CALLISTO
Construction Manual

~ Part of ~
e-CALLISTO
Solar Spectrometer Network

See last page for document revision number

CALLISTO-NA Construction Manual

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Additional information on the CALLISTO Receiver may be found here:
http://www.reeve.com/Solar/e-CALLISTO/e-callisto.htm

Additional information on e-CALLISTO, including a description of the e-CALLISTO Network, may be found here:
http://www.e-callisto.org/

e-CALLISTO logo on cover courtesy of Christian Monstein. Some images and portions of this manual were provided by Christian Monstein and are used with his permission

I. Description

I.1 Introduction

This manual describes the CALLISTO-NA Receiver and how to build it; it primarily is a hardware manual. Also included are specifications and hardware and circuit descriptions. An accompanying CALLISTO Software Setup Guide describes the software application programs and software tools that are used with the CALLISTO Receiver.

I.2 CALLISTO Receiver Versions

The CALLISTO-NA (North America) Receiver is available in kit, partially-built and ready-built and tested versions. The –NA version incorporates all engineering change requests (ECR) and remedies all non-conformance reports (NCR) through October 2011. The main differences between the North American and Swiss Institute of Technology (ETH Zurich) versions are panel layout and the dc power input connector. The receiver is referred to as CALLISTO, CALLISTO-NA Receiver or CALLISTO Receiver in the manuals.

Kit (p/n CR-KIT): The Kit version is no longer available.

Partially-Built (p/n CR-PBT): If you ordered the Partially-Built version, the PCB assembly tasks in Sect. III through VI have been completed. You need to assemble the interconnecting cables and enclosure and perform receiver tests and alignment described in Sect. VII, VIII and IX. Assembly time: Approximately 2 ~ 3 hours. After assembly is completed, go to the CALLISTO Software Setup Guide.

Ready-Built (p/n CR-RBT): If you ordered the Ready-Built version, you do not need to do any construction at all and this manual is your hardware reference document. Assembly time: None. Go to the CALLISTO Software Setup Guide.

I.3 System Description

e-CALLISTO is a worldwide network of frequency-agile solar spectrometers. e-CALLISTO is an acronym for extended Compact Astronomical Low-cost Low-frequency Instrument for Spectroscopy and Transportable Observatory. Callisto is the name of one of Jupiter's larger moons, and the name also is found in Greek mythology – a nymph of Artemis. Additional information on e-CALLISTO can be found at:

http://www.e-callisto.org/

http://www.reeve.com/Solar/e-CALLISTO/e-callisto.htm

The receiver instrument itself is called CALLISTO. CALLISTO was designed by Christian Monstein at ETH Zurich. CALLISTO can be used in a basic system consisting of the receiver, a linear polarized antenna system and control/logging software. A more advanced system includes a tower-mounted preamplifier or low noise amplifier, additional antennas and a focal plane unit (FPU) with antenna polarization switching and noise calibration capabilities. The receiver and associated software can be setup for linear, right-hand circular polarization (RHCP) or left-hand circular polarization (LHCP) but one receiver is required for each polarization.

I.4 Components Required but Not Supplied

Qty	Required for basic operation	Remarks
1	Standard desktop or laptop PC with: ≥ 1 GB hard drive, ≥ 1 GHz clock, one available serial port or USB port, network interface card (NIC) or equivalent. Recommended memory (RAM): ≥ 1 GB for Windows XP and ≥ 2 GB for Windows 2000, Vista and 7	
1	Windows operating system: Windows 2000, Vista, XP, 7 or 10 with firewall and anti-virus programs. All service packs must be installed. XP is the preferred operating system for its relative simplicity. Important note: The software supplied is not compatible with Linux operating systems. DO NOT use Windows emulators on LINUX systems; always use native Windows installations to avoid strange system behavior.	
1	Antenna system with at least one polarization (linear, LHCP, RHCP)	
1	Optional serial interface cable, DB9-F/DB-9M, straight-through wiring, ≤ 3 m	Note
1	Optional USB-serial adapter if native serial port is not available	Note
1	Optional power supply, 12 Vdc, 500 mA minimum (North America only)	Note
	Optional for participation in e-CALLISTO network	
1	Full-time internet connection	
1	FTP-WatchDog software	
	Optional for advanced operation	
1	Tower-mounted preamplifier or low noise amplifier	Note
1	Focal plane unit with LNA and noise calibration	
1	External clock source, 1MHz TTL with cable and 50 ohm termination	

Table note: These optional items may be ordered with the CALLISTO Receiver Kit

NOTICE: All parts in the CALLISTO Receiver Kits are new. However, the reclosable (ziplock) bags holding some parts may be recycled. Your order may include bags with writing or marks on them. Ignore any such markings.

I.5 Receiver Specifications

- Front-end: Philips Semiconductor CD1316LS-I/V3 tuner
- Frequency range: 45 ~ 870 MHz
- Frequency resolution: 62.5 kHz
- Intermediate frequencies:
  - 1st IF: 36.13 MHz, bandwidth 7 MHz
  - 2nd IF: 10.7 MHz, bandwidth 300 kHz
- Observation bandwidth: 300 kHz at 3 dB points, 378 kHz at 10 dB points
- RF input impedance: 50 ohms
- Dynamic range: –120 to –10 dBm (typical) [note 1]
- Spurious-free dynamic range: > 40 dB
- Noise figure: 10 dB [note 1]
- Channel sample rate: 800 channels/second (typically 200 channels in 250 ms)
- Frequency sweep rate: ≤ 30.0 MHz/ms
- Number of channels: 1, 2, 4, 5, 8, 10, 20, ..., 500 (400 typical maximum) [note 2]
- Sample rate: ≤ 800 samples/s (internal clock) or ≤ 1000 samples/s (external clock) [note 3]
- Detector output gradient: 25.4 ±1 mV/dB
- Allan time: > 100 s at 290 K
- Time uncertainty: ≤ 0.3 s
- Analog-digital converter (ADC) resolution: 10 bits (North American version)
- Interfaces:
  - RF input (N-F)
  - Video (detector) output (3.5 mm mono phone jack)
  - External clock (BNC-F)
  - EIA-232 I/O (DB-9F)
  - Focal plane unit control (DB-25F)
  - Power input (North American version: 2.1 mm x 5.5 mm coaxial jack, center +)
- Clock: Internal or external (1 MHz TTL) – NOT required for basic operation
- Auxiliary output control: Focal plane unit (FPU) – NOT required for basic operation
- Control method: Windows software (Callisto)
- COMM parameters: 115200-N-8-1
- Software input:
  - callisto.cfg (ASCII)
  - scheduler.cfg (ASCII)
  - frqxxxxx.cfg, where x = integer 00000 to 99999 (ASCI)
- Software Output:
  - Data – amplitude, frequency, time (XXXX_yyyymmdd_hhmmss_ff.fit) [note 4]
  - Activity log (LOGyyyymmddhhmmss.txt)
  - Lightcurve – amplitude, time for up to five frequencies (LCyyyymmdd_uuu_nnnnn.txt)
  - Spectral overview – amplitude, frequency of whole spectrum (OV_XXXX_yyyymmddhhmmss.prn)
- Input voltage: 12 Vdc nominal (9 ~ 15 Vdc)
- Input current: 255 mA nominal (no focal plane unit control), 465 mA worst case (includes receiver plus focal plane unit control pins sourcing 35 mA each)
- Warm-up time: 15 min
- Weight: 0.9 kg
- Dimensions: 200 mm long x 110 mm wide x 82 mm high, not including connectors

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Notes:

1. Sensitivity and noise figure depends on gain control voltage setting
2. There is some loss of channels at the low end of the sweep due to the finite speed of the VCO in the internal synthesizer. A channel loss of 1.25% of the number of pixels per sweep is typical. For example, for a sweep rate of 800 pixels/s (800 channels/s), a loss of 10 channels is expected. These channels must be ignored during data analysis.
3. Higher measuring speeds are possible but signal-to-noise ratio is reduced.
4. XXXX = Station name, yyyymmdd_hhmmss = Date and time

II. General Building Tips – READ THIS BEFORE STARTING:

- ☐ The CALLISTO Receiver Kit uses surface mount technology (also called surface mount device, SMT/SMD) and is NOT recommended as a first-time kit or inexperienced builders
- ☐ You will need a digital or analog multimeter that is able to read resistance up to 1 Mohm and voltage up to about 20 Vdc to properly assemble and test this kit. An RF signal generator and a noise source (15 dB ENR) covering at least 45 to 870 MHz will aid in performance testing
- ☐ Before starting assembly, perform an inventory of all components – see the README document and Excel file *CALLISTO-NA Parts List.xls* on the CD
- ☐ Parts are packaged in reclosable bags. DO NOT remove SMT components from their bags until you are ready to solder them. Many SMT parts cannot be visually identified, and you must be very careful to not mix-up the parts. SMT parts inventory is limited to confirming the proper quantity. The bags have a label indicating the nomenclature and value of enclosed SMT parts
- ☐ Many parts are very small and easy to lose or may become tangled with other parts (for example, connector contacts), so be careful emptying the reclosable plastic bags and keeping track of the parts
- ☐ As you inventory the parts, put them back into their bags so they are not lost
- ☐ Work slowly and methodically. When soldering SMT components open only one bag at a time and solder all of each value in one session. DO NOT open another SMT bag until all components from the previous bag have been soldered and their location double-checked
- ☐ The parts required for construction are listed in a table at the beginning of each section. As each component or group of components is soldered, place a checkmark in the boxes provided
- ☐ READ ALL NOTES AND COMMENTS in each section before assembling or soldering any components
- ☐ After completing each section, use a magnifying glass and bright work light to examine each and every solder joint for inadvertent bridges or cold solder. Do not proceed with the next section until repairs are made
- ☐ The leads of some components have tape on them. Do not pull the leads out of the tape and then try to solder. The tape gum may make soldering difficult. There is plenty of extra lead so simply cut the part of the lead contacting the tape
- ☐ Leave all integrated circuits and other semiconductor devices in their anti-static carriers until they are to be installed. DO NOT handle the ICs and semiconductor unnecessarily
- ☐ Use anti-static protection (grounded wrist-strap) whenever installing integrated circuits and other semiconductor devices
- ☐ After integrated circuits and other semiconductor devices are installed on the PCB, use static protection whenever handling the PCB
- ☐ Sockets are provided for all dual-inline integrated circuits. They do not have to be used but all test and alignment instructions are based on socketed integrated circuits. Also, when sockets are used, troubleshooting is greatly simplified
- ☐ The diode has a bar or stripe on one end and it must be oriented with the bar indicated on the PCB and drawing
- ☐ Radial through-hole electrolytic and tantalum capacitors are marked with a bar on one side, indicating the NEGATIVE lead, and one of the leads is longer, indicating the POSITIVE lead
- ☐ SMT tantalum capacitors are marked with a silver bar on one end, indicating the POSITIVE end. Be sure to orient these devices properly as indicated on the PCB and drawing
- ☐ Use 0.015 in (0.4 mm) solder for SMT soldering. DO NOT attempt to solder SMT parts with larger diameter solder. You may use ≤ 0.031 in (0.8 mm) solder for soldering non-SMT components
- ☐ Use a temperature controlled soldering iron with 0.6 mm bevel tip or 0.2 and 0.3 mm conical tip or bent tip. Set temperature to 300 ~ 315 °C
- ☐ Dimensions are given in trade sizes where applicable; therefore, you will note that some dimensions are in metric and some in non-metric units

III. Intermediate Frequency Transformers

A. General

CALLISTO uses two IF transformers, one for the 1st IF at 36.13 MHz and another for the 2nd IF 10.7 MHz. Except for the color of the core, the transformer components appear identical. Be very careful to NOT mix up these two different transformers. DO NOT remove the transformer components from the bags until directed to do so. Hand coils of coated magnet wire are provided for the transformers and it is necessary to cut them to length. It takes about 15-30 minutes to wind each transformer.

Tools:

- □ Temperature-controlled soldering iron set to 300-315 °C
- □ 0.015 in (0.4 mm) diameter solder
- □ Pair of sharp tweezers or small needle-nose pliers
- □ Small flush side-cutters
- □ Sharp hobby knife or scalpel
- □ Magnifying goggles or visor

Required parts:

Parts list ID	Qty	Description
☐ L1	1	FM1.1 (516376) transformer kit, black core
☐ L2	1	FM1.0 (516341) transformer kit, yellow core
☐	1	28 AWG green coated magnet wire, secondary, 31 cm long
☐	1	28 AWG red coated magnet wire, primary, 14 cm long

The exact length of the primary and secondary windings depends on which one you put on first. The order of winding is not critical. The length given below is long enough so that either winding can be placed first. You will need to trim the wires and remove their insulating coatings before soldering to the coil form pins.

Scrape away the coating with a sharp knife and then tin the wire. DO NOT attempt to solder the wires to the pins without first removing the coating or else you will damage the coil form. Soldering the tinned wire must be done very quickly and precisely so as to not damage the wire coating or melt the coil form. Solder the wires as close to the base of the pins as possible. Work carefully.

Refer to the drawings for each transformer and to the photographs at the end of this section. The table below summarizes the transformer winding information (Table 1).

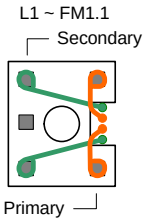
Table 1 ~ Summary of transformer winding data

Designation	Type	Primary color	Primary turns	Secondary color	Secondary turns	Core	Remarks
L1	FM1.1	Red	6	Green	9	Black	
L2	FM1.0	Green	14	Red	2	Yellow	

B. 1st IF Transformer (36.13 MHz), L1

□ Open the bag marked L1: FM1.1 form (black core) and remove the components (figure 1). Use a fine-tip permanent marker to mark the transformer can "L1" and "FM1.1".

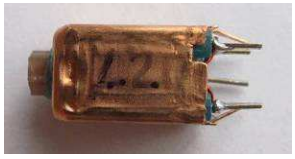
□ From the hand coil of green coated wire, cut 13 cm. Wind 9 turns for the secondary. Trim the pigtails to 3 ~ 4 mm length and prepare them as described above. Solder on the side of the coil form with 3 pins using the two outer pins (see bottom view of coil form below-left).



□ From the hand coil of red coated wire, cut 10 cm. Wind 6 turns for the primary. Trim pigtails to 3 ~ 4 mm length and prepare them as described above. Solder on the side of the coil form with 2 pins.

□ Check resistance between the pins for the primary and secondary windings with an ohmmeter. The resistance should be < 1 ohm for each winding.

□ Place the ferrite jacket on the coil form and screw the black ferrite core into the form. Slip the assembly into the metal can. The can is rectangular and the coil form will fit easily. At the top of the metal can on one side is a small indentation (below). The top of the coil form has four small tabs, one slightly shorter than the other three. This short tab is oriented toward the indentation when the form is inserted in the can. You will feel the tab lightly snap into the indentation – DO NOT force. The very top of the form should be flush with the top of the can when it is inserted all the way. Due to manufacturing tolerances, the hole in the can may be slightly offset from center. If so, simply carve out the hole with a hobby knife so the form fits properly.



□ Use an ohmmeter to check that the coils are isolated from the metal can and from each other (infinite resistance in both measurements).

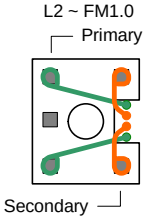
□ DO NOT install the transformer on the PCB at this time. Place the transformer back in the bag and set aside.

Figure 1: FM1.1 parts from left-to-right: metal-can, ferrite jacket, coil form, ferrite core (black). (courtesy of Christian Monstein)

C. 2nd IF Transformer (10.7 MHz), L2

□ Open the bag marked L2: FM1.0 form (yellow core) and remove the components (figure 2). Use a fine-tip permanent marker to mark the transformer can "L2" and "FM1.0".

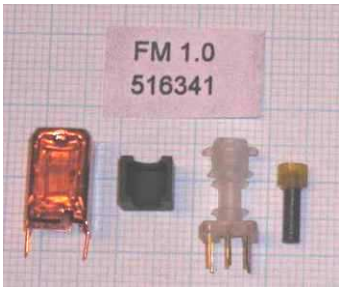
□ From the hand coil of green coated wire, cut 18 cm. Wind 14 turns for the primary. Trim the pigtails to 3 ~ 4 mm length and prepare them as described above. Solder on the side of the coil form with 3 pins using the two outer pins. Note: The color of L2 primary and secondary is different than L1. (see bottom view of coil form right)



- □ From the hand coil of red coated wire, cut 4 cm. Wind 2 turns for the secondary. Trim pigtails to 3 ~ 4 mm length and prepare them as described above. Solder on the side of the coil form with 2 pins.

- □ Check the resistance between the pins for the primary and secondary windings with an ohmmeter. The resistance should be < 1 ohm.

- □ Place the ferrite jacket on the coil form and screw the yellow ferrite core into the form. Note: The core supplied with some forms may be a brownish-red. Slip the assembly into the metal can using the same procedure as L1 above.



- □ Use an ohmmeter to check that the coils are isolated from the metal can and from each other (infinite resistance in both measurements).

- □ DO NOT install the transformer on the PCB at this time. Place the transformer back in the bag and set aside.

Figure 2: FM1.0 parts from left-to-right: metal-can, ferrite jacket, coil form, ferrite core (yellow). (courtesy of Christian Monstein)

D. Completed transformers

The completed transformers should appear generally as shown (figure 3). There may be slight variations in wire color.

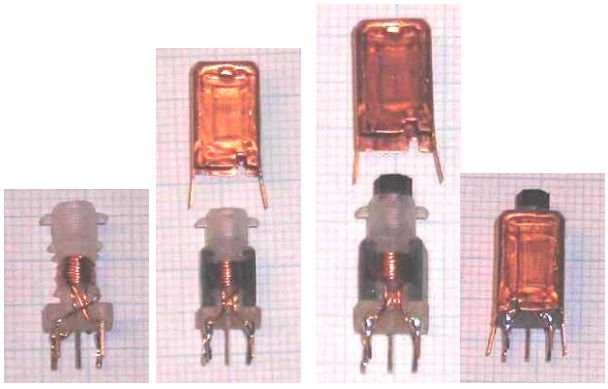


Figure 3 (courtesy of Christian Monstein) ~ Left-to-Right:

(a) Two windings on coil form (ferrite jacket not installed). Wires on the back pins are already soldered and wires in the front are not yet soldered
(b) Two windings installed on the coil form and soldered to the pins. Ferrite jacket installed. Be very careful to prevent short circuits between soldered wires and the metal can
(c) Ferrite jacket mounted and ferrite core screwed into the body, ready to be installed in the metal can
(d) Transformer completed. Carefully check with an ohmmeter for isolation between each pin and the metal case. The resistance should be infinite. In case of a short circuit, remove the metal can and use a small file to remove the solder balls that are causing the short circuit. Reinstall the coil in the metal can and check isolation again with the ohmmeter

IV. Printed Circuit Board

A. General

The printed circuit board (PCB) has circuit traces and components on both top and bottom (see photos of completed PCB at end of this section). The component locations are silkscreened on the PCB. To aid construction, a layout and location grid is provided in Appendix A. Tables are provided in par. B and C below show the grid location for each component. Management of the work will be aided by printing the PCB layouts and then marking each component location with a colored marker pen as it is installed.

Tools:

- □ Temperature-controlled soldering iron set to 300-315 °C
- □ 0.015 in (0.4 mm) diameter solder
- □ SMT soldering tools
- □ Regular soldering tools
- □ Magnifying goggles or visor

B. Surface Mount Technology Parts Installation

SMT PARTS ARE ALMOST IMPOSSIBLE TO RE-IDENTIFY VISUALLY IF THEY ARE ACCIDENTALLY MIXED TOGETHER. TO KEEP THIS FROM HAPPENING, DO NOT REMOVE THE SMT COMPONENTS FROM THEIR RECLOSABLE BAGS UNTIL YOU NEED THEM, AND SOLDER ALL COMPONENTS FROM A GIVEN BAG BEFORE OPENING ANOTHER BAG.

Install all listed components on the top or bottom of the PCB as indicated. It is easier to install the physically lower components first, followed by higher components in stages until the highest components are installed last. There are 67 SMT components and installation time is between 1.5 and 3 hours. Work slowly and methodically to avoid costly mistakes.

- ☐ Solder all SMT resistors in the order given in the parts list
- ☐ Solder all SMT capacitors except C18, C19, C36 and C37 in the order given in the parts list
- ☐ After all other capacitors are soldered, install C36 and C37 (3528 form factor) followed by C18 and C19 (6032 form factor). C18, C19, C36 and C37 are tantalum capacitors and are polarity sensitive. Be sure they are oriented properly. The POSITIVE electrode is indicated by a silver bar on the top of the capacitor and slightly rounded terminal on the bottom. The PCB silkscreen does not indicate polarity so pre-mark polarity locations for these capacitors with an indelible marking pen. See PCB images at end of this sub-section.
- ☐ Solder all SMT inductors

Required parts:

Parts list ID	Qty	Description	PCB location
☐ R8, ☐ R12, ☐ SMD-R1	3	51 ohm, 0805	Bottom
☐ R16, ☐ R25	2	100 ohm, 0805	Bottom
☐ R9	1	330 ohm, 0805	Bottom
☐ R1, ☐ R2	2	560 ohm, 0805	Bottom
☐ R19, ☐ R20, ☐ R5	3	1.0k ohm, 0805	Bottom
☐ R3, ☐ R4	2	1.5k ohm, 0805	Bottom
☐ R15	1	10k ohm, 0805	Bottom

☐ R11	1	120k ohm, 0805	Bottom
☐ R10	1	18k ohm, 0805	Bottom
☐ R7	1	22k ohm, 0805	Bottom
☐ R14, ☐ R6	2	56k ohm, 0805	Bottom
☐ R17, ☐ R18, ☐ R23	3	47k ohm, 0805	Bottom
☐ R21, ☐ R22	2	1.0M ohm, 0805	Bottom
☐ R24	1	27k ohm, 0805	Bottom

☐ C2, ☐ C3, ☐ C4, ☐ C5, ☐ C6, ☐ C7, ☐ C13, ☐ C14, ☐ C15, ☐ C20, ☐ C21, ☐ C23, ☐ C24, ☐ C25, ☐ C26, ☐ C27, ☐ C28, ☐ C31, ☐ C32, ☐ C33, ☐ C34, ☐ C35	22	0.1 μF, 0805	Bottom Bottom Bottom Bottom Bottom Bottom Bottom Bottom
☐ C10, ☐ C16, ☐ C38	3	1.0 nF (0.001 μF), 0805	Bottom
☐ C39 – See Table Note	1	150 pF, 0805	Bottom
☐ C8	1	15 pF, 0805	Bottom
☐ C29, ☐ C30	2	22 pF, 0805	Bottom
☐ C11	1	27 pF, 0805	Bottom
☐ C17	1	33 nF (0.033 μF), 0805	Bottom
☐ C9, ☐ C12	2	5.6 pF, 0805	Bottom
☐ C36, ☐ C37	2	4.7 μF, 3528 ►	Bottom
☐ C18, ☐ C19	2	4.7 μF, 6032 ►	Top

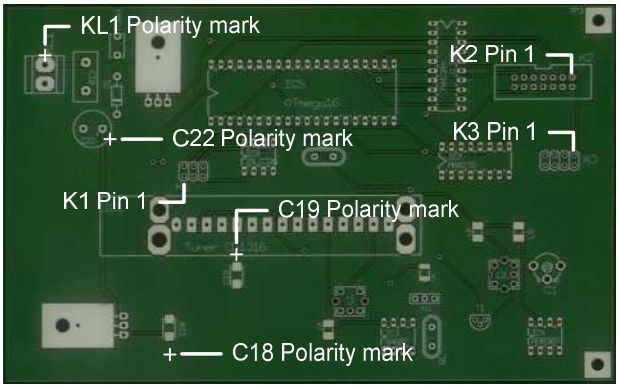
☐ L3, ☐ L4, ☐ L6	3	100 μH, 1210	Top
☐ L5	1	1.5 μH, 1210	Top
☐ L7	1	47 nH (0.047 μH), 1210	Bottom

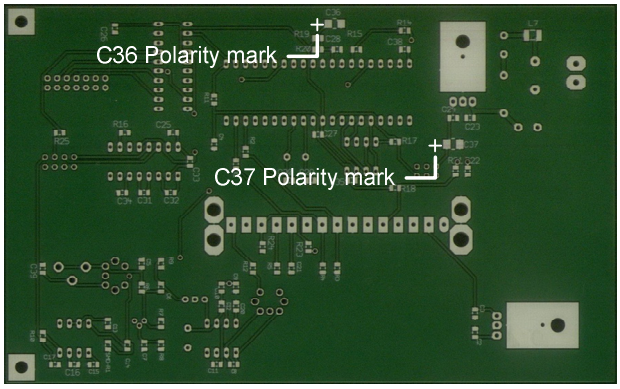
► Indicates pay attention to polarity or direction

Table Note: If your kit is supplied with C1, 6...50 pF trimmer capacitor (orange body), install C39. If your kit is supplied with C1, 6...150 pF trimmer capacitor (black body), DO NOT install C39.

Location Grid (T = Top, see Appendix A for grid layout)

R8-A3	**R12-A3**	**SMD-R1-A4**	**R16-B4C4**	**R25-B4C4**	**R9-A3**	**R1-B3**	**R2-B3**	**R19-C2**	**R20-C2**
R5-A3	**R3-A2**	**R4-A2**	**R15-C2**	**R11-C3**	**R10-A4**	**R7-A3**	**R14-C2**	**R6-A4**	**R17-B2**
R18-B2	**R23-B3**	**R21-B2**	**R22-B1**	**R24-B3**	**C2-A1**	**C3-A1**	**C4-B3**	**C5-A4**	**C6-A3**
C7-A4	**C13-A4**	**C14-A4**	**C15-A4**	**C20-A3**	**C21-A3**	**C23-C1**	**C24-C2**	**C25-B3C3**	**C26-C4**
C27-B2	**C28-C2**	**C31-B4**	**C32-B3**	**C33-B3**	**C34-B4**	**C35-B2**	**C10-A3**	**C16-A4**	**C38-C2**
C39-A4	**C8-A3**	**C29-B3B2**	**C30-B3**	**C11-A3**	**C17-A4**	**C9-A3**	**C12-A3**	**C36-C2**	**C37-B2**
C18-A3T	**C19-A3T**	**L3-B1T**	**L4-A2T**	**L6-B1T**	**L5-A2T**	**L7-C1**			

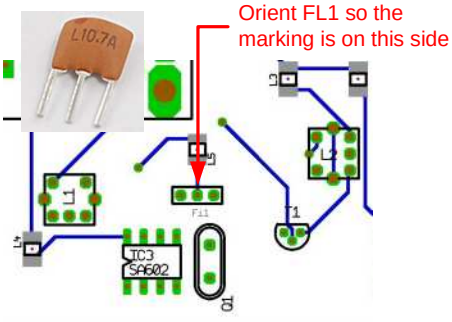




C. Through-Hole Parts installation

Install all remaining PCB components EXCEPT the integrated circuits IC1 through IC9 (these will be installed after the power supplies are tested). Use the same procedures as above – shortest components first and tallest components last – and install them in the order shown in the parts list.

- ☐ The diode D1 is polarity sensitive and must be installed with the proper orientation. The bar or stripe on one end of the diode indicates the cathode and it must correspond with the bar on the PCB silkscreen
- ☐ Cut two small paper insulators to place between the PCB and the two crystals Q1 and Q2 (to prevent their metal case from shorting to the PCB)
- ☐ In North American receivers s/n NA008 and later, crystal Q1 frequency is 25.43 MHz and capacitor C1 is 6...150 pF. In earlier receivers Q1 was 27.00 MHz and C1 was 6...50 pF.
- ☐ The variable capacitor C1 supplied with your kit may have two or three pins. If it has two pins install it with the flat side of the capacitor body as shown on the silkscreen
- ☐ If you use the supplied DIL sockets with the integrated circuits, be sure to orient the end with the alignment notch or dimple as shown on the PCB drawing. Before installing the sockets, check for bent pins
- ☐ The 14-position PCB header connector has polarizing slots. The connector supplied with your kit will have one slot in the middle of one side. Some connectors also may have two slots on the other side. Be sure to orient the side with ONE slot as shown on the PCB drawing
- ☐ The 10.7 MHz bandpass filter FL1 is marked on one side (L10.7A). Install the filter so this marking is oriented as shown on drawing right
- ☐ The two IF transformers L1and L2 can be installed in only one direction. Be sure they are placed in the correct positions: L1 is installed to the left of FL1 and L2 is installed to the right



- ☐ The 6- and 8-position PCB headers K1and K3 are unpolarized. After soldering, put a small dab of red fingernail polish on the PCB next to pin 1 of both PCB headers (see PCB images above). This will be used to align the unpolarized connectors associated with interface Cable 2 and an In-System Programming (ISP) cable (the ISP connector is not required for normal operation but can be used for future firmware updating; see Appendix C). While you have the fingernail polish out, put a small dab on the corresponding end of the 8-pin connector in Cable 2 and on positive side of the power input terminal block KL1

- ☐ Electrolytic capacitor C22 is polarity sensitive and must be installed with the proper orientation. The bar marked on the side of the capacitor indicates the NEGATIVE lead, and the longest lead is the POSITIVE. Be sure to put the long lead in the hole marked with the + polarity
- ☐ Bend the leads on U2 and U6 so the TO-220 tab lies flat on the heatsink and PCB with the holes lined up. Spread a small amount of heatsink compound (not supplied) on the tab before mounting on the heatsink. Use 4-40 hardware (supplied) to secure the tab and heatsink. Insert the screw with a flat washer from the bottom of the PCB and place another flat washer, split lock washer and nut on the top. The larger heatsink goes with IC2 and the smaller heatsink with IC6

Required parts:

Parts List ID	Qty	Description	PCB Location
☐ D1	1	1N4007 ►	Top
☐ Q1	1	25.430 MHz, ±10 ppm, 18 pF	Top
☐ Q2	1	11.0592 MHZ, ±50 ppm, 20 pF	Top
☐ C1 – See Table Note	1	Trimmer, 6…150 pF (black) ►	Top
☐ T1	1	BF199	Top
☐ Socket, IC7	1	16-pin socket ►	Top
☐ Socket, IC8	1	20-pin socket ►	Top
☐ Socket, IC5	1	40-pin socket ►	Top
☐ Socket, IC3, ☐ IC4, ☐ IC9	3	8-pin socket ►	Top
☐ FL1	1	L10.7A bandpass filter ►	Top
☐ Header PCB connector, K1	1	6-pin, 2x3	Top
☐ Header PCB connector, K2	1	14-pin, 2x7 ►	Top
☐ Header PCB connector, K3	1	8-pin, 2x4	Top
☐ Terminal block, KL1	1	2-position, screw-clamp	Top
☐ R13	1	S10K14 varistor (VDR)	Top
☐ Fuse1 socket	1	2-pin socket	Top
☐ Fuse1	1	1.0 A, 250 V, radial	Top
☐ L1	1	FM-1.1 (black core)	Top
☐ L2	1	FM-1.0 (yellow core)	Top
☐ C22	1	470 μF, 35 V, radial ►	Top
☐ IC2, ☐ IC6	2	7805CT voltage regulator	Top
☐ Heatsink (large), IC2	1	32.0 thermal resistance (22 mm)	Top
☐ Heatsink (small), IC6	1	15.6 thermal resistance (6 mm)	Top
☐ Heatsink compound	1	**Not supplied**	
☐ Machine screw	2	4-40 x 3/8 in.	Bottom
☐ Flat washer	4	Standard x #4	Bottom
☐ Split lock washer	2	Standard x #4	Top
☐ Hex nut	2	4-40	Top

► Indicates pay attention to polarity or direction

Table Note: Early kits were supplied with 6...50 pF trimmer capacitor (orange body). Kits s/n NA008 and later are supplied with 6...150 pF trimmer capacitor (black body).

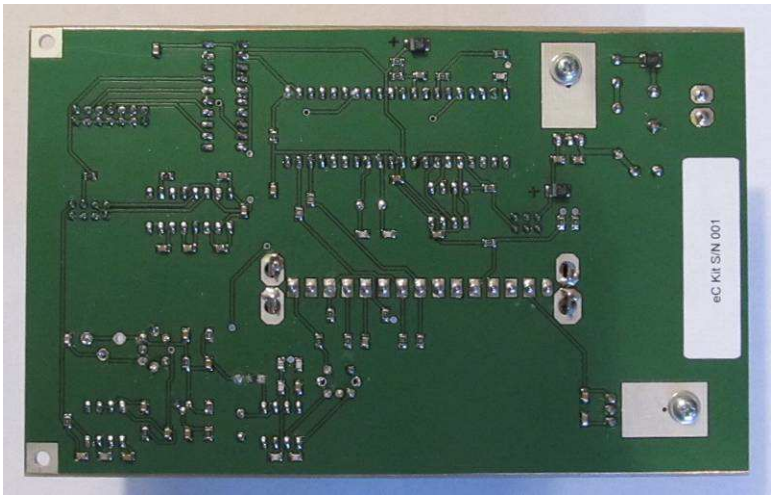
Location Grid (T = Top, see Appendix A)

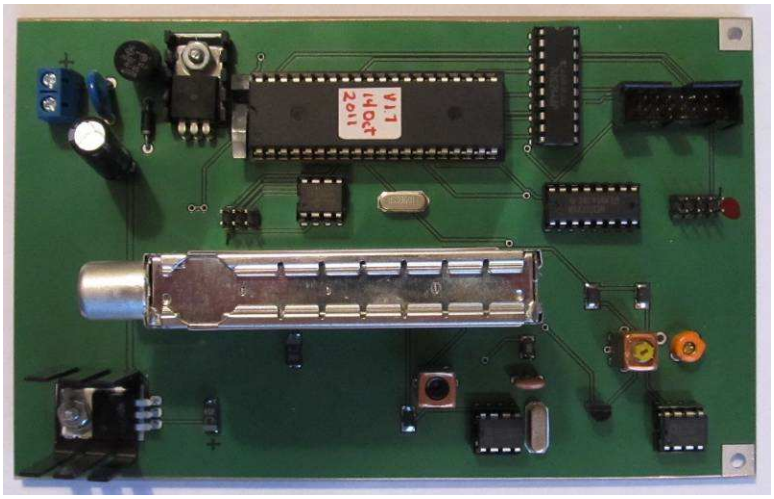
D1 -C4T	**Q1-A2T**	**Q2-B2T**	**C1-A1T**	**T1-A1T**	**IC7-B2B1T**	**IC8-C2T**	**IC5-C3C2T**	**IC3-A2T**	**IC4-A1T**
IC9-B3T	**FL1-A2T**	**K1-B3T**	**K2-C1T**	**K3-B1T**	**KL1-C4T**	**R13-C4T**	**Fuse1-C4T**	**L1-A2T**	**L2-A1T**
C22-C4T	**IC2-A4T**	**IC6-C4C3T**							

D. Check Installation

- ☐ Double-check all components for location and check polarity sensitive components (electrolytic capacitors, diodes), voltage regulators and integrated circuit sockets for proper orientation.
- ☐ Double-check all soldering with a bright light and magnifying visor or magnifying glass
- ☐ Double-check that the fuse is installed

Pictures of PCB bottom and top after all components have been installed (below)





V. Power Supply Tests

A. Power Source

The power supply components are now ready to test. You will need a nominal 12 Vdc power supply.

The power supply or ac adapter should have the following characteristics

- ¤ Output voltage: 9 to 15 Vdc when under load
- ¤ Output current: ≥ 500 ma

AC power adapters are a huge source of problems because they generally are very cheap and many are poorly designed. If you purchased your CALLISTO Receiver Kit with an optional ac adapter (North America customers only), you received a quality brand with sufficient capacity and well-filtered output.

If you supply your own ac adapter for the receiver only and no focal plane unit control, its output must be rated at least 9 Vdc, 500 mA. AVOID ac adapters that use switch-mode technology (they generally are electrically very noisy). DO NOT attempt to power the CALLISTO receiver with an under-rated or low-quality ac adapter. DO NOT use an ac adapter with an output higher than approximately 15 Vdc when under load. The 7805 voltage regulators have a maximum input voltage rating of 35 Vdc but you should allow for a margin of 1/2. Similarly, the CALLISTO input current draw is approximately 255 mA (fully built with integrated circuits installed and in measurement mode) but you should allow for a margin of at least 2.

Note: For reference, each of the six FPU control pins on the FPU connector can source up to 35 mA. Thus, for the situation where the receiver controls a focal plane unit, the receiver can draw its normal operating load plus a maximum of 210 mA additional load for the FPU control. The worst-case load would be approximately 465 mA and the power supply should be rated at least 1.0 A. However, for receiver testing purposes you only need a 500 mA power supply.

Check your ac adapter leads for polarity with a voltmeter before connection. If you connect the power adapter backwards, you probably will not hurt anything but, of course, the receiver will not work. The PCB includes a reverse polarity guard diode (D1) and a fuse (Fuse1).

The North American version of the receiver uses a coaxial dc power input jack (2.1 mm x 5.5 mm). The center pin of the coaxial power connector is positive. The ETH version of the receiver uses a DIN connector for dc power input.

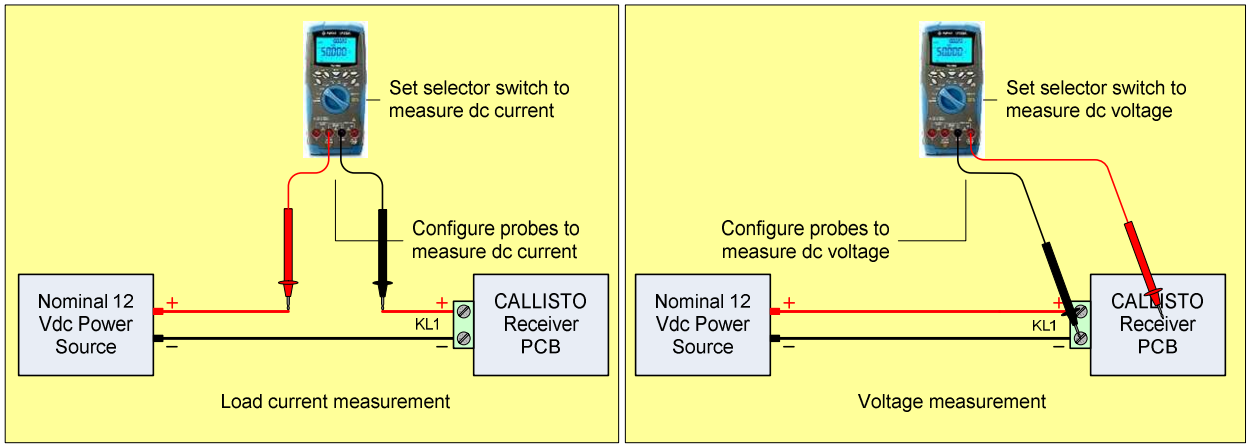
B. Voltage and Current Tests

Tools:

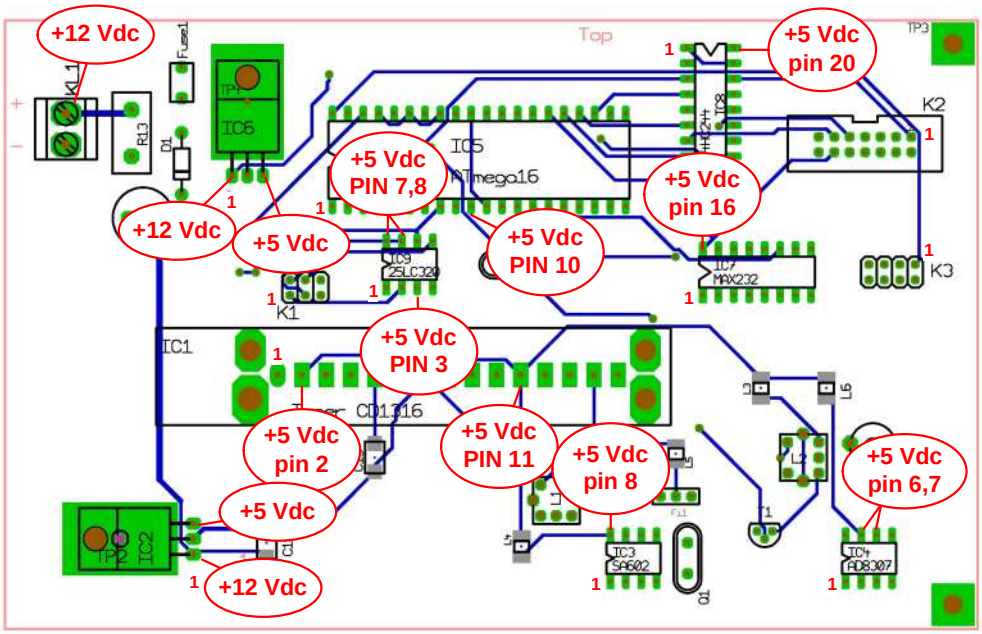
- □ Digital multimeter (DMM) or analog multimeter

Be sure the PCB is not sitting on a conductive surface. Configure the multimeter to measure dc current and connect it between the 12 Vdc power supply and the KL1 terminal block on the PCB (illustration below). Check your setup and then plug the power supply into an ac receptacle. Measure the dc load current. It should be as shown in the table on the next page. If the current is significantly higher than the range shown, there is a short circuit (for example, solder bridge) or faulty component. If the current is significantly lower, there is an open circuit (for example, cold solder joint) or faulty component.

Reconfigure the multimeter to measure dc voltage. With the multimeter set to the 20 Vdc range, check voltages with respect to ground. Connect the meter negative (black) lead to ground (for example, the tab on IC2 or IC6 or the negative terminal of KL1 terminal block) and then probe the measurement points with the meter positive (red) lead. All voltage measurements may be made from the top of the PCB except IC1. Refer to illustration and tables below.



	Nominal input current	Measured range	Remarks
☐	~11 mA dc	10 – 12 mA	No load from integrated circuits
	Nominal voltage		
☐	+5 V dc	+4.75 to +5.25 V	Determined by 7805 voltage regulator
☐	+12 V dc	+9 to +15 V	Actual input voltage at KL1 and actual input voltage less ~0.7 V at other points



If all voltages and load current are within the specified ranges, the power supply components are working properly. Remove the dc power before continuing!

If the voltages or load current are not within the specified ranges, check for shorts, solder bridges and orientation of polarity sensitive components (electrolytic and tantalum capacitors, diodes, and voltage regulator ICs). Do not continue until you have fixed the problem.

	IC	Ground pin	Vcc pin (+5 Vdc)	Vcc Source
☐	IC1 (CD1316LS/IV-3)	Case	2, 11	IC2
☐	IC2 (7805)	2	3 (output)	Pin 1 is input (+12 Vdc)
☐	IC3 (SA602)	3	8	IC2
☐	IC4 (AD8307)	2	6, 7	IC2
☐	IC5 (ATmega16)	11	10	IC6
☐	IC6 (7805)	2	3 (output)	Pin 1 is input (+12 Vdc)
☐	IC7 (MAX232)	15	16	IC6
☐	IC8 (74HC244)	10	20	IC6
☐	IC9 (25LC320)	4	3, 7, 8	IC6

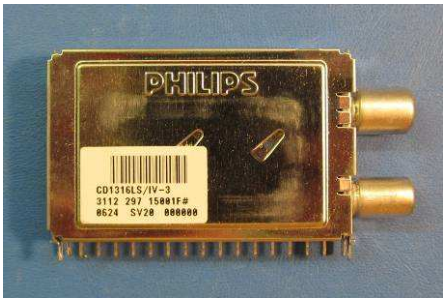
VI. Install the Integrated Circuits

A. General

Use anti-static protection (grounded wrist strap) when handling the integrated circuits. Do not remove them from the anti-static pad until you install them on the PCB.

B. Tuner IC1

IC1 must be installed on the top of the PCB and oriented with the coaxial connectors pointed toward the end of the PCB where the voltage regulators (IC2 and IC6) are located. One ground tab on the bottom corner of the tuner is slightly larger than the other three and it may be necessary to file a small slot in the hole on the PCB for that pin (use a thin jeweler's file). Do not force IC1 into the PCB.



After inserting the tuner in the PCB, tack-solder two ground tabs, one in each corner. Lightly press the tuner case against the PCB and quickly resolder the two tabs to make sure the tuner is completely seated on the PCB and is perfectly vertical. After you are sure it is properly seated, solder the other two ground tabs and then the 15 power/input/output pins. Filling the ground tab holes with solder is NOT recommended (if you ever have to remove the tuner, you will regret having filled the holes with solder).

Required parts:

Parts List ID	Qty	Description
☐ IC1	1	CD1316LS/IV-3 tuner ►

► Indicates pay attention to polarity or direction

FROM THIS POINT FORWARD, DO NOT HANDLE THE INTEGRATED CIRCUITS AND PCB UNLESS YOU ARE WEARING ANTI-STATIC PROTECTION.

C. Remaining Integrated Circuits

Plug in the remaining integrated circuits, being sure they are oriented properly in their sockets. The sockets and ICs have a notch or dimple at one end, and they must line up. Now, just for fun, go back and check all the ICs for proper orientation.

Note: Most ICs are shipped with the leads at a slight angle away from the body. It is much easier inserting them into a socket by first carefully bending the leads so they are at right-angles to the body. To do this, grip the IC at both ends and lay one side of the IC and pins on a hard, flat, smooth surface. Carefully rotate the body toward the pins a few degrees so the pins are uniformly bent at a right angle to the IC body. Flip the IC over and repeat on the other side.

Required parts:

Parts List ID	Qty	Description
☐ IC3	1	Mixer SA602A ► (see Note)
☐ IC4	1	Log detector AD8307 ►
☐ IC5	1	Microprocessor ATmega16-16PU ►
☐ IC7	1	Transceiver MAX232EIN ►
☐ IC8	1	Buffer 74HC244 ►
☐ IC9	1	EEPROM 25LC320 ►

► Indicates pay attention to polarity or direction

D. Check Installation

☐ Double-check all components for location and check polarity sensitive components (electrolytic capacitors, diodes), voltage regulators and integrated circuits and sockets for proper orientation
☐ Triple-check all soldering with a bright light and magnifying visor or magnifying glass
☐ Double-check location and orientation of integrated circuit in their sockets

E. Test Power Supplies with ICs Installed

Repeat the tests described in Sect. VI except use the table below.

	Nominal voltage	Measured range	Remarks
☐	+5 V dc	+4.75 to +5.25 V	Determined by 7805 voltage regulator
☐	+12 V dc	+9 to +15 V	Actual input voltage less ~0.7 V
	Nominal current		
☐	~230 mA dc	225 – 245 mA	Load current does not include the front panel LED. Load increases with CPU activity (for this test, the CPU is not active)

If all voltages and load current are within the specified ranges, there are no major short circuits. Remove the dc power before continuing!

If the voltages or load current are not within the specified ranges, check that all integrated circuits are installed correctly and there are no bent pins. To check for bent pins you will need to remove the ICs from their sockets. Also, check for shorts, solder bridges and orientation of polarity sensitive components (electrolytic and tantalum capacitors, diodes, and voltage regulator ICs). Although you already checked these devices, check them again. Do not continue until you have fixed the problem.

VII. Cables and Panels

A. General

Several cables are used in the CALLISTO receiver including:

- □ Cable 1 – Focal plane unit interface cable
- □ Cable 2 – Serial interface, clock and detector output cable
- □ Cable 3 – RF input cable
- □ Cable 4 – Internal power cable
- □ Cable 5 – External power cable

Cables 1 through 4 are associated with the front and rear panels and, when constructed, one end of each cable is connected to panel-mounted components and the other end connects to the PCB.

Note: If the CALLISTO Receiver will never be used with a Focal Plane Unit or with an External Clock source, the associated cables and connectors do not need to be installed. Elimination of the FPU cable (Cable 1) alone will reduce build time by a couple hours.

Tools:

- □ Soldering iron set to 300-315 °C
- □ 0.031 in (0.8 mm) diameter or smaller solder
- □ Electronic construction hand tools including screwdrivers and assorted small hex nut drivers in non-metric sizes
- □ Magnifying goggles or visor

B. Internal focal plane unit Cable 1

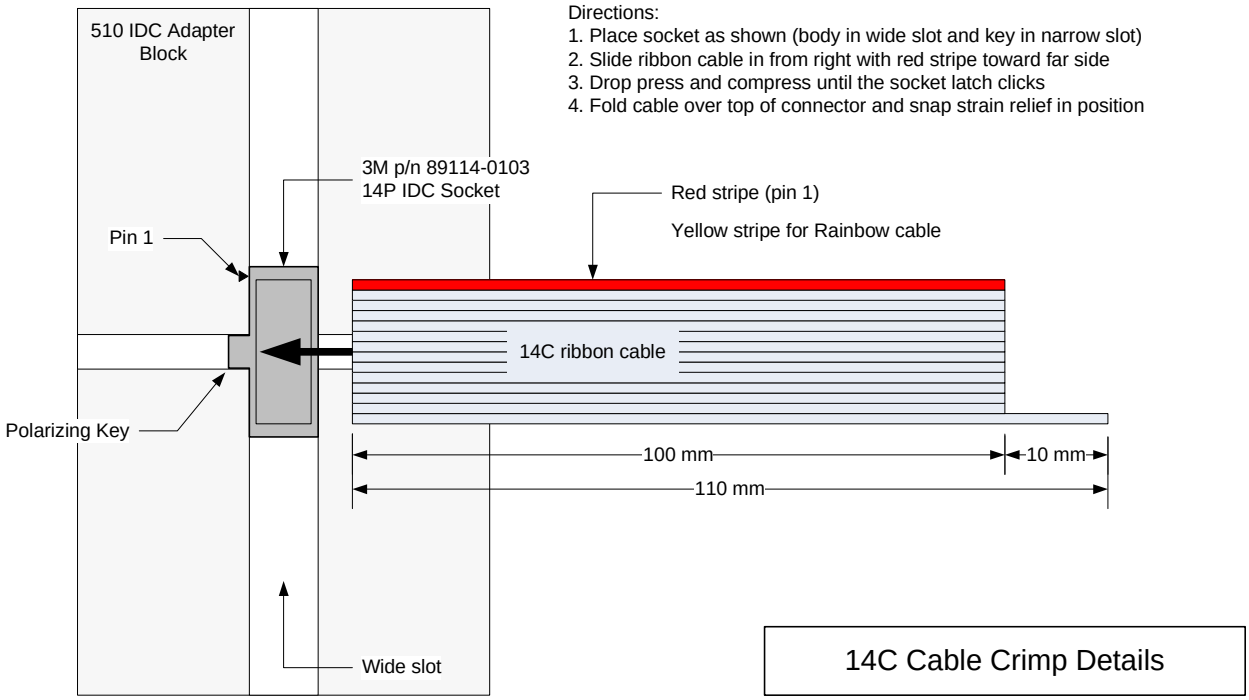
Interface Cable 1 uses a polarized 14-pin header connector at the PCB end and DB-25F connector at the rear panel end. The header connector and ribbon cable are preassembled. Strip, solder and connect the blunt end of the cable to the DB-25F connector as shown in the schematic below. An illustration showing the ribbon cable trimming pattern also is shown. A picture of the completed cable is shown at the end of this section.

Plan your work and trim the ribbon cable so that it has enough slack to allow the rear panel to be removed for troubleshooting but not so much slack that it takes up a lot of space inside the enclosure. You can trim the cable by, say, 3.5 cm but check your own installation beforehand. Use the trimmings to make the ground bridge on pins 22 to 25. Heatshrink tubing is provided for the connections to the DB-25F connector – cut into 5 mm lengths.

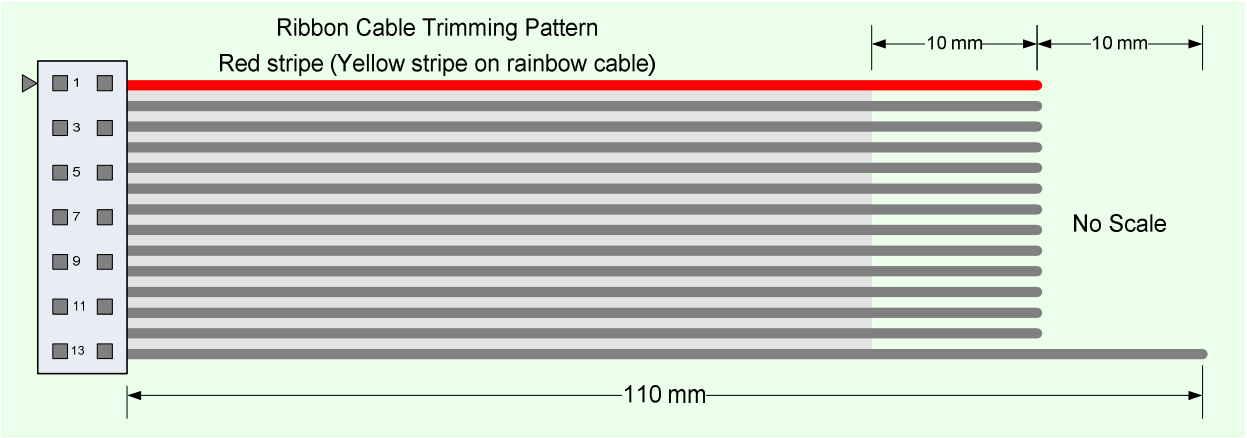
Mount the DB-25F on the rear panel as shown in the detail drawing below. The solder lug for grounding can be installed on the DB-9F connector in Cable 2 or the DB-25F connector..

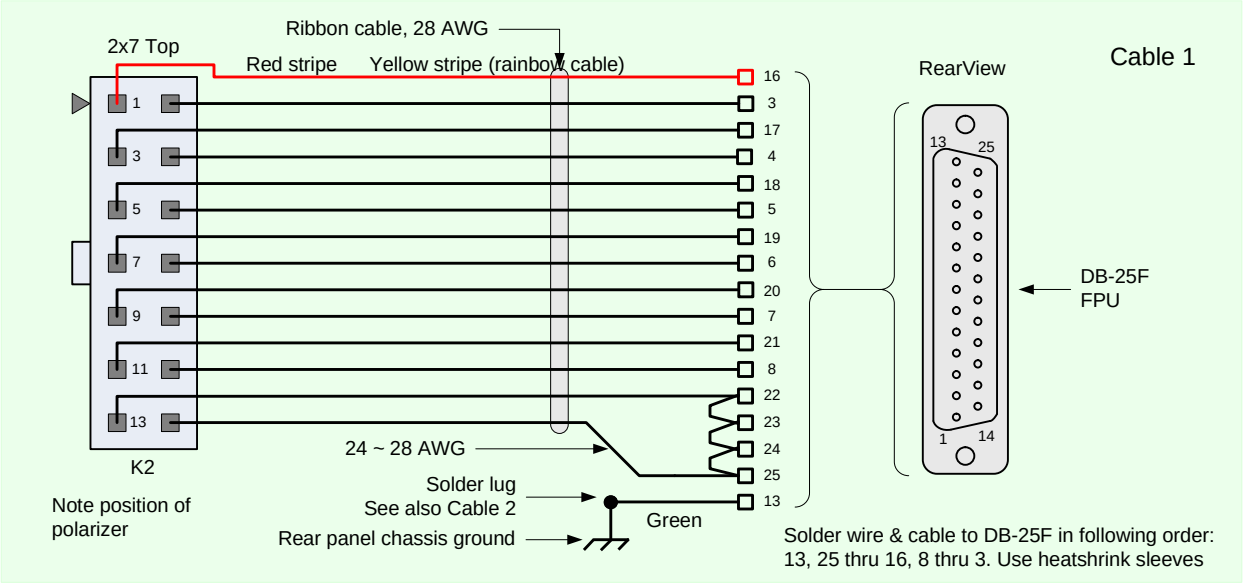
Required parts:

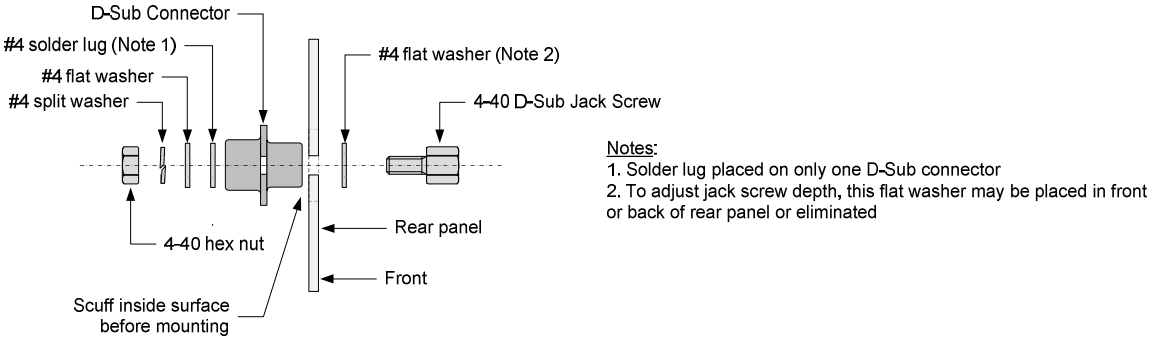
Parts list ID	Qty	Description
☐	1	Rear panel with cutouts
☐ K2 assy	1	Preassembled ribbon cable, 14C with header connector
☐	2	4-40 jack screw set for D-sub connector
☐ FPU	1	DB-25F connector, solder cup
☐	1	Wire, 24 AWG, 300 V, green, 5 cm
☐	1	Heat shrink tubing, 110 mm



14C Cable Crimp Details



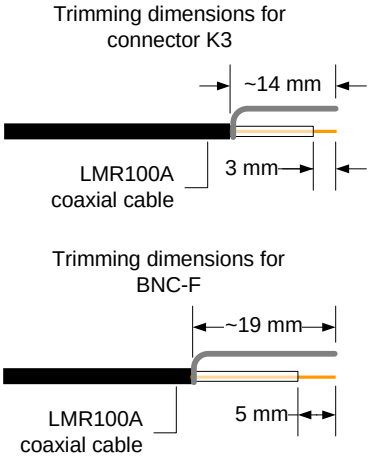




C. Internal interface Cable 2

Interface Cable 2 uses an unpolarized 8-pin header connector (K3) at the PCB end and various connectors at the rear panel end. A picture of the completed cable is shown at the end of this section. Using the provided socket contacts wire the header. If you do not use a crimping tool on the socket contacts, you must solder them. Do not rely on a mechanical crimp made with pliers without solder.

Plan your work in the same way as Cable 1. All panel connectors in Cable 2 EXCEPT the BNC-F clock input connector mount from the rear of the panel. DO NOT solder the coaxial cable to the BNC-F connector until you mount the connector on the rear panel.



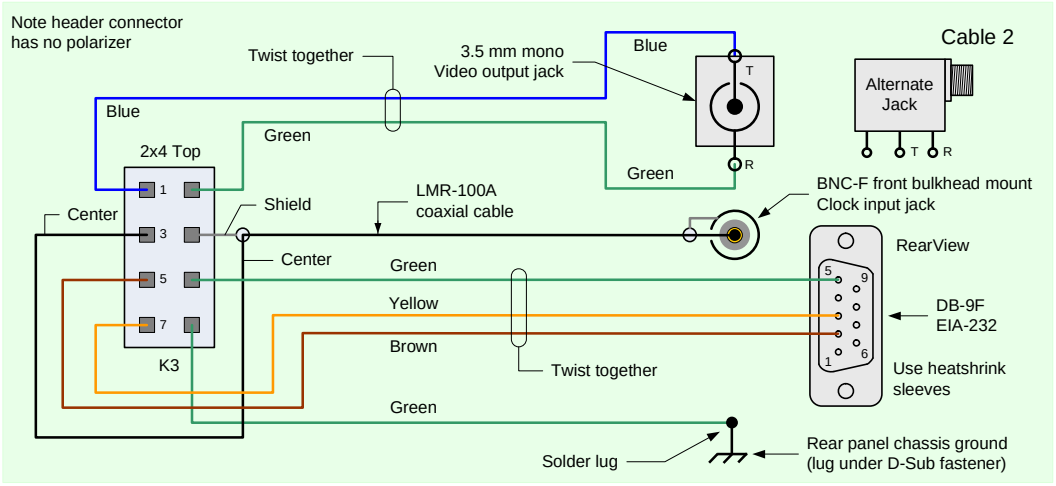
After soldering one end, twist the individual wires together in groups as shown in the drawing. Do a neat job. Heatshrink tubing is provided for the connections to the DB-9F connector – cut to length as required. The solder lug for grounding can be installed on the DB-9F connector or DB-25F connector in Cable 1. You may have to trim or file the solder lug on one side so that it fits properly on the back of the D-sub connector.

Trim the LMR-100A coaxial cable used between connector K3 and the BNC-F connector as shown left. The center conductor is solid so after

crimping the socket contact for K3, apply a small amount of solder to reinforce the crimp. Be careful to not allow solder to wick up into to contact well or spring.

Required parts:

Parts list ID	Qty	Description
☐ EIA-232	1	DB-9F connector, solder cup
☐	2	4-40 jack screw set for D-sub connector
☐ Clock	1	BNC-F connector, front bulkhead mount
☐ Video	1	Phone jack, mono, 3.5 mm
☐	1	Solder lug, #4
☐ K3	1	8-pin header connector, 2x4
☐	9	Socket contact for header connector (1 spare)
☐	3	Wire, 24 AWG, 300 V, green, 15 cm
☐	1	Wire, 24 AWG, 300 V, brown, 15 cm
☐	1	Wire, 24 AWG, 300 V, yellow, 15 cm
☐	1	Wire, 24 AWG, 300 V, blue, 15 cm
☐	1	Coaxial cable, LMR-100A, 15 cm
☐	1	Heatshrink tubing, 40 mm

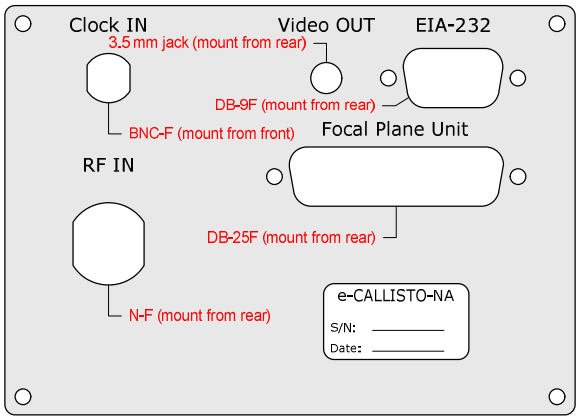


D. Internal RF input Cable 3

The RF input cable is supplied ready-built. Leave it in the plastic bag until directed to install it in Sect. VIII.

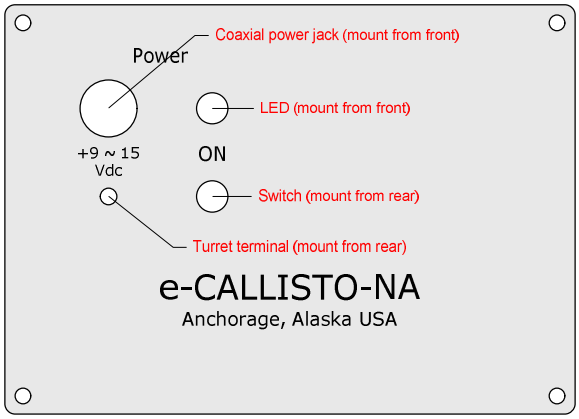
Required parts:

Parts list ID	Qty	Description
☐ RF Cable 3	1	RF input cable, N-F rear bulkhead mount connector to IEC PAL-M right angle connector



E. Installation on Rear Panel

Mount the connectors for Cables 1, 2 and 3 on the rear panel. The drawing left shows the locations of the rear panel components (top). To keep from scratching or marring the panel, lightly tack some masking tape around the mounting holes and then tighten the hardware. Remove the tape when done and set aside the rear panel assembly. If you need to clean the panels, use a damp cloth; DO NOT use chemicals or else the silkscreen may dissolve.



F. Internal power Cable 4

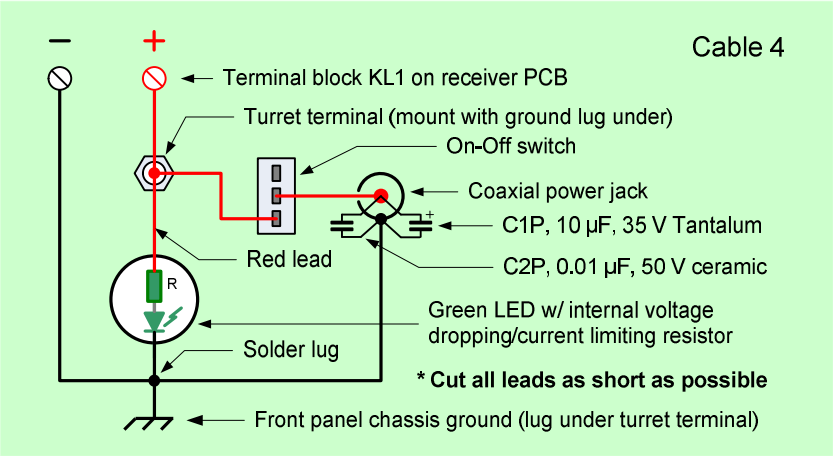
The internal power cable is a collection of interconnected parts mounted on the front panel with pigtails for connection to the PCB. Mount the components to the front panel and wire as shown in the schematic below. A drawing that shows the location of the connectors and controls on the front panel is provided left.

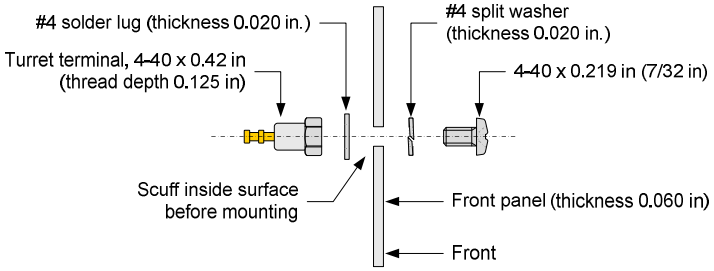
Use the short 4-40 x 7/32 in machine screw to mount the turret terminal and solder lug as shown in the detail drawing below. The LED and coaxial power jack are slipped in their respective cutouts from the front of the panel, so do not connect them until they are mounted. The LED is press-fit. The tantalum capacitor, It is suggested that the plug be inserted in the coaxial power jack before wires are soldered to the jack – this will help minimize distortion of the jack plastic insulator if you use too much heat. C1-P is polarity sensitive, and the positive (+) terminal is indicated on the body (look with magnifier) and is the longest lead. Cut all leads as short as possible to minimize RFI coupling to and from the power supply. When finished, set aside the front panel assembly.

Required parts:

Parts list ID	Qty	Description
☐	1	Front panel with cutouts
☐	1	Turret terminal, 0.42 in x 4-40 x 0.125 in thread depth.
☐	1	Machine screw, 4-40 x 7/32 in
☐	1	Split washer, #4
☐	1	Solder lug, #4
☐ Switch	1	SPDT miniature toggle switch, On-Off
☐ LED	1	LED, Green, with internal resistor and leads ►
☐ Power	1	Coaxial power jack, 2.1 mm x 5.5 mm
☐ C1-P	1	Capacitor, tantalum, 10 µF, 35 V ►
☐ C2-P	1	Capacitor, ceramic, 0.01 µF, 50 V
☐	1	Wire, 24 AWG, 300 V, red, 15 cm
☐	1	Wire, 24 AWG, 300 V, black, 15 cm

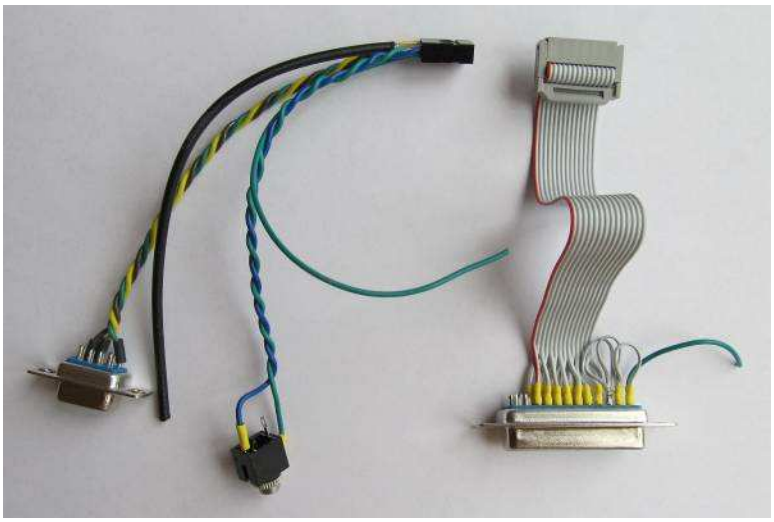
► Indicates pay attention to polarity or direction





G. External power Cable 5

If you purchased the optional ac adapter, it is supplied with coaxial power connector installed and ready-for-use. If you plan to use your own power supply, a 2.1 mm x 5.5 mm coaxial plug is provided with the kit. Wire the plug center-positive and use a large enough wire (not supplied) to minimize voltage drop for the length of cable needed (< 0.5 V). A 2-conductor, stranded, 18 AWG (1.0 mm dia.) cable is suitable for most installations.



Picture of almost completed Cable 1 (right) and Cable 2 (left). Neither cable has the solder lug installed and Cable 2 does not yet have the BNC-F connector installed. They will be installed when the parts are mounted on the panel.

VIII. Assemble the Enclosure

A. General

The enclosure consists of top and bottom sections and front and rear end panels. Assembly consists of installing the PCB, connecting the cables on the end panels and installing screw fasteners to hold the assembly together.

B. Assembly

Tools:

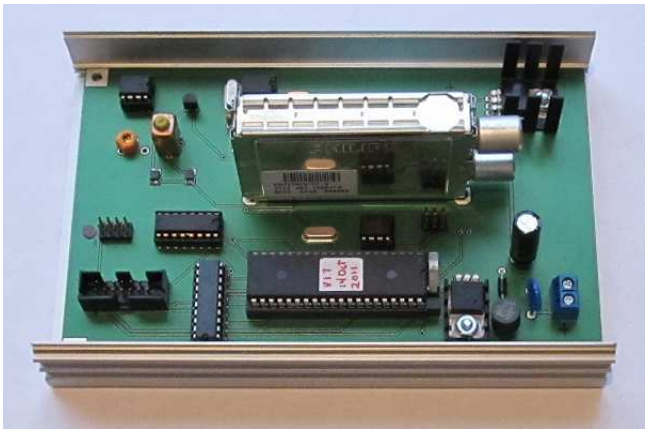
- □ Phillips screwdriver, No. 1 blade
- □ Torx screwdriver, No. T10 bit
- □ Slot screwdriver, 1/8 in (3 mm) blade

Required parts:

Parts list ID	Qty	Description
☐ Cable 1	1	Focal plane unit interface cable from Sect. IV
☐ Cable 2	1	Serial interface, clock interface and detector output cable from Sect. IV
☐ Cable 3	1	RF input cable from Sect. IV
☐ Cable 4	1	Internal power cable from Sect. IV
☐	1	Front end panel, custom machined and labeled
☐	1	Rear end panel, custom machined and labeled
☐	1	Enclosure, two pieces, one shallow and one deep (note)
☐	8	#4 x 3/8 in self-threading screws, Phillips pan head (note)
☐	4	Stick-on rubber feet (note)

Table note: The enclosure, as supplied by the Gie-Tec factory, includes two blank end panels, eight 2.9 x 9.5 mm self-threading screws and four rubber feet. The factory end panels are replaced by the custom machined end panels. The factory screws may require a Torx T10 driver or Phillips driver and may be replaced by the extra Phillips screws listed in the parts table. If you use the factory screws you will have to enlarge the corner holes in the end panels to 3.2 mm diameter.

Before installation of the PCB and panels, run the self-threading screws in the corners of the upper and lower sections of the enclosure to cut the threads. Now, slide the PCB into the bottom section of the enclosure. If necessary, rub some candle wax on the edges of the PCB to help it slide easier. The bottom is the shallow section (see picture below).



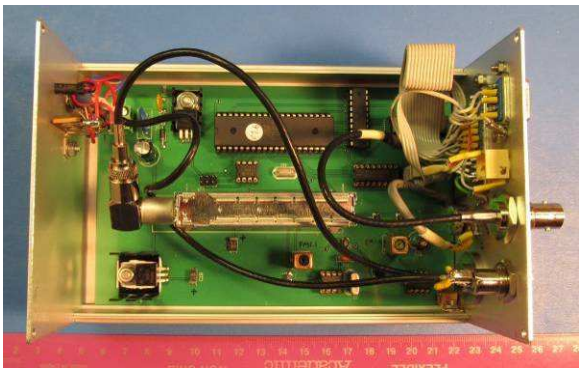
Plug the interface cables into their respective header connectors on the PCB. Cable 1 connector is mechanically polarized and will fit only one way. Cable 2 connector is not polarized so you must be careful to match its pin 1 with pin 1 on the PCB header connector (the red dot made with fingernail polish). Do not force the connectors or you may damage the PCB.

Connect the two power conductor pigtails from the front panel to KL1 on the PCB, observing

polarity: Red + and Black –. DO NOT over-tighten the connector screws.

The right-angle IEC PAL-M connector plug on Cable 3 plugs into the **upper** connector on the tuner IC1. Dress the slack in this cable along the side of the PCB where the IF components are located.

Check the mating interface between the top and bottom sections of the enclosure and you will notice that the rabbets (grooves) line up properly only one way. Place the top section on the bottom section and fasten the end panels to them using the No. 4 or factory supplied self-threading screws. Install the small stick-on rubber feet supplied with the enclosure on the bottom corners.



After the enclosure has been fully assembled, apply power through the coaxial power connector on the front panel. The LED should glow green when the switch is turned on. Measure the receiver input current; it will be about 10 ~ 20 mA higher than listed in the table in Sect. VII (the added current is from the LED).

Electrical and mechanical assembly is now complete. Go to the next section for final tests and adjustments.

IX. Receiver Test and Alignment

A. General

This section provides procedures to test basic receiver serial interface functionality including microprocessor operation and communication between the microprocessor and the front-end tuner. The CALLISTO Software Setup Guide provides detailed descriptions for setting up the receiver for actual operation.

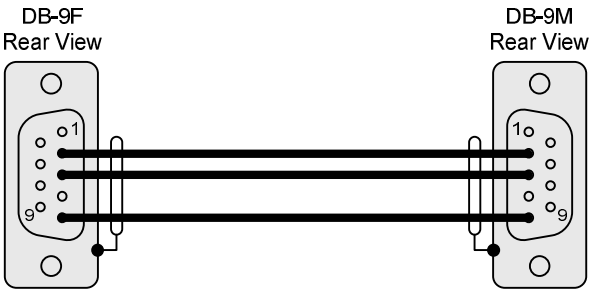
Tools:

- □ Non-metallic coil alignment tool, 2mm (3/32 in) blade

Required parts:

Parts list ID	Qty	Description
☐	1	EIA-232 cable, DB-9M/DB-9F, straight-through, ≤ 3 m long, shielded (optionally available)
☐	1	USB-serial adapter (if required)
☐	1	AC power adapter, 12 Vdc, 500 mA (user supplied or optionally available for North American customers)
☐	1	Antenna (see text)

Connect a serial interface cable between the CALLISTO EIA-232 connector and the serial port on the computer or USB-serial adapter. Note: The cable uses only pins 2, 3 and 5 on the DB-9F and DB-9M connectors. The pins are wired straight-through as shown below. A shielded cable is recommended and it should be no more than 3 m long. If you ordered the optional cable with your receiver you received a quality shielded cable.



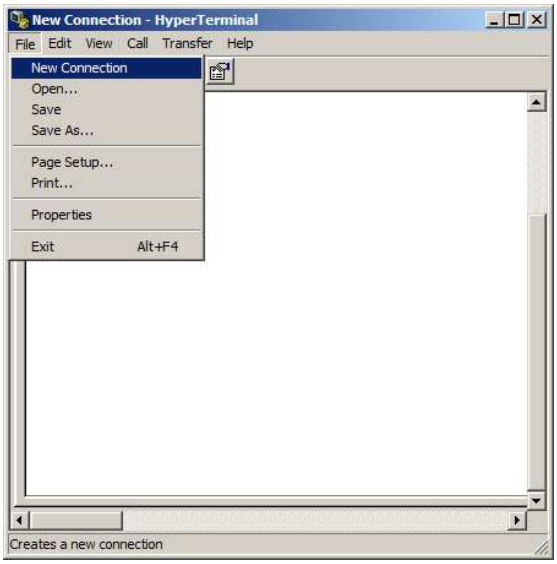
A USB-serial interface adapter (optionally available) is required if your PC does not have a built-in serial port. If you use a USB-serial adapter, be sure that it is installed and working properly and that you are using the latest device drivers. DO NOT proceed until you have verified that you have the latest drivers. This is especially important if you are using Windows 7. Check for the latest drivers now. Note: It has been found that some USB-Serial Adapters built prior to deployment of Windows 7 do not work reliably even though the manufacturer has Windows 7 drivers available. If your serial connection is unreliable, try another, more modern adapter.

For testing purposes, DO NOT connect the USB-serial adapter through a USB hub; connect the adapter directly to the PC. The CALLISTO Receiver has been tested with externally powered USB hubs but a hub should not be used at this time. If you have other USB devices connected to your PC, unplug them (except, of course, your USB mouse and keyboard if you have them) to avoid port conflicts.

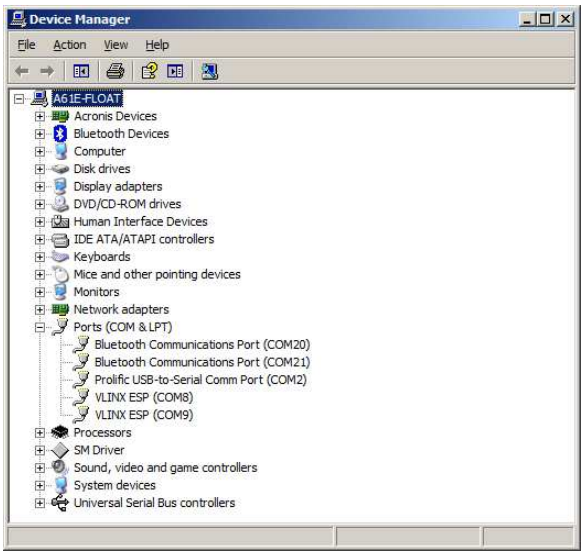
B. Setup HyperTerminal

To test the EIA-232 serial port, it will be necessary to use a terminal emulator program. The following description uses HyperTerminal.

Start the HyperTerminal program (Start – All Programs – Accessories – Communications) and create a new connection. Select File – New Connection and type a name such as CALLISTO or e-CALLISTO and click OK (see screenshots below).

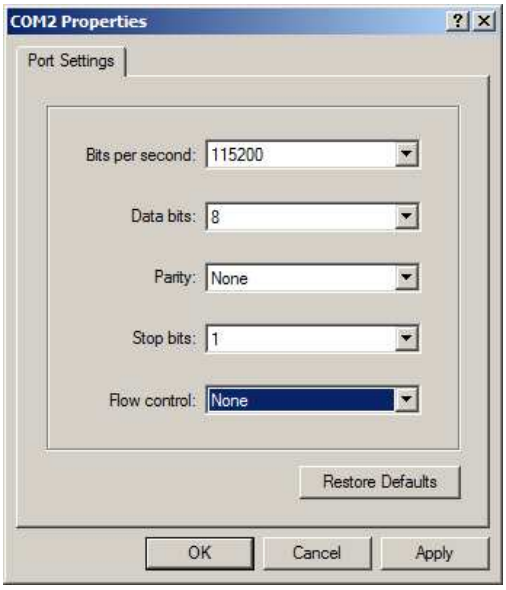


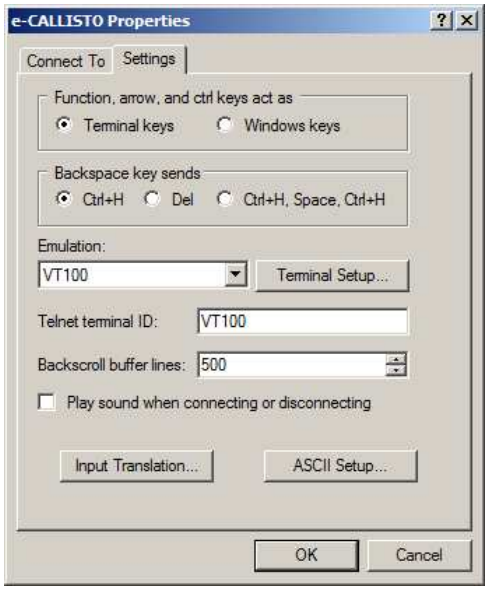
The Connect To window will pop up. Choose the appropriate COM Port from the dropdown list and click OK. If you are using a USB-serial adapter, this is the COM Port used by the adapter. To find the COM Port assigned to the adapter, go to Start – Control Panel – System – Hardware Tab – Device Manager and click the + next to Ports (COM & LPT). If you have multiple COM Ports in use, you can find the one associated with the USB-serial adapter by unplugging and then plugging it back in to the USB port while watching the Device Manager window. For now, unplug all other USB adapters and devices that use COM Ports (except, of course, the keyboard and mouse if they are connected via USB ports).

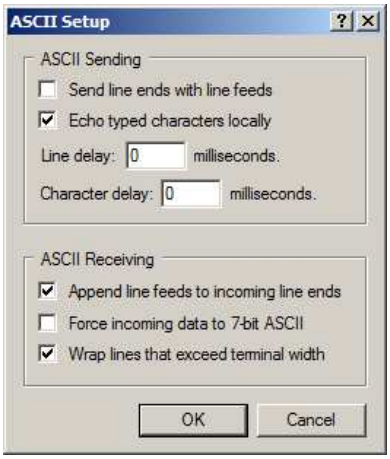


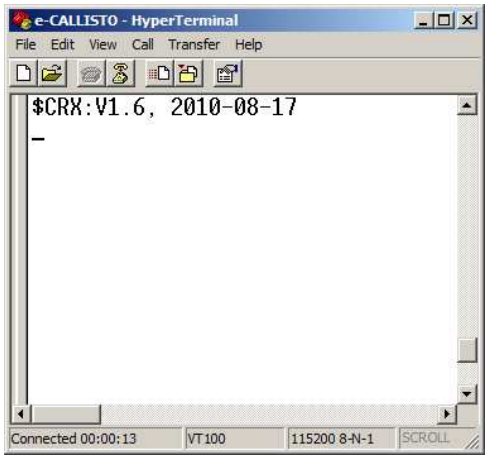
A new COMx Properties window will pop up (below-left). Adjust the COM Port settings in the drop-down boxes as follows: 115200 Bits per second – 8 Data bits – Parity None – Stop bits 1 – Flow control None. Click OK.

In the Connection Properties, select the Settings tab and then ASCII Setup.... The ASCII Setup window will open (below). Place checkmarks in the boxes and select the radio buttons as shown. These settings will ensure that the CALLISTO Receiver will respond to the ENTER key on the main keyboard. Otherwise, the ENTER key on the NUM keypad will have to be used. Click OK until you are back to the main window.









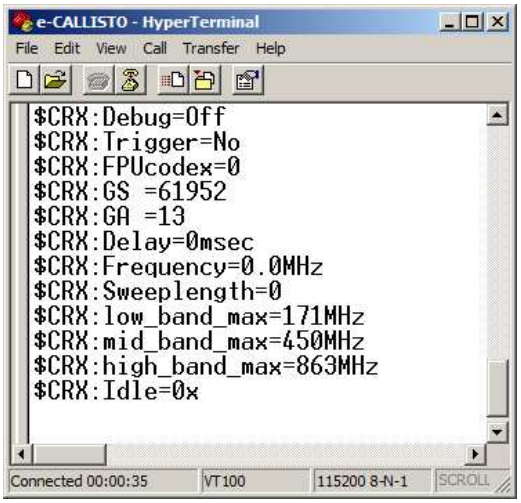
Press the Call icon button on the HyperTerminal menu bar. Now, turn the receiver on or, if it was turned on, cycle the power. If the terminal emulator program (HyperTerminal) is configured properly and the serial port is wired correctly, the HyperTerminal window should show "$CRX:" followed by the firmware version and firmware date as shown. If the initial screen does not appear, leave the serial port connections and HyperTerminal as they are and cycle the power to the CALLISTO receiver. The firmware version in all North American CALLISTO Receivers is v1.7 or later.

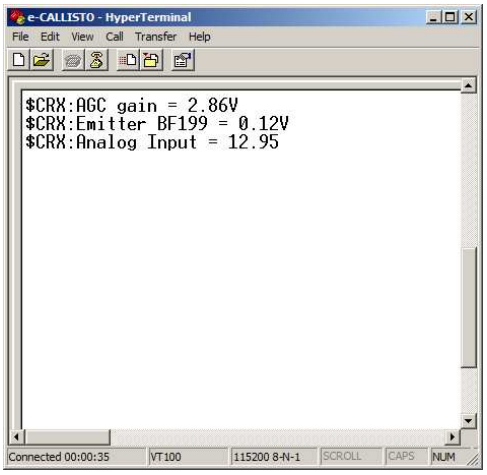
If nothing happens, try unplugging the USB connector of the USB-serial adapter and plugging it back into the PC. There is considerable variability in USB-serial adapters leading to many problems. If you purchased an optional USB-serial adapter with your receiver kit, you received a quality adapter that is known to work with the CALLISTO Receiver.

For additional serial port troubleshooting, use SysInternals PortMon program as described in Appendix B.

C. Test Receiver Basic Functions

Query the Status of the CALLISTO Receiver by typing a question mark "?", as shown below-left and then pressing ENTER. The status of various parameters should appear as shown below-right.





There are many commands (a complete list is provided in an appendix in the CALLISTO Software Setup Guide) but for initial test purposes only a few more commands are used.

One final test will verify that you can read the gain control voltage, 2nd IF amplifier bias voltage and input voltage. Type "U2"+ENTER, "U4"+ ENTER and "U6"+ENTER. When you press ENTER after each command, you should see the respective values on the screen. The actual values may vary from those shown left.

The initial tests are now completed. Disconnect and close HyperTerminal. The next step is to align the 1st and 2nd IF transformers.

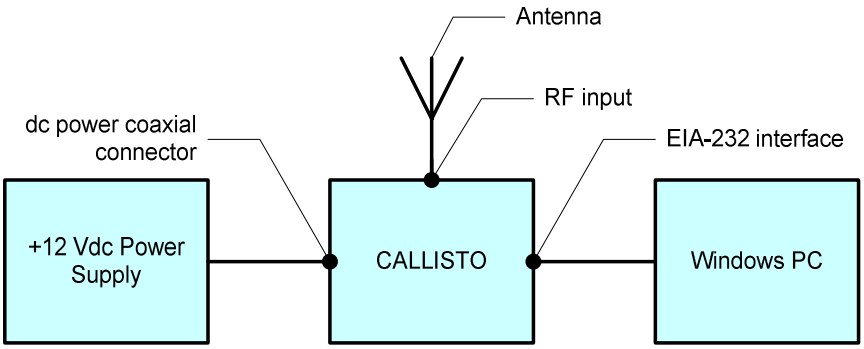
D. IF Transformer Alignment

The CALLISTO Receiver has two variable transformers L1 and L2 and a variable capacitor C1 used in the down-converter section. These are best aligned using a special software tool, *simple.exe*. The program Simple allows setting a test frequency, gain setting, and integration time. In order to use Simple, the CALLISTO Receiver must have passed the previous tests using HyperTerminal.

D.1 Connect CALLISTO Receiver

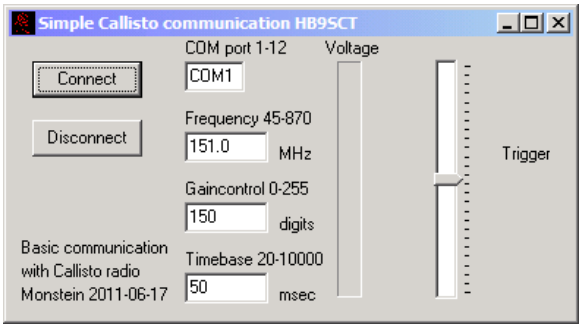
Connect the CALLISTO Receiver serial port to the PC, the RF Input connector to an antenna or a piece of wire (say 0.75 m long) and the power input to a 12 Vdc power source. See block diagram. Turn on the receiver.

Be sure HyperTerminal or another program is not using the specified COM Port before proceeding to the next step.



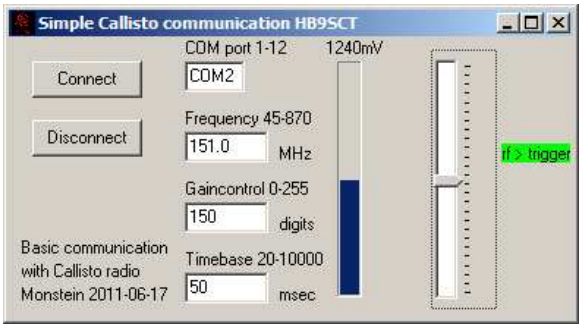
D.2 Simple Tool Setup

Go to the Software folder on the CALLISTO CD and locate and open the file *simple.zip*. Extract the files to a folder on your PC (for example, c:\CALLISTO\Simple). Go to this folder and double-click on *simple.exe* (it must be run from the folder where its support files are located). The window that opens looks something like this:



Set the COM port parameter to the serial port you are using with the receiver. The default values for the other parameters are suitable for alignment but you can change them if desired. The frequency used for IF transformer alignment is not critical. You use the background noise and not a signal for transformer alignment.

Click Connect and you will notice changes to the voltage bar (see below). The voltage bar indicates the receiver output level. You can make minor adjustments to the height of the voltage bar with the *Gaincontrol* parameter – the voltage bar should be about 1/3 ~ 1/2 height. You will adjust the transformers as described below for maximum indication on the voltage bar, so you may have to increase or decrease the *Gaincontrol* setting to achieve the best results.



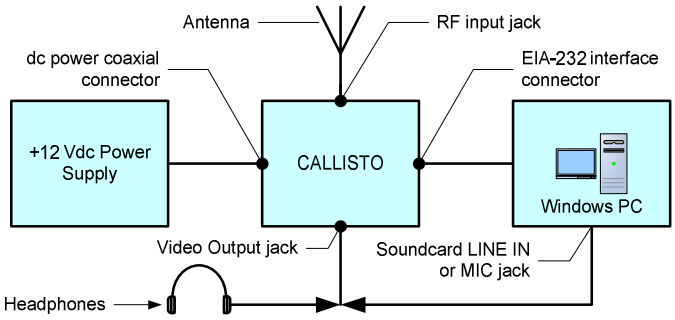
If Simple opens but you cannot connect to the receiver (connection is indicated by an active voltage bar), close it by clicking the ☒ in upper-right corner or, if necessary, right-clicking simple.exe in Windows Task Manager and selecting End Process. Now, go to the folder that holds simple.exe and right-click on the file. Select the Compatibility tab and check *Run this program in compatibility mode for:* From the dropdown, select Windows 95. Click OK and restart simple.exe, set the Com port and click Connect.

Another feature of the Simple tool is the trigger pointer on the right. Left-click on the pointer and drag it up or down. As you slide the pointer up and down you will notice that the text changes to red or green. This helps you determine if the output voltage has increased or decreased. Initially, you will set the slider so that the text just turns red (RF < Trigger). Then, as you adjust the transformers and the output rises, the text will turn green (RF > Trigger).

D.3 Adjust 1st and 2nd IF

Using a small non-metallic screwdriver (a metallic screwdriver will easily damage the transformer core caps and also interact with the settings), adjust the cores in both IF transformers L1 and L2 and the variable capacitor C1 for maximum output by observing the voltage bar in the Simple window. Be careful to not adjust C1 to an extreme position where there is a transition. A transition occurs every 180 deg. at maximum and minimum capacitance. The drawing right shows the capacitor at maximum value (small square imprints on adjustment screw lined up with triangle); minimum value is in the opposite direction. Try to find a compromise between C1 setting and IF transformer L2 setting. Slightly adjust C1 and then L2 for maximum. Slightly adjust C1 again and then L2 for maximum. Find a setting that results in the highest maximum.

If a compromise setting cannot be found, it is possible that a different value is needed for C1 or C39. Stock values for North American receivers s/n NA0008 and earlier are: C1 = 6~50 pF (orange) and for C39 = 150 pF and for North American receivers s/n NA0009 and later are: C1 = 9~150 pF (black) and C1 = not used. After alignment, the yellow plastic cap on L2 core may protrude 1-2 mm above the metal can.



L2 is a non-resonant transformer and its setting generally has only a minor effect on receiver output. DO NOT force L1 or L2 adjustable cores to the bottom of their range.

When finished click the Disconnect button. You can leave Simple open for the next test. Leave the electromechanical setup as-is and go to the next step.

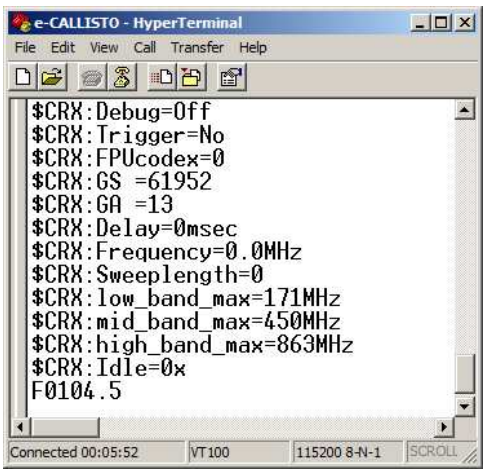
E. Quick Video Output Test

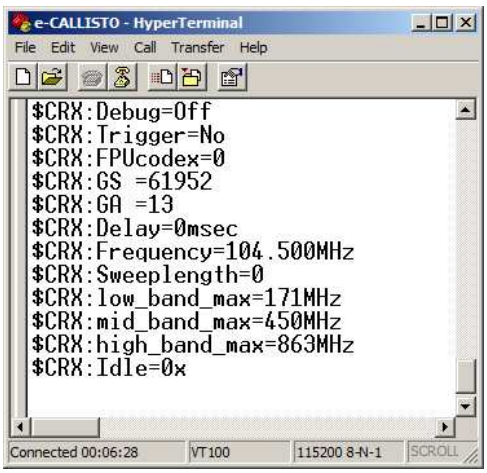
E.1 Setup

Refer to illustration left. Connect mono or stereo headphones to the Video output jack on CALLISTO. Alternately, connect the Video output jack to the LINE IN jack or MIC jack of a PC soundcard. If you use a soundcard, be sure the appropriate input (LINE IN or MIC) is selected for Playback and the Speaker is not muted. In the example screenshot below, the soundcard is set to play from the LINE IN jack. Amplified speakers are required. Connect a wire antenna approximately 0.75 m long or an FM antenna to the RF Input jack on the receiver.

E.2 Set Frequency of Nearby FM Broadcast Radio Station

Using Simple, set the frequency to the frequency of a nearby VHF-FM radio station. Alternately, you can use HyperTerminal as follows: Ensure that no programs are using the receiver COM Port. Run HyperTerminal and open the connection you previously saved. Enter the frequency of a nearby VHF-FM radio station using the “F0x” command, where x is the desired frequency in MHz. For example, say the desired station frequency is 104.5 MHz. Type “F0104.5” as shown at the bottom of the screen below-left and ENTER. This commands the receiver to tune to 104.5 MHz. You can confirm the setting by typing “?” followed by ENTER. You should see the Frequency parameter set to 104.5MHz as shown in the screen below-right.

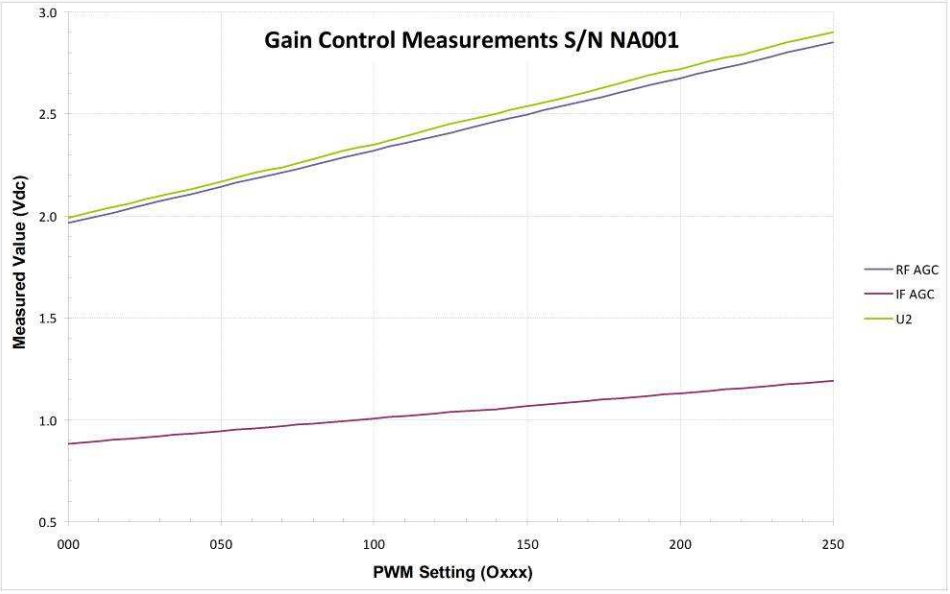




Using HyperTerminal, you can adjust the frequency in small steps by typing “+” or “–” followed by ENTER. You may have to adjust the receiver gain. The “Oxxx” command is used to adjust the gain. The value of xxx ranges from 000 (zero gain) to 255 (maximum gain). Normal operating range is around 100 to 120. You can confirm the gain setting by using the “U2” command (both Oxxx and U2 must be followed by ENTER). The voltage read by the command U2 is proportional to the gain setting value (see chart below).

After the receiver frequency is set to the FM station, you should hear the radio signal (it may be distorted). If the test is successful, your CALLISTO Receiver is ready to use. Disconnect the audio cable.

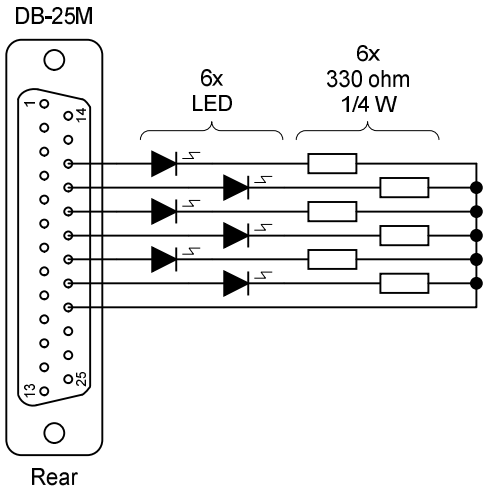
When finished with this test, be sure to remove the audio cable plug from the Video jack on the receiver. The cable capacitance affects the receiver integration time (the log detector output is not buffered).



Go to the CALLISTO Software Setup Guide.

F. FPU Connector Tests

The FPU connector (FC) wiring can be verified with the FC Test software tool. This tool sends FC codes to the receiver, which asserts the corresponding logic level on pins 16 through 21 of the connector. A logic high, corresponding to binary 1, is +5 V and a logic low, corresponding to binary 0, is 0 V. The logic levels may be measured on the respective pins of the FC with a digital multimeter. Alternately, a simple tester may be made from a DB-25M connector, six LEDs and six 330 ohm, 1/4 W resistors as shown right.



See Appendix E for FC pin assignments and Appendix F for the FPU connector logic table. The six control pins in FC represents six bits with allowable decimal values 00 to 63.

G. Optional Performance Tests

See Appendix D

H. Trouble Shooting

If problems occur during testing, double-check the following:

- □ Current drawn by the CALLISTO Receiver
- □ Resistors are correct values and in their correct locations
- □ Diode correctly oriented and in its correct location
- □ Capacitors in their correct locations and electrolytic and tantalum capacitors oriented correctly
- □ IC sockets soldered properly and oriented correctly
- □ ICs oriented correctly in the sockets and no bent pins

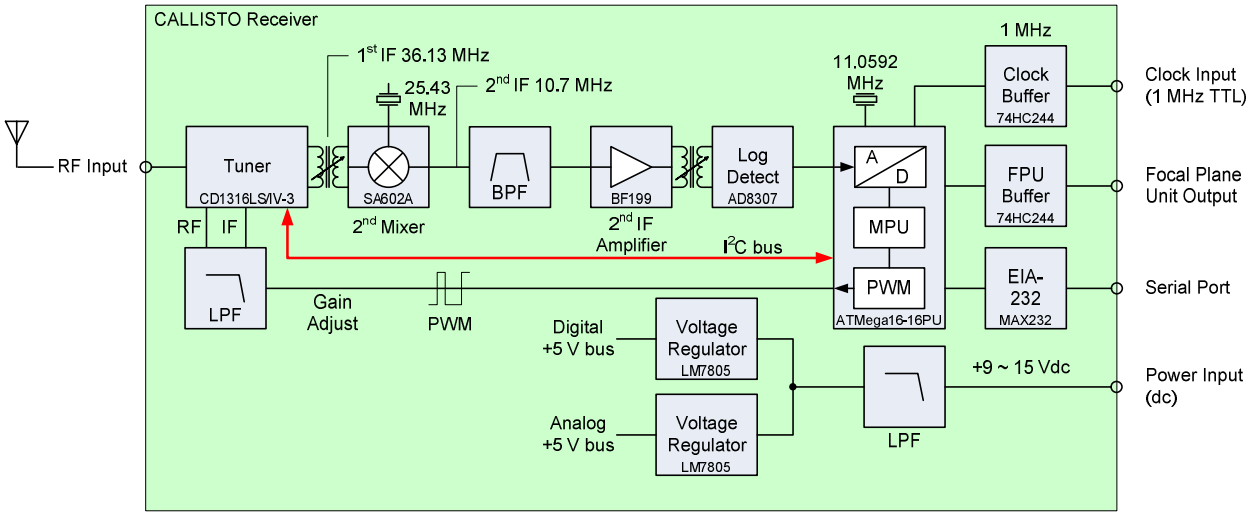
- □ No cold solder joints
- □ All pins soldered
- □ No solder bridges or shorts
- □ Power supply input voltage
- □ Voltage at the U2 and U6 voltage regulator outputs

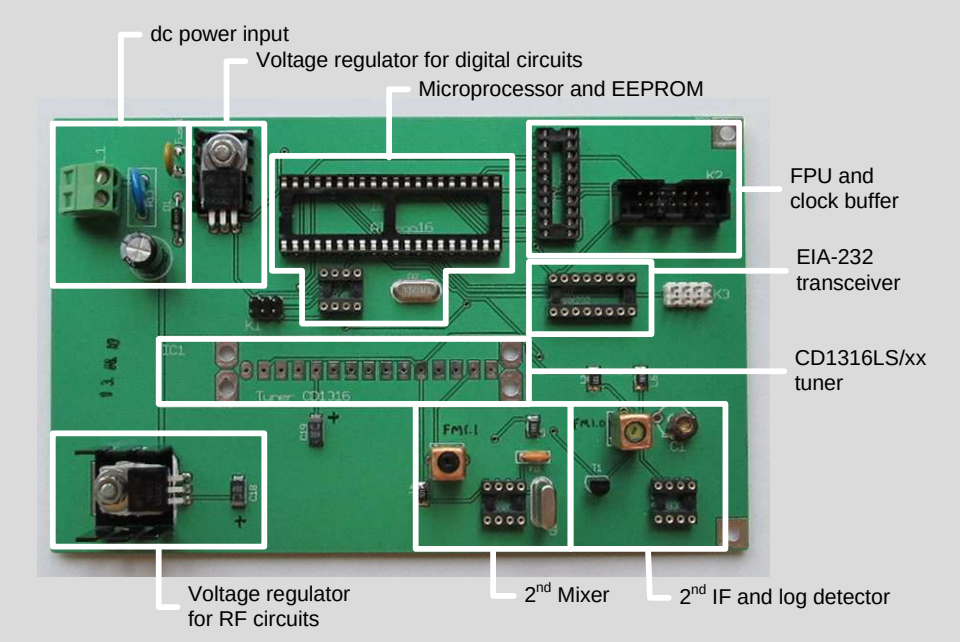
If no problems are found but the CALLISTO Receiver still does not test okay, contact us by email (CallistoInfo@reeve.com).

X. Circuit Description:

For the following descriptions, refer to the block diagram and the schematic diagrams in this section. Enlarged printed circuit board layouts are provided at the end of this section.

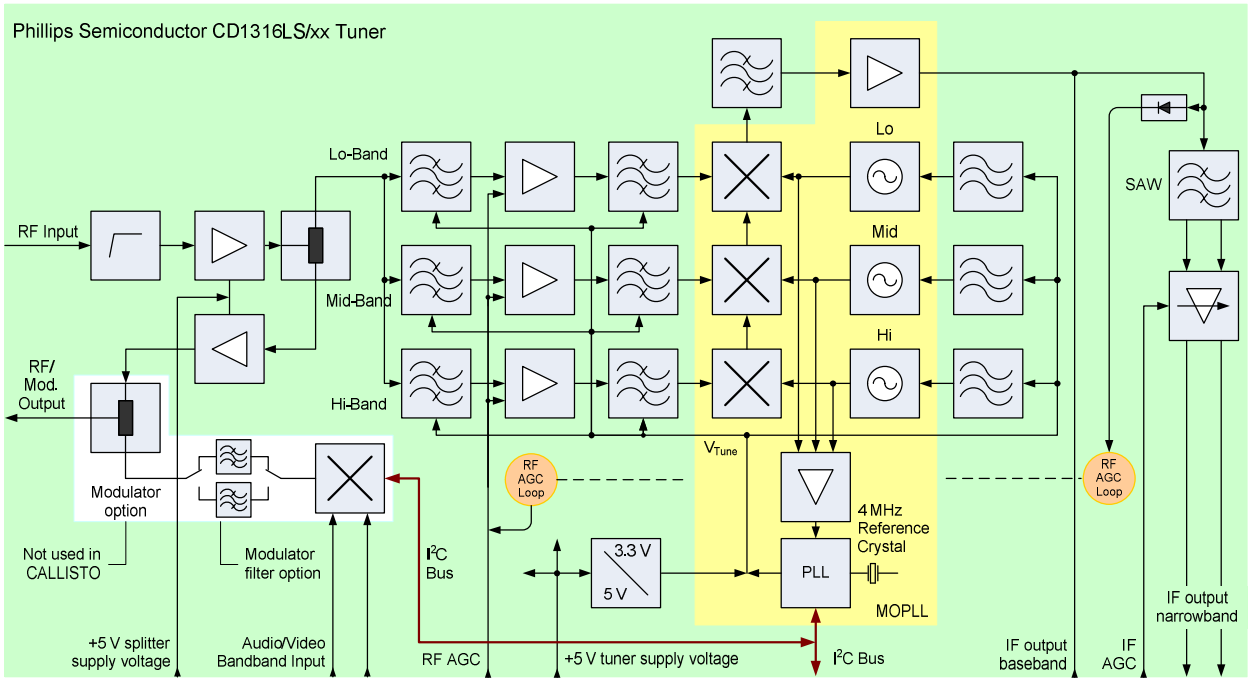
A. CALLISTO Receiver Block Diagram



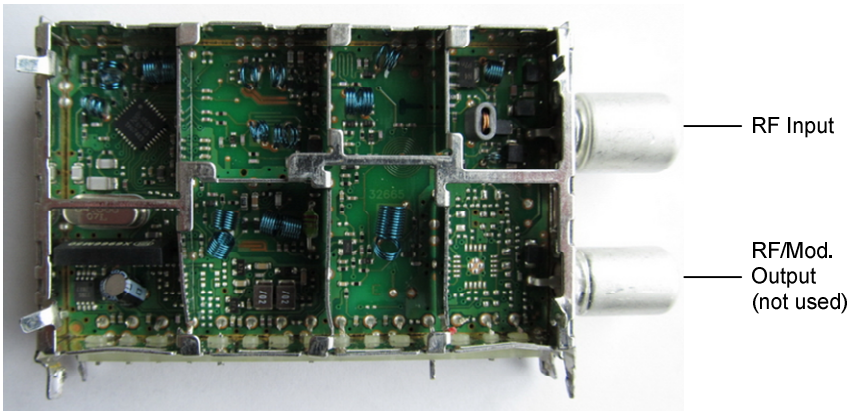


B. Receiver Front End

The receiver front-end is a Philips Semiconductor CD1316L-series television tuner. The European version is used, which has a 36.13 MHz IF output. This is called the 1st IF in the CALLISTO Receiver. Tuner operation is controlled by the microprocessor through the inter-integrated circuit bus, or I2C bus. The frequency can be changed in 62.5 kHz steps with a step interval of 1.25 ms.

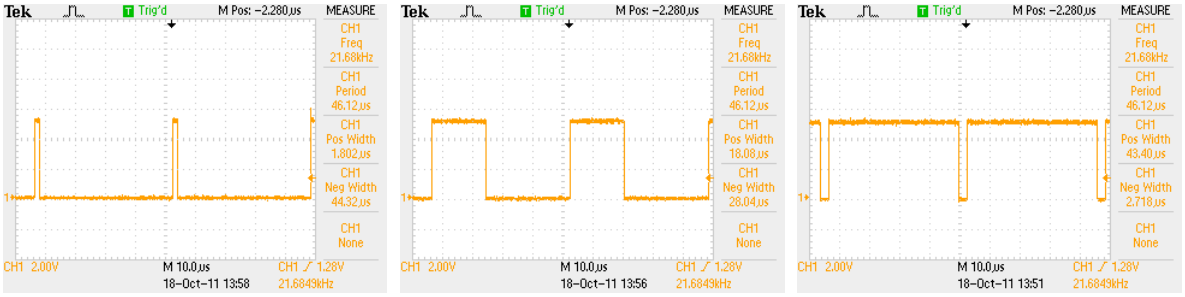


The tuner is compartmentalized and has three superheterodyne RF amplifier/mixer/oscillator sections, one each for low-band, mid-band and high-band operation. The CALLISTO Receiver uses the following band configurations: Low-band – 45 ~ 175 MHz; Mid-band – 175 ~ 450 MHz; and High-band – 450 ~ 870 MHz. The nominal RF voltage gain of the tuner is 47 dB. The balanced narrowband IF output (7 MHz bandwidth as determined by the internal SAW filter) and the RF and IF gain control functions are used in the CALLISTO Receiver. A photograph of the tuner is shown below. This one was sacrificed when it was found to be incompatible with Callisto software.

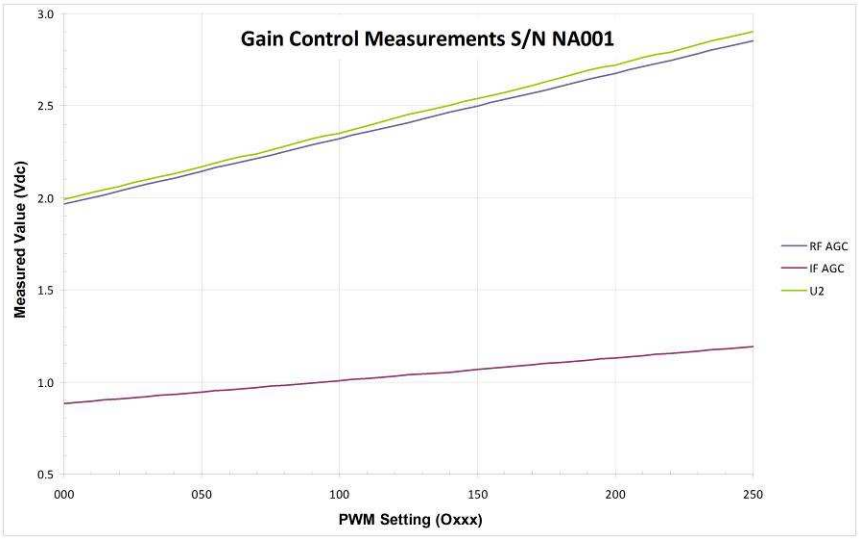


The front-end tuner gain is controlled by biasing the RF AGC and IF AGC inputs of the tuner. Voltage bias, and thus gain, is controlled by the microprocessor IC5, which, in turn, is set by software. Once set in software, the gain is fixed and not automatically adjusted in response to signal level (in other words, in the CALLISTO Receiver application, it is not an *automatic gain control* as implied by the nomenclature AGC).

The microprocessor output (pin 21) is a pulse width modulated (PWM) waveform that is filtered by R21 and C19 to produce the dc bias for the RF AGC input. This dc bias is reduced by voltage divider R23 and R24 for the IF AGC input. In software, the PWM setting is a decimal value ranging from 0 (zero gain) to 255 (maximum gain). These correspond to an RF AGC voltage range of approximately 1.965 to 2.853 Vdc and an IF AGC voltage range of 0.884 to 1.193 Vdc. The gain control pulse period is a nominal 46 µs, corresponding to a frequency of about 21.7 kHz. The duty cycle at a PWM setting of 10 is about 4% and at 240 is about 94% (see oscilloscope screenshots below for settings of 10, 100 and 240, respectively).



The voltages applied to the tuner RF AGC and IF AGC pins are proportional to the PWM setting in software. The chart below shows the relationship.



A.2 2nd Mixer and IF

The 2nd mixer and 2nd IF amplifier are part of the down-converter stage comprised of, in order of signal flow, transformer L1, mixer/oscillator/amplifier IC3, crystal Q1, bandpass filter FL1, bipolar transistor T1 and transformer L2 plus bias and other power filter components. IC3 is the Philips Semiconductor SA602A mixer-amplifier integrated circuit. Note: A Philips Semiconductor SA602A is supplied with the kit but the SA612, SE612 and NE602 are identical and may be used in the receiver.

The 36.13 MHz balanced IF output from the tuner IC1 is coupled to mixer IC3 through the primary winding of impedance matching transformer L1. It has a primary: secondary turns ratio of 1:1.5, providing an impedance ratio of 1:2.25. The output from the 25.43 MHz crystal-controlled oscillator (Q1) is mixed with the 1st IF to produce the 10.7 ±3.5 MHz 2nd IF, among other frequencies. The SA602A output is filtered by ceramic bandpass filter FL1 to eliminate all mixing products except the desired intermediate frequency.

The receiver bandwidth is determined by ceramic filter FL1. FL1 has a center frequency of 10.7 MHz ± 30 kHz, nominal 3 dB bandwidth of 280 ± 50 kHz and 20 dB bandwidth of 650 kHz. Early versions of the receiver used a 27 MHz oscillator in the 2nd mixer, resulting in a 2nd IF frequency of 9.13 ± 3.5 MHz, which easily included the filter center frequency of 10.7 MHz.

The output of FL1 is terminated by 330 ohm resistor R9 and coupled to the 2nd IF amplifier by C6. The amplifier consists of a bipolar junction transistor T1 in a common emitter amplifier configuration. The amplifier output is terminated in impedance matching transformer L2. L2 has a primary: secondary turns ratio of 7:1, providing an impedance ratio of 49:1. The transistor bias components consist of R6, R7 and R8. The amplifier has a power gain of about 20 and its output is coupled through L2 to the log detector.

C. Logarithmic Detector

The secondary (load side) of L2 is terminated by 51 ohm resistor SMD-R1 and ac coupled through C14 to the log detector IC4. IC4, an Analog Devices AD8307, provides a voltage output that is proportional to its power input, having a nominal gradient or slope of 25.4 mV/dB. The analog output of the log detector is connected to a 10-bit analog-digital converter (ADC) in the microprocessor IC5, where it is converted to a digital stream and uploaded through the EIA-232 transceiver IC7 to the logging software on a PC. The log detector output also is connected to a phone jack on the rear panel. Note: Early versions of the CALLISTO Receiver have an 8-bit ADC but all North American versions have 10-bits.

D. Power Supplies

The nominal 12 Vdc input to the receiver is connected through terminal block KL1. An on-board fuse Fuse1 and polarity guard diode D1 protect the receiver from overcurrent and wrong polarity. Two 7805 voltage regulators (TO-220 versions) IC2 and IC6 provide regulated +5 V ±5% for the analog RF circuits and digital logic circuits, respectively. The voltage regulators are lightly loaded but are equipped with heatsinks to draw heat away from the PCB. Filter inductors and capacitors and numerous decoupling capacitors are equipped to limit self-induced on-board radio frequency interference.

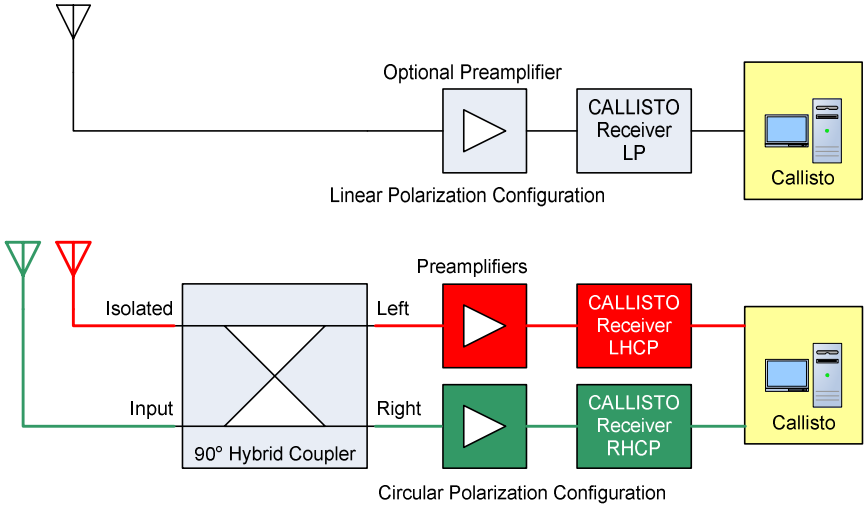
E. Ancillary Functions

The microprocessor IC5 can control a focal plane unit (FPU) through buffer IC8 and the FPU connector on the rear panel. Functions commanded through software control include testing, antenna polarization switching and noise calibrator switching. Up to 64 logic functions may be controlled through six lines.

The control consists of a Vcc line and FPx line (see Appendix E for FPx and Vcc pin assignments and Appendix F for an FPU logic table). Typically, the Vcc line on the FPU connector supplies +5 Vdc to a TTL level interface in a focal plane unit. The FPx line is pulled high (+5 V) when asserted to logic 1 and set low (0 V) when de-asserted to logic zero in software. When the receiver is powered up, all six lines are asserted logic high. The maximum drive current at each FPx line is 35 mA.

The buffer IC8 also is used to couple an external 1 MHz TTL level clock from the BNC-F connector on the rear panel to the microprocessor for precision time stamping of the data (Note: The external clock does not control the microprocessor clocking, it only controls data time stamping).

These ancillary functions are equipped and functional in the North American version of the CALLISTO Receiver but the documentation presently does not provide specific details except as described in the next three sections, Appendix E and Appendix F. The ancillary functions are not required in the basic solar radio spectrometer system.



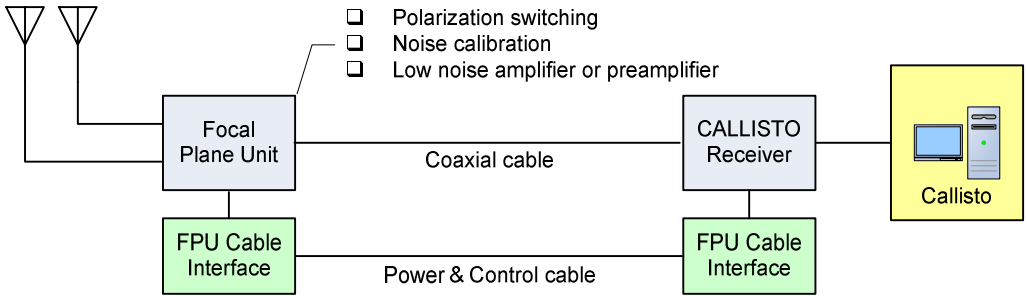
F. Configurations

The diagrams left show the basic (or standard) CALLISTO Receiver configuration for linear polarization and a more advanced configuration using two receivers for circular polarization. The circular polarization setup requires a 90 deg. hybrid coupler, two antennas and two receivers. Two preamplifiers are optionally needed in systems that require additional gain. The hybrid coupler and preamplifiers typically would be installed at or near the antennas with preamplifier power fed through a bias-tee coupler or direct cable.

G. Focal Plane Unit

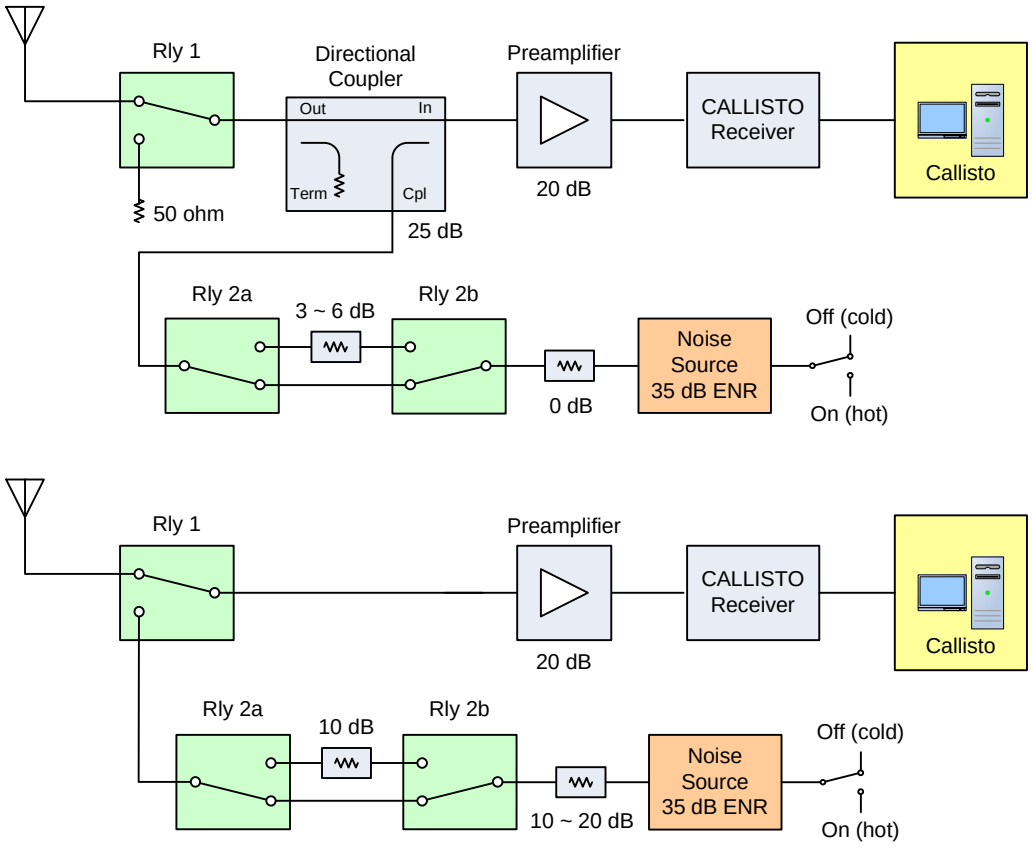
The Focal Plane Unit (FPU) derives its name from the instrumentation normally located at the focal point (feed point) of a large parabolic dish antenna. In e-CALLISTO applications, it is not necessary to use a dish antenna. Other antenna types may be used, such as wideband log periodic antennas or even narrowband antennas.

When the FPU includes noise calibration functions, it normally would be located as close as possible to the antenna to improve calibration accuracy. The basic configuration is shown below. Since the receiver provides a TTL level interface for FPU control, it may be necessary to use an FPU Cable Interface at each end to provide conversion of the TTL levels to levels compatible with the cable media used to carry the control signals to the FPU. Design of the FPU Cable Interface is beyond the scope of this manual. Additional details for control of the FPU are provided in the e-CALLISTO Software Setup Guide.



G.1. Noise Calibration Unit

Referring to the drawing below, the upper configuration uses a directional coupler to couple the noise source and the lower configuration eliminates the directional coupler and is simpler.



H. Signal Chain

The tables below show an estimate of the CALLISTO Receiver performance at 50 and 860 MHz for 7 m and 20 m antenna diameters.

Performance estimate for 50 MHz

Source:	Unit	Quiet Sun 7m	Quiet Sun 20m	Cold load	Hot load
Solar flux	SFU	1.0×10^{-21}	1.0×10^{-21}		
Antenna temperature	K	2354	12343	1260	1997925
RF input power (W)	W	9.10×10^{-15}	4.77×10^{-14}	4.87×10^{-15}	7.72×10^{-12}
RF input power (dBm)	dBm	–110.4	–103.2	–113.1	–81.1
Attenuation (calibration)	dB	–0.5	–0.5	–0.5	–-0.5
Preamplifier gain	dB	28.0	28.0	28.0	28.0
50 m RG-213 at 50 MHz	dB	–2.2	–2.2	–2.2	–2.2
Philips tuner gain (min)	dB	41.0	41.0	41.0	41.0
2nd IF gain (nominal)	dB	20.0	20.0	20.0	20.0
Total gain	dB	86.3	86.3	86.3	86.3
2nd IF power output	dBm	–24.1	–16.9	–26.8	5.2
Log detector offset	dB	–70.0	–70.0	–70.0	–70.0
Log. detector output power	dBm	45.9	53.1	43.2	75.2
Log detector slope	V/dB	0.0254	0.0254	0.0254	0.0254
Log detector output voltage	V	1.67	1.85	1.60	2.41
ADC output (10 bit)	**Digit**	**682**	**757**	**654**	**987**

Table Note: Data provided by Christian Monstein

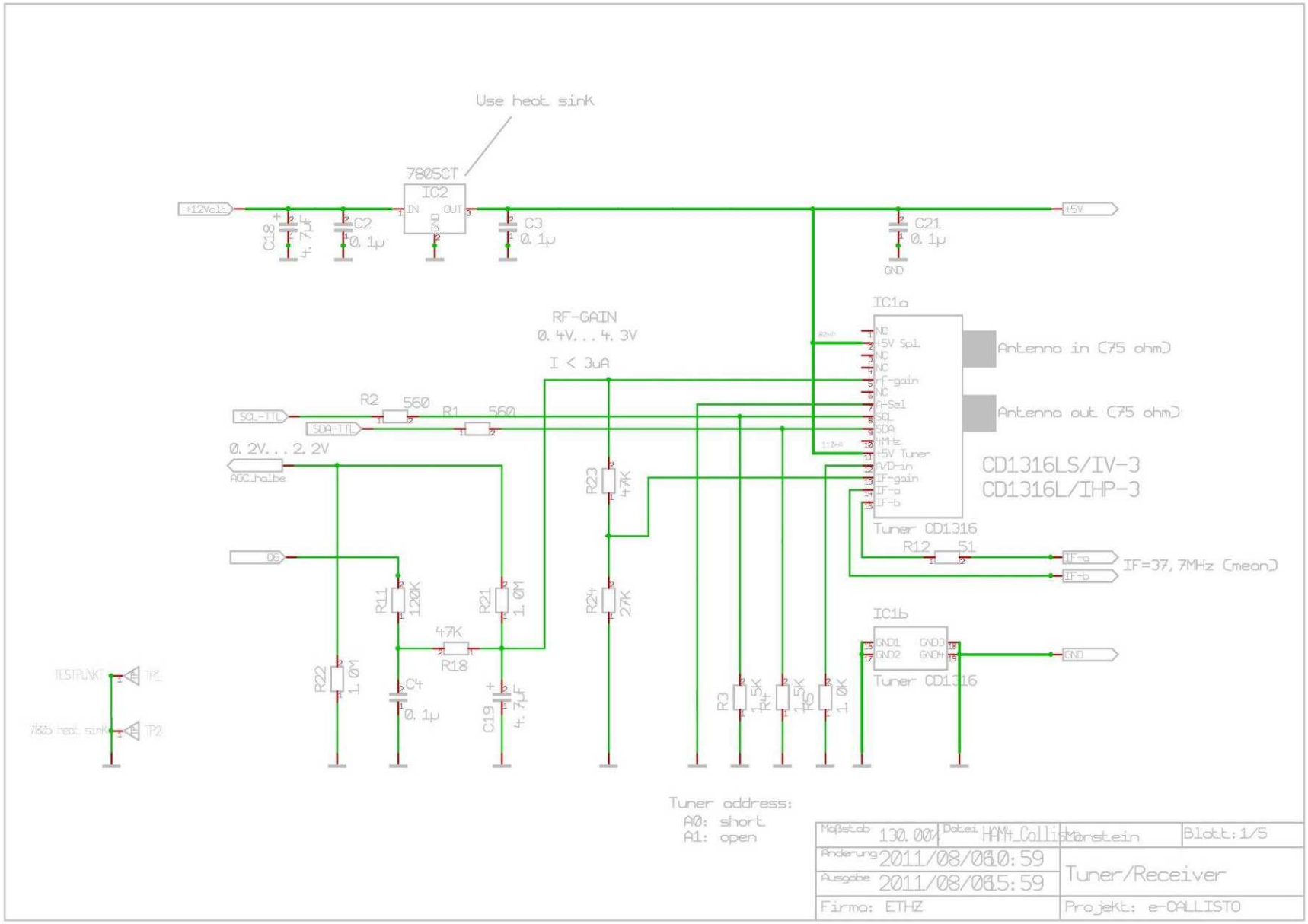
Performance estimate for 860 MHz

Source:	Unit	Quiet Sun 7m	Quiet Sun 20m	Cold load	Hot load
Solar flux	SFU	8.2×10^{-20}	8.2×10^{-20}		
Antenna temperature	K	115298	934332	1253	1986831
RF input power (W)	W	4.46×10^{-13}	3.61×10^{-12}	4.84×10^{-15}	7.68×10^{-12}
RF input power (dBm)	dBm	–93.5	–84.4	–113.2	–81.1
attenuation (calibration)	dB	–0.5	–0.5	–0.5	–0.5
Preamplifier gain	dB	28.0	28.0	28.0	28.0
50 m RG-213 at 860MHz	dB	–9.0	–9.0	–9.0	–9.0
Philips tuner gain (min)	dB	41.0	41.0	41.0	41.0
2nd IF gain (nominal)	dB	20.0	20.0	20.0	20.0
Total gain	dB	79.5	79.5	79.5	79.5
2nd IF power output	dBm	–14.0	–4.9	–33.7	–1.6
Log detector offset	dBm	–70.0	–70.0	–70.0	–70.0
Log. detector output power	dBm	56.0	65.1	36.3	68.4
Log detector slope	V/dB	0.0254	0.0254	0.0254	0.0254
Log detector output voltage	V	1.92	2.15	1.42	2.24
ADC output (10 bit)	**digit**	**787**	**882**	**583**	**916**

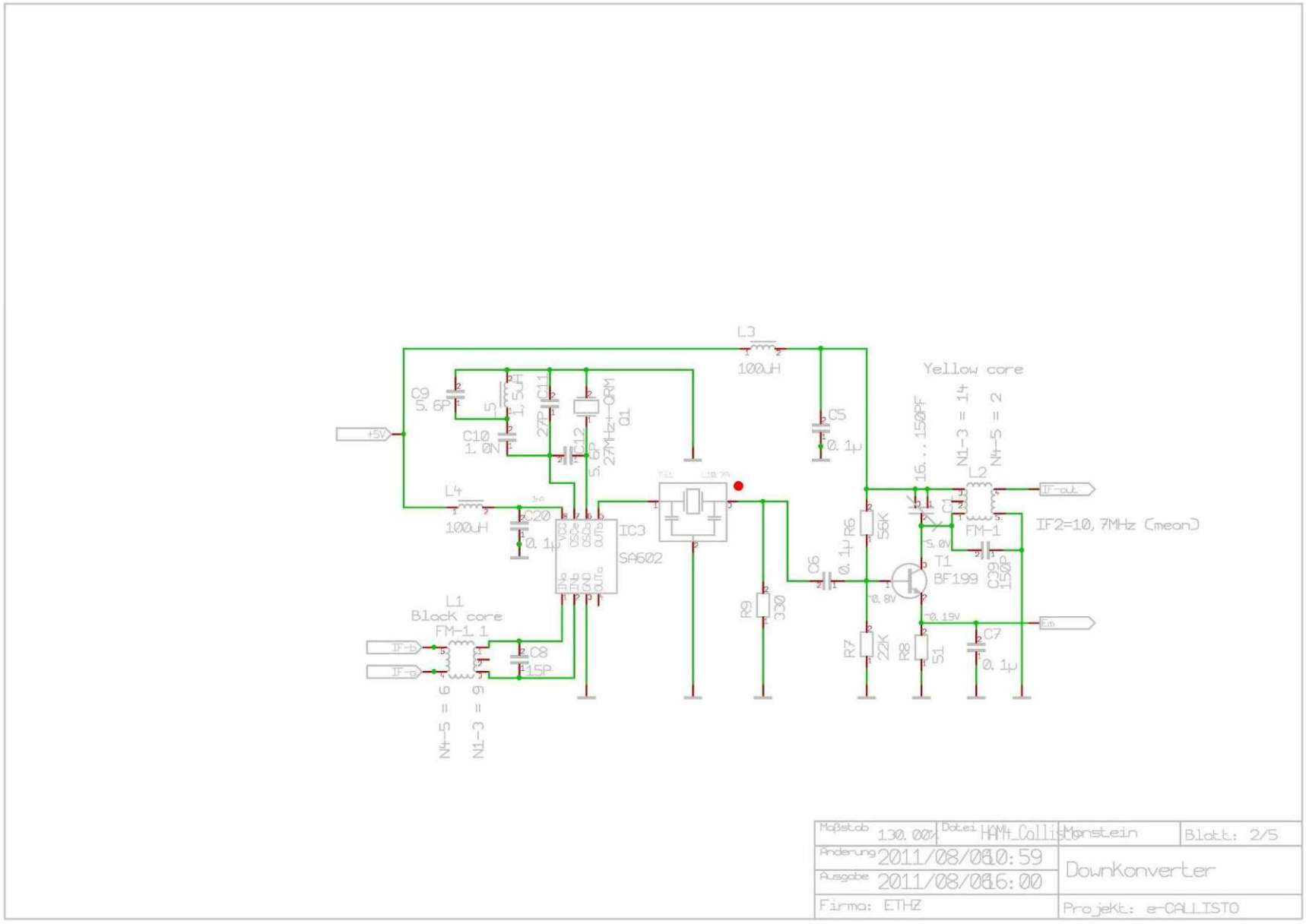
Table Note: Data provided by Christian Monstein

Additional details:
Antenna temperature: Solar flux x Antenna area /(2 x Boltzmann constant) + T_{system} K
RF input power: Boltzmann constant x Antenna temperature x Bandwidth W
Antenna area: (π x Diameter^2)/4
T_{system}: 960 K (estimated)

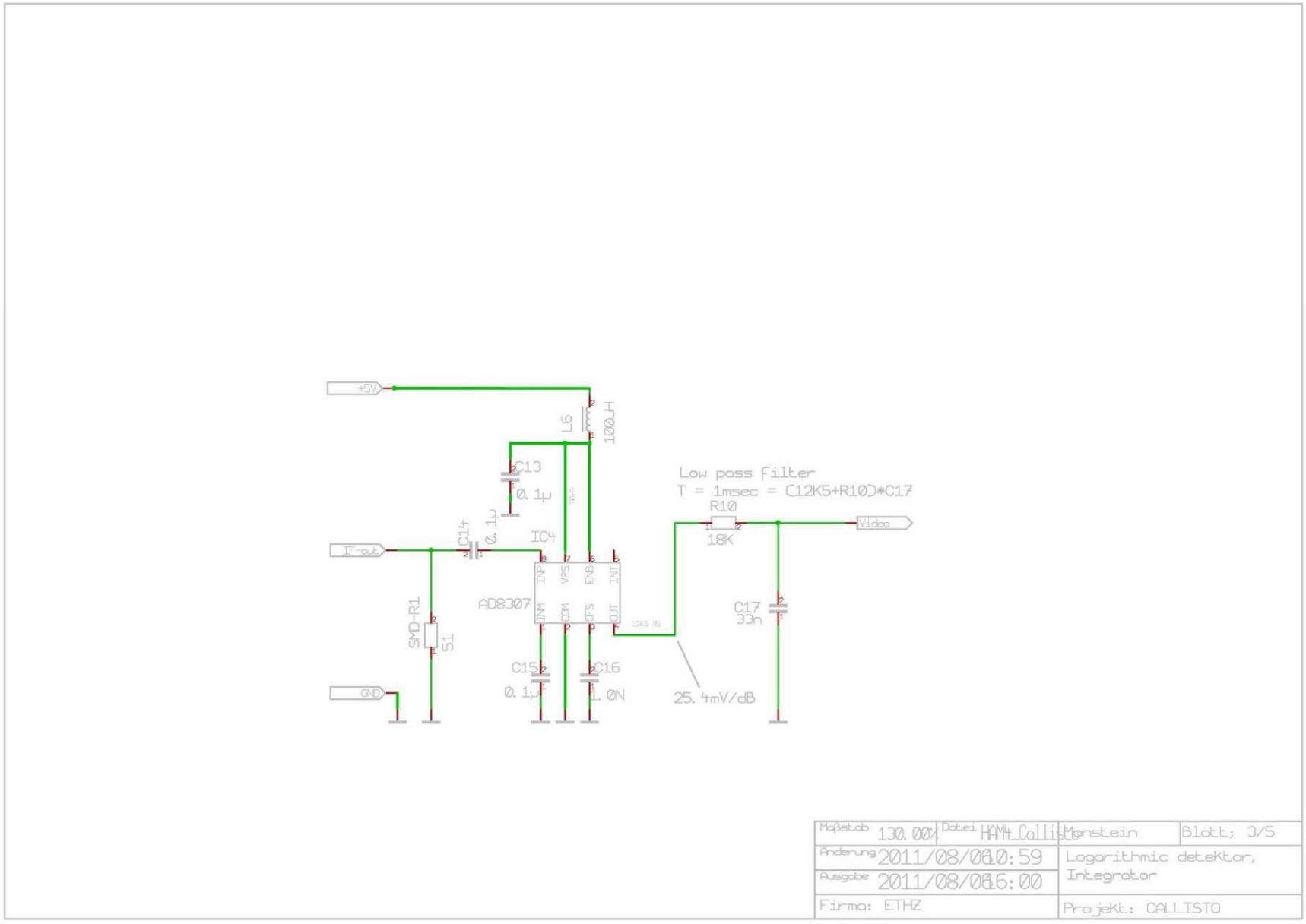
Tuner-Receiver Schematic Diagram



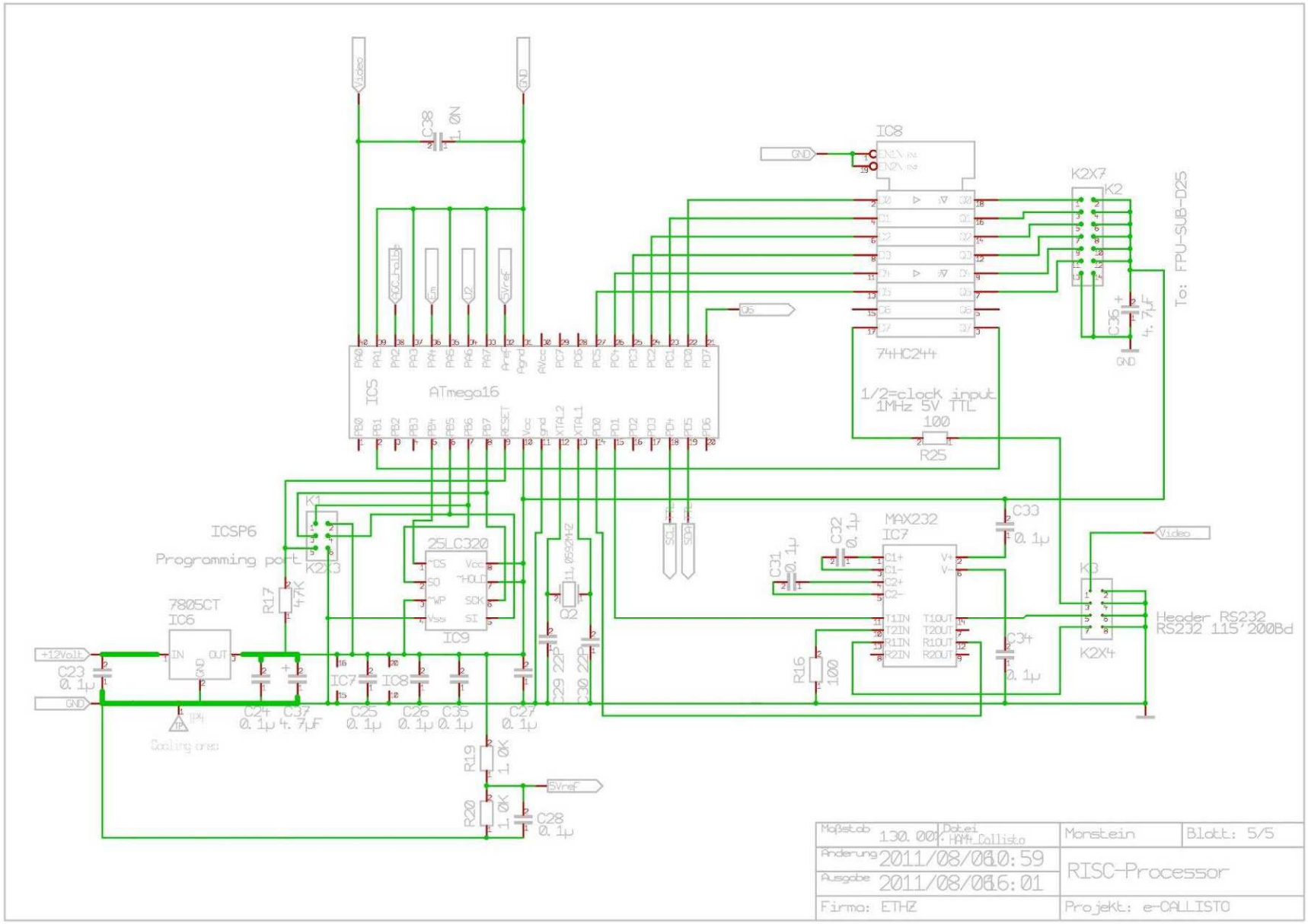
Down-Converter Schematic Diagram



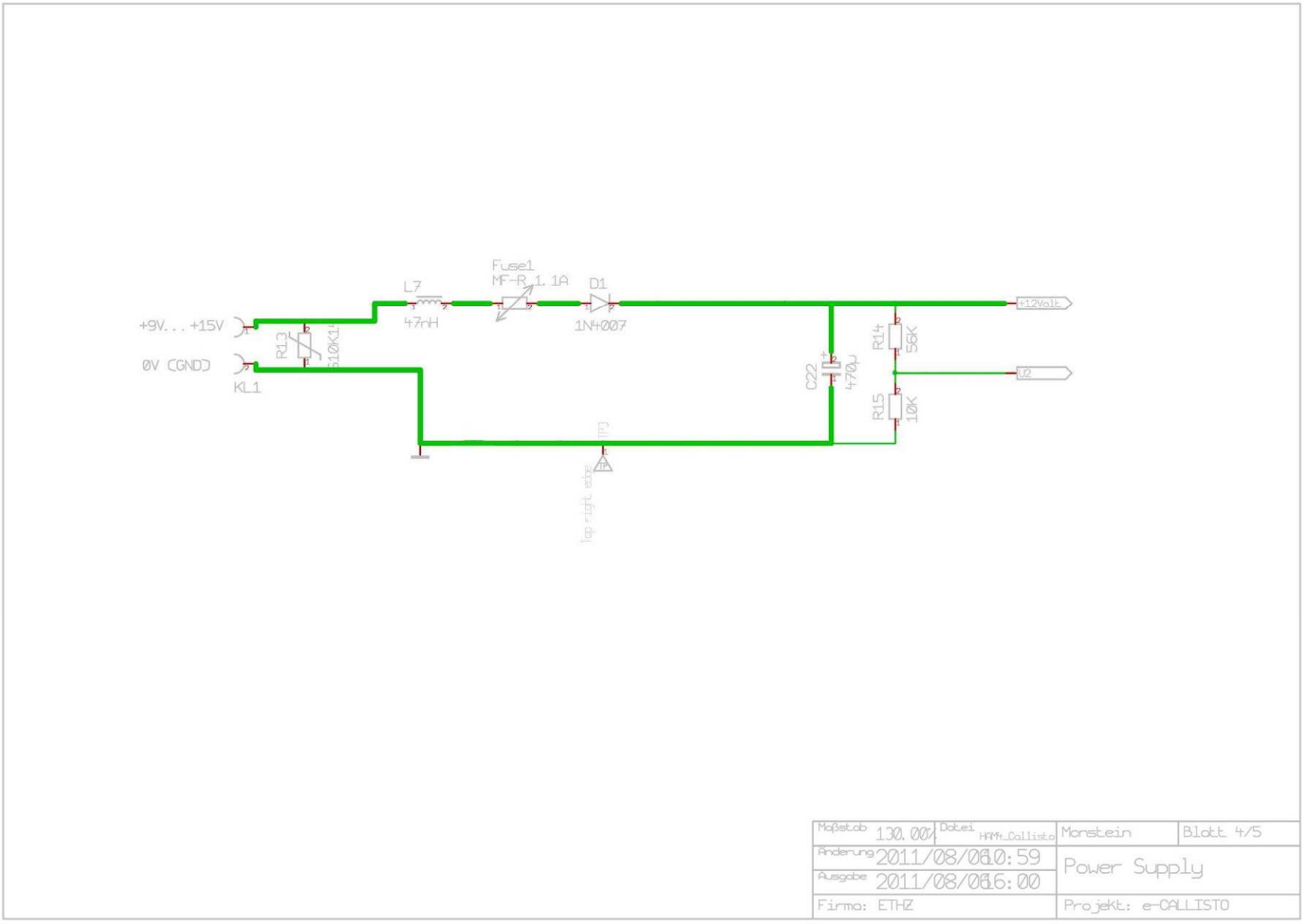
Logarithmic Detector Schematic Diagram



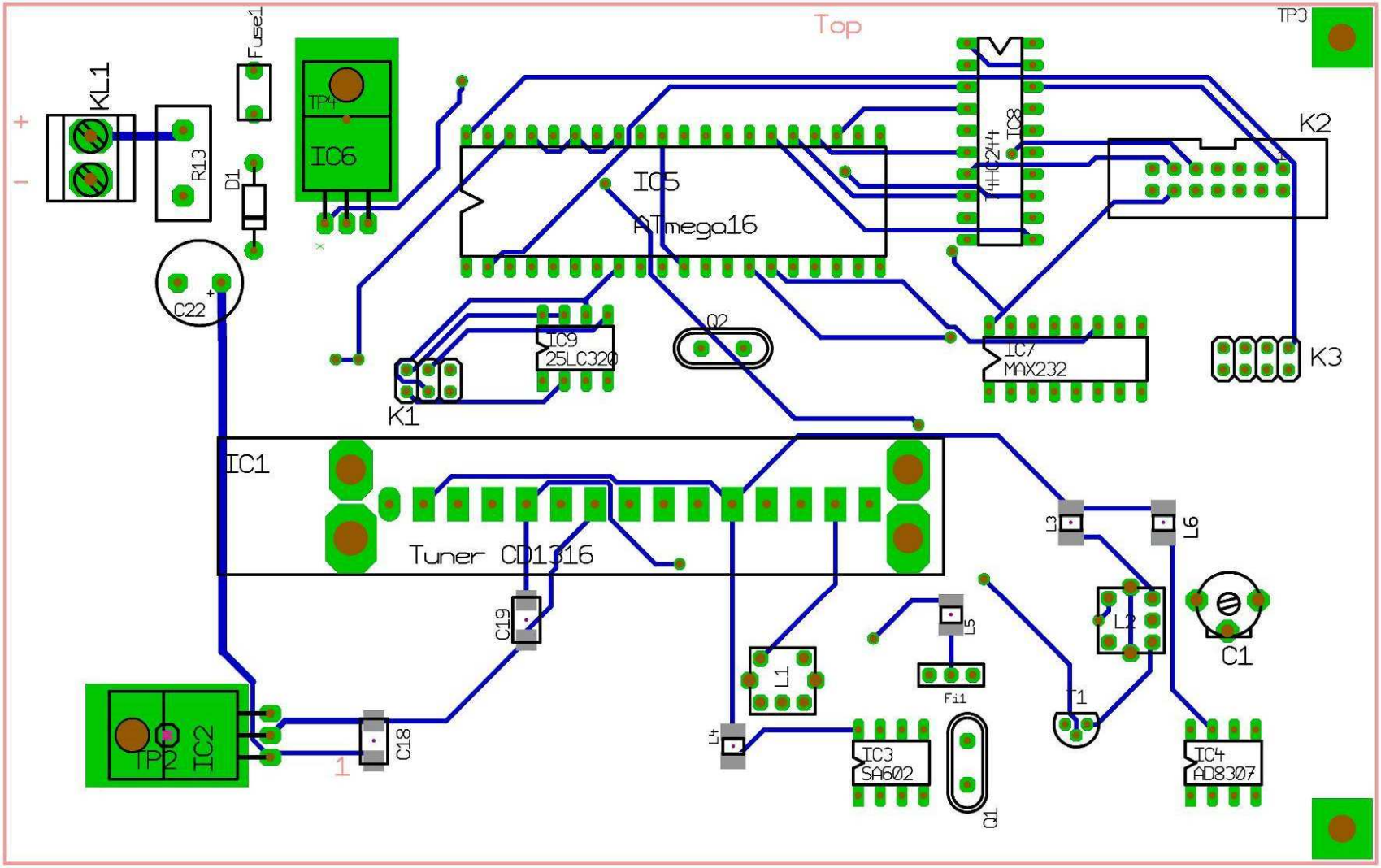
Processor Schematic Diagram



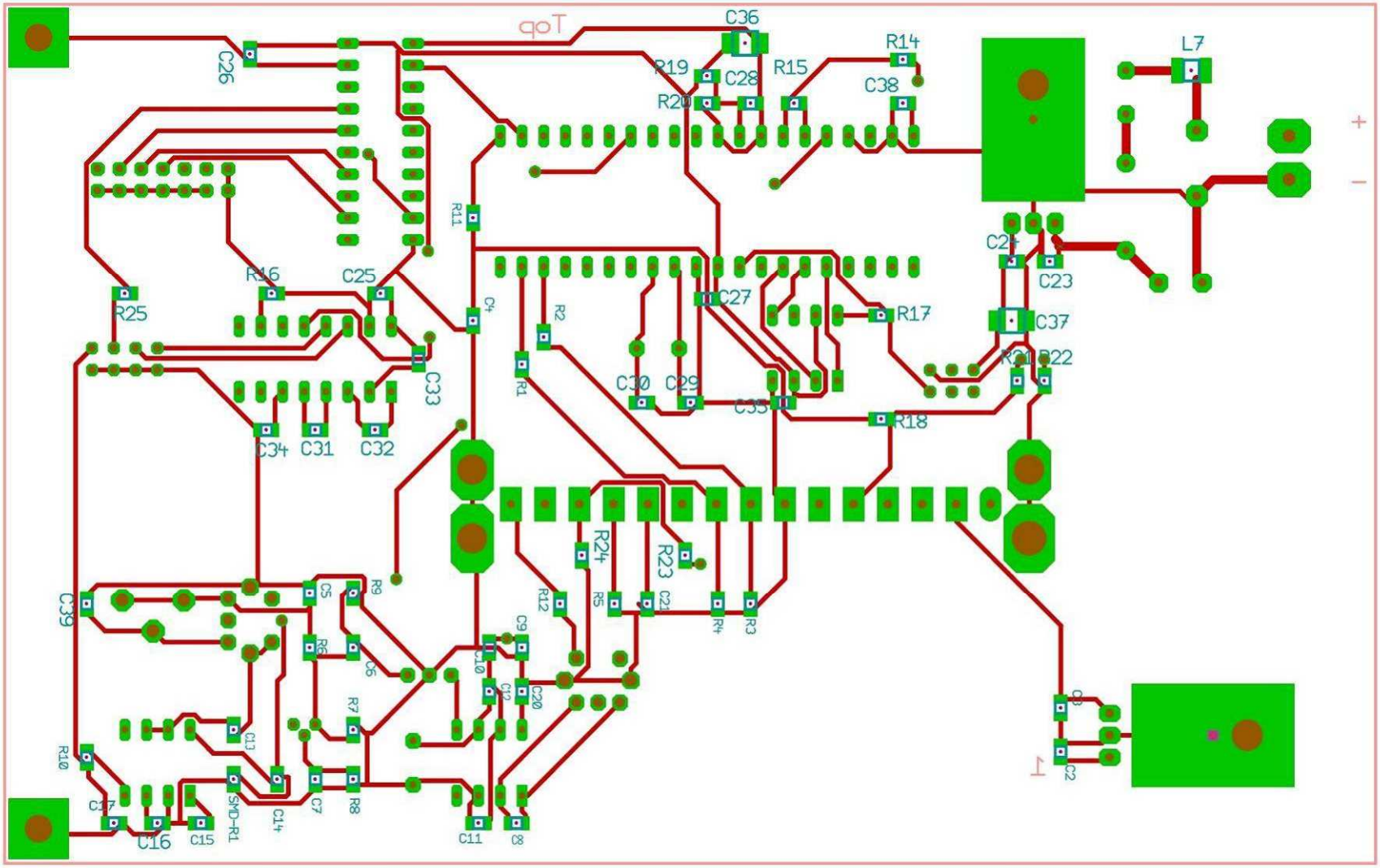
Power Supply Schematic Diagram



Printed Circuit Board Layout - Top



Printed Circuit Board Layout - Bottom



XI. Maintenance

A. Purpose

This section describes preventative maintenance that is performed to ensure the quality and reliability of data collected by the CALLISTO Receiver. The tasks are simple and routine and will keep your receiver and data in top condition.

B. Monthly Preventative Maintenance

- ☼ Verify that the PC is synchronized with an internet time server
- ☼ Verify that the Scheduler file covers time of observation from actual sunrise to sunset and adjust as necessary
- ☼ Brush dust off the instrument being careful to not disturb the connections
- ☼ If additional cleaning of the enclosure and panels is required, use a damp cloth; DO NOT use any chemicals (or else the silkscreen may dissolve)

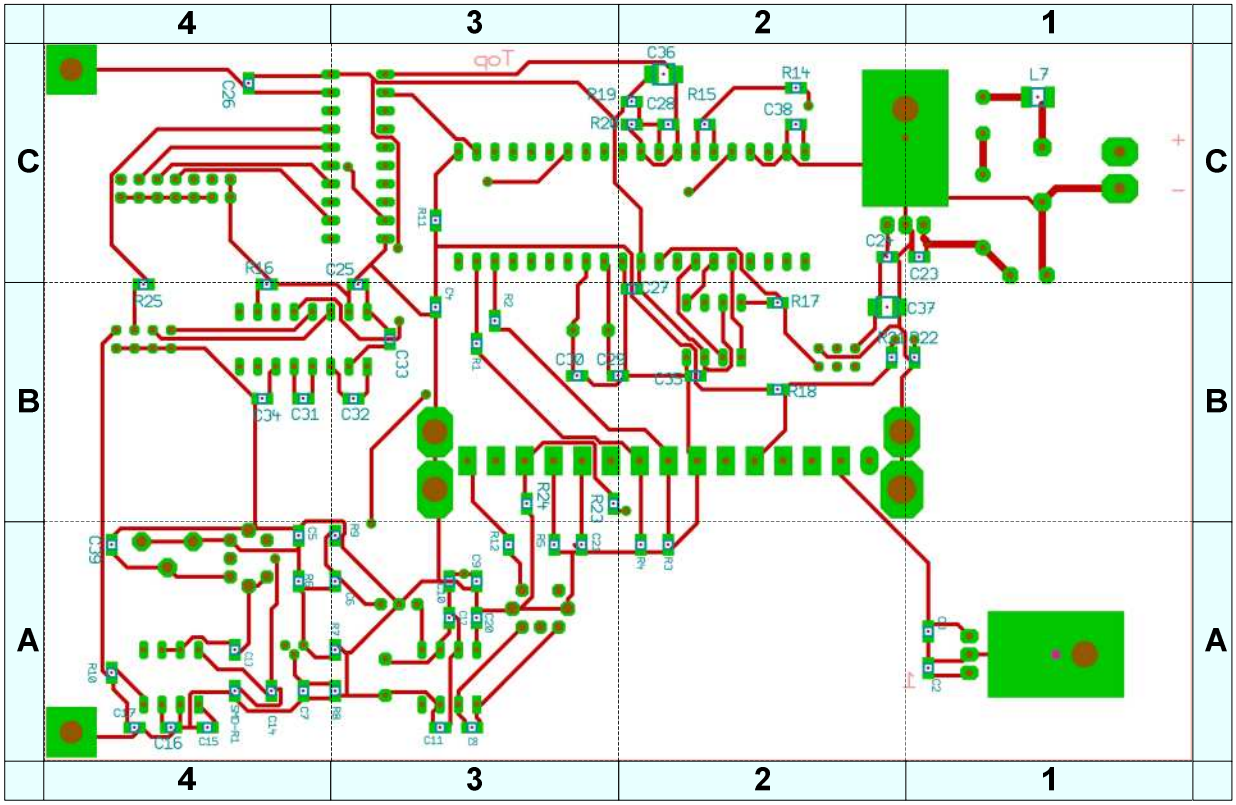
C. Annual Preventative Maintenance

- ☼ Check the spectrum for noisy channels due to RFI. Update/edit the Frequency file to get the best channels with low RFI
- ☼ Check the capacity usage of the hard drive and delete old log files
- ☼ Defragment the hard drives used for Callisto and data storage
- ☼ Check for loose connectors and frayed insulation on cables
- ☼ Check power supply voltage, 9 ~ 15 Vdc
- ☼ If you use an external clock, check the amplitude and signal quality (1 MHz, 5 V TTL signal)
- ☼ If you have access to a wide band noise source check the noise performance of the CALLISTO Receiver by applying about 15 dB of excess noise to the input and analyzing the spectrum.

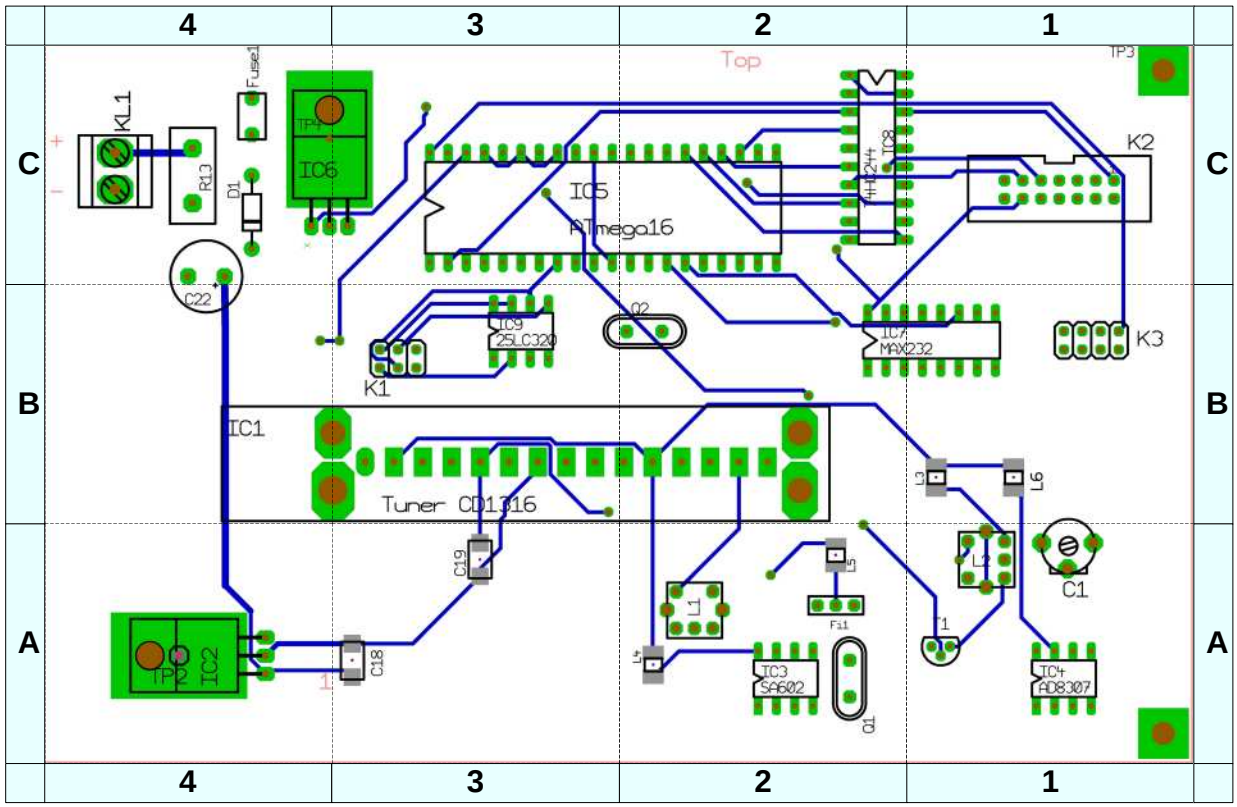
  Derive the noise figure of the instrument as follows (set gain to PWM = 200):
  - ☼ 1) Measure V_{cold} by applying a 50 ohm resistor to the antenna input and take a spectral overview (see CALLISTO Software Setup Guide);
  - ☼ 2) Measure V_{hot} by applying the noise source to the antenna input and take a second spectral overview;
  - ☼ 3) Calculate the Y-factor in dB: $Y(dB) = (V_{hot} - V_{cold})/25.4$ mV/dB;
  - ☼ 4) Convert Y-factor to linear ratio: $Y = 10^{[Y(dB)/10]}$
  - ☼ 4) Derive the noise figure, NF, of the instrument from NF(dB) = ENR(dB) – 10*log(Y-1), where ENR is the excess noise ratio of the noise source adjusted for cable losses. NF should be less than 10 dB without a preamplifier and less than about 3 dB with an external low noise preamplifier.

Appendix A: Printed Circuit Board Layout and Location Grid

Bottom



Top



Appendix B: Using SysInternals PortMon

Download PortMon here: http://technet.microsoft.com/en-us/sysinternals/bb896644

Install PortMon and run. Generally, it will automatically monitor all equipped serial ports (COM Port) but you will need to check this. PortMon will not monitor a port if the port is busy when you start the program. Therefore, be sure HyperTerminal or other program is disconnected before opening PortMon. If necessary, refer to the PortMon Help for assistance setting up the program.

PortMon will display and log (unless logging is shut off) all traffic on a serial port in both directions. When PortMon runs in logging mode for any length of time, say 2 hours or more, it will gradually use up all PC memory and you will notice that the hard drive continuously runs as Windows constantly swaps the cache between RAM and the hard drive. You also will notice the PC becomes sluggish and may appear to freeze (and probably has). Therefore, do not run PortMon in logging mode for more than an hour or two.

To troubleshoot, compare your PortMon logs to those shown.

The following log was obtained when the Connect button on HyperTerminal was pressed followed by the Disconnect button:

```
    Time         Process      Request                      Port             Result    Other
CONNECT
0   0.14938826   hypertrm.exe IRP_MJ_CREATE                ProlificSerial2  SUCCESS   Options: Open
1   0.00000810   hypertrm.exe IOCTL_SERIAL_SET_QUEUE_SIZE  ProlificSerial2  SUCCESS   InSize: 8192 OutSize: 8192
2   0.00000223   hypertrm.exe IOCTL_SERIAL_CONFIG_SIZE     ProlificSerial2  SUCCESS   Size: 0
3   0.00000196   hypertrm.exe IOCTL_SERIAL_GET_BAUD_RATE   ProlificSerial2  SUCCESS
4   0.00000196   hypertrm.exe IOCTL_SERIAL_GET_LINE_CONTROL ProlificSerial2  SUCCESS
5   0.00000196   hypertrm.exe IOCTL_SERIAL_GET_CHARS       ProlificSerial2  SUCCESS
6   0.00000196   hypertrm.exe IOCTL_SERIAL_GET_HANDFLOW    ProlificSerial2  SUCCESS
7   0.00000196   hypertrm.exe IOCTL_SERIAL_GET_BAUD_RATE   ProlificSerial2  SUCCESS
8   0.00000168   hypertrm.exe IOCTL_SERIAL_GET_LINE_CONTROL ProlificSerial2  SUCCESS
9   0.00000196   hypertrm.exe IOCTL_SERIAL_GET_CHARS       ProlificSerial2  SUCCESS
10  0.00000223   hypertrm.exe IOCTL_SERIAL_GET_HANDFLOW    ProlificSerial2  SUCCESS
11  0.00000168   hypertrm.exe IOCTL_SERIAL_SET_BAUD_RATE   ProlificSerial2  SUCCESS   Rate: 115200
12  0.00079088   hypertrm.exe IOCTL_SERIAL_SET_RTS         ProlificSerial2  SUCCESS
13  0.00098644   hypertrm.exe IOCTL_SERIAL_SET_DTR         ProlificSerial2  SUCCESS
14  0.00000251   hypertrm.exe IOCTL_SERIAL_SET_LINE_CONTROL ProlificSerial2  SUCCESS   StopBits: 1 Parity: NONE WordLength: 8
15  0.00097219   hypertrm.exe IOCTL_SERIAL_SET_CHAR        ProlificSerial2  SUCCESS   EOF:0 ERR:0 BRK:0 EVT:0 XON:11 XOFF:13
16  0.00000223   hypertrm.exe IOCTL_SERIAL_SET_HANDFLOW    ProlificSerial2  SUCCESS   Shake:80000001 Replace:80000040
XonLimit:80 XoffLimit:200
17  0.00000168   hypertrm.exe IOCTL_SERIAL_SET_TIMEOUTS    ProlificSerial2  SUCCESS   RI:10 RM:0 RC:0 WM:0 WC:5000
18  0.00000335   hypertrm.exe IOCTL_SERIAL_SET_WAIT_MASK   ProlificSerial2  SUCCESS   Mask: RLSD ERR
19  4.54126935   hypertrm.exe IOCTL_SERIAL_WAIT_ON_MASK    ProlificSerial2  SUCCESS
20  4.54128891   hypertrm.exe IRP_MJ_READ                 ProlificSerial2  CANCELLED Length 80

DISCONNECT
21  0.00001983   hypertrm.exe IOCTL_SERIAL_SET_WAIT_MASK   ProlificSerial2  SUCCESS   Mask: RLSD ERR
22  0.00001034   hypertrm.exe IOCTL_SERIAL_PURGE           ProlificSerial2  SUCCESS   Purge: TXABORT RXABORT
23  0.02377732   hypertrm.exe IRP_MJ_CLEANUP               ProlificSerial2  SUCCESS
24  0.03124140   hypertrm.exe IRP_MJ_CLOSE                 ProlificSerial2  SUCCESS
```

The following log was obtained by typing “?” and then ENTER:

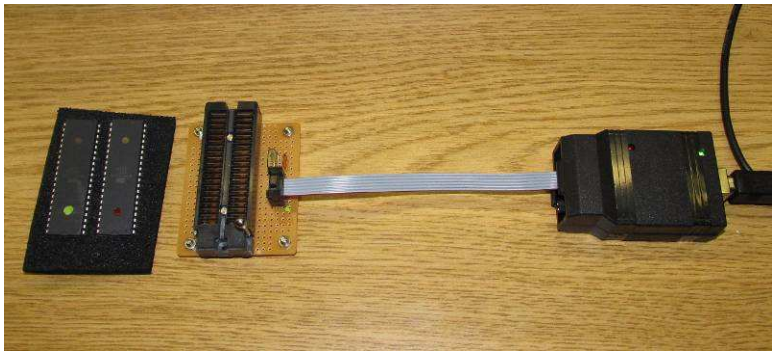
```
    Time         Process       Request                      Port      Result    Other
?
0   0.00035787   hypertrm.exe  IRP_MJ_WRITE  ProlificSerial2 SUCCESS   Length 1: ?

ENTER
1   0.00035479   hypertrm.exe  IRP_MJ_WRITE  ProlificSerial2 SUCCESS   Length 1: .
2   0.00696485   hypertrm.exe  IRP_MJ_READ   ProlificSerial2 SUCCESS   Length 80:
elay=0msec.$CRX:Frequency=0.0MHz.$CRX:Sweeplength=0.$CRX:low_ban
3   0.02986190   hypertrm.exe  IRP_MJ_READ   ProlificSerial2 TIMEOUT   Length 61:
X:mid_band_max=450MHz.$CRX:high_band_max=863MHz.$CRX:Idle=0x.
4  11.42705009   hypertrm.exe  IRP_MJ_READ   ProlificSerial2 SUCCESS   Length 80:
$CRX:Debug=Off.$CRX:Trigger=No.$CRX:FPUcodex=0.$CRX:GS =62208.$C
```

Appendix C: In-System Programming

The ATmega16-16PU microprocessor IC5 provided with the kit is pre-programmed. It does not have a bootloader but it does support In-System Programming (ISP). The 6-pin connector K1 on the PCB is the ISP interface. Refer to the ATmega16-series microprocessor datasheet for ISP support.

The microprocessor IC supplied with the kit was not programmed using the CALLISTO ISP interface. It was programmed as follows:

1. The firmware on the ATmega16 MPU consists of four separate .hex files:
   - ⊕ Lo-Fuse
   - ⊕ Hi-Fuse
   - ⊕ EEPROM
   - ⊕ Flash



2. A new MPU is programmed using AVRDude software, a shop-built USBTiny programmer, and a shop-built chip carrier platform with a Zero Insertion Force (ZIF) socket (left). The chip carrier platform has a 4 MHz crystal and associated load capacitors, which are necessary to verify the programming. Each .hex file is written in turn and then automatically verified.

3. Additional details available on request.

Appendix D: Basic RF Performance Tests

A. The basic RF performance tests include five measurements

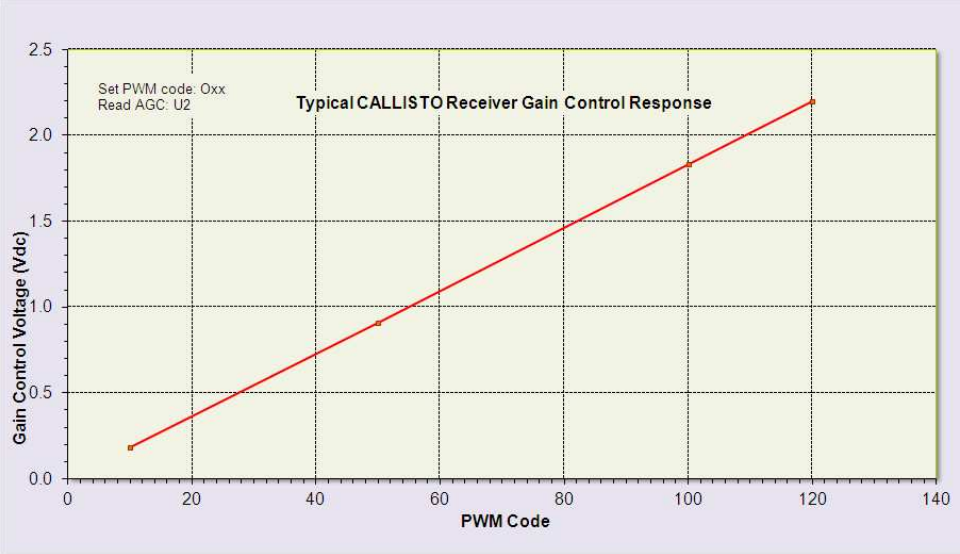
1. Gain Control Test
2. Bandpass Filter Test (Go/No-Go)
3. Noise Figure Test
4. Bandpass Filter Response Test. The resolution of this test is equal to the receiver tuning resolution of 62.5 kHz
5. Minimum Discernible Signal Test

B. Test hardware and software requirements

1. Noise generator (noise source) with a calibrated excess noise ratio (ENR) of 10 ~ 15 dB across the frequency range of 45 to 870 MHz
2. RF signal generator that can be set within the receiver frequency range of 45 to 870 MHz. The output level does not have to be calibrated for the bandpass filter go/no-go test but it should be in the range of –80 to –60 dB. However, for the minimum discernible signal test, the output must be calibrated. If the signal generator output is fixed, calibrated attenuators can be used to reduce the level
3. Terminal emulator program (example, HyperTerminal, see elsewhere in this manual)
4. Callisto software. Callisto software setup is covered in the CALLISTO Software setup Guide

C. Gain Control Linearity Test

1. Open HyperTerminal and connect to receiver
2. Set PWM gain to different values (Oxxx) and read AGC voltage (U2); use PWM values of 010, 050, 100, 150 and 200
3. After each PWM Value change, record the AGC voltage after it has stabilized (three readings in a row read the same voltage)
4. Plot AGC voltage vs PWM value (see example below)
5. Result: Linear
6. Disconnect HyperTerminal

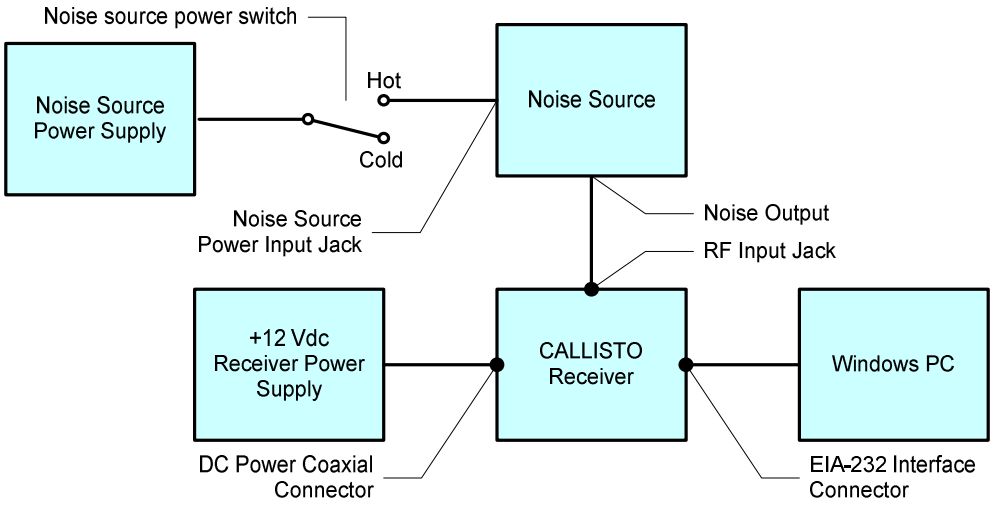


D. Bandpass Filter Test – Go/No-Go

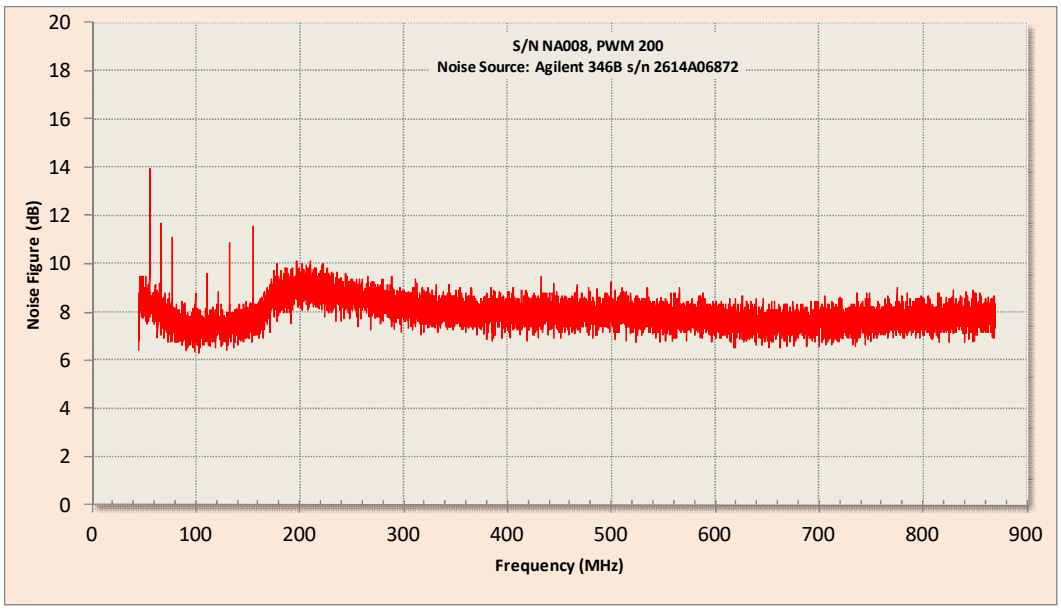
1. Open HyperTerminal and connect to receiver
2. Set PWM gain to 120 (O120)
3. Connect RF signal generator tuned to 150 MHz, –70 dBm
4. Set data format to "decimal mV" (%2)
5. Set Callisto to the same frequency (F0150.0)
6. Adjust signal generator or Callisto frequency to peak level (for Callisto use + and – keys); the peak will be broad. Measure and record frequency at peak and maximum detector voltage, V_{max} (A0)
7. Set Callisto 148 MHz (F0148.0)
8. Measure and record detector voltage, $V_{min,\ low}$ (A0)
9. Repeat for 152 MHz (F0152.0), $V_{min,\ high}$ (A0)
10. Calculate
    $dB_{low} = [(V_{max} – V_{min,\ low})/25.4mV/dB]$ and
    $dB_{high} = = [(V_{max} – V_{min,\ high})/25.4mV/dB]$
11. Result: dB_{low} and $dB_{high} \geq 38dB$
12. Disconnect HyperTerminal

E. Noise Figure Test

1. Connect unpowered (cold) noise source to receiver RF input and make other connections as shown below. Use high-quality coaxial cable and make it as short as possible. Be sure Noise Source power switch is in Cold (Off) position



2. Open Callisto and then click Edit – callisto.cfg. Set [agclevel] parameter to 250. Noise figure is somewhat dependent on gain setting.
3. Select Manual radio button. Click on Start measurement. Run for a moment to warm-up the receiver, and then select Stop measurement
4. Save spectral overview with Callisto (this is the ***cold*** OVS)
5. Apply power to noise source (hot), and Save spectral overview with Callisto (this is the ***hot*** OVS)
7. Open Excel and load both OVS files (see note below)
8. Calculate Y-factor in dB, Y(dB) = $[(V_{hot} - V_{cold})/25.4\ mV/dB]$ at each frequency
9. Calculate Y-factor as a linear ratio, $Y = 10^{[Y(dB)/10]}$ at each frequency
10. Calculate noise figure at each frequency, NF(dB) = ENR(dB) – 10*log(Y – 1), where ENR is the excess noise ratio from the noise source calibration chart
11. Plot NF(dB) vs frequency (MHz)
12. Nominal result: ≤ 10dB across frequency band (somewhat dependent on gain setting [agclevel]). Expect reduced noise figure in middle-band and occasional spikes. Generally, there will be ±1 dB variation around a nominal value. See example chart below



Note: An example Excel file (CALLISTO_NF.xls) is provided on the CD for calculating noise figure. Follow these steps to use this file:

a. Open the noise figure spreadsheet CALLISTO_NF.xls and replace the values in column G with the ENR of your noise source at each frequency (to simplify, but with some accuracy loss, use one ENR for all frequencies). Be sure to adjust the ENR for cable losses (otherwise, the noise figure calculations will be overstated)

b. Open ***cold*** OVS file with Excel. Select the *Semicolon* Delimeter and *General* Column data format. The OVS file has two columns, A is frequency (MHz) and B is measured output voltage (mV) of the log detector, which is proportional to power. Copy column B containing the voltage values to the Windows Clipboard. Paste the Clipboard to Column B of the noise figure spreadsheet

c. Open ***hot*** OVS file with Excel using the delimiter and format as before. Copy column B voltage values to the Clipboard. Paste the Clipboard to Column C of the noise figure spreadsheet

d. If necessary, update calculations (F9)

e. Edit chart title and sheet name so you can identify it in the future. It is helpful for future reference to include the noise source model and serial number and receiver serial number and gain setting in the chart title

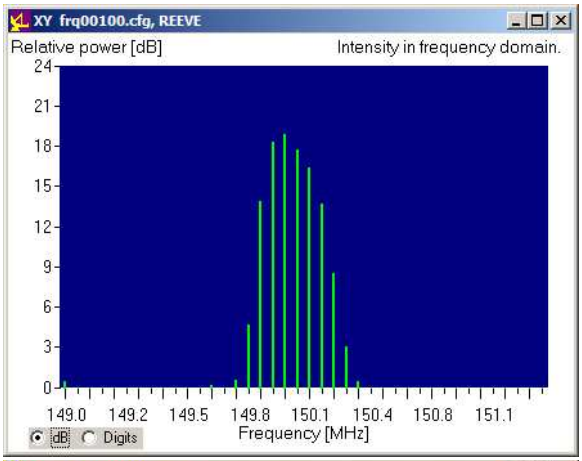
f. To save the chart as an image, right-click the chart border and select Copy. Open Windows Paint or other image editing application and Paste. Use Save As... to save the image in your choice of file format and filename.

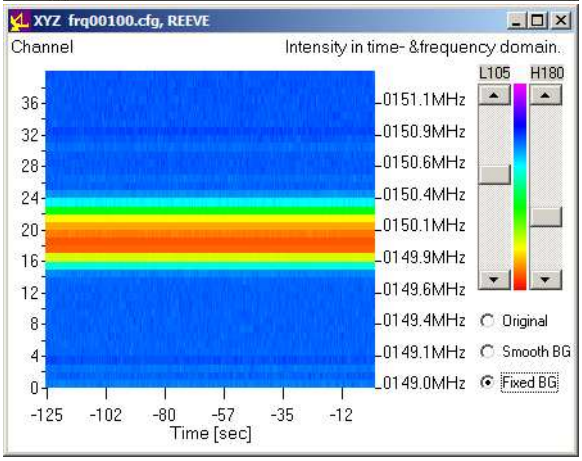
F. Bandpass Filter Response Test

1. Connect RF signal generator to RF Input; tune generator to 150.000 MHz, –70 dBm, Carrier OFF (if the signal generator does not have a carrier ON/OFF control, initially substitute a 50 ohm termination on receiver RF input)

2. Use Frequency Genie to produce a frequency file with 40 channels in a frequency range of 149 to 151 MHz. Save file using a recognizable filename (example, frq00150) and then copy it to the directory used by Callisto

3. Open Callisto and select Manual mode. If necessary, press Stop measurements
4. Press Load frequency file button on Callisto and then select the file produced and saved in step 2
5. From the Callisto menu bar, click on Edit – callisto.cfg. Set the [agclevel] parameter to a mid-range value, say 100 or 120, and set [db_scale]=4. Save the file
6. Click on Start measurement
7. Click the Spectrum y(f) button. When the Spectrum y(f) window opens, select the Digits radio button (if not already selected); wait 5 seconds
8. On the Spectrum y(f) window, select dB
9. Turn ON the signal generator carrier (or replace the 50 ohm termination with the signal generator output). After a moment the spectrum should appear as an individual spike at each frequency. Adjust the signal generator output so the spectral peaks are below the top of the graph. Alternately, adjust the [db_scale] or [agc_level] parameters in callisto.cfg. If [agc_level] is adjusted, click Stop measurement before changing and saving the parameter, then click Start measurement to resume testing
10. The Spectrum y(f) chart (above-right) shows a 62.5 kHz resolution display of the receiver's frequency response
11. On Callisto, click on the Spectrum y(f,t) button and then select Fixed BG (right). As the signal generator output is adjusted, the frequency response is shown on the Spectrum y(f,t) window as horizontal colored bands (next page, right)
12. To measure Minimum Discernible Signal, go to par. G

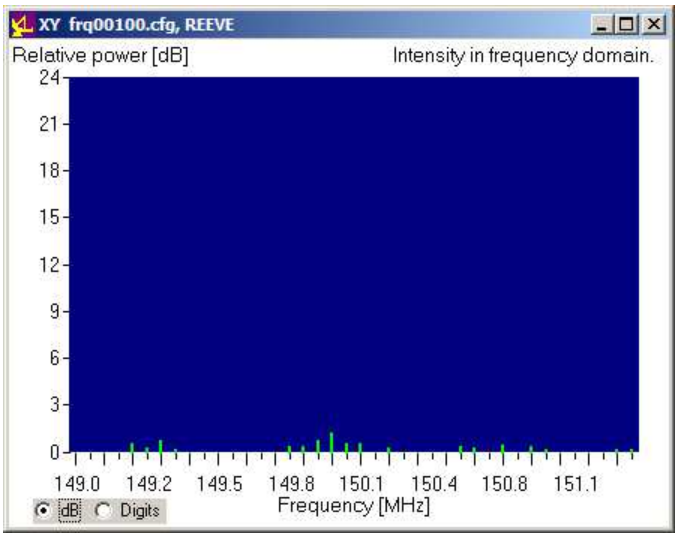




Note: The top window bar in the spectrographs show the default frequency file, which may be different than the file you separately loaded for the tests

G. Minimum Discernible Signal (MDS)

1. Follow steps 1 through 11 in par. F above
2. Decrease signal generator output to around –100 or –110 dBm
3. Slowly decrease the signal generator output until the signal disappears into the random noise spikes seen on the Spectrum y(f) chart. Because of integration and sweep times, the display reacts rather slowly. Be patient. Slowly increase the signal generator output until the signal reappears. This provides a rough indication of the MDS. MDS is somewhat dependent on the receiver gain setting [agclevel].



As you decrease the signal generator output level, it may be necessary to change the [db_scale] parameter in callisto.cfg for better amplitude resolution. To increase the resolution, decrease the [db_scale] parameter and then Save the change. The change takes effect within about 5 seconds. The image right shows the Spectrum y(f) for a –120.0 dBm signal, which for the test receiver is a few dB above the MDS (MDS will vary from receiver-to-receiver). Note that the five green signal spikes at the bottom of the chart around the center frequency of 150 MHz are near the height of the noise spikes on either side

Appendix E: Connector Pin-Outs (courtesy Christian Monstein)

E.1 Power

Type: European version: DIN (rear panel)

Pin	Function	Remarks
1	+12 Vdc supply, 0.5 A	
2	Shield	
3	Ground	

Type: North American version: Coaxial (front panel)

Pin	Function	Remarks
Center	+12 Vdc supply, 0.5 A	
Shell	Ground	

E.2 External Clock

Type: BNC-F (rear panel)

Pin	Function	Remarks
Center	Timer/counter	1 MHz, TTL/5 V, 50 ohm (nominal)
Shell	Shield ground	

E.3 Audio Output

Type: 3.5 mm mono phone jack (rear panel)

Pin	Function	Remarks
Tip	Audio out	To audio input of PC or notebook
Sleeve	Ground	

E.4 Serial Port

Type: DB-9F (rear panel)

Pin	Function	Remarks
2	Tx	Transmit data
3	Rx	Receiver data
5	Common	Signal common

E.5 RF Input

Type: N-F (rear panel)

Pin	Function	Remarks
Center	RF input	50 ohm (nominal)
Shell	Shield ground	

E.6 Focal Plane Unit, FPU

Type: DB-25F (rear panel)

Pin	Callisto	FPU	Remarks
1	Not used	Not used	
2	Not used	Not used	
3	Vcc	FC0+	FPU control bit 0 high potential, LSB
4	Vcc	FC1+	FPU control bit 1 high potential
5	Vcc	FC2+	FPU control bit 2 high potential
6	Vcc	FC3+	FPU control bit 3 high potential
7	Vcc	FC4+	FPU control bit 4 high potential
8	Vcc	FC5+	FPU control bit 5 high potential, MSB
9	Not used	Not used	
10	Not used	Not used	
11	Not used	Not used	
12	Not used	Not used	
13	GND_fpu	Shield	Shield for all conductors
14			
15			
16	FPU0	FC0–	FPU control bit 0 low potential, LSB
17	FPU1	FC1–	FPU control bit 1 low potential
18	FPU2	FC2–	FPU control bit 2 low potential
19	FPU3	FC3–	FPU control bit 3 low potential
20	FPU4	FC4–	FPU control bit 4 low potential
21	FPU5	FC5–	FPU control bit 5 low potential, MSB
22	GND_fpu	GND	
23	GND_fpu	GND	
24	GND_fpu	GND	
25	GND_fpu	GND	

Additional Table Remarks:

1. Each FCx– should be twisted with its partner FCx+ (x = 1 ~ 5)
2. See CALLISTO Software Setup Guide for focus control codes associated with FCx bits.
3. See also Appendix F for FPU connector logic table.

E.7 Printed Circuit Board Connectors

E.7.1: KL1, Power Supply, 2-position screw terminal block

Pin	Function	Remarks
K1.01	+12 Vdc input	9 ~ 15 Vdc at 0.5 A
K1.02	0 V reference, GND	

E.7.2: K1, In-System Programming plug, ISP, 6-position header connector, unpolarized

Pin	Function	Remarks
KL2.1	PB6	MISO
KL2.2	Vcc	+5 V
KL2.3	PB7	SCK
KL2.4	PB5	MOSI
KL2.5	RESET	RST
KL2.6	GND	0 V

E.7.3: K2, Digital output to FPU, 14-position header connector, polarized

Pin	Function	Remarks
K3.01	FOPA_0	
K3.02	+5 V processor	
K3.03	FOPA_1	
K3.04	+5 V processor	
K3.05	FOPA_2	
K3.06	+5 V processor	
K3.07	FOPA_3	
K3.08	+5 V processor	
K3.09	FOPA_4	
K3.10	+5 V processor	
K3.11	FOPA_5	
K3.12	+5 V processor	
K3.13	GND	
K3.14	GND	

E.7.4: K3, EIA-232 and I/O, 8-position, header connector, unpolarized

Pin	Function	Remarks
K4.01	Video	From detector/integrator
K4.02	GND	
K4.03	Clock input	1 MHz, TTL, 5V
K4.04	GND	
K4.05	TX, EIA-232	
K4.06	GND	
K4.07	RX, EIA-232	
K4.08	GND	

Appendix F: FPU Connector Logic Table

fsxx Decimal Code	MSB – Binary - LSB	Pin 21	Pin 20	Pin 19	Pin 18	Pin 17	Pin 16
00	000 000	Low	Low	Low	Low	Low	Low
01	000 001	Low	Low	Low	Low	Low	High
02	000 010	Low	Low	Low	Low	High	Low
03	000 011	Low	Low	Low	Low	High	High
04	000 100	Low	Low	Low	High	Low	Low
05	000 101	Low	Low	Low	High	Low	High
06	000 110	Low	Low	Low	High	High	Low
07	000 111	Low	Low	Low	High	High	High
08	001 000	Low	Low	High	Low	Low	Low
09	001 001	Low	Low	High	Low	Low	High
10	001 010	Low	Low	High	Low	High	Low
11	001 011	Low	Low	High	Low	High	High
12	001 100	Low	Low	High	High	Low	Low
13	001 101	Low	Low	High	High	Low	High
14	001 110	Low	Low	High	High	High	Low
15	001 111	Low	Low	High	High	High	High
16	010 000	Low	High	Low	Low	Low	Low
17	010 001	Low	High	Low	Low	Low	High
18	010 010	Low	High	Low	Low	High	Low
19	010 011	Low	High	Low	Low	High	High
20	010 100	Low	High	Low	High	Low	Low
21	010 101	Low	High	Low	High	Low	High
22	010 110	Low	High	Low	High	High	Low
23	010 111	Low	High	Low	High	High	High
24	011 000	Low	High	High	Low	Low	Low
25	011 001	Low	High	High	Low	Low	High
26	011 010	Low	High	High	Low	High	Low
27	011 011	Low	High	High	Low	High	High
28	011 100	Low	High	High	High	Low	Low
29	011 101	Low	High	High	High	Low	High
30	011 110	Low	High	High	High	High	Low
31	011 111	Low	High	High	High	High	High
32	100 000	High	Low	Low	Low	Low	Low
33	100 001	High	Low	Low	Low	Low	High
34	100 010	High	Low	Low	Low	High	Low
35	100 011	High	Low	Low	Low	High	High
36	100 100	High	Low	Low	High	Low	Low
37	100 101	High	Low	Low	High	Low	High
38	100 110	High	Low	Low	High	High	Low
39	100 111	High	Low	Low	High	High	High
40	101 000	High	Low	High	Low	Low	Low
41	101 001	High	Low	High	Low	Low	High
42	101 010	High	Low	High	Low	High	Low
43	101 011	High	Low	High	Low	High	High
44	101 100	High	Low	High	High	Low	Low
45	101 101	High	Low	High	High	Low	High
46	101 110	High	Low	High	High	High	Low
47	101 111	High	Low	High	High	High	High
48	110 000	High	High	Low	Low	Low	Low
49	110 001	High	High	Low	Low	Low	High
50	110 010	High	High	Low	Low	High	Low
51	110 011	High	High	Low	Low	High	High
52	110 100	High	High	Low	High	Low	Low
53	110 101	High	High	Low	High	Low	High
54	110 110	High	High	Low	High	High	Low
55	110 111	High	High	Low	High	High	High
56	111 000	High	High	High	Low	Low	Low
57	111 001	High	High	High	Low	Low	High
58	111 010	High	High	High	Low	High	Low
59	111 011	High	High	High	Low	High	High
60	111 100	High	High	High	High	Low	Low
61	111 101	High	High	High	High	Low	High
62	111 110	High	High	High	High	High	Low
63	111 111	High	High	High	High	High	High

Note: Low = 0 V, High = 5 V, Receiver defaults to 63 (all High) on power-up

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Author: Whitham D. Reeve, Anchorage, Alaska USA

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Note: Some images and portions of this manual were provided by Christian Monstein and are used with his permission.

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