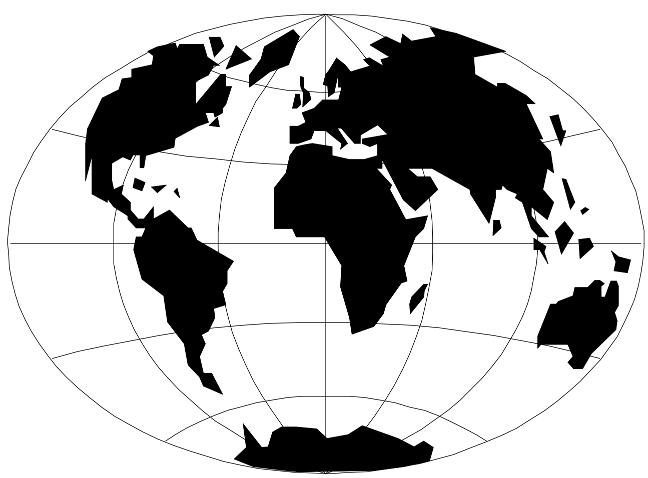
K9GDT
40m CW/SSB
Receiver



by George!

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Introduction

Figure 1-1   K9GDT 40m Receiver

1-1 Description

The K9GDT 40m receiver is a solid state receiver that offers a very high level of performance for the 40m Amateur Radio Band. It has excellent sensitivity, selectivity, and dynamic range. In addition, the receiver features a digital frequency readout and interference reduction circuitry.

The front panel layout is optimized for ease-of-use. Large controls are ergonomically placed in functional groupings, with frequently used controls positioned close to the large, weighted main tuning knob.

A doubly balanced switching-mode mixer is used as the front-end mixer in a single conversion scheme. This technique ensures optimum front-end overload and IMD performance.

The front panel SELECTIVITY switch allows the operator to select either a 2.1KHz or 400Hz IF bandwidth. Each bandwidth is provided by inserting the appropriate eight-pole crystal filter between the post-mixer amplifier and the IF amplifier. When the 400Hz position is selected, a second 400Hz filter is inserted before the product detector to remove broadband noise produced by the IF amplifier.

The PASSBAND tuning control is an operating aid useful in reducing or eliminating interfering signals. It electronically positions crystal filter’s response curve around the displayed frequency. This enables the operator to shift that response such that a nearby interfering signal is positioned down on the filter’s skirt.

The NOTCH TUNE control varies the center frequency of the AF notch filter. This feature is useful for eliminating interference from CW carriers and is especially useful in the upper portion of the band, which is shared with foreign broadcast services.

The receiver features a “tuned” audio section capable of delivering 3.5 watts to an eight ohm speaker. Frequency response is tailored by active, passive, and switched capacitor filtering.

Other features include external mute control, a transmit monitor mode, selectable AGC time constants, an AGC defeat mode, a CW keyer sidetone input, and a convenient tilt bail located on the receiver’s bottom panel.

1-2 Specifications

Frequency Coverage	40m Amateur Radio Band	**Spurious Response**	< 65 dB
Sensitivity	2.1KHz - Less than 0.4 µV for 10 dB $\frac{S+N}{N}$ 400Hz - Less than 0.15 µV for 10 dB $\frac{S+N}{N}$	**Frequency Readout Accuracy**	10ppm ±100Hz
Selectivity	2.1KHz @ –6 dB 3.9KHz @ –60 dB * 400Hz @ –6 dB 1.0KHz @ –60 dB *	**Frequency Stability**	< 1KHz during first 60 minutes after power-up < 100Hz /hr thereafter
AGC	Less than 6 dB output variation for a 100 dB input signal change, referenced to AGC threshold. (< 1µV) <u>Dynamic Characteristics:</u> Attack time - 1 ms. Decay times - 20 ms. 500 ms. 5 seconds	**Notch**	Notch Depth > 40 dB 400Hz -3KHz
Intercept Point	+7 dBm **	**Passband Tuning Range**	The receiver's display frequency ±4KHz
Internally Generated Spurs	None	**Audio Output**	3.5 Watts RMS @ less than 5% THD into 8 Ω
IF Frequency	3.395MHz	**Power Requirements**	102-132 VAC, 50-60Hz 30 Watts max.
IF Rejection	> 100 dB	**Dimensions**	5¼ in. high 17 in. wide 10¼ in. deep

* These values are approximate. Accurate measurements were impeded by the test generator's noise floor.
** Suitable test equipment was unavailable to measure this parameter. So Hayward's rule-of-thumb was used to "guesstimate" it's value.

Circuit Description

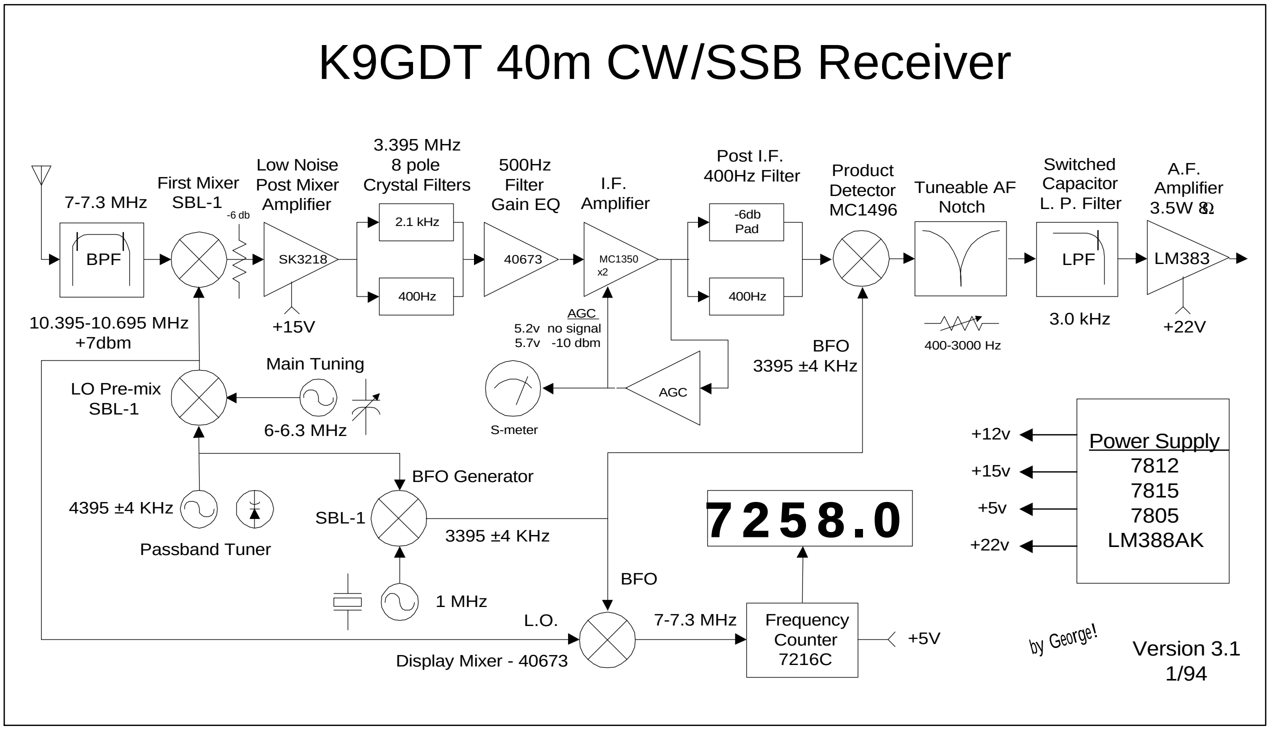

Figure 2-1 Receiver Block Diagram

2-1 Bandpass Filter Module

The Bandpass Filter module has an input and output impedance of 50Ω and consists of two major sections: a dual resonator parallel tuned bandpass filter and a seven element low pass filter for additional attenuation of image frequencies from 13.79 through 14.09MHz. The module's insertion loss is under 1dB.

2-2 Mixer - Post Mixer Amplifier

The mixer stage is a doubly-balanced diode-ring device made by Mini-Circuits Laboratories, model SBL-1. The 10.395-10.695MHz local oscillator drive level is +7dBm.

A 6 dB pad is placed between the mixer output and the post-mixer amplifier, which is a low noise, high dynamic range broadband bipolar amplifier with a 50Ω input impedance. This arrangement assures a proper non-reactive termination at the mixer's IF port for all frequencies present, thereby preserving it's IMD performance and eliminating the requirement for a diplexer. Because a very low noise figure is normally not necessary around 7MHz, the pad's 6 dB insertion loss is tolerable.

The post-mixer amplifier has a gain of 20 dB using an NTE278 transistor, which has an f_T of 1.2 GHz and a noise figure of about 4 dB. This device is heat sunk and biased to a standing current of 70 ma. The amplifier's output is matched to the 2 kΩ input impedance of the crystal filter which follows.

2-3 Crystal Filter - IF Amplifier - AGC Module

Crystal Filters

The received signal is fed to this module and routed to one of two eight-pole crystal filters by steering diodes. The bandwidths are selected by the front panel SELECTIVITY control. For an IF bandwidth of 2.1KHz, this control places +15 VDC on the 2.1KHz filter select input and GND on the 400Hz filter select input lines. To choose the 400Hz filter, the SELECTIVITY control reverses this connection. These filter selection signals are also supplied to the product detector for inserting a second 400Hz filter and to the IF amplifier for filter gain equalization.

IF Amplifier

The signal leaving the crystal filter is connected to a tuned amplifier (3.395MHz) which uses an RCA 40673 dual-gate MOSFET. The purpose of this amplifier is to establish the noise figure for the IF section and to provide gain equalization for the crystal filters. This low noise device provides ample gain that is easily controlled by a voltage at it's second gate. When the 400Hz filter is selected, +15 volts is applied to the GAIN EQ input, resulting in a 3.3 volt level on gate #2 for maximum gain. When the 2.1KHz filter is selected, the GAIN EQ input is grounded and the MOSFET's gate #2 voltage is then controlled by a 0-3.3 volt signal from the 2.1KHz FILTER GAIN EQ trim pot.

The signal is then amplified by a pair of cascaded Motorola MC1350 amplifiers. These devices furnish most of the IF amplifier's gain and over 120 dB of gain control. During no-signal conditions, the IF amplifier's gain control line is set to 5.38 volts. Gain is reduced by increasing the gain control voltage.

AGC

The output of the IF amplifier is coupled to the AGC detector diode. This diode charges a timing capacitor through a resistor which establishes the AGC attack time of approximately 1 millisecond. This value is sufficiently fast to maintain a constant AF output when a strong signal appears while preventing most pops and noises from "hanging" the AGC system.

The AGC decay time is determined by the parallel combination of a timing capacitor and a 22 MΩ resistor at the JFET input of the AGC amplifier. The timing capacitor is one of three selected by the front panel AGC control. This arrangement provides AGC decay times of about 20ms, 500ms, and 5 seconds, thus allowing the operator to match the receiver's AGC characteristics to the received signal's rate of fade. In addition, the front panel AGC control switch has an "OFF" position, which shorts the JFET's input to ground, thereby defeating the AGC system.

The AGC amplifier's output is connected through a diode to the IF amplifier's gain control line. Two other signals are similarly connected such that the most positive signal determines the receiver's gain. The front panel manual RF GAIN control raises the voltage on the control line to limit the maximum receiver gain with the AGC enabled. It will also provide total control of the receiver's gain when the AGC is defeated. The second signal mutes the receiver.

Mute Control

The external mute control system is compatible with that used by the R. L. Drake Co. The receiver is muted when a companion transmitter removes the short to ground (normally supplied when not transmitting) from the EXT MUTE connector. This causes +12 volts to be placed on the IF amplifier's gain control line, effectively silencing the receiver. The EXT MUTE DEFEAT switch on the rear panel provides a ground to the EXT MUTE connector so the receiver can be operated without a transmitter.

The monitor function also defeats the external mute feature by grounding the EXT MUTE input when the front panel function switch is turned to MON. This permits the operator to temporarily override the external mute for monitoring the transmitted signal or setting the transmit frequency.

2-4 400Hz Noise Filter/Product Detector

400Hz Noise Filter

A sample of the IF amplifier's output is fed to the 400Hz noise filter/product detector for conversion to audio. When the SELECTIVITY control is set to 400Hz, the filter selection signal energizes two small relays that insert a 400Hz eight pole crystal filter before the product detector. This filter restricts the effective noise bandwidth to that of the first 400Hz filter. Without it, broadband noise generated by the IF amplifier will reach the product detector and produce an audio output.

When the SELECTIVITY control is set to the 2.1KHz position, the 400Hz filter is removed and a 6dB pad is switched in the signal path. The purpose of this pad is to match the insertion loss of the 400Hz noise filter, thus insuring identical signal levels at the mixer input at both selectivity settings.

The requirement for a noise filter is much less stringent for a bandwidth of 2.1KHz, so one is not included. Almost all of the broadband IF noise at this selectivity setting is removed after detection by limiting the bandwidth of the audio section.

Product Detector

The received signal is then routed to the modulating signal input port of a Motorola MC1496-P balanced modulator used as a product detector. The BFO signal of 3395±4KHz is terminated in 50Ω, attenuated to 850 mV p-p, and applied to the balanced modulator's carrier port.

The audio signal from the output port is connected to a low pass filter which removes any RF energy from the product detector's AF output. The frequency response of this filter, as well as subsequent stages, is limited to 3000Hz. The result of this effort is clean sounding audio that is free from hiss and high pitched background garbage caused by filter "blow-by" from *very* strong adjacent signals.

The audio is then routed to the audio processing board.

2-5 Audio Processing Board - AF Power Amplifier

Audio Processing Board

The signal is sent through an input level set potentiometer to a LF356 low noise op amp, which functions as a 3KHz low pass filter. The amplifier's output is routed through a passive 200Hz highpass filter to another LF356 serving as a tunable notch filter.

The notch filter provides an adjustable response null from 400Hz to 3KHz by summing normal audio with the output of a phase inverting bandpass filter. The notch filter is disabled by removing the audio signal to the input of the bandpass filter.

The signal is routed through another 200Hz highpass filter network to the switched capacitor lowpass filter section.

The switched capacitor filter uses a National Semiconductor MF6-100 6th order Butterworth Lowpass filter. This chip also contains two op amps and an on-board clock. One of the op amps is used as a unity gain buffer to supply the required low-Z drive to the filter input stage. The other is used to provide a "stiff" source of V_{CC}÷2 bias. The clock frequency is adjusted to 300KHz, which sets the filter's cutoff frequency to 3KHz.

Finally, the signal is routed to the board's output connector through another highpass/lowpass network

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AF Power Amplifier

The signal from the Audio Processing board is sent through the front panel AF GAIN control to the AF Power Amplifier board. The amplifier uses a National Semiconductor LM383, which is powered by a 20 volt regulated supply and is capable of delivering 3.5 watts into an 8Ω load.

The SIDETONE input connector on the rear panel allows the receiver's power amplifier and speaker to be used by an accessory CW electronic keyer.

2-6 VFO

The VFO functions as the main tuning element by supplying a 6-6.3Mhz signal to the LO - Passband Generator module. The signal is produced by a temperature compensated series-tuned Colpitts JFET oscillator with 6.3 volt zener diode regulation. Tuning is accomplished by a high quality double ball bearing variable capacitor driven by a zero-backlash flywheel weighted 50:1 gear reduction drive.

The oscillator stage is followed by a two transistor buffer amplifier that produces a 5 volt p-p signal.

2-7 LO - Passband Generator Module

Passband Tuner

The Passband Tuner is an oscillator similar to the VFO described above. However, the 4395KHz output frequency can be shifted ±6KHz by a tuning voltage from the front panel PASSBAND control. This DC voltage is bias for varactor diodes which are part of the oscillator's series tuned circuit.

The effect of the ±6KHz offset is to shift the BFO and LO frequencies. The shifted LO repositions both the received signal and nearby interference around the response curve of the crystal IF filter. This permits the interfering signal to be placed down on the filter's skirt where it's effect will be less severe. Because the BFO frequency is also shifted by the same amount and in the same direction, there is no change in the received frequency.

There is a buffered Passband Tuner signal available at the PBT connector for use by the BFO Generator module.

LO Generator

The 4395KHz output of the Passband Tuner is mixed with the 6-6.3MHz VFO output to produce the local oscillator signal of 10.395-10.695MHz. A Mini-Circuits SBL-1 is used as the mixer and is followed a two transistor amplifier section with suitable bandpass filtering. The 50Ω, +7 dBm LO output is very clean, with mixed products and harmonic energy greater than 65dB below the LO carrier level.

A second, less spectrally pure, LO signal is available at the DISP connector for use by the Display Module.

2-8 BFO Generator

The BFO Generator furnishes a 3395±4KHz signal at +7dBm to the Product Detector, which converts the IF signal to audio. The BFO signal is produced by mixing the 4395±4KHz PBT signal with the output of a 1MHz crystal-controlled offset oscillator. The difference frequency of 3395±4KHz is amplified by a two stage tuned amplifier.

A second BFO output is used by the Display Module for frequency readout.

2-9 Display Module

The display module contains circuitry for the signal strength meter and digital readout. The S-meter is connected to a conventional balanced bridge circuit with one side driven by the AGC amplifier. The traditional ZERO and FULL SCALE adjustments are present for meter calibration.

When the receiver is properly adjusted, the S-meter will indicate S1 when the AGC is off and the RF GAIN control is at it's clockwise end of rotation. When the AGC is enabled, noise output from the IF amplifier will "tickle" the AGC and cause the meter reading to nudge upward slightly. An input of 1µV will indicate approximately S3, with a 50µV input indicating S9. A 30mV input will bring the S-meter to full scale and signals of 100mV and greater will peg the meter.

The digital frequency readout is a straightforward frequency counter which counts a 7-7.3MHz signal that is produced by mixing the 10.395-10.695MHz LO and 3395KHz BFO signals. The counter is based on an Intersil 7216C counter chip. Extensive shielding and decoupling are used in this and other modules to minimize leakage from the Display Module to the receiver front-end circuitry.

2-10 Power Supply

The power supply consists of four regulated outputs of +5, +12, +15, and +20 volts. The +5 volt output is used to power the TTL and CMOS chips used in the frequency display circuitry. The +15 volt section is used to supply power for the crystal filter selection diodes, the local oscillator output amplifier section, and the post-mixer amplifier. The AF power amplifier is operated from the +20 volt section, which is a National Semiconductor LM338AK 4 amp voltage regulator. The remaining circuitry is operated from the +12V section. LM78XX series 1 amp regulators are used for the +12, +15, and +5 volt outputs.

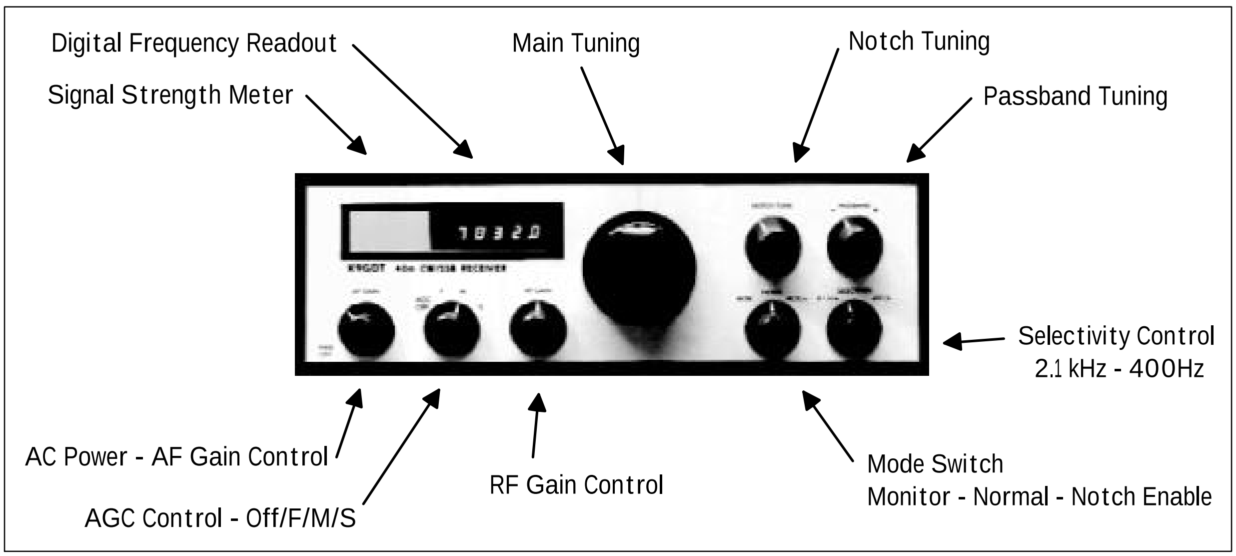


Figure 2-2 Front Panel Layout

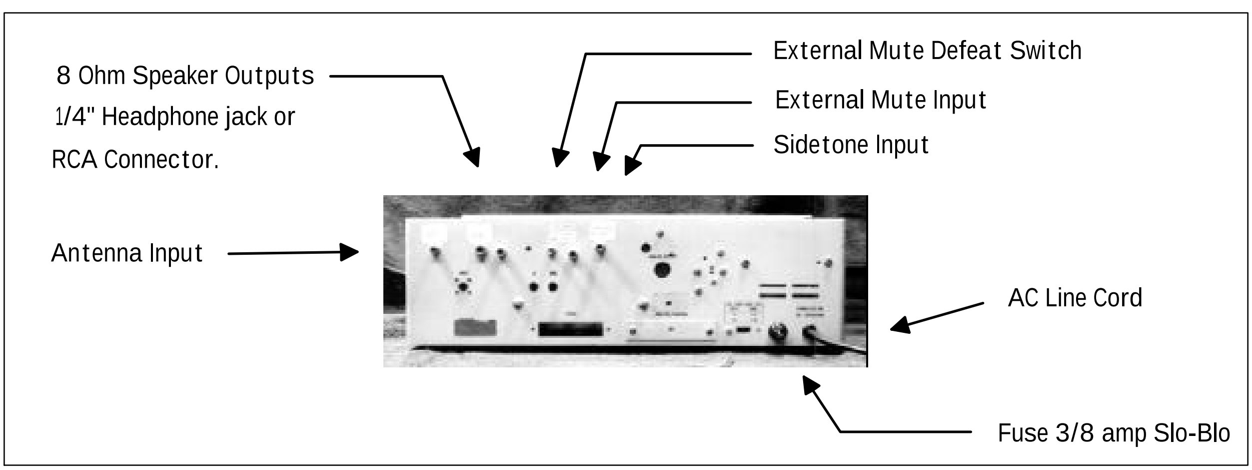
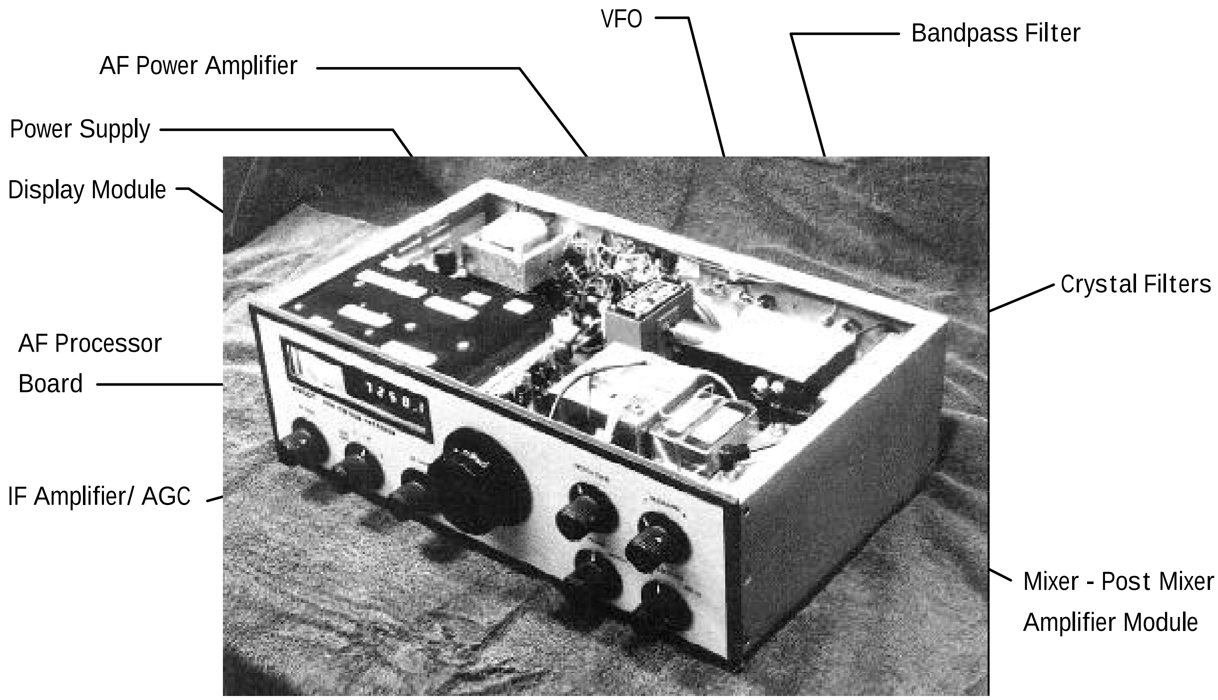
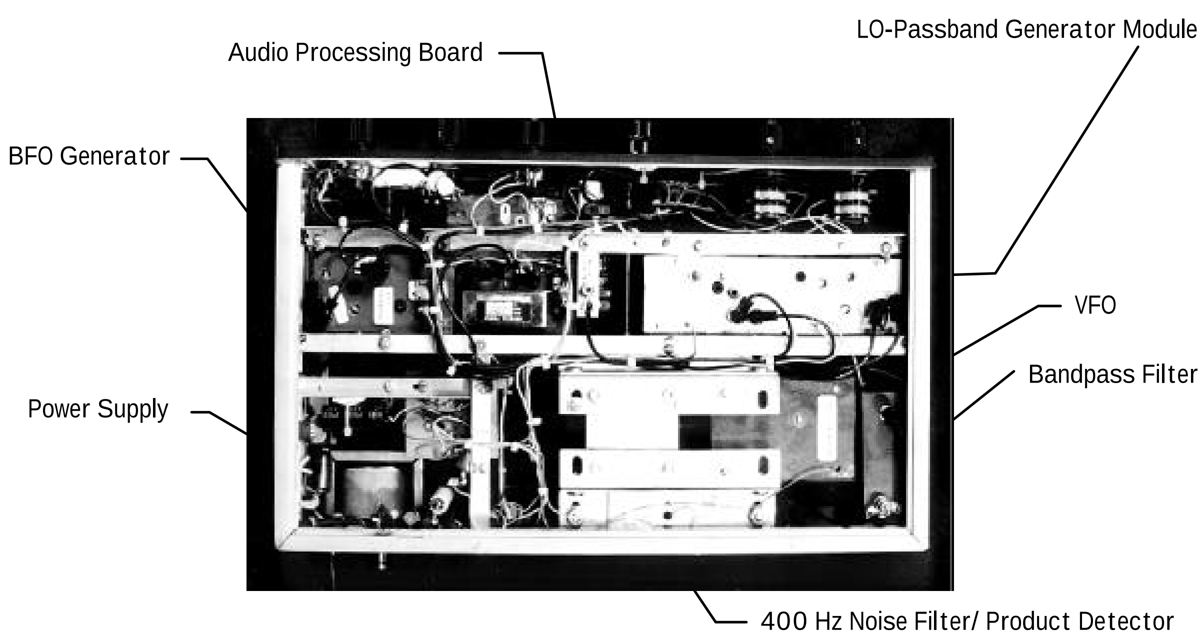


Figure 2-3 Rear Panel Connections and Controls

Figure 2-4 Interior Views - Module Locations



Top View



Bottom View

Alignment and Calibration

3-1 Required Test Equipment

- A DC voltmeter whose measurement uncertainty is better than 0.5% of reading.
- An oscilloscope with a bandwidth of at least 30Mhz.
- A frequency counter with 30MHz capability, 10Hz resolution, and a measurement uncertainty of 10 ppm.
- A spectrum analyzer with at least 70 dB dynamic range to 100MHz.
- A tracking generator for the spectrum analyzer.
- An RF generator with calibrated output from –130 dBm to +10dBm to at least 15MHz.
- A communications receiver with 10MHz coverage of WWV, NIST’s standard time and frequency station.

3-2 VFO

There is only one adjustment on the VFO module. Tune the VFO for an output frequency of 6.1MHz. This corresponds to a reading of 7100.0KHz on the display. Use an oscilloscope to monitor the VFO output at the spare RCA jack. Adjust the tuning slug located below the jacks near the bottom of the side panel for maximum output. Verify that the VFO’s output is about 5 volts peak to peak from 6.0 through 6.3MHz. NOTE: This is a very broad adjustment, which should not be required unless repairs have been made to the VFO.

3-3 LO - Passband Generator Module

Passband Center Frequency Adjustment

Center the front panel PASSBAND control. Connect a frequency counter to the PBT output and adjust L1 for a reading of 4395.0KHz. If a counter is not available, an alternate procedure would be to disconnect the antenna, select the 2.1KHz filter, center the PASSBAND control, and adjust L1 for the lowest pitched noise.

PBT Buffer Amplifier Adjustment

Center the front panel PASSBAND control. Connect the LO output to a spectrum analyzer and observe the signal. Adjust L2, PBT buffer amplifier tune, for maximum output. Keep the spectrum analyzer connected. It will be needed for the next adjustment.

LO Bandpass Filter Adjustment

- Adjust the receiver’s frequency to 7150.0KHz and adjust L3 for maximum output.
- Tune the receiver to 7300.0KHz and adjust C1 for maximum output.
- Tune the receiver to 7000.0KHz and adjust C2 for maximum output.
- Tune the receiver to 7200.0KHz and adjust C3 for maximum output.
- Verify that the LO output is at least +7dBm from band edge to band edge. If this condition is not satisfied, repeat the previous steps.
- Verify that all harmonics and mixed products are at least 65dB below the LO carrier level.

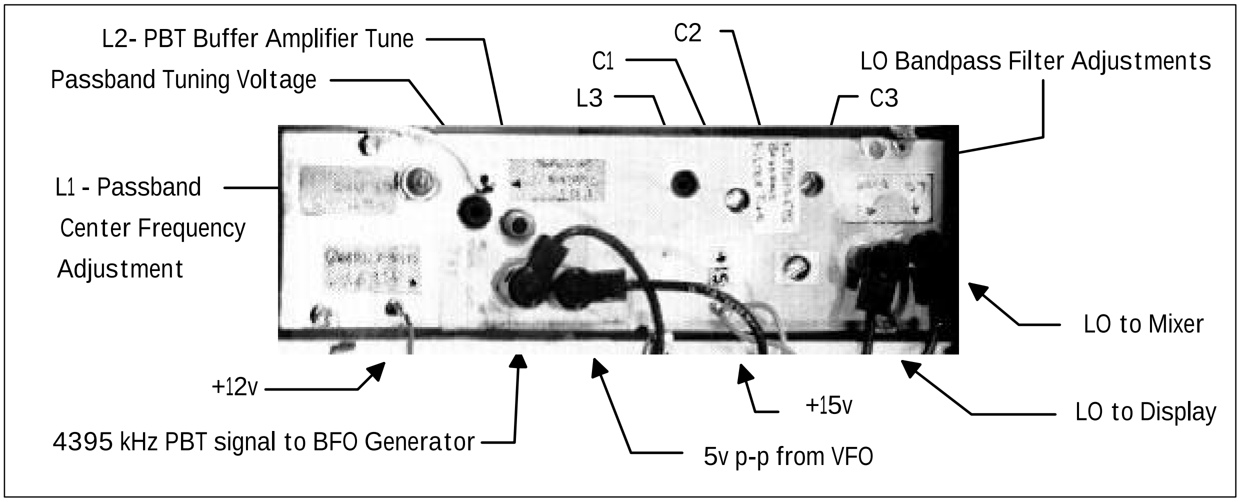


Figure 3-1 LO - Passband Generator

3-4 BFO Generator

1MHz Offset Oscillator Adjustment
Connect an oscilloscope to the 1MHz oscillator test point and adjust L1 for maximum output.

BFO Amplifier Adjustment
Center the front panel PASSBAND control. Use an oscilloscope to observe the signal at the RCA jack labeled DISP. Adjust C1 and C2 for maximum output.

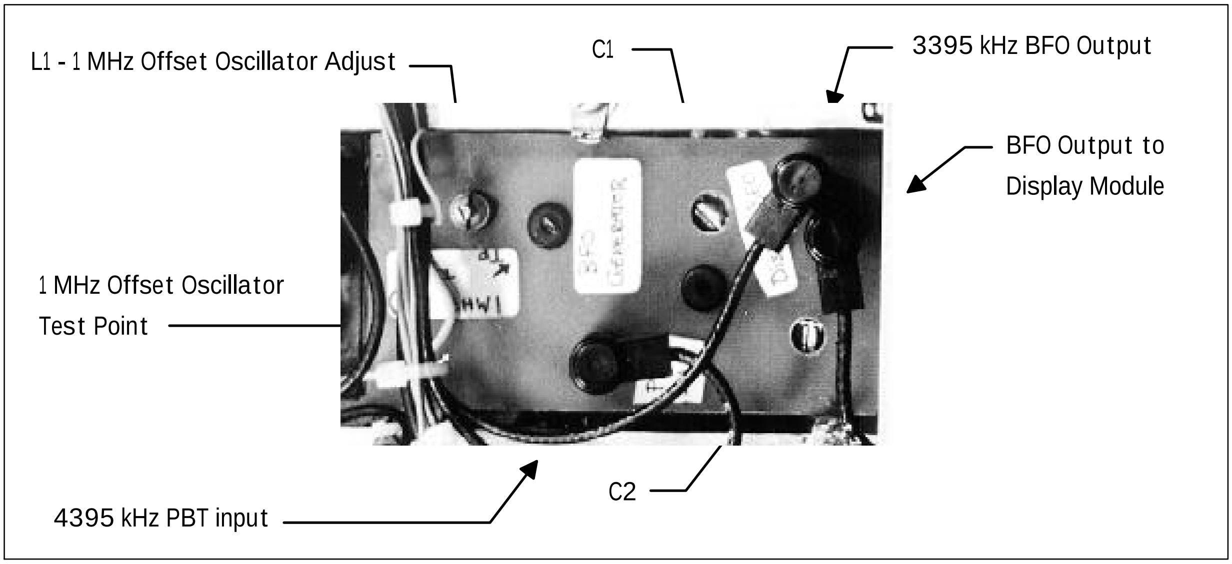


Figure 3-2 BFO Generator

3-5 Bandpass Filter

The two adjustments for the parallel resonators are accessible with the receiver's top cover removed. These adjustments are best made with a spectrum analyzer equipped with a tracking generator. Connect the tracking generator output to the filter input and connect the filter output to the spectrum analyzer's input. Set the spectrum analyzer to sweep from 6 to 8MHz. Adjust the two capacitors for the flattest response from 7.0 to 7.3MHz. Verify that the insertion loss is less than 1dB.

Readjust the spectrum analyzer's center frequency to 14MHz and verify that the filter's response is at least 60 dB down.

3-6 Mixer - Post Mixer Amplifier

The only adjustment for this module tunes the resonator used to match the 50Ω output impedance of the post-mixer amplifier to the 2kΩ input impedance of the eight pole crystal filters. This adjustment is accessible with the receiver's top cover removed.

Connect a signal generator to the antenna terminal and adjust the generator for a 7.05MHz, 3µV signal. Verify that the receiver's AGC is on FAST and the RF GAIN control is fully clockwise. Select the 400Hz filter and tune in the generator's signal. Adjust the trimmer capacitor for maximum indication on the signal strength meter.

3-7 Crystal Filter - IF Amplifier - AGC Module

AGC Bias Adjustment

Rotate the front panel AGC switch to "F" and turn the front panel RF GAIN control fully clockwise. Adjust R1 ten turns CCW and measure the voltage at the AGC test point. Verify the voltage is 5.38±.01 volts. This voltage is determined by a divider circuit formed by some fixed resistors and the RF GAIN potentiometer. Slowly turn R1 clockwise until the voltmeter reading increases by 10 millivolts to 5.39 volts. This ensures that noise output from the IF amplifier "tickles" the AGC system.

IF Amplifier Alignment

Connect the signal generator's output to the receiver input. Adjust the generator for an output of 1µV at 7.05MHz. Set the receiver's AGC to fast and select the 400Hz IF filter.

Tune in the generator's signal and adjust C1, C2, & L1 for maximum deflection on the signal strength meter. The meter should now indicate about S-3.

2.1KHz Filter Gain Equalization

Increase the generator output to 50µV, select the 400Hz filter, and adjust the PASSBAND control for a peak indication on the S-meter. The meter should be indicating approximately mid-scale. Make a note of the exact meter reading, then select the 2.1KHz filter. Readjust the PASSBAND control for a new peak reading. Adjust R2 to obtain a meter reading that matches the peak value noted above for the 400Hz filter.

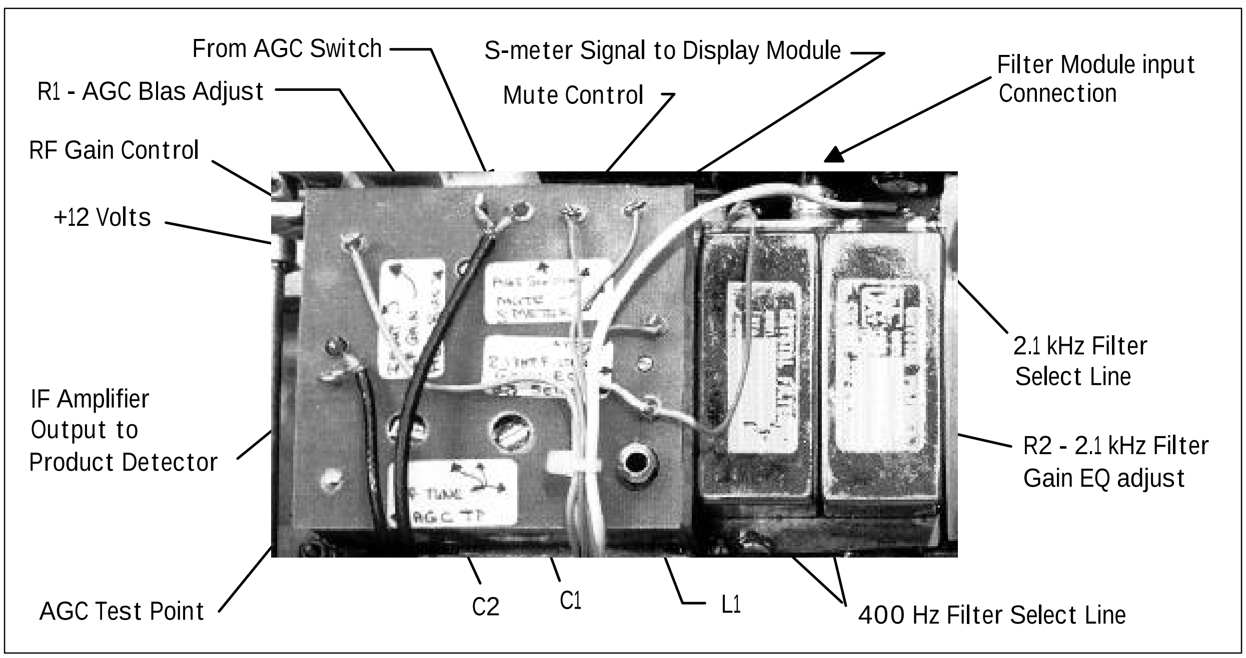


Figure 3-3 Crystal Filter - IF Amplifier - AGC

3-8 Audio Processing Board

Notch Depth Adjustment
Connect the signal generator the receiver and adjust it’s output for a 500µV signal at 7.05MHz. Tune the receiver to 7050.6KHz, select the 400Hz filter and adjust the PASSBAND control for maximum S-meter reading. This will result in an continuous tone audio output of 600Hz.

Enable the notch and adjust the front panel NOTCH TUNE control for minimum audible 600Hz tone. Adjust R1 on the Audio Processing board for minimum audible tone. Note: it may be necessary to increase the AF GAIN control setting to hear the tone. Because there is interaction between R1 and the NOTCH TUNE control, it may be necessary to repeat the steps described in this paragraph. Do not change any settings for the next step.

Input Attenuator Adjustment
Verify that the notch filter is enabled and the 600Hz tone has been removed. Adjust R2 fully CCW and note the presence of substantial harmonic distortion. Slowly rotate R2 clockwise to reduce the input level until all distortion products are inaudible. Rotate R2 for two additional turns. Turn off the notch filter and verify the presence of the 600Hz tone. Adjust the AF GAIN control for a comfortable listening level, enable the notch, and adjust the NOTCH TUNE control until the 600Hz tone disappears. Verify there is no audible output from the receiver. Turn off the notch filter. Do not change any generator settings.

SCF Cutoff Frequency
Connect an oscilloscope to the top arm of the AF GAIN control. Tune the receiver to 7053.0KHz and adjust the PASSBAND control for maximum S-meter reading. This will result in an audio tone of 3KHz.

Turn R3 fully CCW and adjust the oscilloscope for a six division display. Slowly rotate R3 clockwise until the display is reduced to between 4 and 4.2 divisions.

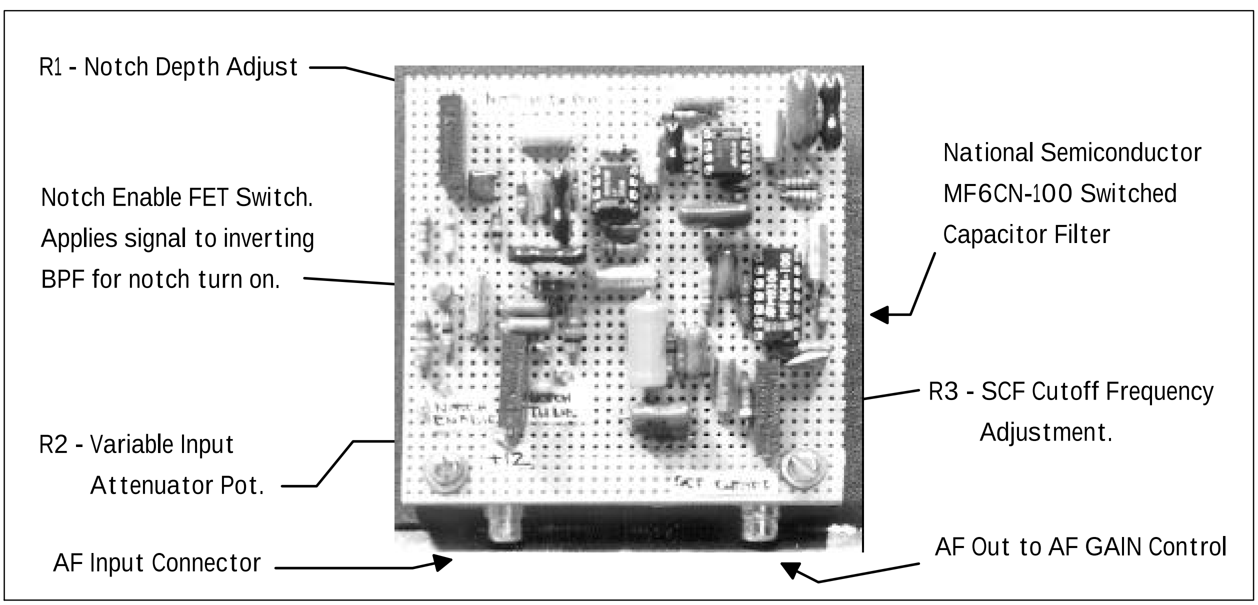


Figure 3-4 Audio Processing Board

3-9 Display Module

Counter Timebase Calibration
Place the communications receiver in the AM mode and tune to WWV at 10MHz. Use a ten foot piece of wire as an antenna and position it near the display module. Adjust the antenna's position such that the strength of the time base signal is comparable to WWV's. Adjust C1 such that the time base signal is zero-beat with WWV's carrier frequency.

Counter Amplifier Adjustment
The counter amplifier tuning is not critical and adjustments should not be required unless repairs have been made to the DISPLAY MODULE. Readjustment is required when the frequency readout will not display reliably from band edge to band edge.

Tune the K9GDT receiver for a display reading of 7125.0KHz. Next, tune the test communications receiver to 7125KHz and pick up the signal generated by the DISPLAY MODULE.

Note: It may be necessary to reposition the test receiver's antenna very close to L3 in order to pick up a good signal.

Tune L1, L2, and L3 for maximum signal strength as indicated on the test receiver's S-meter. Verify that the frequency readout on the DISPLAY MODULE is stable from band edge to band edge.

S-meter Adjustment
Tune the receiver to 7050.0KHz, turn the RF GAIN fully clockwise, the AGC to AGC OFF and select the 400Hz filter. Remove the signal generator and adjust R2 for a reading of S-1.

Reconnect the signal generator and adjust it's output to 30 mV at 7.05MHz. Turn the AGC switch to "F" and adjust the PASSBAND control for maximum reading on the S-meter. Adjust R1 for a full scale meter reading of +60 dB.

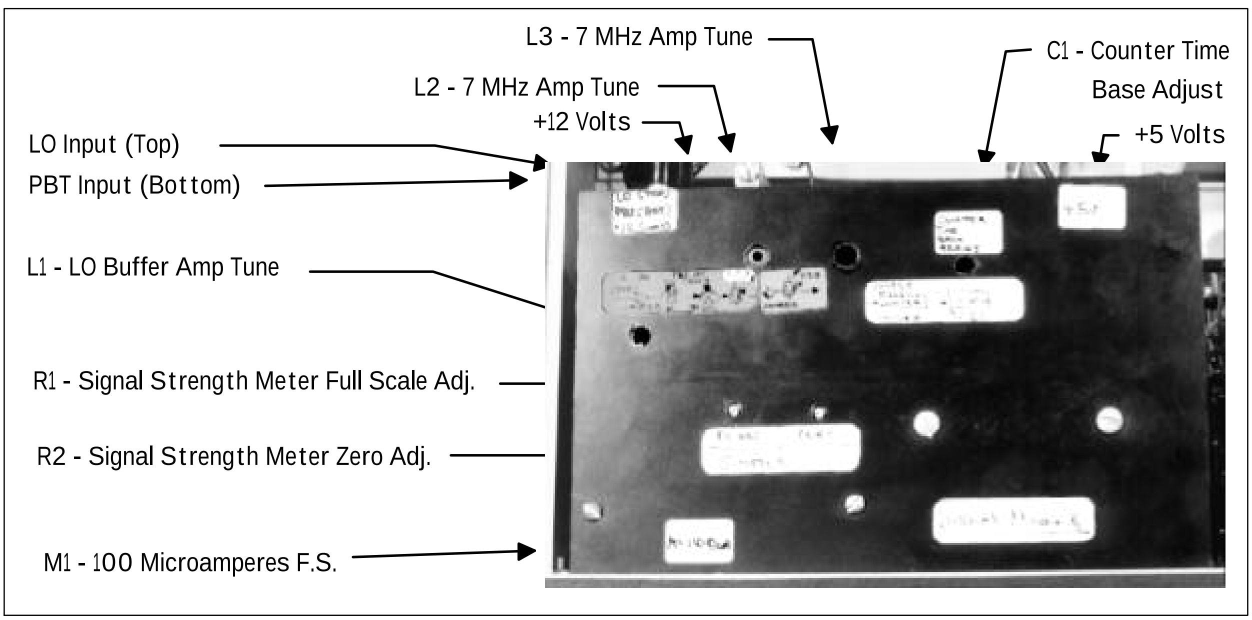


Figure 3-5 Display Module