Solar Sudden Ionospheric Disturbance Monitor
Technical Manual

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SIDMON Chassis Controls, Status, and Connections

Figure 1: SIDMON Front Panel

Number	Connectors / Status / Controls	Parameters	Details (See Circuit)
1	AUDIO (Powered Speakers)	1/8" stereo jack Line-in/out level	Audio Output
2	X1 X5 X10	Post Gain Switch (3 pos)	Post Amp Circuit
3	RF GAIN ADJUST	Preamp (200KΩ R_3)	Preamp Circuit
4	ANTENNA INPUT	TNC Connector	Preamp Circuit
5	POWER ON	Power Status: Green LED = +5v Yellow LED = -5v	Power Supply

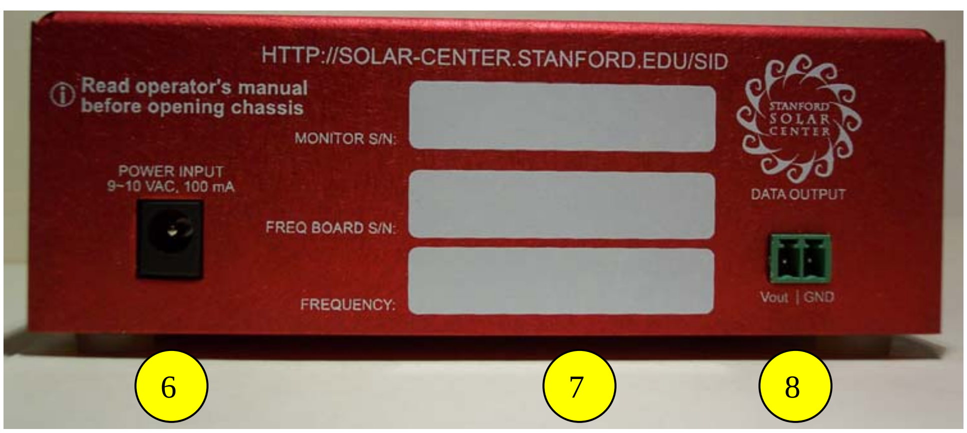


Figure 2: SIDMON Rear Panel

Number	Connectors / Status / Controls	Parameters	Details (See Circuit)
6	POWER INPUT	Mates w/ 2.1 mm x 5.5 mm plug 9 ~ 10 VAC input voltage	Power Supply
7	Serial Number Area	Top line: Serial number S-#### Middle: Serial Number FB-#### Bottom: Frequency / Station ID	N/A
8	DATA OUTPUT	Mates w/ Phoenix connector part# 803578, 3.81 2P PLUG 180DEG	DATAQ Output Circuit

Chassis Dimensions: 5.25" (13.34 cm) L x 3.63" (9.22 cm) W x 1.825" (4.636 cm)

Introduction To The SIDMON Circuit Board

This document describes the circuit design and theory of operation of the SID Monitor circuit; for instructions how to calibrate and use the SID monitor please refer to the user's manual.

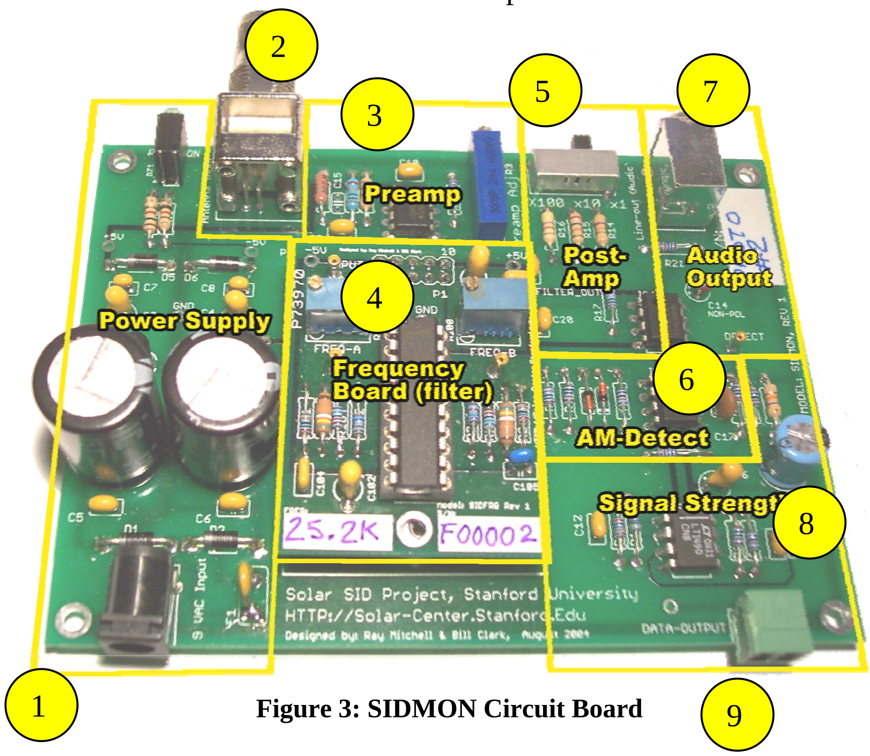


Figure 3: SIDMON Circuit Board

Circuit Overview

Starting at the lower left of the SIDMON circuit board and working around the various signal processing stages or sections in numeric order: ①The *Power Supply Section* takes input from the 9-10 VAC from the transformer and produces both regulated positive and negative 5 volt supplies. ② The TNC input feeds the broadband signal in from the antenna into the ③ *Preamp Stage* with the RF gain control. The signal is then routed into the ④ *Frequency Board Filter Stage* (called FREQBOARD). This section extracts the desired VLF transmitter station frequency as Amplitude Modulation (AM) from the broadband signal. The AM signal leaves the FREQBOARD and routed to the ⑤ *Post-Amp Stage* for a user-selectable signal boost the post-amp switch labeled x1, x5 and x10. ⑥ The signal is routed to the *Signal Detect Stage* that performs a full-wave rectification of the signal making the waveform all positive, i.e. the absolute value of all signal components. The detected signal is then routed to the ⑦ *Audio Output Stage* where the line-level audio signal is sent out the 1/8" audio output jack and monitored through power speakers. Also the detected signal from ⑥ is routed into the ⑧ *Signal Strength Stage*. An integrator (Resistor/Capacitor circuit) converts the detected AM signal into an average DC level, indicating overall signal strength. The DC level (analog output) exits the SID Monitor via ⑨ the 2-position Phoenix connector that is connected to the DATAQ module (ADC) that converts the analog level to digital values that are then transmitted via RS-232 to the computer and recorded by the software.

Power Supply

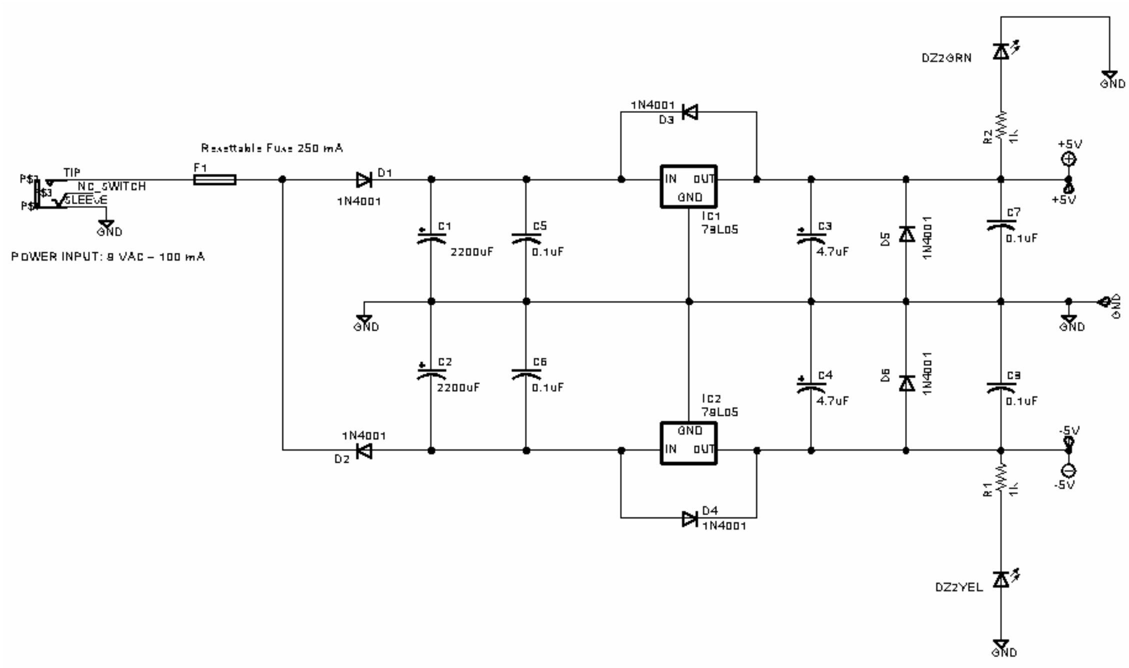


Figure 4: Power Supply

The input is a 2.5mm x 5.0mm jack that accepts the 9-10 volt AC wall transformer. The fuse (F1) is a re-settable 250mA circuit breaker. If there is a short circuit the fuse will open and remain open until the power is removed and the fuse cools down.

The AC to DC voltage conversion is achieved by a half-wave rectifier (diodes D_1 and D2) and smoothed by capacitors C_1 and C_2 (Higher frequencies bypassed by C_5 and C_6). The DC working voltage on these caps should be rated at two times the input voltage, plus we added 50% more as a precaution, therefore: WVDC = 2.5 x V_{ac} (input voltage) = 25 VDC.

The power supply is a typical design per recommendations from the manufacture’s application sheets; for the +5 volt supply IC_1 (78L05) and –5 volt supply IC_2 (79L05). We used the ‘L’ versions of the regulator for their characteristics of both lower dropout voltages and over current regulation properties. The diodes (D_3, D_4, D_5, D_6) prevent a reverse voltage situation that can result when the capacitors are charged up and power reapplied on the input. Caps C_3, C_4, C_7, and C_8 are part of the filtering and recommended design by the manufacturer.

The two status-LED’s visible on the front panel show independently that both power supplies are functioning. The LED color assignments are as follows:

+5V is green.
–5V is yellow.

Overall the current draw on the power supply is small, in the 100-200 milliamps range. It was necessary to design the power supply with lots of filtering in order to provide clean DC power to all of the RF filters and amplification stages.

Preamp Circuit

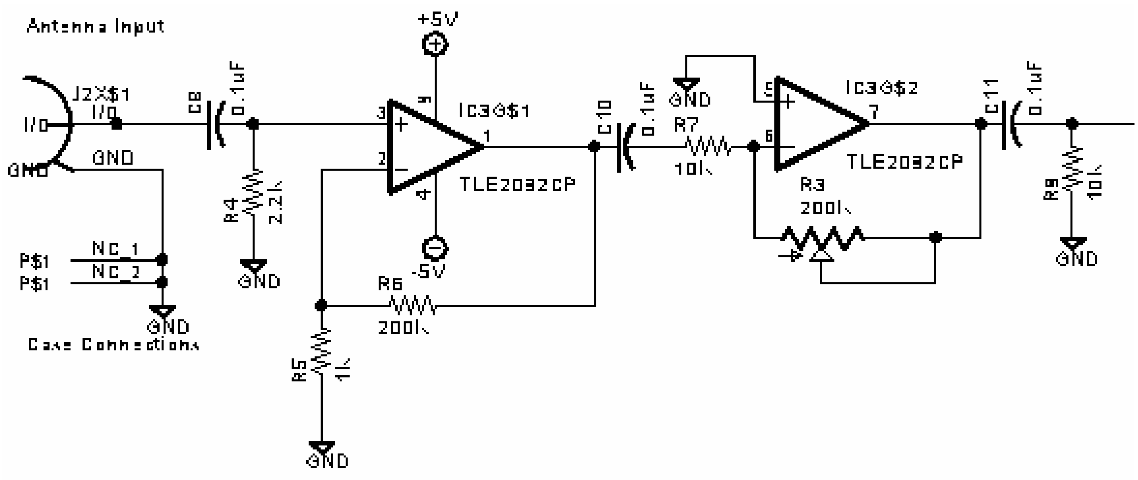


Figure 5: Preamp

Note: this circuit does not include any lightning suppressors; it is the responsibility of the user to install them.

Another protection mechanism suggested by an engineer, but after the PC boards were made, was a signal-limiter clamp made from two signal diodes (1N914's) back-to-back across the input of the first stage op amp. As of the writing of this manual, we have not seen any problems with over-voltage, and not added these components to the boards, however it is worth mentioning for consideration.

The antenna input is inputted through a TNC connector. Capacitor C_8 isolates DC voltage on the input as well as performing a high-pass filter RC function consisting of C_8 (0.1 µF) and R_4 (2.2KΩ) is a high-pass filter (about 723 Hz) to help reject 50/60 Hz power-line hum.

$f_o = 1 / (2\pi RC) = 1 / (2\pi \text{ x } 2.2K\Omega \text{ x } 0.1\mu F) = 1 / (2\pi \text{ x } 2.2\text{x}10^3 \text{ x } 0.1\text{x}10^{-6}) \therefore f_o = 723 \text{ Hz}$

The R_4 resistor could also serve as an AC impedance match to the antenna, however this value cannot be optimized due to the variability of antenna design and consequences to the f_o frequency response of the high-pass filter thus it is better for the user to make up for the loss in the impedance match by increasing the RF gain.

The first stage of the preamp (IC3:G1 TLE2082CP) is a non-inverted input with a gain of 201x. The output (DC decoupled) runs to the next stage, which is an inverted input, has a gain that has an adjustable potentiometer (R_3) from 0 to 20x, giving a total gain from the preamp stage of 0 to 4,020x. The RF gain (R_3) potentiometer adjustment will be made by the end-user and is covered in the user's manual.

IC3 G$1 Non-Inverted op amp gain formula (A = Amplification)
$A = (R_5 + R_6)/ R_5 = (1K\Omega + 200K\Omega) / 1K\Omega \therefore A = 201$ (Fixed gain)

IC3 G$2 Inverted op amp gain formula
$A = R_3 / R_7 = (0\Omega \text{ to } 200K\Omega) / 10K\Omega \therefore A = 0 \text{ to } 20$ (Adjustable gain)

Frequency Board

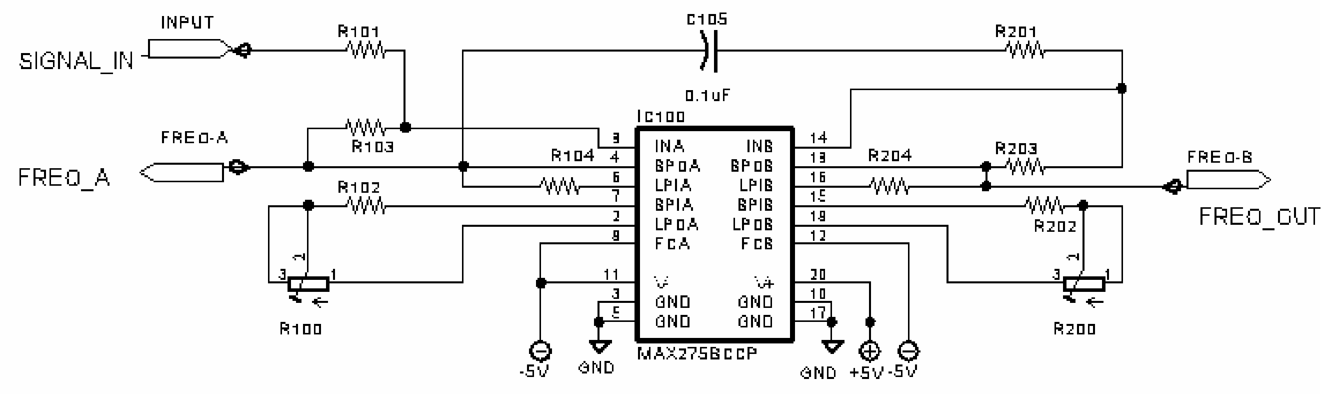


Figure 6: Filter Circuit

The Frequency board (called "Freqboard") is tuned before shipping. The design is based on the MAX275 continuous analog filter configured as a bandpass filter. The filter tuning is based on four resistors per filter, and there are two filters. Resistors R_{100} – R_{104} are for the first filter and R_{200} – R_{204} are for the second filter (or stage)

The Frequency board is a separate PCB to make it easier to change the SIDMON's VLF frequency. It would be simple process to swap this board. When this board is changed, the SIDMON has to go through the same procedures of antenna alignment and qualification procedures (as outlined in the user's manual) as if it were a new monitor.

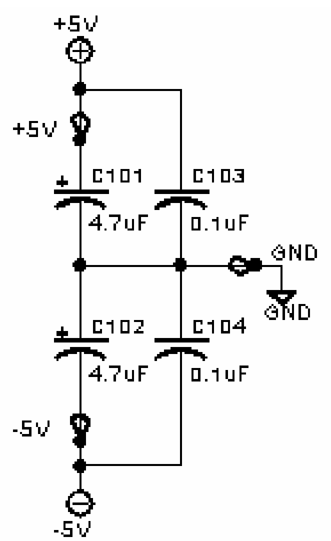


Figure 7: Power Supply Filter Caps

Not much to say about this, pretty standard design principles used. The power supply bypass capacitors were installed per manufacturer's specifications. The 4.7 µF for large DC fluctuations and 0.1 µF for smaller AC spikes.

Frequency Board Tuning Resistor Table

With the components as outlined in the schematic it is possible only to tune a very narrow range of VLF stations: 24.0 NAA, 24.8 NLK, and 25.2 NML. **<u>Frequencies above or below this range are unreachable</u>**. To tune to other frequencies, you need to run the filter design software from MAXIM to determine the correct values for the resistors. Use 1% resistors. We used the Butterworth filter with 4 poles (requires 2 stages to implement the filter).

Frequency Range	**R_{101} / R_{201}** Sets Gain	**R_{102} / R_{202}** Sets Center frequency	**R_{103} / R_{203}** Sets Q	**R_{104} / R_{204}** Sets Center Frequency
18.3 – 19.0 KHz*	200.0 KΩ	115.0 KΩ* ?	549.0 KΩ	90.9 KΩ* ?
24.0 – 25.2 KHz	200.0 KΩ	76.8 KΩ	549.0 KΩ	75.0 KΩ

*Resistor values untested – also: to do add more frequencies to this table.

All resistors are 1% (or better). R_{100} and R_{200} are 10K Potentiometers in series with R_{102} and R_{202} respectively. Calculate resistors in the sequence given below:
(Equations from MAXIM 274/275 Data Sheet)

Formula	Comments
$R_2 = R_{x02} + R_{x00} = (2 * 10^9) / F_0$	Where F_0 is the desired center frequency, this resistor is R_2 in the MAXIM document, it is in series with R_{x00}
$R_{x04} = R_{x02} – 5K\Omega$	R_{x04} might be less than 5KΩ because of internal 5KΩ resistor, limits BPO_ loading
$R_{x03} = (Q * 10^9) / (5 * F_0)$	Limits $5K\Omega < R_{x03} < 4M\Omega$
$R_{x01} = (2 * 10^9) / (5 * F_0 * H_{OLP})$	H_{OLP} is the gain of LPO_ at DC

SIDMON & Frequency Board Connectors

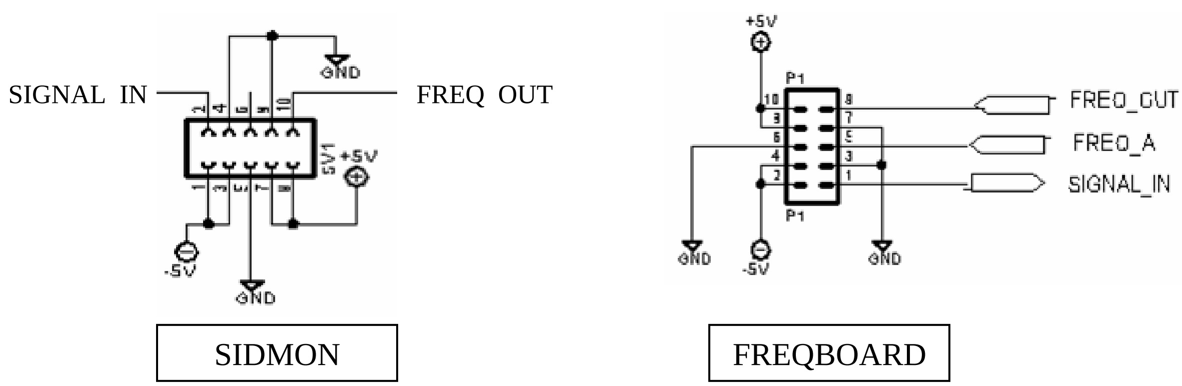
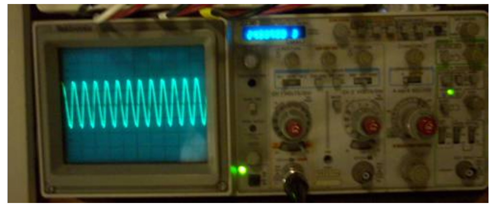


Figure 8: Connections on SIDMON and Frequency boards

Signal Description	Pin# SIDMON Side	Pin# FREQBOARD Side
Neg. 5V	1,3	2,4
GND	4,5,8	3,6,7
Pos. 5V	7,9	8,10
Signal Input	2	1
Freq A (for tuning)	6 (no connection)	5
Freq B (Frequency Out)	10	9

How to tune a Frequency Board

Tools / Supplies you'll need:



- Frequency generator
- Oscilloscope
- Frequency counter
- Small screwdriver, preferably non-metallic (contact with a metal screwdriver seems to affect the readings –keep this in mind while tuning)
- BNC patch cords, oscilloscope probe, etc.
- TNC male to BNC female adaptor / connector
- Resistor / Attenuator test fixture

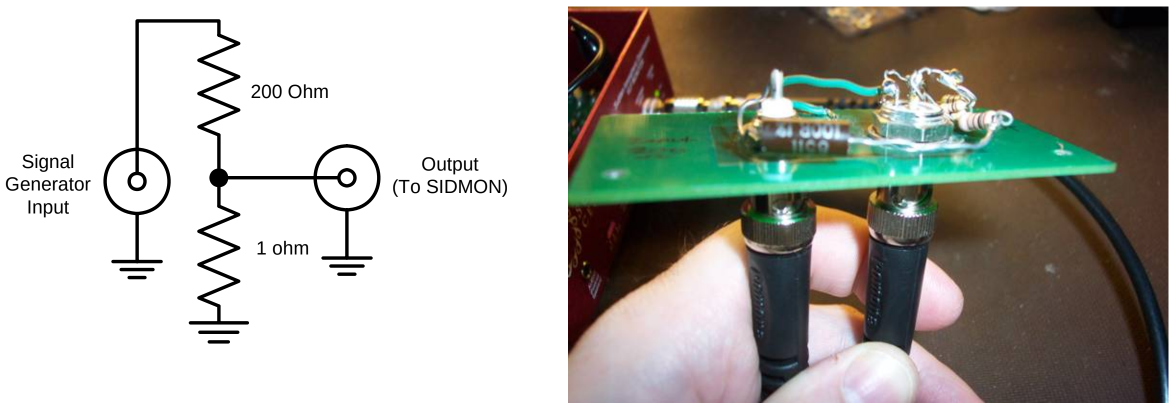


Figure 9: Test Fixture (left: Schematic, right: the homemade attenuator circuit)

Step 1: Plug the FREQBOARD in the SIDMON and turn on the power.

Step 2: Set the frequency generator output to the smallest output signal possible, then attenuate the signal further with a simple 2-resistor circuit See figure above.

Step 3: Connect probe ground lead to a GND point on the SIDMON. (I usually like to connect the ground clip to the top of the TNC connector – see picture on next page.)

Step 4: Use the oscilloscope probe connected to a frequency counter (or oscilloscope w/ a built-in counter) to probe the FREQBOARD at the test point labeled "input." Adjust the RF gain control (R_3) on the main SIDMON board to a voltage level of 100 millivolts peak-to-peak.

Step 5: Verify the proper frequency is present. Adjust the frequency generator, and error of ±100 Hz is okay. Be sure to verify throughout the tuning process that the signal generator is on the desired frequency and hasn't drifted off. I found for best results let the signal generator warm up and stabilize for a couple of hours before tuning the FREQBOARD.

(Procedure continued on next page)

How to Tune a Frequency Board

(Procedure continued from the previous page)

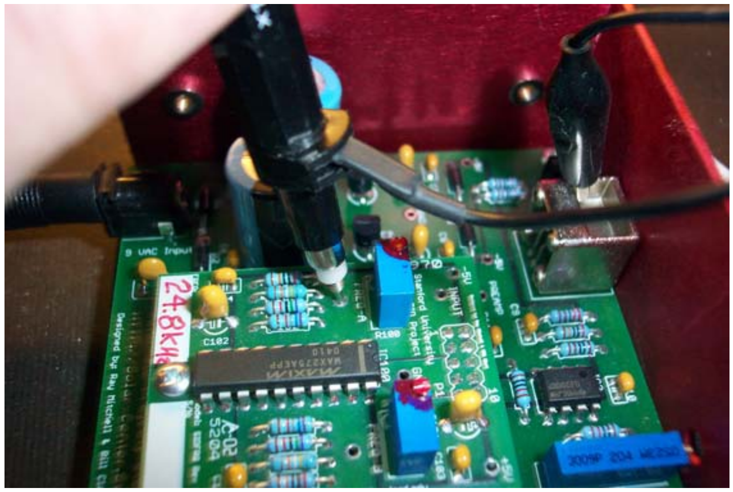


Figure 10: Example of Tuning a SIDMON

Step 6: Put the oscilloscope probe on the test point labeled “Freq A.” (As shown above) Additional comment: The picture above shows the finalized FREQBOARD, that is to say, the two pots are locked down with fingernail polish to finalize the settings and prevent further adjustment as per the instructions of the final step – leave the pots unpainted until that time.

Step 7: Adjust R_{100} to achieve the peak signal response. A peak response is the highest possible response of the filter as seen on the oscilloscope. Watch the amplitude on the scope while turning the pot in either a clockwise or counter-clockwise direction; one of these directions will cause the signal amplitude to rise. At some point the amplitude crosses it maximum and begins to fall. Simply reverse the direction of the pot and the signal will again rise back up. Find the setting on the pot that gives the peak response to the input frequency.

Step 8: Repeat step 7 for test point “Freq B” and adjust pot R_{200}.

It is normal to adjust the volts/division several times during this operation, as the gain will be around 4x per stage. If you hear a clicking sound coming from the pot while turning, then you have reached the end of travel of the pot, try reversing directions. If you traveled to either limit of the pot and still did not find the peak response, then the frequency you are attempting to tune is not possible with the current resistor values on the FREQBORD.

Step 9: The SIDMON is now ready to test, or “burn-in,” we recommend a minimum of 24 hours to verify that the signal is being received and to discover any other electronic failures (such as caps plugged in backwards etc.). To burn-in the SIDMON follow the setup procedure in the User’s Manual, i.e. adjust the RF gain and pointing the antenna towards the transmitter, etc.

Step 10: If the burn-in is successful, then finalize the pots R_{100} and R_{200} by painting them with some fingernail polish. Of course, if the burn-in process reveals a problem, e.g. no sunrise/sunset effect then repeat tuning procedure. One caveat to be aware of: sometimes the VLF stations go down for maintenance – it might not be the receiver’s fault.

Post-amp Circuit

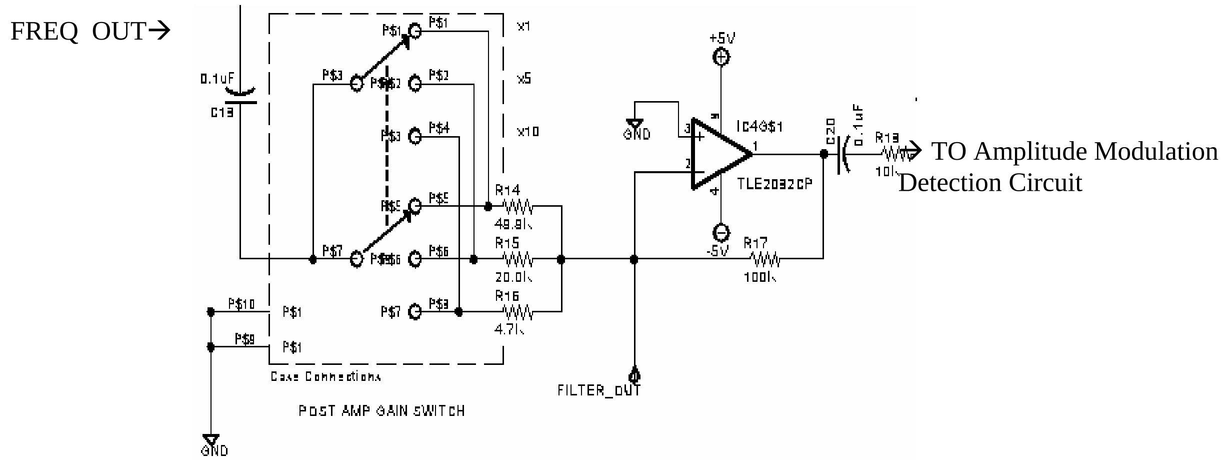


Figure 11: Post-Gain Amp

The post gain amplifier takes the "Frequency Out" signal, now separated from the broadband signal, and this stage amplifies it. The stage was included as a contingency because we were not sure if we needed another gain boost so this was to deal with unknown and variable conditions of a weak signal or poor antenna design. We decided to make this a selector switch instead of adding another potentiometers to avoid confusion. So far all monitors are using x1 with perhaps a few exceptions. I have found the x5 and x10 settings are good to boost the gain enough to make the input signal audible for antenna orientation. It is important to change this setting back to x1 for data logging.

$A = R_{17} / R_x \therefore A = 100K\Omega / R_x$; where R_x is one of R_{14}, R_{15}, or R_{16}

Switch Setting (Label on chassis)	Resistor	Value	Actual Gain (A)
X1	R14	49.9KΩ	2.004
X5	R15	20.0KΩ	5.000
X10	R16	4.7KΩ	21.277

The gain slide switch is a DP3T labeled on the chassis: x1, x5, and x10 note that the actual gains of the amplifier are different than labeled on the box –admittedly this appears to be dishonest. Initially the plan was to make them the same, but as the design went on it was decided to keep the labels on the box simple and make the make-up gains on the output look like 1x, 5x, and 10x instead of the internal circuits be consistent with their external labeling. (For those still curious: When the gains were set "as advertised" the resultant output voltages were not x1, x5, and x10 with respect to the switch setting.)

This was an empirical design, and then we found out later that it wasn't completely consistent with other frequency cards that have different gain characteristics. It is only an approximation… and in the end I have to say that this decision was done mainly for aesthetic appearances.

Amplitude Modulation Detection Circuit

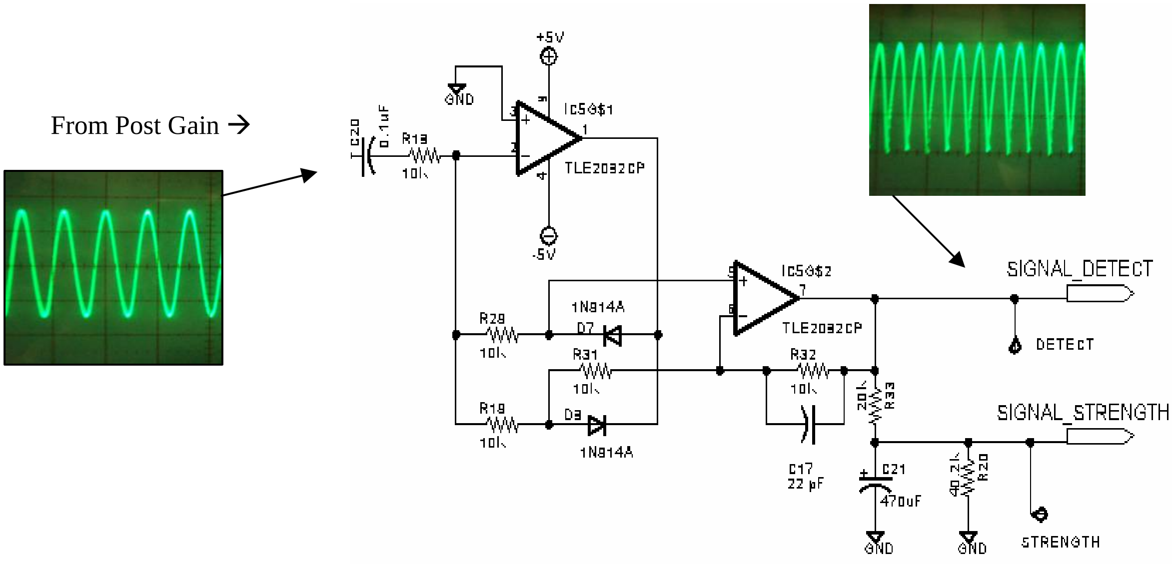


Figure 12: Amplitude Modulation Detection Circuit

This circuit is called an "Absolute-Value Circuit Full-Wave Precision Rectifier" taken from the "Op Amp Design Cookbook" Third Edition by Walter G. Jung pp236-237. We found the circuit would sometimes go into oscillation very easily, thus C_{17} (22 pF) was necessary to eliminate the oscillations.

Test point "Signal Detect" is the full-wave, rectified signal that is sent to the audio buffer circuit. (See: Audio Output for more information)

Test point "Signal Strength" is the integrated signal to produce the signal strength – this is a DC level. The RC circuit (R_{33} and C_{21}) has an RC time constant is approximately between 5 and 9 seconds. ($T = RC = 20K\Omega \times 470\ \mu F = 20x10^3 \times 470x10^{-6}\ \therefore\ T = 9.4$ Seconds). This is approximate because capacitors have lower precision tolerances and we added a discharge resistor, R_{20}, to provide a small load to discharge the capacitor (C_{21}) in order to make the circuit respond to a lowering level faster than allowing its internal resistance to discharge the capacitor.

The design of this filter was chosen carefully to reject short lived signal bursts, such as lightning, but allow longer persistent signal-strength changes such as those caused by solar flares, to affect the overall signal strength characteristics.

Without this filter in place the resultant graph was too noisy to reliably detect solar flares, especially smaller class-C flares. Engineers would often ask me "why not filter in software?" and the answer is that we only sample once every 5 seconds, thus we would need to take more sample and run some sort of median or averaging algorithm to filter out the noise. This eliminates post-processing and allows direct viewing of the data. However, engineers might be interested in experimenting with the RC values or even eliminating the RC circuit so that real-time monitoring of lightning and possible GRB (Gamma Ray Bursts) would be possible (it would also require to increase the cadence of the data logging, etc.)

Audio Output

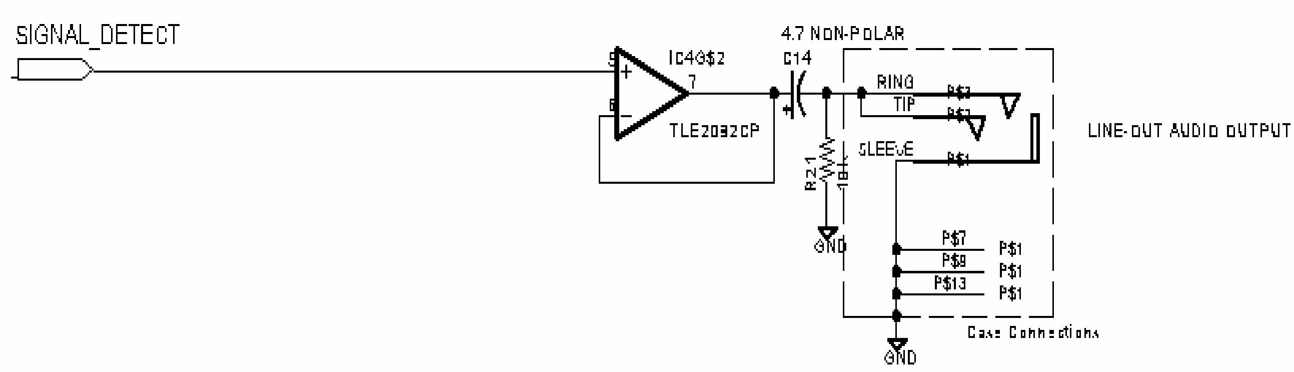


Figure 13: Audio Output

IC4 G$2 is a unity-gain buffer, C_{14} isolates the DC component to the line-out level audio output to be connected to amplified speakers – do not connect directly to an 8 ohm speakers or headphones without an amplifier. The connector is a stereo connector with the left and right channels connected together.

As of the writing of this document it is still unknown why plugging in the speaker would cause a dip in the signal strength level, perhaps there is some ground loop problem that has not been detected (both devices are powered by wall transformers). Whatever the cause, audio monitoring lowers the signal strength.

DATAQ Output Circuit

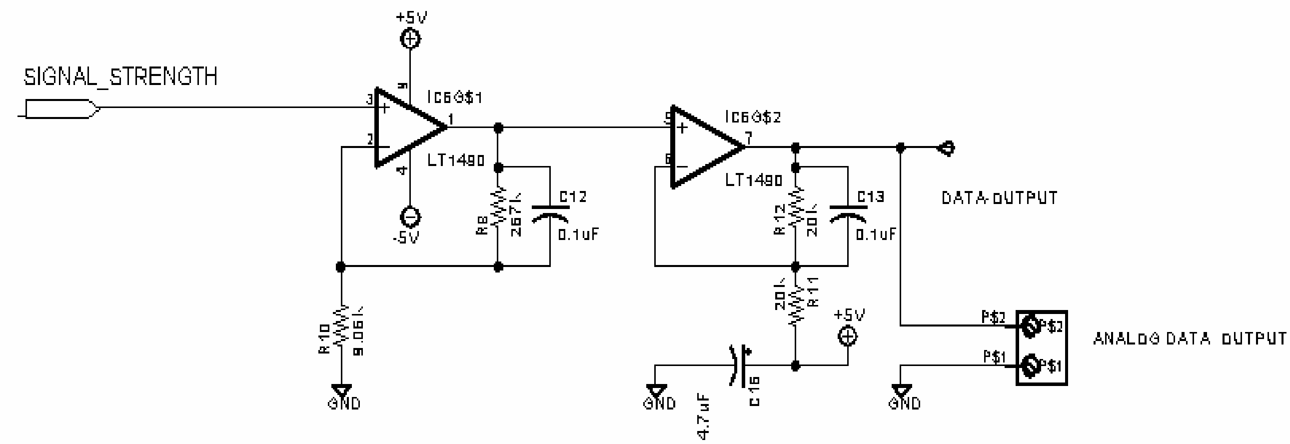


Figure 14: DATAQ Output Circuit

The LT1490 op amp allows voltages to swing from rail-to-rail. Stage 1 (IC6 G$1) has a gain of 33.127 ($A = R_8 / R_{10}$ = 267KΩ / 8.06KΩ ∴ A = 33.127). C_{12} and C_{13} dampen fluctuations and spikes. C_{16} stabilizes the voltage on the input to form a stable reference. Stage 2 (IC6 G$2) is a voltage shifter with a gain of 1. The shifter works because the (-) input is tied to +5 volts through R_{11}, the inverter input makes the output to go to –5 Volts, the midpoint between R_{12} and R_{11} form a summing point therefore translates the input DC level to –5 volts to + 5 volts, a 10 volt range, thus making the overall signal easy enough for the DATAQ to read over it's 20 volt / 10 bit range (approximately 0.0195 volts per bits).

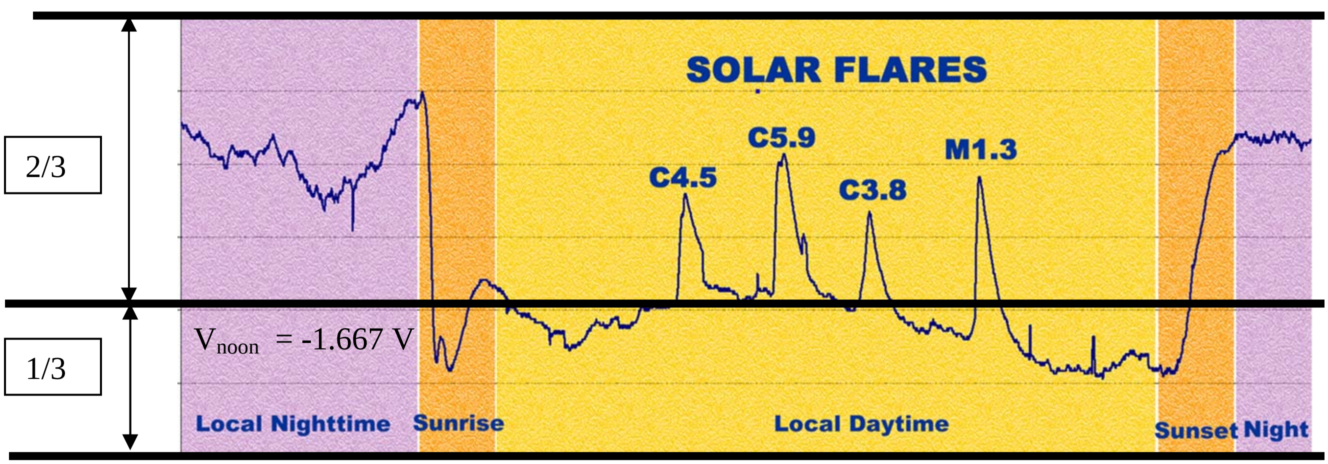


Figure 15: DATAQ Output Calibration Notes

The reason why user's manual suggests setting the RF gain to –1.25 to –1.5 volts at noontime is because while developing the SIDMON we had to resolve the problem of determining how much headroom was required to record M- and X-class flares while not sacrificing resolution for the C-Flares. The value of –1.5 volts was derrived by approximately using the first 1/3 of the graph to allow for noon – the highest point on the graph for daytime allowing the other 2/3 of the graph to be able to record the largest flares, and this level is usually still much higher than sunrise and sunset levels.

V_{noon} = 1/3 (10 volts absolute range) – 5volts = -1.667 Volts

Appendix A: Component Placement

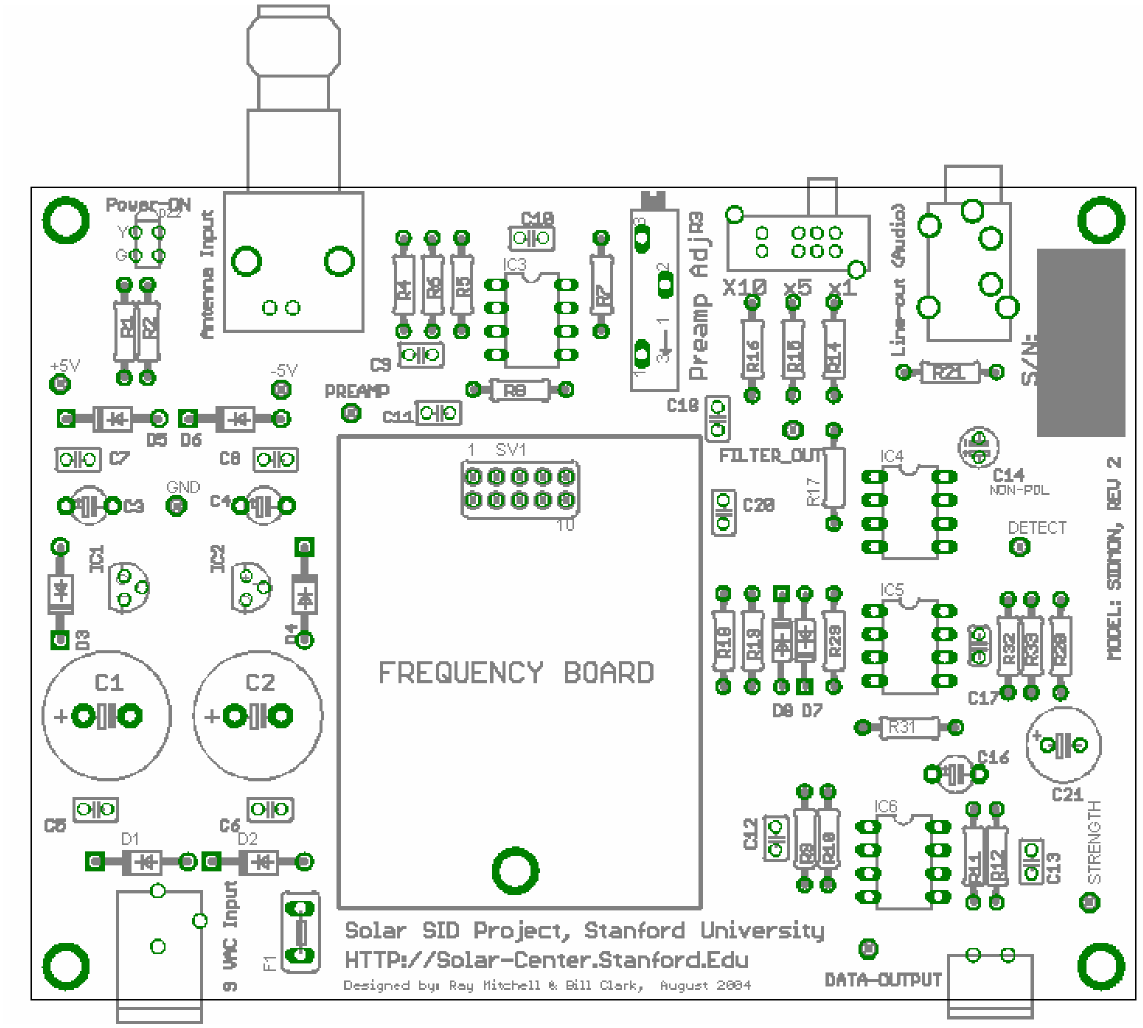


Figure 16: SIDMON Component Placement

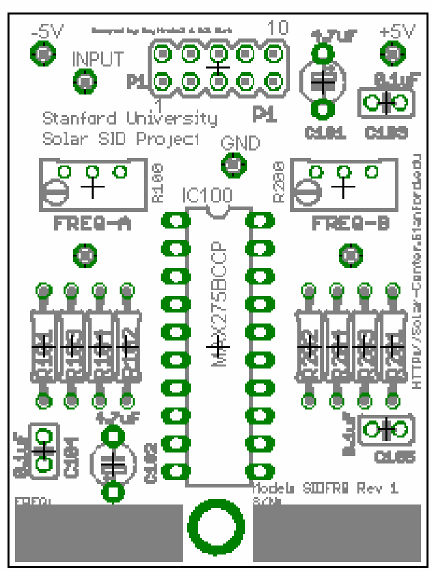


Figure 17: FREQBOARD Component Placement

Appendix B: SIDMON PCB Artwork

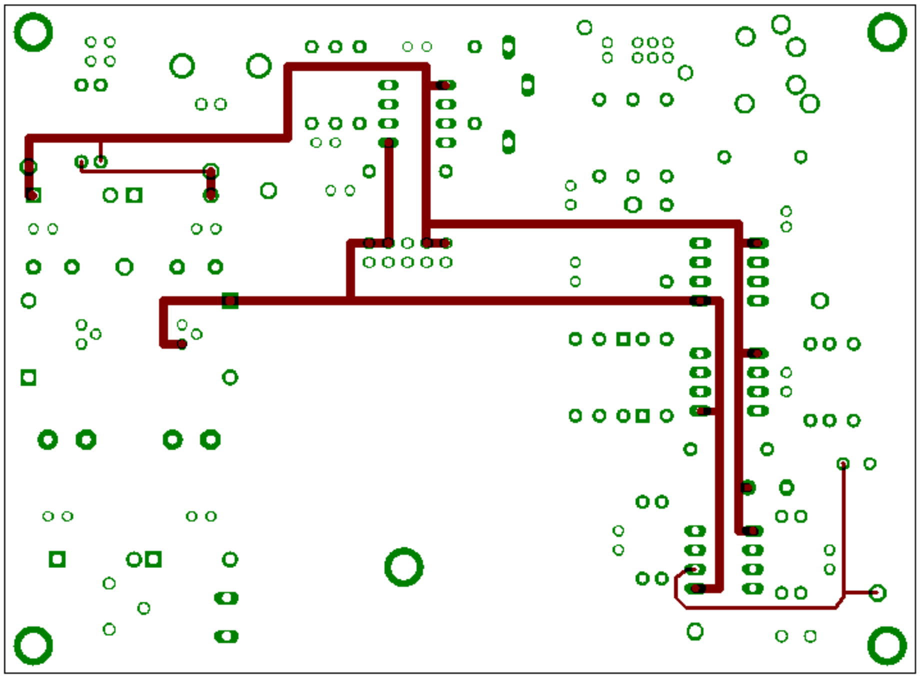


Figure 18: SIDMON PCB Top Layer

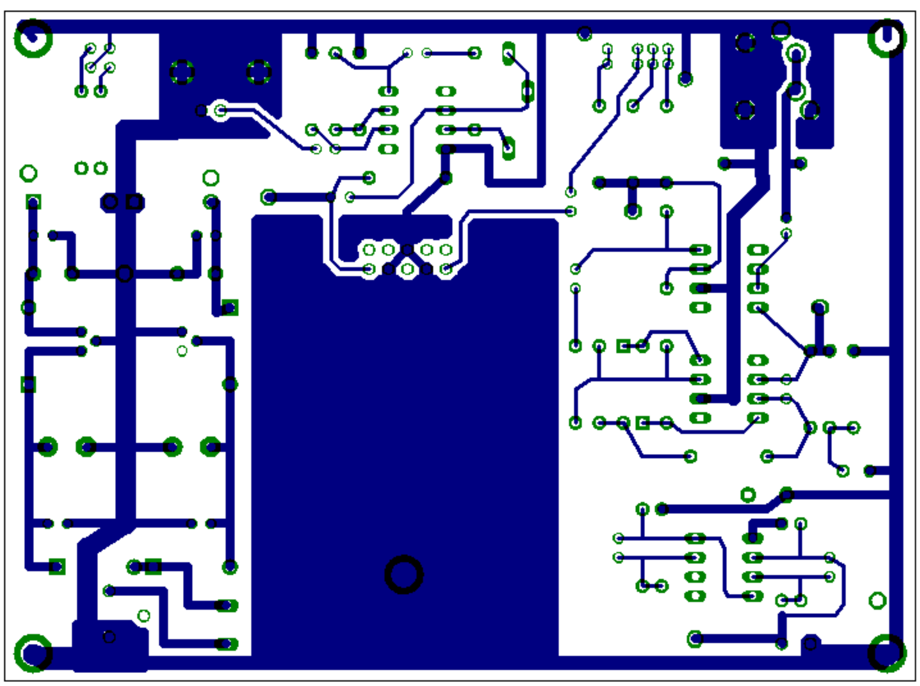


Figure 19: SIDMON PCB Bottom Layer

Appendix C: FREQBOARD PCB Artwork

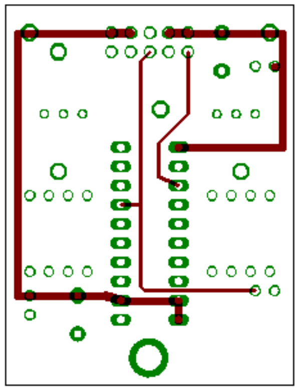


Figure 20: FREQBOARD PCB Top Layer

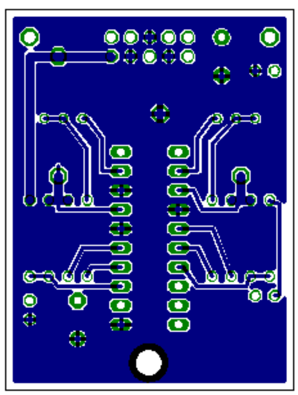


Figure 21: FREQBOARD PCB Bottom Layer

Appendix D Test Points Glossary

SIDMON

Test Point Name	**Meaning**
-5v	-5 Volt supply
+5v	+5 Volt supply
GND	Ground (0 volt / reference)
PREAMP	Antenna signal output from first two stages
FILTER OUT	Return signal from Frequency board, (should have been output of Op Amp IC4 G$1)
DETECT	Output of the full-wave signal rectifier
STRENGTH	Integrated signal (DC level)
DATA OUTPUT	Shifted (DC level)

FREQBOARD

Test Point Name	**Meaning**
-5v	-5 Volt supply
+5v	+5 Volt supply
GND	Ground (0 volt / reference)
FREQ A	First stage frequency filter (used for calibration)
FREQ B	Second stage frequency filter (used for calibration), Same as “FILTER_OUT” Test Point signal on SIDMON board

Appendix E: Parts List

Part#	Part Description	Schematic Designation	Vendor
80-C315C104M5U	0.1uF Monolithic	C5, C6, C7, C8, C9, C10, C11, C12, C13, C18, C20, C103, C104, C105	MOUSER
140-50N2-120J	12 pF	C17	MOUSER
140-XRL25V2200	2200uF	C1, C2	MOUSER
140-NPRL50V4.7	4.7 NON-POLAR	C14	MOUSER
399-1302-ND	4.7uF Tant. Cap	C3, C4, C101, C102	DIGI-KEY
140-XRL10V470	470uF	C21	MOUSER
1N4001RLOSCT-ND	1N4001	D1, D2, D3, D4, D5, D6	DIGI-KEY
1N914CT-ND	1N914A	D7, D8	DIGI-KEY
350-1403-ND	LZR182, LED 2-Color	DZ1	DIGI-KEY
AN78L05-ND	78L05	IC1	DIGI-KEY
AN79L05-ND	79L05	IC2	DIGI-KEY
296-1874-5-ND	TLE2082CP	IC3, IC4, IC5	DIGI-KEY
LT1490CN8-ND	LT1490	IC6	DIGI-KEY
MAX275BCPP-ND	MAX275BCCP	IC100	DIGI-KEY
271-100K	100K	R17	MOUSER
271-10K	10K	R7, R8, R18, R19, R21, R29, R31, R32	MOUSER
271-1K	1K	R1, R2, R5	MOUSER
271-2.2K	2.2K	R4	MOUSER
271-20K	20K	R11, R12, R33, R15	MOUSER
271-200K	200K	R3, R6, R101, R201	MOUSER
271-267K	267K	R9	MOUSER
271-4.7K	4.7K	R10	MOUSER
271-40.2K	40.2K	R20	MOUSER
271-49.9K	49.9K	R14	MOUSER
271-549K	549K	R103, R203	MOUSER
271-75K	75K	R104, R204	MOUSER
271-76.8K	76.8K	R102, R202	MOUSER
271-8.06K	8.06K	R10	MOUSER
72-T93YA-10K	10K Pot Vertical Adj.	R100, R200	MOUSER
652-3006P-1-204	200K Pot Horizontal Adj.	R3	MOUSER
612-EG2308	DP3T	SW1	MOUSER
652-MFR025	Resettable fuse	F1	MOUSER
8400K-ND	4-40, .375 Male/Female Standoff	N/A	DIGI-KEY
H342-ND	4-40 1/4" Screw	N/A	DIGI-KEY
H236-ND	4-40 Internal tooth Star Washers	N/A	DIGI-KEY
H216-ND	4-40 Nut	N/A	DIGI-KEY
CP-102AH-ND	Power Jack: 2.1x5.5mm	J1	DIGI-KEY
A24648-ND	RF Connect JACK TNC Right Angle	J2	DIGI-KEY
651-1803578	Analog output mating Screw terminal	N/A (external part – mates with J4)	MOUSER
651-1803277	Analog Output, PCB Mount	J4	MOUSER
161-3153	Audio output: 3.5mm Stereo jack	J3	MOUSER
649-69168-110	Board-to-Board Male	P1	MOUSER
649-68683-305	Board-To-Board Female	SV1	MOUSER
#210745	10 VAC Transformer	N/A	JAMECO
MM-11892	Chassis	N/A	MARTINEK
P82368	SIDMON PCB (REV 2)	N/A	ADV. CIR.
P73970	FREQBOARD PCB (REV 1)	N/A	ADV. CIR.
DI-194RS	DATA Acquisition Module	N/A	DATAQ

Appendix F: Schematics

+5/-5 Volt Power Supply

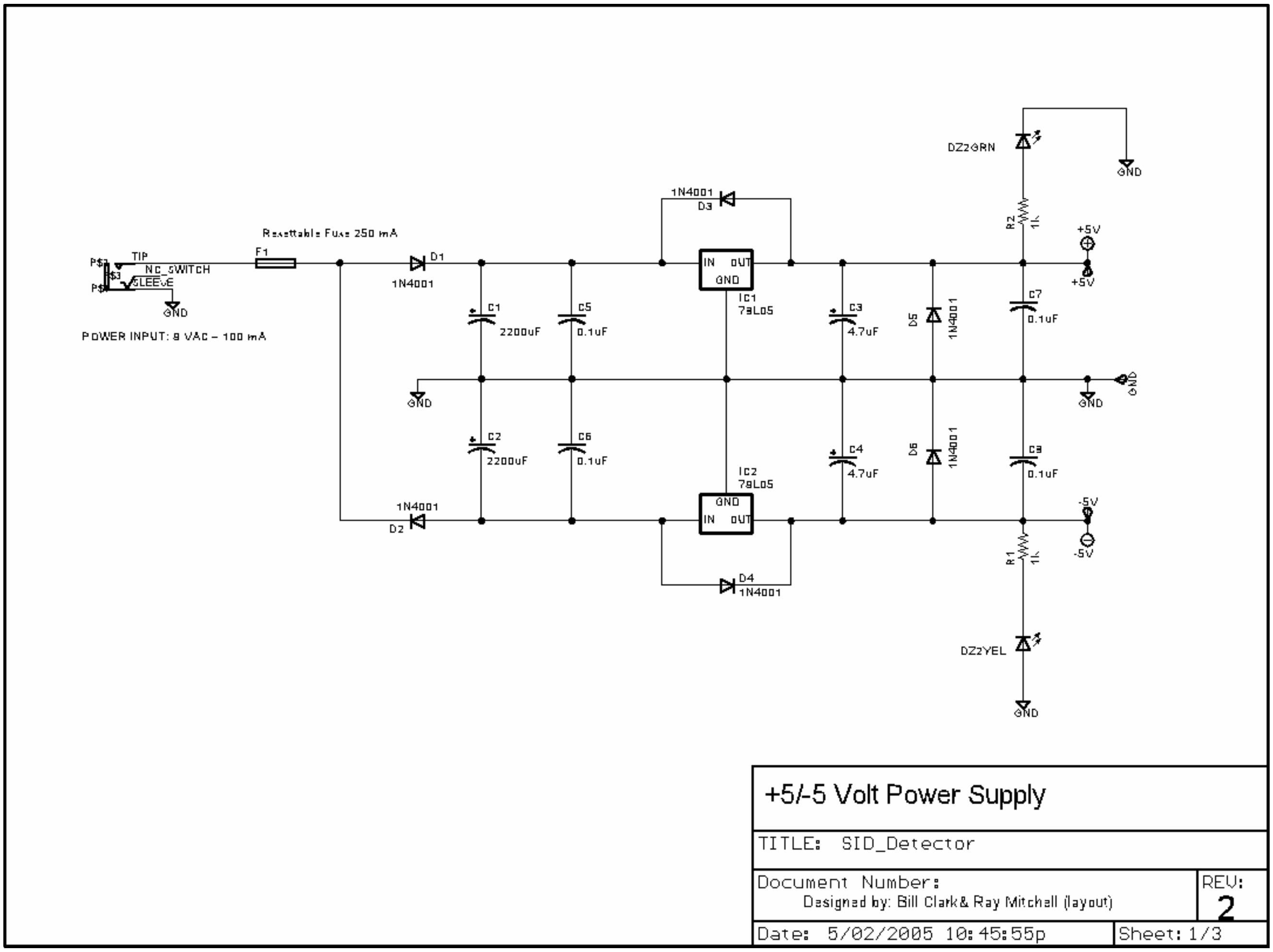


Figure 22: +5/-5 Volt Power Supply

Pre/Post Amplifiers

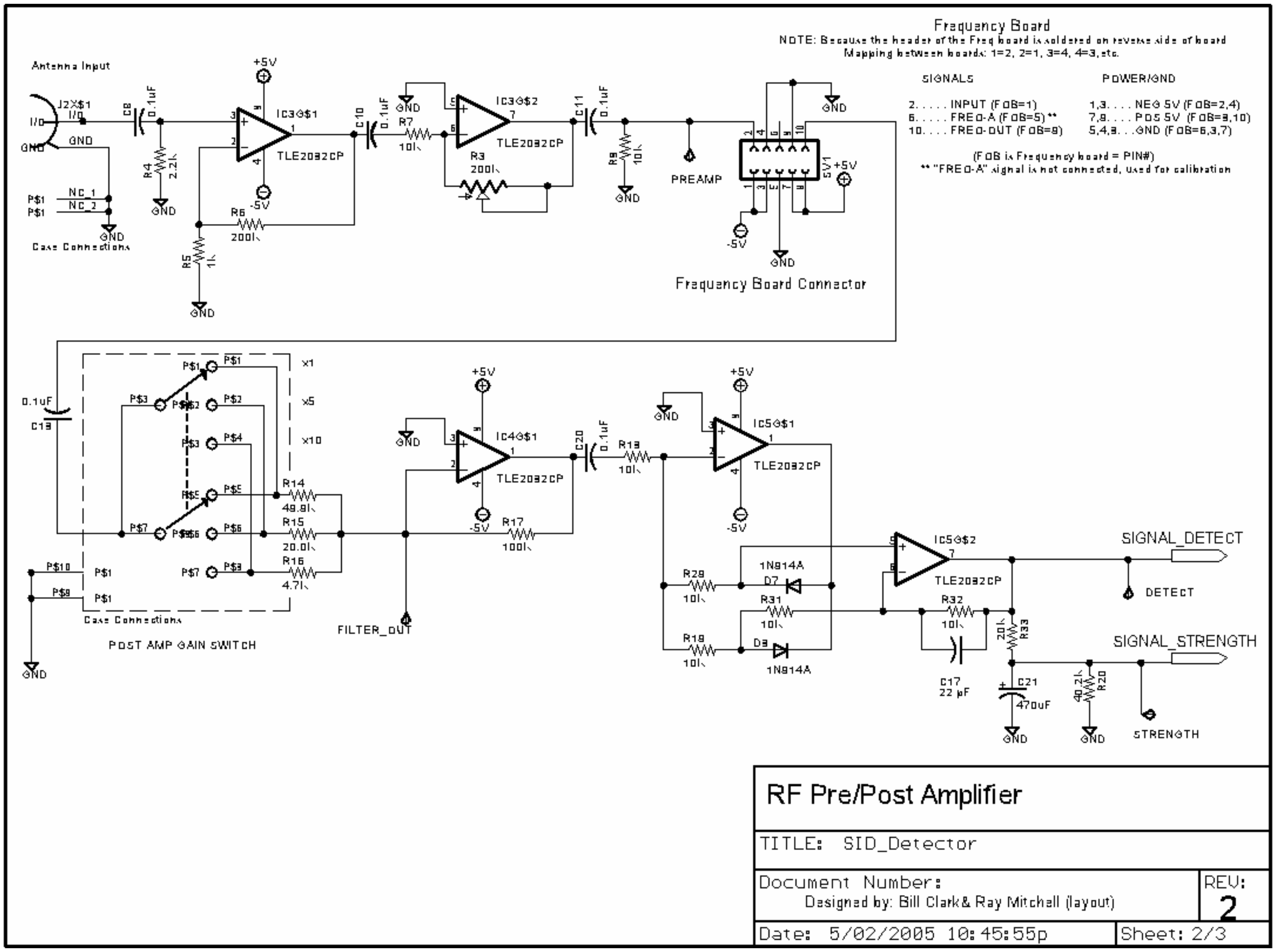


Figure 23: Pre/Post Amplifier

Audio and Analog Data Outputs

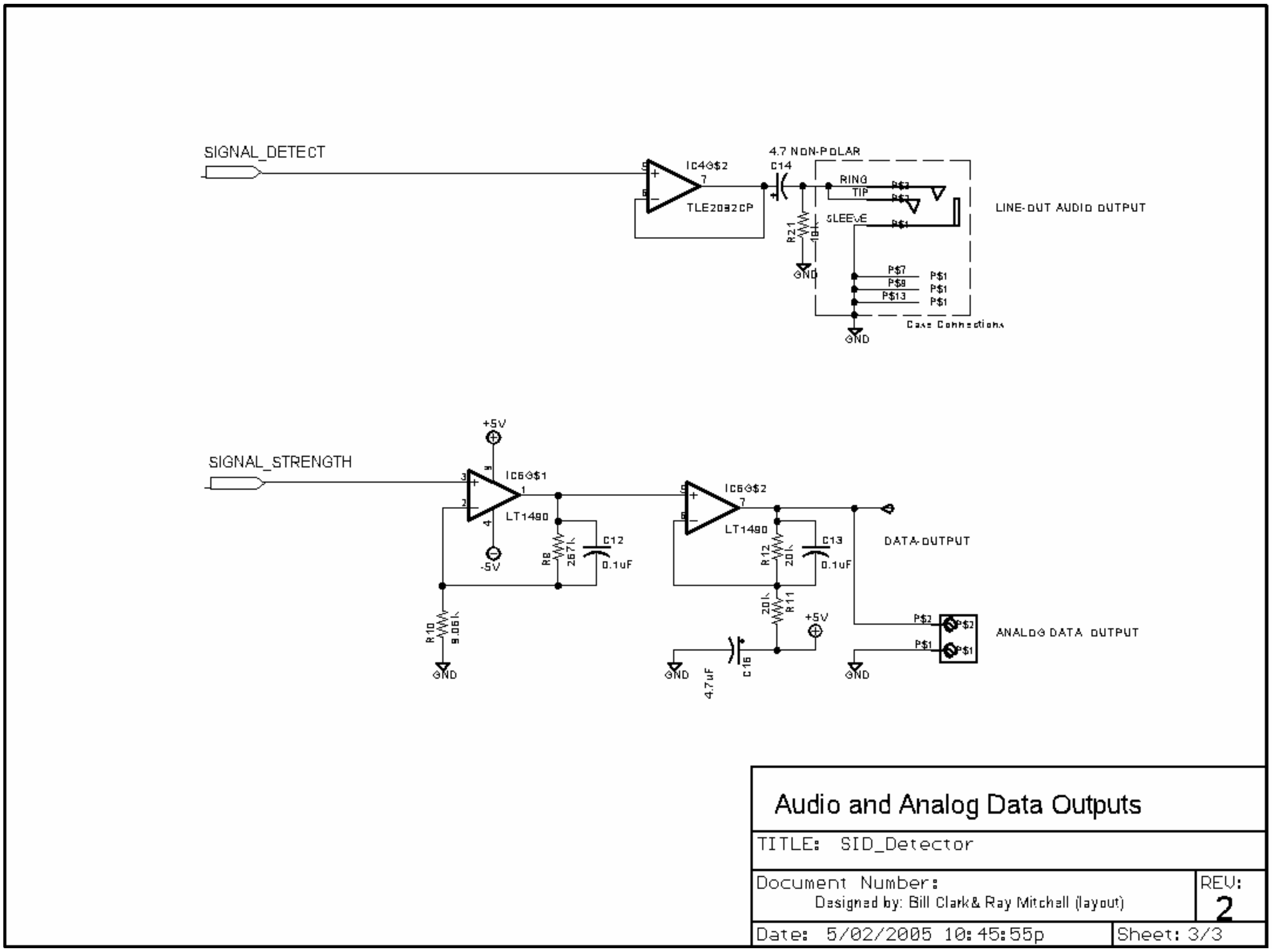


Figure 24: Audio and Analog Data Outputs

Frequency Tuning Board

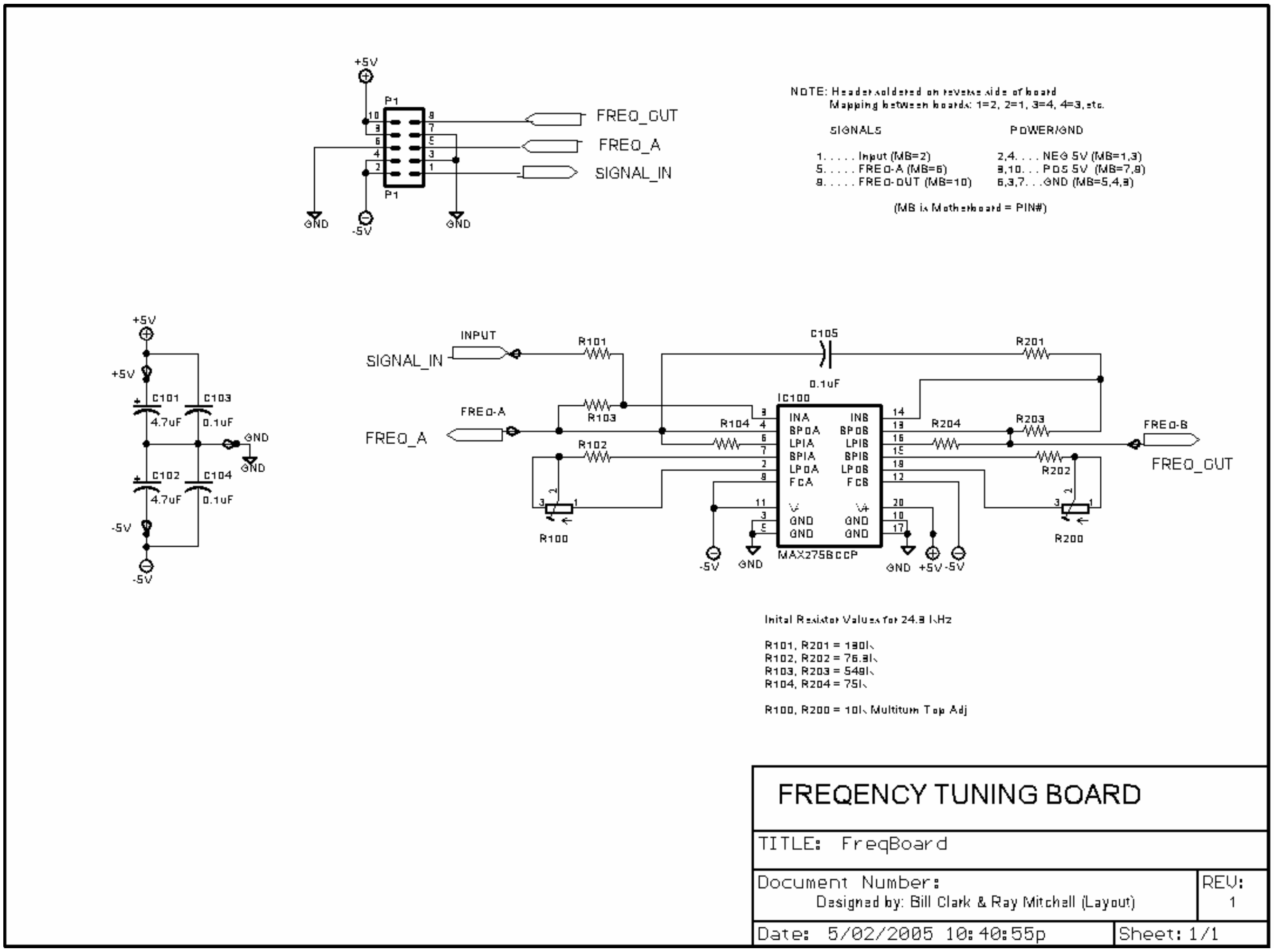


Figure 25: Frequency Tuning Board