Low power operating mode

Application Note

This application note describes power management options for Navman SiRFStarII and SiRFStarIII based modules and sensors. These products provide the functionality necessary to implement the SiRF TricklePower™ and Push-to-Fix™ low power modes of operation.

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Related documents

- Jupiter 30 Product brief LA000575
- Jupiter 30/ Jupiter 20 Integrator's manual LA000577
- Jupiter 30 Development kit guide LA000578
- Navman NMEA reference manual MN000315
- SiRF Binary Protocol reference manual

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1.0 Introduction

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

The baseband processor performs GPS tasks such as satellite signal acquisition, tracking and navigation. 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, SiRF provides two power management schemes: TricklePower and Push-To-Fix.

The power management process can be summarised as follows:

The receiver starts in full power mode until the user's position is fixed and the relevant information gathered. When the receiver is ready to carry out normal processing, different sections of hardware can be turned off or unclocked, depending on the receiver state. After the processing is completed, the receiver will program the RTC (Real Time Clock) wakeup register 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.

Note: Antenna performance is critical for the operation of Low Power modes. If the antenna performance is not sufficient the GPS will not drop into low power modes and will not reliably remain in low power modes. This will result in an increase of power consumption compared to what is obtained with a good GPS antenna. Position accuracy will also be affected.

Average CNO levels for all satellites in Open Sky conditions must be between 36 and 40 CNO for good low power mode operation. Higher CNO levels would be ideal. It will take longer to download the Ephemeris and acquire new satellites if the average CNO levels are not sufficient. This will result in Higher power consumption. Average CNO levels of between 28 and 33 are considered insufficient for reliable Full Power operation.

2.0 Power management overview

TricklePower and Push-To-Fix are designed to meet the demands of applications that have different requirements in position reporting interval and power consumption. These modes perform similarly in principle but provide different output rates and reliability.

TricklePower allows for a continuous tracking mode with a user-selectable position Update Interval. Push-to-Fix allows for a more infrequent, on-demand user position request with short TTFF (Time-To-First-Fix).

TricklePower saves 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 – 10 seconds. TricklePower provides a fixed power savings and provides a constant output rate, but may suffer loss of fixes in a weak-signal environment.

Adaptive TricklePower operates in a similar way to TricklePower. However when signal levels drop, Adaptive TricklePower 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 Adaptive TricklePower should achieve results very similar to full power, but with significant power savings in strong signal conditions.

Push-to-Fix mode is designed for the application that requires infrequent position reporting. The receiver generally stays in a low power mode for 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.

3.0 TricklePower mode

TricklePower is suited for applications where regular updates are required and stronger signal levels are expected.

TricklePower mode provides a method of operating the GPS receiver in a user programmable duty cycle, consisting of a receiver measurement 'ON-time' and a position 'Update Interval', thereby reducing the average power consumption over a period of time. TricklePower mode provides a user-selectable Update Interval over the range of 1 – 10 seconds and a minimum ON-time of 200 milliseconds. Refer to the SiRF Binary Reference Manual (Message ID 151 - 'Set TricklePower Parameters') and also section 6.0 - Navman proprietary NMEA input message. Refer to the SiRFDemo user guide for valid settings. The GPS receiver can be configured in TricklePower mode by using the 'Set Low Power' command in SiRFDemo.

TricklePower mode cycles through three states, referred to as the Tracking state (full power), the CPU state, and the Trickle state. When the receiver is first powered on, or after a system reset, the full power Tracking state is entered. Satellite search, initial acquisition, initial position calculation, and tracking measurements are always taken in full power. Lower average power is achieved by powering down the RF section after the programmed measurement ON-time.

During this CPU state, the navigation solution is computed and output via the serial port, and other longer term tasks are performed. Subsequently, the CPU is shut down after the position calculation and serial I/O functions have been completed, effectively putting the CPU into a low power quiescent state (Trickle state). The overall timing of the TricklePower cycle is controlled by software using the Real Time Clock (RTC) as a trigger.

The RF front-end is partially powered down at the end of the Tracking state via internal control signalling. Activating this allows the continued output of the GPSCLK while powering down all other internal DSP circuits. At the end of the CPU state, the entire RF section is then shutdown completely via internal signalling to control the RF voltage regulator enable pin.

3.1 Tracking state

The receiver enters the Tracking state when the system is first powered on, when a system reset is performed, or when the internal RTC wakeup interrupt is generated. In this state the board is fully powered and performs the functions of signal search, acquisition, measurement and satellite tracking.

All internal DSP and the CPU functions are run from the GPSCLK. Satellite measurement data is written into CPU memory on receipt of the 100 ms (millisecond) Data Ready interrupt from the DSP hardware. The Tracking state must be programmed as an integer multiple of 100 ms to coincide with the measurement interface.

The receiver remains in Tracking state until a Kalman filter navigation solution is obtained, all ephemeris data are collected, and the RTC is calibrated, prior to entering the low power duty cycle mode. The amount of time spent in the initial full power Tracking state after power cycling or a system reset, depends upon the type of start conditions that apply, the number of satellites for which ephemeris must be collected, and the time to calibrate the RTC.

Table 3-1 shows average TTFF values for Jupiter series receivers.

	Average TTF Jupiter 20/21	Average TTF Jupiter 30/32
cold start	45 s	34 s
warm start	38 s	33 s
hot start	8 s	1 s

Table 3-1: Average Time-to-first-fix (TTFF) values

The amount of ephemeris data collection time after the initial position varies with the number of satellites being tracked and is typically 5 - 10 seconds. The RTC calibration takes approximately 15 seconds. Therefore, the total ON-time in the first Tracking state can be calculated as: (average TTFF) + 20 s. During this period, a Hot start by user request will typically be calculated more quickly than indicated in Table 3-1 above.

After the initial position fix, ephemeris collection, and RTC calibration, the low power duty cycle mode is entered. Thereafter, the receiver will automatically wake up every 30 minutes to refresh ephemeris and calibrate the RTC.

The actual receiver ON-time will be greater than the programmed ON-time due to receiver set-up and the processing overhead required to configure the hardware tracker channels and control lines. Preceding each ON period, the receiver requires approximately 40 ms of set-up and hardware initialisation. For example, if the TricklePower cycle has been programmed for a 200 ms ON-time, and a 1-second Update rate, the total ON-time in full power is approx. 240 ms.

The current consumption from the main power supply is typically 75 mA (100 mA max) at 3.3 VDC for the entire receiver (excluding power to the active antenna).

Table 3-2 shows average power consumption values for Jupiter series receivers.

Device	Average power consumption
Jupiter 20	75 mA
Jupiter 20S	85 mA
Jupiter 30	54 mA
Jupiter 32	54 mA

Table 3-2: Average continuous power consumption

3.2 CPU state

The receiver enters the CPU state at the end of the programmed measurement period. Position calculation and UART tasks are done over a 200 ms period, taking into account 30 ms of CPU overhead.

The receiver requires approximately 30 ms in order to perform book-keeping and clock management. In the CPU state, the RF front-end is powered down. The embedded CPU and UART core blocks are running to perform the navigation computation, user tasks (if any), and to allow continued communication over the serial port. The CPU state has an approximate duration of 230 – 280 ms during a normal position update.

The CPU time is a function of the number of satellites being tracked, amount of serial I/O messages in the output queue, and the selected baud rate.

3.3 Trickle state

In the Trickle state, power is still applied to the baseband processor, but the RF section is OFF. Prior to switching to the Trickle state the software reads the time from the RTC counter, adds the expected Trickle state time, and stores the result to a register. The only baseband processor internal circuit that continues to function is the RTC.

The transition from Trickle state back to the Tracking state is described as follows. At the programmed RTC counter value, the internally generated RTC wakeup interrupt is activated. Approximately 200 μs after the wakeup interrupt, the CPU begins to execute instructions. After a short delay of approximately 2 ms the RF regulator is turned on and restarts the RF sections.

3.4 Other considerations

The system will automatically refresh satellite ephemeris data and recalibrate the RTC using the background Push-to-Fix cycle. The system will power up and enter the Tracking state for approximately 30 seconds every 30 minutes in order to perform these tasks.

In TricklePower mode, if the receiver fails to hot start or has not computed a position within 2 minutes, the receiver will force a system reset and fall back to a warm start.

TricklePower mode cycles through full power and low power modes. However, there are some situations where the receiver stays in full power mode. These are:

- To collect periodic ephemeris data
- To collect periodic ionospheric data
- To perform RTC convergence
- To improve the navigation result

3.5 Average power calculation

The average current during a TricklePower cycle can be calculated as the weighted sum of the average current and time interval for each of the three states.

4.0 Adaptive TricklePower mode

The Adaptive Trickle Power mode (ATP) is default for Jupiter 30 and Jupiter 32, standard Trickle power is not supported for these receivers.

ATP is suited for applications that require solutions at a fixed rate, low power consumption and can maintain the ability to track weak signals. SiRF recommends the use of 300 ms / 1 second or 400 ms / 2 second duty cycles for optimum performance.

With ATP enabled the receiver maximizes navigation performance while running TricklePower. Under normal tracking conditions, ATP performs the same as TricklePower, but in harsh tracking environments the receiver automatically switches to full power to improve navigation performance. When the satellites are sorted according to their signal strength, the fourth satellite determines whether 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.

5.0 Push-to-Fix mode

Push-to-Fix puts the receiver into a background duty cycle mode that provides a refresh of position, GPS time, ephemeris data, and RTC calibration every 30 minutes. This mode can not be set at the same time as TricklePower mode.

Push-to-Fix mode sets the receiver in a background duty cycle consisting of:

- 30 seconds of ON-time in the Tracking state at full power
- a position computation in the CPU state
- approximately 29.5 minutes in the Trickle state

During the Tracking state the receiver acquires satellites, computes position, updates ephemeris data, and calibrates the RTC. The CPU state follows the Tracking state for the final position computation and requires negligible time compared to the tracking period. The receiver can be configured in Push-To-Fix mode by using the 'Set Operating Mode' command in SiRFDemo.

The first Tracking state after a power on consists of a Warm or Cold start. During the subsequent background cycles, or when a user requests a position update, a reset is generated and a Hot start will typically be performed.

The receiver will output position data for a total duration of about 15 seconds after initial position TTFF, during which time the RTC calibration is performed. Therefore, the first Tracking state after power on can be calculated as: (Cold start TTFF) + 15 seconds. The subsequent tracking states can be calculated as: (Hot start TTFF) +20 s (ephemeris collection and RTC calibration).

5.1 Other considerations in Push-to fix mode

For Jupiter 32 and Jupiter 30 applications: the best way to avoid a lock up condition when using Push-to-Fix mode and ensure that the WAKEUP line is only triggered when the system has dropped into standby mode is to use an external controller and monitor the voltage level of VCC_RF. If the voltage is low, it is safe to wake up from the standby state. By doing this, a system of built-in checks can be implemented in software which will only enable the WAKEUP pin when the receiver is in the STANDBY mode.

A special external gate may be required for some customer applications. This gate must inhibit the WAKEUP input when the VCC_RF is high. It is important to note that the GPS will automatically wake-up at a default 30 minute period, unless this is changed by reprogramming. Therefore, the WAKEUP line must not be triggered at the same time that the GPS wakes up from the 30 minute default period or this will cause a lock up.

Customers who do not use low power modes should ensure that there is no external pull-up resistor on the WAKEUP pin (pin 26).

Customers already using Push-to-Fix in Jupiter 20 applications will need to implement the extra WAKEUP pin and not use the RESET pin as they previously did.

Average power calculation

Average power consumption in the Push-to-Fix mode depends upon the number of position requests initiated by the user.

6.0 Timing diagrams

Typical timing diagrams for Jupiter series receivers are shown in Figures 6-1 to 6-5.

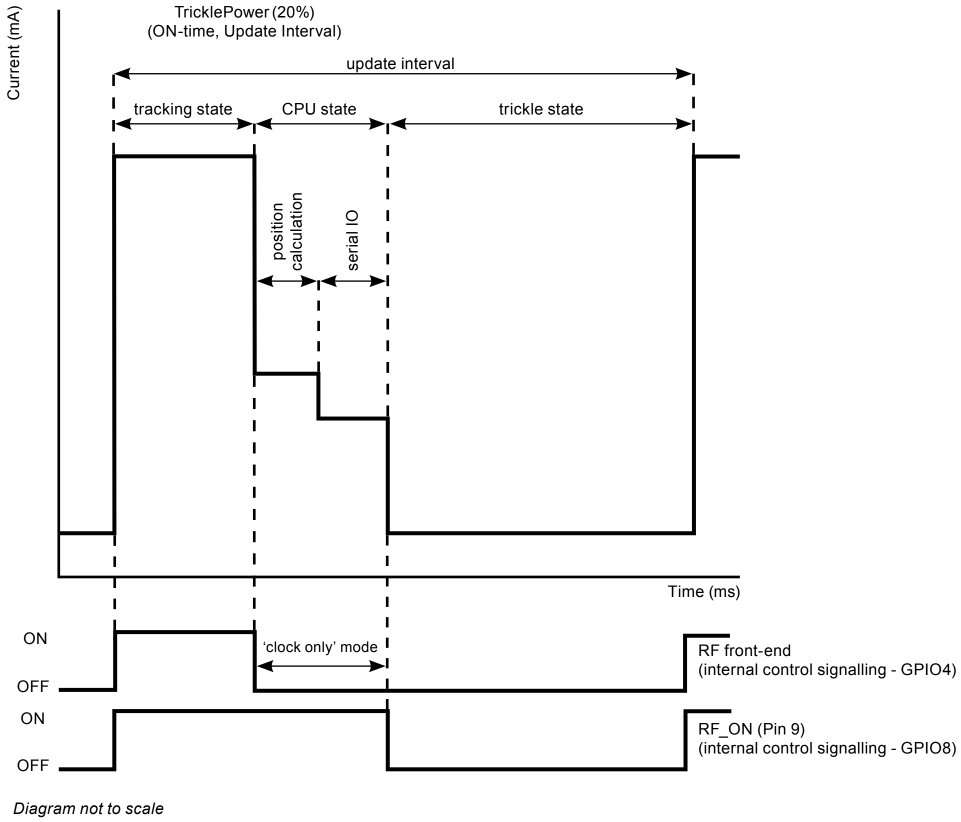


Figure 6-1: Typical Jupiter 20 timing diagram

Notes:

Tracking state – The tracking state is entered immediately after a hardware reset or a power up. In the tracking state, GPIO4 (connected to PWRCTL of the RF front-end) and RF_ON (Pin 9) are defaulted to logic high, the RF section is fully powered on.

CPU state – During the transition to the CPU state, GPIO4 is switched from high to low, which causes the RF section to enter what is referred to as the 'clock only' mode. This effectively disables the RF front-end, but allows the RF section to continue to output the GPSCLK clock source to the baseband processor.

Trickle state – During the transition to the Trickle state, RF_ON (Pin 9) is switched from high to low, which results in the RF regulator to shut down and the RF section to power off. With no clock source available, no UART communication or any other type of CPU functionality is supported during this state.

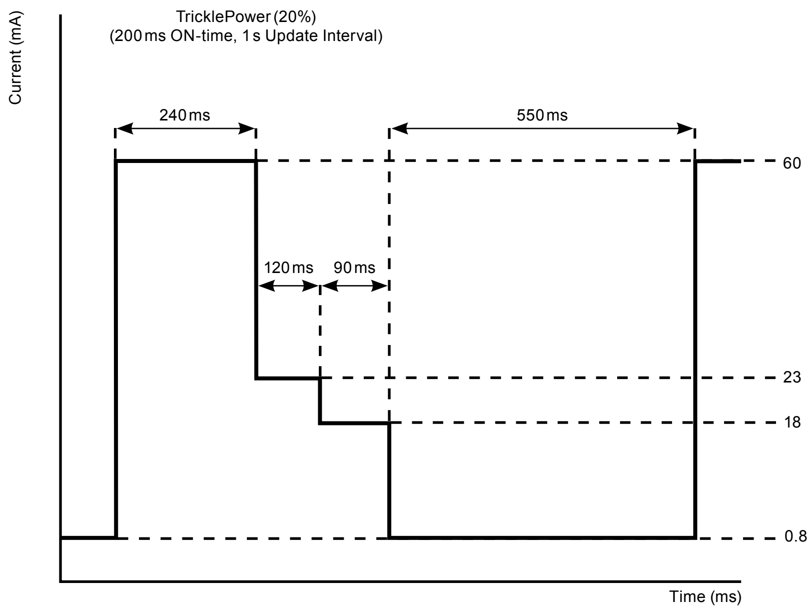


Diagram not to scale

$$I_{AVG} = \frac{\{(240 \times 60) + (120 \times 23) + (90 \times 18) + (550 \times 0.8)\}}{1000}$$

$$I_{AVG} = 20\,mA$$

Figure 6-2: Jupiter 20 standard
(SiRF Binary at 38,400 baud)

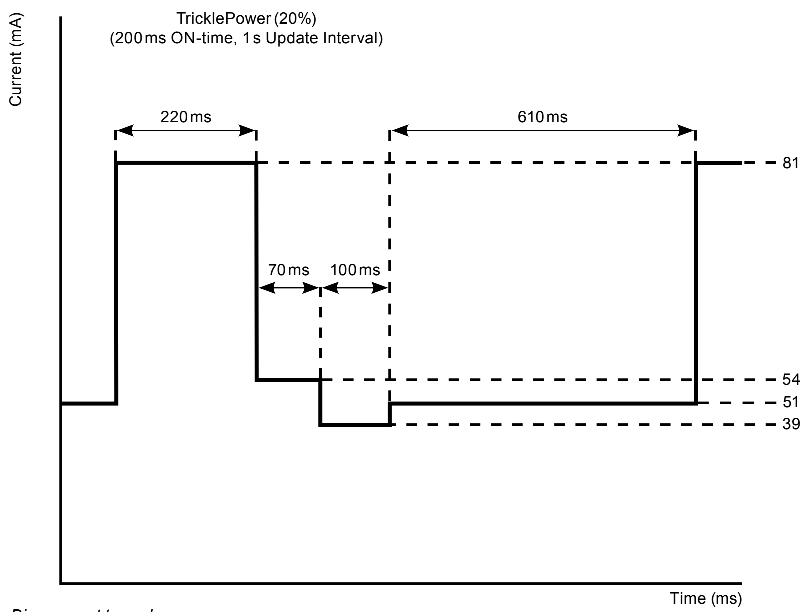


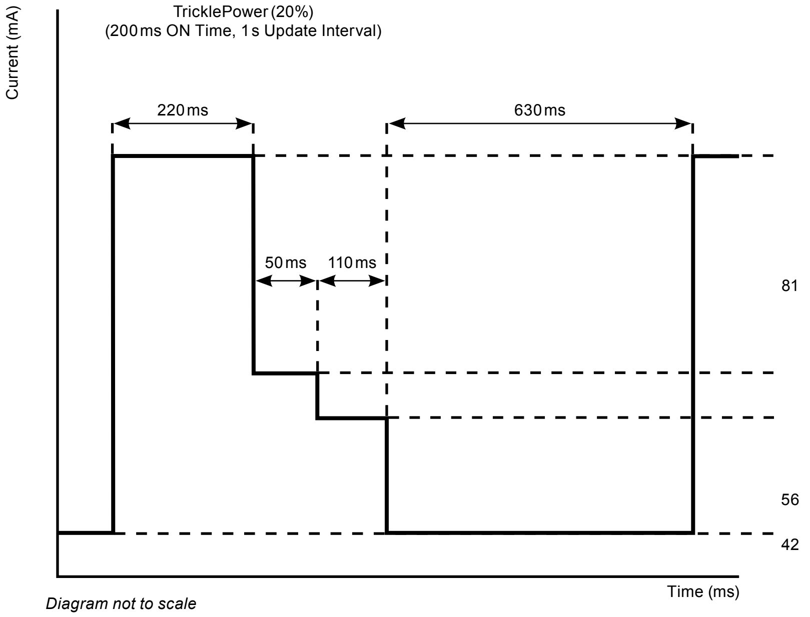
Diagram not to scale

$$I_{AVG} = \frac{\{(220 \times 81) + (70 \times 54) + (100 \times 39) + (610 \times 51)\}}{1000}$$

$$I_{AVG} = 57\,mA$$

Figure 6-3: Jupiter 20S (XTrac) – user tasks enabled
(SiRF Binary at 38400 baud)

Note: the full power saving potential of the TricklePower mode cannot be met due to the implementation of 'user tasks'. User tasks include active antenna detection and protection. Disabling user tasks requires a custom SKU of the firmware.



$$I_{AVG} = \frac{\{(220 \times 81) + (50 \times 56) + (110 \times 42) + (630 \times 1.4)\}}{1000}$$

$$I_{AVG} = 27\,mA$$

Figure 6-4: Jupiter 20S (XTrac) – user tasks disabled
(SiRF Binary at 38 400 baud)

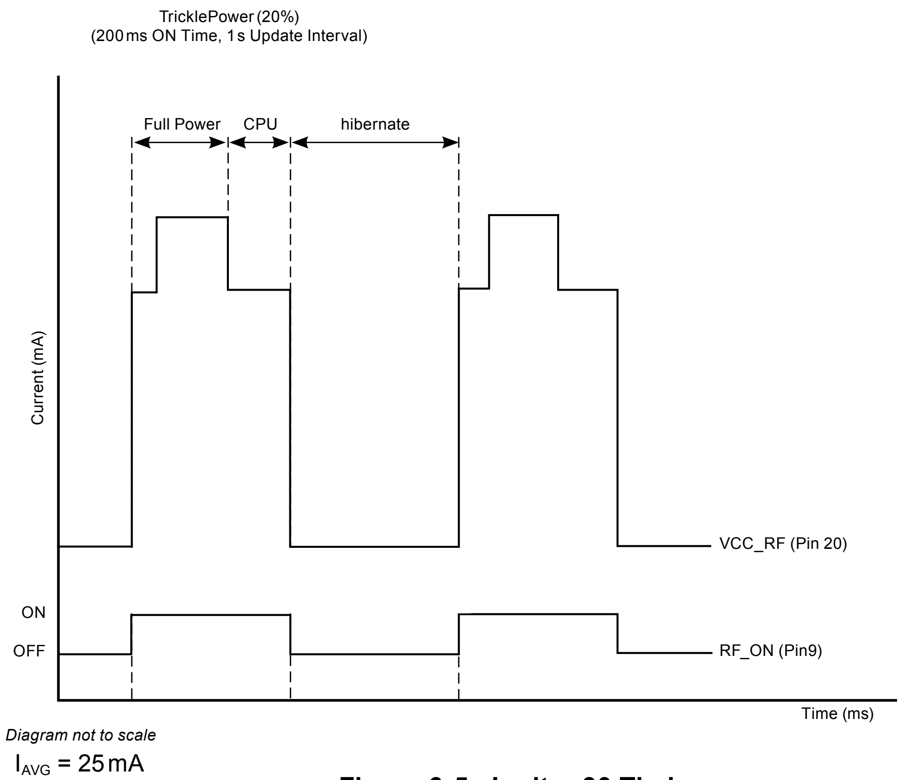


Figure 6-5: Jupiter 30 Timing
NMEA at 38,400 baud

The J30 and J32 have the Hibernate mode that has significant power saving when used in the PTF mode. Hibernate mode currents of 7uA are typical in PTF mode.

During Trickle power mode, Hibernate Mode current is typically 1.2mA.

Average current = (average Full power current x Full power period) + (average CPU mode current x CPU mode period) + (Hibernate current x Hibernate period)

This must now be divided by 1000 to obtain the average current.

For the J30/J32 for a selected 200mS ON time and a 1 second update the average current has been measured at 25mA at a NMEA baud rate of 38400 baud with default messages.

Note: the baud rate selected has a direct impact on the CPU mode period and as a result the average power consumption. Please select the highest baud rate possible if you want the lowest average power consumption. If you limit the number of output messages the CPU period will also be reduced.

7.0 Navman proprietary NMEA input messages

Navman has added a number of proprietary NMEA input messages to configure TricklePower and Push-To-Fix modes.

7.1 Low power configuration

The following message sets the receiver to low power mode:

$PSRF151,a,bbbb,cccc[*CS]

Field	Description
a	Push-To-Fix* (1=on, 0=off)
b	TricklePower duty cycle (parts per thousand)
c	TricklePower On-time (milliseconds)
Note that Push-To-Fix does not require fields b and c so they may be left blank	

This message is the NMEA equivalent of the SiRF Binary input message ID 151. For compatibility with ublox products, an identical input message is used with 107 substituted for 151 in the header:

$PSRF107,a,bbbb,cccc[*CS] <carraige return> <line feed>

System response:

$PTTK,LPSET,a,bbbb,cccc*CS

The updated values returned by the system are as described in the table above.

Note: when TricklePower Mode is active, a high baud rate of minimum 38400 is required for transmission of NMEA messages due to a limited time frame for the transmission of navigation data.

7.2 Low power acquisition configuration

The following message sets the acquisition parameters of the low power mode:

$PSRF167,aaaa,bbbb,cccc,d[*CS] <carraige return> <line feed>

Field	Description
a	maximum off time (milliseconds)
b	maximum search time (milliseconds)
c	Push-To-Fix period (seconds)
d	adaptive TricklePower (1=on, 0=off)

This message is the NMEA equivalent of the SiRF Binary input message ID 167.

System response:

$PTTK,LPACQ,aaaa,bbbb,cccc,d*CS

The updated values returned by the system are as described in the table above.

Field ‘**a**’ is ignored if Push-to-Fix mode is enabled, unless it is set to ‘0’– in this circumstance the reported default for field ‘**a**’ is set to 30000mS and the reported default for field b is set to 120000mS. Push-to-Fix period (field ‘**c**’) is left at its previous value.

The Push-to-Fix period (field ‘**c**’) is used instead of field ‘**a**’ in Push-to-Fix mode. Push-to-Fix period should be set between 10 seconds and 7200 seconds.

$PSRF167,aaaaaa,bbbbbb,cccc,d <carraige return> <line feed>

Field ‘**b**’ should be set anywhere between 10000mS and 600000mS.

Field ‘**a**’ is used if Adaptive Trickle Power is enabled. This should be set anywhere between 10000mS and 600000mS.

Up to 6 digits can be entered for field ‘**a**’ and field ‘**b**’.

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