Orcam GPS35 & GPS36
Data Sheet & Integration Guide

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1. Introduction

1.1 Overview

The Orcam GPS35 & GPS36 are compact, low cost, low power OEM GPS receivers based on the much acclaimed SiRFstar III GPS receiver chip architecture. With a tracking sensitivity of -159 dBm, the GPS35 & GPS36 will continue tracking in the most demanding environments making indoor navigation possible and meeting the challenges of urban canyons and multi path environments.

The GPS35 has no on-board LNA and is designed to be used together with an active GPS antenna, providing min 15 dB gain.

The GPS36 has an on-board LNA and can be used with either a passive or an active GPS antenna.

Designed to operate from 3.3 - 5.5 V DC supply voltage, GPS35 & GPS36 has all necessary power regulation and -management functions on board providing unparalleled SiRF Star 3 acquisition and navigation performance. The wide supply voltage range and a power consumption of less than 150 mW during tracking, makes it easy to integrate into most applications.

In addition to the inherently low power consumption, the GPS35 & GPS36 also supports three additional low-power modes; User-controlled on and off, Adaptive TricklePower and Push-to-Fix.

In the User-controlled on and off mode the the user controls the on and off operation by pulsing the PWR control input. User-controlled on and off mode is best suited for applications where regular updates are required and stronger signal levels are expected.

In Adaptive Trickle Power mode, the receiver automatically switches between TricklePower and Full Power mode depending on signal conditions. In normal conditions the receiver operates in TricklePower mode to save power, but as conditions deteriorate, the receiver will automatically switch to Full Power mode to improve navigation performance at the expense of power consumption.

In Push-to-Fix mode the receiver is normally off but turns on at regular intervals to obtain fixes, collect ephemeris and calibrate the real-time clock (RTC) if necessary. This way a quick GPS solution (Hot Start) will be obtained by toggling the receiver’s PWR line.

1.2 Main features

- ✓ SiRF GSC3f/LP SiRFstar III GPS receiver chip
- ✓ 20 channel L1 receiver at 1575.42 MHz
- ✓ On-board LNA (GPS26) & SAW-filter supports the use of both active and passive antennas
- ✓ SiRF GSW3 GPS software stored in embedded Flash
- ✓ NMEA 0183 and SiRF Binary Protocol
- ✓ Supports SBAS (WAAS, EGNOS)
- ✓ Supports FCC E911 Mandate
- ✓ Supports SiRFLoc™ Client A-GPS
- ✓ Supports SiRF InstantFix™
- ✓ 3,3 - 5,5 V operation
- ✓ < 55 mA (GPS36 acquisition mode)
- ✓ < 45 mA (GPS36 tracking mode)
- ✓ < 22 µA (Hibernate mode)
- ✓ 3 V logic & serial port signal level
- ✓ 1 PPS output

1.3 Part Numbering System

GPS3xFXx

Product revision level

	Serial port A	Serial Port B
A	NMEA 4800 Baud	SiRF Binary 57600 Baud
B	NMEA 9600 Baud	SiRF Binary 57600 Baud

Basic module
GPS35 - No on-board LNA
GPS35 - On-board LNA

2 Technical Specifications

2.1 Electrical Specifications

General Characteristics	Receiver Architecture	20 Channels, 1 satellite /channel simultaneous L1 1575.42 MHz, C/A Code 1.023 MHz chip rate
	Antenna Processor	External active or passive antenna ARM7 / TDMI
Performance Characteristics	Position Accuracy Acquisition Rate	approx. 5 meters, 95% of the time < 35 s Cold start, open sky < 1 s Hot start, open sky 0.1 s reacquisition, typical
	Sensitivity - Cold start autonomous - Tracking	 - 142 dBm - 159 dBm
Communications	Serial Port Supported Protocols port A Supported Protocols port B Digital I/O	Two Serial Ports, 3 V logic NMEA-0183, 4800 or 9600 Baud SiRF Binary Protocol, 57600 Baud WAKE (9): Open-drain 3.6 V max All other Digital I/O: 3 V logic
	NMEA default output messages	4800 Baud: GGA, GSA, RMC, VTG @ 1 s, GSV @ 5 s 9600 Baud: GGA, GLL, GSA, RMC, VTG @ 1 s, GSV @ 5 s
Power Supply	Main power input, VCC Main Supply current	3,3 - 5,5 V DC Acquiring: GPS35 < 45 mA , GPS36 < 55 mA @ 25 °C Tracking: GPS35 < 35 mA, GPS36 < 45 mA @ 25 °C Hibernate mode: < 60 µA (activated using PWR line)
	Battery Backup, VBAT	> VCC - 0,3 V to 5,5 V, ~ 10 µA when VCC = 0 V

2.1.1 Logic Interface Specifications

RTC section Logic signals, PWR (pad 8), WAKE (pad 9)

Symbol	Description	Min	Typ	Max	Unit
V_{OL}	Logic low output voltage			0,2	V
V_{OH}	Logic high output voltage	1,3	1,5		V
V_{IL}	Logic low input voltage	- 0,3		0,45 *1	V
V_{IH}	Logic high input voltage	1,0		1,8 *1	V

* 1 Note: signals are 3.3 V tolerant

3 V Logic signals, all other digital I/O and serial port

Symbol	Description	Min	Typ	Max	Unit
V_{OL}	Logic low output voltage			0,2	V
V_{OH}	Logic high output voltage	2,65			V
V_{IL}	Logic low input voltage	- 0,3		0,8	V
V_{IH}	Logic high input voltage	2,0		3,15	V

2.2 Environmental Specifications

Operating temp.	-40 to +85 °C
Storage temp.	-55 to +100 °C
Altitude	18 000 meters (60 000 feet) max.
Velocity	545 meters /second (1000 knots) max.
Acceleration	4 g max.

2.3 Operational modes

The internal GPS operational modes of the GPS35 & GPS36 are Acquisition, Tracking and Clock Only. In addition to the GPS operational modes, there are two Low Power modes, Standby and Hibernate when the receiver is no longer acquiring and tracking satellites and is not providing any navigation solutions.

All operational modes are accessed and managed through the GPS35 & GPS36 firmware when any of the Low Power Operation Modes are selected, and normally will not be of concern to the user.

- **Acquisition**: In this state, the receiver is running on full power with all sections powered and the DSP core is running at its highest duty cycle. This is the highest power consumption mode of the GPS35 & GPS36
- **Tracking:** In this state, the receiver is running on full power with all sections powered, but the DSP is running at its lowest duty cycle, this is the second highest power mode of the GPS35 & GPS36. This is also the mode that the GPS35 & GPS36 is expected to spend most of its operational time in and, hence, has the greatest impact on battery life.
- **Clock Only:** In this state, the RF receiver chain is turned off, ARM processor, DSP-core, System Clock and Real Time Clock is running.

Low Power Modes

- **Standby:** In this state, the RF receiver chain is turned off; ARM processor, DSP-core and System Clock are powered, but not running; Real Time Clock is running.
- **Hibernate:** In this state only the Real Time Clock is powered and running. This is the lowers power consumption mode of the GPS35 & GPS36.

2.4 Low Power mode operation

There are three modes of low-power operation, User-controlled on and off, Adaptive TricklePower and Push-to-Fix. In the User-controlled on and off mode the PWR pin is used to periodically cycle the receiver between Full Power and Hibernate mode at customer specified intervals. In the Adaptive TricklePower mode, the receives automatically switches between Full Power and TricklePower mode, depending on signal conditions present. In Push-To-Fix mode the receiver is generally off, but turns on at regular intervals to collect ephemeris and maintain real-time clock so that, upon user request, a position fix can be obtained quickly after power-up.

2.4.1 User-controlled on and off

In User-controlled on and off mode, the GPS35 & GPS36 is cycled between Continuous Full Power and Hibernate mode by the use of the PWR input line controlled by the application's Host Processor. The duty cycle and on time is controlled by the user or the application's host processor.

2.4.2 Adaptive TricklePower

Adaptive Trickle Power is an intelligent power saving mode that automatically switches between TricklePower mode and Full Power mode. In good conditions the GPS35 & GPS36 will operate in TricklePower mode but in difficult navigation environments the receiver will switch to Full Power mode to improve navigation performance.

In the TricklePower mode, the power to the receiver's RF- and Baseband sections is cycled periodically and a position is sent at user specified intervals. The receiver is set to a specific update period (max 5 s), and a specific sampling time (200 - 900 ms) by the user. The receiver turns to full power state for the sampling time to collect data, then operates in stand-by state for the remainder of the update period.

The transition to full power mode is determined by the signal strength of the fourth satellite used in the navigation solution, with a threshold of C/N_0 = -26 dB-Hz.

If the C/N_0 of the fourth satellite falls below this threshold, the GPS35 & GPS36 will switch to full power and remain in this mode until normal navigation conditions (4 or more satellite signals with C/N_0 of 30 dB or higher) has been restored, then it will return to TricklePower mode.

Adaptive TricklePower is best suited for applications that require position updates at a fixed rate as well as low power consumption while still maintaining the ability to track weak signals.

By using Adaptive Trickle Power the power consumption can be reduced by half for no noticeable loss of accuracy.

Adaptive TricklePower is enabled / disabled by sending the SiRF Binary Message MID 167 to the GPS35 & GPS36. For optimum performance, it is recommended to use 300 ms, 1 s or 400 ms, 2 s duty cycles. For a detailed description of the MID 167 command, please see the SiRF Binary Protocol Reference Manual.

2.4.3 Push-to-Fix

The purpose of this mode is to support applications where a position output is only needed upon request. In this mode, the receiver normally is in Hibernate mode, and is awakened when a position fix is needed through a pulse on the ON_OFF input or after a preset period no shorter than 10 seconds (default is every 30 min). When the receiver wakes it tries to obtain a position fix (subject to time-out limits), calibrate the real-time clock and collect ephemeris, if needed. The Push-to-Fix mode allows a quick navigation solution to be obtained when the user requests it, by using the PWR-signal (pad 8).

The Push-to-Fix parameters are set by the user using the SiRF Binary Message MID 167.

For more information and a full description of the different power modes please see the following SiRF application notes: GSW3 Software SDK Reference Manual & SiRF Binary Protocol Reference Manual.

2.5 GSWLT3 GPS Software

A large factor in any GPS receivers performance and capabilities is the embedded GPS software.

SiRF GSW3.x, the embedded software used in the Orcam GPS35 & GPS36, runs on the SiRFstar III base band and is highly configurable with the best configuration largely dependant on the intended application and performance requirements. The features available in SiRF GSW3 are:

Feature	Description
Acquisition Accelerator	Improves cold starts and time-to-first-fix.
SnapLock Acquisition	Reacquires satellites within 100 ms if a signal is lost.
SnapStart	Obtains positions in less time when the receiver is powered on.
FoliageLock	Improves positioning performance and satellite tracking ability in difficult environments such as dense tree coverage.
Adaptive TricklePower	Intelligently switches between TricklePower and full power depending on the current GPS signal level.
SingleSat Positioning	Provides additional fixes in an urban canyon and dense foliage environments.
UART Pause	Saves power by idling the UARTs when they are not in use.
Dual Multipath Rejection	Improves position accuracy through enhanced multi path rejection.
Almanac to Flash	Improves cold start times by storing the most recent almanac to flash memory.
Low Signal Acquisition	Acquires satellites and continues tracking in extremely low signal environments.
Low Signal Navigation	Continues navigating in extremely low signal environments.
SiRF Binary Protocol	The standard interface protocol developed and used by SiRF Technology.
NMEA Protocol	The standard ASCII-based protocol used by most GPS applications.

2.5.1 GPS Operating Parameters

When implementing a GPS solution, it is necessary to understand how the final GPS-enabled product is to be used, and to optimise the GPS configuration to best meet the expectations of that application. This can be achieved by configuring various parameters that effect the operation of the GPS receiver. The following table provides an overview of the user-configurable GPS parameters and their typical default settings:

Parameter	Valid Values	Default Values[*1]
Elevation Mask	0 to 90 degrees	7.5 degrees
Track Smoothing	Enabled | Disabled	Enabled
Altitude Hold	Automatic | Always | Disabled	Automatic with last computed altitude
Degraded Mode	Direction then clock | Clock then direction | Direction only | Clock only | Disabled	Clock then direction with a 30 sec timeout
Dead Reckoning	Enabled | Disabled	Disabled
Power Mask	20 to 50 dB-Hz	28 dB-Hz
DOP Mask	Auto PDOP/HDOP | PDOP | HDOP | GDOP | Do not use	Do not use
Static Navigation	Enabled | Disabled	Disabled
SBAS	Auto scan | User Defined | Disabled	Auto scan

[*1]. The listed default values are typical. Actual default values may differ between software types and versions.

2.5.2 GPS Operation Compromises

For each parameter, there is usually a GPS operation compromise. That is, if a parameter is optimised for a particular operational advantage, then it can be expected that the GPS operation will be disadvantaged in some other manner.

Accuracy vs fix density is usually the primary compromise and consideration.

Accuracy	If the GPS receiver is optimised for accuracy, then only the highest accuracy positions are output by the receiver.
Fix Density	If optimised for fix density, the receiver is configured to provide position fixes whenever possible.

Consequently, if the GPS receiver is optimised for accuracy it can be expected that a much lower fix density will result, if the GPS receiver is optimised for fix density lower-accuracy positions can be expected.

In most cases, the compromise is typically accuracy versus fix density.

2.5.3 Operating Modes

Operating modes refer to the type of position and operation allowed by the GPS receiver. Available operating modes include:

- 3D positions only (altitude, degraded, and dead reckoning modes disabled)
- Altitude hold mode
- Degraded mode
- Dead reckoning mode

Each operating mode offers a greater potential fix density and continued navigation, but with continually less accuracy.

The mode the GPS receiver operates in is dependant on the number of satellites available. A GPS position is made up of four unknowns; 3 dimensions of position (X, Y, Z) and time. Therefore, four GPS satellites are required to solve for the four unknown values. If the number of satellites available is reduced to less than four, then different operating modes can be implemented to continue navigation by using assumptions and holding one or more unknowns fixed to reduce the number of variables and propagate the position.

If all operating modes are allowed, and as the number of satellites available are reduced, the following steps occur:

1. Four satellites or more; all unknown variables are solved for; X, Y, Z, and time. This is a 3D position fix.
2. Three satellites; the altitude (or Z) is held fixed and only X, Y and time are solved for. The receiver is now operating in Altitude hold mode and the resultant position is known as a 2D fix.
3. Two and one satellites; when fewer than three satellites are available, additional parameters must be fixed to solve the position. The two parameters that are fixed are clock drift (rate of change in clock bias) and heading.

   The order in which they are fixed depends on the Degraded-Mode setting.

   If the setting is Direction then Clock, then heading is fixed when only two satellites are available, and then clock drift when only one is available.

   If Clock then Direction is selected, the order is reversed. If Clock only or Direction only is selected, the corresponding parameter for a two-satellite solution is fixed, and does not create one-satellite solutions. Instead, the receiver proceeds to a dead-reckoning solution.
4. No satellites; since no satellites are being tracked, no information can be used. The position is propagated by assuming that the receiver is moving in the same direction and at the same speed as the last calculated position. The receiver is now operating in dead reckoning mode.

2.5.3.1 Altitude Hold Mode

In this mode, the last computed Altitude (Z) value is frozen. As the position solution is still computed in three dimensions plus time, with constant altitude, the solution is commonly known as a 2D position.

This allows positioning to continue when less than four satellites are available with a 2D position being the result. As positioning can continue with less than four satellites, the advantage of this mode of operation is a higher fix density.

The trade off when using altitude hold is that an error in the assumed altitude will introduce an error in the horizontal position. As a rule, the possible error in the horizontal position is approximately 30% of the difference between the actual and the used altitude. In other words, 30 cm error in the horizontal position can be introduced for every 1 m error in the altitude. As an example, if the altitude used is 100 m, but the actual altitude of the receiver is 0 m, an error in the horizontal position of 30 m can be expected.

2.5.3.2 Degraded Mode

Degraded mode operation begins when the number of available satellites drops below three.

As with altitude hold mode, as the number of satellites drops, additional parameters must be held constant. While this can cause the introduction of errors, and increases in noise on the solution, it does provide significantly increased fix density. Degraded mode does have a timeout to limit these effects.

2.5.3.2 Degraded Mode (cont.)

The parameters to be held constant are clock drift and heading. The order in which these are held is dependent on the Degraded Mode setting. When the "Clock then Direction" setting is selected, clock drift is held constant as the number of available satellites drops to two, then vehicle heading is held constant as the number drops to one. Selecting "Direction then Clock" reverses this order. Selecting "Clock only" or "Direction only" freezes the selected parameter as the number of satellites drops to two, and stops using degraded mode when the number drops to one.

The table below lists each possible degraded mode option.

Option	Description
Use direction then clock hold	If the number of available satellites is reduced to two, the GPS receiver holds the elevation fixed, and uses the last direction and speed. If the available satellites is then reduced to one, the clockdrift is held constant.
Use clock then direction	This mode is similar to the above Direction then Clock Hold mode. However, the clock drift is held constant, and then the direction.
Direction hold only	This mode restricts degraded mode to two satellites only. When the number of satellites drops below three, vehicle heading is held constant. If the number of satellites drops to one, the receiver goes to dead-reckoning mode, if enabled.
Clock hold only	This mode restricts degraded mode to two satellites only. When the number of satellites drops below three, clock drift is held constant. If the number of satellites drops to one, the receiver will go to dead-reckoning mode, if enabled.
Disabled	This mode prevents the system from using degraded modes when the number of available satellites drops below three. If dead-reckoning mode is enabled, it is entered whenever the available satellites drop below three.

Degraded mode operation is very useful to continue navigation in environments where satellite visibility may be interrupted. However, as the resulting position is based on assumptions, errors can be introduced. An example of this is if a vehicle makes a turn after the receiver has entered into degraded mode. Also, the longer a GPS receiver operates in degraded mode, the less valid the assumptions become.

2.5.3.3 Dead Reckoning

Dead reckoning mode is the next step beyond degraded mode and operates when no satellites are available, or fewer satellites than degraded mode allows. The position is propagated by using the last known heading and speed of the GPS unit. Dead reckoning mode operation can potentially be useful in getting past small blockages in satellite visibility such as bridges and overpasses and continue navigation. However, if there is any variation in speed or direction, then position accuracy will degrade significantly. Like degraded mode, the longer the receiver operates in dead reckoning mode, the higher possibility of significant errors.

2.5.3.4 Static Navigation

Even when a GPS receiver is stationary, each calculated position will be different from the last. This gives the appearance of continuous motion of the GPS receiver.

In a practical situation such as a car stopped at a traffic light, a user expects to see the position to be stationary. It is the static navigation mode that assists in achieving this.

Static navigation mode determines whether a GPS receiver is in fact stationary based on pre-defined velocity and distance values. When static navigation is enabled, if the vehicle's velocity drops below a threshold value, the position and heading are pinned to the last computed value. The position and heading will remain at these values until the receiver detects that the velocity has increased above a slightly higher threshold, or its position is computed to be more than a set distance from that to which it is pinned.

Static navigation is designed specifically for use in motor vehicles where normal speeds are expected to be well above the threshold for pinning. In the hands of a pedestrian, or on a boat drifting with a slow current, the effects of static navigation are likely to be unacceptable since expected velocities are often at or below the threshold for pinning. Even in an automobile or truck, there are likely to be some effects such as delayed starting after a stop, or occasional jumps in position when stopped among high buildings with severe multi path. But the improvement in such displays as maps that place a vehicle's heading at the top can be dramatic.

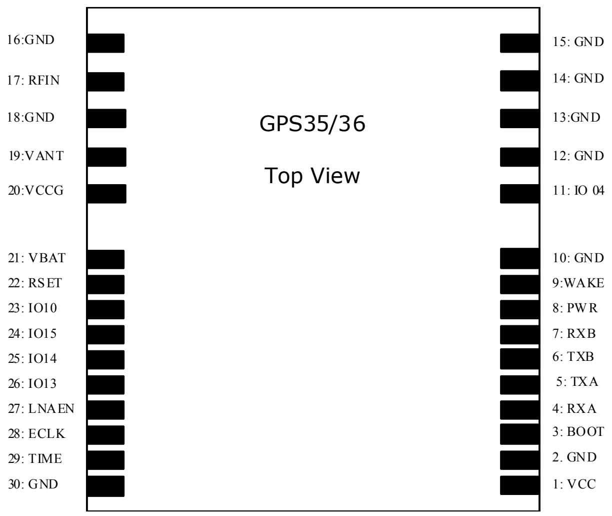
Other navigation parameters include Track smoothing, DOP mask, Elevation mask, Power mask and SBAS. More detail about those can be found in the *SiRF GSC3LTf & GSC3LTif GSWLT3 Evaluation Kit User Guide.*

3. Signal Interface and recommended pad layout

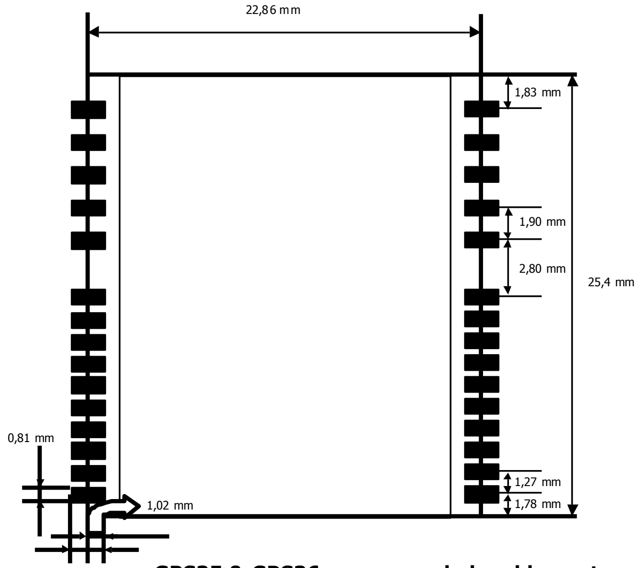
3.1 Signal Interface description

Pad	Name	I/O	Description	Comments
1	VCC	I	Supply voltage 3,3 - 5,5 V	
2	GND	I	Ground	Connect to ground
3	BOOT	I	Boot Mode selector	Leave open if not used (normal operation). Module boots in debug mode if high during reset
4	RxA	I	Serial Port A	3,0V CMOS and 3,0V TTL compatible, pull up if not used
5	TxA	O	Serial Port A	3,0V CMOS and 3,0V TTL compatible, leave open if not used
6	TxB	O	Serial Port B	3,0V CMOS and 3,0V TTL compatible, leave open if not used
7	RxB	O	Serial Port B	3,0V CMOS and 3,0V TTL compatible, pull up if not used
8	PWR	I	GPS Power On	The PWR pin is used to control the Hibernate Mode of GPS3xF. **Do not leave open**, connect to ground if this feature is not used. A rising edge detected on the PWR pin, will change the state of the GPS3xF as follows. • During normal operation, a rising edge on PWR will put the GPS3xF into hibernate mode, • If the GPS3xF is in hibernate mode, a rising edge on PWR will cause the GPS30F to resume normal operation.
9	WAKE	O	Wake up signal	Open Drain, max 3.6 V. Leave open if not used
10	GND	I	Ground	Connect to ground
11	IO 04		General purpose I/O / GND	**Connect to ground.** GPIO pins have no defined function with standard GPS application software. Use of GPIO pins requires special software development.
12 - 16	GND		Ground	Connect to ground
17	RFIN	I	GPS Signal input 50 Ohms @ 1575Mhz	The Orcam GPS2x has no RF-connector, the RF-input signal can be routed directly to pin 17. The track has to be a 50 ohm micro strip. **Note: Apply no DC through this pin**
18	GND	I	Ground	Connect to ground
19	VANT	I	Antenna Bias Voltage	Connecting VCCG and VANT will feed internal 3.0 V into an external active antenna on RFIN. To support active antennas requiring different Bias voltage, external power can be feed into the VANT pad. Leave unconnected if not used. **Note that input voltage shall never exceed 25V.**
20	VCCG	O	Output voltage, RF Section	Regulated +3.0 V supply from RF section of GSC chip. May be connected to VANT to feed internal 2.7 V into the active antenna on RFIN. Leave open if external power is feed into VANT. When using any power saving modes, VCCG will be switched off whenever the RF front end is switched off.
21	VBAT	I	Back-up Voltage supply 2.5 - 5.5 V, not to exceed VCC – 0,3V. Current consumption: ~100 μA in battery back-up mode, VBAT > VCC - 0.3 V	Supply voltage for Battery Backed RAM. As long as VBAT < VCC – 0,3V, there is no current drawn. Connect to GND if not used.
22	RSET	I	Reset (active low)	By pulling down RSET for at least 1μs, the receiver can be reset externally. RSET can also used in Push-to-Fix mode to wake up the receiver when a position is needed. Leave open if not used
23	IO10	I	External Interrupt	Active low
24	IO6	I/O	General Purpose I/O	Leave open. GPIO pins have no defined function with standard GPS application software. Use of GPIO pins requires special software development.
25	IO5	I/O	General Purpose I/O	
26	IO7	I/O	General Purpose I/O	
27	IO1	I/O	General Purpose I/O	
28	ECLK	I	External Clock source for GPS	Leave open if not used
29	TIME	O	1 pulse per second output 3V CMOS level	Leave open if not used. Note pulse width is only ~ 1 μs
30	GND	I	Ground	Connect to ground

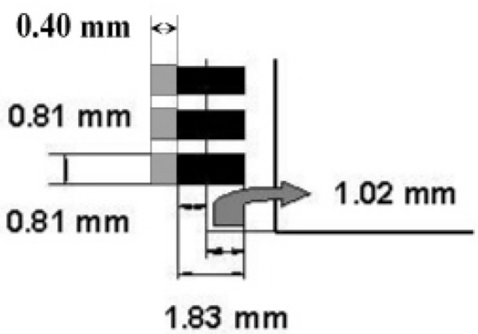
3.2 Pin out & recommended pad layout



GPS35 & GPS36 pin out (top view)
Position of pin 1 identified by dot on label



GPS35 & GPS36 recommended pad lay out



Paste Mask
To ensure high quality of the soldering, define the length of the paste mask to be 0.4 mm longer than the pad length of the copper mask. The recommended thick-ness of the paste mask is 150 µm.

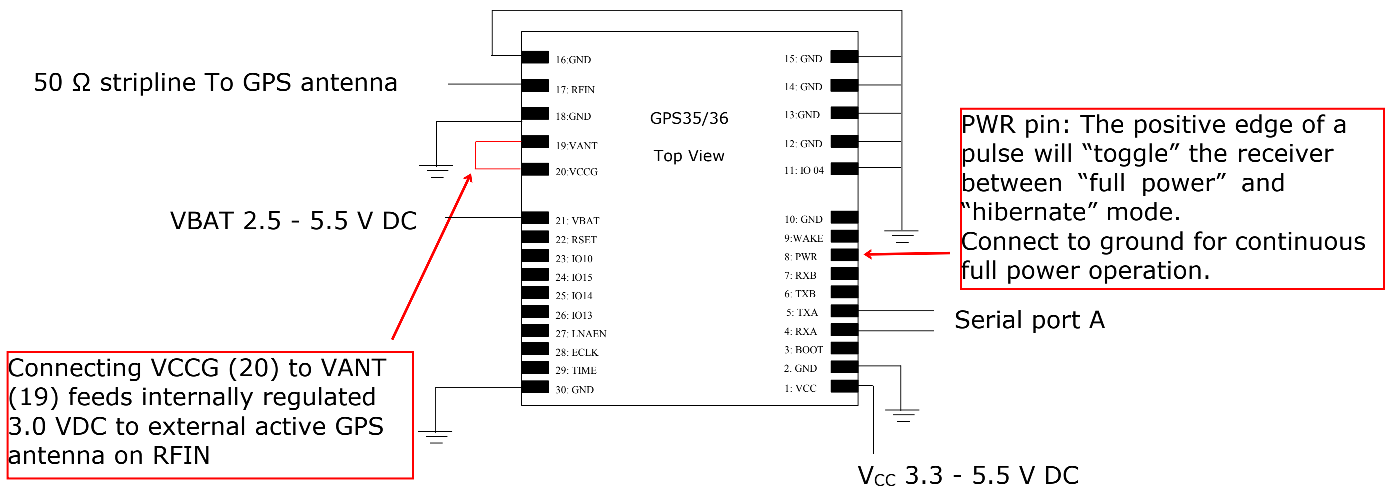
4. Integrating the GPS35 & GPS36

The GPS signal on earth is about 15 dB below the thermal noise floor. To achieve good performance of the system, antenna selection and positioning, grounding, shielding and protection from jamming by other digital devices are the most important topics to consider in the system design. This section provides some hints and guidelines on how to integrate the GPS35 & GPS36 to achieve good overall system performance.

See also sections 5.5 & 5.6 in this document for further information.

4.1 Simple connection diagram for GPS35 & GPS36

This diagram shows the minimum connections required for GPS35 & GPS36 operation.



RxA and RxB are 3.3 V tolerant. An internal pull-up is present on the RxA and RxB input to maintain a "mark" state if the input is disconnected. The input should never be held low to "space" state when idle or not con-nected. Drive levels to RxA input pin must be set to open or driven to zero under all power management or start-up/shutdown conditions and whenever Vcc voltage drops to zero.

For continuous Full Power operation PWR shall be connected to ground.

4.1.1 Power Supply considerations

The GPS35 & GPS36 is designed for a nominal 3.3 V DC supply, and has connection (VBAT) for a separate backup battery to retain information stored in the receiver RAM when VCC is switched off.

VBAT can be any voltage between 2. 5 and 5.5 V DC, but to ensure no current is drawn from the backup battery when VCC is applied, the battery voltage should never exceed VCC – 0,3V.

4.1.2 Hibernate mode control using the PWR pin

The PWR signal (pin 8) on the GPS35 & GPS36 can be used to "toggle" the receiver between Full Power and Hibernate mode to reduce the average power consumption of the receiver. In Hibernate mode, the baseband and RF sections of the receiver are switched off and only the RTC section and memory of the receiver is active, reducing current consumption to ~ 60 µA .

For continuous operation PWR shall be connected to ground. If Power control is required, PWR needs to be connected to a stable logic source providing the pulse to toggle the GPS35 & GPS36 between full power and hibernate mode. The width of the pulse needs to be at least 63 µs long. The PWR connection is 3.3 V tolerant.

A rising edge detected on the PWR pin, will change the state of the GPS35 & GPS36 as follows.

- During normal operation, a rising edge on PWR will put the GPS35 & GPS36 into hibernate mode, with only the Real Time Clock running and the Battery Backed RAM powered.
- If the GPS35 & GPS36 is in hibernate mode, a rising edge on PWR will cause the GPS35 & GPS36 to resume normal operation.
- If the GPS35 & GPS36 has been put in Push-to-Fix mode, the host system, prior to attempting to use the PWR line, must ascertain that the GPS35 & GPS36 is in Hibernate Mode. This can be done by monitoring the WAKE output signal (pin 9).

Do not attempt using the PWR line in Push-to-Fix mode when the receiver is active, as this may cause malfunctions of the receiver.

If the receiver is in Hibernate, a rising edge on PWR will result in the GPS35 & GPS36 waking up, searching for satellites and providing a position before returning to hibernate mode.

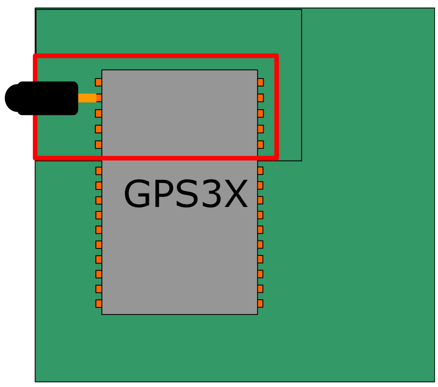
IMPORTANT ! Do not attempt using the PWR control line when Vcc has been switched off, or when the GPS35 & GPS36 is in Adaptive Trickle Power mode as this may damage the receiver.

WAKE is an Open Drain, 3.6 V max output. If WAKE is used to monitor the mode of the GPS35 & GPS36, it should be connected to a high impedance input to assure low current drain. If not used, leave open

4.2 System board layout.

The positioning of the GPS35 & GPS36 GPS receiver on the system board is very important to achieve good performance. The connection to the antenna should be as short as possible, and kept as far away as possible from any digital circuits or other sources of RF radiation on the system board. It is also recommended to place a 10 µF capacitor (ceramic or tantalum) between Vcc and Ground on the system board as close as possible to pin 1 and 2 of the GPS35 & GPS36.

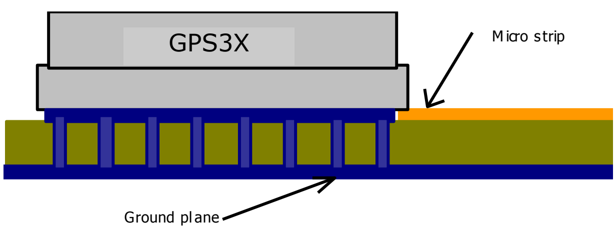
4.2.1 Grounding

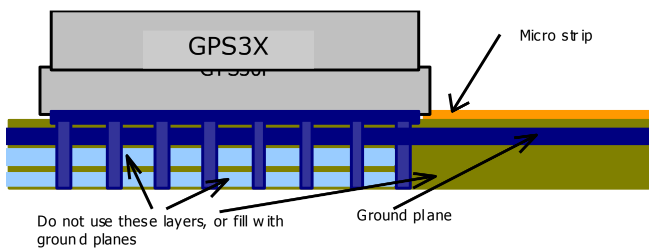


Add a ground plane underneath the whole GPS35 & GPS36 module to reduce interference. An isolated ground area should also be created around and below the antenna connection and the RF input on the receiver. This part of the design should be kept well away from any potential noise sources. The edges of the ground area should be terminated by a dense line of vias. Additional noise isolation is provided by surrounding digital lines with lines of ground vias.

Make sure no power- or signal line cross, or vias of such traces show up on the PCB surface in the area below the RF section of the GPS35 & GPS36 (pins 11 - 20) shown by the red rectangle in the figure. Also the ground plane should be free from digital return currents in this area.

On a multi layer board, the whole layer stack below the red rectangle should be free of digital lines, this because even a solid ground plane provides only limited isolation.





4.2.2 Integrating in systems with GSM transmitters and or CPUs

When integrating the GPS35 & GPS36 in a system containing a high power PA, addition of a notch/bandstop filter on the output of the PA is recommended.

When GPS is co-resident with another CPU or clocked device, there is a high risk that harmonics from other oscillators will appear in the GPS passband. any LCD drive or backlight systems should also be scrutinized for the potential of harmonics within the GPS bandwidth.

Please see section 5.5 of this document for a more detailed discussion about interference issues.

4.3 Antenna Considerations

The Orcam GPS36 has an onboard LNA and SAW-filter and is designed to be used together with either a passive or an active GPS antenna, while the GPS35 does not have an on-board LNA and therefore requires an active GPS antenna for full performance.

When using an active GPS antenna, the antenna should provide enough gain to compensate for cable losses without overloading the RF input stage of the GPS35 & GPS36. Typically an active antenna with ~ 15 dB of gain will be sufficient to obtain good performance. Higher gain active antennas can be used, but the system needs to be carefully evaluated to ascertain performance under strong signal conditions (see below).

When using a passive antenna, conductor lengths (cable and / or micro strip line) should be kept as short as possible to reduce losses and interference. If an omni directional antenna (Helix type) is used, extra care needs to be taken to ensure that the antenna does not pick up noise generated by electronic circuits close to the antenna, including the GPS35 & GPS36 GPS module itself.

Selecting an antenna is a trade off between performance, space available and cost and depends on the actual application. In applications where fixed antenna positions can be expected, a ceramic patch antenna with a sufficiently large ground plane generally gives the best performance.

In applications where the antenna position cannot be controlled, like animal trackers or hand-held or body-worn devices, a Helical or other type of omni directional antenna may provide better results. *See also section 5.4 of this document for further information.*

Regardless of which type of antenna that is selected, care should be taken to ensure that the antenna provides enough gain to allow the GPS receiver to operate with C/N_0 values of 44 - 47 dB-Hz under normal conditions (open sky).

If the C/N_0 value exceeds 50 dB-Hz, the risk for cross correlation increases which may cause increasing TTFF and increase positional errors. If the gain is too low, the receiver's performance deteriorates.

It is recommended that *SiRF Demo* evaluation software be used to verify the C/N_0 values seen under different conditions.

The GPS35 & GPS36 has no RF connector, hence the antenna connection on the system PCB connects the RFIN pin on the GPS35 & GPS36 with the antenna feed point or the signal pin at the antenna connector. The antenna connection needs to be a 50 Ohm micro strip line.

Bias DC voltage for an active antenna can be supplied via the RFIN pin, either internally regulated +2.7 V if VANT is connected to VCCG, or any other well regulated DC voltage connected to VANT.

Important! If VANT is connected to VCCG, care needs to be taken to ensure no short circuits appear during antenna connection / disconnection. A short circuit on VCCG may result in the receiver shutting down, requiring V_{CC} to be removed and reapplied for proper operation after the short circuit has been removed. It is therefore recommended to put the GPS35 & GPS36 in "hibernate mode" or to disconnect V_{CC} prior to connecting or disconnecting the antenna.

4.4 Antenna micro strip design

The antenna connection should be a 50 Ohm micro strip line and kept as short as possible to reduce losses and interference. However, when using a passive Helix omni directional antenna, care needs to be taken to assure noise emanating from the GPS35 & GPS36 itself is not being picked up by the antenna. Positioning the antenna some distance away from the receiver may improve the overall performance.

The micro strip line should, if at all possible, be kept straight to reduce signal reflections. If this is not possible, 45-degree routing is preferred over 90-degree routing.

If possible, the distance between the micro strip line and ground area on the Top Layer should be at least equal to the dielectric thickness.

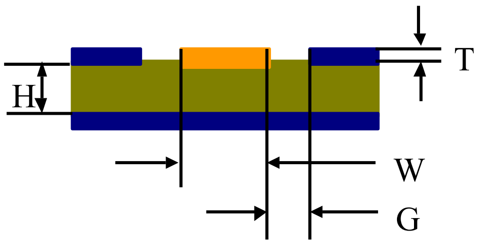
Routing the RF-connection underneath the GPS35 & GPS36 module should be avoided.

Use as many vias as possible to connect the ground planes.In order to avoid reliability hazards, the area on the PCB under the GPS35 & GPS36 should be entirely covered with solder mask and vias should not be open. There are several software tools available for designing micro strip lines on PCB materials, some as freeware. One freeware that can be used is AppCAD by Agilent, that can be downloaded from www.hp.woodshot.com. When using AppCAD, use the Coplanar Waveguide model for calculating the micro strip.

As a rule of thumb, on FR-4 material, the width of the line is roughly double the thickness of the dielectric layer. For the correct calculation of the micro strip impedance, the distance between the top and the first inner layer, the distance between the micro strip and the adjacent ground plane on the same layer needs to be considered.

As an example, on a FR-4 board of 1.6 mm thickness with a 35 µm (1 once) copper cladding, the thickness of the micro strip (T) is comprised of the cladding plus the plated copper (typically 25) and will be 60 µm and the dielectric (H) is 1600 µm. Using AppCAD and selecting G = 600 µm will result in W = 2050 µm for Z_0 = 50 Ohms.

Similarly, for a multi layer PCB with a 18 µm cladding (T = 43 µm) and a 180 µm dielectric (H) between layer 1 and 2 using AppCAD will give a solution with W = 324 µm and G = 250 µm to achieve Z_0 = 50,0 Ohms.



Note:

1. If G > 5 x W, the Micro Strip model can be used in AppCAD to design the micro strip line.

2. For a multi layer PCB, use the thickness of the dielectric between the signal layer and the 1:st ground layer for "H" in the calculation.

4.5 Navigation Messages (Serial ports)

The Serial Ports on GPS35 & GPS36 is used for communicating with the receiver. Messages are received and transmitted using either NMEA-0183 or SiRF Binary Protocol. The GPS35 & GPS36 supports a sub-set of the NMEA-0183 messages allowing some control of the receiver in addition to receiving Navigation messages. Using SiRF Binary Protocol, the ability to control the receiver using software instructions increases. Also, the detail of navigation solution information that can be retrieved increases.

This section describes the standard output messages from the GPS35 & GPS36.

4.5.1 NMEA-0183 Messages

The GPS35 & GPS36 supports the following sub-set of NMEA-0183 messages, developed and defined by SiRF.

GPS35 & GPS36 NMEA Output Messages

MID *1	Description
GGA	Time, position and fix type data.
GLL	Latitude, longitude, UTC time of position fix and status.
GSA	GPS receiver operating mode, satellites used in the position solution, and DOP values.
GSV	The number of GPS satellites in view, satellite ID numbers, elevation, azimuth, and SNR values.
RMC	Time, date, position, course and speed data.
VTG	Course and speed information relative to the ground.
150	OK to send message.
151	GPS Data and Extended Ephemeris Mask
152	Extended Ephemeris Integrity
154	Extended Ephemeris ACK

GPS35 & GPS36 NMEA Input Messages

MID*1	Message	Description
100	SetSerialPort	Set PORT A parameters and protocol
101	NavigationInitialization	Parameters required for start using X/Y/Z*2
102	SetDGPSPort	Set PORT B parameters for DGPS input
103	Query/Rate Control	Query standard NMEA message and/or set output rate
104	LLANavigation	InitializationParameters required for start using Lat/Lon/Alt *3
105	Development Data On/Off	Development Data messages On/Off
106	Select Datum	Selection of datum to be used for coordinate transformations
107	Extended Ephemeris Proprietary 1	Extended Ephemeris Proprietary message
108	Extended Ephemeris Proprietary 2	Extended Ephemeris Proprietary message
110	Extended Ephemeris Debug	Extended Ephemeris Debug
200	Marketing Software Configuration	Selection of Marketing Software Configurations
MSK	MSK Receiver Interface	MSK Command message to a MSK radio-beacon receiver

*1 Message Identification (MID).

*2 Input coordinates must be WGS84.

*3 Input coordinates must be WGS84.

For a complete description of the SiRF NMEA-0183 Protocol Messages supported by GPS35 & GPS36, please see the SiRF NMEA Reference Manual

4.5 Navigation Messages (Serial port)

The Serial Port on GPS35 & GPS36 is used for communicating with the receiver. Messages are received and transmitted using either NMEA-0183 or SiRF Binary Protocol. The GPS35 & GPS36 supports a sub-set of the NMEA-0183 messages allowing some control of the receiver in addition to receiving Navigation messages.

Using SiRF Binary Protocol, the ability to control the receiver using software instructions increases. Also, the detail of navigation solution information that can be retrieved increases.

This section describes the standard output messages from the GPS35 & GPS36.

For a full description of the NMEA and SiRF Binary Protocol, Reference Manuals are available.

4.5.1 NMEA-0183 Messages

The GPS35 & GPS36 supports the following sub-set of NMEA-0183 messages, developed and defined by SiRF.

<u>GPS35 & GPS36 NMEA Output Messages</u>

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RMC	Time, date, position, course and speed data.
VTG	Course and speed information relative to the ground.
150	OK to send message.
151	GPS Data and Extended Ephemeris Mask
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154	Extended Ephemeris ACK

<u>GPS35 & GPS36 NMEA Input Messages</u>

MID[*1]	Message	Description
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101	NavigationInitialization	Parameters required for start using X/Y/Z[*2]
102	SetDGPSPort	Set PORT B parameters for DGPS input
103	Query/Rate Control	Query standard NMEA message and/or set output rate
104	LLANavigation	InitializationParameters required for start using Lat/Lon/Alt [*3]
105	Development Data On/Off	Development Data messages On/Off
106	Select Datum	Selection of datum to be used for coordinate transformations
107	Extended Ephemeris Proprietary 1	Extended Ephemeris Proprietary message
108	Extended Ephemeris Proprietary 2	Extended Ephemeris Proprietary message
110	Extended Ephemeris Debug	Extended Ephemeris Debug
200	Marketing Software Configuration	Selection of Marketing Software Configurations
MSK	MSK Receiver Interface	MSK Command message to a MSK radio-beacon receiver

[*1] Message Identification (MID).

[*2] Input coordinates must be WGS84.

[*3] Input coordinates must be WGS84.

For a complete description of the SiRF NMEA-0183 Protocol Messages supported by GPS35 & GPS36, please see the SiRF NMEA Reference Manual

4.5.2 SiRF Binary Protocol Messages

The SiRF Binary protocol is the standard interface protocol used by all SiRF-based products, and also used in the GPS35 & GPS36 Evaluation receiver. The listing below shows which messages that are supported by the GPS35 & GPS36.

SiRF Binary Messages - Input Message List

Hex	Decimal	Name	Description
80	128	Initialise Data Source	Receiver initialisation and associated parameters
81	129	Switch to NMEA Protocol	Enable NMEA messages, output rate and baud rate
82	130	Set Almanac (upload)	Sends an existing almanac file to the receiver
83	131	Handle Formatted Dump Data	Outputs formatted data
86	134	Set Main Serial Port	Baud rate, data bits, stop bits, and parity
87	135	Switch Protocol	Obsolete
88	136	Mode Control	Navigation mode configuration
89	137	DOP Mask Control	DOP mask selection and parameters
8B	139	Elevation Mask	Elevation tracking and navigation masks
8C	140	Power Mask	Power tracking and navigation masks
8F	143	Static Navigation	Configuration for static operation
90	144	Poll Clock Status	Polls the clock status
92	146	Poll Almanac	Polls for almanac data
93	147	Poll Ephemeris	Polls for ephemeris data
95	149	Set Ephemeris (upload)	Sends an existing ephemeris to the receiver
96	150	Switch Operating Mode	Test mode selection, SV ID, and period.
97	151	Set TricklePower Parameters	Push to fix mode, duty cycle, and on time
98	152	Poll Navigation Parameters	Polls for the current navigation parameters
A5	165	Set UART Configuration	Protocol selection, baud rate, data bits, stop bits, and parity
A6	166	Set Message Rate	SiRF Binary message output rate
A7	167	Set Low Power Acquisition Parameters	Low power configuration parameters
A8	168	Poll Command Parameters	Poll for parameters
AA	170	Set SBAS Parameters	SBAS configuration parameters
AC	172	SiRFDRive-specific Class of Messages	

SiRF Binary Messages - Output Message List

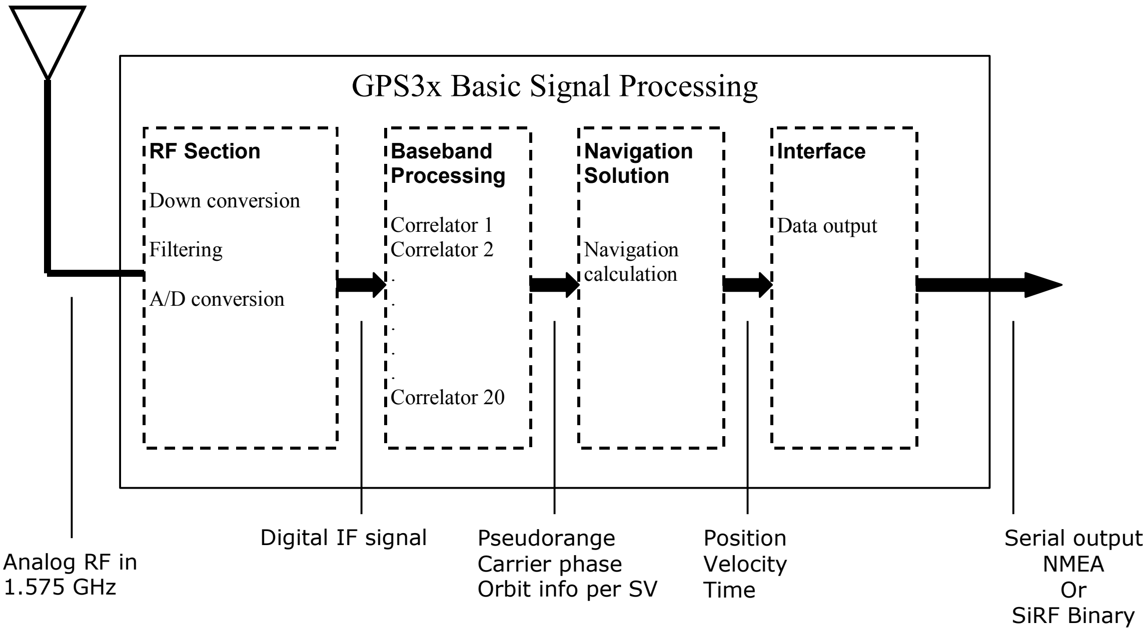
Hex	Decimal	Name	Description
02	2	Measured Navigation Data	Position, velocity, and time
04	4	Measured Tracking Data	Satellite and C/No information
06	6	SW Version	Receiver software
07	7	Clock Status	Current clock status
08	8	50 BPS Subframe Data	Standard ICD format
09	9	Throughput	Navigation complete data
0A	10	Error ID	Error coding for message failure
0B	11	Command Acknowledgment	Successful request
0C	12	Command NAcknowledgment	Unsuccessful request
0D	13	Visible List	Auto Output
0E	14	Almanac Data	Response to poll
0F	15	Ephemeris Data	Response to poll
12	18	OkToSend	CPU ON / OFF (TricklePower)
13	19	Navigation Parameters	Response to Poll
14	20	Test Mode 2/3/4	Test Mode or 4 test data
1C	28	Nav. Lib. Measurement Data	Measurement data
1E	30	Nav. Lib. SV State Data	Satellite state data
1F	31	Nav. Lib. Initialisation Data	Initialisation data
29	41	Geodetic Navigation Data	Geodetic navigation information
2B	43	Queue Command Parameters	Command Parameters
2E	46	Test Mode 3	Additional test data (Test Mode 3)
37	55	Test Mode 4	Track Data
38	56	Extended Ephemeris Data	Extended Ephemeris Mask and Integrity data
E1	225	SiRF internal message	Reserved
FF	255	Development Data	Various status messages

For a complete description of the SiRF Binary Protocol Messages, please see the SiRF Binary Protocol Reference Manual

5. GPS Basics

5.1 Theory of Operation

The basic operation of the GPS35 & GPS36 can be described using the functional block diagram below.



RF Section

In the RF Section the GPS signal detected by the antenna is amplified, filtered and converted to a digital IF signal.

Baseband Processing

The digital IF signal bit stream is then passed to the base band section, where it is fed into the correlators. The function of the correlators is to acquire and track the satellite signals. Up to 20 channels are used in parallel, with each correlator looking for a characteristic PRN code sequence in the bit stream. Once the correlator has a valid signal, Pseudorange, Carrier Phase and Orbit Information can be extracted from the GPS signal and fed to the processor.

Navigation Solution

The on-board processor uses the Pseudorange, Carrier phase and Orbit information to calculate the navigation solution (position, velocity and time), and converts it into the desired coordinate system, e.g.. Latitude/ Longitude/ Altitude.

Interface

The data from the navigation solution is presented at the serial interface port either in NMEA or SiRF Binary format.

5.2. Basic Operation

When the receiver is powered up, it goes trough a sequence of actions until it can initially determine it's position, velocity and time. Once this is done, the satellite signals are tracked continuously and the position is calculated periodically.

To generate a position for 3D solution the receiver needs measurements (Pseudorange, Carrier phase & Ephemeris) to at least 4 different satellites. To calculate a position for a 2D solution 3 different satellites are required.

Pseudo Range and Carrier Phase information is available when the receiver has been able to acquire & track a Satellite. Ephemeris data for a satellite are normally downloaded and decoded from the orbit data the individual satellite transmits. Each satellite transmits its own ephemeris data, the broadcast lasts for 18 seconds, repeating every 30 seconds. Ephemeris data stored in the receiver in battery-backup memory, is valid for 2 hours and can be used in future startup's to improve the time to first fix (TTFF).

Ephemeris can also be supplied to the receiver via the serial port (SiRF Instant Fix).

Depending on which information is available to the receiver at start-up, different start-up strategies will be used to initiate navigation, these are :

Cold start

In a Cold Start, the receiver has no knowledge of its last position or time. This happens when the real time clock (RTC) has not been running or no valid ephemeris data or almanac data is available. For the GPS35 & GPS36 a Cold Start typically takes ~35 s in an open sky environment

Warm start

In a Warm Start, the receiver has access to valid almanac and time and has not significantly moved since the last valid position calculation. This happens when the receiver has been shut off for more than 2 hours, but has its last position, time and almanac stored in memory and the RTC has been running. The receiver then can predict the current visible satellites, and start acquiring data . However, since valid ephemeris data is not available, the receiver needs to wait for the ephemeris broadcast to complete before a position can be calculated and reported.

Hot start

In a Hot Start, the receiver has access to valid ephemeris data, almanac and precise time. Normally this happens when the receiver has been shut off for less than 2 hours, with the RTC running from battery back-up and valid ephemeris data is stored in memory.

As the receiver can predict the currently visible Satellites and ephemeris is already known, the time needed to calculate a navigation solution and output navigation data is short, for the GPS3x typically < 1 s.

5.3. GPS Performance Considerations

GPS works with very weak signals, approximately 15 dB below the thermal noise floor. To design a reliable GPS enabled system requires careful design, taking into consideration all parameters affecting the GPS performance. Some areas to pay special attention to are:

Antenna

- ✓ Gain of the GPS antenna
- ✓ Directivity (radiation pattern) of the GPS antenna
- ✓ Orientation of the antenna to the sky
- ✓ Matching between antenna and cable impedance
- ✓ Noise performance of the receivers input stage or the antenna amplifier

Electrical Environment

- ✓ Jamming from external signals
- ✓ Jamming from signals generated by the receiver itself

GPS Environment

- ✓ Signal path obstruction by buildings, foliage, covers, snow, etc.
- ✓ Multi-path effects
- ✓ Satellite constellation and geometry

The effects of the factors mentioned above is discussed in more detail in the following sections.

5.4 Antenna

The importance of the antenna selection and design cannot be overstressed, as even the best receiver cannot compensate for a poor antenna. The GPS signal is right-hand circular polarized (RHCP). This results in a style of antenna that is different from the well-known whip antennas used for linear polarized signals.

The most common GPS antenna is the patch antenna, another common style is the helix antenna.

A small antenna will present a smaller aperture to collect the signal energy from the sky, resulting in a lower overall gain of the antenna and tight manufacturing tolerances become more critical to the performance of the antenna.

This is the result of pure physics and there is no "magic" to get around this problem. Amplifying the signal after the antenna will not improve the signal to noise ratio.

5.4.1 Active or Passive Antennas

The use of an active antenna (with a built in LNA) is always advisable if the RF-cable length between receiver and antenna exceeds about 10 cm. This will prevent cable losses to affect the overall noise figure of the GPS receiver system. Care should be taken that the LNA gain of the active antenna does not lead to an overload of the RF front-end of the receiver. For the GPS35 & GPS36 an antenna LNA gain of 15 dB is usually sufficient, even for cable lengths up to 5 m, and there's no need for the antenna LNA gain to exceed 26 dB for use with Orcam receivers.

The GPS35 & GPS36 will achieve best performance if the signal strength C/N_0 at is between 44 - 47 dB-Hz in good, open sky conditions. If C/N_0 exceeds 50 dB-Hz, the risk for cross-correlation of increases, prolonging the TTFF and deteriorating the receivers performance. It is recommended that C/N_0 is monitored and measured during development, for example using the *SiRF Demo* evaluation software supplied with the Orcam Evaluation Kits.

When comparing gain figures of active and passive antennas, keep in mind that the gain of an active antenna is composed of two components, the antenna gain of the passive radiator, given in dBic, and the LNA power gain given in dB.

As the antenna gain is important for the overall noise figure, a low antenna gain cannot be compensated by high LNA gain as the LNA will also amplify the noise. If a manufacturer provides one total gain figure, this is not sufficient to judge the quality of an active antenna. Information on antenna gain (in dBic), amplifier gain (in dB), and amplifier noise figure are needed to make a proper decision.

5.4.2 Antenna Matching

All common GPS antennas are designed for a 50 Ohms electrical load, therefore, one should use a 50 Ohms cable or a 50 Ohms strip line to connect the antenna to the receiver.

There are however, circumstances under which the matching impedance of the antenna might shift considerably, meaning that the antenna no longer presents a 50 Ohms source impedance.

Typically what happens is that the center frequency of the antenna is shifted away from GPS frequency - usually towards lower frequencies by some external influence. The reason for this is usually objects in the near field of the antenna. This can be a ground plane, which does not have the same size as the antenna was designed for, an enclosure with a different dielectric constant than air, or in case of hand-held applications the effects from the human body in close proximity to the antenna.

Reducing the size of the antenna will decrease the antenna bandwidth and make it more sensitive to distortions in the near field, making it harder to achieve optimum tuning

If the application requires a very small antenna, a LNA can help to match the impedance of the antenna to a 50 Ohms cable or strip line even if the distance between the antenna and the receiver is short. In this case, there's no need for the gain of the LNA to exceed ~10 dB, as the purpose of the LNA is to provide impedance matching and not signal amplification.

Usually, antenna manufacturers offer a selection of pre-tuned antennas, so the user can test and select the version that fits his environment best. However, equipment such as a scalar network analyzer is needed to verify the matching.

5.4.3 Patch Antennas

Patch antennas are ideal for an application where the antenna sits on a flat surface, e.g.. the roof of a car, as they can show a very high gain, especially when mounted on top of a large ground plane. Ceramic patch antennas are very popular because of the small size, typically measuring from 25 x 25 mm down to 12 x 12 mm. Very cheap solutions might also use ordinary circuit board material like FR-4 or even air as dielectric, but this will result in a much larger size, typically in the order of some 10 x 10 cm.

Ceramic patch antennas, RF Morecom

To achieve optimum performance from a patch antenna, it requires a properly sized and designed ground plane. If the ground plane is small, the antenna will have a certain backlobe in their radiation pattern, making it susceptible to radiation coming from the backside of the antenna, e.g.. multi-path signals reflected off the ground, and also increase the sensitivity to disturbances in the antenna near-field causing the antenna source-impedance to shift.

The larger the size of the ground plane, the less severe these effects becomes.

Manufacturers of patch antennas normally supply design data, showing Gain and Axial Ratio vs ground plane size. For an ideal circular polarization the Axial Ratio is 0 dB, so the lower the Axial Ratio, the smaller the polarisation loss of the antenna.

Most patch antennas, however, do not have minimum Axial Ratio and maximum gain at the same size of ground plane. The patch antenna ground plane, in the end, usually becomes a compromise between the Axial Ratio and antenna gain.

A good trade-off for the ground plane size is typically in the area of 50 to 70 mm square. This number is largely independent of the size of the patch itself (when considering ceramic patches).

Smaller size patches will usually reach their maximum gain with a slightly smaller ground plane compared to a larger size patch. However, the maximum gain of a small sized patch with optimum ground plane may still be much lower than the gain of a large size patch on a less than optimal ground plane.

Not only gain and axial ratio of the patch antenna is affected by the size of the ground plane but also the matching of the antenna to the 50 Ohms impedance of the receiver.

5.4.4 Helix Antennas

In contrast to patch antennas, helix antennas can be designed for use with or without a ground plane. As with patch antennas, filling the antenna with a high dielectric constant material can reduce the size of helix antennas. Ceramic helix antennas with sizes in the order of 18 mm length and 10 mm diameter are being offered to the market. Again, antenna gain will decrease with decreasing size of the antenna.

Ceramic Helix Antenna GeoHelix-SMP, Sarantel Ltd.

The gain of a ceramic helix antenna is usually lower than that of a ceramic patch of the same size. The main lobe of a helix antenna usually is larger than that of a patch, making it more omni directional in nature, while the back lobe of the helix generally degrades much smoother and does not show any sensitivity at the 180 degree direction.

A helix antenna might result in "more satellites on the screen" in difficult signal environments when directly compared with a patch antenna. This is due to the fact that the helix will more easily pick up reflected signals through its omni directional radiation pattern. However, one need to be aware of the uncertain path of the reflected signals and realise that the navigation solution will be degraded because of distorted range measurements in a multi-path environment.

If possible, test the actual performance of different antenna types in a real life environment before starting the mechanical design of the GPS enabled product.

5.4.5 Patch or Helix ?

As there are pros and cons for both antenna styles, in practical applications the possibility of integrating a certain style of antenna into the device usually determines the type of antenna to be used.

Some designs are natural to the patch type of antenna, e.g.. rooftop applications, while others prefer the pole like style of the helix antenna, similar to the style of mobile phone antennas.

If the application is a hand held device, the antenna should be designed in a way that natural user operation results in optimum antenna orientation. The helix antenna seems to be more appropriate, and "forgiving" in applications where the direction of the antenna cannot be controlled, due to it's omni directional characteristics.

However, keep in mind that comparable antenna gain requires comparable size of the antenna aperture, which will lead to a larger volume filled by a helix antenna in comparison to a patch antenna. Helix antennas with a "reasonable" size will therefore typically show a lower sensitivity compared to a "reasonably" sized patch antenna.

5.5 Interference Issues

In an ideal GPS application, the antenna will only see thermal noise in the GPS frequency band as the peak power of the GPS signal is ~15 dB below the thermal noise floor. Therefore a typical GPS receiver is designed with a very low dynamic range. The thermal noise floor is usually very constant over time, and most receiver architectures use an automatic gain control (AGC) circuitry to automatically adjust to the input levels presented by different antenna and pre-amplifier combinations. The control range of these AGC's can be as large as 50 dB.

However, the dynamic range for a jamming signal exceeding the thermal noise floor is typically only 6 to 12 dB, due to the one or two bit quantization schemes commonly used in GPS receivers. If there are jamming signals present at the antenna exceeding the thermal noise power, the AGC will regulate on the jamming signal, suppressing the GPS signal buried in thermal noise even further.

Depending on the filter characteristics of the antenna and the front end of the GPS receiver, the sensitivity to such in-band jamming signals decreases more or less rapidly if the frequency of the jamming signal moves away from the GPS signal frequency.

A jamming signal exceeding the thermal noise floor within a reasonable bandwidth (~100 MHz) around the GPS signal frequency will degrade the performance significantly. Even out-of-band signals might affect GPS receiver performance. If the jamming signal is so strong that the antenna and front-end filter attenuation are not sufficient, the AGC will still regulate on the jamming signal. Very high jamming signal levels can also result in non-linear effects in the pre-amplifier stages of the receiver, desensitising the whole receiver. When integrating GPS with other RF transmitters special care is necessary to ensure jamming is minimised.

If the the antenna is to be integrated with other digital systems, one also need to make sure that jamming signal levels are kept to an absolute minimum. Harmonics of a CPU clock can still at 1.5 GHz exceed the thermal noise floor.

There is not much that can be done to the GPS receiver itself to reduce the effects of jamming without significant effort. Instead, one should concentrate on removing or minimizing the interfering signals at the source. This section contains general recommendations and ideas on how to proceed to reduce interference. It is however totally dependent on the actual application if any of these concepts will apply.

In applications where an active antenna is used in a remote position, e.g.. >1 m away from other electronics, interference should not be an issue.

5.5.1 Noise Sources

Two sources of noise are responsible for most of the interference issues with GPS receivers:

1. Strong RF transmitters close to GPS frequency, e.g.. GSM, DCS at 1710 MHz or radars at 1300 MHz.

When integrating the GPS35 & GPS36 in a system containing a high power PA, addition of a notch/bandstop filter on the output of the PA is recommended. The second harmonic of an 800 or 900 MHz cellular transmitter is at power levels of -50 to -80 dBm, depending on the filtering, the PA characteristics, and the isolation possible. Adding a shunt LC filter in a series resonant configuration at 1575 MHz will reduce the noise power coming from this offending signal, with a small penalty in PA output power (est. 0.2 dB).

Not only must harmonics be attenuated but also broad spectrum noise and spurious signals from the power amplifier must be reduced below -160 dBm-Hz within +/- 20 MHz of 1575.42 MHz. Any in-band power above this level will have the risk of desensitising the GPS receiver.

Even if the transmitter is quiet in the GPS band, a very strong emission close to the GPS band can cause saturation in the front-end of the receiver, like the transmission of a DCS handset (max. 30 dBm at 1710 MHz). If the filtering between the antenna and the GPS receiver is not sufficient, the receiver's front-end stage will reach its compression point. This in turn increases the overall noise figure of the receiver.

Also the GPS receiver may require additional filtering to be placed between the antenna and the receiver to reduce the effect of strong emissions outside the vicinity of the GPS band.

2. Harmonics of the clock frequency emitted from digital circuitry.

This problem is more common but can also be hard to solve. Here, the emitting source is not well specified and the emission can be of broadband nature, making specific countermeasures more difficult.

Any processor, LCD drive and backlight systems should be scrutinized for the potential of harmonics within the GPS bandwidth. When GPS is co-resident with another CPU or clocked device, there is a high risk that harmonics from other oscillators will appear in the GPS passband.

For example, the 97th harmonic of a square clock signal is only 60 dB below the power level of the fundamental frequency. With clock power level of -30 dBm and coupling loss of 20 dB, the 97th harmonic level is at -110 dBm – which is still 10 dB higher than the strongest GPS signal at -120 dBm and 50 dB higher than the low signal floor of the GPS signal at -160 dBm.

Analysis is simple: for any oscillator or clocked signals, determine if there is any harmonic that falls between 1565 MHz and 1585 MHz – this is a strict keep-out range unless the clock is well shielded. Harmonics that fall between 1555 MHz and 1595 MHz are at risk of overloading the RF section or causing unwanted mixer products.

Simple spreadsheet calculations allow determination of risk clock frequencies: *Fref* is the frequency of the reference clock an *n* is any integer that results in a harmonic within the ranges identified. The values are based on a nominal 10 MHz passband for the IF and a 40 MHz passband for the RF filters.

Risk	**Frequency Range**
High	1565 MHz ≤ n × Fref ≤ 1585 MHz
Moderate	1555 MHz ≤ n × f ≤ 1565 MHz, 1585 MHz ≤ n × Fref ≤ 1595 MHz
Low	n × Fref ≤ 1555 MHz, 1595 MHz ≤ n× Fref

Clock Harmonic Frequencies At-Risk to GPS

The GPS band also is far beyond the 1 GHz limit that applies to almost all EMC regulations. So, even if a device is compliant with respect to EMC regulations it might still disturb a GPS receiver severely.
If the GPS antenna is to be placed very close to some other electronics, e.g.. the GPS receiver itself or a PDA-like appliance, the EMC issue has to be taken very seriously right from the concept phase of the design. One of the most demanding tasks in electrical engineering is to design a system that is essentially free of measurable emissions in a certain frequency band.

5.6 Reducing Digital Noise Sources

Digital noise is caused by short rise-times of digital signals. Data and address buses with rise-times in the nanosecond range will emit harmonics up to several GHz. The following sections contain some general hints on how to decrease the level of noise emitted from a digital circuit board that eventually sits close to the GPS receiver or the antenna.

5.6.1 Power and Ground Planes

Use solid planes for power and ground interconnect.

This will normally result in a PCB with at least four layers, but will also result in much lower radiation. Solid ground planes, in the sense that there are no slots or large holes inside the plane, also ensure that there is a defined return path for the signals routed on the signal layer, thereby reducing the "antenna" area of the radiating loop.

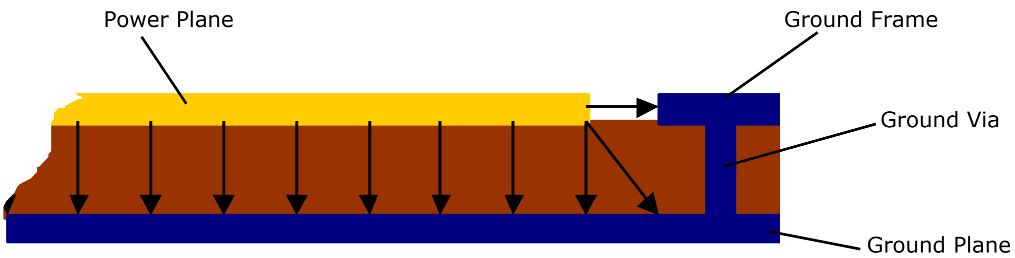
The outer extent of the power plane should be within the extent of the ground plane.

This prevents the edges of the two planes to form a slot antenna at the board edges.

Place a ground frame on the circumference of every layer.

The ground frame should be connected to the ground plane with as many vias as possible. If necessary, a shield can then be easily mounted on top of this frame. Free space on the top and bottom layers can be filled with ground shapes connected to the ground plane to shield radiation from internal layers.

Example of good Power plane design



5.6.2 High Speed Signal Lines

Keep high-speed lines as short as possible.

This will reduce the area of the noise-emitting antenna, i.e. the conductor traces.

Use line drivers with controlled signal rise-time.

This is suggested whenever it comes to driving large bus systems. Alternatively, high-speed signal lines can be terminated with resistors or even active terminations to reduce high frequency radiations originating from overshoot and ringing on these lines.

Place ground traces between signal lines.

If dielectric layers are thick compared to the line width, ground traces between the signal lines will increase shielding. This is especially important if only two layer boards are used.

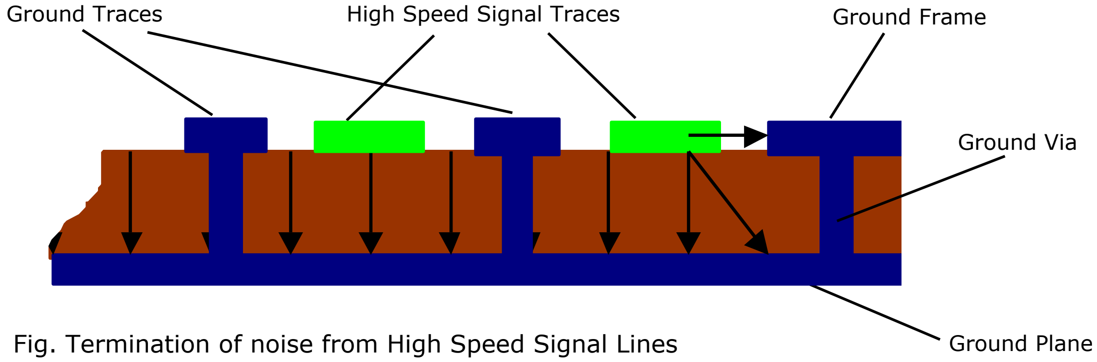


Fig. Termination of noise from High Speed Signal Lines

5.6.3 Decoupling Capacitors

Use a sufficient number of decoupling capacitors, placed in parallel between power and ground nets. Without an efficient capacitor network connecting the power and ground plane, the power plane may act as a radiating patch antenna with respect to ground.

- Small size, small capacitance types reduce high-frequency emissions.
- Large size high capacitance types stabilize low frequency variations.

It is usually better to have a large number of small value capacitors in parallel rather than having a small number of large value capacitors. Capacitors has an internal inductance in series with the specified capacitance and above its resonance frequency, the capacitor will behave like an inductor. If many capacitors are connected in parallel, total inductance will decrease while total capacitance will increase.

Ceramic capacitors are preferred over Tantalum, as the high ESR of Tantalum Capacitors limits their useful frequency band to a few 100 kHz.

Ceramic capacitors are available with different types of dielectric material. These materials has different temperature properties, and it is important to consider the intended operating temperature range when selecting type of capacitor to be used. For industrial temperature range applications, at least a X5R quality should be selected. Y5V or Z5U types may loose almost all of their capacitance at low and high temperatures, resulting in potential system failure at the temperature extremes because of excessive noise emissions from the digital part.

Detailed information about temperature and frequency behaviour of Capacitors is available from the capacitor manufacturers.

5.6.4 Shielding

If the measures suggested above cannot solve the EMI problems, the remaining solution will be shielding of the noise source. The shielding effectiveness you can expect from a solid metal shield is somewhere in the order of 30-40 dB. If a thin PCB copper layer is used as a shield, these numbers might even be lower.

Perforation of the shield will also lower its effectiveness and has to be weighed against the advantages they bring in form of stress relief and reduced weight. Lengthy slots should be avoided, as they might even turn a shield into a radiating slot antenna.

A good shield has to be tightly closed and very well connected to the circuit board.

5.6.5 Feed through Capacitors

The concept of shielding is that a metal box will terminate all electrical fields on its surface. In a real application, we still need to route some signals from inside to outside of this box.

By using a feed through capacitor, all high frequency content is removed from the outgoing signal line. It's important to notice that any conductor traveling through the shielding box is subject to picking up noise inside and re-radiating it outside, regardless of the actual signal it is intended to carry. Therefore, also DC lines needs to be filtered with feed through capacitors.

When selecting feed through capacitors, it's important to choose capacitors with the appropriate frequency behaviour. As with ordinary capacitors, small value types will show better attenuation at high frequencies,

A feed through capacitor will only achieve its specified performance if it has a proper ground connection.
Remember that a feed-through capacitor is basically a high frequency "short" between signal line and ground. If the ground point that the capacitor is connected to is not ideal, meaning the ground connection or plane has a finite resistance, noise will be injected into the ground net. Therefore, try to place any feed trough capacitor far away from the most noise sensitive parts of the circuit.

If a feed through capacitor cannot be used, a simple capacitor between signal line and shielding ground placed very close to the feed through of the signal line will also help. A 12 pF SMD capacitor usually works quite well at the GPS frequency range.

If there is no good ground connection available at the point of the feed through, or injection of noise into the non-ideal ground net must be avoided totally, inserting a component with a high resistance at high frequencies might be a good alternative.

Ferrite beads are ideal if a high DC resistance cannot be accepted. For ordinary signal lines, where DC resistance is not an issue, insert a 1 kOhm series resistor which, together with the parasitic capacitance of the conductor trace, will form a low-pass filter.

6. Related Documents, Software and Evaluation tools

6.1 Related Documents

Orcam Handling & Soldering Application note

SiRF GSW3 Software SDK Reference Manual
SiRF Binary Protocol Reference Manual
SiRF NMEA Reference Manual

6.2 Evaluation Software

SiRF Demo - is the configuration and monitoring software provided with the Orcam Evaluation Kit. It can be used to monitor real-time operation of the Evaluation Receiver, log data for later analysis, and configure the Evaluation Receiver operation.

6.3 GPS35 & GPS36 Evaluation Kit

The GPS35 Evaluation Kit contains a GPS35 based Evaluation Receiver, an active patch GPS antenna, Power Supply, Cables and all necessary documentation & software to evaluate the GPS35 module.

7. Document Revision History

Version	Released	Description of revision
1.0	Aug 2008	Initial release
2.0	Nov 2008	V_{CC} specification changed to 3,3 - 5,5 V DC
2.1	Nov 2008	V_{CCG} specification changed to + 3.0 V DC. Description of pin 11 added