HAMTRONICS® R313 VHF FM RECEIVER: INSTALLATION, OPERATION, & MAINTENANCE

GENERAL INFORMATION.

The R313 is the latest in a series of popular receivers for demanding applications which require exceptional sensitivity and selectivity. It is especially suited for repeaters, audio and data links, and remote control. It is a single-channel vhf fm receiver available in several models for reception in the 144 MHz ham band, the 138-175 MHz commercial band, or 72-73 MHz. Channel frequency is set by dip switch.

The R313 is our 10th generation vhf fm receiver, and it packs in features you've told us are important to you during our 50 years of designing receivers. It's up to the difficult jobs you've told us you have.

The R313 retains all of the popular features Hamtronics® receivers have been noted for. It uses triple-tuned circuits in the front end and excellent crystal and ceramic filters in the i-f with steep skirts for close channel spacing or repeater operation. The i-f selectivity, for instance, is down over 100dB at ±12 kHz away from the carrier, which is 40-50 dB better than most transceivers. Low noise fet's in the front end provide good overload resistance and excellent sensitivity.

The R313 is designed for narrow-band fm with ±5 kHz deviation. Other bandwidths are available on special order.

The R313 features a positive-acting, wide-range squelch circuit and additional output terminals for low-level squelched audio and discriminator audio as well as COS.

The audio output will drive any load as low as 8Ω with up to 1 Watt continuous output. Volume and squelch are adjustable with trim pots on the pc board.

There are several models, which have minor variations in parts and microcontroller programming, to provide coverage of several bands, as shown in the table on page 8. The frequency is set at the factory and is aligned to frequency; so you have no adjustments to do at installation.

The TCXO (temperature controlled xtal oscillator) provides a temperature stability of ±2ppm over a temperature range of -30°C to +60°C.

INSTALLATION.

Mounting.

Some form of support should be provided under the pc board, generally mounting the board with spacers to a chassis. The receiver board relies on the mounting hardware to provide the dc and speaker ground connections to the ground plane on the board; so metal standoffs and screws should be used for mounting.

Electrical Connections.

Power and input audio or data signals should be connected to the solder pads on the pc board with #22 solid hookup wire, which can be attached to a connector or feed-through capacitors used on the cabinet in which it is installed. Be very careful not to route the wiring near the components on the left hand side of the board, which contains sensitive loop filter and vco circuits which could pick up noise from the wiring.

Power Connections.

The receiver operates on +13.6 Vdc at about 100 mA peak with full audio. Current drain with no audio is only about 38 mA. A well regulated power supply should be used.

Be sure that the power source does not carry high voltage or reverse polarity transients on the line, since semiconductors in the receiver can be damaged. The positive power supply lead should be connected to the receiver at terminal E3, and the negative power lead should be connected to the ground plane of the board through the mounting hardware or E6. Be sure to observe polarity!

Speaker.

An 8-ohm loudspeaker should be connected to E2 with ground return to E6. Use of lower impedance speaker or shorting of speaker terminal can result in ic damage.

Antenna Connections.

The antenna connection should be made to the pc board with an RCA plug of the low-loss type made for rf. We sell good RCA plugs with cable clamp. See A5 plug on website.

If you want to extend the antenna connection to a panel connector, we recommend using a short length of RG-174/u coax with the plug and keep the pigtails very short.

We do **not** recommend trying to use direct coax soldered to board or another type of connector. The method designed into the board results in lowest loss practical. When soldering the cable, keep the stripped ends as short as possible.

We recommend you always use antennas with a matching network which provides a dc ground on the driven element to avoid static buildup damaging the input stage of the receiver.

OPTIONS.

Repeater Use.

E5 provides a COS (carrier operated switch) output which may be connected to a COR module to turn a transmitter on and off. The output level is about 5V unsquelched and 0V squelched. There is a resistor in series with the output to limit current. Therefore, the voltage that appears at the COR board will depend on the load resistance at the input of that board. For best results, be sure that the input resistance of the COR board is at least 47K. If the input resistance is too low, no damage to the receiver will occur; but the squelch circuit hysteresis will be affected.

If your repeater controller uses discriminator audio, rather than the speaker output, filtered discriminator audio is available at E4. The level is about 2V p-p. *Note that discriminator audio is not de-emphasized or squelched.*

If your controller uses low level audio and has a high input impedance (20K or higher), squelched audio can be obtained from Repeater Audio terminal E1 independent of the volume control.

Subaudible Tone Decoder.

To use our TD-5 Subaudible Tone Decoder or a similar module, connect its audio input to *DISCRIMINATOR* terminal E4. If you want to use it to mute the audio (instead of inhibiting a repeater transmitter as is normally done), connect the mute output of the TD-5 to E1 on the receiver.

FREQUENCY SETTING.

The channel frequency is determined by frequency synthesizer circuits, which use the DIP switch in conjunction with programming in the microcontroller to set the frequency. The microcontroller reads the dip switch information and does mathematics, applying data to the synthesizer ic. Following is a discussion of how to set the dip switch to the desired channel frequency.

NOTE: *If the frequency is changed more than about ±1 MHz, a complete alignment of the receiver should be performed, as described in later text. Optimum operation only occurs if the synthesizer is adjusted to match the fre-*

Table 1. Quick Specification Reference
Frequency Range: Can be supplied for any frequency in range of 138-175MHz or 72-73 MHz.
Sensitivity (12dB SINAD): 0.15 to 0.2µV
Squelch Sensitivity: 0.15µV
Normal signal bw: ±5kHz deviation
Adjacent Channel Selectivity: ±12 kHz at -100dB (narrower bandwidth available as an option)
Image Rejection: 60-70dB
Modulation Acceptance: ±7.5 kHz
Frequency Stability: ±2ppm -30°C to +60°C
Audio Output: up to 1 Watt (8 ohms).
Operating Power: +13.6Vdc (+10 to +15Vdc) at 38-100 mA, depending on audio level.
Size: 4 in. W x 3 in. D

quency switch setting and all the tuned amplifier circuits are peaked for the desired frequency. It is anticipated that most customers will continue to use the alignment done at the factory for the frequency they specified. There is no reason to do anything unless you need to change frequencies. Be careful not to disturb the DIP switch if you don't need to change frequencies.

To determine what channel frequency to use, the microcontroller adds the frequency information from the dip switch to the "base" frequency, which is the lowest frequency in the band the unit was made for.

Dip switch settings are binary, which means each switch section has a different weighting, twice as great as the next lower section. Sections have weights such as 5 kHz, 10 kHz, 200kHz, etc.

You might want to record the switch settings in table 3 for future reference in case the settings are disturbed.

We make it easy by publishing a long table of possible settings on our website. Refer to the following link …

http://www.hamtronics.com/dipswitch_R313_R307.htm

Look up the frequency, and it will give you all the binary switch settings. To determine which setting to use, subtract the "base" frequency to see what "adder" setting to use.

For example, if your receiver was made for the 144-154 MHz band, subtract "144.000" from the channel frequency to determine the switch setting to use.

ALIGNMENT.

General Information.

It is assumed that the Receiver was ordered for a particular frequency and aligned at the factory for that frequency. The following procedure is only necessary if you change frequencies by more than 1MHz. Most customers will never have to perform alignment.

Following are three alignment procedures. The first is alignment of the frequency synthesizer and receiver front end (rf amplifier and mixer). This must be done whenever the channel frequency is changed by more than 1 MHz. The R313 is a high performance receiver and is designed to be very selective. Therefore, retuning is necessary for optimum performance. The second procedure is alignment of the i-f stages, which normally is only necessary if some parts are replaced. The third procedure is trimming the TCXO (temperature compensated crystal oscillator) to exact frequency, which normally is never necessary.

Equipment Needed.

Equipment needed for alignment is a sensitive dc voltmeter and a stable and accurate communications service monitor for the channel frequency.

The slug tuned coils in the receiver should be adjusted with the proper hex tuning tool to avoid cracking the powdered iron slugs. Variable capacitors and i-f transformers should be adjusted with a plastic tool having a small ceramic or metal bit. See our A1 Tuning Tool if you don't have one.

Channel Frequency Alignment.

Alignment is needed whenever the frequency is changed by more than about 1 MHz. Alignment ensures that the frequency synthesizer is optimized at the center of the vco range and that all stages are tuned to resonance.

a. Set dip switches for desired frequency.

b. Connect dc voltmeter to Osc Tune test point TP1 (pad on top of pcb). Adjust vco coil L1 for +2Vdc. (Although the vco will operate over a wide range of tuning voltages from about 1V to 5V, operation is optimum if the vco is adjusted to 2V.)

c. Connect dc voltmeter to buffer TP2 (pad on top of pcb). Adjust buffer coil L2 for a peak.

d. Connect dc voltmeter to RF Tune test point TP4 (pad on top of pcb), or alternately, use a SINAD meter.

e. Connect service monitor signal generator output to J1 using a coax cable with RCA plug. Adjust signal generator to exact channel frequency, and set it for carrier output only, unless you are using a SINAD meter.

f. During tuning, adjust service monitor signal output level as needed to get an indication within the range of the noise detector driving the test point for the voltmeter. Note that the test point level will be effective for tuning only with a relatively weak signal and will saturate with too strong a signal. Basically, you are reading the noise level in the squelch circuit.

g. Adjust L4, L5, L6, L7, and L8 for minimum voltage. Voltage goes down, not up, with increased signal level (trying to minimize noise).

Alignment of I-F Stages.

a. Connect dc voltmeter to DISC pad E4 on top of pcb.

b. With no input signal (just noise), adjust i-f transformer T3 for +2Vdc on the meter.

💣 *Be careful not to turn the slug tight against either the top or bottom because the winding of the transformer can be broken.*

Oscillator Trimming.

If you suspect that the TCXO needs adjustment, which normally it does not, proceed as follows.

a. First, perform step b of the Channel Frequency Alignment procedure to be sure vco is set to frequency.

b. Set the service monitor for 10.700 MHz and connect rf output to TP3 on top of board.

c. Connect dc voltmeter to E4 as indicated for discriminator alignment above.

d. Use a 0.4 x 0.9mm ceramic tuning tool to adjust the small variable capacitor in the TCXO for +2V.

THEORY OF OPERATION.

Low noise dual-gate mos fet's are used for RF amplifier Q4 and mixer Q5. The output of the first mixer is coupled through a 10.700 MHz crystal filter to the second mixer, which is in U3.

U3 provides IF amplification, a 2nd mixer to convert to 455 kHz, an fm detector, and squelch. Ceramic filter FL2 provides additional adjacent channel selectivity at 455 kHz.

The output of the fm detector at pin 9 of U3 is applied to an active filter stage, which is peaked at 10,000 Hz, looking for noise when there is no signal. The noise output is detected by D3/D4 and drives the squelch detector input at pin 12. A variable dc voltage from SQUELCH pot R25 is also applied to pin 12 through a summing circuit to allow squelch threshold adjustment.

The injection frequency for the first mixer is generated by vco (voltage controlled oscillator) Q1. The injection frequency normally is 10.700 MHz below the receive channel frequency, except that the 72MHz version of the receiver uses mixer injection 10.700MHz above the channel frequency. The output of the vco is buffered by Q2 to minimize effects of loading and voltage variations of following stages from modulating the carrier frequency. The buffer output is applied through a double tuned circuit to gate 2 of mixer Q5.

The frequency of the vco stage is controlled by phase locked loop synthesizer U2. A sample of the vco output is applied through the buffer stage and R1 to a prescaler in U2. The prescaler and other dividers in the synthesizer divide the sample down to 5kHz.

A reference frequency of 10.240 MHz is generated by a temperature compensated crystal oscillator (TCXO). The reference is divided down to 5 kHz. The two 5kHz signals are compared to determine what error exists between them. The result is a slowly varying dc tuning voltage used to phase lock the vco precisely onto the desired channel frequency.

The tuning voltage is applied to carrier tune varactor diode D1, which varies its capacitance to tune the tank circuit formed by L1/C15/C16. C12 limits the tuning range of D1. The tuning voltage is applied to D1

Table 3. My Switch Settings
Frequency:____________________ MHz
Switch Sections Turned On: (circle)
1 2 3 4 5 6 7 8 9 10

through a third order low pass loop filter, which removes the 5kHz reference frequency from the tuning voltage to avoid whine.

Serial data to indicate the desired channel frequency and other operational characteristics of the synthesizer are applied to synthesizer U2 by microcontroller U1. Everything the synthesizer ic needs to know about the band, division schemes, reference frequency, and oscillator options is generated by the microcontroller. Information about the base frequency of the band the receiver is to operate on and the channel within that band is calculated in the controller based on information programmed in the eprom on the controller and on channel settings done on dip switch S1. The microcontroller sends several bytes of serial data to the synthesizer, using the data, clock, and /enable lines running between the two ic's.

+13.6Vdc power for the receiver is applied at E3. U6 is a 5V regulator to provide stability and C55 and C56 eliminate noise. Additional filtering for the vco and buffer stages is provided by capacitance amplifier Q3, which uses the characteristics of an emitter follower to provide a very stiff supply, eliminating any possible noise on the power supply line.

TROUBLESHOOTING.

General.

The usual troubleshooting techniques of checking dc voltages and signal tracing with an RF voltmeter probe and oscilloscope will work well in troubleshooting the R313. DC voltage charts and a list of typical audio levels are given to act as a guide to troubleshooting. Although voltages may vary widely from set to set and under various operating and measurement conditions, the indications may be helpful when used in a logical troubleshooting procedure.

Current Drain.

Power line current drain normally is about 38 mA with volume turned down or squelched and up to 100 mA with full audio output.

If the current drain is approximately 100 mA with no audio output, check to see if voltage regulator U6 is hot. If so, and the voltage on the 5V line is low, there is a short circuit on that bus somewhere and U6 is limiting the short circuit current to 100mA to protect the receiver from damage. If you clear the short circuit, the voltage should rise again. U6 should not be damaged by short circuits on its output line; however, it may be damaged by reverse voltage or high transient voltages.

Audio Output Stage.

Note that audio output ic U5 is designed to be heatsunk to the pc board through the ground pins on the ic.

If audio is present at the VOLUME control but not at the speaker, the audio ic may have been damaged by reverse polarity or a transient on the B+ line. This is fairly common with lightning damage.

If no audio is present on the VOLUME control, the squelch circuit may not be operating properly. Check the dc voltages, and look for noise in the 10 kHz region, which should be present at U4-pin 11 with no input signal. (Between pins 10 and 11 of U4 is an op-amp active filter tuned to 10 kHz.)

RF Signal Tracing.

If the receiver is completely dead, try a 10.700 MHz signal applied to TP-3 using coax test lead. Set level just high enough for full quieting. At 1 µV, you should notice some quieting, but you need something near full quieting for the test.

You can also connect the 10.700 MHz test lead through a blocking capacitor to various sections of the crystal filter to see if there is a large loss of signal across one of the filter sections. Also, check the 10.245 MHz oscillator with a scope or by listening with an hf receiver or service monitor.

A signal generator on the channel frequency can be injected at various points in the front end. If the mixer is more sensitive than the RF amplifier, the RF stage is suspect. Check the dc voltages looking for a damaged fet, which can occur due to transients or reverse polarity on the dc power line. Also, it is possible to have the input gate (gate 1) of the RF amplifier fet damaged by high static charges or high levels of RF on the antenna line, with no apparent change in dc voltages, since the input gate is normally at dc ground.

Synthesizer Circuits.

Following is a checklist of things to look for if the synthesizer is suspected of not performing properly.

a. Check the output frequency of the vco buffer with a frequency counter.

b. Check tuning voltage at TP1. It should be about +2.0Vdc. Actual range over which the unit will operate is about +0.5Vdc to about +4.5Vdc. However, for optimum results, the vco should be tuned to allow operation at about +2.0Vdc center voltage.

c. Check the operating voltage and bias on the vco and buffer.

d. Check the TCXO at pin 1 of the synthesizer ic. A scope should show strong signal (1.5 Vp-p) at 10.240 MHz.

e. The data, clock, and latch enable lines between the microcontroller and synthesizer ic's should show very brief and very fast activity, sending data to the synthesizer ic. Because this happens very fast, it can be difficult to see on a scope. Use 1mSec/div, 5Vdc/div, and normal trigger.

Microphonics, Hum, and Noise.

The vco and loop filter are very sensitive to hum and noise pickup from magnetic and electrical sources. Some designs use a shielded compartment for vco's. We assume the whole board will be installed in a shielded enclosure; so we elected to keep the size small by not using a separate shield on the vco. However, this means that you must use care to keep wiring away from the vco circuit. Having the board in a metal enclosure will shield these sensitive circuits from florescent lights and other strong sources of noise.

Because the frequency of a synthesizer basically results from a free running L-C oscillator, the tank circuit, especially L1, is very sensitive to microphonics from mechanical noise coupled to the coil. You should minimize any sources of vibration which might be coupled to the receiver, such as motors.

Excessive noise on the dc power supply which operates the receiver can cause noise to modulate the synthesizer output. Various regulators and filters in the receiver are designed to minimize sensitivity to wiring noise.

To varying degrees, whine from the 5kHz reference frequency may be heard on the signal under various circumstances. If the tuning voltage required to tune the vco on frequency is very high or low, near one extreme, the whine may be heard. This can also happen even when the tuning voltage is properly near the 2.0Vdc center if there is dc loading on the loop filter. Any current loading, no matter how small, on the loop filter causes the phase detector to pump harder to maintain the tuning voltage. The result is whine on the signal. Such loading can be caused by connecting a voltmeter to TP1 for testing, and it can also be caused by moisture on the loop filter components.

Typical DC Voltages.

Tables 4-6 give dc levels measured with a sensitive dc voltmeter on a sample unit with 13.6 Vdc B+ applied. All voltages may vary considerably without necessarily indicating trouble. The charts should be used with a logical troubleshooting plan. All voltages are positive with respect to ground except as indicated.

Use caution when measuring voltages on surface mount ics. The pins are close together, and it is easy to short pins together and damage the ic. Try to connect meter to a nearby component connected to the pin under question.

Typical Audio Levels.

Table 7 gives rough measurements of audio levels. Measurements were taken using an oscilloscope, with no input signal, just white noise so conditions can be reproduced easily.

Table 4. Typical Test Point Voltages		
TP1	Tuning V.	Normally set at 2V
TP2	Buffer	approx. 0.3 – 0.6V
TP3	Test Input	(No reading)
TP4	Noise det.	With SQUELCH control fully ccw, varies from -0.3 Vdc with no to +0.9 Vdc full quieting.
E4	DISC	Varies with frequency of input signal. Voltage at this point normally is adjusted for +2Vdc with a signal exactly on frequency. Can vary a little without being a problem.

Table 5. Typical Xstr DC Voltages

Xstr	Stage	E(S)	B(G1)	C(D)	G2
Q1	vco	0.9	1.6	3.8	-
Q2	buffer	0	0.7	2.4	-
Q3	dc filter	4.1	4.8	5	-
Q4	RF ampl	0	0	4.6	2.3
Q5	Mixer	0	0	4.9	0
Q6	sq. open	0	0	5	-
	sq. closed	0	0.65	0.14	-

Table 6. Typical IC DC Voltages

U2-1	2.4	U4-1	5
U2-2	2.4	U4-2	4.4
U2-3&4	5	U4-3	4.8
U2-5	0 – 5V	U4-4	5
	(~2V tuned)	U4-5	3.8
U2-7	5	U4-6	3.8
U2-8	1.6	U4-7	3.8
U2-9	0	U4-8	5
U2-10	0	U4-9	2 (aligned)
U2-11	0	U4-10	0.8
		U4-11	2
U5-1	1.4	U4-12	0.6 (with squelch just closed)
U5-3	0.01		
U5-5	6	U4-13	0 (sq open) 7.5 (squelch closed)
U5-6	13.6		
U5-7	7	U4-14	0
U5-8	1.4	U4-15	0
		U4-16	1.8

Table 7. Typical Audio Voltages

Audio Test Point	Normal Level
U4-9 (Discriminator)	3V p-p audio
E4 (Disc Output)	2V p-p audio
E1 (Repeater Output)	1V p-p audio
U4-11 (noise ampl)	3V p-p noise
CW lug of VOL cont.	400mV p-p audio
U5-3 (af ampl input)	0 to 200mV p-p
U5-5 or E2 (speaker ampl output)	0 to 7V p-p audio

PARTS LIST FOR R313 RECEIVER.

Note: Values which vary with freq. band are shown in a table below. Resistors and capacitors are 0805 or 0603 smt type unless noted otherwise.

Because this pcb is also used for our airport runway light controllers, not all components shown on the pcb layout are populated in this model. Therefore, some parts on the board layouts used for controlling runway lights are not shown on the schematic or parts list.

💣 Caution: IC's are static sensitive. Use appropriate handling precautions to avoid damage.

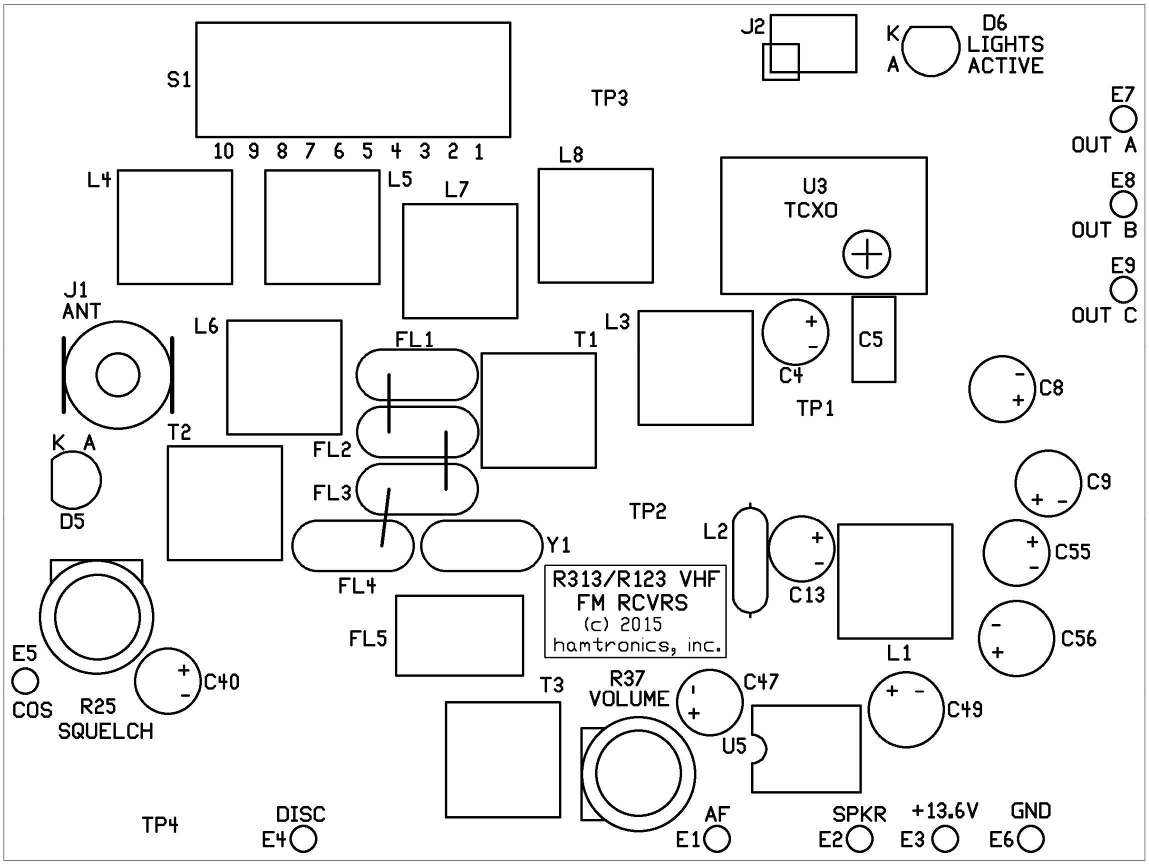
* Polarity for varicap diode D1: bar end is cathode, opposite end (anode) goes on pad next to grounding via.

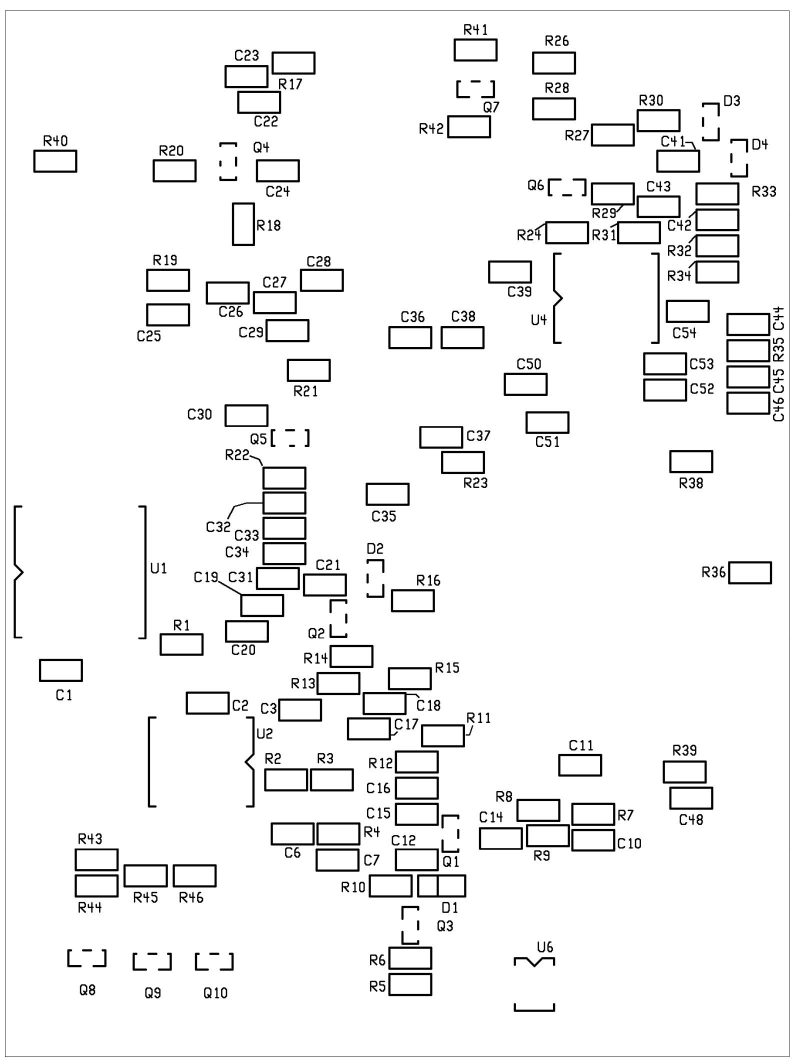
Ref Desig	Value (marking)
C1	0.1µf
C2	100pf
C3	0.1µf
C4	100µf electrolytic
C5	0.15µf mylar
C6	.01µf
C7	.001uf
C8-C9	100µf electrolytic
C10	0.1µf
C11	390pf
C13	100µf electrolytic
C14	390pf
C17	7pf
C18	390pf
C21	3pf
C24-C25	390pf
C32	4pf
C35	.033µf
C36	7pf
C37	4pf
C38	7pf
C39	.001uf
C40	1µf electrolytic
C41	0.1µf
C42-C43	.001µf
C44-C45	.033µf
C46	0.1µf
C47	4.7µf electrolytic
C48	0.1µf
C49	100µf electrolytic
C50	68pf
C51	220pf
C52-C54	0.1µf
C55-C56	100µf electrolytic
D1	BB132 varactor diode *
D2	MMBT5179 (used as diode)
D3-D4	MMBT3904 (used as diode)
FL1-FL4	10.7MHz crystal filter (matched set of 4)
FL5	LT455DW ceramic filter
J1	RCA Jack
J2	6 pin header
L2	0.33µH RF choke (red-sil-orn-orn)
Q1-Q2	MMBT5179
Q3	MMBT3904
Q4-Q5	BF998 MOS FET
Q6	MMBT3904
R1	180Ω
R2	27Ω
R3	10K
R4	47K
R5	27Ω
R6	1K
R7	27Ω
R8-R10	10K
R11	180Ω
R12	47Ω
R13	10K
R14	3.9K
R15	470Ω
R16	1meg
R17	1K
R18	10Ω
R19-R20	100K
R21	27Ω
R22	47K
R23	27Ω
R24	330K
R25	100K trim pot
R26	47K
R27	100K
R28	15K
R29	2meg
R30	47K
R31	510K
R32	4.7K
R33	680Ω
R34	1K
R35	22K
R36	100K
R37	100K trim pot
R38	47K
R39	10Ω
S1	10 pos. dip switch
T1-T2	10.7MHz IF xfmr (T1005)
T3	455kHz IF xfmr (T1003)
U1 💣	MC9S08PA4 µP
U2 💣	LMX1501A PLL
U3 💣	10.240 MHz TCXO
U4	MC3361BPD IF ampl
U5	LM386N-1 AF output
U6	78L05ACD regulator
Y1	10.245 MHz crystal

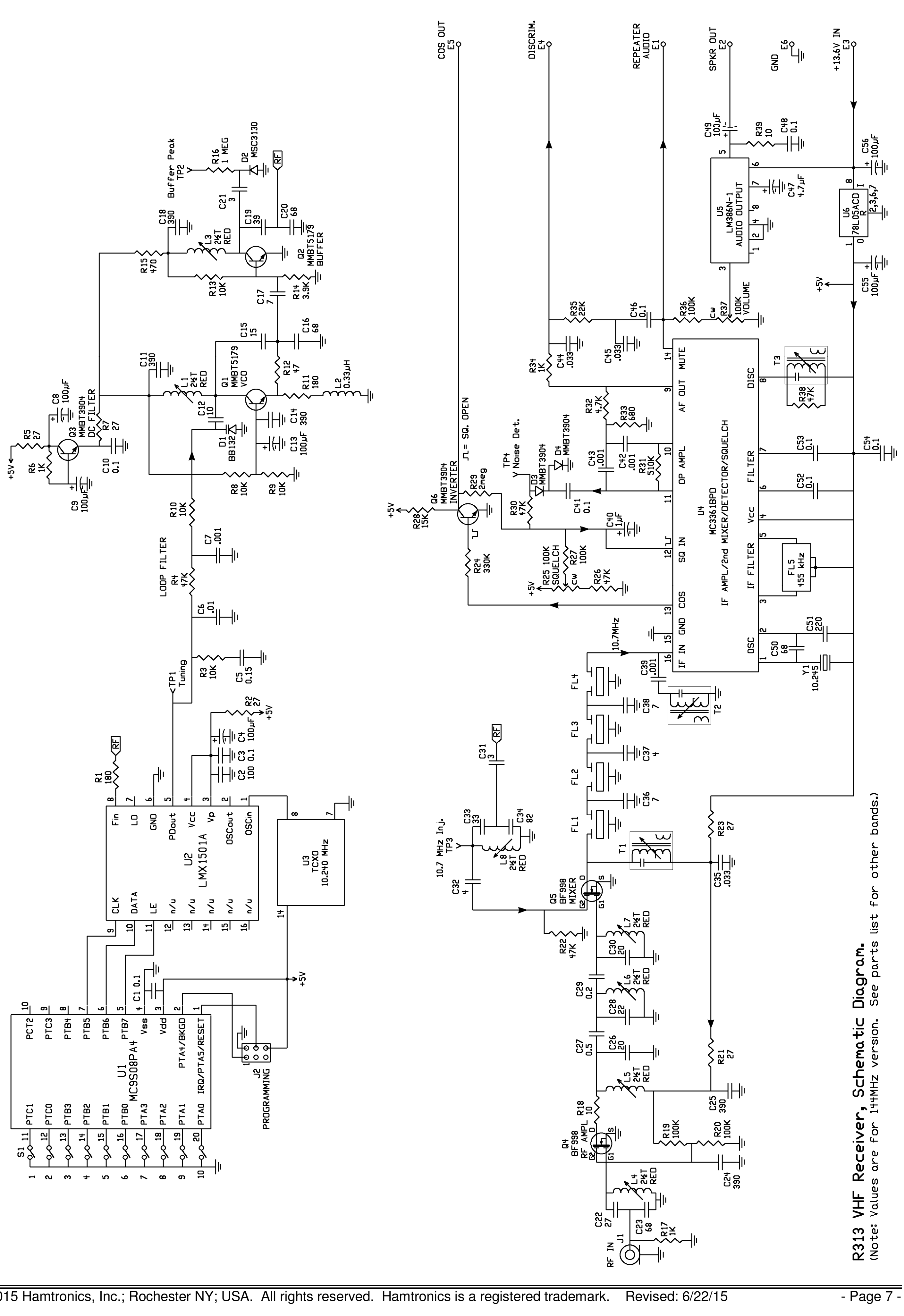
Values which vary with frequency band:

R313-1 is 138 - 144 MHz
R313-2 is 144 - 154 MHz
R313-3 is 154 - 164 MHz
R313-4 is 164 - 174 MHz
R313-5 is 220 - 225 MHz
R313-0 is 72 - 73 MHz

Ref	-1	-2	-3	-4	-5	-0
C12	10	10	10	10	8	10
C15	20	15	12	10	8	15
C16	68	68	62	47	47	68
C19	43	39	30	27	12	33
C20	82	68	62	62	33	62
C22	30	27	22	20	10	43
C23	82	68	62	62	27	100
C26	22	20	18	15	6	30
C27	0.5	0.5	0.5	0.5	0.3	0.5
C28	22	22	18	15	8	27
C29	0.2	0.2	0.2	0.2	n/u	0.5
C30	22	20	18	15	7	27
C31	3	3	3	3	1	4
C33	39	33	27	22	10	27
C34	82	82	68	62	27	82
L1 & L3-L8	2½t (red)	2½t (red)	2½t (red)	2½t (red)	1½t (brn)	6½t (blue)


R313/R123 VHF
FM RCVRS
(c) 2015
hamtronics, inc.
S1
J2
D6
LIGHTS
ACTIVE
TP3
U3
TCXO
OUT A
OUT B
OUT C
J1
ANT
SQUELCH
VOLUME
DISC
AF
SPKR
+13.6V
GND
COS





R313 VHF Receiver, Schematic Diagram.
(Note: Values are for 144MHz version. See parts list for other bands.)