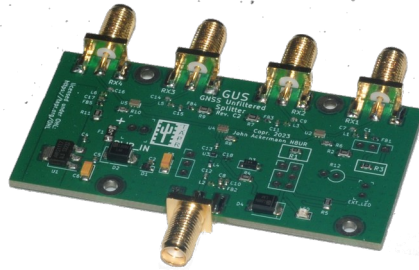


# GNSS Unfiltered Splitter (“GUS”) Preliminary Assembly and Operation Manual

GNSS Amplifier and Splitter – Revision C4

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## Introduction

The GNSS Unfiltered Splitter (“GUS”) allows up to four GNSS receivers to operate from a single antenna. It includes a low noise amplifier to compensate for loss in the RF splitter network.

Unlike many available GPS/GNSS antenna splitters, the GUS does not provide any RF filtering. This is meant as a Good Thing as it allows the splitter to operate with signals from all GNSS constellations in all three of the currently assigned frequency bands – L1, L2, and L5; in fact, it performs well from below 1000 MHz to at least 1700 MHz. While interference from out-of-band signals can be a problem with GNSS receivers, most antennas include filters and unless you are located near a transmitter site additional filtering is not usually needed. Providing filters that cover all three frequency bands is complex and can be expensive, so by dispensing with them the GUS provides both flexibility and economy.

Another unique feature of the GUS is its flexible DC power input and output configuration. Most GNSS antennas need a DC voltage on their feedline to power the antenna’s low noise amplifier, and most GNSS receivers provide power on their antenna outputs to do so. But sometimes the receiver provides a different voltage than the antenna requires, or an external power source is desired for some other reason. Sometimes the antenna output should carry no voltage at all. The GUS provides for many power input and output options. Its default configuration matches the most common case – whatever DC voltage appears at the RX1 port will power the GU and also appear at the ANT port – but jumpers allow other configurations.

An extruded aluminum enclosure with custom end plates is available for the GUS.

# Circuit Description

The GUS's RF design is very straightforward. Most of the complexity relates to DC power options.

The signal from the antenna enters at J1 and is amplified by U3, an MXDLN14TP low noise amplifier that is designed for mobile positioning devices and has about 18 dB of gain and a 0.6 dB noise figure.<sup>1</sup> The amplified signal goes to hybrid coupler U4, and each of U4's outputs go to another identical coupler, yielding four outputs. The string of couplers reduce the amplitude at each output by a theoretical 6dB, but U3's gain more than makes up for that. The overall gain is about 7 dB  $\pm$  2 dB.<sup>2</sup>

The GUS uses three 90 degree hybrid couplers in a branch configuration to split the signal, so in theory port 1 is delayed by 90 degrees from the input, port 2 is 90 degrees behind port 1 (as is port 4 relative to port 3), and ports 3 and 4 have an additional 90 degree shift relative to ports 1 and 2. 90 degrees is about 5 cm at 1500 MHz, or 165 picoseconds in free space. The result is phase shifts of 90, 180, 180, and 270 degrees on ports 1 through 4 relative to the input signal. For timekeeping purposes, the relative time delay between channels is usually more important than absolute phase, and the four channel delays are within a few picoseconds of each other.

GNSS splitters that use SAW or other filters typically add significant delay to the signal path – sometimes 20 nanoseconds or more (which is equivalent to 15 feet or so of additional antenna feedline). With its broadband response the GUS has much smaller delay, typically less than 2 ns.

A key attribute of the GUS is its very flexible DC power management, which is described in the “Configuration” section below. The default configuration uses 0-ohm resistors R1 and R2 to pass power from the RX1 port to the ANT port and requires setting no jumpers or switches. The GUS itself requires less than 10 ma at 3.3 volts and can operate with power sources from about 2 to 15 volts.

Bias tee networks at the input and each of the four outputs separate the RF and DC paths. As is the case in most GNSS splitters, the default configuration uses DC voltage from the RX1 port to power the LNA, and passes that voltage on to the antenna port. The bias tee networks on ports RX2, RX3, and RX4 provide a 200 ohm DC load, which is required to convince some GNSS modules that they are connected to an antenna.

The various power options will become more clear in the “Configuration” section below.

Removing R1 allows J1 to route any of RX1, external DC, or the output of 3.3 volt regulator U1 to the amplifier and antenna connector. If the regulator is used, J7 allows its input to come from either RX1 or the external power connector.<sup>3</sup> No matter the power source, Zener diode D3 and resistor R4 limit the voltage reaching U3 to 3.6 volts (the LNA is spec'd to operate from 1.6 to an absolute maximum of 4 volts). With 3.3 volt input, the LNA sees about 2.8 volts, which is its nominal operating voltage.

With more than 9 volts input, R4 starts to dissipate more power and will get warm. At higher input voltages, if your antenna can operate from 3.3 volts, it's best to configure the board to use regulator U1 to drop the voltage to that level.

R3 may be removed to disconnect the DC path from RX1, and in that case installing a jumper at J5 can put a 200 ohm DC load on the port, as is done with the other RX ports.

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1 By the way, this is the tiniest IC I've ever worked with – 1.1 x 0.7 mm!

2 RF performance depends on the load at the other receiver outputs. Unless noted otherwise, all measurements in this document were made with 50 ohm loads on the unterminated ports.

3 Despite the notation on the schematic, regulator U1 is installed on all production GUS boards.

Note that after removing R1 or R3, original operation can be restored via the jumpers, so there's no need to resolder those tiny components. Just knock them off the board with a soldering iron.

Diodes D1, D2, and D4 all provide protection against transients and reverse polarity.

PCB jumper JP1 ("ANT\_PWR\_ENA") can be cut to remove any DC voltage from the antenna input connector. Doing so allows a filter or attenuator to be used ahead of the GUS.

PCB jumper JP2 (LNA\_ENA") can be cut to disable the on-board LED to reduce power consumption.

J13 ("EXT\_LED") can be used to power an external LED in which case user-installed R12 ("EXT\_LED RESISTOR") provides its current limiting. The external LED is not affected by the setting of JP2.

# Typical Performance

The overall gain of the GUS varies from a bit under 5 dB to a bit under 8 dB at the 3 L-band GNSS frequencies across the four output channels. The noise figure is below 1.5 dB.<sup>1</sup>

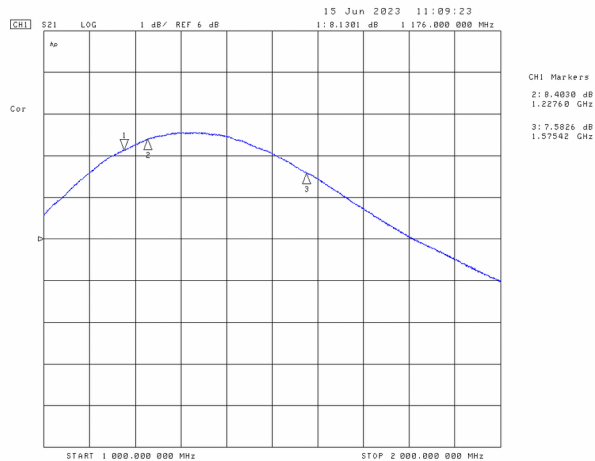


Figure 1: RX Port 1 Gain

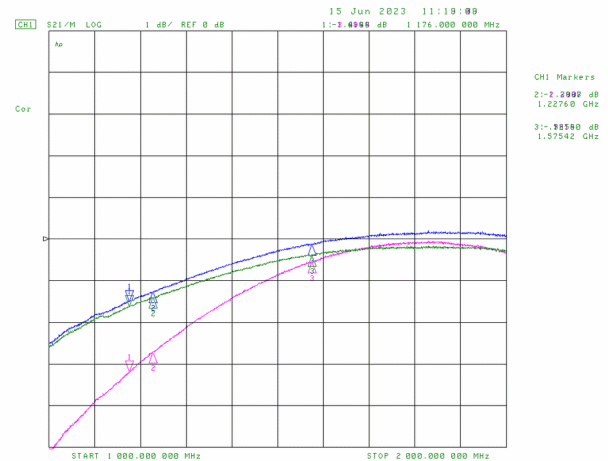


Figure 2: Gain Relative to RX Port 1

Figure 1 shows the gain from antenna input to receiver port 1 output, and figure 2 shows how ports 2, 3, and 4 differ versus port 1 (note the 1 dB per division scale). The hybrid couplers are optimized for the 1700 – 2000 MHz frequency range, and their datasheet shows that the amplitude balance between ports can be nearly 2 dB greater at 1175 MHz than at 1575 MHz. That is the likely explanation why the variation between ports is more at lower frequencies than at L1.

Why port 3 is a further two dB below ports 2 and 4 at lower frequencies is currently a mystery. This difference is consistent across multiple units tested. It should not affect operation, as port 3 still has at least 5 dB gain at all three frequencies. Also note that at L1, the most commonly used frequency, (marker 3) all four ports are within about 0.5 dB of each other.

<sup>1</sup> This is not as good as the specification for the LNA by itself, but includes the real-world losses of the input network. It was measured at port 1 with an HP 8970B /436A noise figure meter.

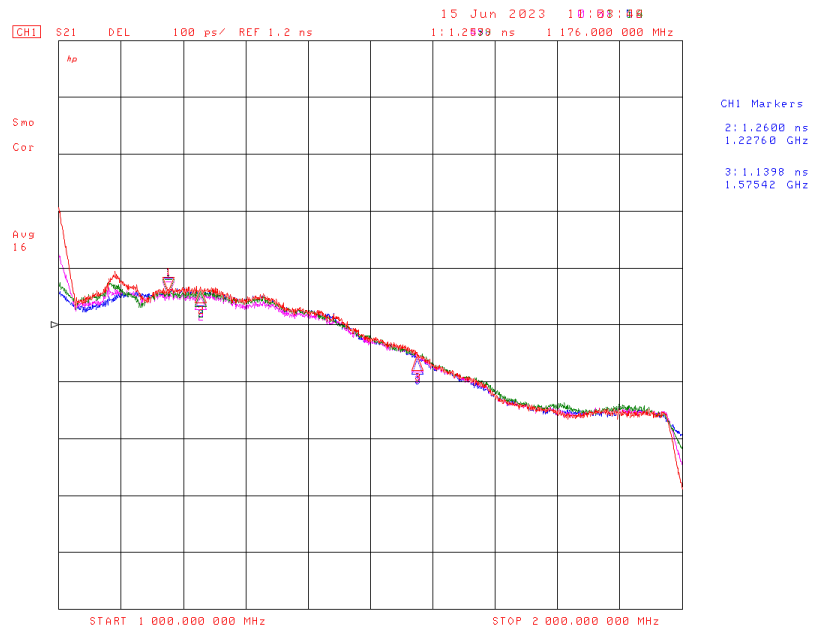


Figure 3: Group Delay, Channels 1 through 4 (100ps/div, referenced to 1.2 ns)

Figure 3 shows the propagation delay through the GUS of each channel (the center reference point is 1.2 ns). The delay of each channel varies by only a few picoseconds from the others, and the difference between L1 and L5 is a little more than 100 ps.

# Assembly

Minimal assembly requires only soldering the SMA connectors which mount on the edge of the PC board. Solder all the ground pins of each connector, on both the top and bottom of the board. If you plan to use an enclosure, be sure the connectors are installed straight and flush against the circuit board.

For operation with a power source other than the receiver at port 1, use a soldering iron to remove resistors R1 and R3 (each surrounded by a white box on the silkscreen) off the board. You can use the iron to heat both sides at once and knock them off the board, as the original configuration can be reset later via the jumpers. Headers with jumper blocks can be installed at J1, J5, and J7, or you can simply solder wires across the appropriate pins.

The GUS PC board slides into the second slot above the bottom “shelf” in the enclosure body. Use the provided screws to secure the front and rear panels to the extrusion, and the washers and nuts to secure the SMAs. The front and rear panel have copper beneath the solder mask and will provide conductivity with the extrusion and possibly some shielding.

# Configuration

In many cases the GUS will require no configuration at all. If the GNSS receiver connected to port 1 provides the voltage required for the antenna's LNA, nothing further need be done. When other power configuration is required, the GUS is very flexible. The table below shows some of the power possibilities and how to enable them.

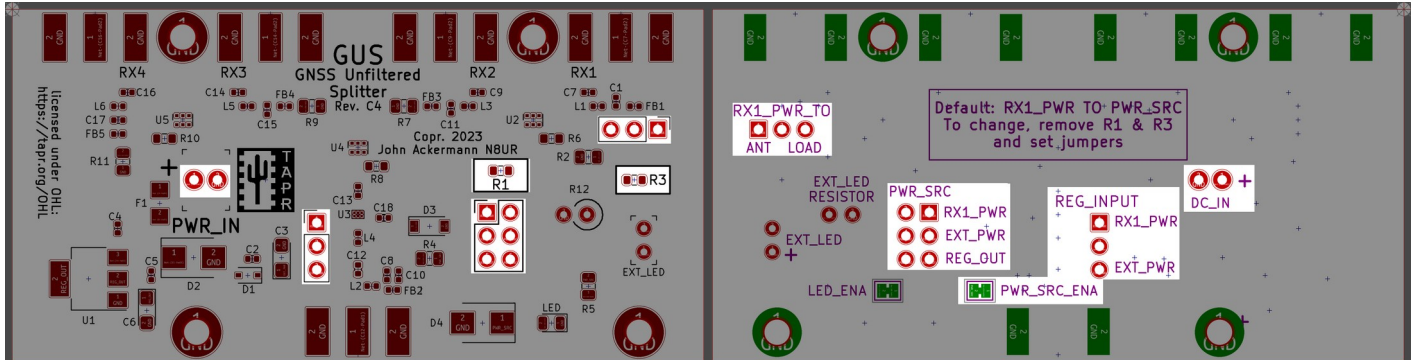


Figure 4: Gus Power Configuration Top (left) and Bottom (right)

RX1 direct to ANT (default)	R1 and R3 in place	<u>OR:</u> RX1_PWR_TO to ANT PWR_SRC to RX1_PWR REG_INPUT open
RX1 through regulator to ANT	R1 removed, R3 in place	<u>AND:</u> PWR_SRC to REG_OUT REG_INPUT to RX1_PWR
External DC direct to ANT	R1 and R3 removed	<u>AND:</u> RX1_PWR_TO to LOAD PWR_SRC to EXT_PWR
External DC through regulator to ANT	R1 and R3 removed	<u>AND:</u> RX1_PWR_TO to LOAD PWR_SRC to REG_OUT REG_INPUT to EXT_PWR
Power to LNA; no power to ANT	Any of above	Any of above <u>AND:</u> PWR_SRC_ENA opened

R3 does not enter into the DC power routing as such, but if you are using external power you should remove it and jumper the center of J5 to the “LOAD” pin. That will prevent external power from back-feeding (and possibly damaging) the receiver and will provide a DC load to make the receiver think it has an antenna connected; some applications test for current to determine the antenna is present and working.

To open the PWR\_SRC\_ENA jumper, use a hobby knife to remove the trace between the two pads. Operation may be restored later by putting a solder blob across the pads. If your antenna can get power from another source (like another splitter ahead of the GUS, or a separate voltage injector), opening the PWR\_SRC\_ENA jumper permits placing an attenuator or filter at the GUS input without the risk of shorting power to ground via a DC path in the external device.

**Do not apply external power without first removing R1 and/or R3 and setting the appropriate jumpers as directed in the table.** Improper configuration could damage the GNSS receiver, and possibly the GUS itself.

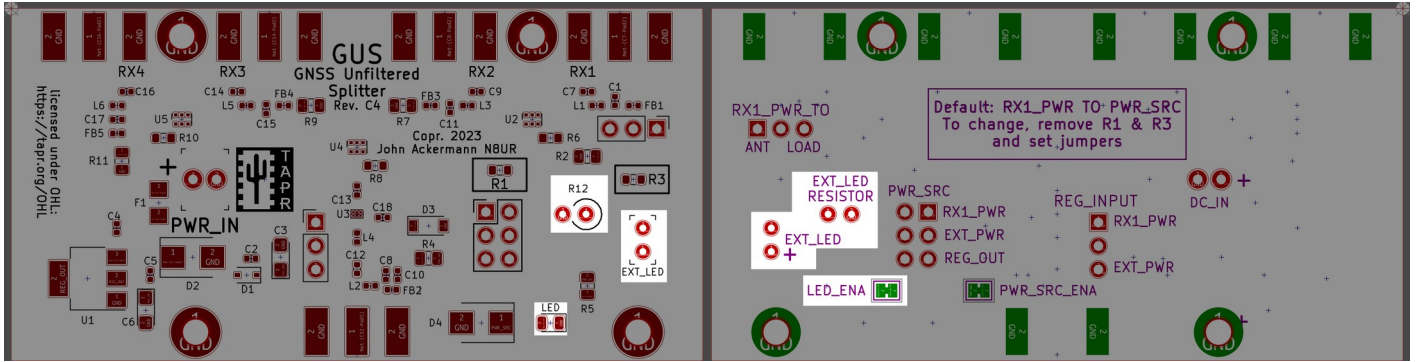


Figure 5:Gus LED Configuration Top (left) and Bottom (right)

Figure 5 shows LED configuration options. By default, the on-board LED will illuminate when power is present. To disable the LED, open PCB jumper LED\_ENA. You can use a hobby knife to remove the trace between the two pads; to restore operation later, put a solder blob across the pads.

An external LED can be attached at the EXT\_LED pads. In that case, install an appropriate current limiting resistor at R12. The LED\_ENA jumper does not affect operation of the external LED.



# Schematic

