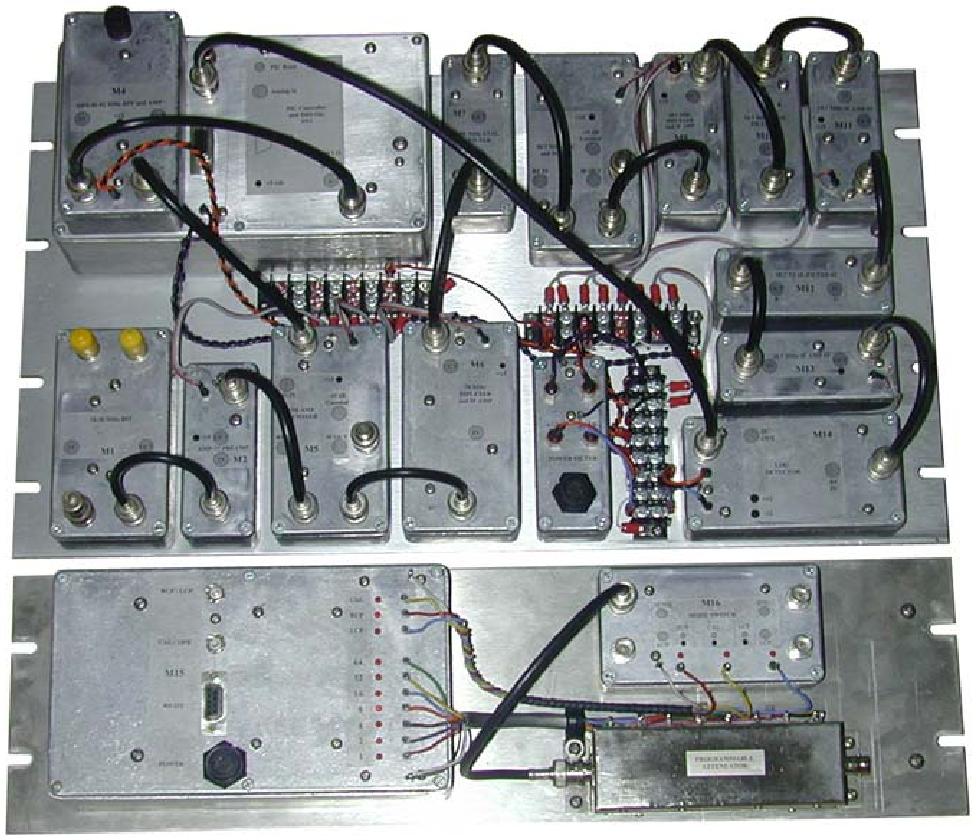
FS-200B Radio Spectrograph System

Instruction Manual

December 2003



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FS-200B Radio Spectrograph System

The FS-200B radio spectrograph system includes a radio spectrograph receiver, mode switch/calibrator, computer, controlling software, and power supply.

Spectrograph

The spectrograph receiver has a pre-detection bandwidth of 30 kHz and steps thru 200 channels in the frequency range 18 to 30 MHz ten time each second. A wide dynamic range log-detector develops an analog voltage proportional to signal strength as the spectrograph steps thru each channel. This analog voltage is digitized and passed to the computer for processing and display. The spectrograph frequency is set by a direct digital synthesis (DDS) oscillator controlled by a microcontroller (PIC), which communicates with the main computer via an RS232 serial link.

Mode Switch/Calibrator

The mode switch selects the RF source for the spectrograph – for the Florida installation this is either RCP, LCP or a calibrator. The calibrator comprises a high temperature RF noise source followed by a commercial programmable attenuator. The step attenuator and mode switch are controlled by a microcontroller (PIC), which communicates with the main computer via an RS232 serial link.

Computer

An HP a300y desktop computer with a 2.4 GHz processor and 512M of RAM is used to control the FS-200B system. An expansion card has been added to the computer so that it has two serial ports – one for communications with the DDS PIC and the second for communication with the Mode/Cal PIC. The a300y runs custom spectrograph software that allows remote control of the instrument as well as streaming of spectrograph data over the Internet. Connectivity to the observatory LAN is via Ethernet.

Spectrograph Software

Custom spectrograph software running on the a300y computer communicates with both PIC microcontrollers and also generates a local spectrogram display, streams data to the Internet for remote viewing using custom client software, and provides an interface for remote control of the instrument.

Power Supply

An Elenco Quad power supply provides +5, +12, -12 and +15 volts to the spectrograph system through two power cables – one connecting to the spectrograph receiver and one to the mode switch/calibrator assembly.

A block and signal flow diagram of the FS-200B system is seen in Figure 1. Functional modules are designated as M1 thru M16 – these are individual modules mounted on two 19” rack panels. The spectrograph receiver itself comprises modules M1 thru M14 while the mode switch/calibrator includes M15 and M16.

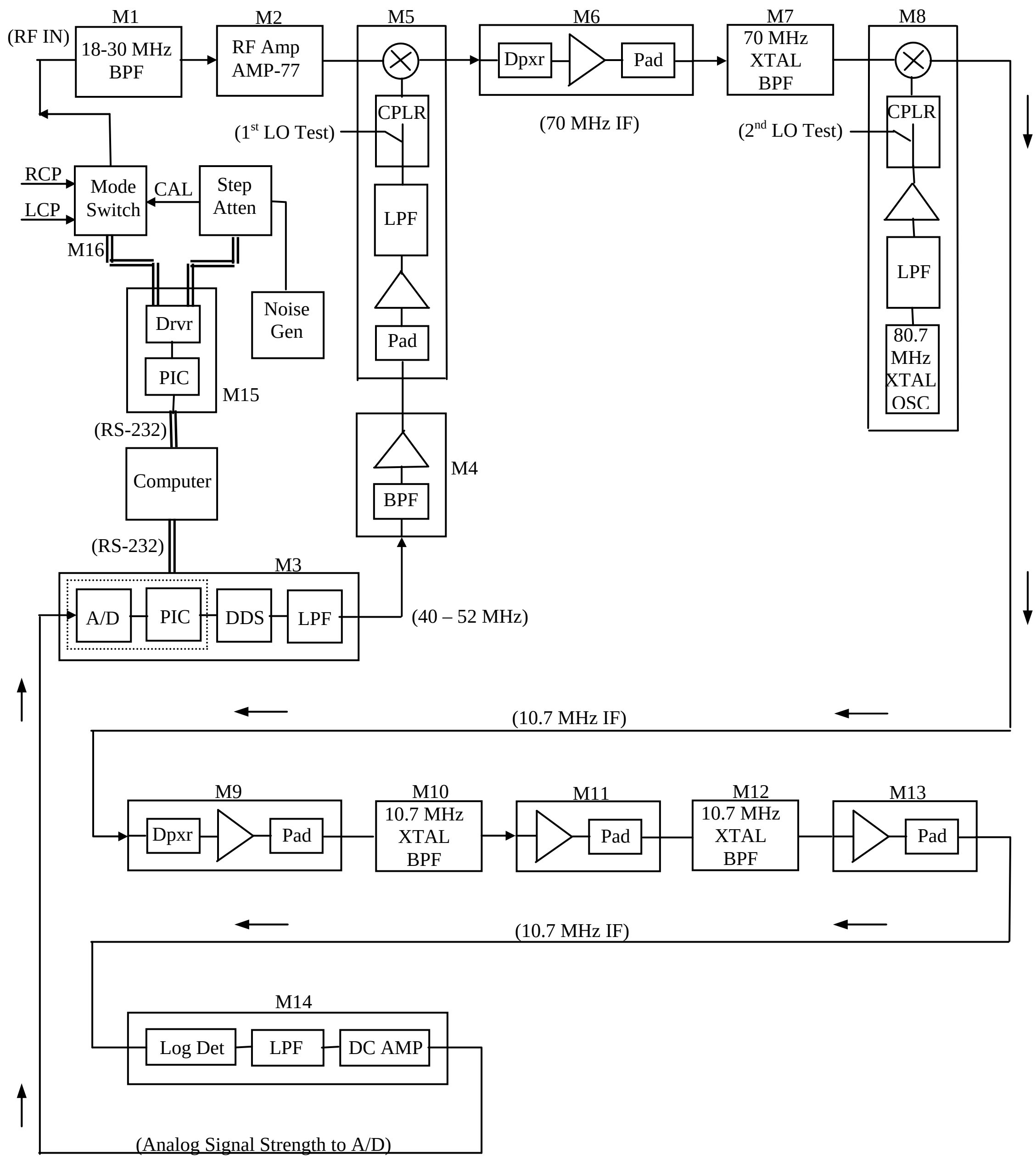


Figure 1 FS-200B Radio Spectrograph functional modules and signal flow

Signal Flow

The FS-200 radio spectrograph is a dual conversion superheterodyne design that operates in the range of 18 to 30 MHz. High level (+17dBm) mixers provide strong signal handling capability.

A direct digital synthesis (DDS) oscillator operating between 40 and 52 MHz serves as the 1st local oscillator (LO). This oscillator steps thru 200 frequencies 10 times each second. The sweep range of the oscillator may be changed remotely via control software so that the spectrograph views different segments of the 18 to 30 MHz range in greater detail. The number of channels (200) and the sweep rate (200 channels per 0.1 seconds) are fixed. If a total sweep range of 18 to 28 MHz (10 MHz wide) is selected, then each channel is separated from its neighbors by 50 kHz. If a sweep range of 6 MHz is selected then the channel separation is 30 kHz.

The 1st IF frequency is 70 MHz. A 50 kHz wide, 70 MHz crystal filter protects the second mixer from strong out of band signals. An 80.7 MHz crystal controlled oscillator serves as the 2nd LO. The 2nd IF frequency is 10.7 MHz and an IF bandwidth of 30 kHz is determined by a pair of 4-pole crystal filters.

A sensitive, wide dynamic range log-detector develops an output voltage proportional to the log of the input power. The detector develops a DC output voltage that changes by 25 millivolts for each 1dB of change of input power. A low pass filter and a DC amplifier with variable gain and offset controls follow the detector. The resulting signal feeds a 10-bit analog to digital converter.

The log-detector itself (an Analog Devices AD8307) is extremely sensitive with a minimum detectable signal below –70 dBm. The 10.7 MHz IF signal delivered to the log-detector from the last IF amplifier is set to approximately –65 dBm.

RF Analysis

The signal flow diagram (Figure 2) shows the distribution of gains and losses within the spectrograph as well as in that portion of the UFRO RF system preceding the spectrograph. Net gain as measured from the antenna terminals (at the top of a TP antenna) are shown in little "lollipop" circles between each RF stage. Gains, noise figures, and losses of each circuit element are included in the signal flow diagram.

Signal levels may be calculated at any point in the system given the input signal at the antenna. For the sake of this analysis it is assumed that the antenna temperature due to the galactic background is 40,000 degrees. This is equivalent to a –108dBm signal in a 30 kHz bandwidth. Given this antenna temperature, the output of the UFRO system (the input to M1 - the spectrograph bandpass filter) is –98 dBm with a signal level of –41 dBm developed at the input to the log-detector. This is almost 25 dB more signal than required at the input of the log-detector and is a result of excess gain being built into the spectrograph. In operation at UFRO the total spectrograph gain will be reduced either by setting of the step attenuator, insertion of attenuator pads, or removal of the final IF-amplifier stage (M13). The gain will be reduced to achieve a signal input level of approximately –65 dBm at the input to the log detector.

System Noise Figure

Noise figure and system temperature calculations have been performed at 3 different reference points using an Excel spreadsheet.

1. Input to the spectrograph bandpass filter M1. NF = 5.9dB, Tsys=852 deg K

2. Input of the UFRO bandpass filter in the field. NF = 5.1dB, Tsys = 646 deg K

3. Calculated at TP antenna terminals. NF = 8.1dB, Tsys=1578 deg K

Receiving system noise compared to the galactic background level is insignificant.

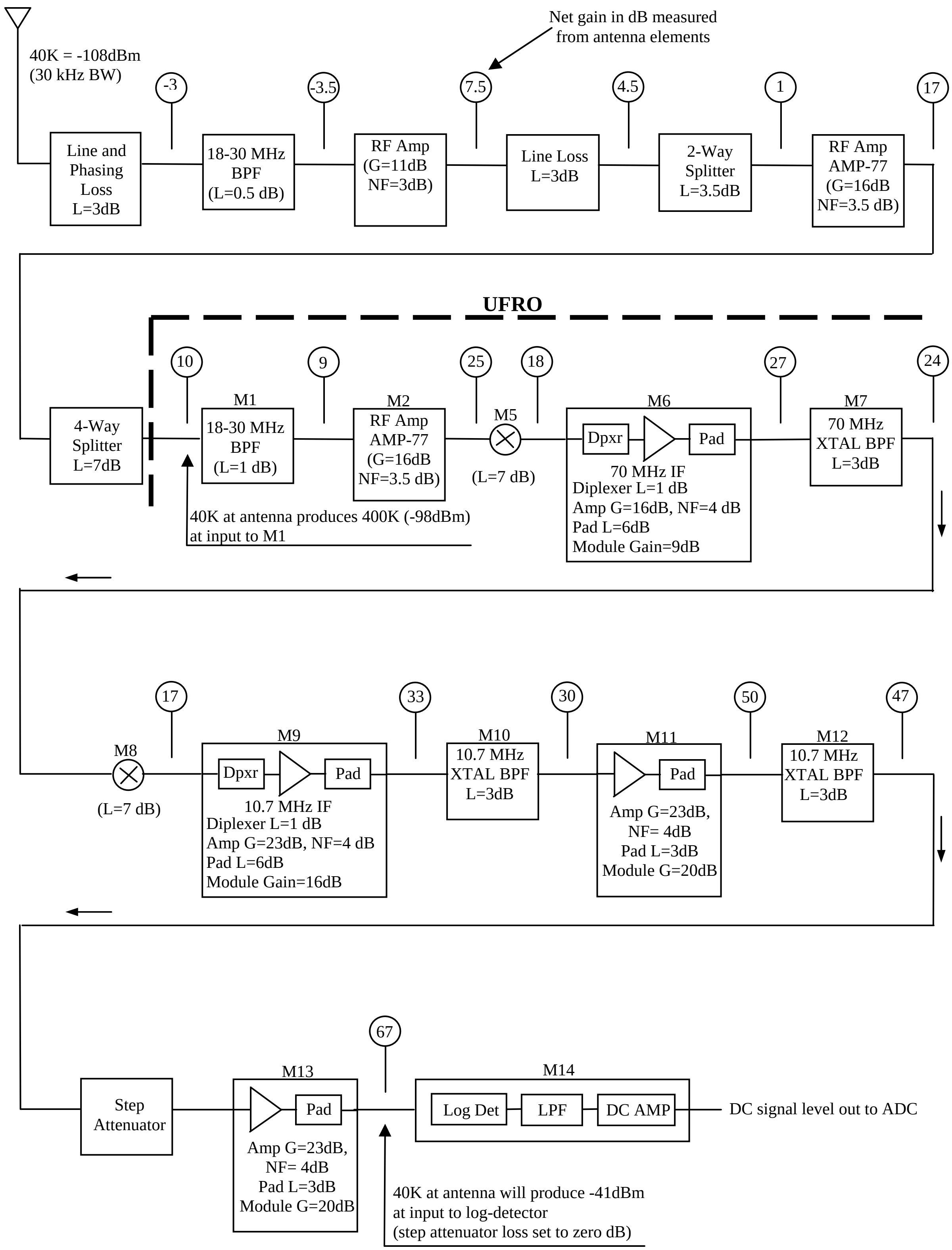


Figure 2 FS-200 system gains and losses as installed at UFRO

Loss 1 in dB	1	1.259	75.09	-1	
Gain 1 in dB	16	39.811		15	
NF 1 in dB	3.5	2.239	452.2		
Loss 2 in dB	8	6.310	48.69	7	
Gain 2 in dB	16	39.811		23	
NF 2 in dB	4	2.512	87.48		
Loss 3 in dB	17	50.119	71.39	6	Tsys =
					852.007
Gain 3 in dB	23	199.526		29	
NF 3 in dB	4	2.512	110.13		
					NF =
Loss 4 in dB	9	7.943	2.53	20	5.95
Gain 4 in dB	23	199.526		43	
NF 4 in dB	4	2.512	4.38		
Loss 5 in dB	3	1.995	0.01	40	
Gain 5 in dB		1.000		40	
NF 5 in dB	4	2.512	0.04		
Loss 6 in dB		1.000	0.00	40	
Gain 6 in dB		1.000		40	
NF 6 in dB		1.000	0.00		

FS200 System Noise Figure and Temperature as measured at input to bandpass filter M1

Loss 1 in dB	0.5	1.122	35.39	-0.5	
Gain 1 in dB	11	12.589		10.5	
NF 1 in dB	3	1.995	323.8		
Loss 2 in dB	6.5	4.467	89.60	4	
Gain 2 in dB	16	39.811		20	
NF 2 in dB	3.5	2.239	143.01		
Loss 3 in dB	8	6.310	15.40	12	Tsys =
					646.179
Gain 3 in dB	16	39.811		28	
NF 3 in dB	3.5	2.239	22.67		
					NF =
Loss 4 in dB	8	6.310	2.44	20	5.09
Gain 4 in dB	16	39.811		36	
NF 4 in dB	4	2.512	4.38		
Loss 5 in dB	17	50.119	3.58	19	
Gain 5 in dB	23	199.526		42	
NF 5 in dB	4	2.512	5.52		
Loss 6 in dB	9	7.943	0.13	33	
Gain 6 in dB		1.000		33	
NF 6 in dB	4	2.512	0.22		

FS200 System Noise Figure and Temperature as calculated at input to bandpass filter in field

Loss 1 in dB	3.5	2.239	359.23	-3.5	
Gain 1 in dB	11	12.589		7.5	
NF 1 in dB	3	1.995	646.2		
Loss 2 in dB	6.5	4.467	178.79	1	
Gain 2 in dB	16	39.811		17	
NF 2 in dB	3.5	2.239	285.35		
Loss 3 in dB	8	6.310	30.72	9	Tsys =
					1577.922
Gain 3 in dB	16	39.811		25	
NF 3 in dB	3.5	2.239	45.22		
					NF =
Loss 4 in dB	8	6.310	4.87	17	8.09
Gain 4 in dB	16	39.811		33	
NF 4 in dB	4	2.512	8.75		
Loss 5 in dB	17	50.119	7.14	16	
Gain 5 in dB	23	199.526		39	
NF 5 in dB	4	2.512	11.01		
Loss 6 in dB	9	7.943	0.25	30	
Gain 6 in dB		1.000		30	
NF 6 in dB	4	2.512	0.44		

FS200 System Noise Figure and Temperature as calculated at antenna terminals

Radio Spectrograph Receiver Functional Modules (M1 thru M14)

The spectrograph receiver is a dual conversion design with a 70 MHz 1st IF followed by a 10.7 MHz 2nd IF amplifier. The function of each module is described briefly below.

M1 – This **18 to 30 MHz bandpass filter** passes the desired band of RF signals from the antenna and provides image rejection and overload protection from out of band signals to the following RF preamplifier stage. In-band insertion loss is 1 dB or less.

M2 – The broadband **RF-preamplifier** has 16 dB of gain, a 3.5 dB noise figure and 50 ohm input and output impedance providing a good power match to the input filter (M1) and to the following mixer.

M3 – The **PIC microcontroller and DDS oscillator** generates the 1st local oscillator signal, which is stepped thru 200 channels in the frequency range 40 to 52 MHz. The output of the DDS is passed thru a 70 MHz elliptic low pass filter to reduce out of band spurious signals generated by the DDS. RF output from M3 is at a level of –9 dBm.

M4 –The **DDS local oscillator bandpass filter and amplifier** further filters out-of-band oscillator signals and amplifies the desired LO signal to a level of +1.5 dBm.

M5 – amplifier and filter to further condition the 1st LO signal to drive the double balanced **mixer** (DBM) at a level of +17dBm. In addition, a 19.2 dB directional coupler is included to provide a sample of the LO signal for test purposes. With an RF signal from M2 in the range of 18 to 30 MHz and a 1st LO signal in the range of 52 to 40 MHz the 1st IF frequency is 70 MHz.

M6 – A **diplexer** provides a broadband low VSWR termination for the mixer IF port. The **70 MHz IF amplifier** includes a 6 dB, 50 ohm pad on the output to provide a good impedance match, both to the following filter and also to the IF amplifier itself.

M7 – The **1st IF (70 MHz) crystal filter** has an input and output impedance of 50 ohms, a 3 dB bandwidth of 50 kHz, and a center frequency insertion loss of 3 dB.

M8 – The **2nd local oscillator mixer assembly** generates a crystal controlled 80.7 MHz signal at a level of +17 dBm. A 19.2 dB directional coupler is included to provide a sample of the 2nd LO signal for test purposes. With a 1st IF signal frequency of 70 MHz and a 2nd LO of 80.7 MHz the 2nd IF frequency is 10.7 MHz.

M9 - A **diplexer** provides a broadband low VSWR termination for the mixer IF port. The **10.7 MHz IF amplifier** includes a 6 dB, 50 ohm pad on the output to provide a good impedance match, both to the following filter and also to IF amplifier itself.

M10 – This **4 pole 10.7 MHz crystal filter** has a 3 dB bandwidth of 30 kHz. The 5K ohm filter elements are impedance matched to 50 ohms. Insertion loss is 3 dB.

M11 – A high dynamic range **10.7 MHz IF amplifier** followed by a 3 dB pad provides a net gain of 20 dB.

M12 - This **4 pole 10.7 MHz crystal filter** has a 3 dB bandwidth of 30 kHz. The 5K ohm filter elements are impedance matched to 50 ohms. Insertion loss is 3 dB.

M13 - A high dynamic range **10.7 MHz IF amplifier** followed by a 3 dB pad provides a net gain of 20 dB.

M14 – The **logarithmic detector** which has a dynamic range in excess of 35 dB is followed by a 2 kHz **low pass filter** matched to the 0.5 msec per channel dwell time of the stepped oscillator. The LPF feeds a **DC amplifier** with variable offset and gain controls. The DC amplifier output signal, which lies in the range of 0 to +5 vdc, is fed to the DDS PIC (in M3) where it is processed by a 10 bit A/D converter within the PIC.

The spectrograph receiver modules are mounted on a 10.5” by 19”wide rack panel and interconnected using BNC terminated RG-58 coax jumpers. Wherever possible the modules have been designed with 50 ohm input and output impedances to facilitate testing. The physical layout of the modules and their interconnecting signal cables is seen in Figure 3.

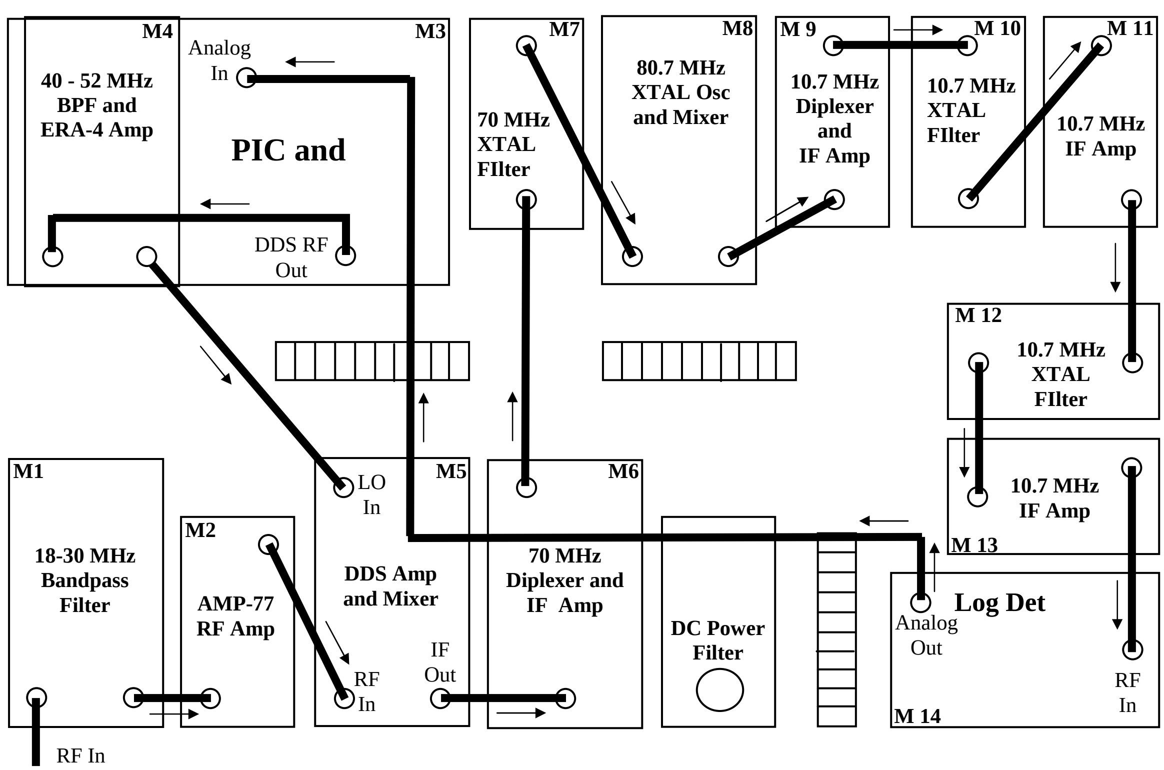
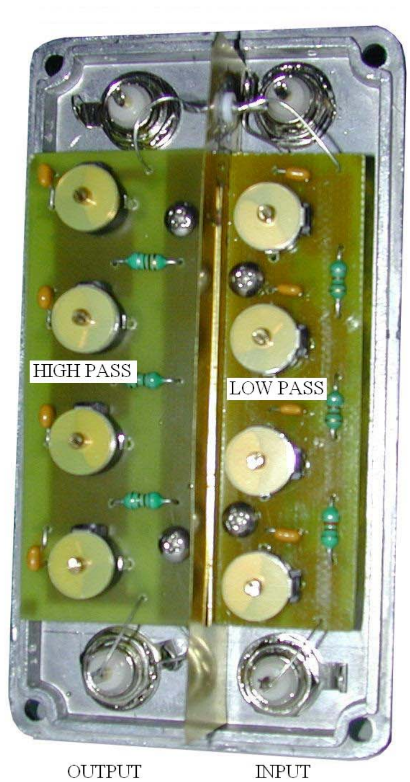
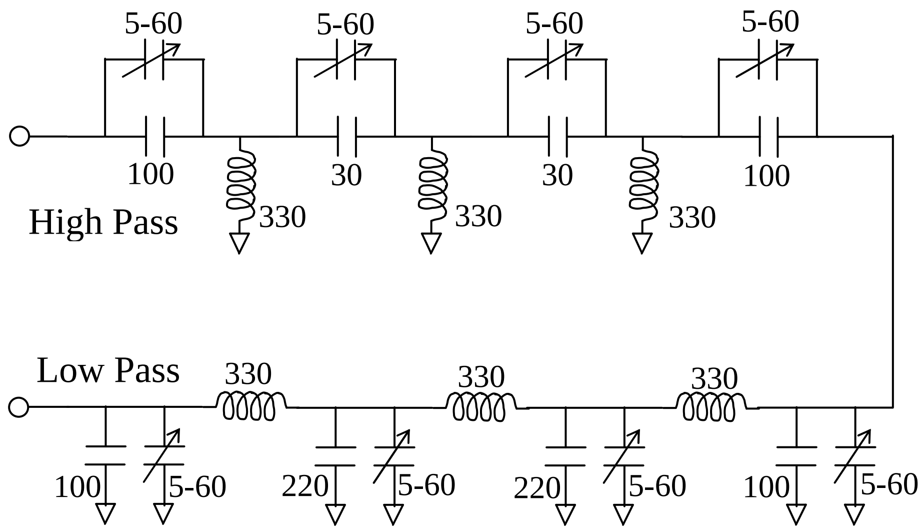


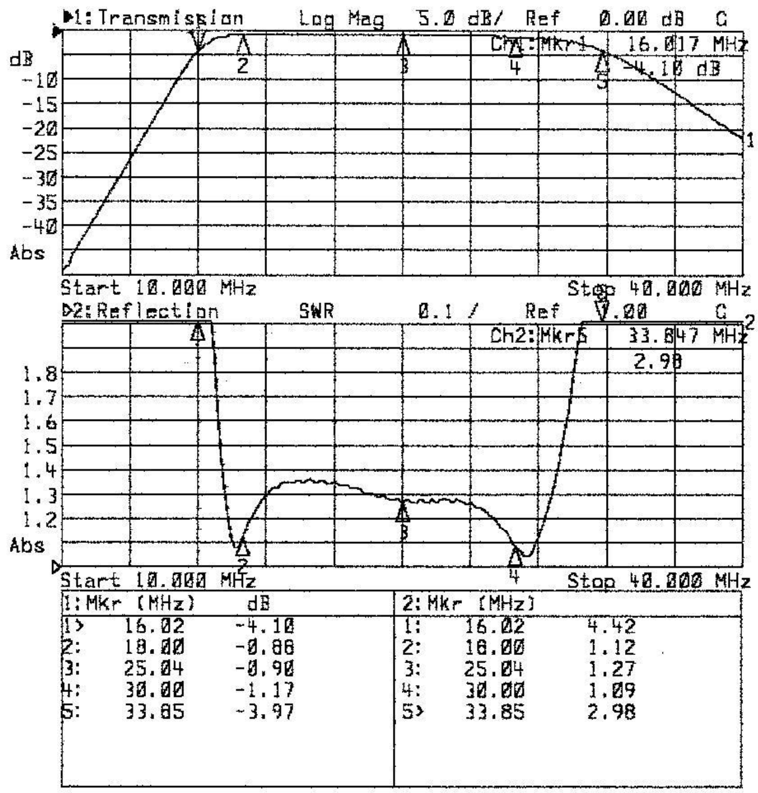
Figure 3 Spectrograph receiver module locations and interconnecting coax jumpers.

M1
18-30 MHz Bandpass Filter

The 18-30 MHz RF band pass filter includes a low pass and a high pass filter. Total in-band insertion loss is 1 dB or less, and input and output VSWR is under 1.5:1.



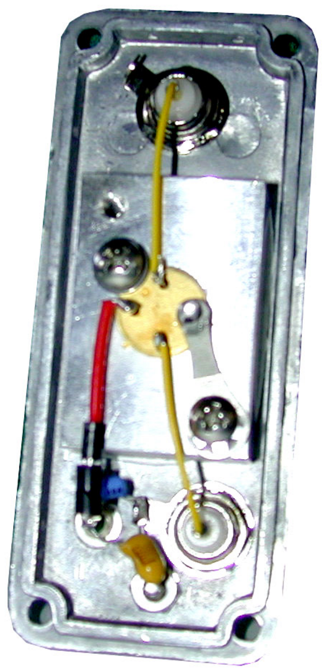


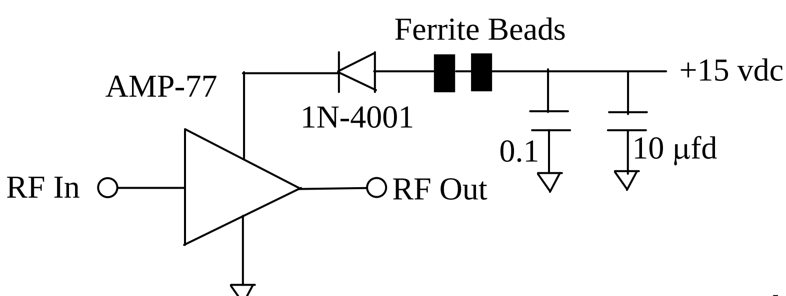


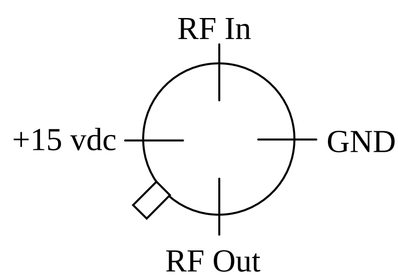
18 - 30 MHz bandpass filter amplitude response and VSWR

M2
RF Preamplifier

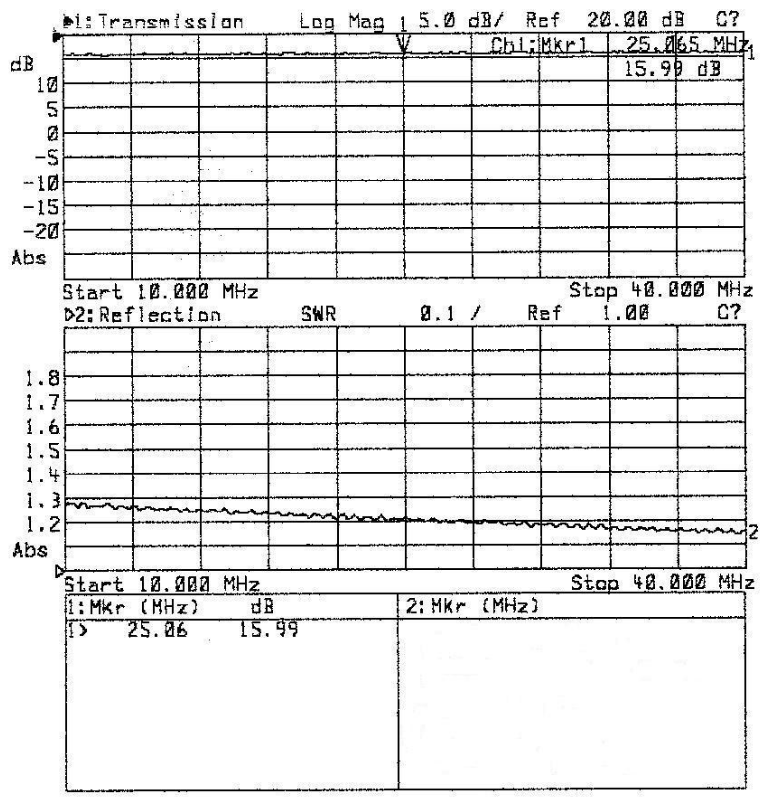
The broadband RF-preamplifier which uses a MiniCircuit Labs AMP-77 device running at 15 volts has 16 dB of gain, a 3.5 dB noise figure and low 50 ohm VSWR providing a good power match to the input filter (M1) and to the following mixer.







Bottom View



RF Preamplifier (AMP-77) Gain and input VSWR response.

M3
PIC Microcontroller and DDS 1st Local Oscillator

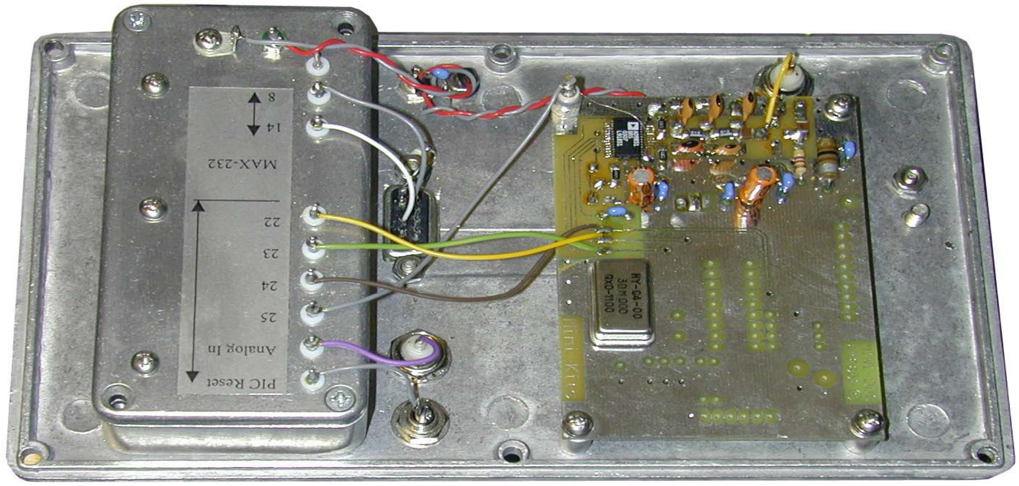
The PIC microcontroller performs several functions.

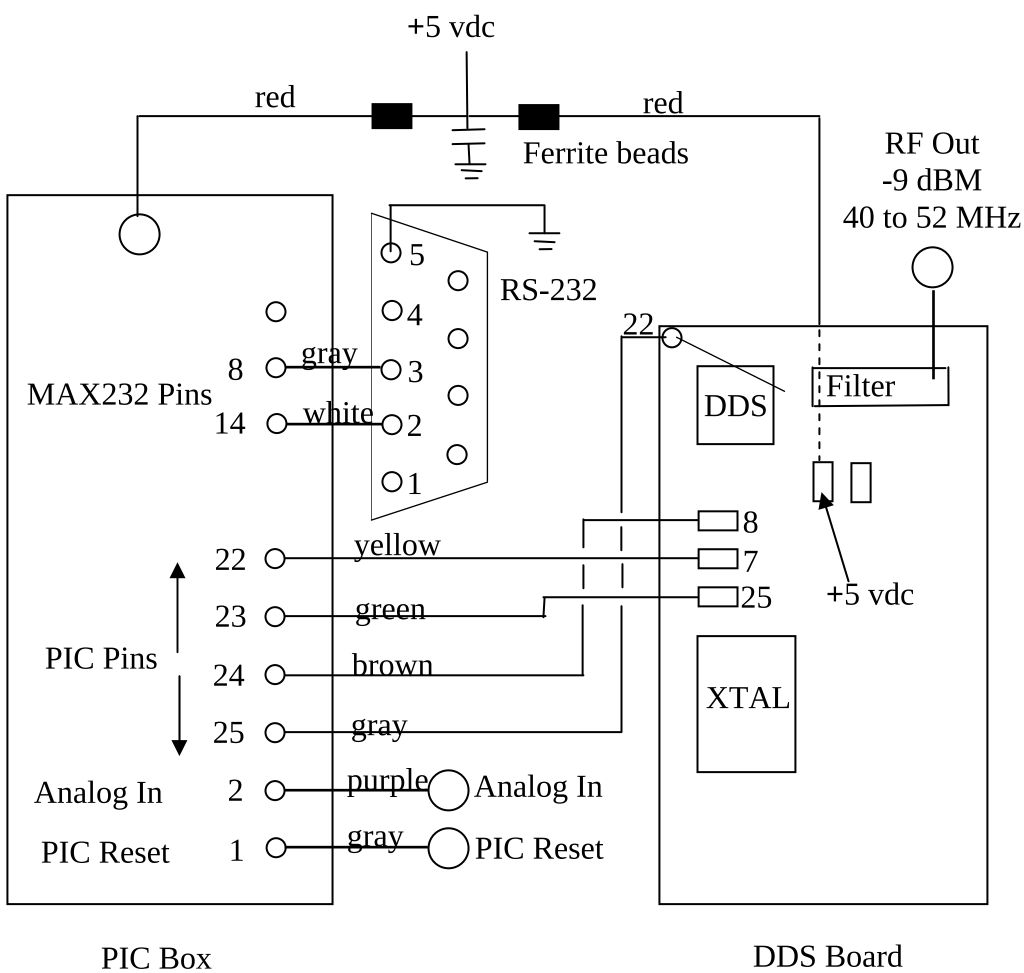
1. Control the direct digital synthesis (DDS) oscillator frequency
2. Digitize the analog signal strength voltage using its internal 10-bit A/D converter.
3. Communicate via an RS-232 serial connection with the HP a300y computer

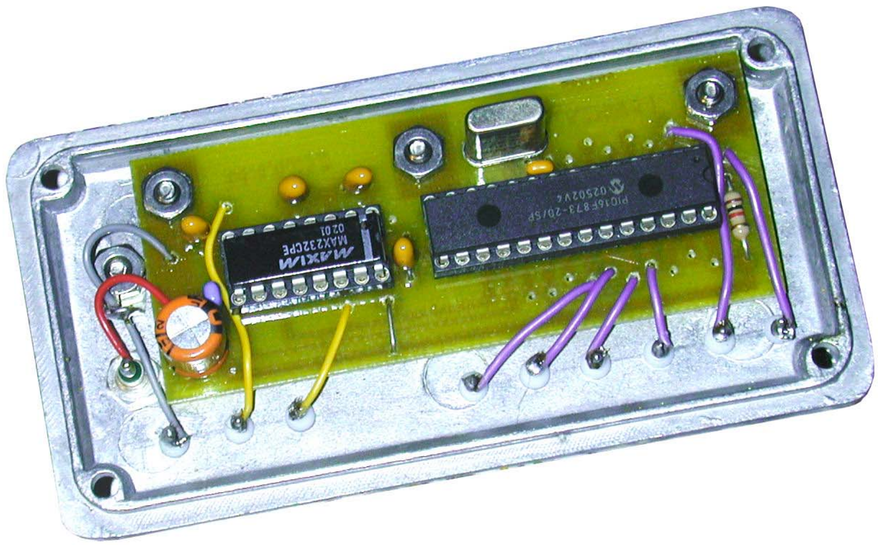
The PIC16F873 microcontroller communicates with the main a300y computer via a MAX232 RS-232 chip. Serial communications rate is 56 K bits, which is derived from an 18.432 MHz crystal. The 16F873 contains the custom control code for the DDS oscillator and is connected to the DDS board by 4 control lines. The PIC and MAX232 are mounted on a PC board inside of a small diecast box. Connections to the DDS board and RS232 9 pin D-connector are via Teflon insulated feedthroughs. The PIC box is mounted inside a larger diecast box, which also contains the DDS board.

The DDS board contains an Analog Devices AD9851 DDS and a 70 MHz elliptic low pass filter. The 180 MHz clock for the DDS chip is derived within the 9851 from a 30 MHz signal generated in an on-board crystal oscillator module. The DDS board was supplied by Mini-Kits in Australia with the 28 pin 9851 surface-mount DDS oscillator already mounted on the board. The Mini-Kits board is modified by cutting the trace between pins 22 and 24 of the DDS chip. A very fine wire is soldered to pin 22 and run to a solder post mounted on the corner of the DDS board. A control wire runs from the solder post to the PIC enclosure.

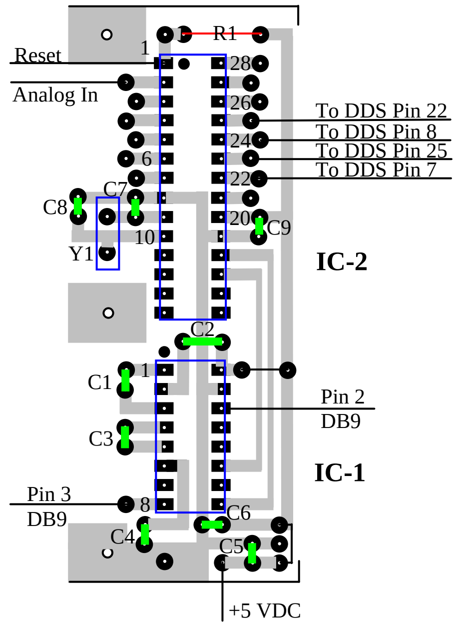
CAUTION – *when servicing the DDS board do not to break the fine wire running between pin 22 of the DDS chip and the solder post mounted on the corner of the DDS board.*

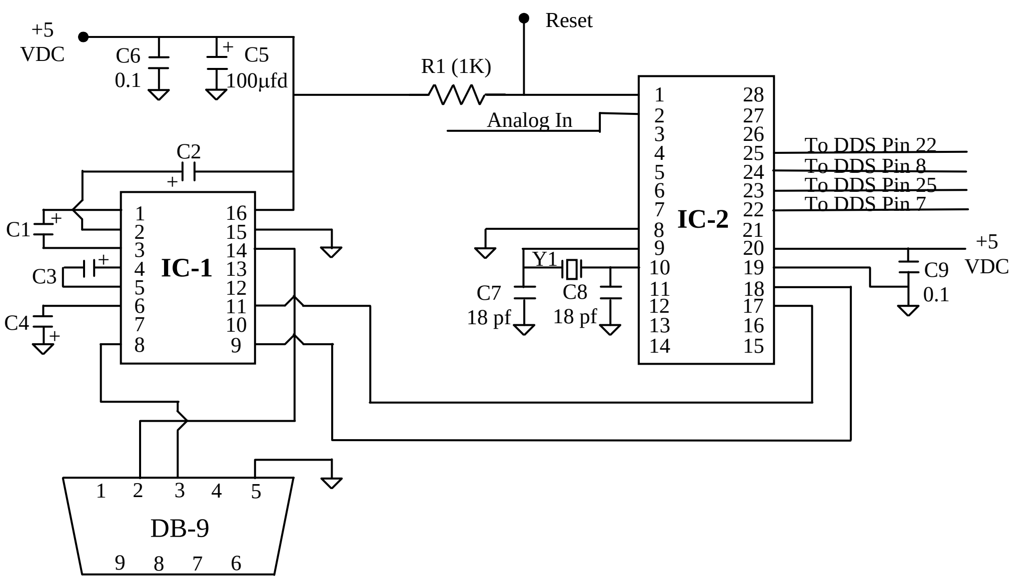



+5 vdc
red
red
Ferrite beads
RF Out
-9 dBM
40 to 52 MHz
RS-232
5
4
3
2
1
22
MAX232 Pins
8
14
gray
white
DDS
Filter
8
7
25
+5 vdc
22
23
24
25
PIC Pins
yellow
green
brown
gray
XTAL
Analog In
2
purple
Analog In
PIC Reset
1
gray
PIC Reset
PIC Box
DDS Board



PIC BOX
MAX 232 serial communications and PIC16F873 microcontroller



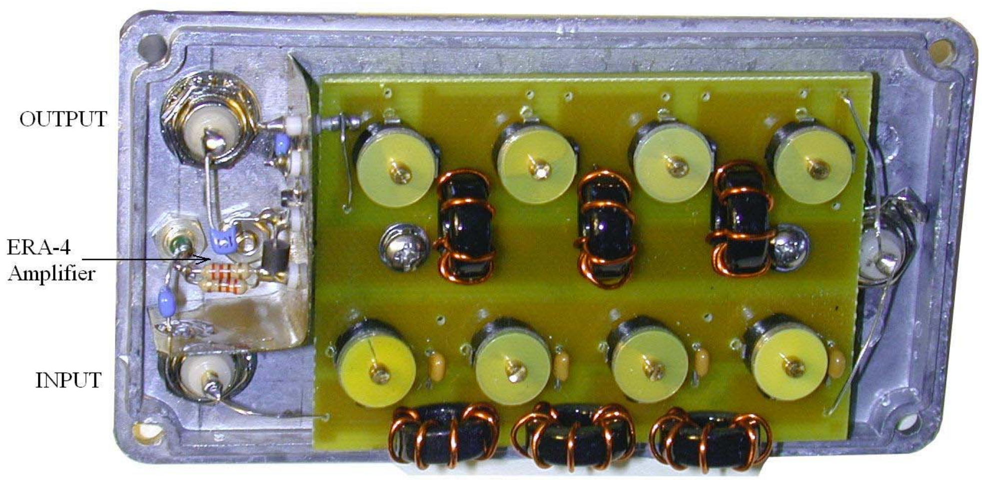


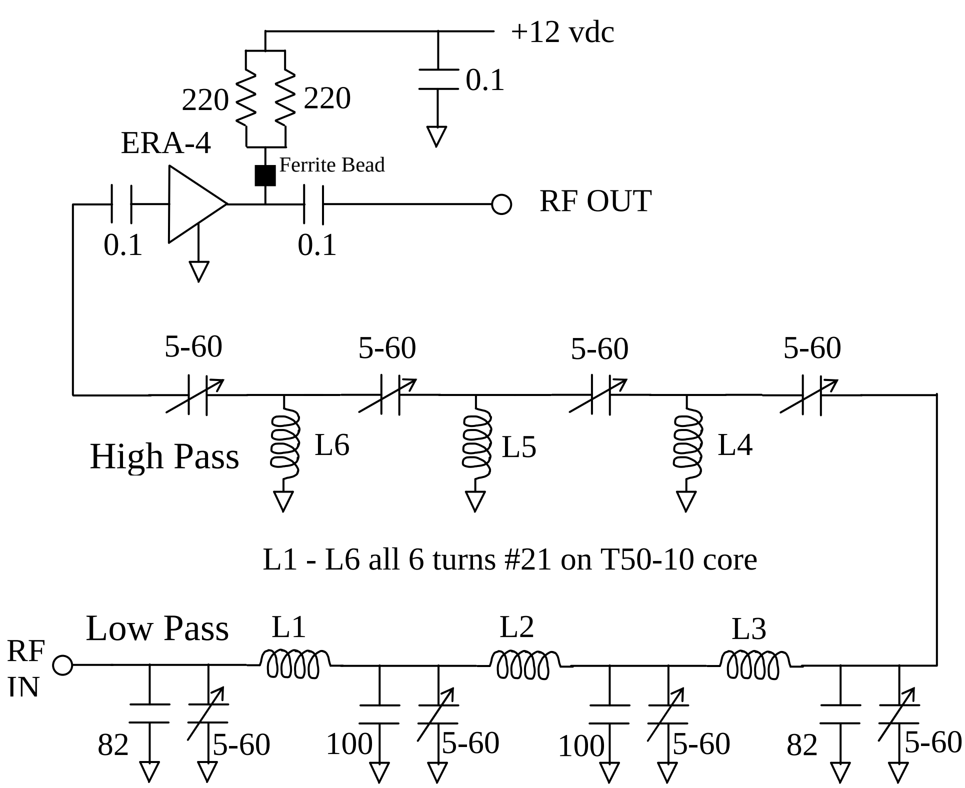
Note: C1, C2, C3, C4 are 1 µfd
IC1 = MAX-232, IC2 = 16F-873, Y1 = 18.432 MHz
Ground RESET line to reset PIC

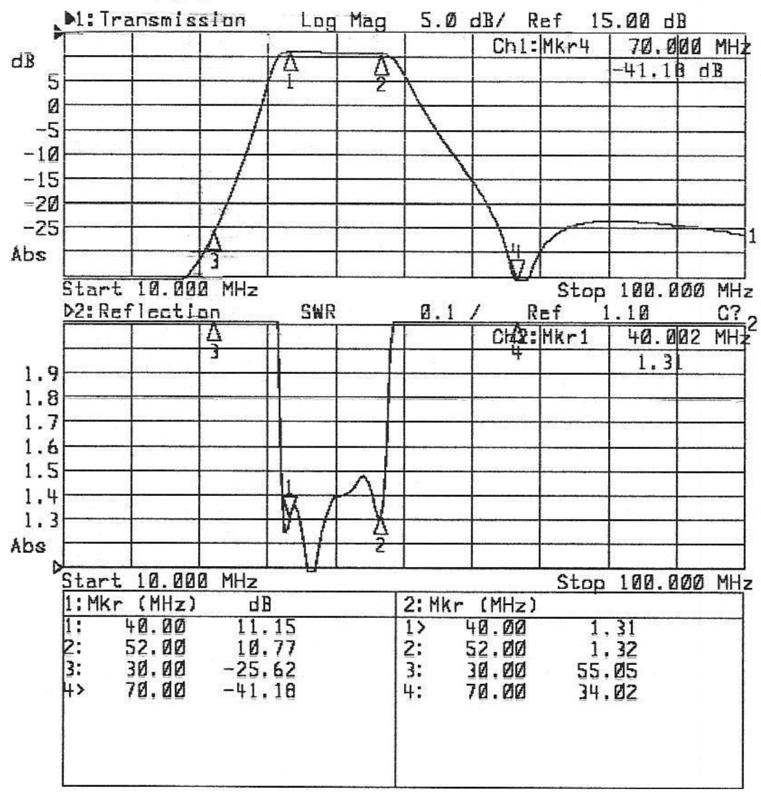
FS-200 Spectrograph PIC 16F783 Microcontroller and MAX232

M4
1st LO Bandpass Filter and Amplifier

The 40 to 52 MHz signal available at the output of the DDS local oscillator module (M3) contains numerous spurious signals lying both above and below the oscillator frequency range. In order to attenuate these out-of-band DDS oscillator signals module M4 contains a 40-52 MHz bandpass filter. A MiniCircuits ERA-4 MMIC amplifier follows the filter and boosts the LO signal level to +1.5 dBm.







DDS Bandpass Filter and Amplifier Response

M5

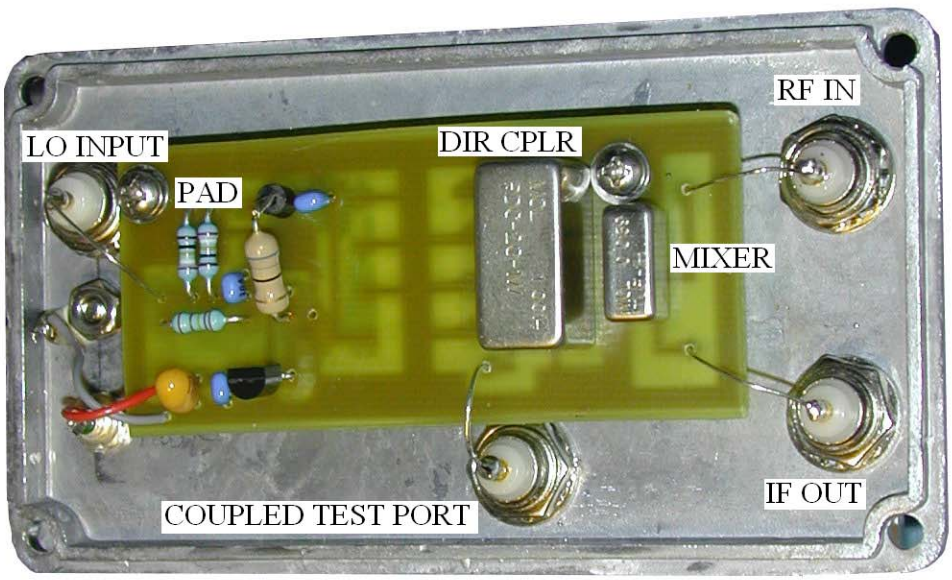
DDS LO Amplifier, Low Pass Filter, Mixer

Module M5 contains the first mixer, a MiniCircuits double balanced TUF-1H requiring an LO drive level of +17 dBm. Module M4 delivers an LO signal level of +1.5 dBm so further amplification of the LO signal is required. A MiniCircuits ERA-5 capable of delivering a maximum power level of +18 dBm is used. Since the ERA-5 has a gain of 19 dB a 3 dB resistive pad is used to adjust the drive level to the ERA-5 so that an output power level of approximately 17 dBm will be achieved.

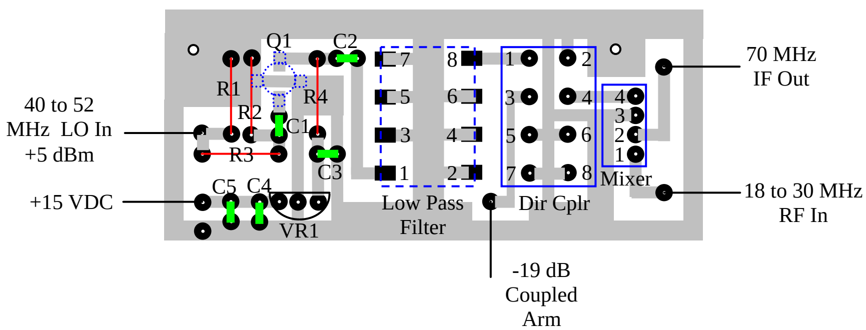
Following the ERA5 amplifier a MiniCircuits SCLF-65 low pass filter provides additional suppression of spurious high frequency signals from the DDS oscillator.

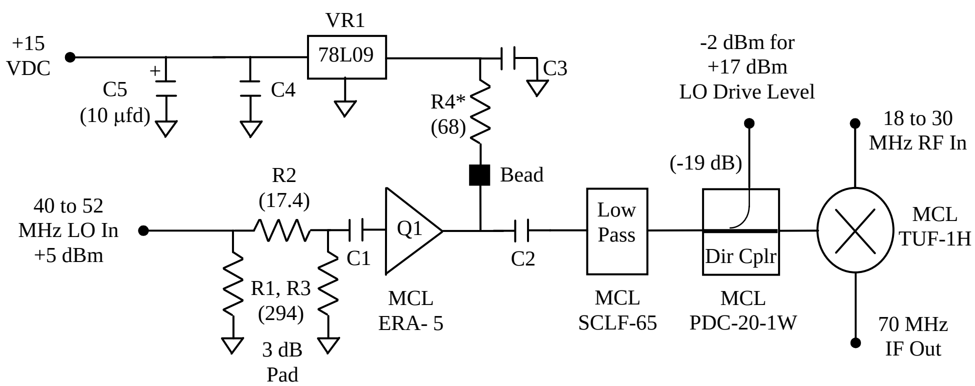
A MiniCircuits 19.2 dB directional coupler (PDC-20-1W) located just before the LO port of the mixer is included to provide a sample of the LO signal for test purposes. This test port should be terminated in 50 ohms when unused. Since the normal LO drive level is approximately +17 dBm the power available at the coupled arm test port is approximately –2 dBm.

With an RF signal from M2 in the range of 18 to 30 MHz and a 1st LO signal in the range of 52 to 40 MHz the 1st IF frequency is 70 MHz

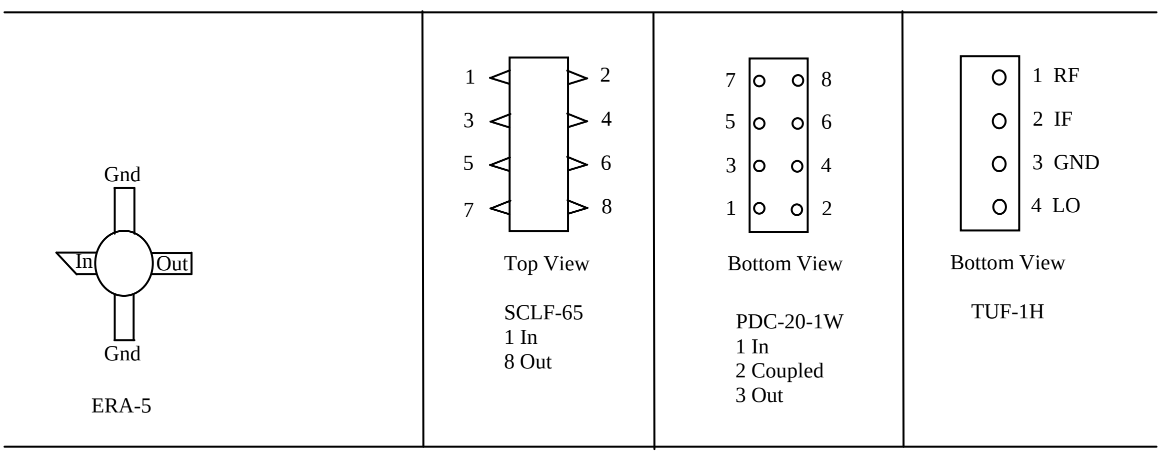


DDS LO Amp, Low Pass Filter, Directional Coupler , and Mixer





Note: C1, C2, C3, C4 are 0.1 µfd
*R4 is 68 ohms ½ watt



DDS LO Amp, Low Pass Filter, Directional Coupler , and Mixer

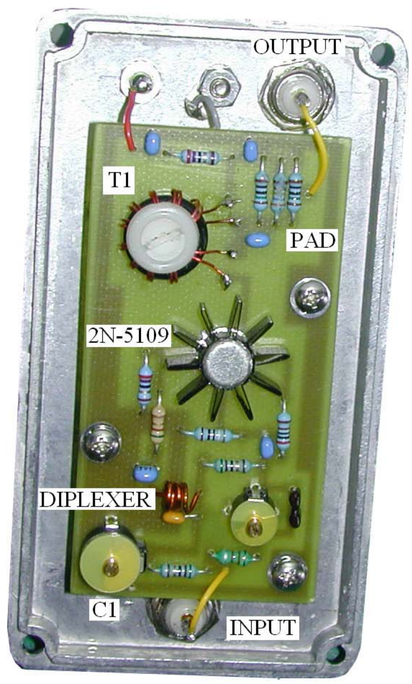
M6

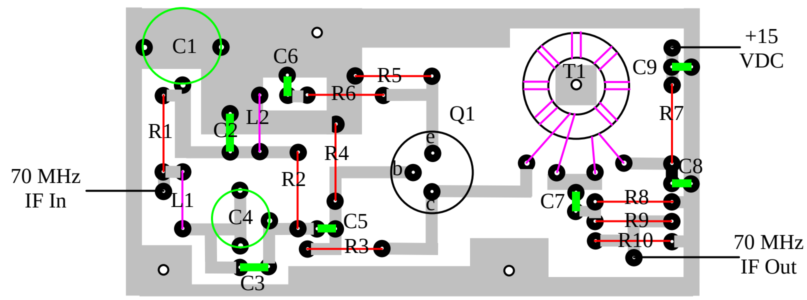
Diplexer and 70 MHz IF Amplifier

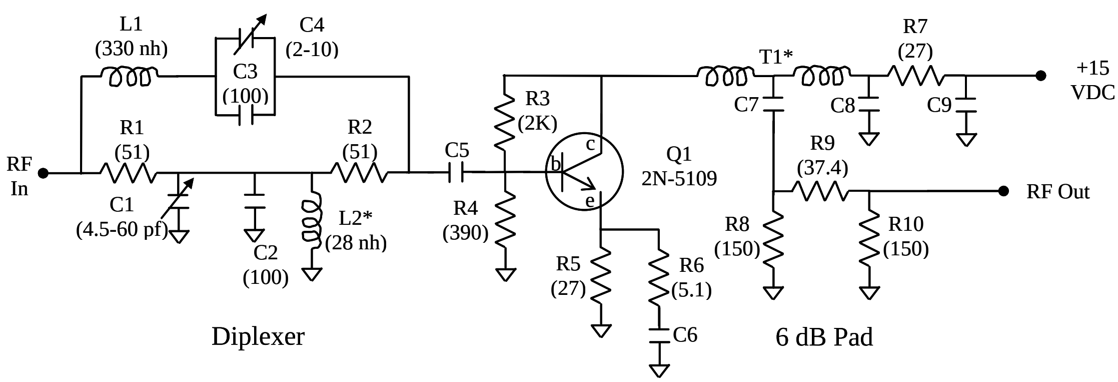
The input diplexer provides a broadband low VSWR termination for the mixer IF port.

The 70 MHz IF amplifier uses a low noise 2N5109 transistor drawing approximately 50 ma. The 2N5109 is a silicon NPN transistor in a TO39 type package designed specifically for broadband applications requiring good linearity. The noise figure of the 2N5109 is rated at 3 dB at 200 MHz Transformer T1 is a 4:1 balun. A 6 dB, 50 ohm pad on the output helps to provide a good impedance match to the following filter and also stabilizes the input impedance of the IF amplifier itself.

Gain from input to output of the module is 9 dB, which includes the 1 dB loss in the diplexer and the 6 dB loss in the pad. The 2N5109 amplifier itself therefore has a gain of 16dB at 70 MHz.

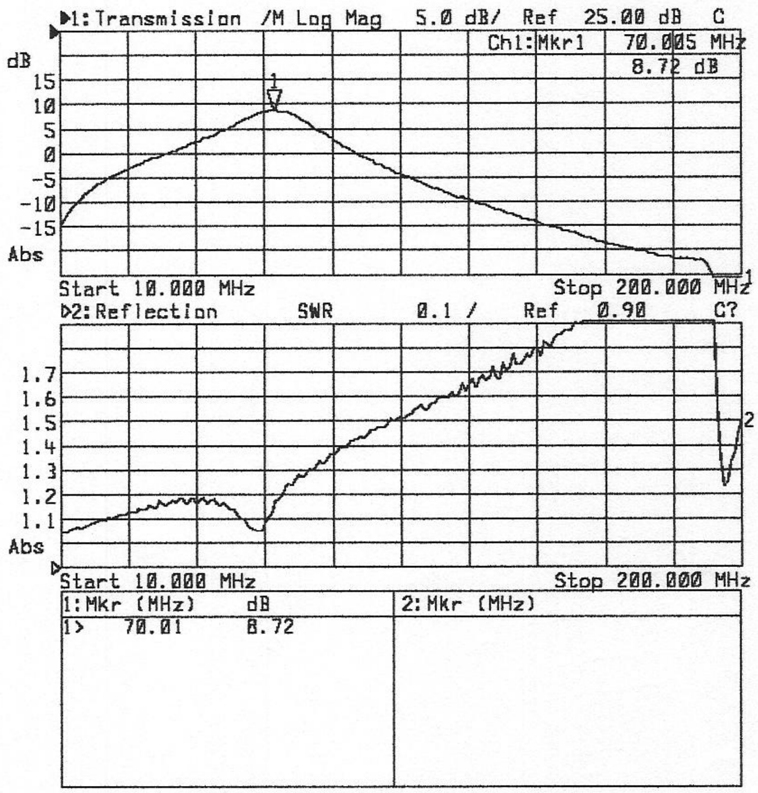






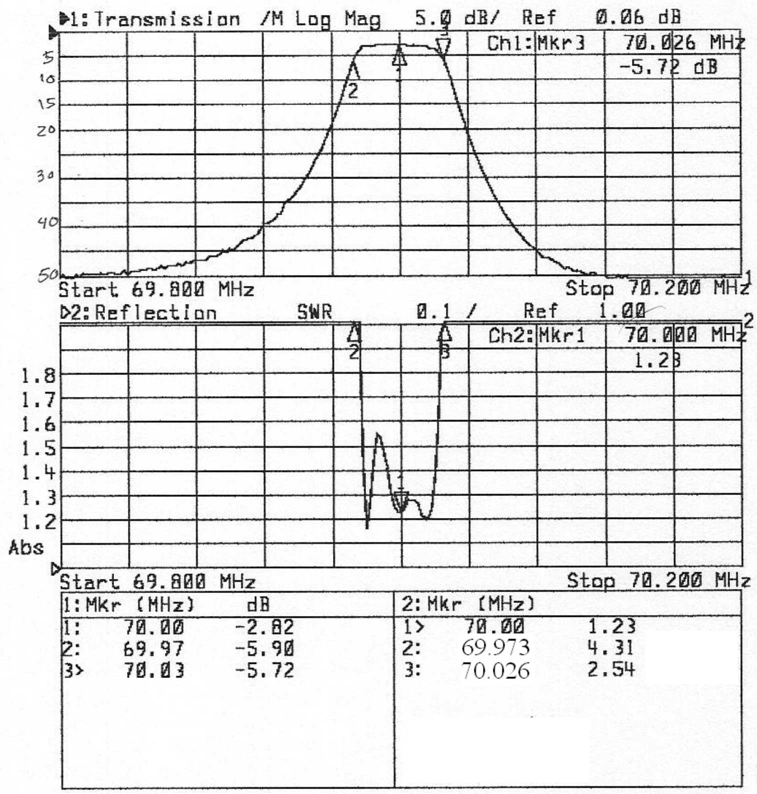
Note: C5, C6, C7, C8, C9 are 0.1 μfd
Q1 requires a heat sink
*T1 is 10 bifilar turns of #26 wire on Amidon T50-10 core
*L2 is 3T #21 wire close wound on 1/8” drill bit

70 MHz Diplexer, 2N-5109 Amp, and 6 dB Pad


▶1:Transmission /M Log Mag 5.0 dB/ Ref 25.00 dB C
Ch1:Mkr1 70.005 MHz
8.72 dB
dB
15
10
5
0
-5
-10
-15
Abs
Start 10.000 MHz
Stop 200.000 MHz
▷2:Reflection SWR 0.1 / Ref 0.90 C?
1.7
1.6
1.5
1.4
1.3
1.2
1.1
Abs
Start 10.000 MHz
Stop 200.000 MHz
1:Mkr (MHz) dB
1> 70.01 8.72
2:Mkr (MHz)

M7
1st IF (70 MHz) Crystal Filter

The 1st IF (70 MHz) crystal filter (Filtronetics FN2009) has an input and output impedance of 50 ohms, a 3 dB bandwidth of 50 kHz, and a center frequency insertion loss of 3 dB. Ultimate attenuation is specified as 60 dB with a maximum of 1dB of in-band ripple. The filter bandwidth marked on the unit is 26 kHz but this is actually +/- 26 kHz.



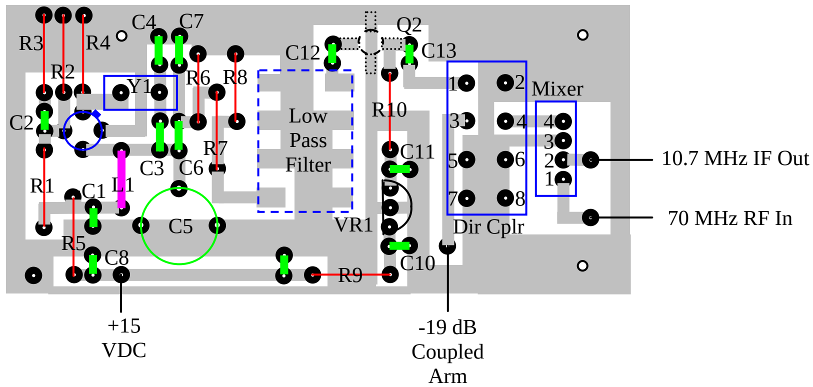
Filtronetics FN-2009 SN 1847

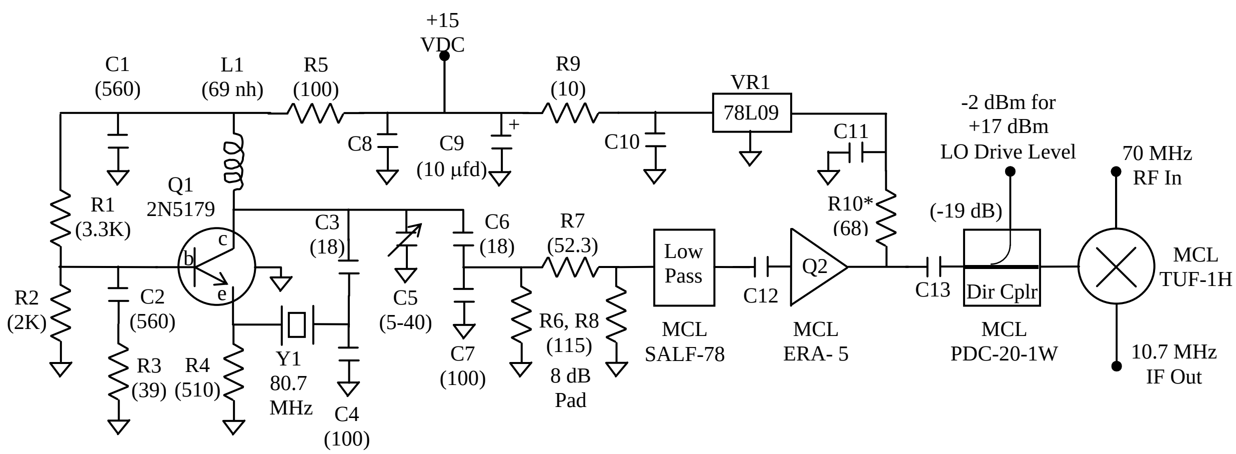
M8
2nd Local Oscillator (80.7 MHz) and Mixer

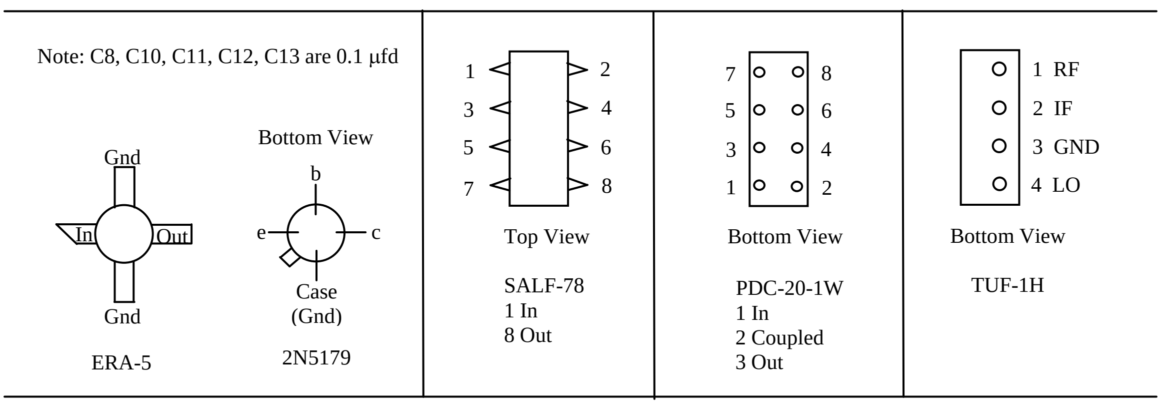
An 80.7 MHz crystal oscillator (2N-5179) is followed by an 8 dB pad, a low pass filter (MCL SALF-78), an ERA-5 amplifier, an MCL PDC-20-1W directional coupler, and a MCL TUF-1H high level mixer. The second LO signal is injected into the mixer at a level of +17 dBm.

The ERA-5 is capable of delivering a maximum power level of +18 dBm. Since the ERA-5 has a gain of 19 dB, an 8 dB resistive pad is used to adjust the drive level from the oscillator so that an output power level of approximately 17 dBm is achieved.

The 19.2 dB directional coupler is included to provide a sample of the 2nd LO signal for test purposes. This coupled port should be terminated in 50 ohms when not in use. With a 1st IF signal frequency of 70 MHz and a 2nd LO of 80.7 MHz the 2nd IF frequency is 10.7 MHz.







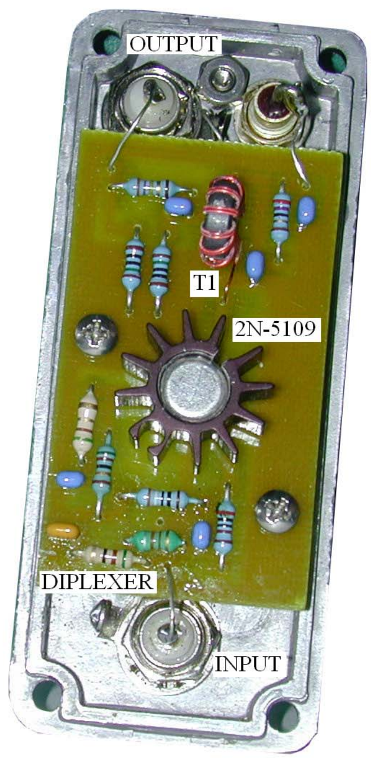
80.7 MHz XTAL Osc, Low Pass Filter, Directional Coupler, and Mixer

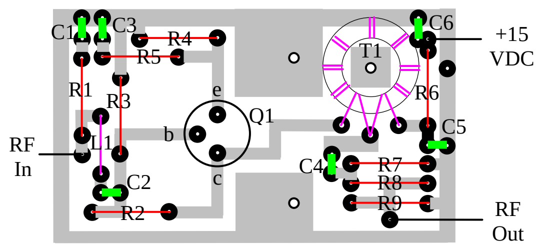
M9
Diplexer and 10.7 MHz IF Amplifier

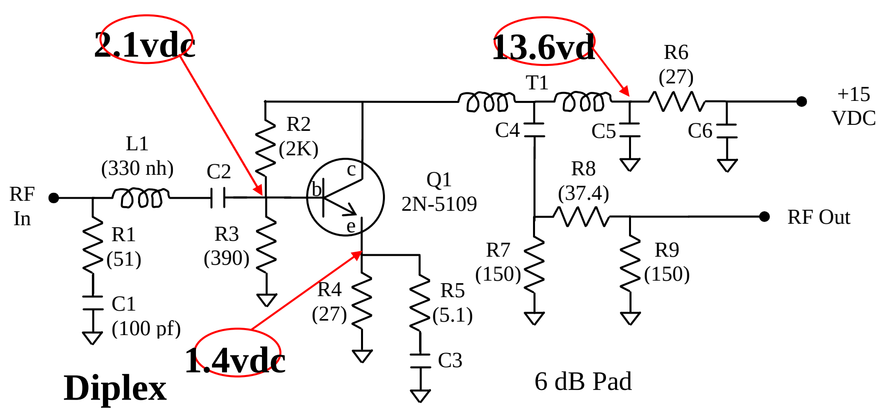
The input diplexer provides a broadband low VSWR termination for the mixer IF port.

The 10.7 MHz IF amplifier uses a low noise 2N5109 transistor drawing approximately 50 ma. The 2N5109 is a silicon NPN transistor in a TO39 type package designed specifically for broadband applications requiring good linearity. The noise figure of the 2N5109 is rated at 3 dB at 200 MHz   Transformer T1 is a 4:1 balun. A 6 dB, 50 ohm pad on the output helps to provide a good impedance match to the following filter and also stabilizes the input impedance of the IF amplifier itself.

Gain from input to output of the module is 16 dB, which includes the 1 dB loss in the diplexer and the 6 dB loss in the output pad. The 2N5109 amplifier itself therefore has a gain of 23 dB at 10.7 MHz.





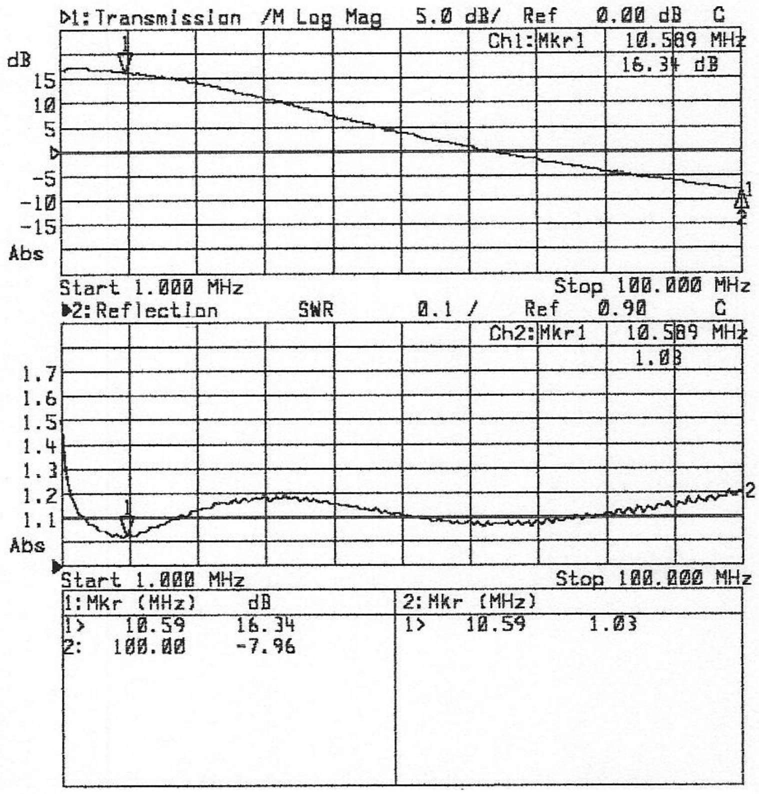


Note: C2, C3, C4, C5, C6 are 0.1 µfd

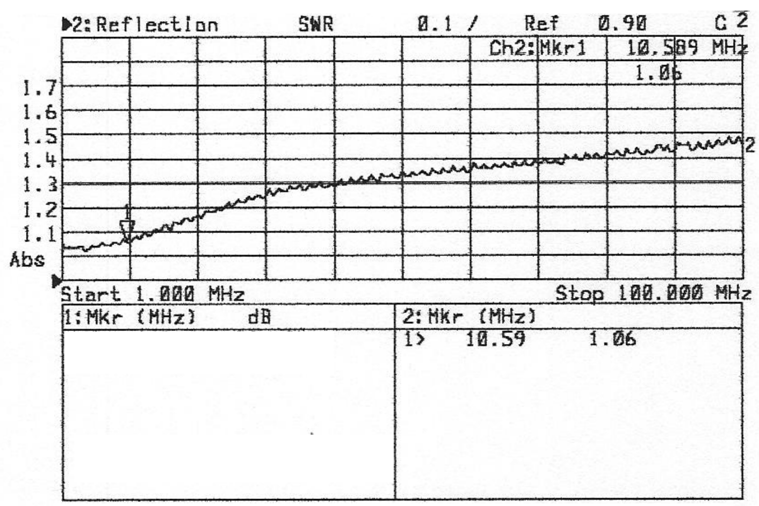
T1 is 10 bifilar turns of #28 wire on Amidon FT37-43 core (4:1 Transformer)

Heat Sink required on Q1 (2N5109), current 50 ma

10.7 MHz Diplexer, 2N5109 Amp, 6 dB Pad



10.7 MHz Diplexer, 2N-5109 Amp and 6 dB Pad
Gain and Input VSWR

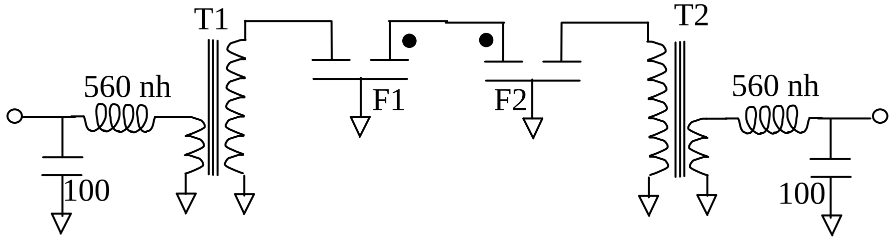


10.7 MHz Diplexer, 2N-5109 Amp, 6 dB Pad Output VSWR

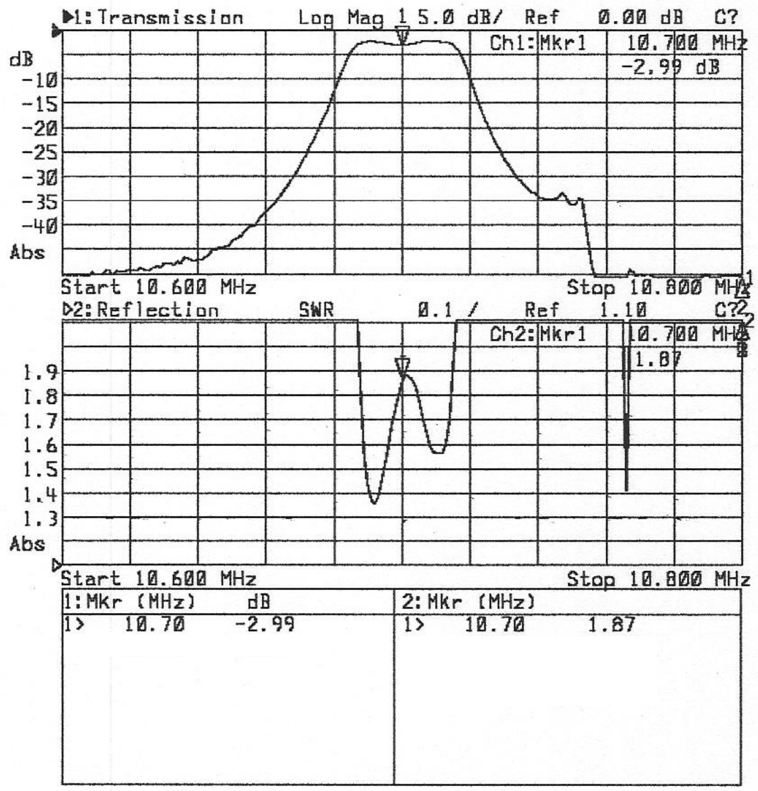
M10, M12
10.7 MHz 4 pole Crystal Filter

Each IF crystal filter module uses a pair of International Crystal Manufacturing (ICM) 10M-30B matched, two-pole, crystal filters with a 3 dB bandwidth of 30 kHz. Each filter element has a characteristic impedance of 5 K ohms. Ferrite toroid transformers are used to match the filter impedance down to 50 ohms. The module input and output VSWR is under 2:1. Typical insertion loss is 3 dB with an ultimate attenuation better than 50 dB.

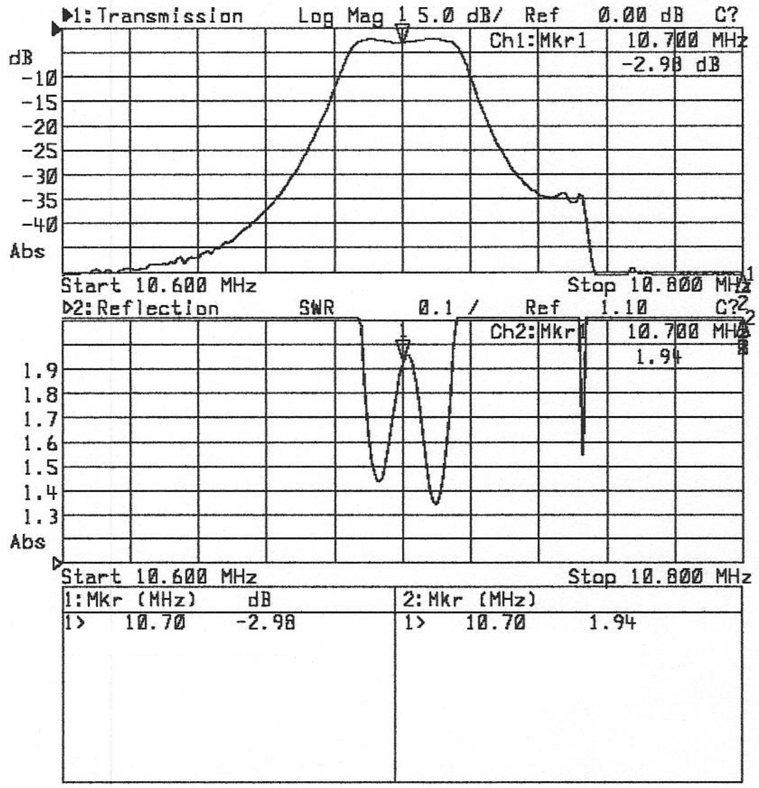
Each toroid is mounted to the PC board using nylon screws. The crystal filters are mounted under the PC board and are not visible in the photograph Each filter has two ports designated as port (A) and port (B). For a given filter module, the SWR response is practically identical, regardless of the port being measured.



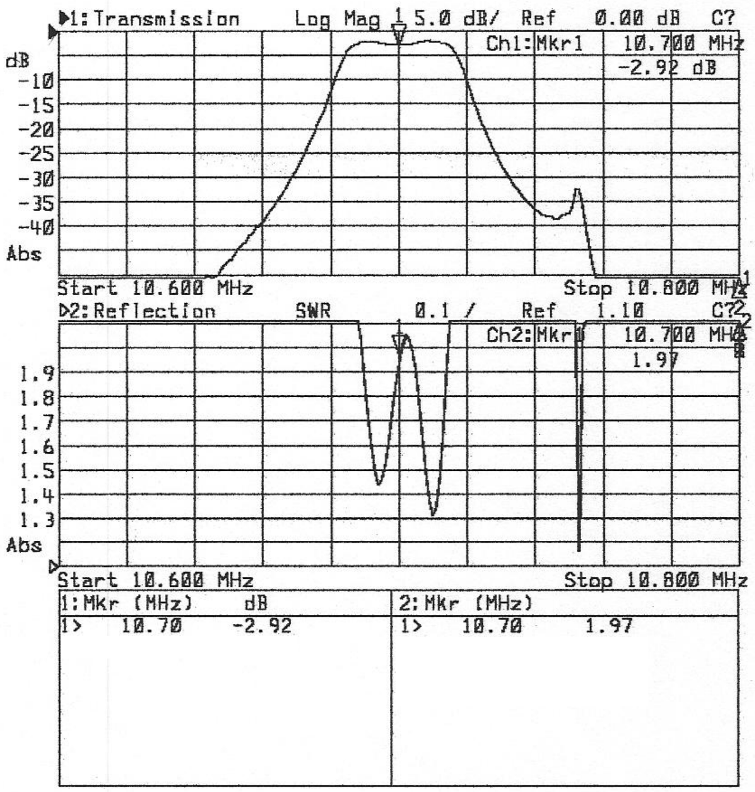
T1, T2: Primary 5T #24, Sec 40T #28, Core FT50-43
F1, F2: ICM 10M-30B, 10.7 MHz Crystal Filter, 30 kHz bandwidth



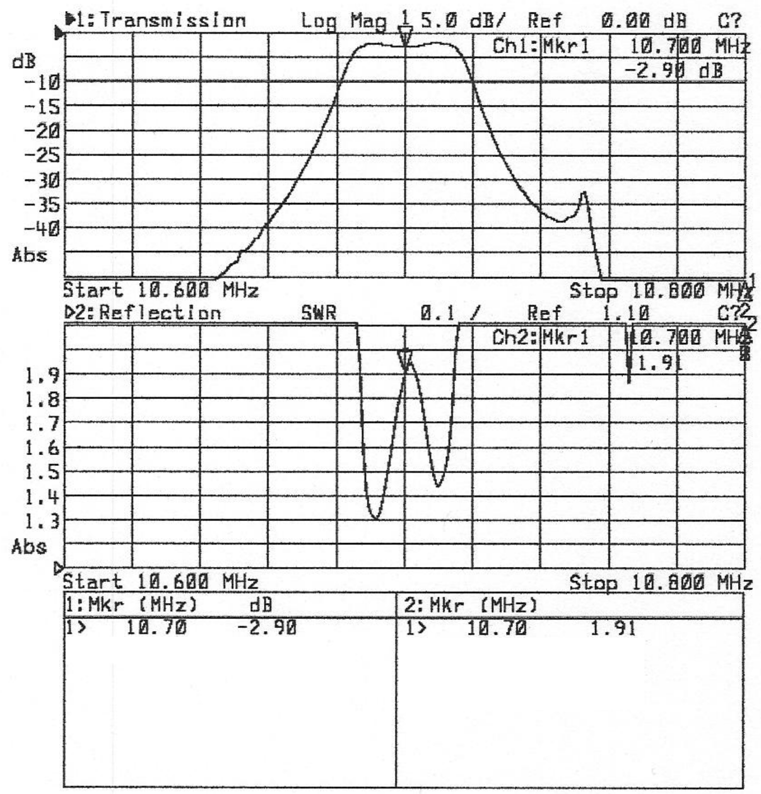
FILTER #1 PORT A



FILTER #1 PORT B



FILTER #2 PORT A

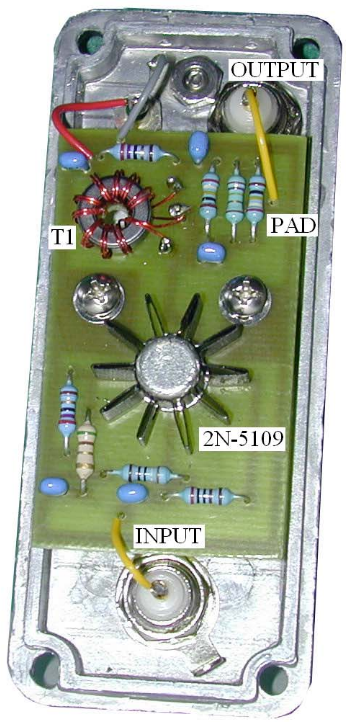


FILTER #2 PORT B

M11, M13
10.7 MHz IF Amplifier

The 10.7 MHz IF amplifier uses a low noise 2N-5109 transistor drawing approximately 50 ma. The 2N5109 is a silicon NPN transistor in a TO39 type package designed specifically for broadband applications requiring good linearity. The noise figure of the 2N5109 is rated at 3 dB at 200 MHz   Transformer T1 is a 4:1 balun. A 3 dB, 50 ohm pad on the output helps to provide a good impedance match to the following stage as well as stabilize the input impedance of the IF amplifier itself.

Gain from input to output of the module is 20 dB, which includes the 3 dB loss in the output pad. The 2N-5109 amplifier itself therefore has a gain of 23dB at 10.7 MHz.



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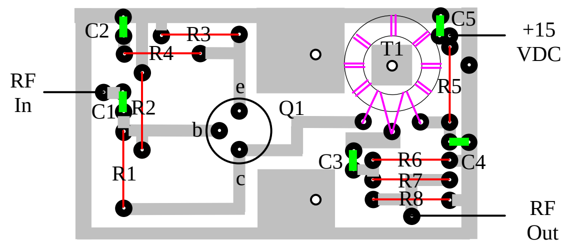
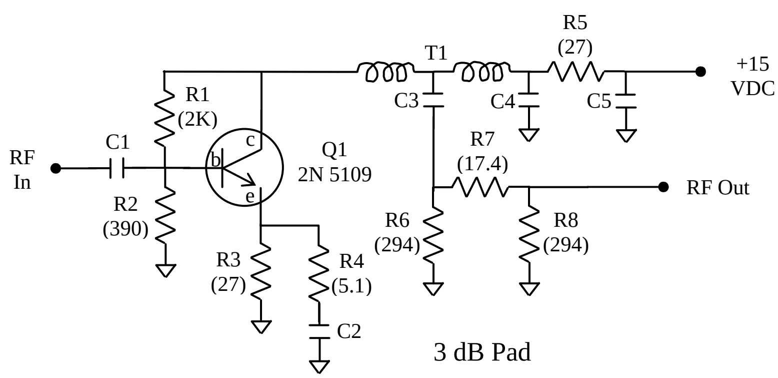


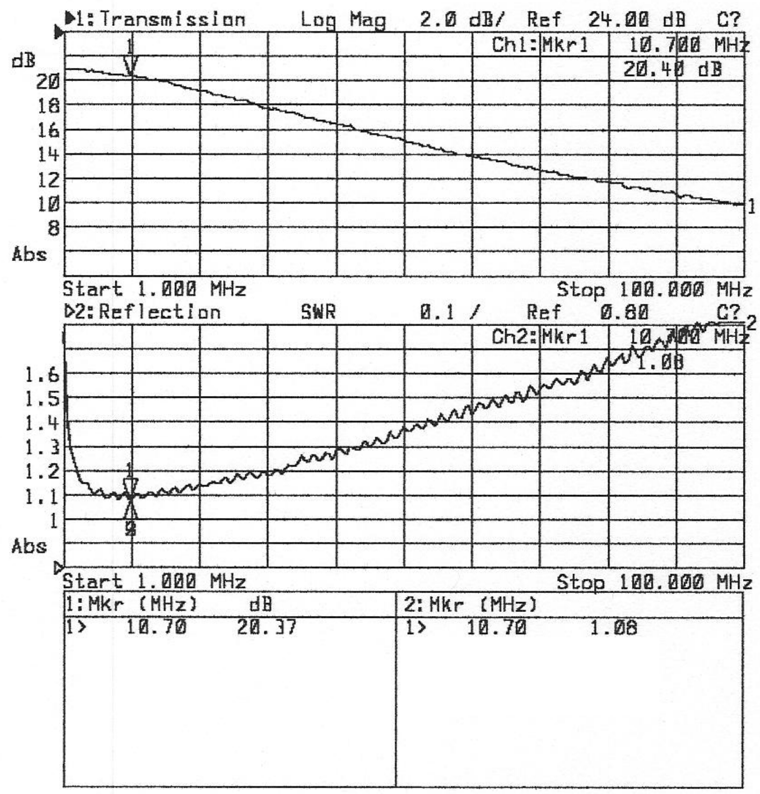


Note: C1, C2, C3, C4, C5 are 0.1 μfd

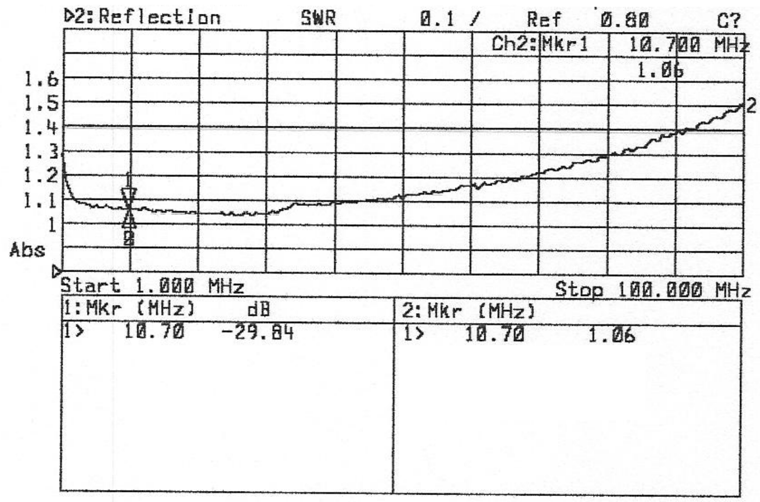
T1 is 10 bifilar turns of #28 wire on Amidon FT37-43 core (4:1 Transformer)

Heat Sink required on Q1 (2N5109), current 50 ma

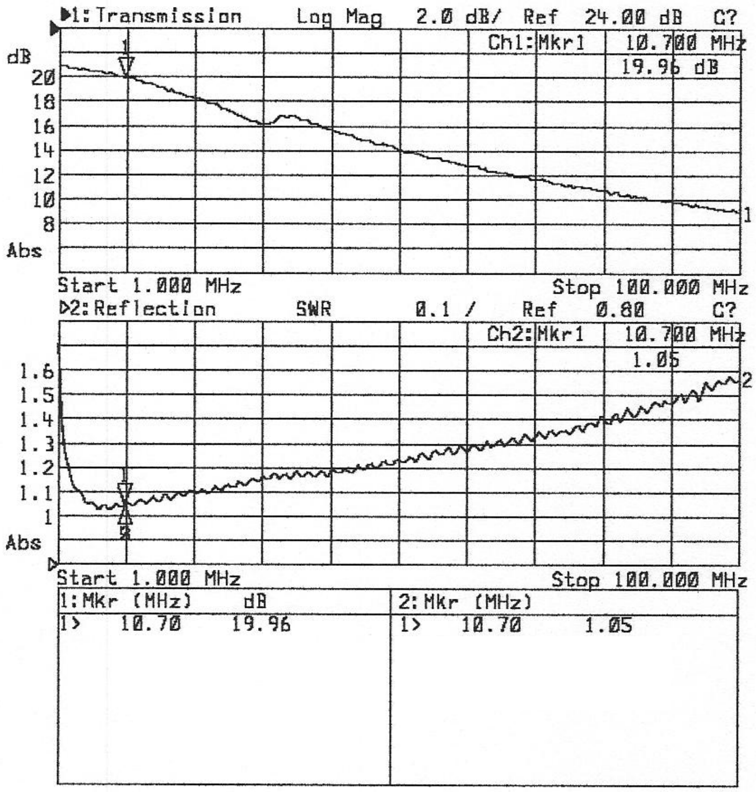
10.7 MHz 2N-5109 Amp and 3 dB Pad



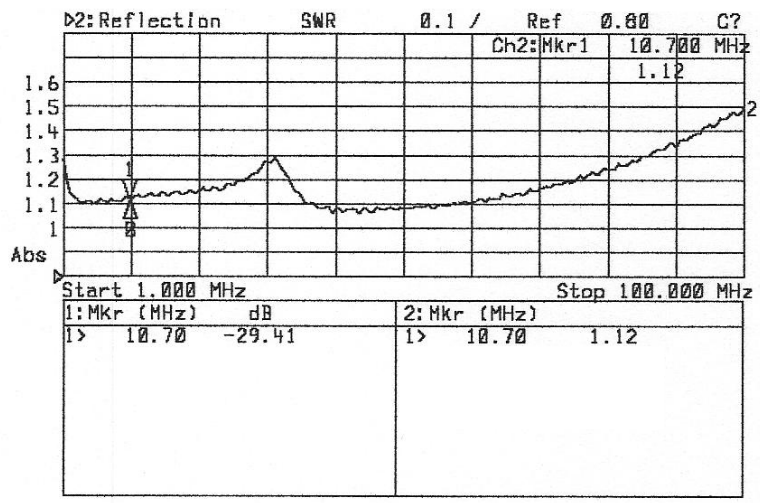
10.7 MHz IF AMP #1 GAIN and INPUT SWR



10/7 MHz IF AMP #1 OUTPUT SWR



10.7 MHz IF AMP #2 GAIN and INPUT VSWR



10.7 MHz IF AMP #2 OUTPUT SWR

M14
Detector

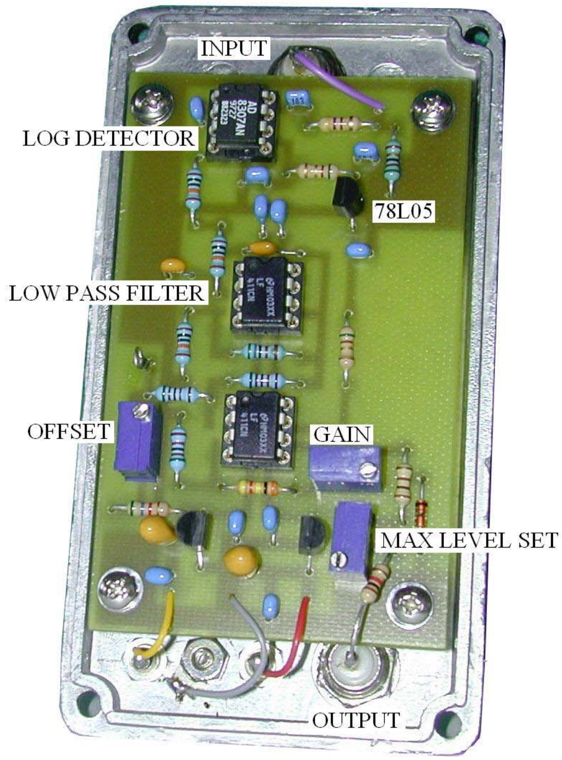
The logarithmic detector (AD8307) develops an output voltage proportional to the log of the input power. It is followed by an active 2 kHz low pass filter matched to the 0.5 msec per channel dwell time of the stepped oscillator. The LPF feeds a DC amplifier with variable offset and gain controls. The DC amplifier output signal, which lies in the range of 0 to +5 volts, is fed to the DDS PIC (in M3) where it is processed by a 10 bit A/D converter within the PIC. The low pass filter and DC amplifier both use low offset, low drift, JFET input LF411 op amps.

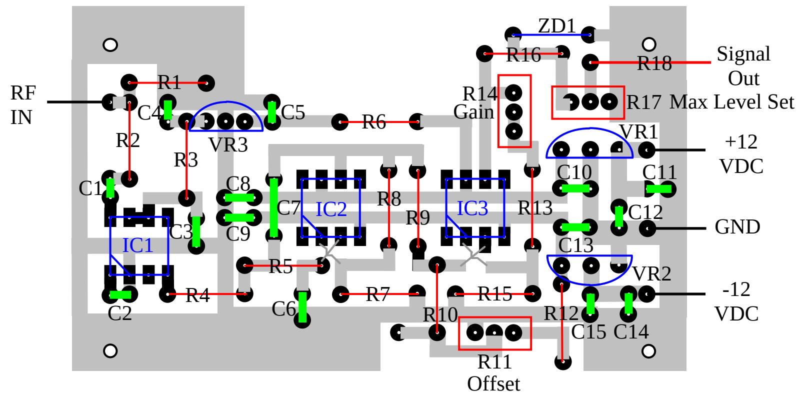
The 8307 is extremely sensitive, with a minimum detectable signal level of below -70 dBm and a dynamic range of over 90 dB. With its input terminated in 50 ohms, the 8307 output is approximately one hundred millivolts. The 8307 DC output voltage is proportional to the log of input power. A 1 dB change of input power produces a 25 millivolt change in output voltage. The maximum output voltage from the detector is 2.5 volts.

As used in the spectrograph, the output of the log detector is low pass filtered to remove noise, and offset to remove the 8307 quiescent output level of approximately 100 millivolts. Then the signal is amplified to cover the full (0 to 5 volt) range of the A/D converter. Amplification increases the scale factor from the original value of 25 millivolts per dB to over 100 millivolts per dB. Amplification of the 8307 signal increases its sensitivity to weak signals but reduces the dynamic range of the detector to less than 35 dB. A 5 volt zener diode and trimpot at the output of the DC amplifier limit the maximum voltage produced by the detector module thus protecting the A/D converter from over-voltages that could be produced by very strong signals.

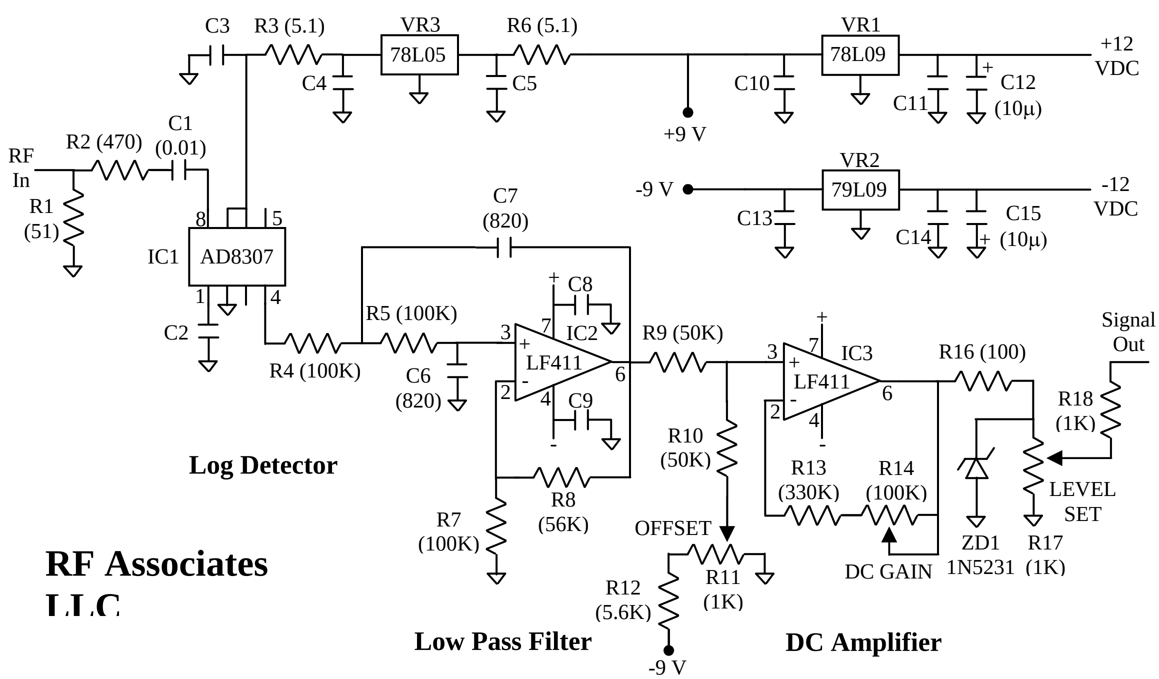
Trimpots are used for gain, offset and to set the maximum signal level that is delivered to the A/D converter. These trimpots are accessed thru holes in the bottom of the diecast box holding the detector. The box must be removed from the front mounting plate and adjustments made thru holes in the bottom of the box. The cover of the box cannot be opened for access to the trimpots because the detector is very sensitive to stray fields. Any adjustments to the trimpots must be done with the box tightly sealed.

Plus and minus 12 volts DC is supplied to the log detector module. Internal 3- terminal regulators (78L09, 79LO9) develop +9 and –9 volts for the op amps and a 78L05 produces +5 volts for the AD8307.


INPUT
LOG DETECTOR
78L05
LOW PASS FILTER
OFFSET
GAIN
MAX LEVEL SET
OUTPUT

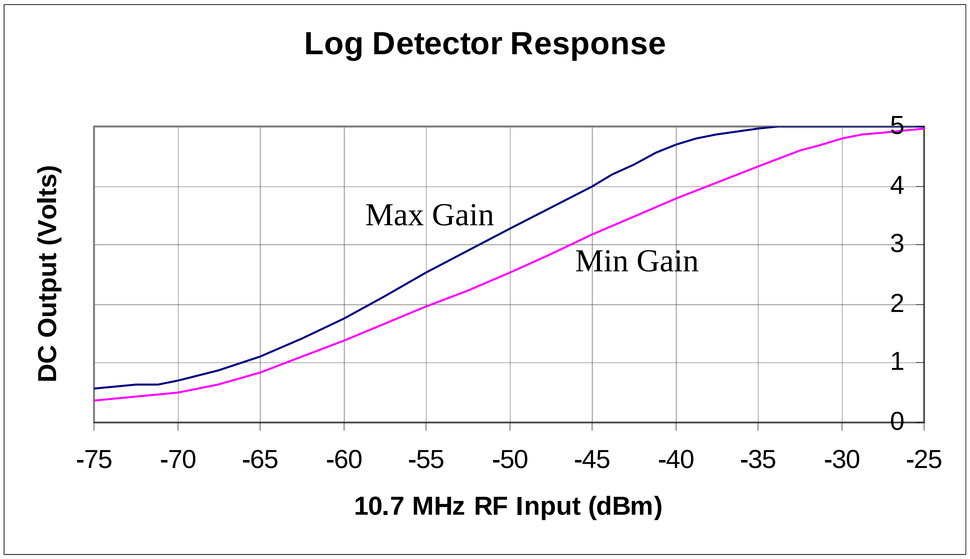


Due to a PC board layout error pins 2 and 3 of the LF-411s have been cross - jumpered



Note C2, C3, C4, C5, C8, C9, C10, C11, C13, C14 are 0.1µfd

Log Detector, Low Pass Filter, DC Amp with Variable Gain and



The Log Detector response curves were obtained as follows.

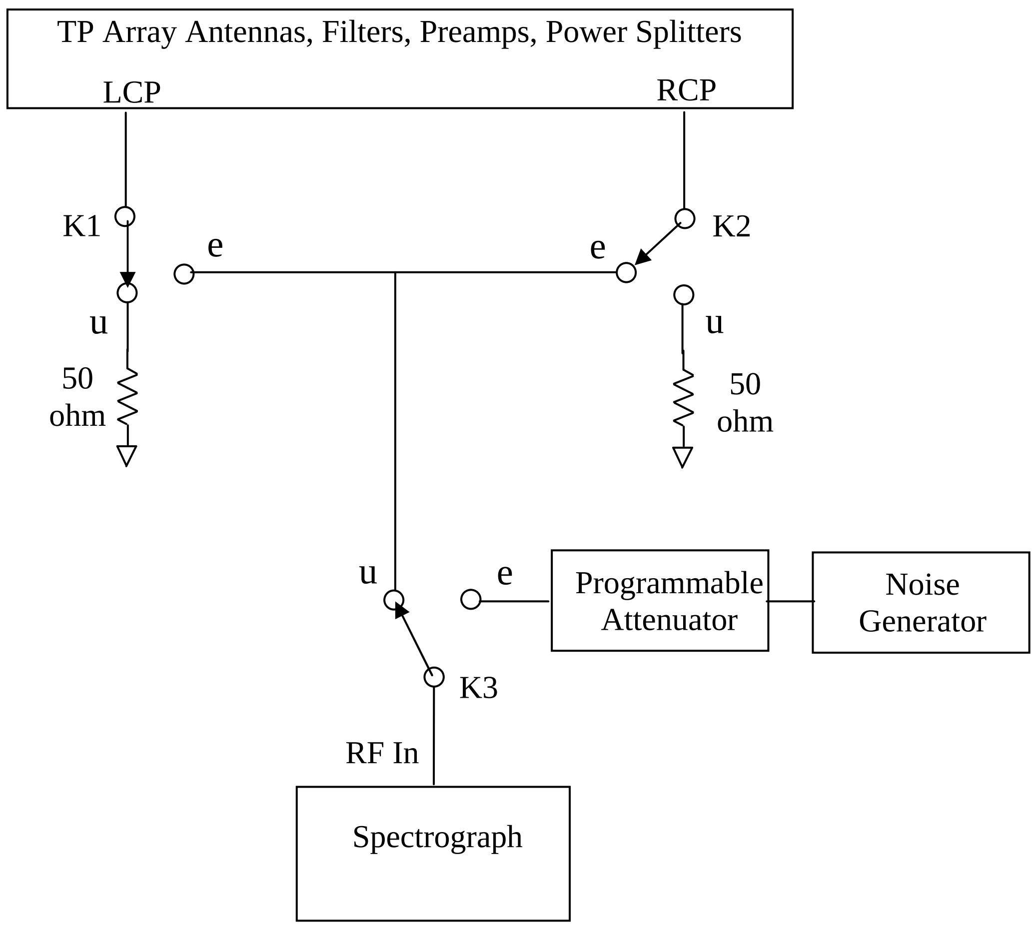
1. Terminate the input to the log detector in 50 ohms and adjust the OFFSET trimpot for zero output.
2. Using a 10.7 MHz signal generator set the output level trimpot so that the maximum output level from the detector module is 5 volts as the generator output is increased above –25 dBm.
3. Set the gain trimpot for the desired response – in the plot above the top curve (with a slope of 150 mv/dB) is maximum gain and the lower trace (with a slope of 115 mv/dB) is with the trimpot set for minimum gain. The dynamic range for the maximum gain setting is 65-45=20 dB and the dynamic range for minimum gain is 65-30=35 dB. For normal spectrograph operation adjust the gain trimpot for minimum gain.

The spectrograph gain in front of the detector module is set (using attenuator pads or a step attenuator) so that the input signal to the detector module is approximately –65 dBm on the galactic background. This corresponds to a DC output from the detector of approximately +1 volt. The total attenuation used will depend upon the amount of RF and IF gain ahead of the detector module. Attenuation is normally inserted into the spectrograph at the time of installation and should not need to b e changed. The location and distribution of the attenuation may affect the spectrograph noise figure and should only be installed or changed after proper analysis.

Notice that this set up procedure for the detector does not utilize the full dynamic range of the A/D converter as the signal level out of the detector is approximately 1 volt on the galactic background. However if the offset and gain controls were set to give zero volts out on the background and an amplifier in the front end were turned off then the offset would be so large that it would drive the detector module output voltage negative – possible damaging the PIC micro-controller and its internal A/D converter.

Mode Switch/Calibrator
A mode switch (M16) with 3 coaxial relays (K1, K2, and K3) selects the RF source for the spectrograph (for the Florida installation this is either RCP, LCP or a calibrator).

The calibrator comprises a high temperature RF noise source followed by a commercial programmable attenuator.



K1 is LCP select relay (**e**nergize to select LCP)
K2 is RCP select relay (**e**nergize to select RCP)
K3 is CAL/OPR relay (**e**nergize for CAL)

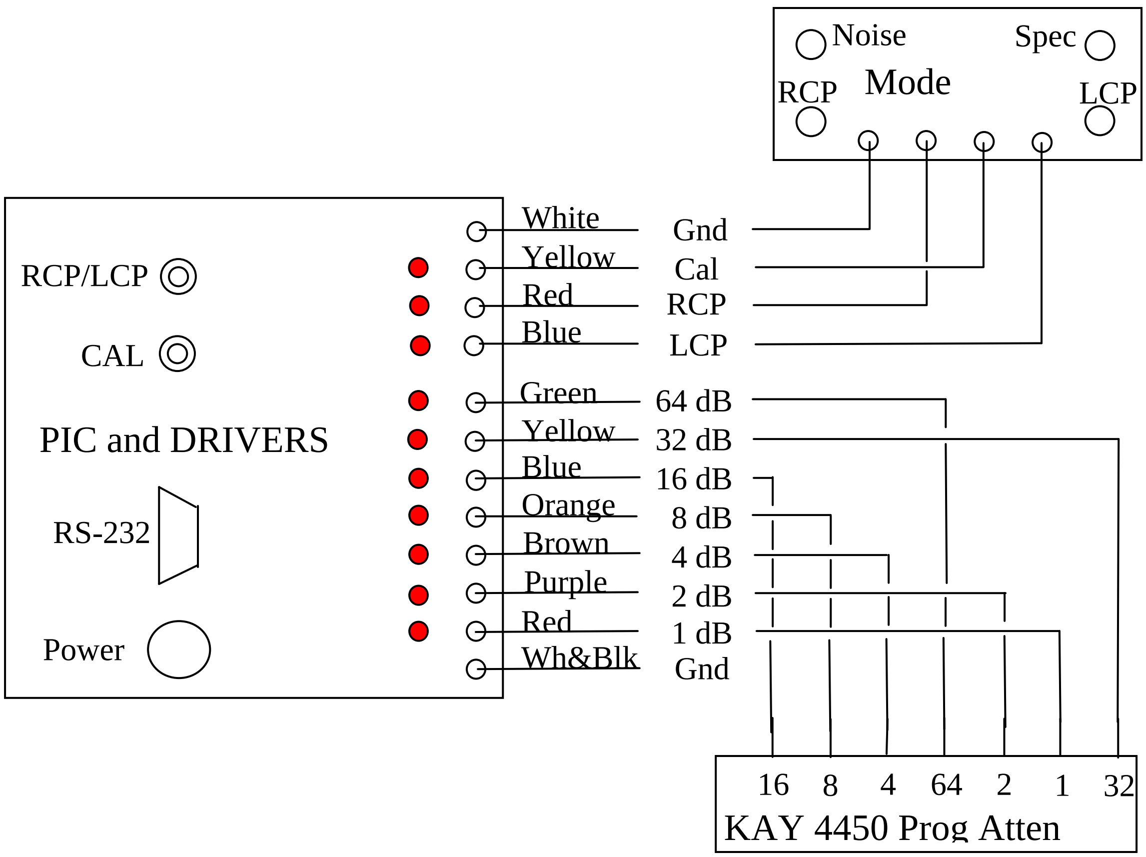
During CAL both K1 and K2 are **u**n-energized, terminating both antenna ports in 50 ohms

Both the mode switch and the step attenuator are controlled by a microcontroller (PIC), which communicates with the a300y computer via an RS232 serial link.

The mode switch/calibrator components are mounted on a 5.25” by 19”wide rack panel.

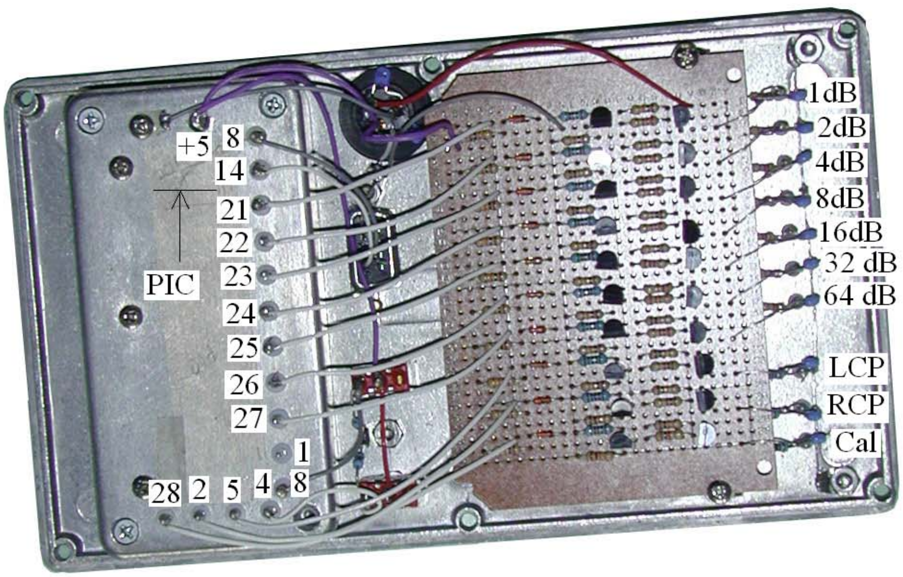
M15 – A **PIC microcontroller and driver circuit** generate command signals to control a commercial step attenuator and the mode switch. Three control lines operate the LCP, RCP, Cal/Opr Mode switch and seven control lines drive the individual 1, 2, 4, 8, 16, 32, and 64 dB cells of the step attenuator. The PIC communicates with the a300y computer via an RS232 line.

The physical layout of the modules and their interconnecting signal cables is seen below.

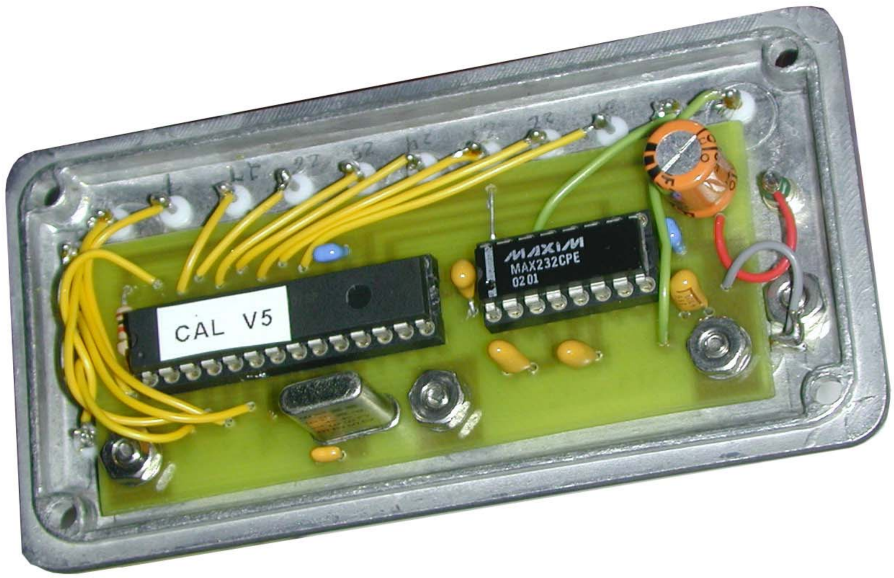


The PIC controller module is connected to the Elenco Power Supply by a 3-wire cable supplying +5, and +12 volts.

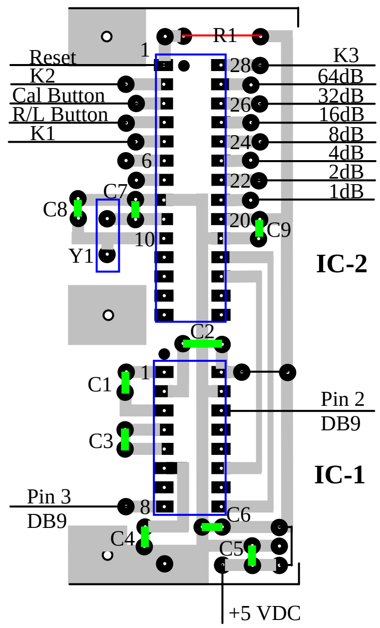
Pushbuttons on M15 can be used to test the RCP/LCP polarization select relays as well as the calibrate function. One push of the CAL button initiates the CAL sequence while pushing the RCP/LCP button toggles the spectrograph input between the RCP and LCP antennas.

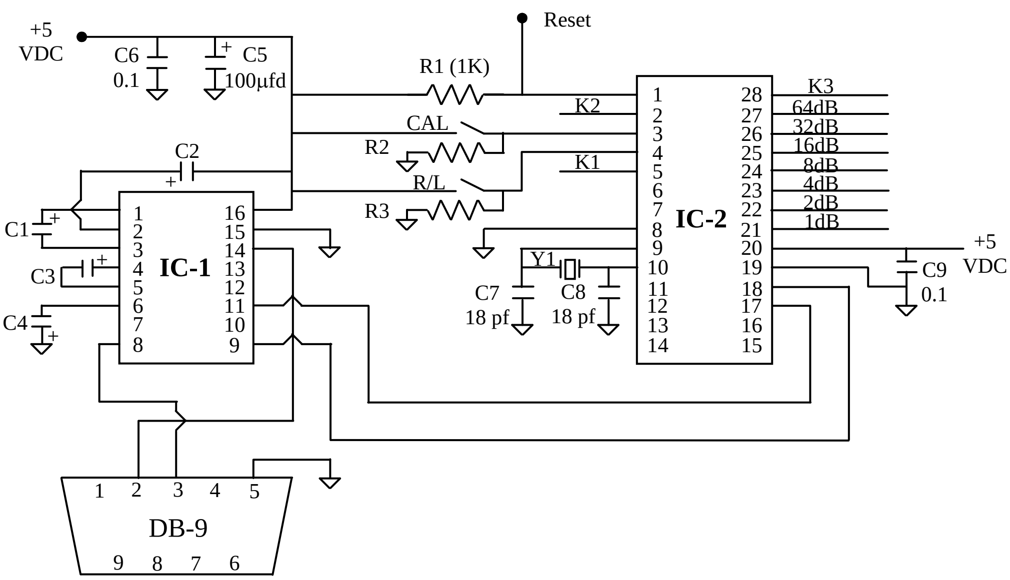


PIC Microcontroller and Driver Module (M15)
Numbers on PIC controller box indicate PIC and MAX-232 pin numbers.



The PIC16F873 microcontroller communicates with the main a300y computer via a MAX232 RS-232 chip. Serial communications rate is 56 K bits, which is derived from an 18.432 MHz crystal. The 16F873 contains the custom control code for the mode switch and the calibrator programmable attenuator. The PIC and MAX232 are mounted on a PC board inside of a small diecast box. Connections to the driver board and RS232 9 pin D-connector are via Teflon insulated feedthroughs. The PIC box is mounted inside a larger diecast box, which also contains the relay driver board.

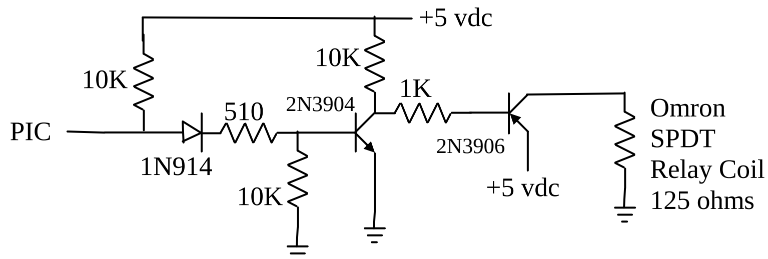


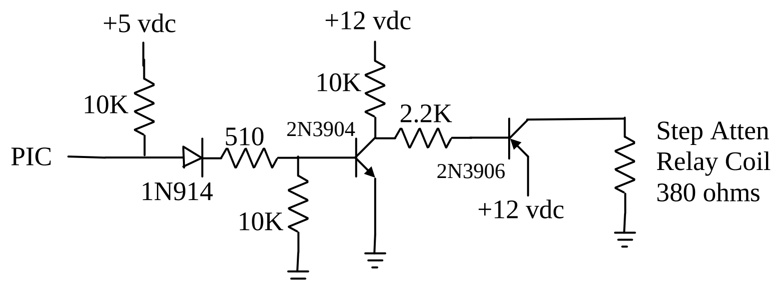


Calibrator PIC Controller

Note: C1, C2, C3, C4 are 1 µfd
IC1 = MAX-232, IC2 = 16F-873, Y1 = 18.432 MHz
Ground RESET line to reset PIC

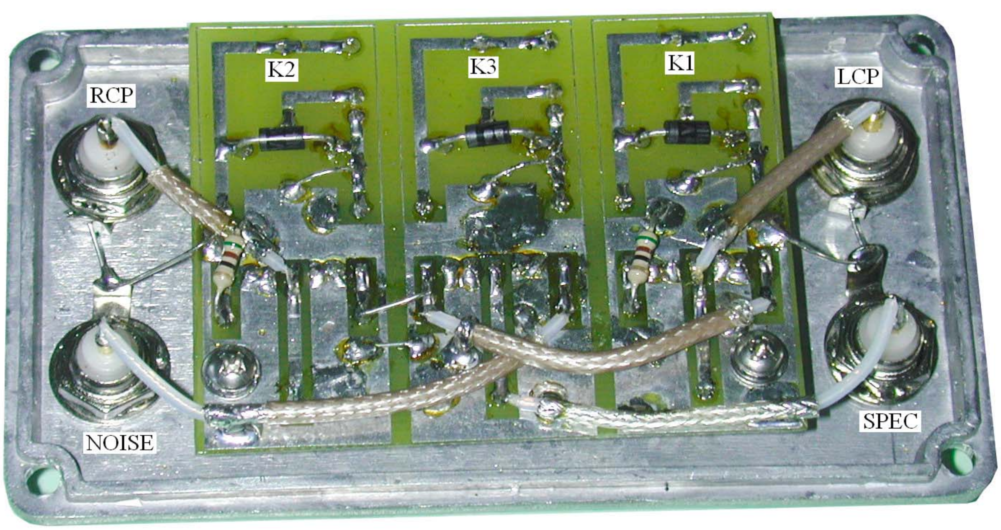
Driver circuits.
Two different driver circuits are used – one to control the 5 volt OMRON RF relays in the mode switch (M16) and the other, a 12 volt circuit used to drive the solenoids in the Kay programmable step attenuator. Each relay solenoid requires a dedicated driver circuit. The drivers turn on their solenoid when a +5v signal is applied by the PIC.





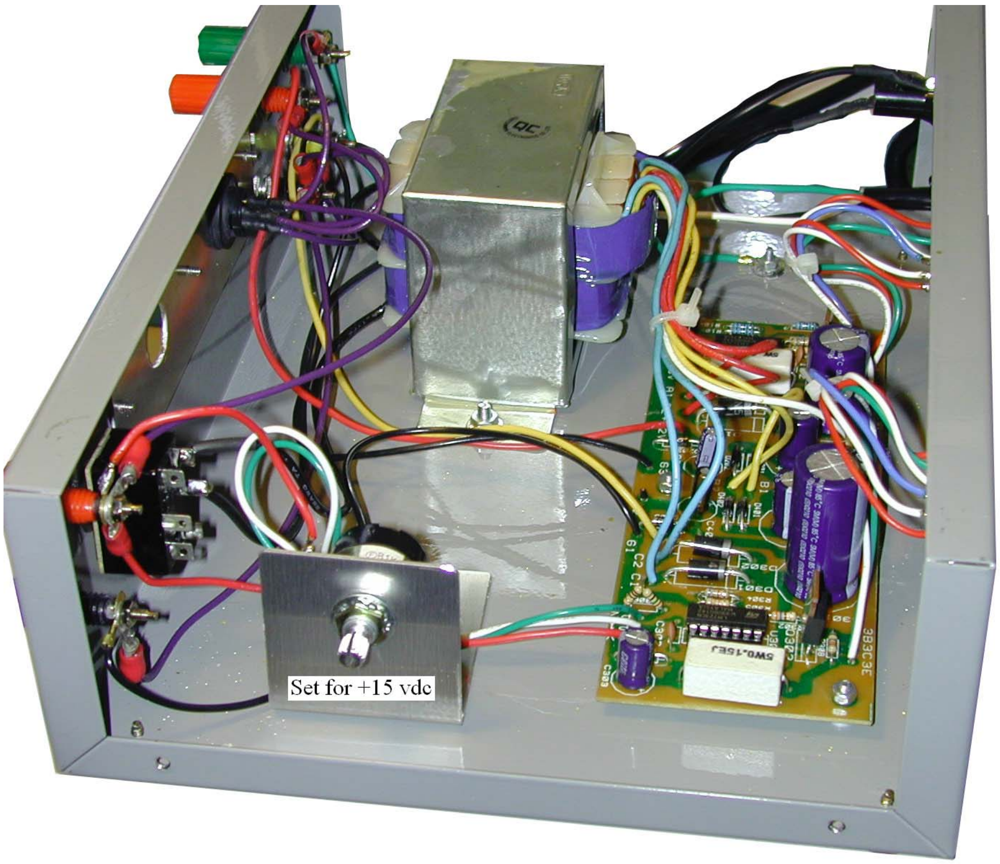
M16
Mode Switch

The mode switch contains three, 5 volt, SPDT Omron RF relays. These relays allow selection of either RCP or LCP signals and also control selection between calibrate and operate modes. The relays are controlled by signals generated by the PIC and amplified in the driver circuits located in module M15.

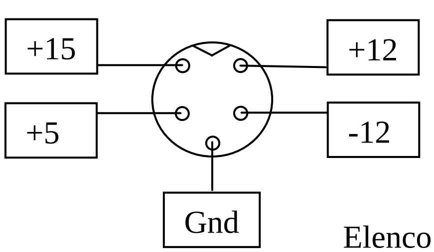


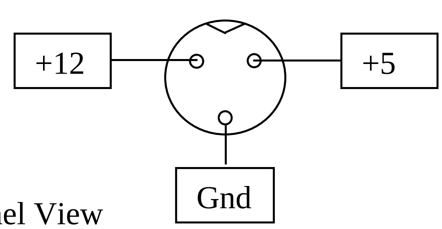
Spectrograph System Power Supply and Power Distribution

Power for the FS-200 spectrograph receiver and mode switch/calibrator assembly is provided by an Elenco Quad power supply. This unit supplies all necessary voltages for the system (+15, +12, -12, and +5 vdc). The +12, -12, and +5 supply voltages are fixed by internal regulators, while the +15 volt supply output voltage is set using a potentiometer mounted inside the Elenco enclosure.



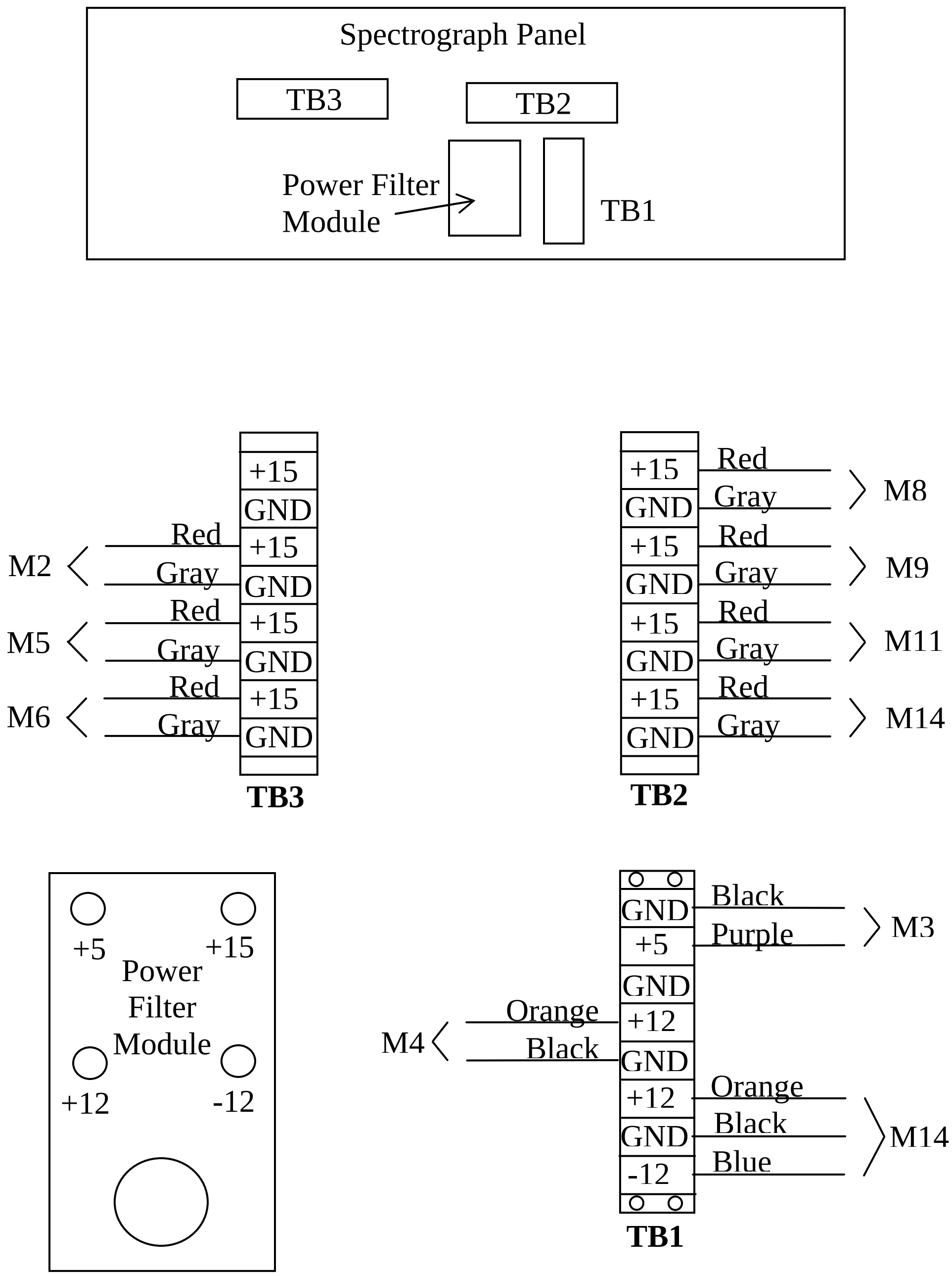
The Elenco supply has been modified by adding a 5-pin female circular power connector (to provide +15, +12, -12, and +5 volts to the spectrograph receiver), and a 3-pin female power connector (to provide +12, and +5volts to the mode switch/calibrator assembly).





Elenco Front Panel View

Two power cables are provided, one with 5 conductors for the spectrograph, the other with 3 conductors for the mode switch/calibrator assembly.



Spectrograph power distribution – barrier strip wiring