HAMTRONICS® R901 FM RECEIVER
INSTALLATION, OPERATION, AND MAINTENANCE INSTRUCTIONS

GENERAL INFORMATION.

The R901 is a commercial grade single-channel fm receiver for the 902-928 MHz amateur band and the 928-960 MHz commercial band. With modifications, we can also supply it for the 800-902 MHz band.

It features a sharp tuned-line front end, an 8-pole crystal filter plus a ceramic filter for superior if selectivity, hysteresis squelch circuit to lock onto fading signals, and automatic frequency control to compensate for off-frequency transmissions.

CRYSTALS.

The channel crystal plugs into sockets identified in component location diagram as Y1. We can order crystals for any frequency desired. If you order your own, be sure to supply these specs.

The receiver uses 32 pF parallel resonant crystals in HC-25/u holders. Crystals operate in the fundamental mode at a frequency of (F-10.7)/63. Frequency tolerance is .0005%. We recommend that crystals be ordered directly from us to be sure that they will perform properly over the -30 to +60°C range for which the unit was designed. This is especially true for commercial receivers with the TCXO option, since the crystal must be matched exactly to the compensation circuit in the receiver. If you use an OV-1 crystal oven, specify a crystal with a 60°C breakpoint.

If you use an OV-1 crystal oven, specify a crystal with a 60°C breakpoint. The crystal is inserted into sockets on the board. The oven is installed on the board over the crystal, observing polarity by matching the 3-lead pattern to the holes in the board (see component location diagram). Then, the pins of the oven are soldered to the board.

INSTALLATION.

Mounting.

Some form of support should be provided under the pc board, generally mounting the board with spacers to a chassis. 3/8 inch holes should be provided in a front panel for the bushings of the squelch and volume controls. After sliding bushings through panel, washers and nuts (not supplied) are installed on the outside of the panel. Be sure to provide support for the board; do not rely on the controls to support the board. For repeater applications, the receiver should be mounted in an rf tight box, such as our model a16.

Power Connections.

The receiver operates on +13.6Vdc at about 150 mA peak with full audio. Current drain with no audio is only about 40-50 mA. A crystal oven adds about 500 mA peak current drain when cold and only about 25 mA when warm. A well regulated power supply should be used. Positive and negative power leads should be connected to the transmitter at E3 and pc board ground plane, respectively. Observe polarity, and be certain that the power source does not carry high voltage or reverse polarity transients on the line, since semiconductors in the receiver can be damaged. If the pc board is not mounted to a grounded chassis, power supply ground must be connected to the pc board ground plane through a separate wire.

Speaker.

An 8-ohm loudspeaker should be connected to E2 with ground return to the pc board ground plane. Use of lower impedance speaker or shorting of speaker terminal can result in ic damage. The receiver can also drive higher impedances, like 1K to 10K input impedances of cor boards, etc. There is no need to load down the output to 8 ohms.

Antenna Connections.

The antenna connection should be made to the receiver with a short length of RG-174/u miniature coax as shown in the detail above the parts location diagram. Remove 3/8 inch of jacket from the cable, and separate the shield braid from the center conductor. Strip 1/8 inch at the end of the center conductor, and insert through hole from the bottom of the board at the center of L1. Pull the cable up tight against the bottom of the board. Wrap the center conductor around the center of L1, and tack solder to the coil. Then, tack solder the braid to the ground pad on the bottom of the board.

Caution: at these frequencies, it is necessary to keep the stripped part of cable just as short as possible to avoid losses.

The other end of the cable should be trimmed to the length required to reach a panel mounted connector, such as a type N, BNC, or SMA. Once the receiver board is mounted in the chassis or cabinet, the cable can be stripped (short leads again) and soldered to the chassis jack. This method of cable connection was chosen to allow the best possible low-loss connection to the input circuit of the board from presumably (at these frequencies) rather heavy cable running to the antenna system. Its success depends on your workmanship.

THEORY OF OPERATION.

Signal flow is quite obvious with one exception: the channel oscillator signal is the source of injection for not only the first mixer but the second mixer as well. A triple-conversion process is used for optimum image rejection.

The input signal is amplified by GaAsFET Q1 and applied to the first mixer, GaAsFET Q2, along with multiplied oscillator injection from L4/C27 at 54 times the oscillator frequency. Q2 converts the signal to a first i-f in the range of 123 to 146 MHz, depending on the channel frequency.

Because the same oscillator is used to derive both the first and second mixer injections in order to take advantage of the oven or TCXO when used, the first i-f varies in frequency: the higher the channel frequency, the higher the i-f. The second mixer, FET Q3, then uses an injection frequency of 9 times the oscillator to convert the signal to 10.7 MHz, where it is processed through 8-pole crystal filter FL1-FL4.

L16 and L17 trim the load

Ant.	Xtal Freq	2nd Mix Inj	1st I-F	1st Mixer Inj
800	12.52857	112.7571	123.4571	676.5429
850	13.32222	119.9000	130.6000	719.4000
902	14.14762	127.3286	138.0286	763.9714
928	14.56032	131.0428	141.7428	786.2571
960	15.06825	135.6143	146.3143	813.6857

impedance for the crystal filter for optimum passband ripple.

Following are examples of the frequency scheme at various channel frequencies to illustrate how they vary.

The 10.7 MHz signal is converted to 455 kHz within U2, using Y2 as the oscillator crystal. Ceramic filter FL5 provides further bandpass filtering, and L18 adjusts the center of the detector curve. C68 and C59 provide deemphasis.

A sample of the audio from detector output at U2 pin 10 is amplified in an op-amp active filter (U2 pins 12-13), selecting any noise in the area of 10 kHz. The amplified noise is detected by CR2, adding to a dc bias voltage from the squelch pot. This summed voltage at pin 14 operates several transistors in U2, which provides COS output at E4, drives hysteresis transistor Q4, and mutes the audio going to speaker driver U1. The channel oscillator, i-f ic, and FET's are operated on +8 Vdc from regulator U3. The FET's have a low breakdown voltage and are sensitive to voltage transients, so the regulator protects them from damage.

Note that the R901 design is adapted from our lower frequency receivers, which use AFC (automatic frequency control) to compensate for drift in the oscillator or error in the transmitter frequency. We have found that AFC is impractical in the 900 MHz band because a little bit of afc voltage can cause the oscillator to change frequency enough to go out of the passband; and once that happens, it will not capture a signal which should be heard. For this reason, AFC normally is not used in the R901 Receiver, and components for the AFC circuit are not installed.

ALIGNMENT.

Equipment needed for alignment is an fet voltmeter, a good uhf signal generator, a regulated 13.6Vdc power supply with a 0-200 mA meter internally or externally connected in the supply line.

The slug tuned coils in the transmitter should be adjusted with the proper .062" square tuning tool to avoid cracking the powdered iron slugs. Variable capacitors should be adjusted with a plastic tool with a small metal bit on the end.

The small variable capacitors should be set to the center of their range (turn them 90°) if they have not previously been aligned. The squelch pot should be set fully ccw.

Note: The values in the parts list are for the 902-928 MHz band. Some capacitor values may be different for the commercial bands.

a. Install channel crystal in socket Y1.

b. Connect speaker and 13.6 Vdc. You should hear white noise.

c. Connect dc voltmeter to TP1. Adjust first L8, then L7 and L8 alternately for maximum response. (Typical indication is +1 to 2 Vdc.)

d. Connect dc voltmeter to TP2. Adjust L9 and L10 alternately for maximum response. (Typical indication is +1 to 2 Vdc.)

e. Connect dc voltmeter to TP3. Adjust C22 and C23 alternately for maximum response. (Typical indication is +0.7 to 1.5 Vdc.)

f. Connect stable signal generator to gate-1 of Q3 (rear lead), using coax clip lead, and being careful not to short adjacent transistor leads. Connect coax shield to pcb ground. Set generator to exactly 10.7000 MHz. Use a frequency counter or synthesized signal generator. Set level just high enough for full quieting. (At 10 uV, you should notice some quieting, but you need something near full quieting for the test.

g. Adjust discriminator transformer L18 for +4Vdc with meter connected to AFC test point TP5 (top lead of R2). Note that the voltage changes very rapidly with tuning. Full AFC swing of about 1.5 to 8V occurs within a few kHz, and a little drift may be noticed. It is only necessary to be within about 0.3V of 4V.

Note: There are two methods of tuning the mixer and front end. One is to use an fet voltmeter with test point TP4, which is the rear lead of R30. The voltage is proportional to the noise detected in the squelch circuit; so it gives an indication of quieting. A *signal peak,* therefore, is read as *minimum* noise voltage.

The other method is to use a regular professional SINAD meter. In either case, a weak to moderate signal is required to observe any change in noise. If the signal is too strong, there will be no change in the reading as tuning progress; so keep the signal generator turned down as the sensitivity of the receiver increases during tuning. If you use TP4 with a voltmeter, the signal can be modulated or unmodulated. If you use a SINAD meter, the standard method is a 1000 Hz tone with ±3 kHz deviation.

h. Check that signal generator is still on 10.7000 MHz. With weak signal applied to Q3 as before, adjust L16 and L17 for a peak. (If a SINAD meter is used, adjust for best SINAD.) This step is critical to get lowest distortion in the crystal filter.

i. Reconnect signal generator to the rf input cable attached to L1. (If none is attached, refer to "Antenna Connections" section on page 1, and attach one before proceeding. Connect signal generator to stripped pig tails at open end of cable, not directly to L1.) Adjust generator to exact channel frequency, and turn output level up fairly high. Adjust frequency trimmer capacitor C3 to net the crystal to channel frequency, indicated by 4V at AFC test point TP5. If you can't find the signal at all, tune your signal generator up and down the band slightly. (Also check that oscillator is peaked as per step c.)

If your crystal has the wrong load correlation or is slightly out of tolerance, you may be able to compensate by changing the value of C2 so C3 can net the crystal on frequency.

j. Connect fet dc voltmeter to TP4 (top lead of R30). Set signal generator for relatively weak signal, one which shows a little change in the dc voltage indication. Alternately peak C26, C27, C38, C36, and C34 until no further improvement can be made.

k. Alternately adjust L13, L14, and L15 until no further improvement can be made. Note that L13 may peak at the input i-f frequency as well as the injection frequency. The proper peak is at the injection frequency, which is the lower of the two. This occurs with the tuning slug more toward the center of the coil. The false peak would occur with the slug near the top of the coil.

When properly tuned, the sensitivity of the receiver should be about 0.25 uV for 12 dB SINAD and about 0.3 uV for 20 dB quieting.

OPTIONS.

Squelch Circuit.

The squelch circuit has about 3 to 6 dB of hysteresis built in, so that once the squelch opens, the signal must drop 3 to 6 db below the opening threshold before squelching again. This allows for some fading on mobile stations and prevents squelch pumping on heavy modulation. of course, this requires setting the threshold a little higher than if there was no hysteresis so that it will close with no signal. If you prefer the older type squelch, you can simply remove Q4 from the circuit. If you want more or less hysteresis, you can decrease or increase the value of R28, respectively.

Repeater Use.

E4 provides a "carrier operated switch" output which may be connected to a cor module to turn a transmitter on and off. The output level is about 7v unsquelched and 0v squelched. There is a resistor in series with the output to limit current. refer to COR module instructions for details.

Audio Muting.

If the receiver is used as a part of a transceiver, audio muting can be accomplished without switching the power or speaker lines. If the transmitter is keyed by applying B+ to the exciter, simply connect the keyed B+ through a 100k resistor and diode to the junction of R28, R29, and R30 on the receiver board. The dc level will be sufficient to trigger the squelch circuit in U2, regardless of the rf signal level coming into the receiver. Of course, some means of disconnecting the receiver from the antenna must be provided, and we recommend our TRR Coax Relay Module if the power level is under 25 watts. Otherwise, a larger coax relay will be required.

Discriminator Meter.

If you need a discriminator meter and you are handy in designing with op-amps, you can run a sample of the dc voltage at the junction of R26 and C59 to one input of an op-amp and tie the other input to a voltage divider pot set to provide a reference voltage of about 4 vdc. Values in the circuit depend on your meter and are beyond the scope of this discussion. (Sorry, we do not have a circuit to recommend.)

TROUBLESHOOTING.

The usual troubleshooting techniques of checking dc voltages and signal tracing work well in troubleshooting the receiver. A dc voltage chart 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.

The most common troubles in all kits are interchanged components, cold solder joints, and solder splashes. Another common trouble is blown transistors and ic's due to reverse polarity or power line transients. Remember if you encounter problems during initial testing that it is easy to install parts in the wrong place. Don't take anything for granted. Double check everything in the event of trouble.

If the receiver is completely dead, try a 10.700 MHz signal applied to Q3 gate-1 with a coax cable clip lead. You should be able to hear the quieting effect of a 100 uV carrier at 10.700 MHz. You can also connect the 10.700 MHz clip 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 sect ions. Also, check the 10.245 MHz oscillator with a scope or by listening with an hf receiver or service monitor.

The next step is to inject a signal on the first i-f frequency into gate-1 of mixer Q3. Determine the first i-f by the formula (9 x osc freq) + 10.7 MHz.

A signal generator on the channel frequency can be injected at various points in the front end, for instance, gate-1 of mixer Q2 or rf amplifier Q1. If the mixer is more sensitive than the rf amplifier, the rf stage is suspect. Check the dc voltages looking for a damaged fet.

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. 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 applied to noise detector CR2 with no input signal. (Between pins 12 and 13 of U2 is an op-amp active filter tuned to 10 kHz.)

Typical Dc Voltages.

The following dc levels were measured with an 11 megohm fet vm on a sample unit with 13.6 vdc B+ applied. All voltages may vary considerably without necessarily indicating trouble. The chart should be used with a logical troubleshooting plan. All voltages are positive with respect to ground except as indicated. Voltages are measured with no signal applied but oscillator running properly and with squelch open unless otherwise specified.

Typical Audio Levels.

Following are rough measurements of audio circuits, using an 11 megohm fet vm. Measurements were taken with no input signal, just white noise so conditions can be reproduced easily.

U2 pin 10:	400 mV rms
U2 pin 13:	2V rms
Top of volume control:	70 mV rms
Across 8 ohm spkr term:	3 V rms

GaAs FET LEAD IDENTIFICATION.

If you find it necessary to replace the FET's, proper lead orientation is indicated by a long lead for the drain. Be careful to install FET with the lettering on the case up away from the board so you can read it with the transistor installed. If you accidentally flip it, the source and gate-2 leads will be reversed and it will not work.

IC SOCKETS.

Note that audio output ic U1 is designed to be heatsunk to the pc board through the many ground pins on the ic. When running moderately low audio levels as most applications require, it is no problem to use an ic socket; so we have provided one for your convenience. If you will be running high audio levels, you should not use the ic socket; instead, solder the LM-380 ic directly to the board for better heatsinking.

Also note that using a socket is not recommended for i-f amplifier U2 because of the extra inductance the socket would add to the high frequency circuits; therefore, a socket has not been supplied.

XSTR	SOURCE	GATE-1	GATE-2	DRAIN
Q1-Q3	1.5 to 2	0	4	8
	E	**B**	**C**	
Q4 Squelched	0	0	0.6	
Q4 Unsquelched	0	0.6	0.03	
Q5 Xtal Out	2.75	3.5	7.5	
Q5 Xtal In	3.5	2.75	7.5	
Q6	1.7*	0	13.6	
Q7	1.8*	-0.08*	13.6	
Q8	1.1*	0	13.6	

* Indicates drops to 0 with insufficient rf drive.

U1	1	6	8	14
	7	0	7	13.6

U2	1	2	3	4	5	6	7	8
	8	7.5	7.5	8	1.1	1.1	1.1	8

U2	9	10	11	12	13	14
	4.5	4	4.5	2.5	2.7	0.7(SQ),0.09(UNSQ)

U2.	15	16	17	18
	0(SQ),7.2(UNSQ)	0	0	2.1

PARTS LIST FOR R901 RCVR.

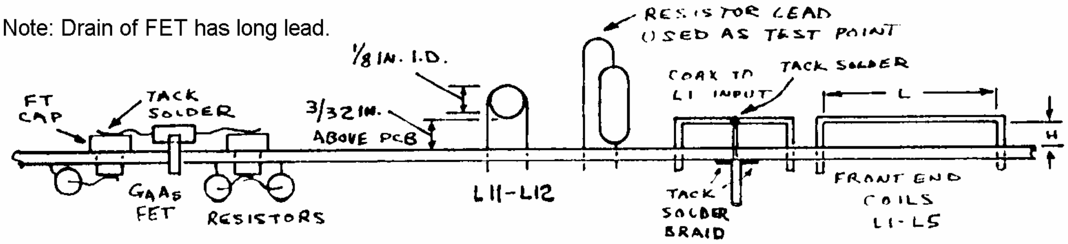
Notes: Parts listed are for the 902-928 MHz band. Slightly different values (not supplied in kit) may be required for commercial bands above or below this range.

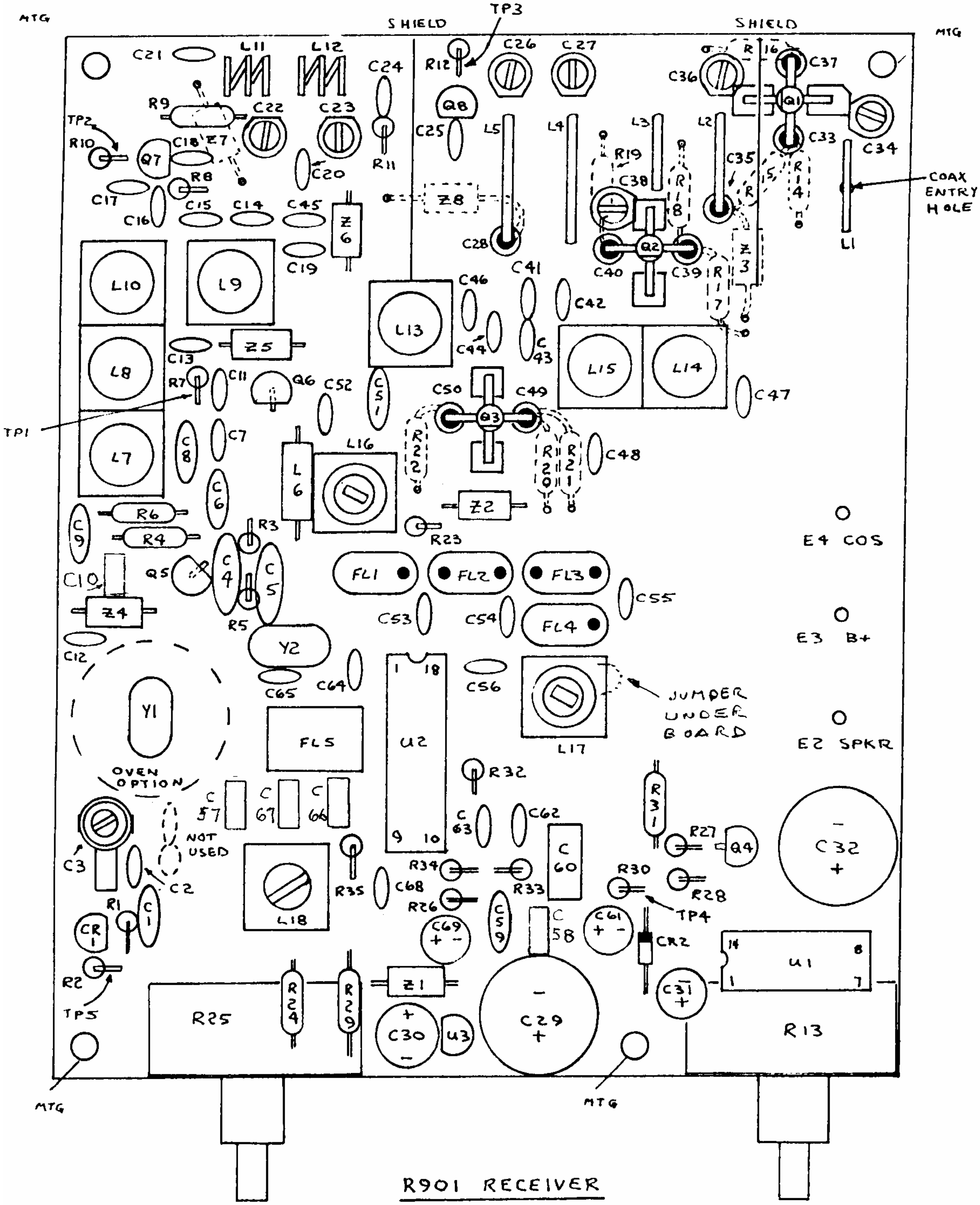
❶ indicates surface mount part under board

❷ Note that there is an error on the pc board which needs to be patched. The ground lug of the piston trimmer cap is isolated from the ground plane. Tack solder a short bus wire across to bridge between ground plane and lug of trimmer cap.

Ref #	Value ------------ (marking)
C1❶	.01 uf disc (103)
C2	39 pf
C3 ❷	10 pf piston trimmer
C4-C5❶	150 pf (151)
C6	82 pf
C7	1 pf
C8	82 pf
C9❶	.001 uf (102, 1nM, or 1nK)
C10	0.1 uf monolithic (104)
C11	220 pf (221)
C12❶	.001 uf (102, 1nM, or 1nK)
C13	220 pf (221)
C14	5 pf
C15❶	0.5 pf
C16	10 pf
C17	20 pf
C18	30 pf
C19-C20	220 pf (221)
C21	30 pf
C22-C23	4.5 pf ceramic trimmer
C24	4 pf
C25	30 pf
C26-C27	4.5 pf ceramic trimmer
C28	Feedthru cap
C29-C31	47 uF electrolytic
C32	470 uF electrolytic
C33	Feedthru cap
C34	4.5 pf ceramic trimmer
C35	Feedthru cap
C36	4.5 pf ceramic trimmer
C37	Feedthru cap
C38	4.5 pf ceramic trimmer
C39-C40	Feedthru cap
C41	18 pf
C42❶	0.5 pf
C43	18 pf
C44-C45❶	0.5 pf
C46	8 pf
C47	15 pf
C48	220 pf (221)
C49-C50	Feedthru cap
C51❶	.01 uF disc (103)
C52	220 pf (221)
C53	8 pf
C54	7 pf
C55	8 pf
C56❶	.001 uf (102, 1nM, or 1nK)
C57-C58	0.1 uf monolithic (104)
C59❶	.01 uF disc (103)
C60	0.15 uf mylar (red)
C61	0.47 uf electrolytic
C62-C63	680 pf (681)
C64	62 pf
C65	220 pf (221)
C66-C67	0.1 uf monolithic (104)
C68	220 pf (221)
C69	0.47 uf electrolytic
CR1	not used
CR2	1N4148 (may be unmarked)
E2-E4	Socket pins
FL1-FL4	Matched set crystal filters (see text)
FL5	Ceramic filter (blue)
L1-L5	Tuned lines, formed from #18 bus wire
L6	100 uH rf choke (sil-brn-blk-brn-sil)
L7-L10	6-1/2 turns (blue)
L11-L12	2-3/4 turns #22 bus wire, 1/8" I.D.
L13	6-1/2 turns (blue)
L14-L15	2-1/2 turns (red)
L16-L17	7A-691F IF transformer, 10.7 MHz
L18	YMC-15002 or 831-5 IF xfmr, 455 kHz
Q1-Q2	GaAs FET, NEC 3SK174 (25137) Static Sensitive!
Q3	MOS FET, NEC 3SK122 Static Sensitive!
Q4-Q5	2N3904
Q6	2N5770
Q7-Q8	PN5179
R1	not used
R2	330K
R3-R4	14K (two 6.8K tack soldered at the junction)
R5	2.2K
R6	100 ohms
R7❶	270 ohms
R8	1.2K
R9	27 ohms
R10❶	270 ohms
R11	1.2K
R12❶	270 ohms
R13	100K Pot
R14-R15	100K
R16	180 ohms
R17-R18	100K
R19	180 ohms
R20-R21	100K
R22	180 ohms
R23	4.7K smt
R24	2 meg
R25	100K Pot
R26	27K
R27	150K
R28	510K (do not confuse with 150K)
R29	68K
R30	150K
R31	27K
R32	330K
R33	1.2K
R34	4.7K smt
R35	47K
U1	LM-380N 2W Speaker Amplifier
U2	MC-3359P IF Ampl, Det, Squelch
U3	78L08 8Vdc Voltage Regulator
Y1	Channel Xtal (see text)
Y2	10.245 MHz xtal
Z1-Z8	Ferrite beads

Note: Drain of FET has long lead.





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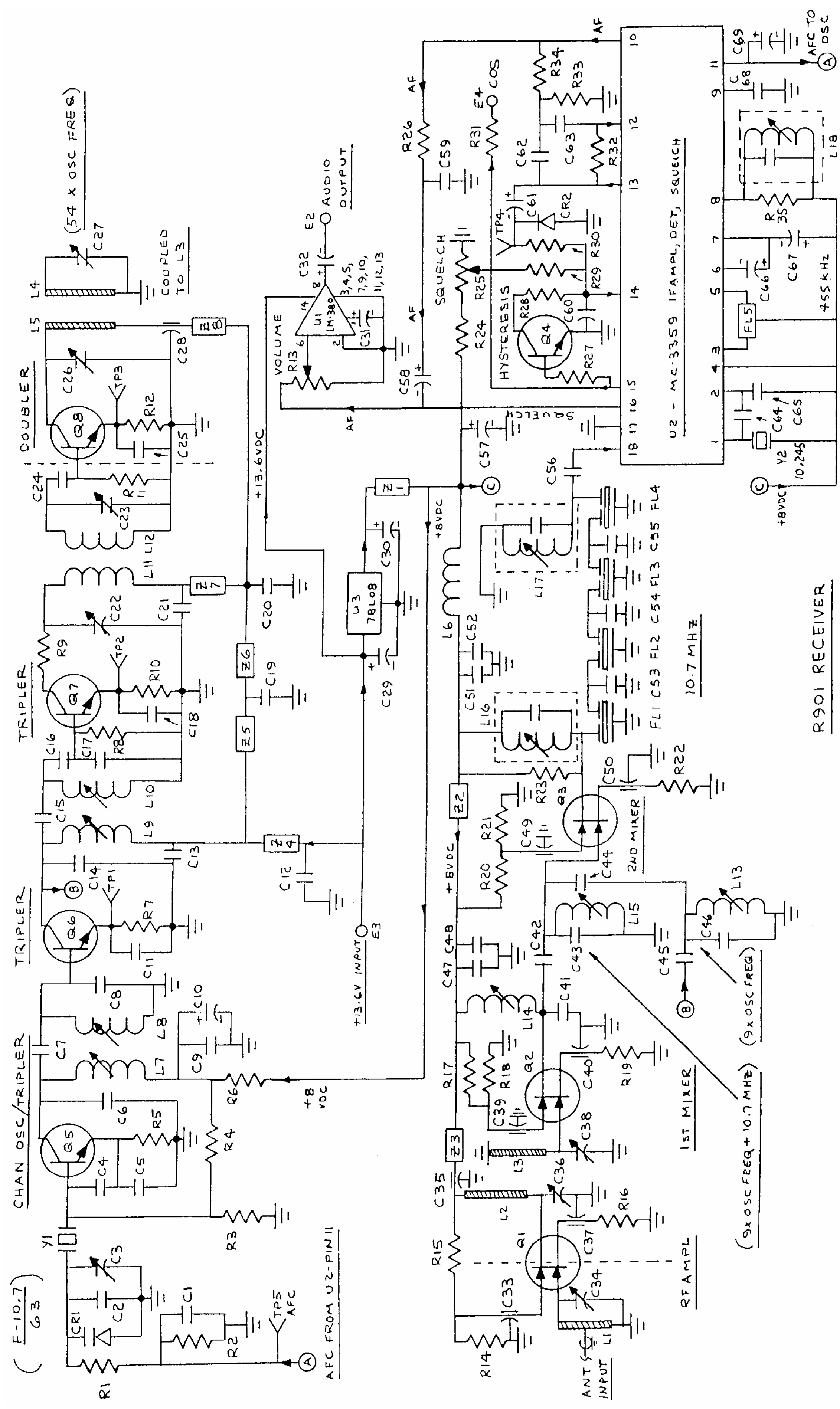
R901 RECEIVER
CHAN OSC/TRIPLER
TRIPLER
TRIPLER
DOUBLER
(54 x OSC FREQ)
COUPLED TO L3
(F-10.7 / 63)
AFC FROM U2-PIN 11
RF AMPL
1ST MIXER
2ND MIXER
ANT INPUT
(9x OSC FREQ + 10.7 MHz)
(9x OSC FREQ)
10.7 MHz
FL1 C53 FL2 C54 FL3 C55 FL4
U2 - MC3359 IFAMPL, DET, SQUELCH
455 kHz
AFC TO OSC
VOLUME
AUDIO OUTPUT
SQUELCH
HYSTERESIS
COS
+13.6V INPUT
+13.6VDC
+8VDC
U3 78L08
U1 LM380

