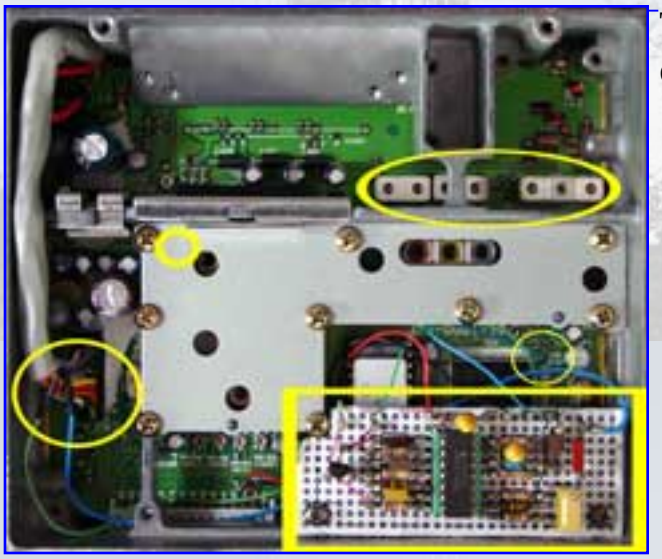
TK-931 Receiver Modifications

This page identifies all the hardware modifications necessary to adapt a Kenwood TK-931 transceiver for 902 MHz repeater receive operation. Not shown here is the effort required to program the radio for the desired operating frequency. This is accomplished using the Kenwood KPG-5D programming software and KPG-4 programming cable, or equivalent. It also assumes that the receiver portion of the radio was properly operating in its original frequency range prior to modification. Check-out and alignment of the receiver after modification is recommended.

Many thanks to Gene Colson (W7UVH) for help in getting the Kenwood radios going. Gene provided much of the initial modification information.



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This photo shows the inside of the modified TK-931. Areas of modification (highlighted in yellow) include:

- Front-end filter replacement
- VCO Modification
- Audio/COR Interface board addition
- Connection of Audio/COR board to the radio
- Radio to controller interface mods

Front-end filter replacement

The front-end of the TK-931 consists of a three-pole dielectric filter followed by a low-noise amplifier transistor (2SC4093) followed by an additional 4-pole dielectric filter. The LNA transistor is specified over a fairly wide frequency range, so there is no problem operating in the 902 band. The filters, on the other hand, have a ± 12.5 MHz bandwidth. The original filters were centered at 938 MHz to cover the intended 935 to 941 receive range. To handle the frequency change, both filters must be replaced. Although an optimum filter for repeater receive operation would be centered around 902 MHz, the easiest filters to obtain are centered at 915 MHz. Their availability is probably associated with all the ISM applications which can make use of them. These filters also have the benefit of working for

repeater or mobile service, as they cover 902 to 928 MHz. The pre-LNA filter is pretty easy to come by. You can find Toko or Murata filters from various sources. This three-pole filter is the same part that is used for modification of Motorola Maxtrac radios to amateur service. The part that I used was a Toko 6DFB-915E-10. The four-pole filter is a little trickier. While Toko does list a four-pole part that would be appropriate for repeater use (6DFC-902E-10), inventories of this rather specialized part appear to be pretty thin. What is typically done instead (and can be applied to repeater or mobile service) is to construct the physically equivalent part from two 2-pole filters. Either two Toko 6DFA-915E-10 or Murata DFC2R915 parts can be used.

The first step in replacing the filters is to remove the original components. The filters are thru-hole parts. To gain easy access to the filter pins, the transmitter shield should be removed from the bottom side of the main circuit board. The shield is held in place by three (gold) screws to main chassis and by two (black) screws that also secure the bottom receiver shield. Once the shield is removed, the filters should be carefully unsoldered from the circuit board. Insert the new filters and then reinstall the transmitter shield. After filter replacement, the matching capacitor (TC300) should be adjusted to produce best receiver sensitivity.

Original filters in place.

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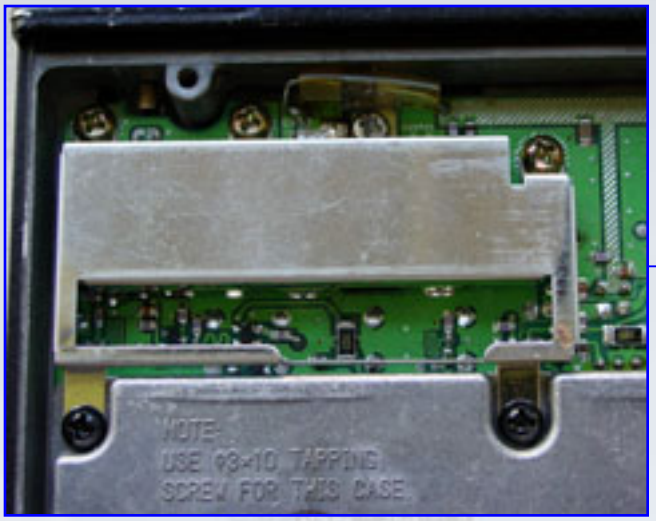

This shield should be taken-off to gain easy access to the filter pins. It is held in place with the three gold screws at the top and the two black screws that are screwed into the receive shield.

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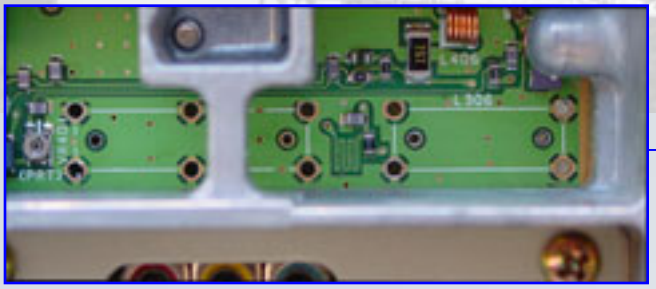

This shows the main circuit board after the filters have been removed.

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The two original (4-pole and 3-pole) 938 MHz filters and the replacement dual 2-pole and 3-pole 915 MHz filters.

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The final configuration with the replacement filters installed. After filters have been changed, the matching capacitor (TC300) should be adjusted to obtain best receive sensitivity

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VCO Modification

The receiver operating frequency range of the stock TK-931 is 935 to 941 MHz. The tuning range of the VCO is adequate to handle normal mobile receive operation in the 927 MHz band. For reliable repeater performance in the 902 MHz band, it is necessary to slightly modify the VCO to accommodate the frequency shift. The modification simply requires the addition of a small capacitor from one end of the VCO tuning coil to ground.

The added VCO capacitor needs to be placed on the bottom side of the radio circuit board. This portion of the circuit is under the lower shielding cover. To access the circuit board, the Final Section Shield must first be removed. This shield is attached with five screws, two of which also attach the Lower Shielding Cover to the circuit board. Once the shield is removed, the larger shielding cover can be removed by extraction of the remaining seven screws.

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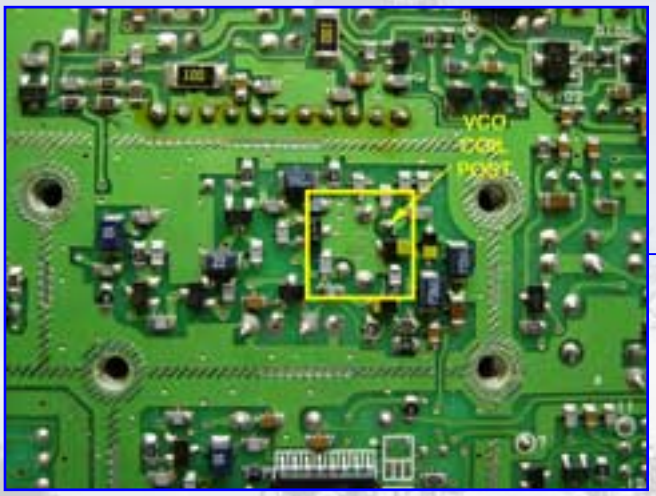

With the shielding removed, the VCO circuitry needs to be located. With the radio oriented with the rear panel facing upwards, the VCO circuitry is located in the top-right corner of the area previously covered by the shielding cover. The capacitor will be added bewtween the top-right post of the VCO coil (coil located on opposite side of circuit board) and ground.

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To shift the frequency range of the VCO, a 2.2 - 4.0 pF capacitor is added between the VCO coil post and ground. A high quality ceramic disc or chip capacitor should be used (chip capacitor shown). Once the capacitor is installed, the shields can be replaced.

Note: After the capacitor is added, the receiver most likely will not operate in the normal 927 MHz range. The radio should be reprogrammed for the 902 MHz repeater input range and checked for VCO lock.

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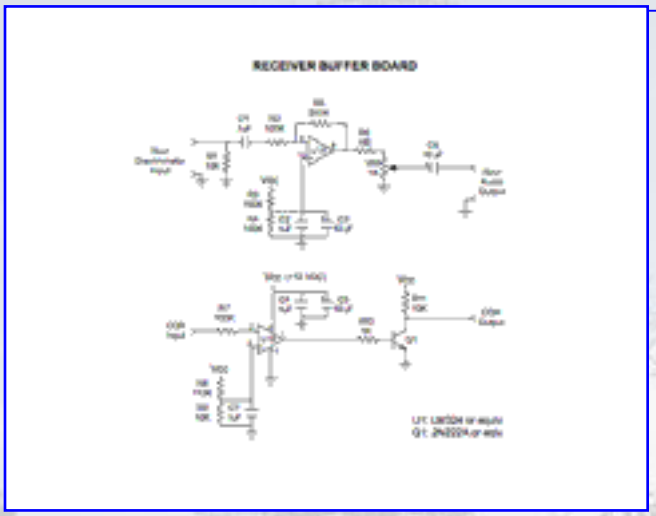
Audio/COR Interface board addition

Three signals are needed to interface the receiver to the controller:

- Tone Squelch Enable (assuming tone squelch is programmed)
- Receive Audio
- Carrier Operated Relay (COR)

Tone squelch enable can be accomplished by grounding the "Hook Switch" signal of the receiver. This signal is available on the accessory connector on the back of the radio.
The other two signals (audio and COR) should be buffered to assure that the controller does not load either of these lines.



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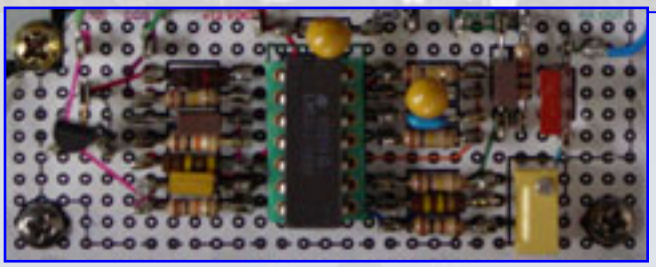
This is the schematic of a simple op-amp based circuit used to provide buffered discriminator audio and COR to the controller. The gain of the audio stage was chosen to produce roughly 2 volt peak-to-peak for a 1 kHz audio tone with a deviation of 2.5 kHz.
The COR section is a comparator circuit that produces a grounded output with signal present.



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The above circuit was implemented on a copperclad perf-board. An LM324 quad op-amp was used. Only two of the stages were needed, but these single-supply low power amplifiers are readily available and I had the space.

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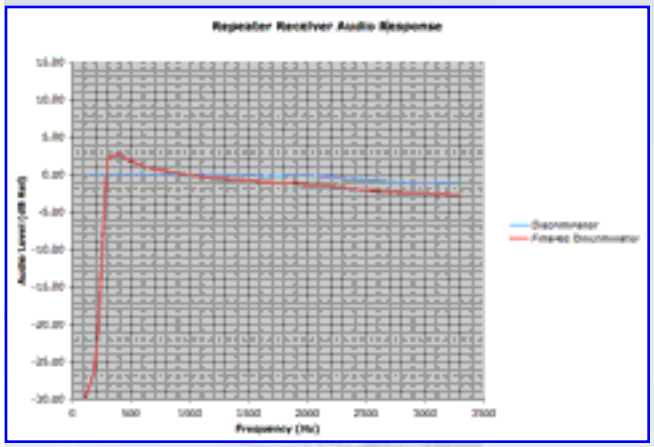
Connection of Audio/COR board to the radio

The overall receiver modification photo shows the audio/buffer interface board installed in the front,

right section of the top cavity of the receiver. This area is located near the microprocessor of the radio. The board is drilled on the two front corners to coincide with two unused holes in the radio frame. Not only is this area of the radio available for convenient mounting of the interface board, but it also provides the necessary interface points for receive audio and signal present.
For the receive audio signal, an unsquelched line is preferred. The audio switching (squelch) of the TK-931 is done prior to the de-emphasis circuitry, therefore any pick-off point will have flat (relatively) audio. Two easily accessible pick-off points are available in the vicinity of the microprocessor. One point is an unfiltered buffered version of discriminator audio. There is another point that has a sharp filter to remove the PL and DPL signals below 300 Hz. The plot below shows the frequency response of the two points.



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While some applications may prefer having the low PL frequencies filtered-out prior to injection into the controller and transmitter, I chose to use the unfiltered point. The unfiltered discriminator point offers a much flatter response as compared with the filtered point. This point is a via located near pin 32 of the microprocessor (IC4). The soldermask can be removed and a small wire can be soldered between this point and the audio input of the Audio/COR interface board.

The signal present line is also directly available on top of the receiver circuit board in the vicinity of the microprocessor. This point is at the intersection of D101 and R118. A small wire can be attached between this point and the COR input of the Audio/COR interface board.

This photo shows the interface points for the Audio/COR board. The small via near the corner of the microprocessor IC (IC4) is the discriminator audio pick-off point. The COR input to the buffer board can be wired to the interface between R118 and D101 of the receiver board.
The photo also shows the alternative audio pick-off point. This point is located on the right side of C121. It is a filtered version of discriminator audio that has frequencies below 300 Hz removed.

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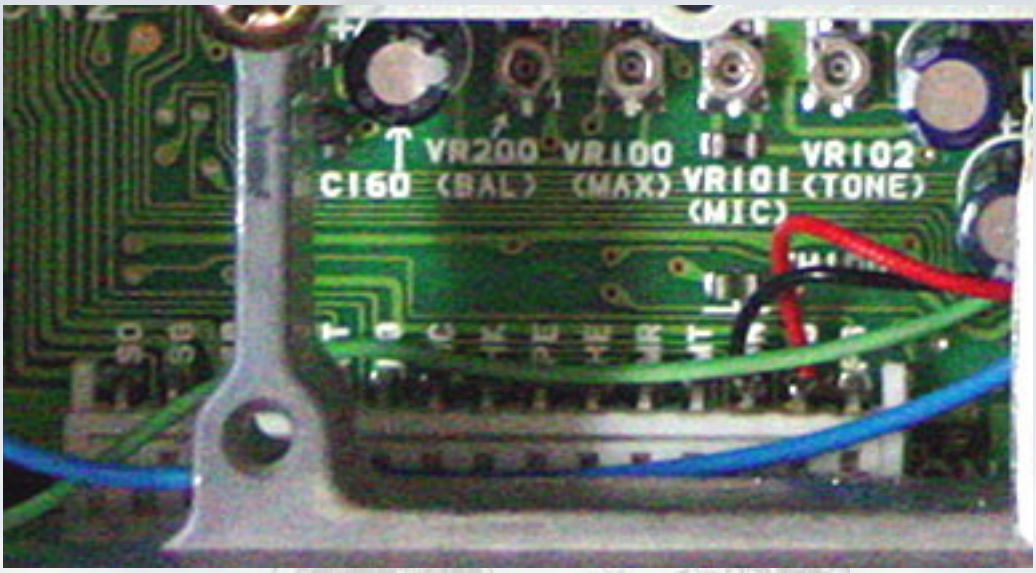

DC input to the Audio/Interface board can be taken from the CN1 connector (connects front panel to main circuit board). Switched 13.8 VDC is on pin 2 (SB) and return is on pin 3 (GN).

-----Audio/COR Board Adjustment

Once the Audio/COR board is installed and connected to the receiver interface points, the board can be checked and adjusted. One of the reasons the buffer board is used is to provide a high level, low impedance audio source to the controller, thereby greatly improving noise immunity. With this particular controller (Arcom RC210), a level of 2 volts peak-to-peak at rated deviation level was found to work well. A signal generator is used to produce a strong RF signal (-70 dBm) to the receiver. The deviation on the generator is set to maximum rated deviation (in this case +/- 2.5 kHz) at a modulation rate of 1 kHz. The trimpot on the Audio/COR board is adjusted until 2 volts peak-to-peak is observed.
Also verify that the COR output of the board goes from high to low when signal is applied to the receiver (assumes squelch is set to open and close normally).

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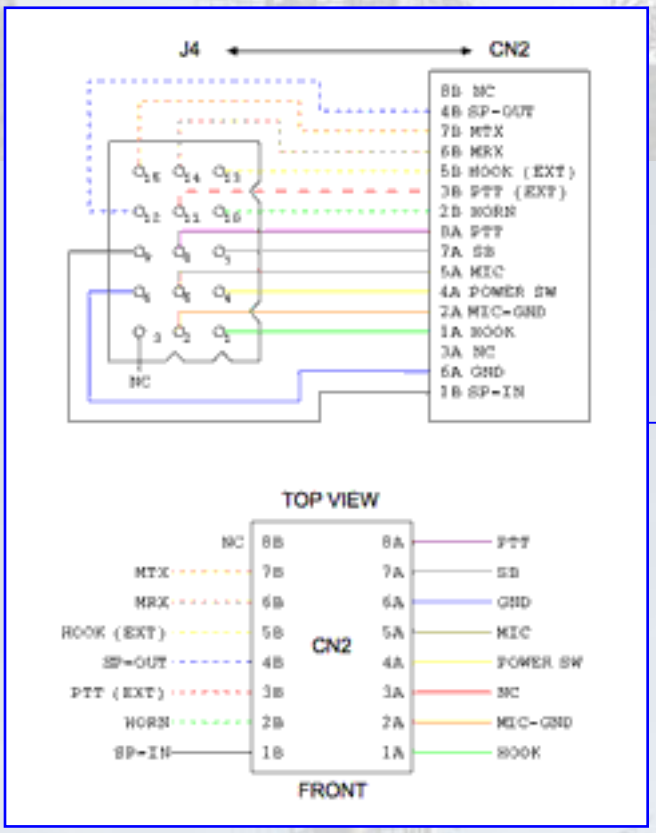
Radio to controller interface mods

To interface the TK-931 receiver to the controller, the accessory connector (J4) on the rear of the radio may be used. If the mating connector (J5) did not come with the radio, a standard 15 pin Molex connector (Housing P/N 03-06-2152, Pin P/N 02-06-2103) can be used.



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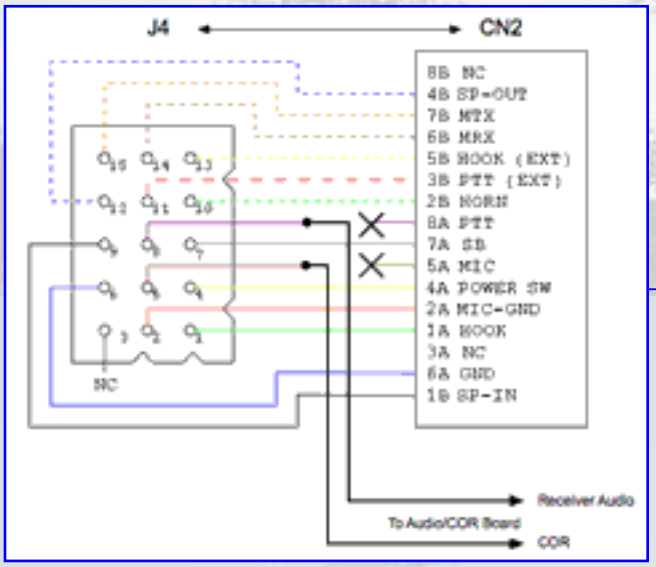
The J4 accessory connector is routed to an internal circuit board connector (CN2) via a multi-conductor cable. This diagram shows the factory wiring between the two connectors. The colors reflect the color coding or the wires in the cable.

Interfacing the receiver to the controller requires the following four signal lines:

- Receiver (Discriminator) Audio
- COR
- PL Enable (Hook Switch)
- Ground

The discriminator audio and COR signals will come from the outputs of the Audio/COR buffer board. The Hook Switch and Ground signals exist on J4 (pins 1 and 6, respectively) and can be used as is. The Hook Switch signal is used to switch the receiver from PL (or DPL) decode to carrier access. Pulling this line to ground puts the receiver into PL decode.
Since discriminator audio and COR aren't originally present at J4, minor modifications are required to provide access to these signals. Being that this radio is now used only as a receiver, transmit related signal lines on the J4 connector can be hijacked. The MIC and PTT lines will be converted to receive interfaces.



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At the CN2 side of the J4 cable, cut the brown wire going to pin 5A (pin 5 of J4) and the purple wire going to pin 8A (pin 8 of J4). Reconnect the brown wire that runs back to J4 to the COR output of the Audio/ COR buffer board. Reconnect the purple wire that runs back to J4 to the audio output of the Audio/ COR buffer board. Note that it may be necessary to remove some of the cable jacket to gain easy access to the internal wires. The previous connections on CN2 connector can remain unterminated.

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The receiver can be connected to the controller by constructing a cable which interfaces to the rear connector as follows:

J5 Pin	Signal
1	CTCSS Enable (ground to enable)
5	COR (low when signal present)
6	Ground
8	Receive Audio (2 V P-P, 2.5 kHz dev, 1 kHz rate)
9	Speaker In (Loop to pin 12)
12	Speaker Out (Loop to pin 9)

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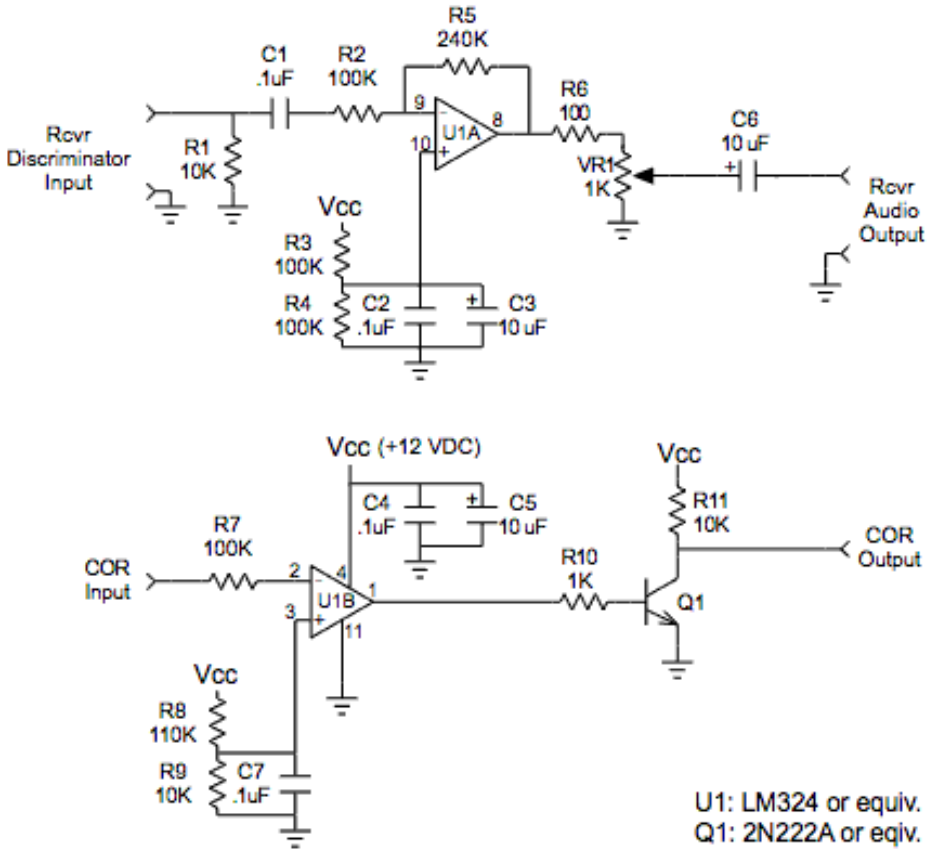
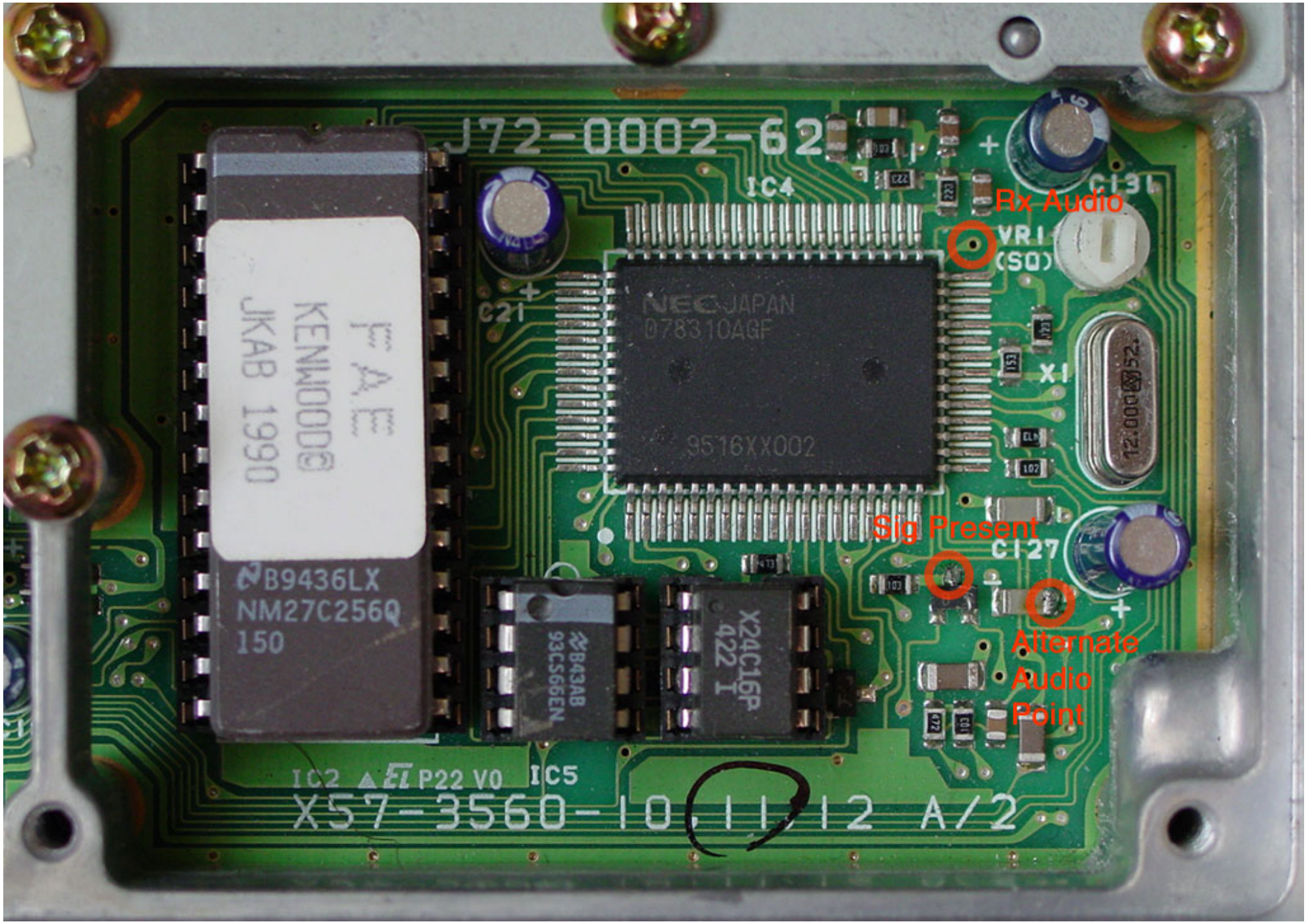
RECEIVER BUFFER BOARD

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VR1
(SQ)
C21
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12.000MHz
Sig Present
C127
Alternate
Audio
Point
KENWOOD
JKAB 1990
B9436LX
NM27C256Q
150
B43AB
93CS66EN
X24C16P
422 I
IC2
P22 V0
IC5
X57-3560-10,11,12 A/2