http://www.cubesatkit.com/

CubeSat Kit™
GPSRM 1 GPS Receiver Module
Hardware Revision: B

GPS Receiver for Space Use

Applications
- CubeSat nanosatellite GPS

Features
- For use with 104-pin CubeSat Kit™ Bus
- Utilizes space-grade NovAtel® OEM615V GPS receiver
- Compatible with a wide range of active GPS antennas
- With dedicated nanopower supervisor MCU for:
  - GPS power control
  - GPS power monitor
  - GPS reset and external events
  - GPS isolation from CSK bus signals
  - I2C interface / "back door"
  - Additional user-defined functionality
- OEM615 receiver communication ports:
  - TXD1/RXD1 ↔ CSK Bus
  - TXD2/RXD2 ↔ supervisor MCU
  - USB ↔ host via micro-AB connector
- OEM615 receiver outputs:
  - 50Ω PPS signal (x2)
  - Variable frequency signal (VARF)
  - Position Valid (PV) indicator
- Enhanced EMC / EMI design yields improved SNR over unshielded receiver
- Integrated heatsink / EM shield is tied to thermal conductive pads for use with CSK thermal standoffs in all four corners (top and bottom)
- Flexible interface to CSK –RESET signal
- Auto-selected power sources:
  - +5V & +3.3V from CSK Bus
  - +5V from USB
- Independent latchup (device overcurrent) protection on critical subsystems
- Stackable 104-pin CubeSat Kit Bus connectors includes processor's complete I/O space, user-assignable signals and more
- Wiring-free module interconnect scheme

ORDERING INFORMATION

Pumpkin P/N 710-00908

Option Code	CubeSat Kit Bus Connector[1]
/00 (standard)	non-stackthrough
/10	stackthrough

Contact factory for availability of optional configurations.
Option code /00 shown.

CAUTION

Electrostatic Sensitive Devices

Handle with Care

- PC/104-size footprint
- 6-layer gold-plated blue-soldermask PCB with triple ground planes for enhanced signal integrity
- Supervisor MCU programmed with Pumpkin's space-proven Salvo™ RTOS for easy user customization

[1] Stackthrough connectors are used in CubeSat Kit configurations where the MB is not in Slot 0.

CHANGELOG

Rev.	Date	Author	Comments
A	20130804	AEK	Initial version, from hardware Rev A design.
B	20130807	AEK	Updated with better figures, add PPS traces, clarified some specifications.
C	20130809	AEK	Added photo, merged PPS and VARF sections with related screen captures.
D	20130924	AEK	Added current consumption for various typical configurations.
E	20131114	AEK	Fixed jumper settings for alternate GPS receivers. Added section on I2C speeds and pull-ups.

OPERATIONAL DESCRIPTION

The GPSRM 1 GPS receiver adds GPS functionality to the CubeSat Kit™ (CSK) by integrating a NovAtel® OEM615 series receiver onto a CSK-compatible module. A supervisor MCU controls power and interface to the CSK bus. The interface to the supervisor MCU is via I2C.

The GPSRM 1 is designed to mount directly above the combination of a CSK Motherboard (MB) + Pluggable Processor Module (PPM), at the standard inter-module distance of 0.600" (15.24mm), using a GPS antenna cable terminated in a right-angle MCX plug. This arrangement provides the necessary clearance for the GPS antenna cable's connector.

The GPSRM 1 utilizes the NovAtel® OEM615V-G1S-B0G-TT0-H GPS L1 receiver module with a 20Hz update rate and a vibration-resistant TCXO. As fitted on the GPSRM 1, these GPS receiver modules have had their COCOM limits removed / unblocked.

Power to the GPS receiver is under the control of the PIC24E-series supervisor MCU and can switched on or off via I2C commands. Power is automatically selected from available power: either (external) USB or the CubeSat Kit bus.

The OEM615 receiver's **–RESET**, **EVENT1** and **EVENT2** inputs are under the control of the supervisor MCU.[2]

The first serial port of the OEM615V module is normally used to communicate with the rest of the CubeSat via one of the three CubeSat Kit bus signal pairs **IO.4** & **IO.5**, **IO.16** & **IO.17** or **IO.32** & **IO.33**. This serial port can be isolated from the CubeSat Kit bus via I2C commands. The second serial port of the OEM615V module is connected to the supervisor MCU and can be used to transfer data and commands between the OEM615V module and the supervisor MCU. The third serial port of the OEM615V module – implemented as USB – is connected directly to a micro-AB USB connector. This USB connection can also power the OEM615V module.

A Position Valid (PV) LED indicator from the OEM615 receiver is provided, as well as a status LED from the supervisor MCU.

The 50Ω **TIMEMARK** (**PPS**) signal from the OEM615 receiver is available in one of two user-selectable forms: on an MCX jack for use with discrete RF cabling, and on the CubeSat Kit bus **PPS** signal.

The **VARF** (variable frequency) signal from the OEM615 receiver is present on an MMCX jack for use with discrete RF cabling, and also (optionally) on **IO.31** of the CubeSat Kit bus.

An additional TX/RX debug port to the supervisor MCU is provided, to aid in supervisor MCU firmware development & debugging. Additionally, a 20-pin connector is provided as a means of connecting expansion boards (where possible) under the control of the supervisor MCU. Lastly, an MMCX connector is provided for measuring the supervisor MCU's unbuffered internal clock frequency.

Particular attention has been paid to the shielding and heatsinking of the OEM615 receiver. An integrated EMC / EMI shield and heatsink covers the entire OEM615 receiver and is electrically and thermally tied to all four corner standoff locations. Special attention in the PCB design has been paid to avoid any isolated dielectric regions resulting from unconnected swatches of copper.

A related module – GPSRM 2 – provides similar features and performance in a form factor designed expressly for Pumpkin's MISC 3 bus.

[2] The OEM615 receiver's **CAN2TX** and **CAN2RX** signals are left unconnected.

ABSOLUTE MAXIMUM RATINGS

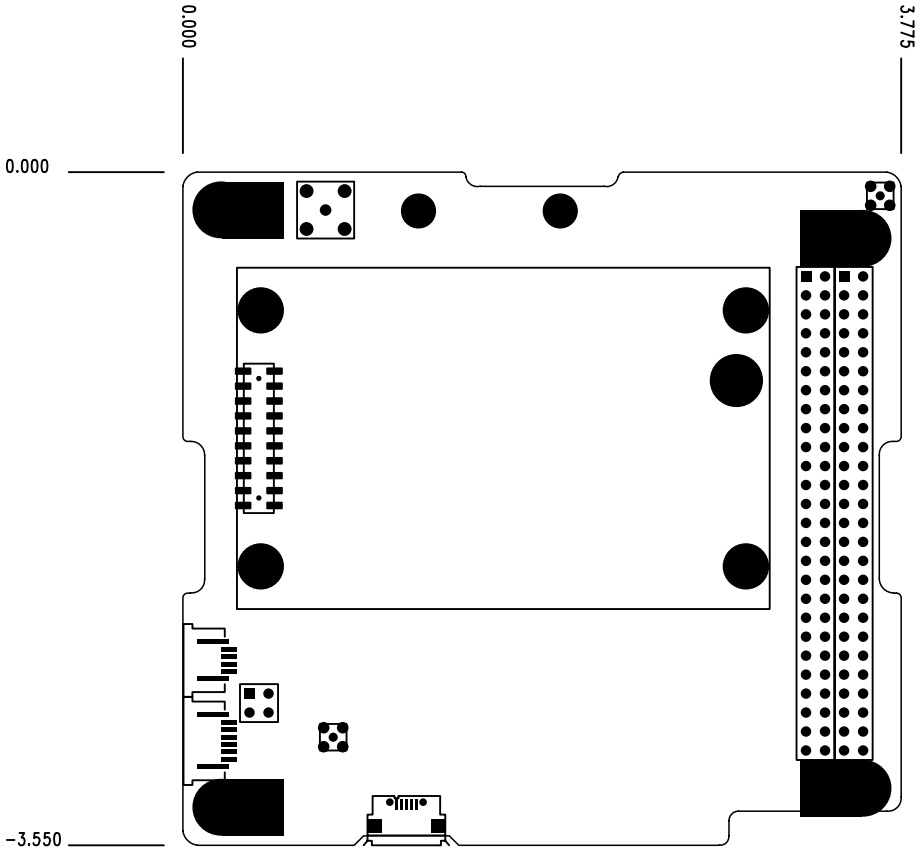
Parameter	Symbol	Value	Units
Operating temperature	T_A	-40 to +85	ºC
Voltage on **+5V_USB** bus		-0.3 to +6	V
Voltage on **+5V_SYS** bus			
Voltage on **VCC_SYS** bus			
Voltage on local **VCC_MCU** bus		-0.3 to +5.5	V

PHYSICAL CHARACTERISTICS

Parameter	Conditions / Notes	Symbol	Min	Typ	Max	Units
Mass [3]	With aluminum heatsink / EM shield			106		g
Height of components above PCB	With mating cable to MCX PPS jack				11	mm
Height of components below PCB	Without GPS antenna cable connected				2.75	mm
	With GPS antenna cable connected via RA MCX plug				5.5	
PCB width	Corner hole pattern matches PC/104			96		mm
PCB length				90		mm
PCB thickness				1.6		mm
CubeSat Kit Bus Connector terminal pitch	Horizontal or vertical distance to nearest terminal			2.54		mm

[3] With heatsink / EM shield fitted.

SIMPLIFIED MECHANICAL LAYOUT [4]



[4] Dimensions in inches.

ELECTRICAL CHARACTERISTICS

(T = 25ºC, +5V bus = +5V unless otherwise noted)

Parameter	Conditions / Notes	Symbol	Min	Typ	Max	Units
Operating power consumption	Supervisor MCU & GPS active, no antenna connected	$P_{OP\_SUP\_GPS\_LNA}$		1.3		W
	Supervisor MCU active, GPS unpowered	P_{OP_SUP}		25		mW
Operating current [5]	Supervisor MCU & GPS active, with active antenna connected	$I_{OP\_SUP\_GPS\_LNA}$		300		mA
	Supervisor MCU & GPS active, no antenna connected	$I_{OP\_SUP\_GPS}$		260		mA
	Supervisor MCU active, GPS unpowered	I_{OP_SUP}		4.5		mA
	Supervisor MCU asleep, GPS unpowered	I_{SLEEP}		1.5		mA
Supervisor MCU internal clock frequency	Base frequency, can be multiplied by onboard PLL	f_{CLK_MCU}		7.4		MHz
USB bus current [6]	Powered over USB	I_{USB_MAX}			500	mA
Overcurrent trip point for OEM615V	For +3.3V, set by R19 & R20	$I_{TRIP\_3V3\_GPS}$		TBD		mA
	For +5V, set by R15 & R16	$I_{TRIP\_+5V\_GPS}$		TBD		mA
Data rate through any on-board isolator (**U4** & **U5**)			50			MHz

OEM615 GPS RECEIVER ELECTRICAL CHARACTERISTICS

Parameter	Conditions / Notes	Min	Typ	Max	Units
PPS Output at **J7**	Impedance		50		Ω
	Rise & fall times		6		ns
	Negative pulse width		1.000		ms
	Amplitude (3V3_GPS = +3.3V, unterminated)		3.24		V
	Amplitude (3V3_GPS = +3.3V, terminated with 50Ω)		2.40		
Effect on GPS SNR of GPSRM 1's EM shield	Observed SNR improvement of multiple, individual GPS satellites with GPSRM 1 EM shield present and absent, using NovAtel® receiver software.		5		dB

[5] Terrestrial GPS receiver tracking a minimum of 5 satellites when active antenna with LNA is connected.

[6] The OEM615V's USB interface is configured at the factory as a bus- or self-powered device and reports a maximum current of 100mA to the attached USB host.

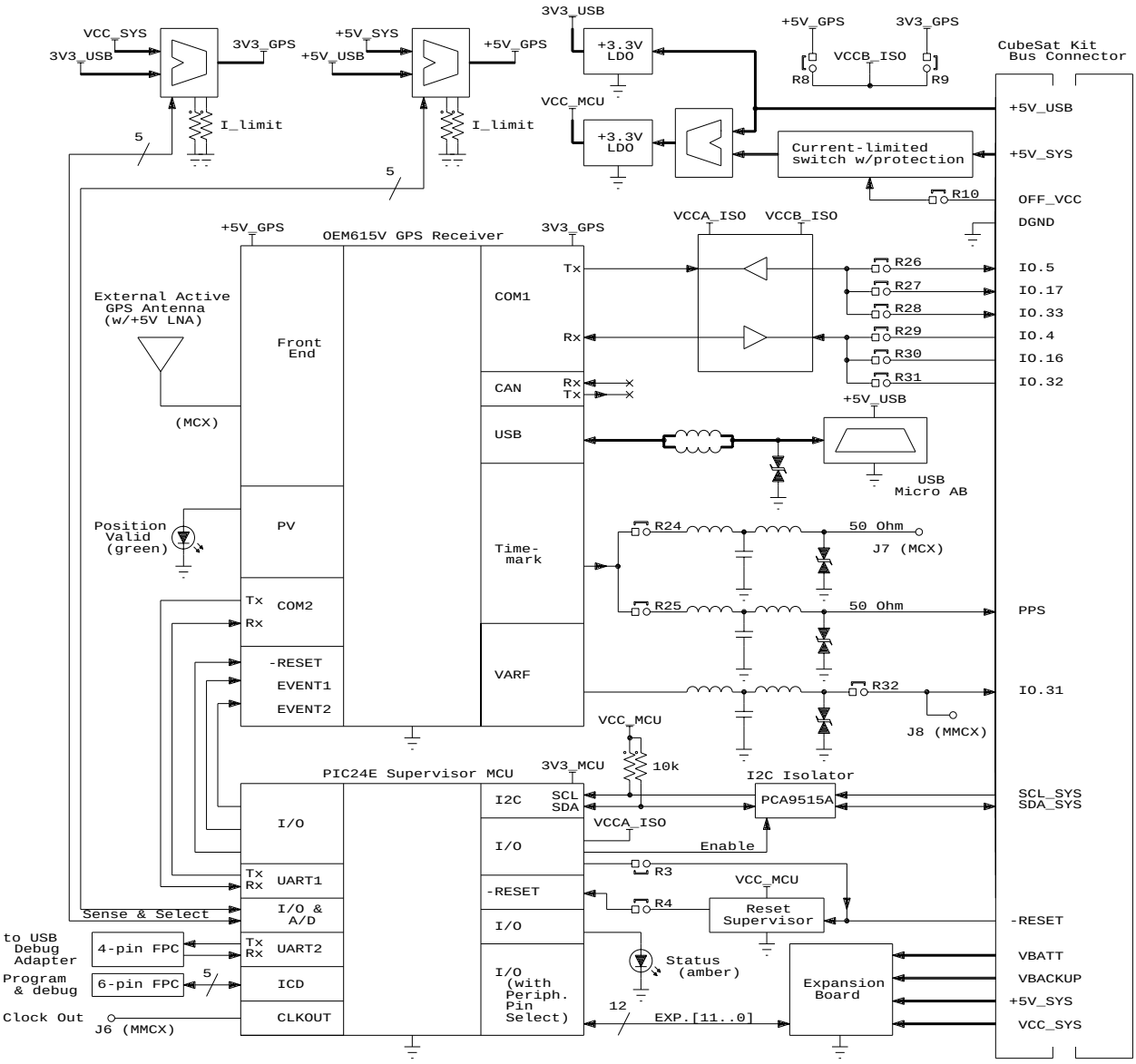
I2C CHARACTERISTICS

Parameter	Conditions / Notes	Min	Typ	Max	Units
I2C address	7-bit I2C address		0x51		
I2C clock speed				400	kHz
I2C pull-up resistors	No pull-up resistors are fitted to **SCL_SYS** or **SDA_SYS**		∞		Ω

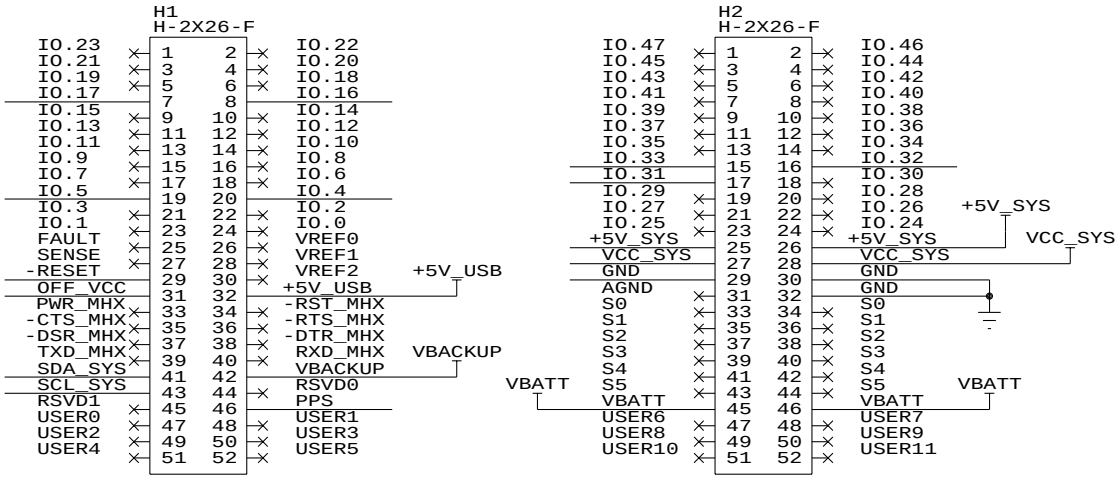
USB DEVICE CHARACTERISTICS

Parameter	Conditions / Notes	Value
Speed	USB 2.0 compatible	Full Speed (12Mbps)
Vendor ID (VID)		0x09D7
Product ID (PID)		0x0100
Required driver	Supplied by NovAtel	

BLOCK DIAGRAM



CubeSat Kit Bus PIN DESCRIPTIONS



CubeSat Kit Bus PIN DESCRIPTIONS – I/O

Name	Pin	I/O	Description
IO.0	H1.24		Not connected.
IO.1	H1.23		Not connected.
IO.2	H1.22		Not connected.
IO.3	H1.21		Not connected.
IO.4	H1.20	I	Serial input to the OEM615 receiver's **RX1D** pin. This input receives data from **IO.4** if/when jumper **R29** is fitted. Typically serial data **UTX0** from the PPM processor.
IO.5	H1.19	O	Serial output from the OEM615 receiver's **TX1D** pin. This output sends data to **IO.5** if/when jumper **R26** is fitted. Typically serial data **URX0** to the PPM processor.
IO.6	H1.18		Not connected.
IO.7	H1.17		Not connected.
IO.8	H1.16		Not connected.
IO.9	H1.15		Not connected.
IO.10	H1.14		Not connected.
IO.11	H1.13		Not connected.
IO.12	H1.12		Not connected.
IO.13	H1.11		Not connected.
IO.14	H1.10		Not connected.
IO.15	H1.9		Not connected.
IO.16	H1.8	I	Serial input to the OEM615 receiver's **RX1D** pin. This input receives data from **IO.16** if/when jumper **R30** is fitted. Typically serial output from a module to the OEM615.
IO.17	H1.7	O	Serial output from the OEM615 receiver's **TX1D** pin. This output sends data to **IO.17** if/when jumper **R27** is fitted. Typically serial input to a module from the OEM615.
IO.18	H1.6		Not connected.
IO.19	H1.5		Not connected.
IO.20	H1.4		Not connected.
IO.21	H1.3		Not connected.
IO.22	H1.2		Not connected.
IO.23	H1.1		Not connected.
IO.24	H2.24		Not connected.
IO.25	H2.23		Not connected.
IO.26	H2.22		Not connected.

IO.27	H2.21		Not connected.
IO.28	H2.20		Not connected.
IO.29	H2.19		Not connected.
IO.30	H2.18		Not connected.
IO.31	H2.17	O	Variable-frequency output from the OEM615 receiver's **VARF** pin. This output places the **VARF** square wave on **IO.31** if/when jumper **R32** is fitted. Typically used by modules desiring a high-accuracy clock signal.
IO.32	H2.16	I	Serial input to the OEM615 receiver's **RX1D** pin. This input receives data from **IO.32** if/when jumper **R31** is fitted. Typically serial output from a module to the OEM615.
IO.33	H2.15	O	Serial output from the OEM615 receiver's **TX1D** pin. This output sends data to **IO.33** if/when jumper **R28** is fitted. Typically serial input to a module from the OEM615.
IO.34	H2.14		Not connected.
IO.35	H2.13		Not connected.
IO.36	H2.12		Not connected.
IO.37	H2.11		Not connected.
IO.38	H2.10		Not connected.
IO.39	H2.9		Not connected.
IO.40	H2.8		Not connected.
IO.41	H2.7		Not connected.
IO.42	H2.6		Not connected.
IO.43	H2.5		Not connected.
IO.44	H2.4		Not connected.
IO.45	H2.3		Not connected.
IO.46	H2.2		Not connected.
IO.47	H2.1		Not connected.

CubeSat Kit Bus PIN DESCRIPTIONS – Analog References

Name	Pin	I/O	Description
VREF0	H1.26		Not connected.
VREF1	H1.28		Not connected.
VREF2	H1.30		Not connected.

CubeSat Kit Bus PIN DESCRIPTIONS – Reserved

Name	Pin	I/O	Description
RSVD0	H1.44	–	Not connected.
RSVD1	H1.45	–	Not connected.

CubeSat Kit Bus PIN DESCRIPTIONS – I2C Bus

Name	Pin	I/O	Description
SDA_SYS	H1.41	I/O	I2C data. To/from supervisor MCU (an I2C slave device) via a PCA9515A I2C isolator. Typically from the PPM processor.
SCL_SYS	H1.43	I	I2C clock. To supervisor MCU (an I2C slave device) via a PCA9515A I2C isolator. Typically from the PPM processor.

CubeSat Kit Bus PIN DESCRIPTIONS – Control & Status

Name	Pin	I/O	Description
-FAULT	H1.25		Not connected.
SENSE	H1.27		Not connected.
-RESET	H1.29	I/O	Input to and/or output from reset supervisor controlling supervisor MCU. Functionality depends on resistors **R3** & **R4**.
OFF_VCC	H1.31	I	When resistor **R10** is fitted and no USB power is present, an active signal on this pin will disable **VCC_MCU** power to the supervisor MCU.
PPS[7]	H1.46	O	**PPS**. From the OEM615 receiver's **TIMEMARK** (PPS) output. This output is present whenever the OEM615 is powered and operating. 50Ω impedance.

CubeSat Kit Bus PIN DESCRIPTIONS – RBF and Separation Switches

Name	Pin	I/O	Description
S0	H2.33 H2.34		Not connected.
S1	H2.35 H2.36		Not connected.
S2	H2.37 H2.38		Not connected.
S3	H2.39 H2.40		Not connected.
S4	H2.41 H2.42		Not connected.
S5	H2.43 H2.44		Not connected.

CubeSat Kit Bus PIN DESCRIPTIONS – Power

Name	Pin	I/O	Description
VBATT	H2.45 H2.46	I	Battery voltage. EPS-dependent. Typically +7V to +10V. To expansion connector **H3.5** & **H3.6** only.
+5V_USB	H1.32	I/O	+5V USB power. From USB host.
+5V_SYS	H2.25 H2.26	I	+5V system power.
PWR_MHX	H1.33		Not connected.
VBACKUP	H1.42	I	Battery backup voltage. To expansion connector **H3.8** only.
VCC_SYS	H2.27 H2.28	I	VCC System power. Assumed to be +3.3V.
AGND	H2.31		Not connected.
GND	H2.29 H2.30 H2.32	–	Digital ground.

CubeSat Kit Bus PIN DESCRIPTIONS – Transceiver Interface

Name	Pin	I/O	Description
-RST_MHX	H1.34		Not connected.
-CTS_MHX	H1.35		Not connected.
-RTS_MHX	H1.36		Not connected.
-DSR_MHX	H1.37		Not connected.
-DTR_MHX	H1.38		Not connected.
TXD_MHX	H1.39		Not connected.
RXD_MHX	H1.40		Not connected.

[7] This signal was formerly called **RSRVD2** and was reserved.

CubeSat Kit Bus PIN DESCRIPTIONS – User-defined

Name	Pin	I/O	Description
USER0	H1.47		Not connected.
USER1	H1.48		Not connected.
USER2	H1.49		Not connected.
USER3	H1.50		Not connected.
USER4	H1.51		Not connected.
USER5	H1.52		Not connected.
USER6	H2.47		Not connected.
USER7	H2.48		Not connected.
USER8	H2.49		Not connected.
USER9	H2.50		Not connected.
USER10	H2.51		Not connected.
USER11	H2.52		Not connected.

PPS Output

The OEM615 GPS receiver has a 50Ω output driver for its **TIMEMARK** (PPS) signal. The default valid PPS signal is a low-going, 1.000ms pulse every second that is synchronized to GPS time when a valid position has been computed. Its behavior can be configured via commands to the OEM615.

The GPSRM 1 module provides two PPS outputs from the OEM615 receiver's **TIMEMARK** signal:

1. PPS is available at connector **J7** – an MCX jack – when jumper **R24** is fitted.
2. PPS is available on connector **H1.46** when jumper **R25** is fitted.[8]

By default, jumpers **R24** (for PPS to **J7**) and **R24** (for PPS to **H1.46**) are both fitted, thus making PPS available on both **J7** and **H1.46**. Customers can choose to remove one or the other based on their system-level design in an attempt to maximize the quality of the PPS signal at its endpoint(s).

For proper operation and accurate timing, the **TIMEMARK** (PPS) output requires a 50Ω termination. No termination is provided on the GPSRM 1 module. It is up to the end-user to provide the proper 50Ω termination if/when utilizing the GPSRM 1's PPS feature. Only one 50Ω termination should be applied to the PPS signal; either via **J6** or via **H1.46**.

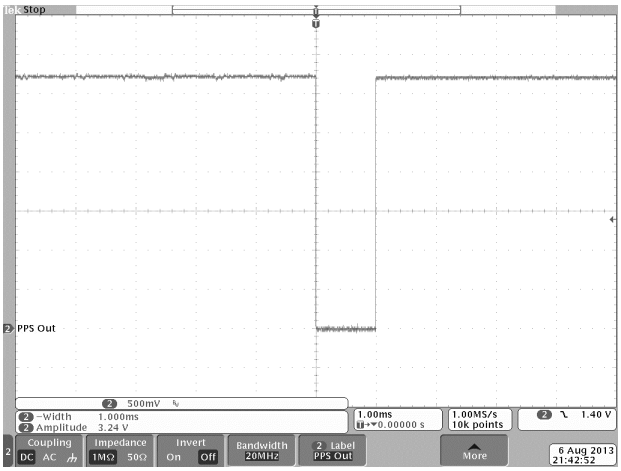


Figure 1: PPS at **J7**, unterminated, at oscilloscope. **R24** & **R25** fitted.

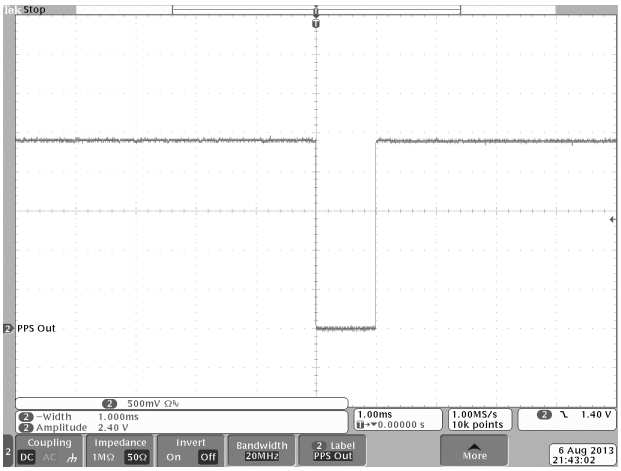


Figure 2: PPS at **J7**, terminated (50Ω) at oscilloscope. **R24** & **R25** fitted.

VARF Output

The OEM615 GPS receiver has a programmable variable-frequency output (VARF), that can be synched to its PPS signal. Its enabled / disabled status, period and duty cycle can all be configured via commands to the OEM615. VARF's period and duty cycle can be set with 10ns resolution.

The GPSRM 1 provides the OEM615 receiver's VARF in two forms to the user:

1. On MMCX connector **J8**.
2. On the CubeSat Kit Bus Connector **IO.31**, if zero-Ohm jumper **R32** is fitted.

VARF can replace a user's TCXO on another module, as long as the need for a stable and accurate frequency reference is compatible with the power requirements of the OEM615 receiver.

[8] The signals on the CubeSat Kit Bus Connector are not controlled-impedance signals. Therefore the customer will have to experiment with the ideal termination (e.g., on another module in the module stack) in their particular application in order to achieve the best possible waveform from the PPS signal.

Power Sources

The GPSRM 1 module uses controllable ideal diodes with programmable current limits to route +5V and +3.3V power to the OEM615 receiver's **LNA_PWR** and **3V3** power pins, respectively.

Whenever **+5V_SYS** is present on the CubeSat Kit bus connector, the supervisor MCU actively selects **+5V_SYS** and **VCC_SYS** as the sources for the OEM615 receiver's **+5V** and **+3.3V** power, respectively. Therefore, even if **+5V_USB** is present in these conditions, the GPSRM 1 module will not draw appreciable power from it.

If/when **+5V_SYS** is not present, then the GPSRM 1 may draw its power from +5V via USB, either from a directly connected USB host (via connector **J3**) or via the CubeSat Kit bus signal **+5V_USB**. This depends on the MAXPOWER attribute of the OEM615, which by default is 100mA, but may be configurable to something greater (e.g. 500mA) via firmware updates to the OEM615.

Use with USB

When powered via the CubeSat Kit bus, the GPSRM 1 module provides a means of communicating to the OEM615 receiver's USB COM port via a USB cable ending plugged into connector **J3**. This feature is provided so that the module can be easily reconfigured and used with e.g. NovAtel's NovAtel Connect software.

I2C Interface

The GPSRM 1 functions as an I2C Slave device.

The GPSRM 1's I2C interface is compatible with 100kHz and 400kHz I2C clock speeds.

When being written to or being read from by an I2C Master device, the GPSRM 1 (as a clock-stretching I2C Slave device) may stretch the I2C clock (**SCL_SYS**) as a means of avoiding overruns. This is part of the I2C protocol.

No pull-up resistors are present on the GPSRM 1. Pull-up resistors must be implemented elsewhere in the system; typically, they are on or close to the system's I2C Master device.

Signal Grounds

In an effort to minimize conducted and radiated emissions, all of the grounds of the GPSRM 1 are tied together into a single net: **DGND**. Those nodes tied to **DGND** include:

1. The grounds for the OEM615 GPS receiver (i.e., pins 10, 13, 16 & 18 of Its 20-pin connector P1101).
2. The grounds for the PIC24E Supervisor MCU (both analog and digital).
3. The ground of the USB micro AB connector.
4. **DGND** from the CubeSat Kit Bus Connector **H2**.
5. The (RF) ground of the OEM615 receiver's MCX GPS antenna connector.
6. The grounds of connectors **J6**, **J7 and J8**.
7. The heatsink cover / EM shield.
8. The four corner mounting holes of the module, along with their thermal pads.

Communicating with the OEM615 Receiver's COM1

For applications that wish to talk serially to the OEM615 receiver via its COM1 port, four different configurations are supported via the selective jumpers implemented as zero-Ohm resistors **R26**-**R30**:

Configuration	Description	Example Host	Jumpers	
			Fitted	Omitted
A	Maps OEM615 receiver's **TXD1** to **IO.5** (**URX0**) and **RXD1** to **IO.4** (**UTX0**).	All PPMs that map **UTX0** to **IO.4** and **URX0** to **IO.5**.	**R26**, **R29**	**R27**, **R28**, **R30**, **R31**

B	Maps OEM615 receiver's **TXD1** to **IO.17** and **RXD1** to **IO.16**.	PPM D1 (PIC24FJ256GA110), configured via PPS to map UART3 to **IO.16** (data out) & **IO.17** (data in).	**R27**, **R30**	**R26**, **R28**, **R29**, **R31**
C	Maps OEM615 receiver's **TXD1** to **IO.33** and **RXD1** to **IO.32**.	With PPM B1 (which has no connections to **IO.[33.31]**), a user module with e.g. expansion I2C-to-UARTs can connect to **IO.32** & **IO.33**.	**R28**, **R31**	**R26**, **R27**, **R29**, **R30**
D	OEM615 receiver's COM1 is isolated from CubeSat Kit Bus Connector – interface only through GPSRM 1 Supervisor MCU via I2C.	Any PPM that needs to interface to the GPSRM 1 solely via I2C on **SCL_SYS** and **SDA_SYS**.		**R26**, **R27**, **R28**, **R29**, **R30**, **R31**

N.B. For proper operation, a maximum of one pair of jumpers (**R26** & **R29**, **R27** & **R39**, or **R28** & **R31**) should be fitted at any time. Fitting more than one pair of jumpers may damage the GPSRM 1. Jumpers are to be soldered in place by a qualified technician.

Use with alternate GPS Receivers

Bare COCOM-unblocked GPS receiver rated for space use can cost thousands of dollars. If/when an alternate GPS receiver has a compatible pinout and connectors, then it may be possible to use with the GPSRM 1 in place of the OEM615 receiver for ground-based development and test. The following caveats must be observed:

1. The integrated heatsink / RFI cover will likely not fit and should not be used.
2. All of the alternate GPS receiver module's I/O must match or be a subset of those of the OEM615 receiver series.
3. No part of the alternate GPS receiver may touch the GPSRM 1 PCB.
4. The protection circuits of the GPSRM 1 may not be compatible with those of the alternate GPS receiver.

For alternate GPS receivers that are powered exclusively via +3.3V on pins 3 and 4 of the 20-pin header **GPS1**,

1. Remove and do not plug in any USB cables to connector J3.
2. Fit two shorting jumpers on **J5**: 1-3 and 2-4.[9]
3. If necessary, prevent the existing +5V and +3.3V power on the header **GPS1** from reaching pins 1 and 2 of the alternate GPS receiver. This may require cutting the connector pins on the alternate GPS receiver.

This will feed the GPSRM 1's local +3.3V supply to pins 3 and 4 of the 20-pin header **GPS1** for use with a alternate, compatible GPS receiver (i.e., one other than the OEM615 receiver).

A sample, low-cost GPS receiver that can be used in this manner is the Royaltek REB-21R, in its 3.3V TTL & RS-232 output configuration.[10]

[9] When installed, these jumpers are parallel to the H1 and H2 CubeSat Kit Bus connectors.

[10] The particular model tested (with a datecode of 2003, found at an electronics surplus store for under $10) had to have its right-angle MCX jack removed and replaced with a straight MCX plug on the opposite side of the PCB so as to be able to mate to the 20-pin connector on the GPSRM 1 PCB.

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