuitry except the RTC. When the wakeup interrupt occurs, the receiver re-starts the system and resumes GPS tasks.

TricklePower, Push-To- Fix, and Micro Power are designed to meet the demands of applications that have different requirements for the interval between position updates and for power consumption. All of these modes perform similarly in principle but provide different output rates and reliability. TricklePower is a duty cycling mode with a user-selectable position update interval, providing high quality GPS accuracy and dynamic motion response at a reduced average current draw. Push-to- Fix allows for infrequent, on-demand user position requests with short TTFF (Time-To-First-Fix). Micro Power mode is an autonomous power mode that keeps the receiver in Hot Start conditions while Hibernating.

3. System Power States

There are six system power states (other than OFF) that are used for power management. Low power operating modes transition the receiver between these states.

Power Mode	BB							RF				
	KA	DSP RAM	Data RAM	Patch RAM	ARM	DSP	BIU	SPI	RX	PLL	LNA	TCXO/XO
FULL_ON	On	On	On	On	On	On	On	On	SW	SW	SW	FSM/SW
ACQCLK_ONLY	On	On	On	On	On	On	On	Off	Off	On	Off	FSM/SW
DLL_ONLY	On	On	On	On	On	Off	On	On	Off	Off	Off	FSM/SW
STANDBY	On	Off	On	On	On[1]	Off	On	Off	Off	Off	Off	FSM/SW
HIBERNATE	On	Off	Off	On	Off	Off	Off	Off	Off	Off	Off	FSM/SW
KA	On	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	FSM/SW

[1] ARM is powered but unclocked.

Table 3-1 System Power States

3.1. Full-Power State

This is the state of the receiver where both the RF front-end and baseband processor are fully powered. The receiver enters this state after an ON_OFF pulse at power-up and stays in this state during initial acquisition, until an initial position is calculated and is estimated to be reliable. Afterwards, the receiver re-enters the full-power state whenever it must perform satellite search and acquisition, satellite tracking, range measurements, or data collection. Note that in this state there is a difference in power consumption between satellite signal acquisition and signal tracking. During acquisition, processing is more intensive, thus consuming more power.

3.2. ACQCLK_Only State

The DSP is left on and clocked to access DSP RAM in order to get measurement information from the DSP memory. The RF PLL is left on to convert the raw TCXO frequency into the clock signal that feeds into the DSP while the rest of the RF chain is turned off.

3.3. DLL_Only State

The PLL is disabled and the RF is turned off. The TCXO enable line is forced OFF to turn off the TCXO. The DSP clock is turned off which disables the DSP.

3.4. Stand-by (Trickle) State

In this state the RF front-end is completely powered off and thus there is no clock signal to the baseband processor. In this state, typically 90 µA of current is drawn from the un-clocked (but still energized) baseband processor, the RTC and battery-backed RAM depending on process, voltage, and temperature variations.

This state can be entered when a position fix has been calculated and reported through the serial port. Prior to entering this state, the RTC wakeup register is programmed to wake the system at a specific time in the future.

3.5. Hibernate State

This state is an ultra-low power state that was introduced in Jupiter3. It is intended for very low power consuming applications. Both the RF and baseband power regulators are turned off, leaving only the patch RAM, the ARM code, and the KA domain powered (KA domain clocked by RTC). This avoids reloading code and patch at the next start-up. These memories are supplied by a reduced voltage to reduce leakage. When operation resumes, the processor must cold start. In this state, typically 20 µA of current is drawn depending on process, voltage and temperature variations.

3.6. KA_Only State

The Jupiter-F2 enters the KA_Only state when the system is initially powered. Leaving KA_only mode requires an external H/W signal on the ON_OFF pin. In this state, only the RTC oscillator, clock monitor, RTC time counter and battery-backed RAM are powered. Current levels are typically a few A depending on process, voltage and temperature.

Note: Software support is not provided to switch to the KA_Only state

4. Power Management Modes

The software based power management modes are:

- Full-Power
- TricklePower™
- Push-to-Fix
- Micro Power/SiRFAware™ mode

The fundamental assumption for all the power control modes is that power is maintained continuously to the receiver's RTC, BBRAM, and FSM. If power to the KA section is lost, the system reverts back to its original factory settings, which can result in a very long start-up TTFF.

These power management modes are available to meet applications that have different requirements in position report interval and power consumption

Sophisticated power management schemes attempt to avoid the occurrence of cold and warm starts by managing enough ON time to attempt to refresh ephemeris information and recalibrate internal frequency references and clocks. In principle, these modes operate similarly but provide different output rates and reliability.

4.1. Full-Power Mode (Continuous Navigation)

Full-power mode is also known as Continuous Navigation mode. This is the most accurate navigation mode and supports the most dynamic motion scenarios. The RF block produces continuous RF samples that are continuously processed by the acquisition and tracking processes.
Measurements and decoded GPS demodulated data are continuously sent to the host GPS software for the highest quality and dynamic mode of GPS navigation. Full-power mode is expected to draw approximately:

- 33mA average while tracking (LNA low gain mode)
- 41mA average while in acquisition (LNA low gain mode)

The receiver remains in the initial full-power state until all required satellite ephemeris data are collected, a navigation solution is obtained, and the RTC is calibrated. The amount of time spent in the initial full-power state depends upon the type of start conditions that apply, which in turn affects Time-To-First-Fix (TTFF) as shown in the table below.

Mode	TTFF @ -130dBm	
	Typical	90%
cold start	33s	35s
warm start	31s	35s
hot start	500ms	<1s

Table 4-1 Jupiter-F2 TTFF values

4.2. TricklePower™

TricklePower mode is a duty cycled mode. The fixed-rate cycling of power states provides fixed power savings with a constant output rate.
In TP Mode, the system selects a minimum rate of navigation solution updates and minimizes average current. This mode focuses on update rate and navigation solution quality. As a result, when conditions are difficult, or satellite navigation data must be demodulated, the software will transition to FP mode for a specified limited period. This results in variable power savings, but much more reliable performance for a fixed message output rate. Applications using TricklePower should achieve results very similar to full power, but with significant power savings in strong signal conditions.

4.2.1. TricklePower State Cycling

TP mode cycles between 4 states:

- STANDBY
- DLL_ONLY
- ACQCLK_ONLY
- FULL_ON

Position requests are set for a specific update period (user selectable 1 to 10 seconds), and a specific RF sampling time during each period (user selectable 100ms to 900ms). The receiver returns to the FULL_ON state for the sampling time to collect measurements, reduces power to the ACQCLK_Only state to obtain measurement data from the DSP, reduces power again to the DLL_ONLY state to process the navigation solution, and then operates in STANDBY state for the remainder of the update period. The next FULL_ON state is initialized by an RTC wake-up.
The time taken to turn off the baseband before going to STANDBY state depends upon the time taken to complete the transmission of any serial messages over the SPI, I^2C, or UART interface. This time depends upon the number of messages generated in the immediately preceding cycle and the data-rate/line-speed of the interface. Slow SPI, I^2C, or UART line speeds can extend the on-time of each cycle.
TP Mode cycles through FULL_ON and three other power states. However, there are some situations where the receiver stays in FP mode:

- Collecting periodic ephemeris data
- Collecting periodic almanac data
- Collecting periodic ionosphere and UTC data
- Perform RTC convergence
- Improve navigation result

After tracking is completed, the measurements are used for position computation. The receiver remains in CPU-only state (also known as DLL_ONLY and ACQCLK_ONLY states combined) until the position is computed. It then performs maintenance checks on the GPS data and commands the mode change to STANDBY.

4.2.2. Adaptive Behavior

Under normal tracking conditions, the TP Mode performs normal TP Mode cycles. But in harsh tracking environments, the receiver automatically switches to FP Mode to improve navigation performance. When the satellites are sorted according to their signal strength, the fourth satellite determines if the transition occurs or not. Currently the thresholds are

- 30dB-Hz to enter TP Mode cycling
- 26dB-Hz to return to FP Mode cycles

When tracking conditions improve (4 or more satellites in use with C/N0 of 30dB-Hz or higher), the receiver switches back to TP Mode. Consequently, navigation results improve in harsh GPS environments at the cost of using more power.

4.2.3. Recommended Usage

TP Mode is best suited for applications that require solutions:

- At a fixed rate
- Low-power consumption
- Maintain the ability to track weak signals

SiRF recommends the use of 300ms with a 30% duty cycle (full power for 300ms with a 1 second update interval), or 400ms with a 20% duty cycle (full power for 400ms with a 2 second update interval) for optimum performance.

4.2.4. Timing Diagram

A typical timing diagram for 300ms full-power and 30% duty cycle is shown below. Note: CPU_Only is ACQCLK_ONLY and DLL_ONLY combined.

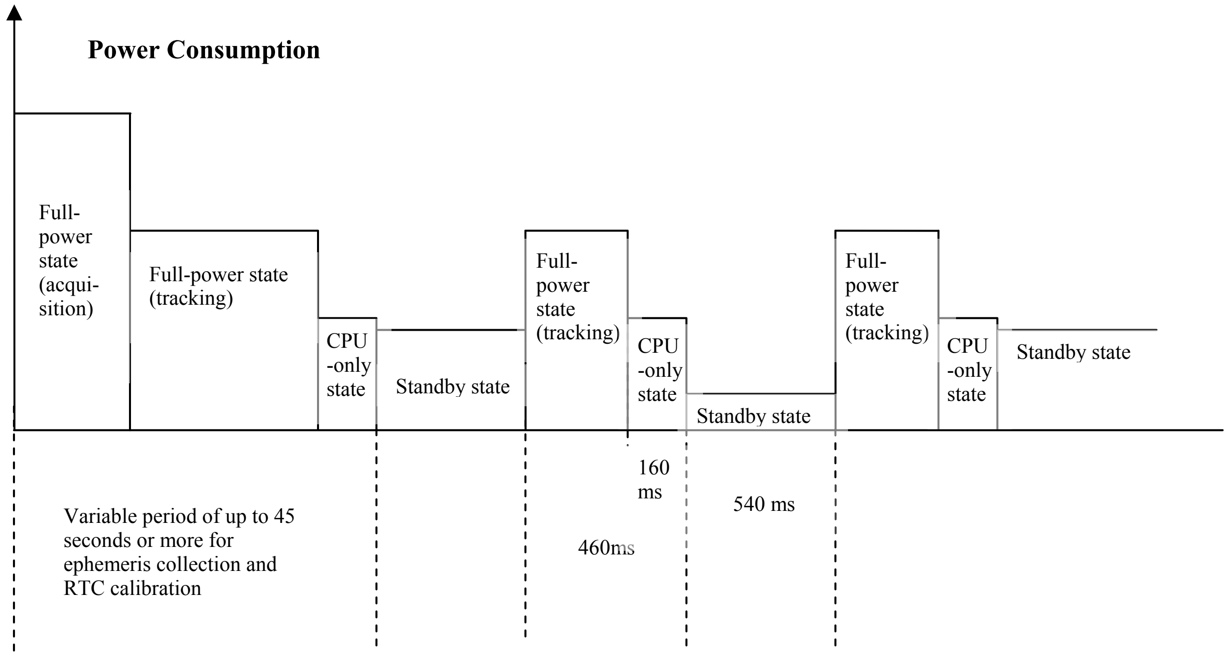


Figure 3-1. Timing Diagram for TricklePower™ mode

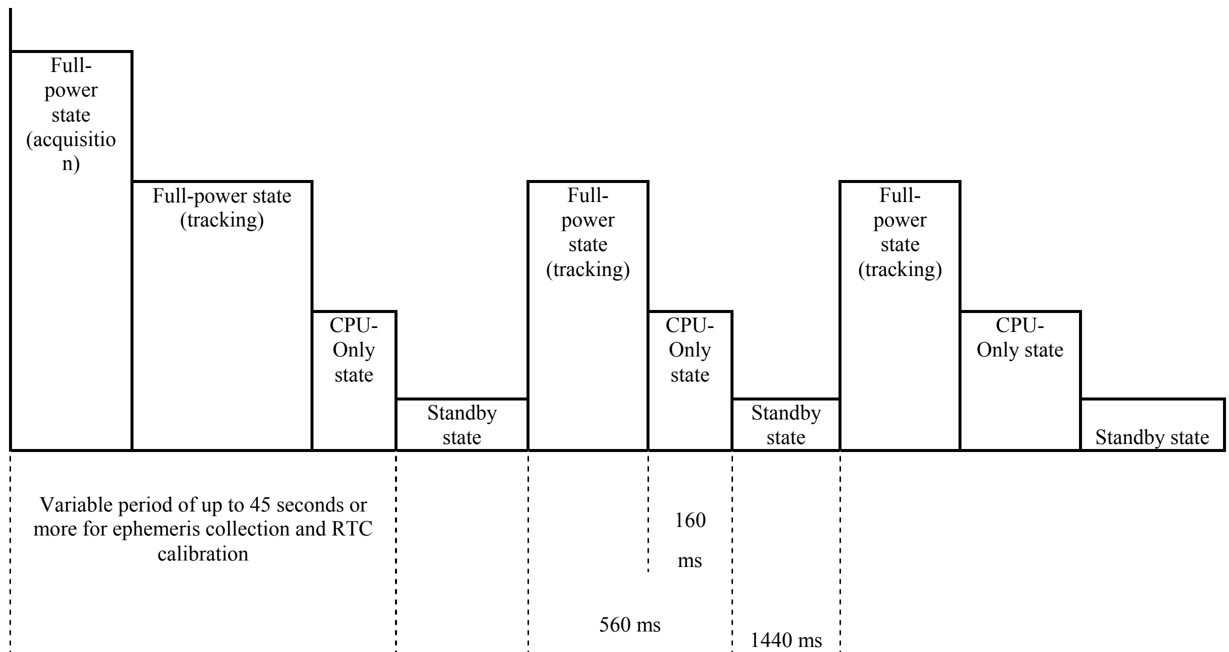


Figure 3-2. Timing Diagram 400ms On 20% Duty Cycle. 2 Second Update

4.3. Push-To-Fix™

Push-to-Fix™ mode is designed for applications that require infrequent position reporting. The receiver generally stays in hibernate system power state, but wakes up periodically to refresh position, time, ephemeris data and RTC calibration. A pulse on the external ON_OFF line to the receiver acts as a position update request. The request wakes up the receiver, which is then able to supply a position within the hot start time specification.
Average current levels are proportionally lower relative to TP Mode duty-cycling because in PTF mode the receiver stays longer in a reduced power state. Additionally, the reduced power state used in PTF mode is the Hibernate state, which consumes less power than does the Standby state used by TP mode. However, because the system comes up from the HIBERNATE state, it must initialize the ARM state and data RAM. This requires a longer time spent in the Full Power state.

4.3.1. Initial Full-Power State

When the receiver is powered up in PTF mode or a new PTF Mode cycle, it remains in the initial full power state until a good navigation solution is computed and RTC calibration is completed. The HIBERNATE state follows for the remainder of the period. If it takes 36 seconds to fix position and refresh ephemeris on the default period of 30 minutes, the GPS sleeps/hibernates for the 29 minutes and 24 seconds.

Note:

The time taken to turn off the baseband also depends on the time taken to complete the transmission of any serial messages over the SPI, I2C, or UART interface. This time is dependent on the number of messages generated in the immediately preceding cycle and the data-rate/line-speed of the interface. Slow SPI, I2C, or UART line speeds can extend the on-time of each cycle.

4.3.2. Refresh Cycle

PTF puts the receiver into a background duty cycling mode in which the receiver repeatedly wakes from the HIBERNATE state and transitions to the full-power state. When the receiver wakes up after a background cycle period has elapsed, an internal reset is generated and a hot start acquisition is performed. After the receiver verifies position and time, it updates ephemeris data and calibrates the RTC as needed to maintain hot start conditions at the next scheduled refresh cycle.
The background cycle period is user-selectable from 10 seconds to 2 hours, with the default value being 30 minutes. Note that this period is also used by TricklePower to update ephemeris data and RTC calibration. However, Push-to-Fix mode and TricklePower mode cannot be enabled at the same time.

4.3.3. Use of ON_OFF Signal

When the user application needs a position report, it can apply a pulse to the ON_OFF line to initiate a PTF cycle. The pulse is positive-going and must have a duration of at least 100 milliseconds. When the receiver awakes from the ON_OFF pulse, it behaves the same as when it awakes due to the background refresh cycle period. Additionally, a new background cycle period begins, which resets all variables related to handling the wake-up and sleep time. Note that the ON_OFF line can be pulsed at any time except within 1 second of a previous pulse.

4.3.4. Timing Diagram

A typical timing diagram for the default 30-minute background update cycle is shown below.

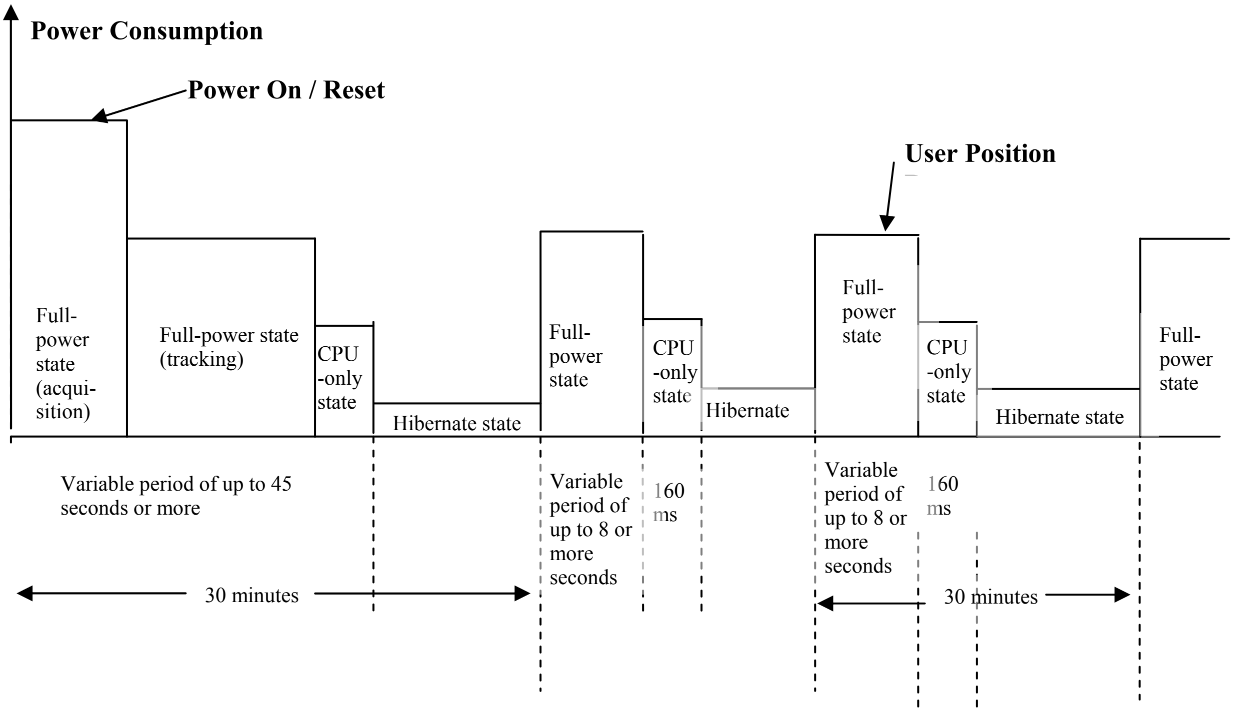


Figure 3-3. Timing Diagram for Push-to-Fix™ mode

4.4. Micro Power/SiRFAware™ Mode

Micro Power mode (MPM) is a low power mode that delivers continuous availability. It continuously maintains fine time, ephemeris, and frequency aiding. The receiver goes to a very low power state while maintaining Hot Start conditions.
When this mode is turned on, the receiver goes into update cycles (usually every 1-10 minutes) or maintenance cycles (usually every 30 to 60 minutes). The frequency of these cycles is not user configurable.

4.4.1. Update Cycles (1-10mins)

This mode puts the receiver in Hibernate state and keeps the RTC circuit of the Keep-Alive block active. The timer is automatically set for 60 seconds update cycle, then the receiver wakes up to check 3 parameters: RTC absolute time, frequency drift, and valid ephemeris. After the update cycle, the receiver goes back to Hibernate state.

4.4.2. Maintenance Cycles (30 to 60mins)

If all 3 parameters checks OK after the update cycle, the unit will only stay on for a couple of seconds. The internal temperature sensor is used to characterize the RTC and predict the drift rate. If not enough ephemeris is available to compute position, the unit first analyzes the C/N_0 values to determine if the signal is strong enough to collect new ephemeris.
The receiver will stay on for about 30 seconds to update the receiver. If the signal is weak, then the receiver will return to Hibernate state and look again later. If the receiver has valid synthetic ephemeris (Extended Ephemeris) modeled, then each maintenance wake up cycles will only be a couple of seconds for time and frequency checks.

4.4.3. State Transition

When the MPM request is sent from full power mode, a direct transition is requested as soon as sufficient ephemeris data is available, and a valid navigation solution is calculated at near zero user velocity.
If the request is sent when the receiver is in any other low power mode, it will first switch to Full-Power Mode, then switch to MPM.

4.4.4. Use of ON_OFF Signal

When the receiver is in MPM, pulsing the ON_OFF signal will send the receiver to Full-Power mode.

4.4.5. MEMS Wake-up

The MEMS Wake-up, or MEMS interrupt has been implemented for use with MPM. This feature utilizes a 3-axis accelerometer to determine if the receiver is moving or not.
An acceleration threshold is programmed into the actual sensor device. If the programmed threshold is exceeded, the interrupt output from the accelerometer device becomes active. The interrupt is processed only if (1) MPM is already in a degraded mode, and (2) the software is configured to allow sensor wakes.
The software determines if MPM is in a degraded state caused by a lack of signal acquisition during the periodic update cycles that keep the receiver calibrated and in hot start conditions. The degraded state is known ahead of time in order to enable the receiver chip wake-up for interrupt controls.
If calibrated conditions are not maintained, the MEMS wake-up causes the receiver to attempt more frequent calibration cycles under the assumption that movement of the receiver may result in different and/or better signal conditions. Increased frequency is only about one extra cycle every 10-20 minutes based on event timing.

5. Antenna Performance Considerations

Antenna performance is critical for effective operation of low power modes. If the antenna performance is not sufficient, the GPS will not drop from full-power into low system power states, nor will it reliably remain in low system power states once they are entered. This will result in an increase of power consumption compared to what would be obtained with good GPS antenna performance. Position accuracy will also be affected.

Average C/N_0 levels for all satellites in open sky conditions must be between 36 and 40 dB-Hz for good low power mode operation. Higher C/N_0 levels would be ideal. It will take longer to acquire new satellites and collect ephemeris data if the average C/N_0 levels are not sufficient, which in turn will result in higher power consumption.

6. Low Power Input Messages

Input messages used for configuring low power operating modes are described below.

6.1. OSP Binary Commands

Low power operation using TricklePower or Push-To-Fix modes can be configured using Message ID 151 (Set TricklePower Parameters) and Message ID 167 (Set Low Power Acquisition Parameters). These messages are defined in the *GSD4e OSP Manual*. The description of each message in the manual shows how to specify the relevant configuration parameters.

Specific low power modes can be commanded using Message ID 218, which is also defined in the GSD4e OSP Manual. Sub ID 3 of this message is used to command TricklePower mode, sub ID 4 is used to command Push-To-Fix mode, and sub ID 2 is used to command Micro Power mode. The parameters used when commanding TP or PTF mode are the same as those used in MID 151 and MID 167. The receiver can also be commanded back to Full Power mode by using Message ID 218, sub ID 0.

6.1.1. Duty Cycle

The duty cycle, which represents the percentage of time spent in full power mode during TricklePower operation, can be specified from 0 to 100% (0 to 1000). Specifying 0% however is a special case that is also interpreted as 100% duty cycle. The duty cycle is modified by the Jupiter module if necessary in order to produce a valid update interval that is an integer value in seconds. Update intervals can be from 1 to 10 seconds. If the input duty cycle is too low and causes the update interval to exceed 10 seconds, the low power parameters are not updated.

6.1.2. ON Time

The TricklePower ON-time can be specified between 100 and 900ms. However, for 1 second update rates, the maximum ON-time value is 600ms. If the commanded ON-time exceeds the allowed maximum value, the low power parameters are not updated.

6.1.3. Maximum Off Time

When the Jupiter module is unable to acquire satellites while in a low power operating mode, it will drop into a low power system state for a period of time before re-attempting acquisition. The Maximum Off Time specifies this low power period. The default value is 30000 (30 seconds). Although the module will accept values from 1ms to the maximum 32-bit value, the recommended range limits are 1000 to 1800000 (1 second to 30 minutes).

The Maximum Off Time should be set to fit the predominant dynamics of the signal environment. If received signal power is relatively static and changes infrequently, longer times, perhaps 3 to 5 minutes, are more appropriate. If signal power changes more rapidly due to intermittent blockages, as for example in a vehicle going into and out of tunnels, shorter times should be used so that a position fix can be obtained more readily in changing conditions.

6.1.4. Maximum Search Time

This is the maximum amount of time that the Jupiter module attempts to acquire satellites and obtain a navigation solution while in a low power operating mode. If unsuccessful the module drops into a low power system state as described above. The default value is 120000 (2 minutes). The module will accept values from 1ms to the maximum 32-bit value, although the recommended minimum limit is 1000 (1 second).

Note that the Maximum Search Time also applies to initial acquisition if the module is in a low power operating mode at start-up or when it is reset. For these situations, it should be set to a value that can accommodate the average TTFF for the initial acquisition conditions, e.g. warm start or cold start, plus an additional 15 to 30 seconds for margin. Otherwise, the Maximum Search Time can be set to a value from 15 to 30 seconds for most open-sky situations during normal operation. For receivers that experience frequent blockages or weak signal conditions, as for example a receiver frequently used in-doors, larger values should be used in order to accommodate the longer times needed to acquire and track satellites.

6.1.5. Examples

The following examples show how Message ID 218 can be used to command a low power mode.

6.1.5.1. TricklePower

Duty cycle is determined by (desired ON-time) / (desired update interval). For 300ms of ON time, a 1 second update rate, the duty cycle is 300ms/1000ms, or 30%. To enable this, with Max Off Time of 30s and Max Search Time of 120s, the command would be:

A0 A2 00 10 DA 03 01 2C 00 00 01 2C 00 00 75 30 00 01 D4 C0 03 71 B0 B3

6.1.5.2. Push-To-Fix

For PTF, here is the complete byte stream for a 60s period with 120s maximum search time and 30s maximum sleep time.

A0 A2 00 0E DA 04 00 00 00 3C 00 01 D4 C0 00 00 75 30 03 54 B0 B3

7. Document History

Revision	Date	Changes
1	28-Mar-11	Preliminary Release
2	30-Jun-11	Update MPM section to MPM2.0
3	7-Jul-11	Minor formatting edits
4	20-Jul-11	Add Figure 3-2 Tricklepower Timing Diagram