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SiRF Application Note Power Management Considerations of SiRFstarIII

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1. INTRODUCTION

This application note describes the power management considerations of SiRFstarIII based on either the GSP3f baseband and a GRF3w RF chip or GSC3 single chip. Three power management methods are described with timing diagram and estimated power consumption. Where appropriate, differences in performance due to the selection of chips are illustrated.

1.1. Background

As GPS gains popularity with consumers, it has found its way into more and more battery-powered devices. For those devices, saving power is critical. SiRF offers several power saving modes that give customers the ultimate flexibility in the ever-constant power-versus-performance trade-off.

The GSP3f or GSC3 ASIC utilizes an embedded ARM7 TDMI core running at 50 MHz to perform GPS tasks such as satellite signal acquisition, tracking, and navigation. An RF ASIC 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 power and clock carefully, power consumption can be managed more efficiently. For that purpose, SiRF provides three power management schemes.

In general, the power management scheme goes as follows:

The receiver starts in the full power mode until the user's position is fixed and relevant information is gathered. In a cold start (autonomous operation), it will take about 30 to 40 seconds on average to compute the first position fix and extract other information. The time will be shorter in other cases, such as aided or hot starts.

Once the receiver is ready to do normal processing, different portions of hardware can be turned off or unclocked, depending on the receiver state. After all the processing is completed, the receiver will program the Real Time Clock (RTC) wakeup register to wake up at some time in the future, and then go to sleep by turning off most of the circuitry except the RTC. When the wakeup interrupt occurs, the receiver starts up the system and resumes GPS tasks.

2. GLOSSARY

APM: Advanced Power Management, designed for use with SiRFstarIII in wireless networks. This feature is part of SLC3 software.

ATP: Adaptive TricklePower designed for use with SiRFstarIII in autonomous operation. This feature is part of GSW3 software.

CP: Call Processor. This term usually refers to the hardware and software that interfaces to the SiRFLoc client. For example, in a GPS-enabled mobile phone, the phone section is the call processor.

GSC: GPS Single Chip. This term refers to a single package that contains both RF and baseband.

GSW: GPS Software. This term refers to the SiRF software that runs the SiRFstarIII for use in autonomous systems.

PTF: Push-to-Fix ™, a power-saving mode characterized by infrequent power-on times and fix as available in 2 to 8 seconds on demand.

SLC: SiRFLoc Client. This term usually refers to the hardware section and associated software that contains the GPS receiver that runs in an aided mode.

TBD: To Be Determined

TP: TricklePower ™, a power-saving mode characterized by frequent, short power-on times and continuous fixes.

3. APPLICABLE DOCUMENTS

1055-1034 GSP3f Datasheet

1055-1035 GRF3w Datasheet

1055-1039 GSC3 Datasheet

1050-0053 GSW3 Software System Development Kit Reference Manual

APNT3001 SiRFstarIII System Design Guidelines and Considerations

APNT3005 GPIO Pin Functionality for SiRFstarIII

4. POWER MANAGEMENT MODES OVERVIEW

Three kinds of power saving modes are offered to meet demanding applications that have different requirements in position report interval and power consumption. These modes perform similarly in principle but provide different output rates and reliability. They are Adaptive TricklePower (ATP), Push-to-Fix ™ (PTF), and Advanced Power Management (APM).

SiRF offers two different types or flavors of software, GSW3 and SLC3. GSW3 software works for a standalone application which is the traditional GPS operation. SLC3 software focuses on aided applications. SLC3 can achieve faster time to first fix by supplying relevant data to the receiver from an external source.

In the current implementation, GSW3 software supports ATP and PTF. SLC3 aided software supports APM. At the time of this writing, all modes except ATP have been implemented. ATP is planned to be implemented soon. Please check the SiRF developer's site for availability.

Key characteristics of power management modes are as follows:

- Adaptive TricklePower (ATP) is a variant of TricklePower ™ (TP). Only ATP is supported on SiRFstarIII. TP is intended to save power by cycling between full power, a reduced power setting using just the CPU, and a low-power setting in a fixed-rate cycle. Cycle times range between 1 and 10 seconds. TP provides a fixed power savings and provides a constant output rate, but may suffer lost fixes in a weak-signal environment. ATP operates similar to TP. However, when signal levels drop, ATP returns to full power so that message output rates remain constant even in difficult environments. This results in variable power savings but much more reliable performance for a fixed output rate. Applications using ATP should give performance very similar to full power, but with significant power savings in strong-signal conditions.

- Push-to-Fix ™ (PTF) mode is designed for the application that requires infrequent position reporting. The receiver generally stays in a low-power mode, up to 2 hours, but wakes up periodically to refresh position, time, ephemeris data and RTC calibration. A position request acts as a wakeup to the receiver, which is then able to supply a position within the hot-start time specification.

- Advanced Power Management (APM) is designed for wireless devices. It gives the user more options to configure the power management. In addition to setting the position report interval, a Quality of Service (QoS) specification is available that sets allowable error estimates and selects priorities between position report interval and power saving. Typical output rates for a receiver using APM range from 10 to 180 seconds between fixes.

4.1. Power Management Circuitry and System States

The following features of SiRFstarIII are being used for power management circuits (see also Figure 1).

- An internal, battery-backed RTC that is used to maintain time and to wake up the receiver.
- nWAKEUP, a signal that controls the GSP3f baseband regulator
- RFPWRUP (GPIO [8]), which controls the RF regulator that supplies power to the RF chip and TCXO.
- SPI bus used to program the RF chip
- ON_OFF, a pin that the user can use to wake the receiver from one of the sleep states. This pin triggers on the rising edge of the input signal. **Caution: with the current version of GSP3f, only use the ON_OFF pin to wake the chip from either a stand-by or hibernate state. Asserting this signal when the receiver is already awake can cause the receiver to behave improperly, or to hang up entirely. A RFPWRUP (GPIO [8]) pin can be monitored since when its level is low, the receiver is either in a stand-by or hibernate state (see Table 1).**
- GPIO [0] that controls power to the LNA in the RF section.

Depending on different states of the power management circuits, the receiver belongs to one of four system states (see Table 1).

1. Full-power state

This is the initial state of the receiver where all RF circuitry and the baseband are fully powered. The receiver stays in this state until a position solution is made and estimated to be reliable. Even in this state, there is a difference in power consumption during acquisition mode and tracking mode. During the acquisition mode, processing is more intense, thus consuming more power.

2. CPU-only state

This is the state when the LNA in the RF section is shut off. The other parts of the RF section, including the TCXO and fractional synthesizer are still powered in order to provide a clock to the CPU.

This state is entered when the satellite measurements have been collected but the navigation solution still needs to be computed. The RF and DSP processing are no longer needed and can be turned off. This state is available only with a GSC3 chip.

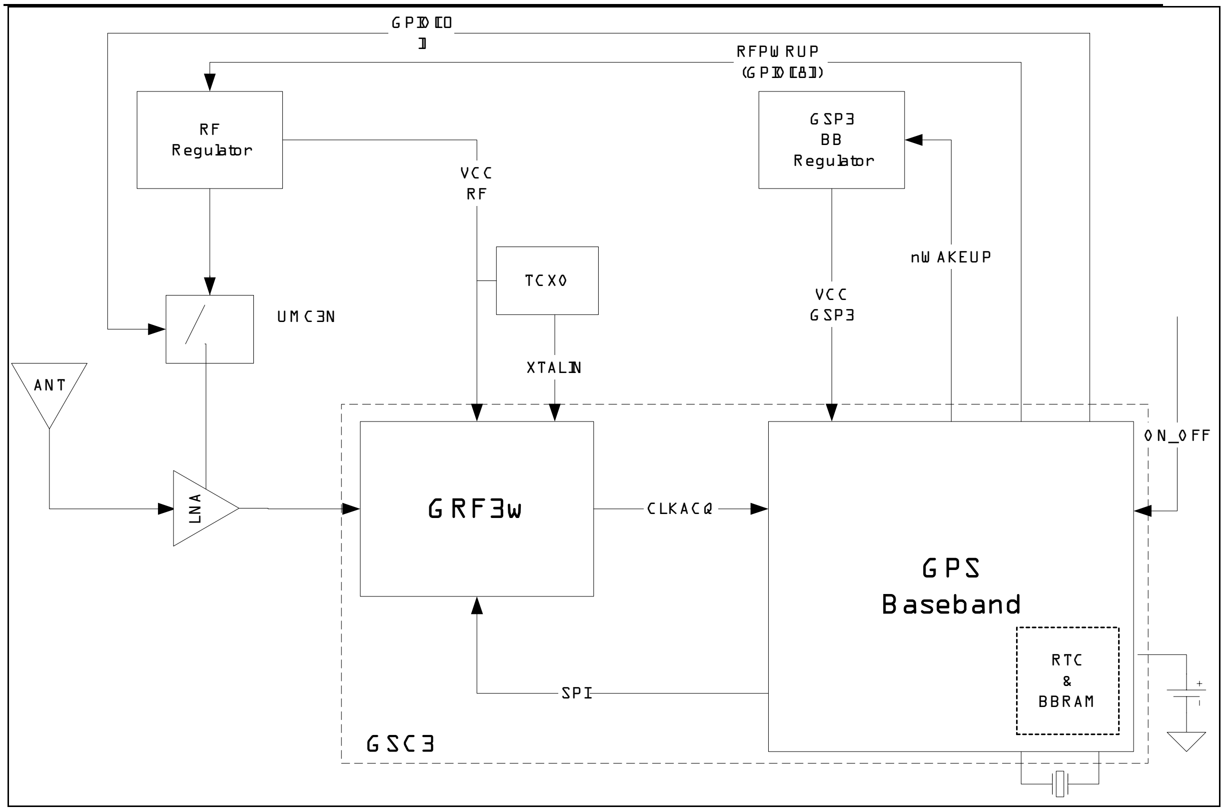

Figure 1 Block Diagram for the Power Saving Mode

3. Stand-by state (or Trickle state)

In this state, the RF section is completely powered off and the clock to the baseband is stopped. About 1 mA of current is drawn in this state for the internal core regulator, RTC and battery-backed RAM.

The receiver enters this state when a position fix has been computed and reported. Typically, before shutting down the RTC wakeup register is programmed to wake up the system sometime in the future. In some cases, programming the wakeup register is skipped when an external host wakes up the receiver.

4. Hibernate state

This is a new feature that is introduced in SiRFstarIII. It is intended for ultra-low power consuming applications. Both the RF and the baseband are turned off, leaving only the RTC and battery-backed RAM running. In this state, less than 50 µA of current is drawn. This state is not available yet.

Table 1 shows the status of GSP3f or GSC3 pins for each state.

Table 1 Pin levels of system states

	nWAKEUP	RFPWRUP (GPIO[8])	GPIO[0]	VDD to the baseband
Full power	L	H	H	H
CPU-only[1]	L	H	L	H
Stand-by	L	L	L	H
Hibernate[2]	H	L	L	L

"1". CPU-only mode is not available with a GRF3w chip.
"2". Not available now.

4.2. Adaptive TricklePower Mode

When Adaptive TricklePower (ATP) is enabled the receiver will maximize the navigation performance while running TricklePower. TP is described later. Under normal tracking conditions, Adaptive TricklePower performs the same as TricklePower, but in harsh tracking environments the receiver automatically switches to full power state to improve navigation performance. When the satellites are sorted according their signal strength, the fourth satellite determines if the transition will occur or not. Currently, the threshold is 26 dB-Hz.

When tracking, conditions return to normal (four or more satellites with C/No of 28 dB-Hz or higher), the receiver switches back to TricklePower. Consequently, navigation results can then be improved in harsh GPS environments at the cost of using more power.

Adaptive TricklePower is best suited for applications that require solutions at a fixed rate as well as low power consumption and still maintain the ability to track weak signals. For this purpose SiRF recommends the use of 300 ms, 1 second or 400 ms, 2 seconds duty cycles for optimum performance.

TP is best suited for applications where regular updates are required, and where stronger signal levels are expected. The receiver is set for a specific update period (range from 1 to 10 seconds), and a specific sampling time during each period (range from 200 to 900 ms). The receiver turns to full power state for the sampling time to collect data, and then operates in stand-by state for the remainder of the update period. The next full-power state is initiated by an RTC wakeup.

TP mode cycles through full-power and stand-by state. However, there are some situations where the receiver stays in full-power mode. They are:

- To collect periodic ephemeris data,
- To collect periodic ionospheric data,
- To perform RTC convergence, and

- To improve navigation result.

Timing diagrams are shown in Figure 2 and Figure 3 for GSP3f with GRF3w and GSC3, respectively, based on the TricklePower ™ parameters of 1 second interval and 300 ms on-time. Those figures are simplified for ease of understanding and may not represent true timing.

After tracking is completed, it takes approximately 160ms to compute the navigation solution and drain the UART before going to the stand-by state. In Figure 2, due to the constraints of the GRF3w, it takes 200 ms longer during the start of the TricklePower ™ cycle when it runs off the RTC clock speed of 32.768 kHz. In the future, if the application can supply an ECLK with TBD MHz, that extra processing time will become small enough to be negligible. Also, it can be noted in Figure 2 that there is no difference in current consumption between full-power and CPU-only state. When GSC3 is employed, three behaviors are observed: power consumption during the CPU-only state; no extra 200 ms switching to the full-power state; and lower power consumption (see Figure 3).

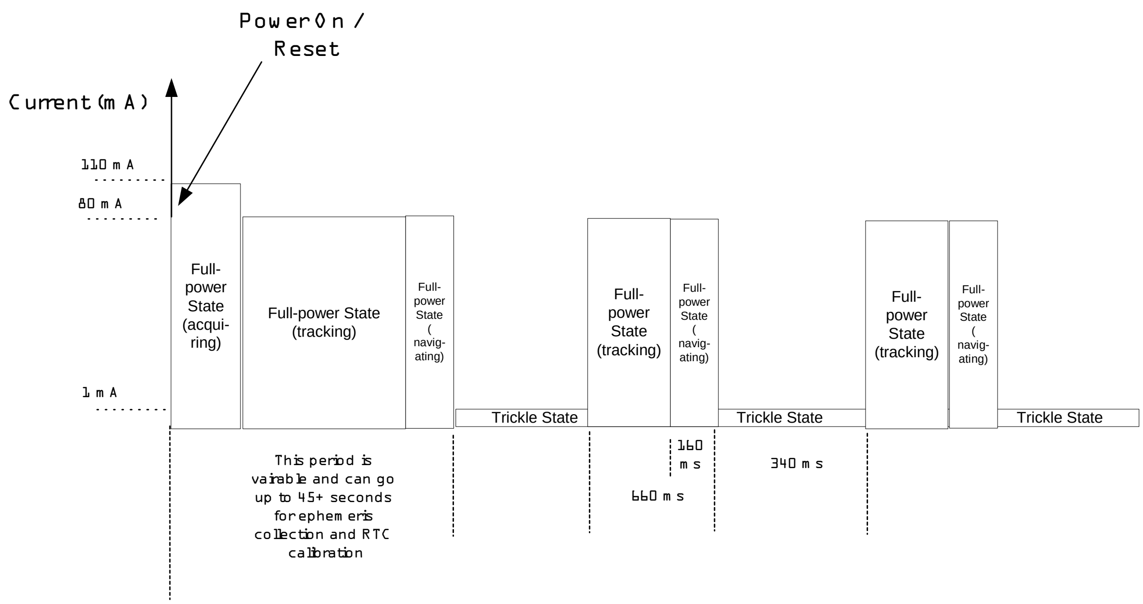

Figure 2 Timing Diagram for the Adaptive TricklePower ™ mode (GSP3f/GRF3w)

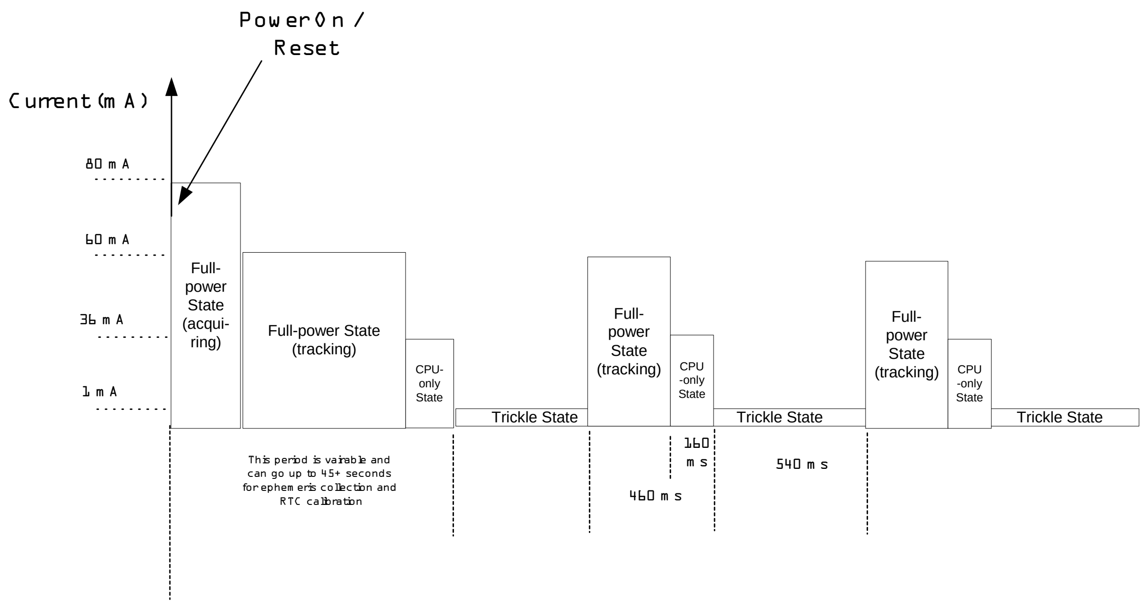

Figure 3 Timing Diagram for the Adaptive TricklePower ™ mode (GSC3)

4.3. Push-To-Fix™ Mode

The Push-to-Fix ™ mode puts the receiver into a background duty cycle mode that provides a periodic refresh of position, GPS time, ephemerides, and RTC calibration every 10 minutes to 2 hours. Typical PTF operation is illustrated in Figure 4 and Figure 5 for GSP3f with GRF3w and GSC3, respectively.

The PTF period is 30 minutes by default but can be anywhere between 10 seconds and 2 hours. When the PTF mode is enabled, upon power on or a new PTF cycle, the receiver will stay on full power until the good navigation solution is computed. The stand-by state will follow for the remainder of the period. If it took 36 seconds to fix position and refresh ephemeris on the default period of 30 minutes, the receiver will sleep for the 29 minutes and 24 seconds. When the application needs a position report, it can toggle the ON_OFF pin to wake up the receiver. When the receiver wakes up, a valid position can be computed in the normal hot-start time.

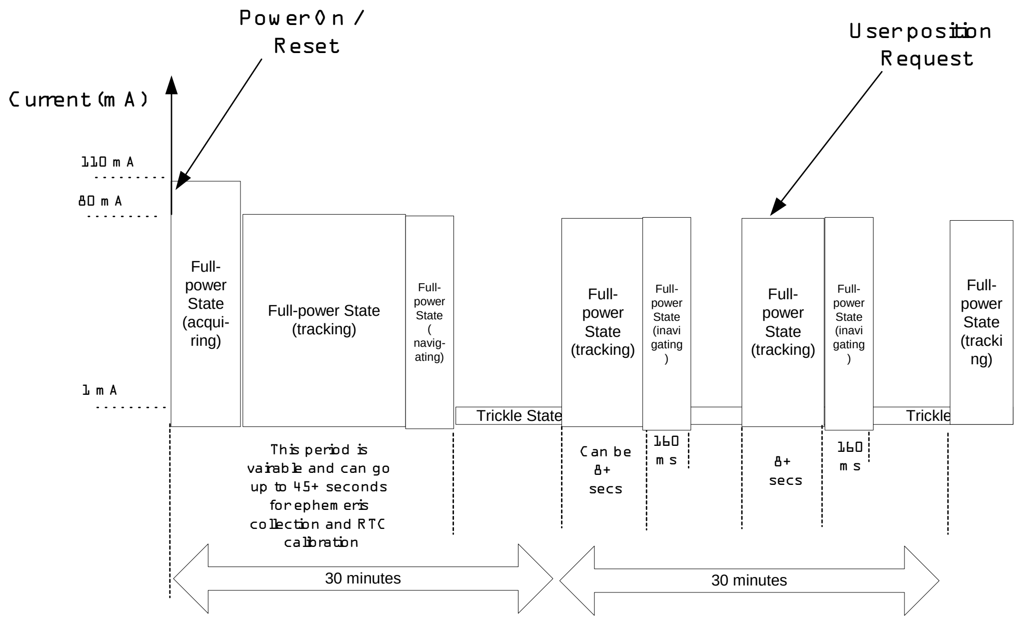

Figure 4 Timing Diagram for the Push-to-Fix ™ mode (GSP3f/GRF3w)

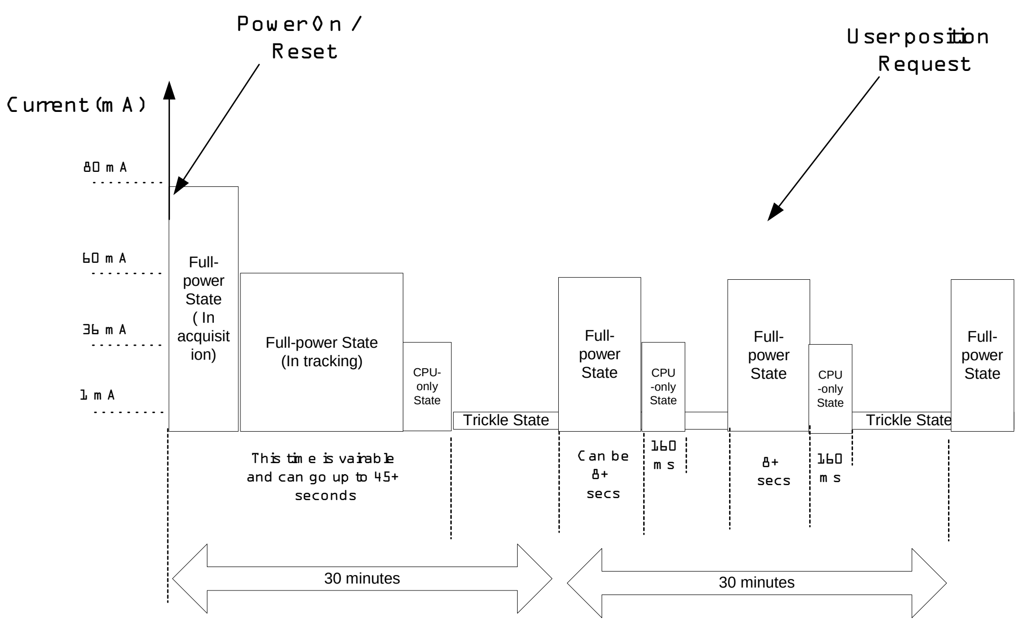

Figure 5 Timing Diagram for the Push-to-Fix ™ mode (GSC3)

4.4. Advanced Power Management (APM)

APM is designed for SLC wireless applications. The APM is designed to put the receiver into certain low power modes in an autonomous fashion. At all times (unless a Session Close message is requested) the Call Processor (CP), an external controller, has to maintain power to the receiver. The actual power consumption is dependent on the APM. For the most part, the receiver is either in Full power or in the stand-by state. The board enters the CPU-only state briefly in the transition between the Full Power and stand-by state to do some power and serial-I/O bookkeeping.

The APM behavior highly depends on whether the user has selected the "Duty" or Time-Between-Fixes (TBF)" priority. The "Duty" priority is designed to maximize battery life. The board monitors the On time of its current cycle and sets its subsequent Off time to maintain the indicated Duty Cycle. The time between two fixes (TBF) when "Duty" is selected becomes a variable number. This variable number is generally stable when the signal conditions are not changing. In this case, the board makes no attempt to maintain the TBF. The only exception is if the Off time based on the On time and Duty Cycle result in a smaller TBF then requested by the user. In this case, the Off time is extended to provide the requested TBF. The assumption is that the user does not need fixes at a faster rate then indicated by the TBF. The Off time is calculated from the On time and Duty Cycle based on the following formula:

$$OffTime = OnTime \cdot \left(\frac{1 - DutyCycle}{DutyCycle} \right),$$

Where *OffTime* and *OnTime* are in seconds, and duty cycle is a number between 0.05 and 1.00.

If the user selects the "TBF" priority, the behavior is quite different. In general, the board tries to maintain the TBF. In certain situations, this could mean that the board goes to full power between fixes. Figure 6 demonstrates the concept behind duty cycle and TBF priority. The diagram is fairly simplistic and is meant only to show general behavior during a GPS signal power transition. "Low" power in this case refers to the stand-by state. To further simplify the explanation, the initial cycle period for the Duty priority (middle graph) and TBF priority (bottom graph) is shown as being the same. The intent is to show potential behavior after the signal level drops significantly.

The top line of Figure 6 shows the GPS signal level as a function of time. At point '1', the signal level drops significantly, which results in requiring more time to acquire the signal and to generate a fix after starting the next APM cycle. A receiver using Duty priority (middle graph) recognizes that the On time of the current cycle was suddenly longer (point '2') in order to maintain the duty cycle the subsequent Off time must also be longer. It can be seen that the Time-Between-Fixes value in the Duty cycle case is variable but generally is constant for a given signal level. In the TBF priority case (bottom graph), the receiver recognizes (point '3') that it has missed sending out a fix when the CP expected it (after a TBF interval has elapsed). The receiver enters in the full power mode because it knows that it cannot acquire a fix in the requested TBF time given the current signal conditions. Once the signal conditions improve, the receiver will be allowed to enter the low power mode again. Note that except for missing the first fix when the signal level dropped, this mode produces fixes at the specific rate.

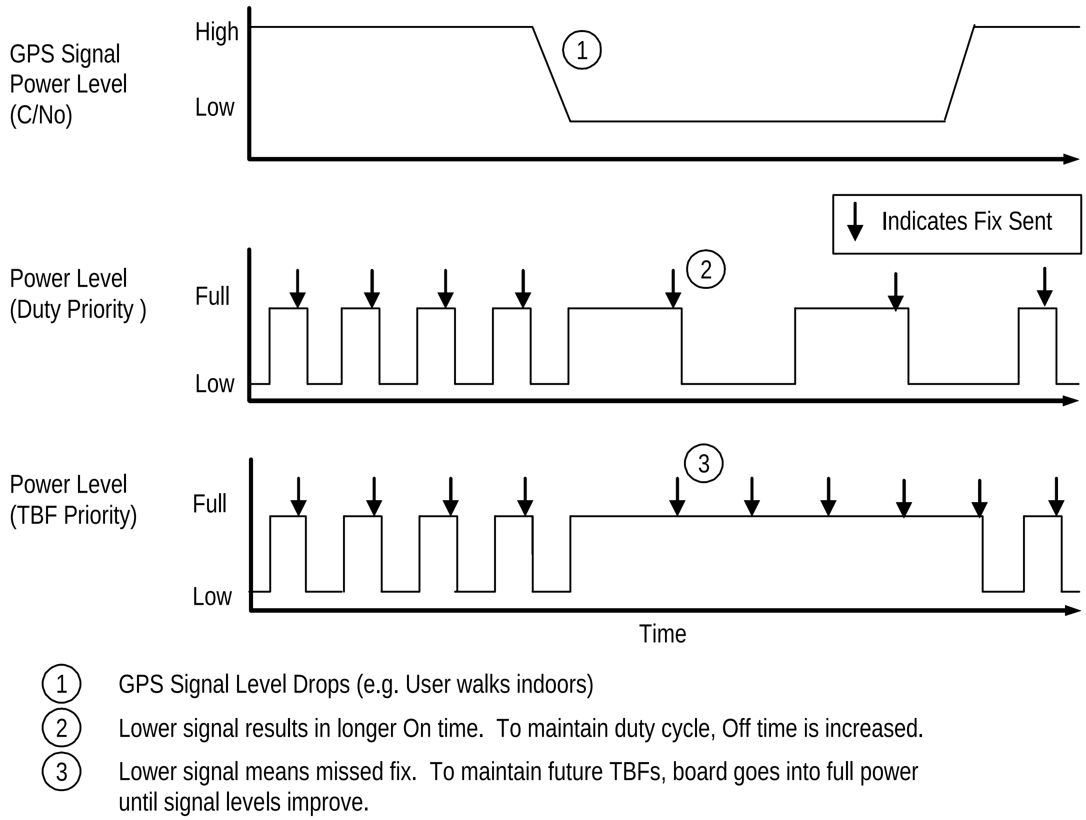

Figure 6 Duty/TBF Priorities in APM

In the TBF priority case, the receiver estimates the time required to obtain a fix for each cycle and assumes that the next cycle will require the same amount of time in order to generate a fix. Just before shutdown, the receiver sets the Real Time Clock (RTC) interrupt to wake up the receiver for the next fix. In order to generate this fix at the appropriate time (i.e. maintaining the TBF value) the receiver will wake-up early to allow the board time to acquire, track and navigate. The amount of time between when the receiver wakes up and when it determines it has to send the fix is set based on the last time-to-fix estimate. A receiver running in the TBF priority mode would enter full power (an exception state) if any of the following conditions occur:

- No satellite signal above 25 dB-Hz.
- Receiver fails to get a fix.
- Time to obtain a fix is longer than the requested TBF value.

To recover from full power, the receiver compares the current signal conditions with the signal conditions that were present at the time the exception occurred. If the C/No value of the 4th strongest satellite is 2 dB-Hz greater than it was when the exception occurred, the receiver resumes cycling. The assumption in GPS positioning is generally for the 4th satellite to make or break the position. If the average signal level of the top 4 satellites is above 32 dB-Hz, the board resumes cycling regardless. More information about SLC and APM can be found in Section 7.

5. Software Interface

Power saving mode is not enabled by default. It can be enabled by changing default values in SRAM or by calling a function. See GSW3 Software System Development Kit Reference Manual for detailed information. The same MI_ calls used in GSW2 software can be utilized in GSW3 software with same parameters. Description of the parameters used in Adaptive TricklePower, or Push-to-Fix ™ is listed in Table 2.

To implement the APM, certain parameters must be initialized in the APM module. These parameters are provided to the receiver through the F and AI3 interfaces. The APM module will not engage until it has received all of the information (i.e. it has received both messages). Table 3 details the parameters which are required from the AI3 interface.

Note that there are some differences in the possible values for TIME_BTW_FIXES between the AI3 specification and the APM module. In the APM module, the time between fixes is limited from 10 s to 180 s. The lower limit is imposed in recognition of the fact that power savings are essentially trivial in weak signal environments if we require higher update rates. The upper limit of 180 s is imposed by the capability of the Real-Time Clock (RTC) to propagate accurate time. Currently, the last four values in Table 3 are not implemented in the APM. The parameters required from the F interface are defined in Table 4.

Table 2 TricklePower/Push-to-Fix™ mode parameters

Parameter	Description	Range	Default Value
PowerCyclingEnabled	Enable Trickle Power.	TRUE/FALSE	FALSE
PushToFix	Enable Push-to-Fix (For Push-to-Fix to be enabled, PwrCyclingEnabled must be TRUE and OnTime = 200, LPInterval = 1000.)	TRUE/FALSE	FALSE
OnTimeMs [1]	System on-time in milliseconds.	200..900	
LPIntervalMs [1]	Trickle power interval in milliseconds	1000..10000	
MaxAcqTimeMs	The maximum allowable interval from the start of a Trickle Power cycle to the time a valid position fix is obtained from navigation. If this time elapses and no fix is obtained, the receiver is deactivated for up to *MaxOffTime*, and when the receiver reactivates, a hot start is commanded. The integer must be in multiples of 1000 ms. The smallest allowable value is 1000 ms. There is no upper limit.	1000..No Limit	120000
MaxOffTimeMs	The longest period (in ms) for which the receiver will deactivate due to the *MaxAcqTime* timeout.	1000..1800000	30000
PushToFixPeriodSec	Push-to-Fix cycle time in seconds.	10..7200	1800
TPAdaptive	Enable Adaptive Trickle Power	TRUE/FALSE	FALSE

'1' – SiRF recommends the use of 300 ms, 1-second or 400 ms, 2-second for optimum performance.

The premise behind the specific parameter breakdown between the two interfaces is the following: The position request via the AI3 interface does not know (or care) what type of device is on the other end and cannot possibly make decisions about power management for a device it cannot identify. It is only concerned with obtaining a particular number of positions at a certain rate and given quality. The implementation of power savings, being specific to the local handset, is therefore made by the CP through the F interface. Please see Section 7.3 for typical call scenarios between the CP and SLC.

Table 3 APM parameters from AI3 interface

Parameter	Description	Range	Default Value
NUM_FIXES	Number of requested fixes.	0->255 [1]	0
TIME_BTW_FIXES	Time between requested fixes.	0->255 [2]	10
HORI_ERR_MAX	Maximum requested horizontal error. MS shall try to provide a position with horizontal error less than this specified value in 95% of the cases.	(not used by APM)	No limit.
VERT_ERR_MAX	Maximum requested vertical error. MS shall try to provide a position with vertical error less than this specified value in 95% of the cases.	(not used by APM)	No limit
RESP_TIME_MAX	Maximum response time. MS shall try to provide a position within the specified time.	(not used by APM)	No limit
TIME_ACC_PRIORITY	Time/Accuracy priority 0x00 = No priority imposed 0x01 = RESP_TIME_MAX has higher priority 0x02 = HORI_ERR_MAX has higher priority	see desc.	0x00

'1' – A value of zero for the NUM_FIXES value indicates that continuous fixes are requested.
'2' – The bounds for the TIME_BTW_FIXES value for the APM is limited from 10 s to 180 s. This is slightly different then the AI3 limits.

Table 4 APM parameters from F interface

Parameter	Description	Range	Default Value
APM_ENABLED	APM Enable flag	TRUE (Enable) FALSE (Disable)	FALSE
POWER_DUTY_CYCLE	Power Duty Cycle, defined as the time in full power to total operation time.	1->20; duty cycle (%) is this value *5.[1]	10 (50%)
TIME_DUTY_CYCLE	Time/Power Duty cycle priority. 0x01 = Time between two consecutive fixes has priority 0x02 = Power Duty cycle has higher priority		0x01

'1' – If a duty-cycle of 0 is entered, it will be rejected. If a duty-cycle value of 20 is entered, the APM module will be disabled and continuous power operation will resume.

6. PERFORMANCES

When estimating power consumption, there are many variations to consider, such as power management mode parameters, signal strength and availability. A typical case for

ATP, PTF, and APM in standalone mode is described in Table 5. The table illustrates current consumption for each mode.

Table 5 Current consumption for each state (Preliminary)

State	GSP3f/GRF3w (mA)	GSC3 (mA)
Full power (acquiring)	110	80
Full power (tracking)	80	60
CPU-only[1]	80	36
Stand-by	1	1
Hibernate[2]	.05	.05

"1". CPU-only mode is not available with a GRF3w chip.
"2". Not available now.

6.1. Power consumption in the TP mode

For a typical setting of 300ms on time and 1 second update interval, GRF3w will result in, 660 ms of full-power state and 340 ms of stand-by state.

The average current and power consumption of each typical cycle is,

Iavg = 80 mA * 500 ms + 80 mA * 160 ms + 1 mA * 340 ms = 53.14 mA

Pavg = 3.3 V * 53.14 mA = 175.362 mW

For GSC3, with the same setup, there will be 300 ms full-power, 160 ms CPU-only state, and 540 ms stand-by state.

The average current and power consumption of each typical cycle is,

Iavg = 60 mA * 300 ms + 36 mA * 160 ms + 1 mA * 540 ms = 24.3 mA

Pavg = 3.3 V * 18.78 mA = 80.19 mW

Table 6 Average Current and Power Calculation for TP mode (Preliminary)

State	GSP3f/GRF3w	GSC3

	Current (mA)	Time (ms)	Current (mA)	Time (ms)
Full power (tracking)	80	500	60	300
CPU-only[1]	80	160	36	160
Stand-by	1	340	1	540
Average Current	53.14 mA		24.3 mA	
Average Power	175.36 mW		80.19 mW	

"[1]". CPU-only mode is not available with a GRF3w chip.

6.2. Power consumption in the PTF mode

Again, a typical setting of 1800 second PTF interval is considered for GRF3w. Assuming it takes 8 seconds to compute a good position since the start of a cycle, the average current and power consumption of each typical cycle is,

I_{avg} = (80 mA * 8000 ms + 80 mA * 160 ms + 1 mA * 1791840 ms) / 1800 seconds = 1.358 mA

P_{avg} = 3.3 V * 1.358 mA = 4.482 mW

For GSC3, they will be as follows:

I_{avg} = (60 mA * 8000 ms + 36 mA * 160 ms + 1 mA * 1791840 ms) / 1800 seconds = 1.27 mA

P_{avg} = 3.3 V * 1.27 mA = 4.18 mW

Table 7 Average Current and Power Calculation for PTF mode (Preliminary)

State	GSP3f/GRF3w		GSC3	
	Current (mA)	Time (ms)	Current (mA)	Time (ms)
Full power	80	8000	60	8000

(tracking)				
CPU-only[1]	80	160	36	160
Stand-by	1	1791840	1	1791840
Average Current	1.36 mA		1.27 mA	
Average Power	4.48 mW		4.18 mW	

"1". CPU-only mode is not available with a GRF3w chip.

6.3. Power consumption in the APM mode

Based on a typical setting of 10 seconds time-between-fixes interval and assuming that a position fix can be made in 3 seconds in each APM cycle using GRF3w. The resulting average current and power consumption of each typical cycle are:,

Iavg = (80 mA * 3000 ms + 80 mA * 160 ms + 1 mA * 6840 ms) / 10 seconds = 25.964 mA

Pavg = 3.3 V * 25.964 mA = 85.681 mW

For GSC3, those numbers are as follows:
Iavg = (60 mA * 3000 ms + 36 mA * 160 ms + 1 mA * 6840 ms) / 10 seconds = 19.26 mA

Pavg = 3.3 V * 15.468 mA = 65.558 mW

Table 8 Average Current and Power Calculation for APM mode (Preliminary)

State	GSP3f/GRF3w		GSC3	
	Current (mA)	Time (ms)	Current (mA)	Time (ms)
Full power (tracking)	80	3000	60	3000
CPU-only[1]	80	160	36	160
Stand-by	1	6840	1	6840

Average Current	25.96 mA	19.26 mA
Average Power	85.68 mW	65.558 mW

"1". CPU-only mode is not available with a GRF3w chip.

7. SLC Considerations

7.1. CP/SLC Communication

This section deals exclusively with the SLC/CP communications related to the APM implementation.

7.1.1. Required Messaging before APM Engages

The APM is disabled by default. To start the APM, both the F and AI3 messages described in Section 5 must be received and validated by the APM module. Once the F message is received, the related parameters remain valid as long as the SLC remains powered by the CP. The only way to change the F parameters is to cycle the power to the board or send another F message. Timekeeping inside the APM module will begin when the AI3 message is received (i.e. the start time of the current cycle will be set at that point). Whenever an AI3 message is received, the internal bookkeeping of the APM module will be reset (including the start time of the current cycle and the number of fixes sent). The APM module can receive an AI3 message at any time a session is open, even if an AI3 message was previously received. If an AI3 message is received (and APM is currently enabled), the APM will check to see if the GPS module is currently running. If not, the APM will take any steps necessary to put the SLC into full power mode and then start the GPS.

Note that the APM does not currently take into account the number of fixes that were sent before the APM was enabled. That is, if the SLC has sent 3 fixes and then the APM is engaged, the CP will get 3 + 10 more fixes.

7.1.2. Ephemeris Aiding after APM is Enabled

Currently, there is no mode in the APM which allows for the collection of ephemeris off of the satellite data stream. Ephemeris records must be delivered through the network. The consequence of this is that the network must update the SLC with new ephemerides as the satellite constellation changes. Ephemeris records received at startup are only considered valid for two hours. The update rate of satellite records from the network must be somewhat faster than this as the number of visible satellites with ephemeris records will decrease steadily over the two hour period as these satellites disappear from view and others appear. In general, the network should expect to send an unsolicited AI3 message containing new ephemeris records every half hour.

7.1.3. Closing and Starting a Session

A Session Close message can be received at any time after the APM has been enabled. If the Session Close message is received before all fixes are sent, the SLC will shutdown without sending the remaining fixes. When the Session Close request is received, the GPS tasks will be disabled and the "AI3 Message Received" flag will be cleared in the APM. The SLC will ignore the standard 5 second serial counter and go to sleep (enter the low power mode) as soon as all tasks have completed and all serial I/O queued for transmit from the SLC have been delivered. It can only be awakened from the low power mode by an ON_OFF (followed by a serial message) or a reset.

Once the Session Close message has been acknowledged by the SLC, the only messages that are valid to send to the SLC are an APM F interface message or a Session Open message. As mentioned in Section 7.1.1, the APM parameters set from the F interface message are maintained until another F message is received or the SLC is reset. When a Session Open message is received, the GPS will be turned back on. Currently, no aiding requests will be made after the first Session Open message has been received (after reset). The APM will not be re-enabled until an AI3 message is received (assuming that the APM is still enabled with the F interface message).

7.2. Entering Different Power modes

Figure 7 shows the possible APM transitions and the manner in which these transitions are initiated. Certain power states are only obtainable with the APM module engaged. If the APM module is disabled, the SLC will be in full power mode and will be continually tracking (or trying to track) GPS satellite signals. If the APM module is enabled, the SLC could be in one of several power states. The dotted lines represent power level transitions which are initiated by the APM independent of external output. The APM algorithms are designed to optimally manage the power of the SLC based on the parameters received from the CP. Once the APM module is enabled, the SLC could be in any power state except "Off". The CP can send an "APM Disable" F interface message at any time to put the SLC back into full power. If the SLC is in the low power mode, a rising edge on an ON_OFF pin will put the SLC into the FULL power mode for 5 seconds to allow for the reception of serial messages. After 5 seconds if there is not any received message, the APM module will put the SLC into the low power mode again.

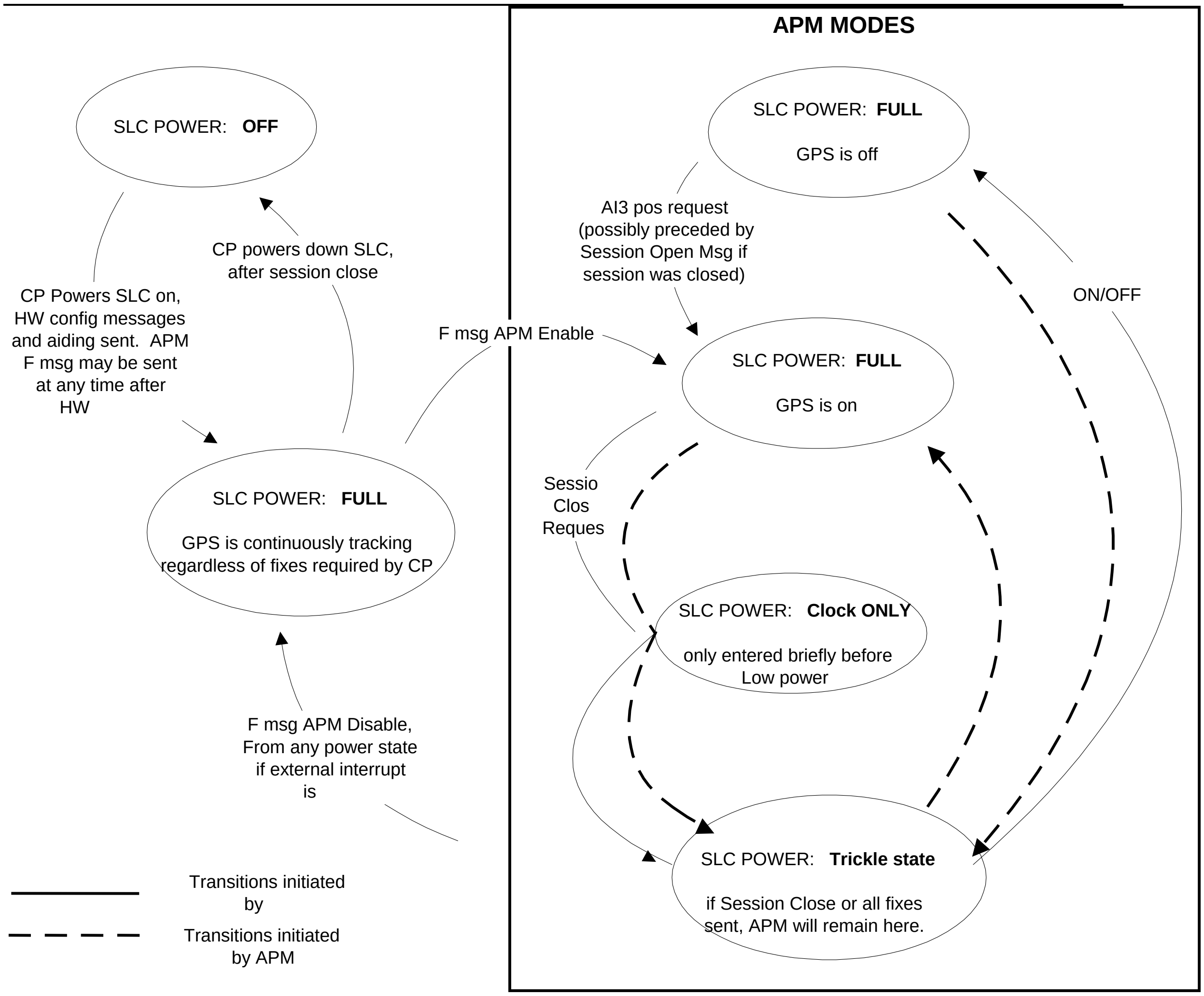

Figure 7 APM Transition Diagram

7.3. Typical Scenarios

Two possible scenarios of using APM are presented in this section.

7.3.1. CP enables APM at start of session

- CP powers on the SLC, SLC enters full power mode, APM module is disabled by default. GPS is started after reset.
- CP and SLC exchange HW configuration and aiding information as per interface control documents.
- CP sends APM message on the F interface to enable the APM module.
- SLC will attempt to get first fix, if first fix is obtained, SLC will enter the sleep mode for a duration dependent on the parameters the APM module received from CP. The behavior if no fix is obtained is

dependent on whether Time-Between-Fixes (TBF) or Duty cycle priority has been selected. In the TBF case, the APM module will reset the GPS and stay in full power mode. In the Duty priority case, the SLC will attempt to maintain the Duty cycle and will enter the low power mode. If multiple fixes are requested, the APM Module will set the Real-Time Clock (RTC) to wake up the SLC for the next fix.

- The APM module monitors the GPS signal situation and enters the various power states based on the parameters received from the CP. When all fixes have been delivered, the APM will enter the low power mode indefinitely.
- At any point, if the CP wishes the SLC to enter the low power mode, it can send a session close message. In order to restart the SLC, the CP will have to send a Session Open message followed by an AI3 position request (the CP will have to assert the ON_OFF pin to wake up the GPS first).
- If the SLC is in the low power mode after sending all fixes, the CP could send another AI3 position request message to get more position fixes. The ability of the SLC to obtain more fixes will be extremely dependent on the length of time that the SLC has been in the low power mode. In the APM module, the maximum amount of time that the SLC is allowed to be in the low power mode between fixes is 3 minutes.

7.3.2. CP wants to put SLC into low power mode

- CP powers on the SLC, SLC enters full power mode, APM module is disabled by default. GPS is started after reset.
- CP and SLC exchange HW configuration and aiding information as per interface control documents.
- SLC starts delivering position fixes as per CP request. SLC is always on, GPS is always running.
- CP decides that no more position fixes are necessary and that the SLC should enter the low power mode.
- CP sends F message to enable the APM, closely followed by a Session Close message.
- APM puts SLC into low power mode.
- To wake up the SLC, CP needs to toggle the ON_OFF pin and sends a *Session Open* message followed by an AI3 position request. If power saving is not required, the CP can send an F interface message to disable the APM module.

8. DOCUMENT MAINTENANCE

8.1. Required Approval for Changes

Changes to this document require the approval of Application Engineering, Program Manager, and Quality.

8.2. Revision History

Rev	Rev Date	CN Number	Description	Author/Editor
1	1/4/04	2664	Initial Release	Young Lee, Reza Abtahi