4 RECEIVER CIRCUITS

Now that you understand how the various mixing frequencies are generated, we'll analyze the most complicated part of a CB, the receiver. There's a lot more happening in the receiver than in the transmitter, and troubleshooting can be more difficult. Several circuits are shared by Receive and Transmit and will indicate problems different than Receive-only circuits. Logic is the key to repair, once you know what every circuit does and how they interact. In this chapter we'll examine those circuits unique to the receiver. After some basic theory, we'll start at the "front end" and work down to the speaker, catching other special circuits along the way.

THE TRANSISTOR AMPLIFIER

Although tube radios are still around, you'll do the most repair work on solid-state radios. ICs are widely used in modern transceivers but the plain old bipolar transistor is still the workhorse of a CB radio. Let's review a little about their operation.

Figure 4-1 shows the basic classes of bipolar transistor amplifiers again. NPN devices are shown but can just as easily be PNP types by reversing supply voltage polarities. The Common Emitter and Common Base are what you'll find most. Note again the input/output phase relationships of each. FETs are also used, both junction and dual-gate MOS types, most commonly in RF amplifiers, receiver mixers, and synthesizer mixers. You can identify a transistor's basic frequency range by the type of associated components; in this example they're low-frequency (audio or DC) circuits. The distinguishing feature of all RF/IF amplifiers is the use of tuned circuits rather than the RC circuits shown in the figure.

SINGLE-CONVERSION VS. DUAL-CONVERSION

Figure 4-2 shows block diagrams of the two basic CB receiver types: the single-conversion and double- or dual-conversion superheterodyne. ("Heterodyne" is another term for mixing.) The "superhet" has been around virtually unchanged since the early 1930s, which tells you something about its usefulness. Its most important advantage is that the bulk of the gain and selectivity takes place in a single narrow-bandwidth IF (or two, in the case of dual-conversion) regardless of the actual input frequency band. This allows simpler and cheaper circuits, since gain blocks are most effective when designed for a single frequency.

Techs have argued for years about the relative merits of each, but in my opinion there's only one real determining factor: cost. The dual-conversion circuit is more complicated, requires more parts, and is therefore more expensive. The main advantage of single-conversion is that fewer stages are needed to produce a given signal-to-noise ratio, since each stage adds more noise along the way. The reason AM/SSB single-conversion types are found at all in today's crowded bands is because improved manufacturing techniques allow more selective crystal IF filters to be used. But you get what you pay for and to prove it, compare the receiver performance of chassis like the Cobra 140/142GTL or 146GTL/PC244 (single-conversion) to the Cobra 148/2000GTL (dual-conversion) chassis on AM.

As shown, the dual-conversion circuit requires a second Local Oscillator (L.O.) and a second mixer stage. The IF frequencies are usually 10.695 MHz and 455 KHz, universal standards for which parts are readily available. Some popular chassis use a 7.8 MHz or 11.275 MHz IF in a single-conversion circuit, or as the high IF of a dual-conversion circuit with 455 KHz as the 2nd AM IF. There are a few unusual CB IFs, like the 4.3 MHz used in some Johnsons. The dual-conversion type has superior image rejection.

Incidentally, the reason for using the same IF path on AM and SSB in most single-conversion receivers is because only one of the two AM sidebands will be detected. Each sideband has exactly the same voice intelligence. Since SSB uses a very narrow IF filter, one AM sideband of up to 2.5 KHz width can pass through it, but not both. Another "economy" move...

FIGURE 4-1
BASIC TRANSISTOR AMPLIFIERS

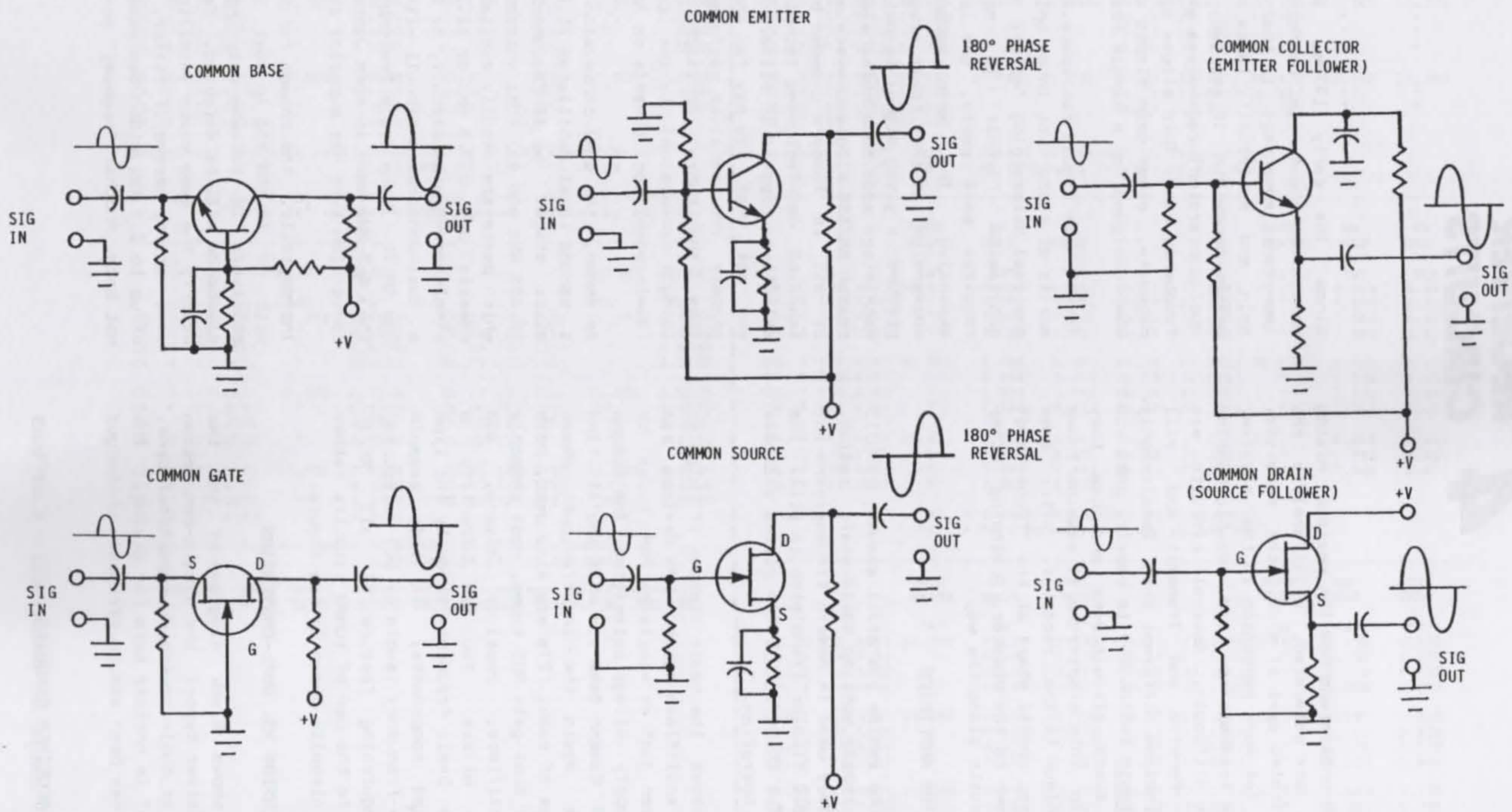
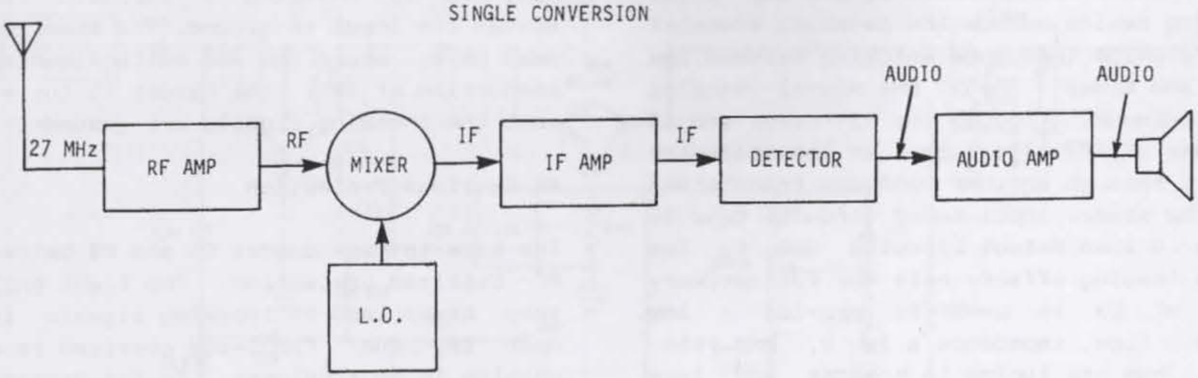
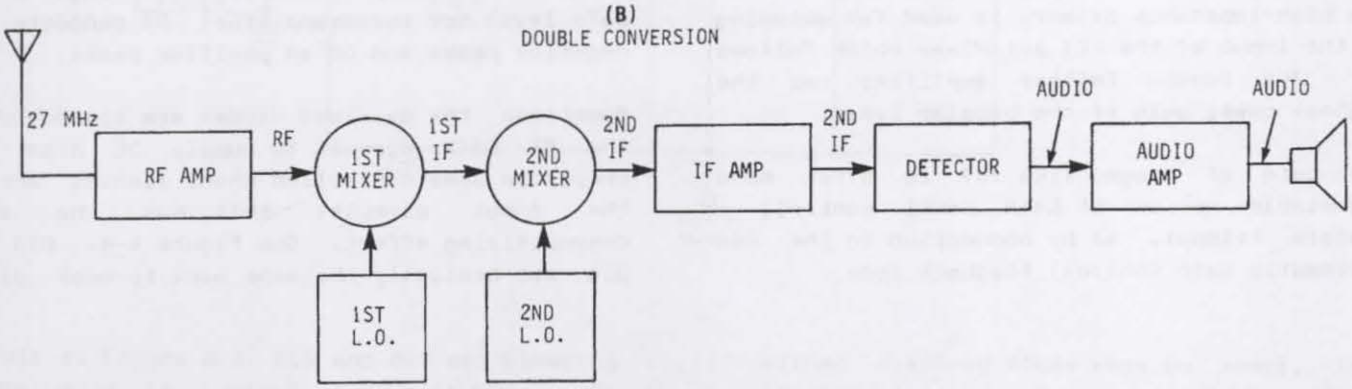


FIGURE 4-2
BASIC RECEIVER BLOCK DIAGRAMS

(A)
SINGLE CONVERSION



(B)
DOUBLE CONVERSION



THE RF AMPLIFIER

This stage is called the receiver "front end," since it's closest to the antenna. Depending upon its design relative to the mixer and IF stages, it may or may not affect performance greatly. The main purpose is to provide some selectivity ahead of the mixer and overcome the internal noise generated by the other stages. (Actually though at 27 MHz, external man-made noise has a greater effect on weak-signal reception.) Thus the RF Amplifier improves the Signal-to-Noise or S/N ratio.

A poorly-designed front end degrades the receiver's dynamic range by overloading the mixer, causing spurious signals. The RF stage is broadly tuned, since it must pass a band of frequencies rather than just one channel. For CB receivers a single active RF stage is all that's needed. Gain is typically 10-20 dB.

Symptoms of a bad RF amplifier stage include:

1. No Receive.
2. Signals very weak; can only hear extremely strong nearby stations.
3. Signal strenth fluctuates because AGC is missing.

There are basically four transistor RF amp circuits: the Common Emitter, Common Base, JFET, and dual-gate MOSFET. For CB use about 90% are split between the Common Emitter and Common Base; FETs are rare because they cost more than bipolar devices. You'll find FETs used mostly in radios from the old premium independent manufacturers like CPI, Johnson, Motorola, or SBE, all of whom priced themselves right out of the CB business!

Common Emitter RF Amp

Figure 4-3 shows a Common Emitter RF amp. Base bias is supplied from the resistive divider R12/R13. Tuned transformers before and after the active device narrow the passband somewhat and also provide impedance matching between the antenna and mixer. The 27 MHz signal couples from the antenna, through the pi-filter and L2 to the base of TR7. The output at the collector is coupled through another bandpass transformer (L3) to the mixer. Input tuned circuits tend to be lower Q than output circuits due to the antenna's loading effect; note the full primary winding of L2 is used to provide a low impedance. (Low impedance = low Q, and vice-versa.) Thus its tuning is broader and less critical than the output circuit, L3. Rather than using the secondary of L3, a sample from its high-impedance primary is used for matching to the input of the FET 1st Mixer which follows it. The Common Emitter amplifier has the highest power gain of the bipolar types.

The gain of stages like TR7 is often made adjustable by an RF GAIN panel control, a chassis trimpot, or by connection to the AGC (Automatic Gain Control) feedback loop.

The RF GAIN control is sometimes replaced by a simple "DX/LOC" switch using fixed resistor values. Regardless of the method, the effect is to control the gain by adjusting the bias on TR7, or by shunting a variable resistance across its input to ground. The shunt method is used here, where the AGC voltage controls the conduction of TR6; the harder it turns on, the more the incoming signals are grounded.

RF Overload Protection

The back-to-back diodes D1 and D2 below are for RF overload protection. The front end has a very heavy load of incoming signals impressed upon it, and front-end overload is a major problem in CB receivers. In the presence of a very strong signal or noise spike, the diodes turn on to clamp excess signal voltage at a safe level for the transistor. D1 conducts on negative peaks and D2 on positive peaks.

Sometimes the overload diodes are connected to the RF GAIN circuit to supply DC bias and therefore some controlled shunt loading across the input circuit; this has the same desensitizing effect. See Figure 4-4. D13 and D14 are basically the same back-to-back diode

FIGURE 4-3
COMMON EMITTER RF AMPLIFIER
(Cobra 29GTL, 29LTD, etc.)

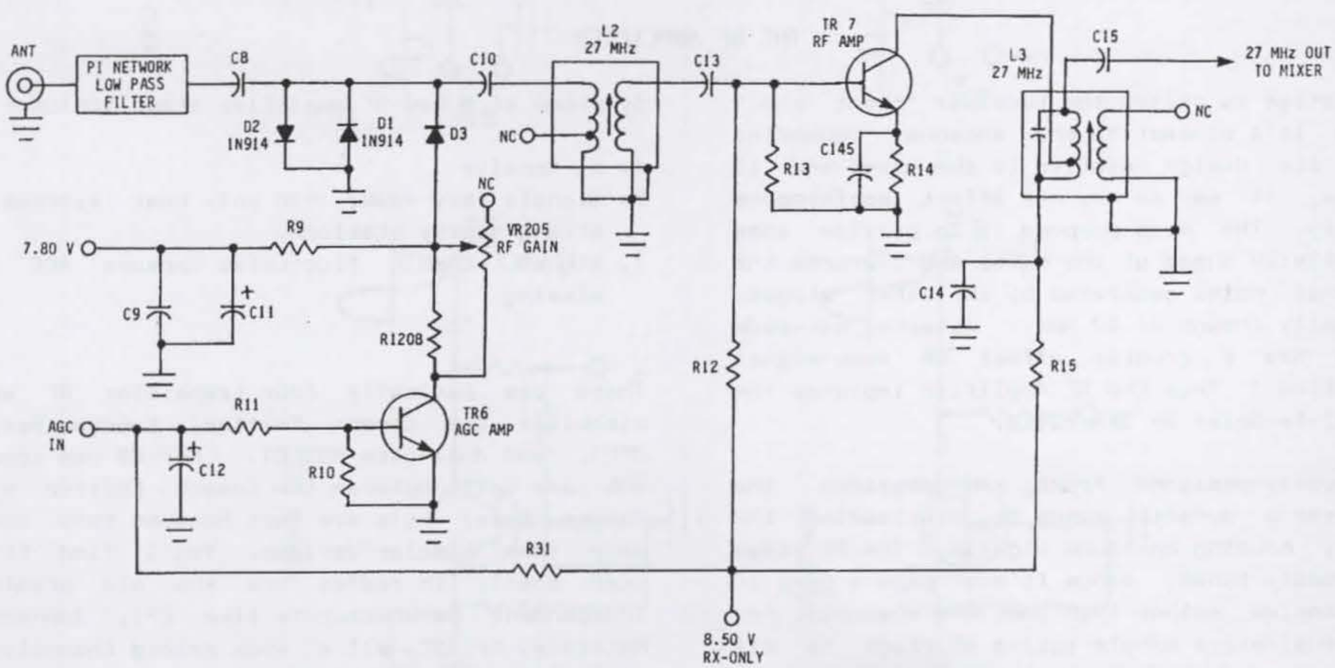
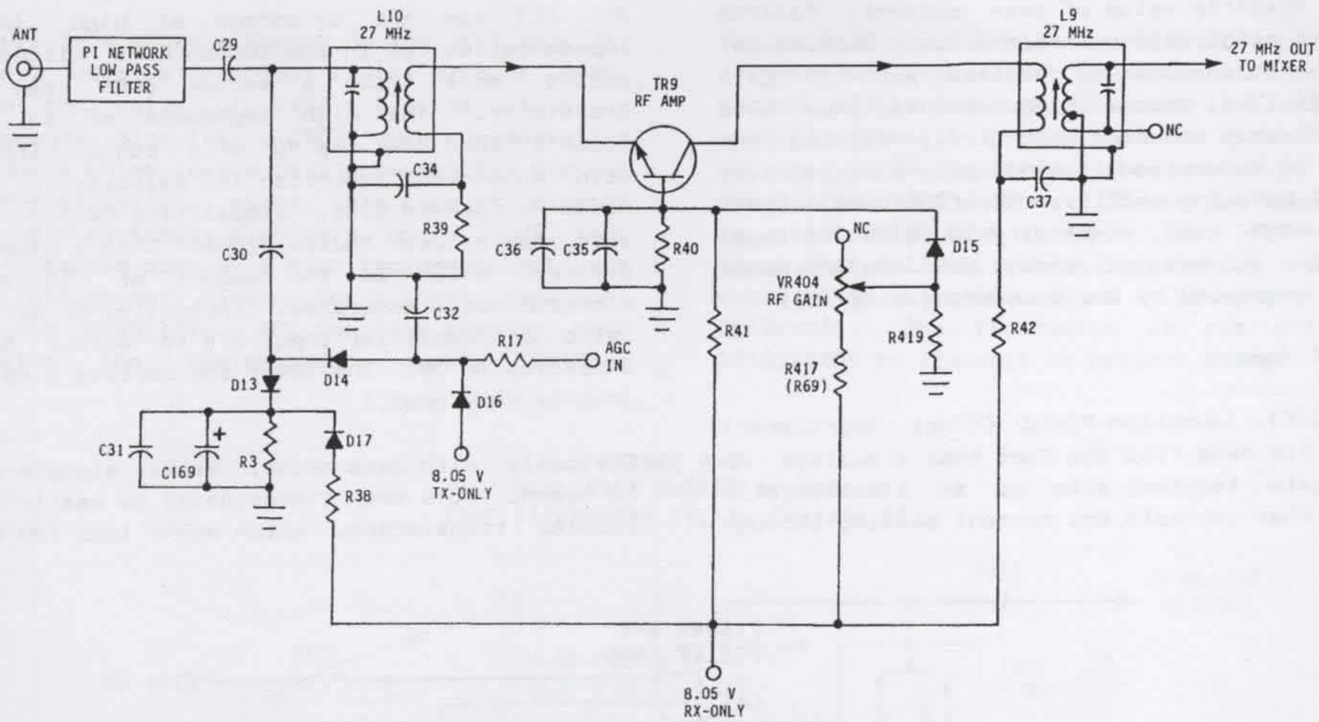


FIGURE 4-4
COMMON BASE RF AMP USING CONTROLLED LOADING FOR RF GAIN
(Cobra 140/142GTL, Realistic TRC490, Uniden Washington, etc.)



circuit as Figure 4-3. D16 and D17 are steering diodes used to control T/R switching. On Receive D17 is turned on, reverse-biasing D13 somewhat. But on strong enough positive peaks, D13 conducts through C30 and C31. D14 clamps on negative RF peaks through C30 and C32. R17 applies AGC voltage proportional to the strength of the incoming signals, controlling the conduction of D14 and D13 to lower gain.

In the Transmit mode, D13 and D14 are heavily forward-biased by D16 and the Transmit-only voltage. This shunts any transmitted RF and prevents it from overloading and possibly destroying TR9. The use of such steering diodes for electronic T/R control is a common technique discussed further in CHAPTER 7.

The overload diodes are silicon types, which conduct at about 0.6 VDC. Sometimes replacing silicon types with germanium or hot-carrier diodes will improve a specific overload situation (like a close neighbor or truck stop) by lowering the turn-on voltage. But this could also generate IMD and other distortion if the diodes turn on too easily with normal signals. Silicon diodes were meant for this function.

If either overload diode were to short, the sensitivity would drop like a rock and produce the "No Receive" symptom, since there'd be a direct short across the signal input path. When troubleshooting this particular problem, check these diodes as well as the RF amp and its alignment. The RF overload circuit is especially important with electronic T/R switching, since the full transmitter output can be coupled directly into the front end if a shunt switching circuit fails to work right.

Common Base RF Amp

Figure 4-4 is a Common Base RF amp. The signal is coupled to the emitter of TR9 instead of the base. Otherwise the main difference is the input/output impedance ratios. The Common Base has a lower input impedance; note the use of the full L10 primary winding. In fact it's already close to 50 ohms, making it a better match for the 50Ω antenna input. The collector circuit has a high impedance, so the secondary of L9 is tapped down. This high impedance accounts for the high voltage and power amplification of the Common Base type circuit. The figure shows one possible method of RF GAIN control; i.e., controlling gain by controlling the base bias on TR9.

The maximum gain for a bipolar RF stage occurs at a specific value of base current, falling off on either side of this value. Because of this, it's common practice with RF GAIN circuits to use a higher-than-optimum base current when reducing gain (i.e., driving the stage to saturation), since this also improves signal handling ability. The front end doesn't need much gain, typically 10-20 dB maximum. Ideally it has just enough gain to overcome noise generated by the succeeding mixer(s).

FET RF Amps

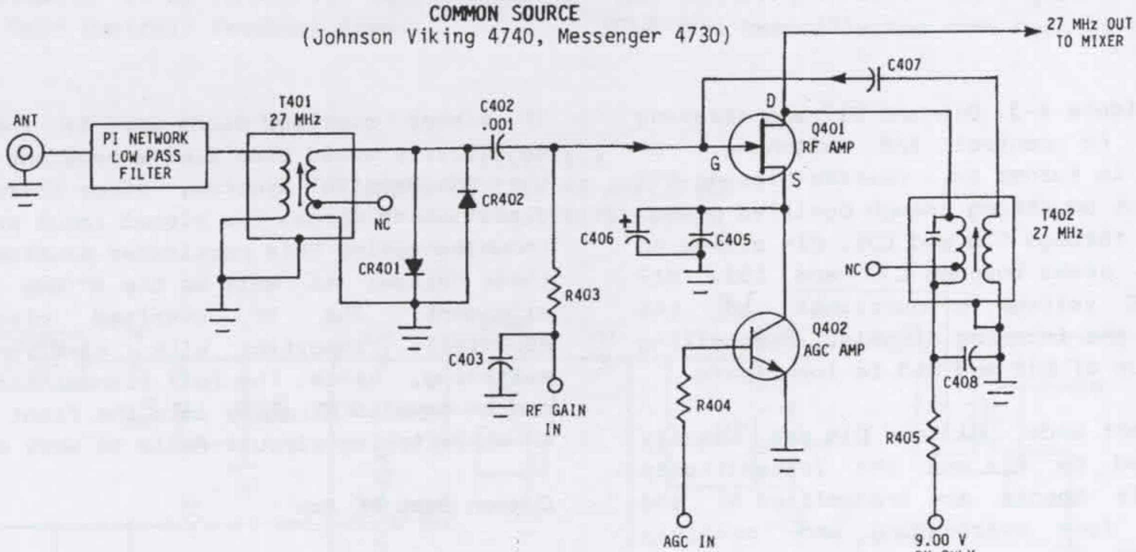
The JFET (Junction Field Effect Transistor) gets its name from the fact that a voltage on its gate terminal sets up an electrostatic field that controls the current passing through it, almost exactly like a triode vacuum tube. The more negative the gate voltage, the less current between source and drain.

An FET has the advantage of high input impedance (except in the Common Gate circuit), acting more like a vacuum tube than a transistor. The high impedance of an FET doesn't load down the "Q" of a tuned circuit with subsequent reduction in selectivity. It needs no forward bias, simplifying design. It also has a lower "Noise Figure" than a bipolar device, which is the amount of internal electron noise generated. (Actually, NF is the ratio of amplifier input S/N to output S/N, expressed in dB. The lower the better; 6 dB or less is very good.)

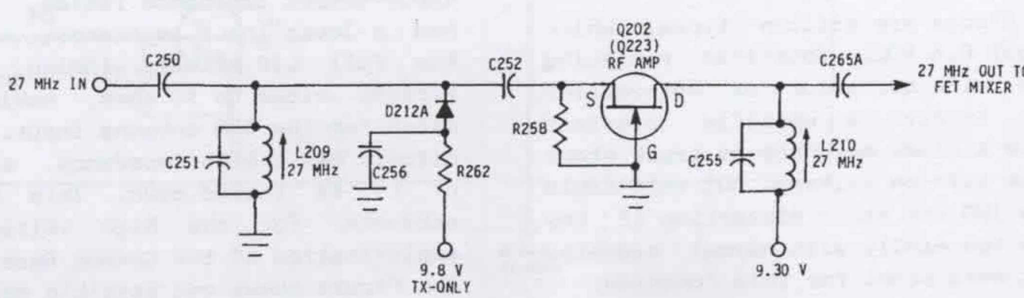
Obviously with less noise, weaker signals can be heard. FETs aren't overloaded as easily as bipolar transistors, which means less IMD and

FIGURE 4-5
JFET RF AMPS

(A)
COMMON SOURCE
(Johnson Viking 4740, Messenger 4730)



(B)
COMMON GATE
(CPI 300/400/2000)

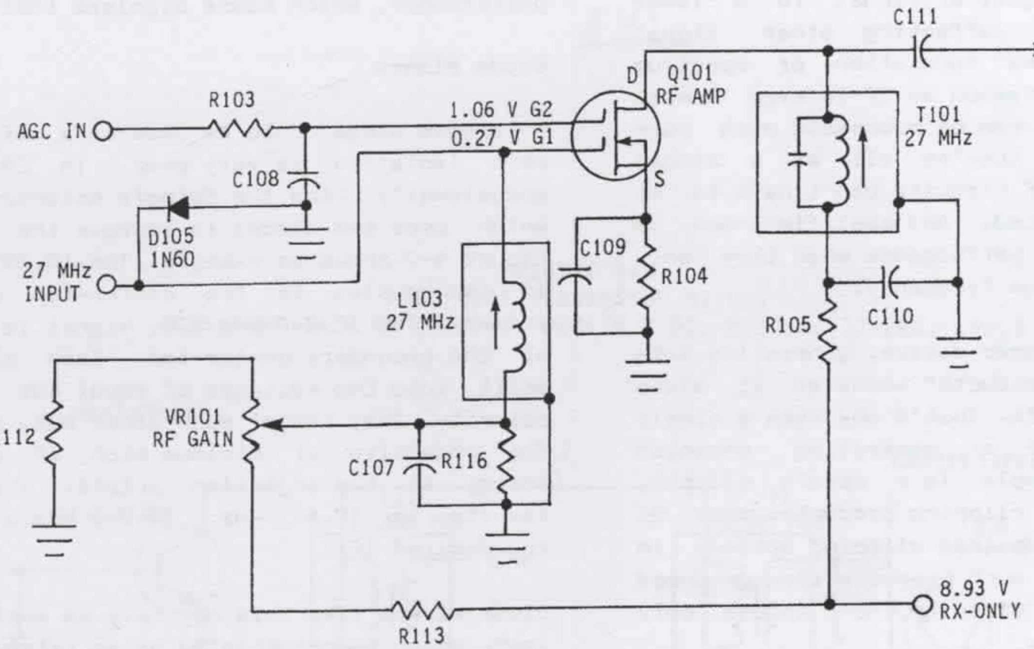


cross-modulation. Thus it offers the highest possible front end sensitivity and selectivity and greater signal handling ability (dynamic range) than a bipolar transistor.

Figure 4-5A shows a Common Source JFET amp. The signal couples from T401 to the gate of Q401. Note the value of C402, typical of high-impedance circuits. C407 adds degenerative feedback which lowers gain somewhat to prevent self-oscillation, since this type of circuit can have extremely high gain, up to 25 dB. T402 isn't tapped down at a high impedance, but uses the full primary winding for a lower impedance to aid stability. AGC controls gain by both varying the drain-source supply voltage directly (Q402), and by a negative-going feedback voltage on the gate (R403). C405 keeps the source at RF ground, while C406 adds the required AGC delay.

Figure 4-5B shows the Common Gate RF amp. This is much more stable than the Common Source type because of its lower gain, about 12-15 dB. No special stability precautions are needed. The extremely low input impedance makes a good match for a 50Ω antenna. The output impedance is relatively high to match the JFET mixer input that follows, which is no doubt why they chose this circuit. Class A biasing is by C252/R258. The transistor is cut off by D212A/L209 on Transmit to prevent damage.

FIGURE 4-6
DUAL-GATE MOSFET RF AMP
(SBE Sidebander IV, V, Console V)



In Figure 4-6 a dual-gate MOSFET is used. It has the same advantages as the JFET with even better dynamic range. The MOS construction is a special process in which the doped silicon acts like a variable resistor. The resistance is controlled by the gate bias, which in turn controls the drain-source current. The MOSFET requires a positive gate voltage to amplify, as shown. The signal is applied to gate 1 and the AGC bias to gate 2. RF gain is controlled by manually varying the bias on gate 1 through VR101 and the associated divider resistors.

Unlike JFETs, MOSFET gates are electrically insulated from the rest of the silicon wafer. (MOS means "Metal Oxide Silicon," the physical process of depositing the insulation on the wafer.) MOS devices are easily damaged by static electricity, which can punch right through the insulation; use proper handling techniques when replacing them. A germanium diode, D105, is included externally to help clamp large voltage spikes. Many MOSFET devices have internal diode protection (i.e., "gate-protected") which is also supposed to clamp such spikes to a safe level. But don't count on it; use proper grounding procedures!

The MOSFET is far superior to bipolar transistors, but their higher cost makes them very rare in CB use. I was pleasantly surprised to find them used in the new Midland 77-250 for both the front end and the 1st mixer stages!

RF MIXERS

There are as many varieties of CB RF mixers as RF amplifiers. Again you'll find bipolar and FET devices as well as ICs and simple diode mixers. All of these except diode mixers are also used for synthesizer mixers, so knowing how they work will help you fix those too.

The purpose of the (1st) mixer stage is to convert the 27 MHz signal to a lower frequency, the Intermediate Frequency or IF, for further processing. (In tube radios it's often called the "converter" stage.) In dual-conversion receivers the IF is converted a second time to an even lower frequency. A mixer simply translates the higher RF signal to a lower frequency without affecting other signal characteristics like modulation or spectrum distribution. The reason an IF is even needed is because signals can be processed much more efficiently when they're all at a single frequency. Tuned IF circuits don't have to be constantly readjusted. And amplifiers can be designed for best performance when they only have to deal with one frequency.

A mixer is a non-linear device, generating lots of harmonics or "products" whenever it mixes two different signals. That's why even a simple diode is capable of generating unwanted harmonics. An example is a speech clipper, where the unwanted clipping products must be removed after the desired clipping action. In the case of mixers such products are produced on purpose; tuned circuits then choose only the desired product.

Mixers can be divided into the general classes of active and passive. The passive kind uses diodes and ideally has no loss or gain, but in practice does have several dB loss. At 27 MHz diodes also generate a lot of noise. Since they have no gain, they need much higher L.O. injection voltages. Their advantages include circuit simplicity and strong signal-handling ability. Since diodes are naturally broadbanded they have a wide dynamic signal range. Active mixers may have up to several dB gain, reducing the L.O. injection requirements. A careful mixer design adds very little noise. About 90% of CB mixer circuits use active devices, mostly bipolar transistors but occasionally FETs in some better models.

Mixer design considerations include: level of available L.O. injection, isolation between the two signal injection ports, IMD, and noise. The mixer should receive only enough incoming signal to overcome its own noise. Extremely strong input signals result in desensitization, cross-modulation, and IMD. Thus the mixer must handle strong signals well, which normally means an FET for the active device. Unfortunately for CB use the tradeoffs are usually low cost and simplicity vs. high performance, which means bipolars instead.

Diode Mixers

A single diode could be used as a mixer, but port isolation is very poor. In CBs you'll occasionally find the "single balanced mixer" which uses two diodes to improve the balance. Figure 4-7 shows an example. The 10.695 MHz 1st IF is coupled to the center-tap of T13's primary. The 10.240 MHz L.O. signal is injected at the secondary center-tap. Each signal is split into two voltages of equal but opposite polarity. They cancel each other out, realizing the objective of minimum high IF and L.O. energy at the injection points. The mixing results in 10.695 MHz - 10.240 MHz = 455 KHz, the desired IF.

Diode mixers like this may have as much as 8 dB loss, which is compensated by an extra stage of IF amplification following the mixer. Note the diodes are germanium; the 10.695 MHz IF is very weak at this point, and the lower turn-on voltage of germanium is desirable. If a mixer diode ever needs replacement you should replace the pair, matching both for equal forward resistance with your ohmmeter.

The new Midland 77-250 uses a similar active balanced mixer, with FETs instead of diodes for even better performance. (Incidentally, this rig is one of the hottest new receiver designs in a long time, with great sensitivity and selectivity!) FET replacement in such radios should also include both devices of a pair.

FIGURE 4-7
SINGLE-BALANCED DIODE MIXER
(Cybernet PTBM048 chassis: J.C. Penney 981-6247,
Lafayette Telsat SSB140, Midland 79-892, etc.)

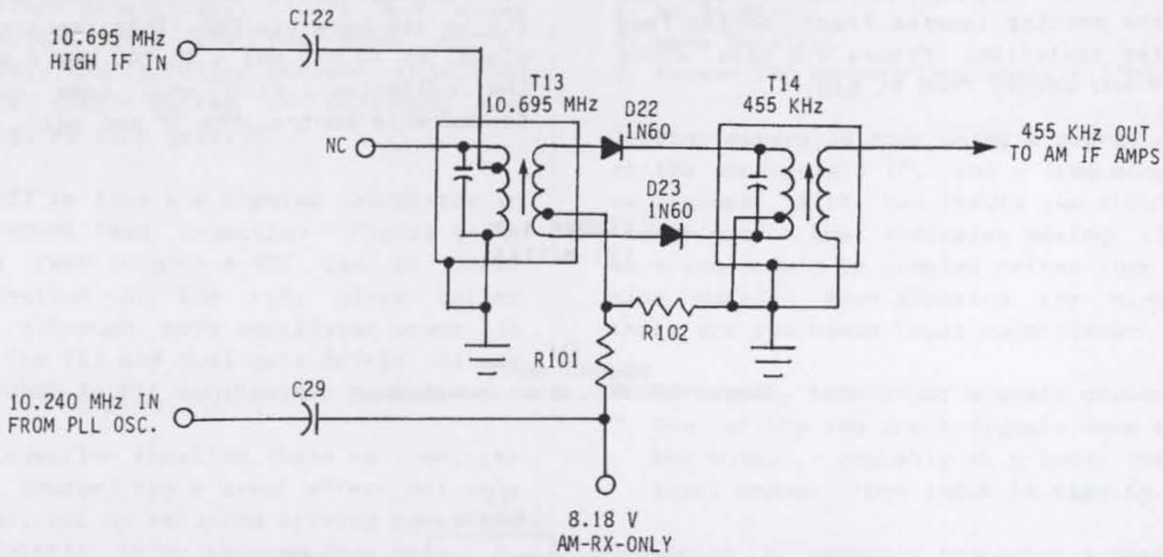
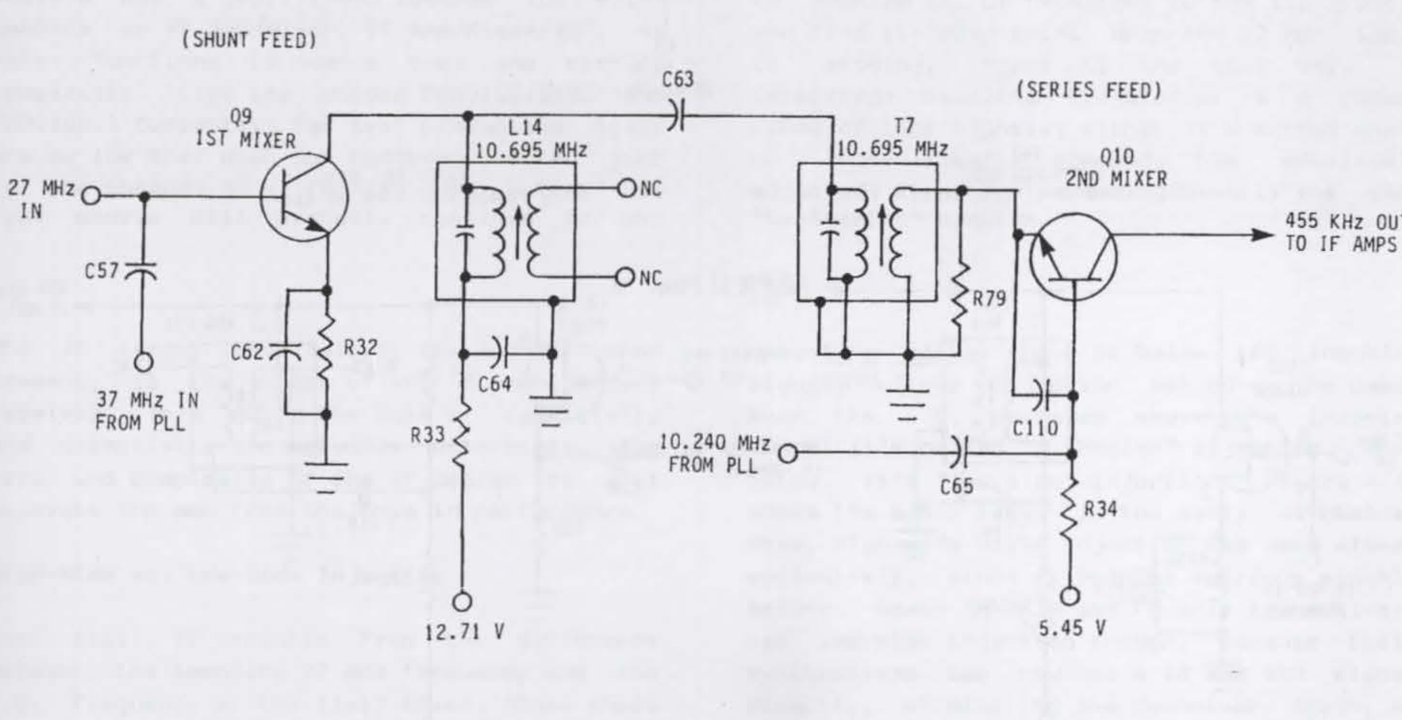


FIGURE 4-8
BIPOLAR TRANSISTOR MIXERS
(Cybernet late AM chassis: HyGain 2702, Midland 77-888, etc.)

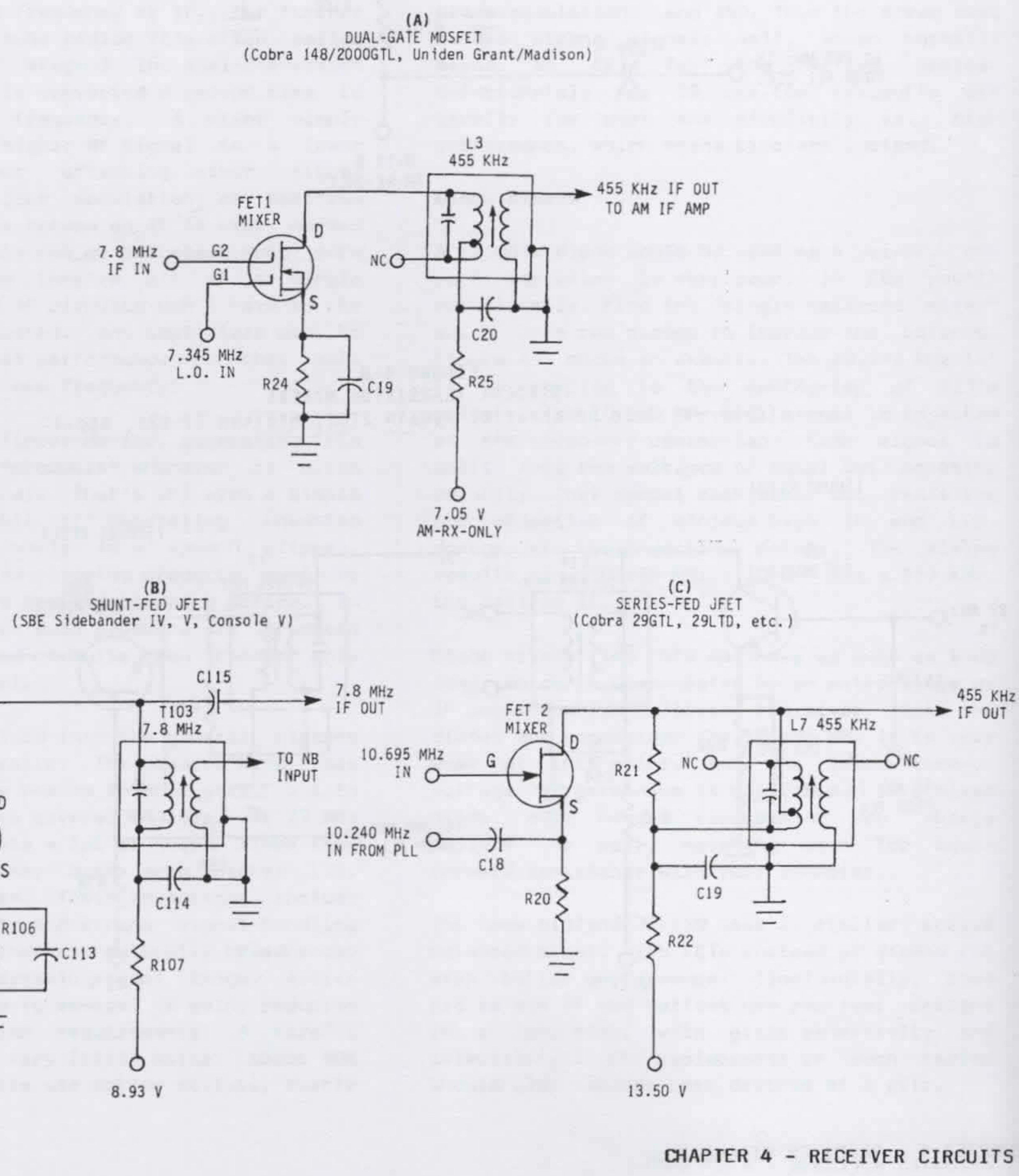


Bipolar Transistor Mixers

This is the most common active mixer device. Usually both mixing signals are applied to the base (shunt feed), although you'll also see the RF and L.O. signals applied to both the base and the emitter (series feed). Series feed gives better isolation. Figure 4-8 uses shunt feed at Q9 and series feed at Q10.

Q9 combines the 27 MHz input and the 37 MHz PLL input at the base. The Ch.1 synthesizer input is 37.660 MHz, giving the IF of 37.660 MHz - 26.965 MHz = 10.695 MHz at Q9's collector. The 2nd mixer, Q10, couples the 10.695 MHz input to its emitter via T7 and the 10.240 MHz from the PLL to its base via C65. This results in the IF signal of 10.695 MHz - 10.240 MHz = 455 KHz at the collector. C110 adds some degenerative feedback to control the IF amp gain.

FIGURE 4-9
FET MIXERS



FET Mixers

The JFET or dual-gate MOSFET has superior mixer performance. The greater signal handling ability makes them more resistant to overloading and IMD. The lower Noise Figure also improves sensitivity. Figure 4-9 shows three examples. With the dual-gate MOSFET (Figure 4-9A), the isolation between injection ports is a simple matter of injecting one mixing signal at each gate.

Note the JFET is like the bipolar transistor in that both shunt feed injection (Figure 4-9B) and series feed (Figure 4-9C) can be used. Source injection of the L.O. gives better isolation, although more oscillator power is required. The FET and dual-gate MOSFET mixers are also common in PLL synthesizer circuits.

The L.O. injection location (base vs. emitter or gate vs. source) has a great effect not only on isolation, but on required driving power and loading. Emitter injection requires more L.O. drive voltage but has the advantage of lighter loading on the synthesizer oscillator that drives it. On the other hand the lower drive requirement for base injection, which has a lower impedance, means more driving power is taken from the driving stage. That's why a VCO Buffer stage is often added between the synthesizer and mixer to minimize such loading.

There's now a small trend towards ICs which combine an RF Amp/Mixer, IF Amp/Mixer/AGC, or other functions to reduce cost and circuit complexity. (Like the Uniden PRO510E/520E and PRO710E.) Currently, Far East production costs are so low that such use has been limited just to the cheaper AM or FM rigs. The better SSB type models will probably continue to use discrete components for a long time yet.

MIXER TROUBLESHOOTING

The symptoms of a faulty receiver mixer are:

1. No Receive.
2. Weak Receive.
3. Excess IMD or spurious signals ("birdies").

Testing mixers is done using a signal generator at the appropriate IF, and a frequency counter or 'scope. With two inputs you should see a 'scope output that indicates mixing. (I.e., the waveform should be complex rather than a single sine wave.) When checking the mixer stage there are two basic fault conditions:

1. No output, both input signals present.
2. One of the two input signals does appear in the output, probably at a lower-than-normal level though. (One input is missing.)

Condition #1 probably indicates a dead active mixer device. Check its DC voltages and interpret them. If the device is good you'll have to check associated parts like resistors, capacitors, coils, etc.

For #2, one input is missing and you'll have to trace back to its source to find the open signal path. If the IF is missing, inject one from your signal generator into the base/gate to confirm it. Or backtrack to the L.O. until you find its open point. When the 27 MHz input is missing, inject it the same way. An interstage coupling transformer is a common cause of lost signals; either it's burned open, or (more likely) somebody has previously adjusted it wrong, producing exactly the same "No Receive" symptom.

IF AMPLIFIERS

The IF stage, particularly the 2nd IF when present, is the heart of any communications receiver. It's where the bulk of sensitivity and selectivity are actually determined. The care and complexity of the IF design are what separate the men from the boys in performance.

High-Side vs. Low-Side Injection

The (1st) IF results from the difference between the incoming 27 MHz frequency and the L.O. frequency at the (1st) mixer. Since these difference frequencies can result from the L.O. operating either above or below the incoming signal, either injection method can be used. When the L.O. operates above the incoming signal it's called "high-side" injection. When below, it's "low-side" injection. Figure 4-10 shows the basic idea. In the early 40-channel days, high-side mixer injection was used almost exclusively, since it reduces spurious signals better. Newer AM-only and FM-only transceivers use low-side injection though, because their synthesizers can now use a 16 MHz VCO signal directly, eliminating the downmixer. Again, an economic tradeoff of parts vs. performance.

FIGURE 4-10
MIXER INJECTION METHODS

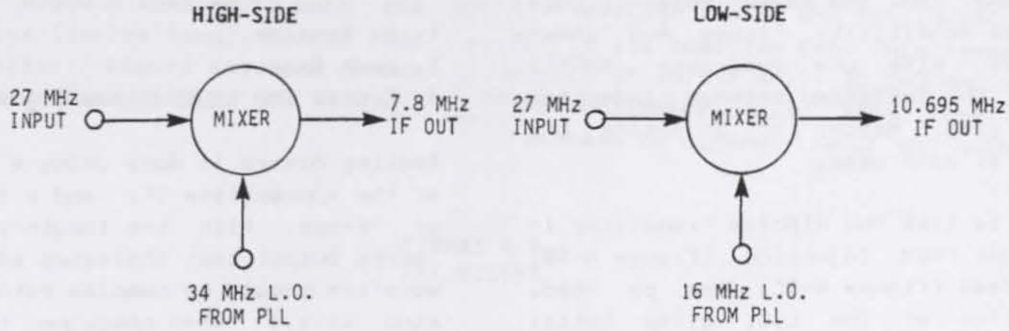


Image Rejection

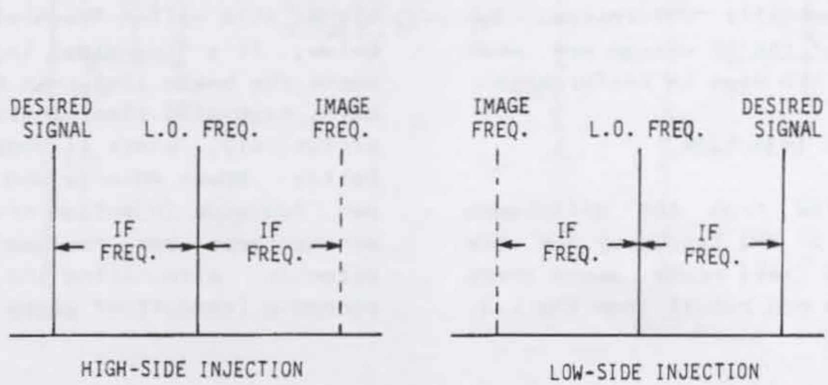
A basic mixing problem is the generation of "image" frequencies. It's most noticeable in single-conversion receivers. See Figure 4-11. Mixing causes not only the desired sum or difference frequency to be generated, but also an image frequency which is the same as the IF but on the opposite side of the L.O. from the desired IF. Since its mixing results in the same IF frequency, it can easily pass through the IF amplifier and degrade performance.

An example might be a single-conversion receiver with a 1 MHz IF, tuned to a station at 20 MHz. Using high-side injection, this means the L.O. would be at 21 MHz. (21 MHz - 20 MHz = 1 MHz, the IF). Now suppose there was a strong undesired station at 22 MHz. This station would produce the same 1 MHz IF, but on the opposite side of the L.O.: 22 MHz - 21 MHz = 1 MHz. Even though the front end is tuned to 20 MHz, it's not selective enough to eliminate the 22 MHz signal completely. So what happens? Both the 20 MHz and the 22 MHz signals look "right" to the IF, and are amplified and passed along. If the undesired station is strong enough it can totally wipe out the desired station!

From this example you can see it's the ratio of the desired frequency to the IF frequency that's important. By using a much higher IF like 7.8 MHz or 10.695 MHz, image rejection is greatly improved because the images are so far removed from the desired frequency (in this case 7.8 MHz or 10.695 MHz away) that they're out of the passband. The tuned circuit might pass something 1 MHz away, but not 8 MHz away. This is why a high IF is always chosen when designing single-conversion receivers.

The tradeoff in doing this means reduced gain and selectivity. The choice of IFs is therefore a compromise between several important factors. That's why the dual-conversion receiver, which has more tuned circuits, generally offers better performance; not only is image rejection improved with a high first IF, but a second IF conversion offers cheap selectivity and gain too. It's the best of both worlds...

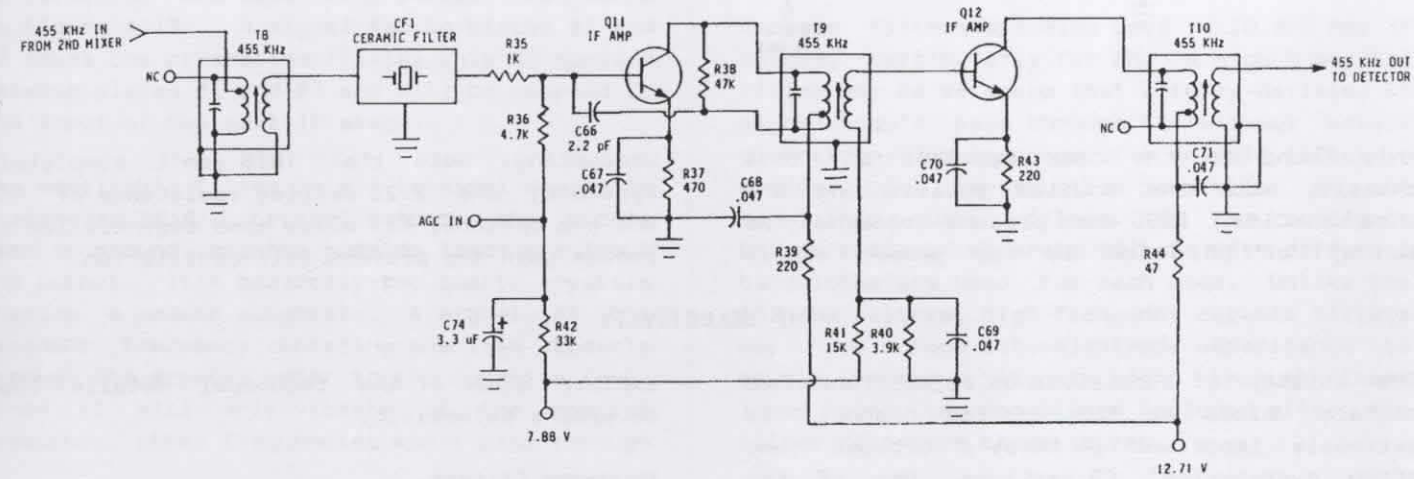
FIGURE 4-11
MIXER IMAGE FREQUENCIES



Images can't be removed after the fact; the only way to eliminate them is by good selectivity <u>before</u> the mixer stage. This selectivity is achieved by the use of crystal and ceramic filters in the high and low IF stages respectively. Dual-conversion receivers rarely use amplifiers at the high IF, because it's cheaper to get the gain and selectivity at the lower IF frequency. (Ceramic filters are cheaper than crystal filters.) The purpose of the high IF is to improve image rejection by the addition of its tuned circuits.

For FM, images aren't a problem because of its inherent "capture effect." If more than one station is present only the strongest signal will even be detected; it captures the channel. On AM or SSB, all signals passing through the IF can be heard by a listener.

FIGURE 4-12
TYPICAL 455 KHz IF STRIP
(Cybernet late AM chassis: HyGain 2702, Midland 77-888, etc.)



Typical IF Amplifier Strips

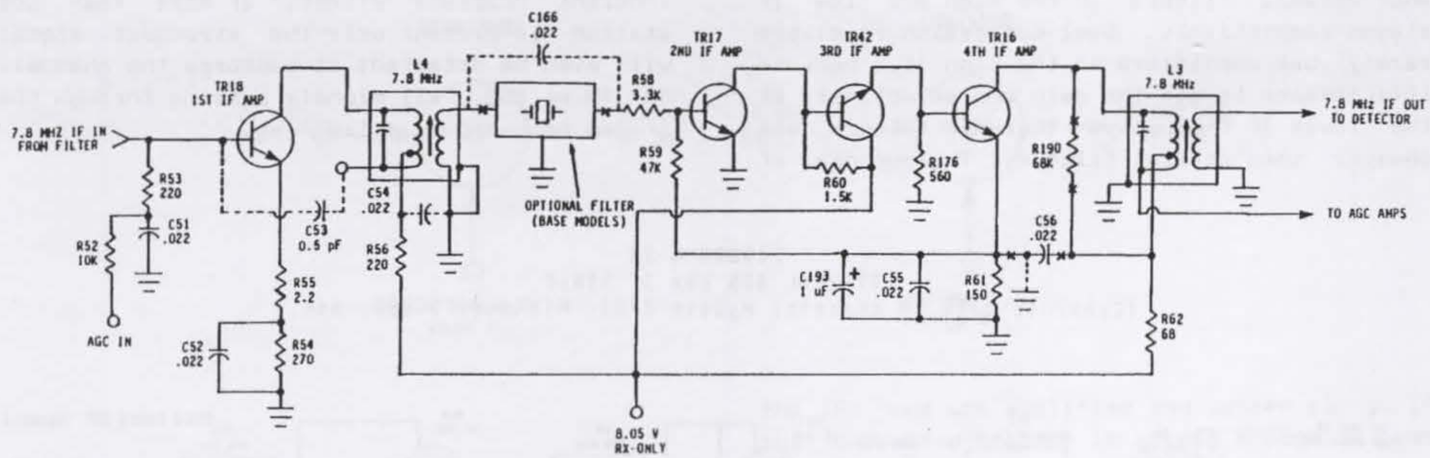
Figure 4-12 shows the IF stages of a very common dual-conversion AM/FM receiver. Bipolar transistors in the Common Emitter configuration are almost always used. Inputs are at the base, outputs at the collector. There are several tuned transformers and one or more ceramic filters to shape the passband response and improve selectivity and adjacent-channel rejection. Voltage gains in transistor IF amps are about 10 dB, depending upon the number of filters and tuned circuits. This particular circuit will be described in more detail later.

DC coupling between transistor IF amps is also commonly used, like the improved IF strip of Figure 4-13. This is popular in all the Uniden SSB (American and export) models. TR42 is actually not an amplifier; it's an Emitter Follower (i.e., Common Collector) circuit that couples TR17 to TR16. This is like the Cathode Follower in tube circuits, where a high-to-low impedance change is needed. Think of it as a buffer stage. The name comes from the fact that the emitter voltage "follows" the base voltage, always being 0.6 V lower. TR42 saves the cost of another interstage transformer but more importantly, it preserves the high gain of TR17 by virtue of its high input impedance. You can always couple from a low impedance into a higher impedance, but never the other way around without losing a lot of signal.

The net result is greater signal handling ability and dynamic range without the kind of desensitizing and blocking suffered by less sophisticated designs. The AGC spec for this popular chassis is typically 80-90 dB, which is excellent. If you've ever listened to one of these, you know it's practically impossible to shut it down with a strong signal.

The "Xs" and dotted lines in the drawing indicate optional parts which may only be used if needed. The 7.8 MHz monolithic filter is

FIGURE 4-13
TYPICAL DC-COUPLED IF STRIP
(Cobra 140/142GTL, Realistic TRC490, Uniden Washington, etc.)



only found in the base versions of this chassis, with the mobiles substituting the cheaper C166. R190 when present broadens the tuning of L3. C56 is for power supply decoupling. Note that TR18 isn't completely bypassed; the 2.2Ω emitter resistance of R55 and the optional C53 allow some degeneration to reduce gain and prevent self-oscillation.

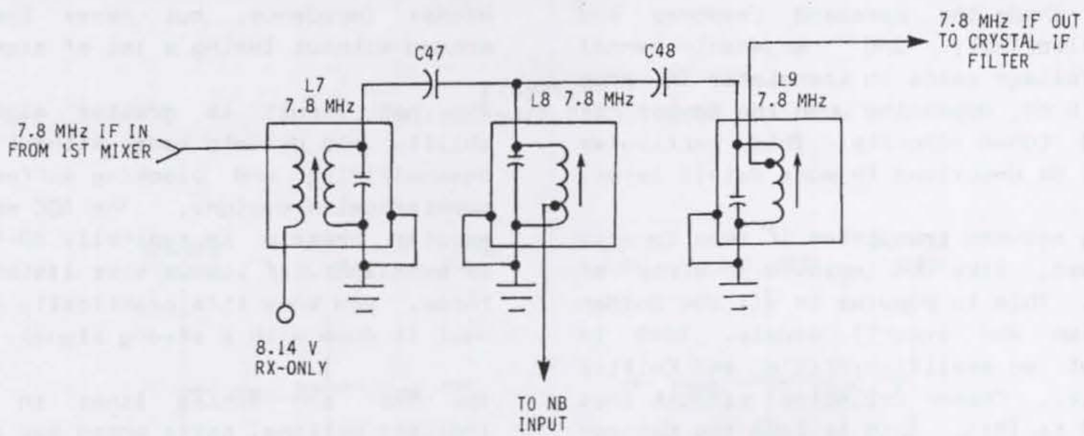
IF SELECTIVITY

The ability of a receiver to reject unwanted signals close to the desired channel is extremely important in today's crowded (and often overpowered) CB services. One of the most common complaints of CB operators is "bleedover" interference from strong local stations that may be many channels away from the actual channel being received. Let's explore some of the technical details that determine selectivity.

Bandpass Filters

The high IF stages may or may not have additional selectivity besides the transformers themselves. One of the best ways to establish

FIGURE 4-14
BASIC IF SELECTIVITY USING BANDPASS FILTER
(Cobra 148/2000GTL, Uniden Grant/Madison)



some basic selectivity after the 1st mixer is with a bandpass filter. Figure 4-14 shows an example. It consists of two or three capacitively-coupled IF transformers. This gives a good response characteristic and better bleedover rejection than the more conventional inductively-coupled IF stages found in tube radios. Its relatively broad response isn't that important anymore, because now there are inexpensive crystal and ceramic IF filters to increase selectivity further downstream.

Monolithic IF Filters

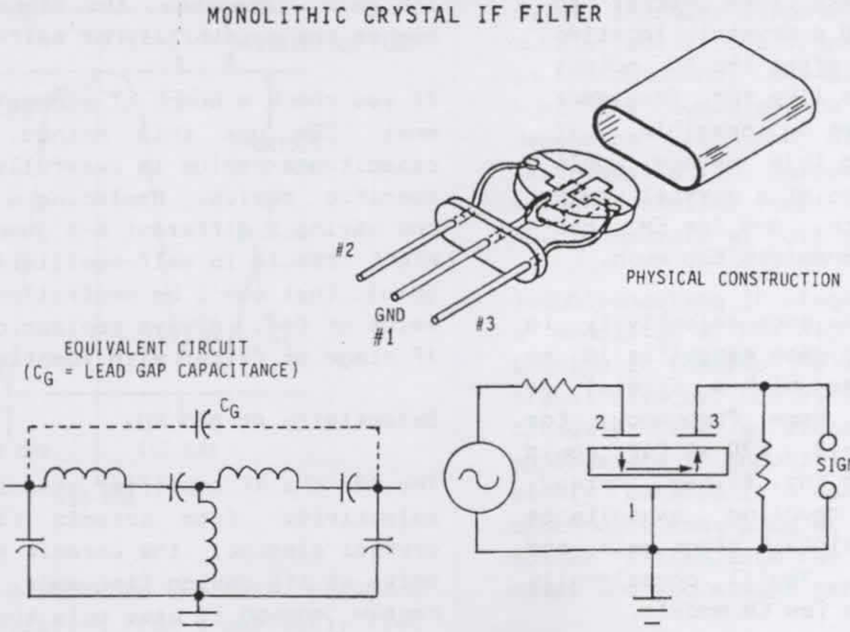
Besides a bandpass filter, the better models will include a 10.695 MHz "monolithic" crystal filter between the 1st and 2nd mixers. Its construction and equivalent circuit are shown in Figure 4-15. A signal fed to plates #1 and #2 makes the crystal oscillate; this AC appears between plates #1 and #3 and will be coupled to the input of the next IF stage.

The monolithic filter is a 3-terminal device in a standard HC18/U crystal holder; the middle lead is ground, and the outside leads are input and output. It's basically two quartz crystals sharing a common substrate. A signal at the resonant frequency entering one lead travels through the crystal wafer to the opposite lead. Since it will only vibrate at the correct frequency, other frequencies won't pass through and are sharply attenuated. The thickness of the wafer at the two points determines its bandpass characteristic. In CB IFs they've been used quite effectively for interstage coupling at 10.695 MHz and 7.8 MHz.

For base and mobile CBs having the same main chassis, you'll often find a monolithic crystal filter only in the base versions; the mobiles will substitute a capacitor in the two input/output holes to couple the IF signal across. Examples include the Cobra 138/139XLR chassis, and the Cobra 140/142GTL chassis. Selectivity in the mobile versions can be greatly improved by replacing this capacitor with the missing monolithic IF crystal filter. These can be ordered from Cobra, Uniden, or us.

Ceramic filters are also used in 10.695 MHz IF stages, particularly for FM. A high-Q crystal filter may be so sharp that a fully-deviated FM signal can't pass through it without severe distortion. The response of a ceramic filter is broader. Its construction is similar to the monolithic quartz filter. In the multimode Uniden radios, separate filters with different bandwidths are used for each mode. Unlike the 455 KHz filters, high-frequency ceramic filters may have enough interelectrode capacitance to couple spurious signals right through them. Tuned circuits are always included after the filter to remove these spurs.

FIGURE 4-15
MONOLITHIC CRYSTAL IF FILTER



Tips On Improving Selectivity

Selectivity can often be vastly improved by the simple addition of an ordinary series coupling crystal in the high IF stage. This applies to both tube and solid-state transceivers. Most of these stages are capacitively coupled, like C47 in Figure 4-14. Remove the capacitor and install the crystal instead. Solder a wire to the crystal case and ground it to the chassis common foil. The most eligible radios are those with a first IF of 7.8 MHz, 10.695 MHz, 11.275 MHz or 9.785 MHz. (This is the idea behind our **CHANNEL GUARD** IF filters, except they're even sharper than a single crystal.) When ordering crystals, specify the series mode type, 10 pF load capacitance, solder leads.

You can do the same for tube radios, which often had no IF filtering at all. Add a 455 KHz ceramic filter in the low IF. In those circuits there wasn't always a coupling capacitor, so you might need to cut a hard PC trace between the 2nd mixer and the 1st 455 KHz IF amp to do it. And if money's no object, replace a coupling capacitor in a 455 KHz stage with a 455 KHz crystal (cost about $20) instead of a ceramic filter. In vintage radios like the Trams and Brownings the cost is justified, since this can add tremendous IF selectivity.

> CAUTION: If the radio has a Noise Blanker, don't use this technique when the crystal location falls inside the NB loop, since the increased selectivity will lengthen the noise pulses and make them harder to remove. You must find a crystal location before the NB input or after the NB output point. In some radios like the President Jackson, this may not be possible. If stages are DC-coupled this method won't work, since installation of a crystal would block the DC supply path. And for FM, this trick may narrow the bandwidth too much.

Another method which also adds selectivity is to replace the emitter bypass capacitor in an appropriate IF amp stage with a crystal or ceramic filter of the same frequency. For example back in Figure 4-12, C70 at Q12 could be replaced with a 455 KHz filter instead; there's still enough coupling capacitance through the filter to maintain stage gain and prevent AC degeneration. You'll occasionally see this method used in a few CB models.

Finally, in circuits where the IF transformer windings aren't needed to supply DC to the transistors or tubes, you could simply replace the transformer itself with a filter soldered across the appropriate input and output signal connections. This trick is especially useful in older radios that used double-tuned IF coupling transformers between the active stages.

Controlling Filter Response

The passband response of an IF filter is critically dependent upon proper impedance matching of its input and output terminals. Any change in input or output impedance will effect the response characteristic. Too high an impedance will increase its "Q" and sharpen the bandwidth, with possible self-oscillation; too low an impedance and the bandwidth becomes too broad. In many circuits the impedances are controlled by tuned circuits on both sides. In others the input has a tuned circuit but the output couples to the base of the following stage through some series resistance of about 2KΩ or less. Since IF amplifiers are always Common Emitter types, the typical 2KΩ input impedance can be easily matched this way.

To keep the input impedance of the succeeding stage as constant as possible, it's carefully biased and usually includes some degenerative feedback to control gain. Returning again to Figure 4-12, the small capacitor C66 supplies a bit of collector-to-base feedback on Q11. Since Q11 is a Common Emitter amp, this feedback is 180° out of phase with the base and will lower its gain. (Remember, the higher the gain, the higher the possibility of self-oscillation.)

If you check a bunch of schematics, you'll find most CBs use this method. The feedback capacitance value is carefully chosen for the specific device. Replacing a transistor with one having a different b-c junction capacitance might result in self-oscillation (or reduced gain) that can't be controlled by the existing value of C66. Always replace components in the IF stage or filter with identical types.

Selectivity At 455 KHz

The 455 KHz IF amplifier stages get their basic selectivity from ceramic filters. Like a crystal element, the ceramic element resonates only at its design frequency. This makes it narrow enough to pass only the desired signal and sharply roll off anything outside this passband. Most AM and FM CBs use a single

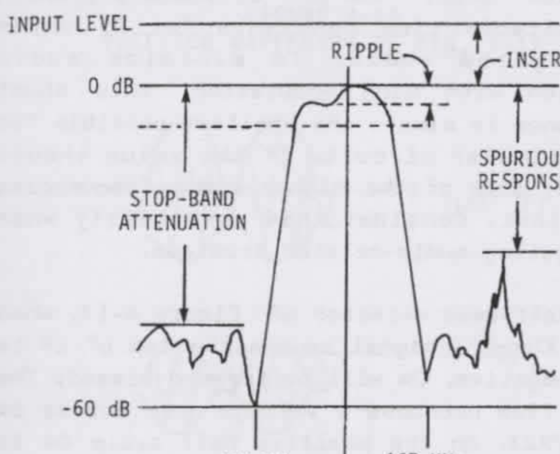
Murata CFU455H or CFW455H filter, a small plastic block having three or five leads respectively. Radios like the Tram D201/D201A and Midland 77-250 may cascade two or three of these to sharpen the selectivity even more. Many older tube-type radios had no filtering at all; they were made in the uncrowded (!) days of CB radio, when selectivity and bleedover weren't problems. Following are the specifications for the Murata filters; note the "CFW" series with its greater number of resonators has slightly better rejection.

MODEL	CENTER FREQ.	-6 dB WIDTH	-50 dB WIDTH	STOP BAND ATTEN.	INSERTION LOSS	IN/OUT IMPEDANCE
CFU455H	455 KHz	±3 KHz	±10 KHz	25 dB	6 dB	2KΩ
CFW455H	455 KHz	±3 KHz	±9 KHz	35 dB	6 dB	2KΩ

IF Skirt Selectivity

The IF "skirt selectivity" is a graphic representation of a particular receiver filter characteristic. When the preceeding specs are plotted on a graph of attenuation vs. center frequency like Figure 4-16, the result is a curve shaped like a bell or a woman's skirt. The steeper the sides, the better the selectivity. But a tradeoff with extremely narrow passbands is that frequency stability is much more critical; as a practical matter the real bandwidth is often made wider than the minimum possible to compensate for drift.

FIGURE 4-16
IF "SKIRT" SELECTIVITY



The flat top of the skirt is the main passband response. Any deviation from a perfectly flat response is called "ripple" and means that all IF frequencies aren't being passed equally. A good filter shouldn't exceed 1-2 dB of ripple.

IF TROUBLESHOOTING

Problems related to the IF section include:

1. No Receive.
2. Weak Receive.
3. Audio distortion.
4. Squeal (self-oscillation).
5. Improper (or no) AGC action.
6. Poor selectivity.

The most common failures are the transistors, coupling transformers, capacitors, or filter element, in that order. Opens and shorts in any of these will kill the normal signal level. Misalignment of transformers causes similar symptoms and is extremely common, since there are "screwdriver wizards" everywhere these days! Improper alignment of the IF can be more subtle too: if the transformers aren't centered in the passband, the sidebands may be cut such that the audio sounds either tinny or bassy, depending upon the direction of mistuning. Self-oscillation narrows the IF response to produce similar results, and also causes the AGC to operate at full gain reduction.

Troubleshooting IF stages is done by injecting a modulated 27 MHz signal at the front end and tracing it towards the speaker with a 'scope or signal tracer, or by injecting the IF signal directly from a signal generator into the appropriate IF input. I prefer the first method simply because it's easier to attach a quick-disconnect coax plug at the coax socket than to solder a lead into the IF stage. It's not as messy and you always have both hands free.

Remember that receiver signal levels at this point are extremely low, making them very difficult to view directly on a 'scope even with inputs of several thousand microvolts. The signal tracer method is easier, since you just listen for the modulated signal as you probe, without having to take your eyes off the PC board. There's nothing more aggravating than accidentally blowing a good circuit with a test probe that slips and shorts something!

Probe your way from inputs to outputs until the signal is lost. It may be something obvious, like an open transformer or ceramic filter. More likely it's the active device. Measure the transistor voltages and interpret them. If you don't find an obvious short or open and voltages appear normal, suspect a capacitor like the emitter bypass. (Like C67 or C70 in Figure 4-12.) An open bypass will drastically reduce stage gain.

DIODE DETECTOR CIRCUITS

Diode detector circuits in CB radios are very straightforward. But there are several detectors besides the one for audio, like those for AGC and S-Meter voltages, and sometimes squelch. The Automatic Noise Limiter (ANL) is also found in this general circuit area. With all these extra diodes, it's hard to tell which recover audio and which perform the other functions. If unmarked on the schematic, you can usually tell the audio detector by backtracking from the VOLUME control wiper.

There's little to go wrong with detector circuits. Either the diode's working or it's open, leaky, or shorted. This can be checked very quickly with some front-to-back ohmmeter measurements like any other diode. (NOTE: most Detector diodes are germanium and normally show higher reverse leakages than silicon.) With all the other diodes around the audio diode, it's possible to detect audio even if the actual audio diode is bad. You have to logically match the symptom with the appropriate stage being affected, such as:

DETECTOR DIODE
1. No receiver audio, S-Meter working.
2. Weak receiver audio.
3. Distorted audio.

S-METER/AGC DIODE
1. No S-Meter function, receiver audio normal.
2. Weak receiver audio due to excess gain reduction from faulty AGC detector.
3. Extremely garbled or distorted audio on strong signals due to total lack of AGC action; RF/IF amps running at full gain.

ANL DIODE
1. No receiver audio with ANL switch turned on.
2. No ANL noise supression.

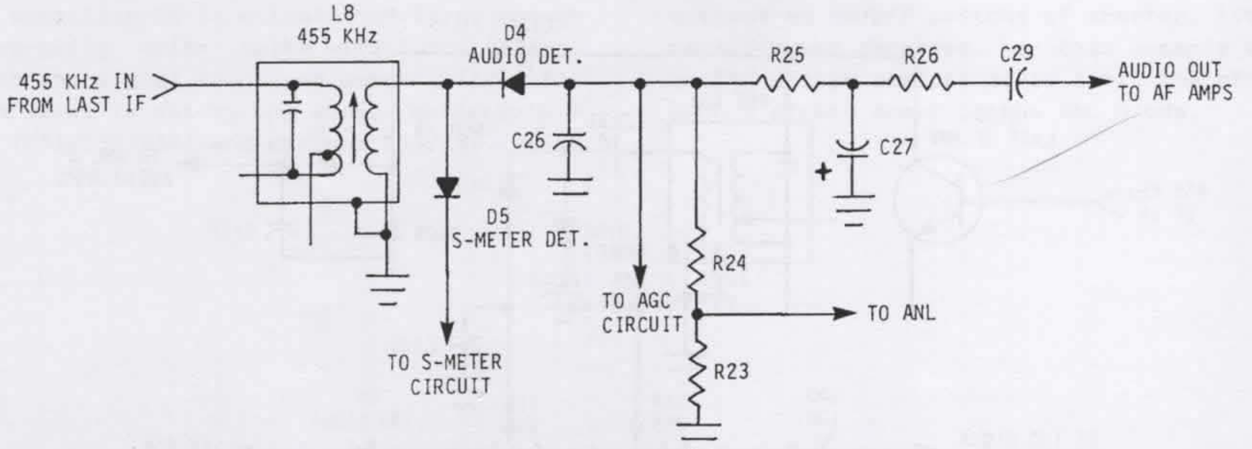
The AM Audio Detector

Most AM CBs use one of two detector types: the half-wave, and the voltage doubler. These are identical to those used in DC power supplies. The simplest and cheapest is the half-wave using a single diode in series with the IF signal path. Detector diodes are always germanium (1N34, 1N60, 1N270, ECG109, etc.) for their lower turn-on voltage. Since diodes are low-impedance devices when conducting, they do load down the last IF stage and reduce its selectivity somewhat. But the lost selectivity isn't a problem as long as the detector is working properly and the last IF transformer wasn't previously replaced with the wrong impedance type. Hopefully the real selectivity occurred long before the last IF stage!

The detector is always followed by RF decoupling and a low-pass filter. Bypass values range from about 470 pF to .0068 µF, which have suitable time constants for RF while ignoring the audio. To minimize audio distortion with high modulation, this shunt capacitance is always the smallest possible for the particular circuit. If the value should increase, some of the higher audio frequencies may be lost. Consider this possibility when investigating audio-related problems.

In the half-wave detector of Figure 4-17, when the 455 KHz RF signal causes the top of L8 to become negative, D4 will be forward-biased. The current flow produces a voltage drop across D4 and R24/R23. On the positive half cycle D4 is reverse-biased. Thus the detector output is a series of negative pulses that follows the modulation envelope rather than the individual signal components. But all frequency components must be passed unchanged in amplitude or the detected audio will be distorted. Filtering is by C26 and the T network R25/C27/R26. When a single diode is placed in series with the IF

FIGURE 4-17
HALF-WAVE AM DETECTOR
(Cobra 29XLR, 89XLR, etc.)



path like this, it's called a "voltage detector"; a "current detector" would be one that's placed in shunt across the IF path. CBs generally use voltage type audio detectors.

Figure 4-18 shows the waveforms present in Figure 4-17. The detector output voltage at C26 is the average of the resulting RF input pulses, and varies at the same rate as the original modulating signal. With a single detector diode (D4) only half the RF waveform appears, as shown. The DC component is still present in the waveform but is later removed by C29. This DC is useful for AGC and S-Metering, which is why those are sampled before C29. When the varying DC component is coupled across C29 only the voltage variations appear on the other side, resulting in the pure audio signal shown. This detected signal has a very low level and is coupled to the audio chain for power amplification to speaker levels.

FIGURE 4-18
DETECTOR WAVEFORMS OF FIG. 4-17

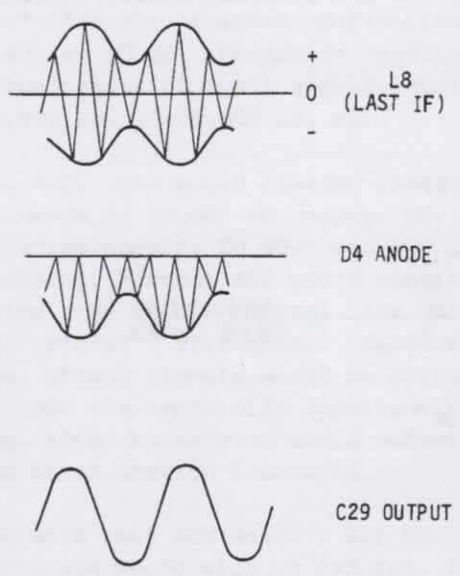
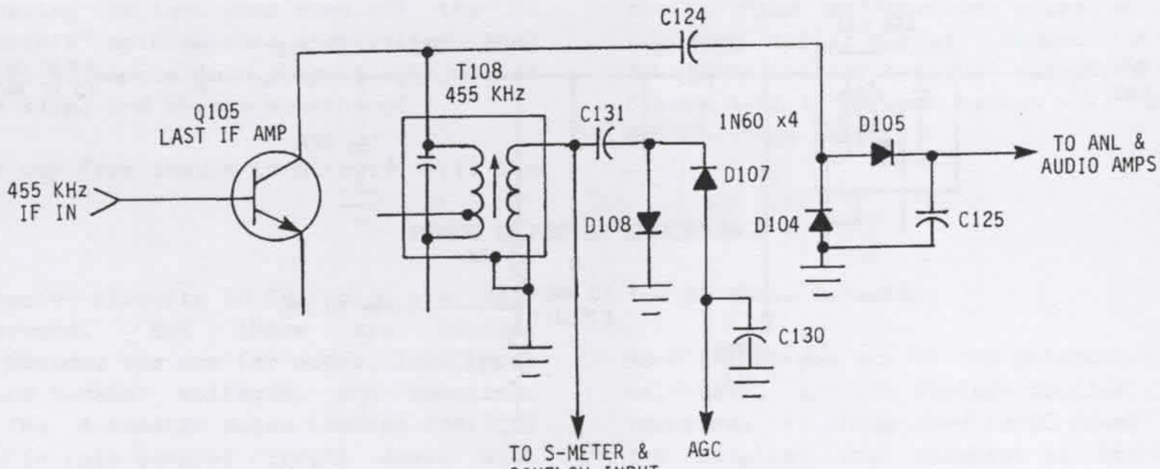


Figure 4-19 is a voltage doubler detector. The doubler circuit has several advantages. Both halves of the RF cycle are rectified, producing twice as much audio voltage output. In this circuit D105 conducts on the positive half cycle, and D104 on the negative half. (It doesn't matter which diode is which, as long as the other is wired oppositely. You'll find such detectors either way.) In addition to higher output there's less loading on the last IF amplifier stage. The doubler also reduces audio distortion, because simpler RF filtering can be used with less attenuation of the higher audio frequencies. Note the AGC detector is also a doubler (D107/D108) for higher control voltage.

A common symptom of a bad detector is what appears to be poor sensitivity. When the diode is leaky and has low front-to-back resistance with one lead disconnected, don't hesitate to replace it. Remember, germanium normally shows higher ohmmeter leakages than silicon, so don't be fooled. They're also more heat-sensitive when soldering, so be quick about it or use a small clip-lead for a heatsink.

FIGURE 4-19
VOLTAGE DOUBLER AM DETECTOR
(Kraco KCB4004)



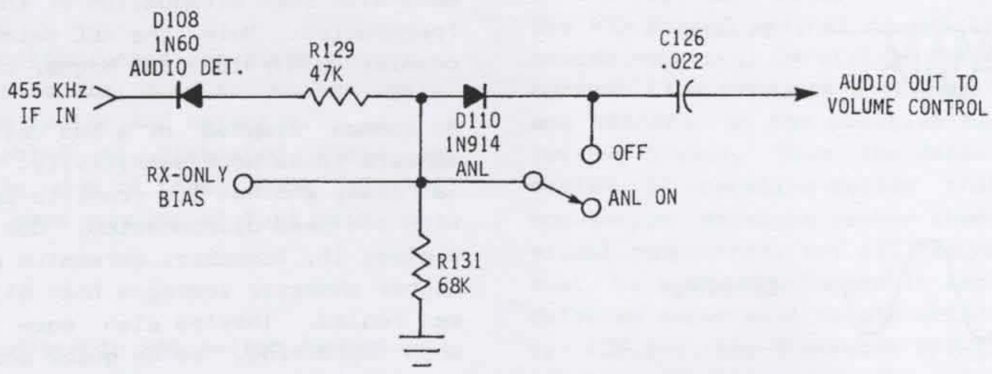
Most tube-type radios used a 6AL5 or similar diode detector. If you suspect a detector problem, confirm by tube substitution.

AUTOMATIC NOISE LIMITER (ANL)

Noise limiters are rather simple circuits used to reduce noise spikes that get through the detector. Any short duration, high-intensity noise exceeding the average audio level is cut off. The diode acts like a clipper for this function. Silicon fast-switching diodes of the 1N914 type are used. The disadvantages of diode noise limiters are reduction of the higher audio frequencies and distortion on strong signals, since modulation peaks may also be clipped unintentionally.

There are two basic ANL circuits: the series gate, and the shunt. Both appear about equally. Figure 4-20 shows the simplified series gate circuit. D110 conducts in the "ON" position and audio can pass through it. R129/R131 and the Receive-only voltage source set the proper bias level. When a noise burst occurs, a large negative voltage develops across R129/R131. The diode is momentarily reverse-biased or cut off, preventing noise from reaching the audio chain. In the "OFF" position audio passes around D110. When this type of ANL follows a half-wave detector (like this example) it doesn't act on the positive-going noise pulses, since the

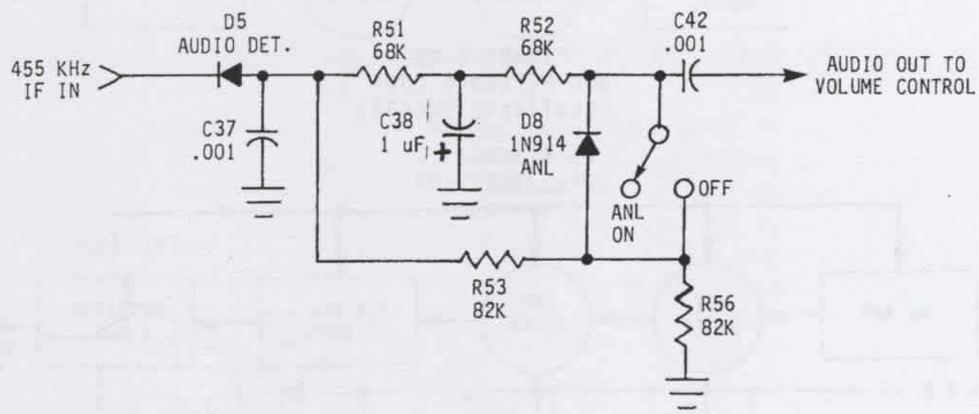
FIGURE 4-20
SERIES-GATE ANL CIRCUIT
(Cobra 90LTD, Midland 76-300)



detector itself passes only the negative-going part of the signal.

Figure 4-21 shows the shunt ANL circuit. In normal operation D8 is cut off. A large enough negative-going noise spike will turn it on, shunting the signal to ground momentarily. The turn-on level is set by the audio detector's T filter (R51/C38/R52) and divider R53/R56. With the switch in the "OFF" position signals pass around D8. If D8 were open it would simply have no limiting action. Many older radios had this diode permanently connected in the circuit without an ON/OFF switch; if shorted, little or no audio was received. In this example there's enough series resistance to limit the effect of such a direct short in the ANL diode.

FIGURE 4-21
SHUNT ANL CIRCUIT
(Uniden PC77)



AUTOMATIC GAIN CONTROL (AGC)

The purpose of AGC (sometimes called Automatic Volume Control or AVC) is to keep the audio output level constant with widely varying input levels. Otherwise you'd be blasted out of your seat if a stronger station came on the channel. "Constant" for the CB specs definition means less than a 10 dB change in audio output between the specified input signal levels, such as 1-100,000 µV, 10-50,000 µV, etc.

With good AGC, the audio remains linear over a dynamic range of 60 dB or more; the better AM/SSB radios specify 80 dB, and 100 dB would be outstanding. Without AGC you'd constantly be readjusting the VOLUME control for different incoming signal strengths. Besides this annoyance, strong signals would be distorted or garbled. AGC is especially important for SSB reception, since there's no audio output anyway until the other station transmits.

It's desirable that AGC doesn't act too quickly or weak signals would also be reduced. To avoid this, AGC begins only after the incoming signal reaches a predetermined level. This is known as "delayed AGC" and is used in most CBs. Delayed AGC is the preferred method and usually works only in the IF; excess reverse bias on an RF amp can sometimes degrade the dynamic range and Noise Figure. Many CBs get around this problem by using controlled loading on the front end coupling transformer instead of directly controlling the RF amp transistor bias.

The stronger the incoming signal, the more AGC voltage developed. Since AGC is usually a negative-going voltage, it will reverse-bias an amplifier and lower its gain. Weak signals won't develop AGC, letting the amps run at full gain. The AGC "threshold" is the point where AGC action first begins, and depends on the detector diode characteristics and the total amount of gain preceeding it. In HF receivers like CBs, this threshold will be about -100 dBm to -110 dBm (about 1.0 µV), which means it doesn't take much signal to start AGC action!

Finally, the AGC circuit must have a "fast attack and slow decay" characteristic; the fast attack ensures that the gain reduction will occur almost instantaneously, with a slow decay time long enough to maintain the level between syllables of SSB speech or a rapidly fading AM carrier. The time constants are set with RC networks. For CB these times range from about 50-200 mS attack and 0.5-3.0 seconds decay. Figure 4-22 shows the basic AGC feedback loop.

The control voltage is developed by sampling some of the IF signal at the detector, rectifying it to DC, filtering it, and using this average DC voltage to control the bias on several receiver stages. For good AGC a minimum of two stages must be controlled, which in CBs usually means the 27 MHz front end and one of the IF amplifiers. In this example, both mixers are also controlled for superior AGC action.

There are two main sampling locations for AGC. In "audio-derived AGC" the voltage comes from the same place as the audio; i.e., on the audio side of the detector diode(s). A superior method used for SSB is "RF-derived AGC," with the sample coming from the last IF amplifier stage. Audio-derived AGC is generally poor in SSB/CW communications receivers because it causes the annoying problem of "clicking" or "pumping" due to its long attack time. But it is acceptable, and is used for AM-only CBs.

FIGURE 4-22
AGC FEEDBACK LOOP
(Realistic TRC433)

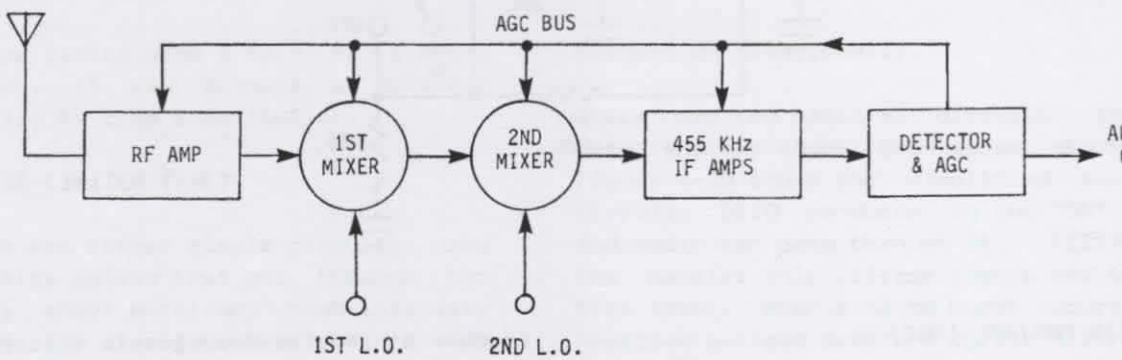


Figure 4-23 shows the simplest kind of audio-derived AGC, similar to that of the Cobra 29XLR in Figure 4-17. The AGC sample is tapped off the audio detector diode. Like the detected audio, the AGC thus derived is a negative-going voltage which when connected to the base or gate of a transistor will lower its gain. In this case it controls the base bias of the RF amp and both mixers. C123 removes RF, and with R124 lengthens the time constant so the AGC voltage is mainly DC.

Figure 4-24 shows adjustable AGC. R42/VR6 set the conduction bias for AGC diode D10. C44 and C13 filter RF. C46/R41 establish a suitable time constant. Note the AGC/S-Meter and AM detectors come from separate IF points. In most AM radios a single germanium diode of the 1N34/1N60 type is used for AGC. The improved detector circuit back in Figure 4-19 also used a diode voltage doubler for AGC. In either case the use of separate AGC and audio diodes is preferred, since it reduces loading and therefore distortion on the audio detector.

Diodes also help produce the delayed AGC. The action of D10 will be delayed somewhat because it doesn't conduct until a signal strong enough to overcome the preset bias appears. Until that happens, C46 sees a pure AC signal and no AGC voltage develops. When a signal appears D10 conducts on negative signal peaks, effectively shorting out the negative IF output from T12. C46 therefore sees a more positive than negative signal and filters it to a smooth positive AGC voltage. As the received signal gets stronger, D10 conducts harder and harder, dropping more voltage from the AGC line. In this particular chassis the no-signal AGC bus is about 1.48 VDC, dropping to about 0.60 VDC with an extremely strong input signal. The negative-going voltage starts turning off the bases of the associated transistors.

The basic diode AGC is usually found in AM-only radios. This limits the amount of AGC voltage

FIGURE 4-23
AUDIO-DERIVED AGC
(Cobra 19XS)

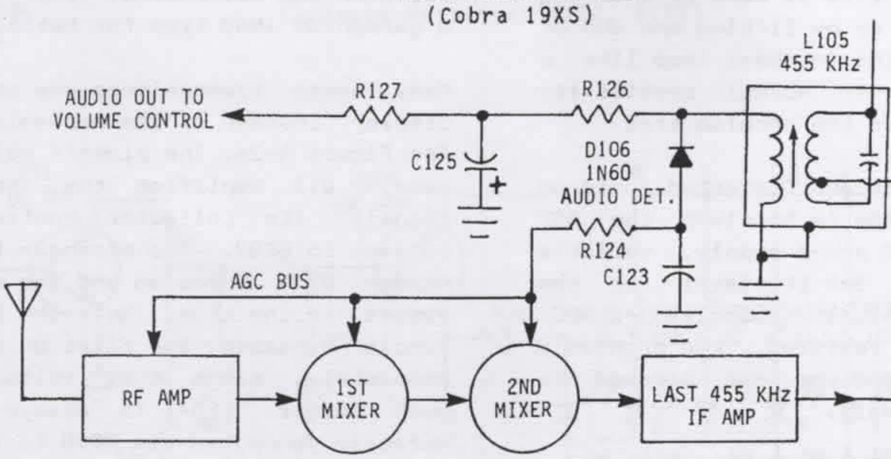
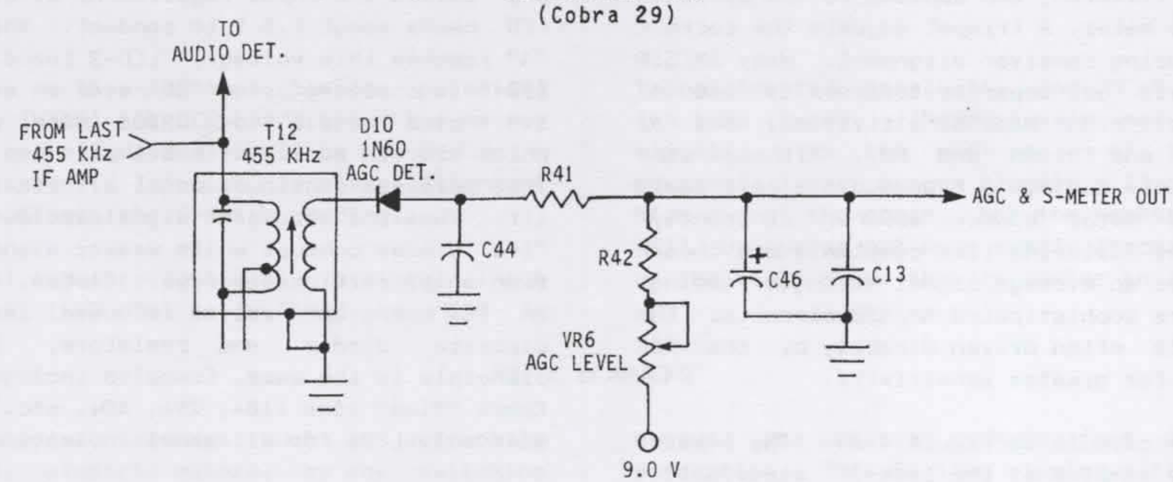


FIGURE 4-24
ADJUSTABLE AGC
(Cobra 29)



that can be extracted, which also limits the dynamic range. A better method uses several stages of DC amplification to develop a large control voltage; this voltage can also be shared with the squelch and S-Meter for improved sensitivity in those circuits. This is called "amplified AGC" and is always used in AM/SSB transceivers for superior performance.

AGC TROUBLESHOOTING

Troubleshooting is best done by monitoring the AGC bus while injecting signals of different strengths. The AGC voltage should change. Depending upon your measuring point, it will get either more positive or more negative as signal strength increases, with the no-signal level usually around 1-2 VDC. Since AGC is negative-going, a defective part could produce the symptom of "No Receive" or "Weak Receive" due to excess gain reduction, or conceivably cut off an amplifier completely. With no AGC action at all, signals would blast in with severe audio distortion because the receiver gain is running wide open all the time.

Any self-oscillation in an IF stage also causes full AGC action, characterized by a very strong S-Meter reading even when the antenna has been disconnected. (Assuming the S-Meter circuit and its adjustment are working correctly.) Such oscillations may be due to changing capacitor values, an open negative feedback capacitor, misalignment, or IF transistor replacement with the wrong type. These possibilities will be evident by unusual 'scope or bias measurements.

With the "No Receive/Weak Receive" symptom, you can disable the AGC and recheck for proper sensitivity. Usually this is done by shorting the AGC bus to ground, or by lifting one end of a series component in the feedback loop like a diode or resistor. If normal sensitivity returns, you've isolated the problem area.

A technique for the "No AGC/Distorted Audio on Strong Signals" symptom is to clamp the AGC line with a separate DC power supply, variable from perhaps 1-5 VDC. Set its level for the normal no-signal AGC value, typically 1-2 VDC. If proper reception is restored, the problem's in the AGC circuit and you can proceed to localize it more precisely.

THE S-METER CIRCUIT

The S/RF meter movement requires DC to operate. A signal sample is tapped off and rectified by a diode, filtered, and applied to the positive end of the meter. A trimpot adjusts the correct reading during receiver alignment. Many AM/SSB transceivers use separate trimmers to account for the different mode sensitivities; one for SSB, and one for AM (and FM). Although the diode detects audio, a true audio signal could make the meter bounce around constantly. Instead the filtering time constants are chosen to produce an average signal strength reading. In the more sophisticated AM/SSB circuits, the S-Meter is often driven directly by the AGC amplifier for greater sensitivity.

A typical circuit is Figure 4-25. The S-Meter is usually sampled at the last IF stage, like the detector and AGC. A 455 KHz IF signal from T10 is rectified by D8 and filtered by C79 to remove RF. R56 may or may not be present, depending upon the sensitivity of the meter and the required deflection voltage. Like the detector and AGC diodes, the S-Meter diode is a germanium 1N60 type for better sensitivity.

Many newer transceivers use an LED bar/graph display instead of the mechanical S/RF meter. See Figure 4-26. The pickoff point is still the same. Q11 amplifies the sampled receiver signal; its collector controls the base current in Q209. The stronger the signal, the harder Q209 turns on and the more current it passes to the LEDs. Note the RF Meter voltage sample bypasses the first DC amplifier (Q11) completely, since that voltage is normally much larger. LED-1 is always on, since it's directly connected via R250 to V_{CC}.

R251-R255 form a resistive ladder. Diodes CR206-CR210 also control how many LEDs other than LED-1 and LED-2 will turn on, since each one raises the input requirement by 0.6 V. An LED needs about 1.5 V to conduct. When point "A" reaches this voltage, LED-2 turns on. For LED-3 to conduct, point "B" needs an additional 1.5 V plus the 0.6 V of CR206 (total of 2.1 V) which is in series with its path to ground. This process continues until all six LEDs are lit. Thus the strongest signal would make all five diodes conduct while weaker signals would turn on proportionally fewer diodes. Nowadays an IC bar/graph driver is used instead of discrete diodes and resistors, but the principle is the same. Examples include the new Cobra "Plus" line (18+, 29+, 40+, etc.), which uses only LEDs for all panel indications.

Troubleshooting the S-Meter is a matter of tracing the signal continuity from the sampling point to the indicating device itself. If

FIGURE 4-25
TYPICAL S-METER CIRCUIT
(Cybernet late AM chassis: HyGain 2702, Midland 77-888, etc.)

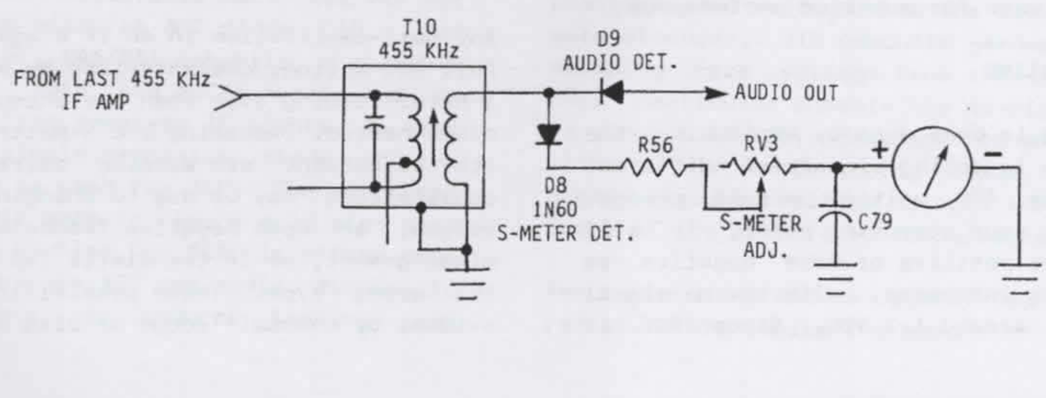
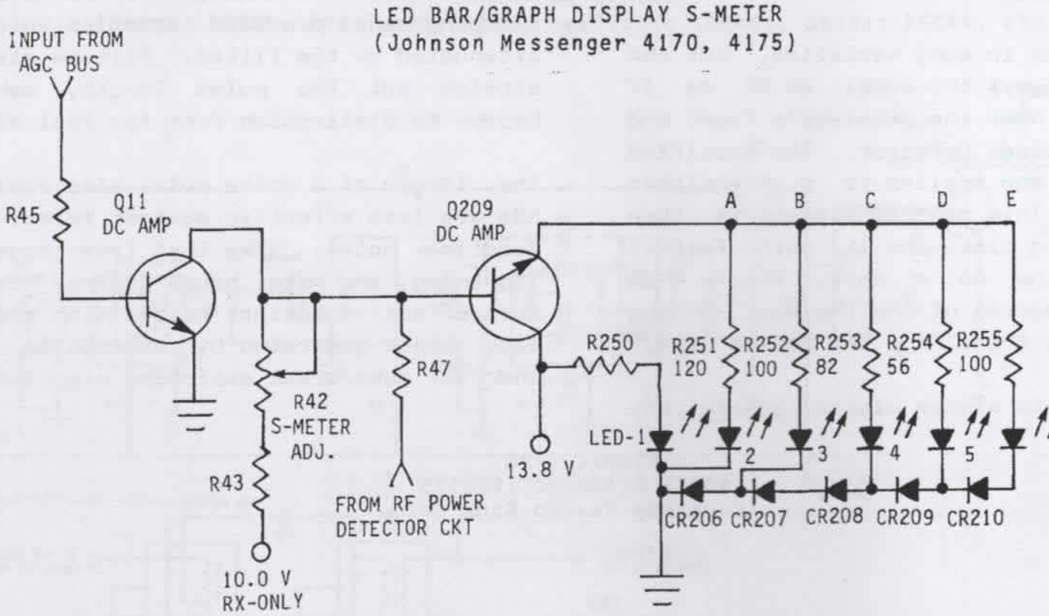


FIGURE 4-26
LED BAR/GRAPH DISPLAY S-METER
(Johnson Messenger 4170, 4175)



driven by active AGC amps they're potential problems. With the LED bar/graph, the driver circuit and all diodes should be checked in a logical order. Improper receiver alignment directly affects the S-Meter reading.

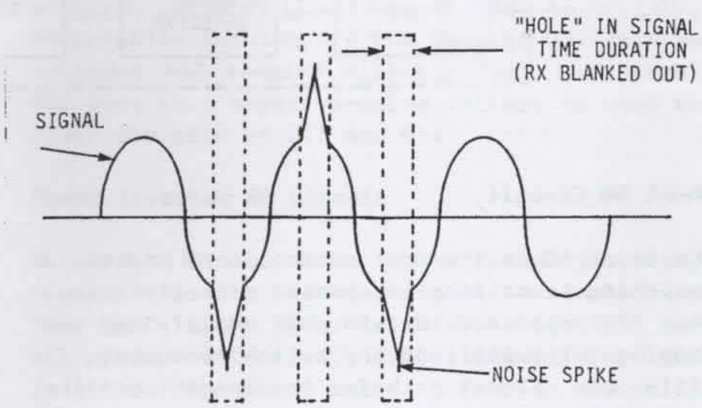
By general industry agreement, a signal input of 100 µV (-67 dBm) is defined as "S9" in transistorized receivers, and 50 µV (-73 dBm) in tube types. These levels set "S9" at slightly over the mid scale of the meter movement; very strong signals will crowd the high end of the scale, but the weaker signals will be spread out more evenly across the rest of the scale where they're easier to interpret.

NOISE BLANKERS

Man-made noise sources such as automobile ignitions, electric motors, or any switching high-current load are very troublesome in HF receivers. The noise impulses are amplitude-modulated and although they're of short duration compared to the signal, it's not unusual for them to have amplitudes 1,000 times greater than the desired signal. The diode type limiter can only remove the most obvious noise above a predetermined amplitude. That leaves plenty of lower-level noise to get through and irritate the listener.

A circuit more sophisticated than a diode clipper is needed. See Figure 4-27. While ANL works on noise amplitude, the Noise Blanker works on noise <u>time duration</u>. It takes advantage of the fact that most noise pulses generally have a much shorter time period than signals. Reception is "blanked out" during the time of the noise pulse, literally punching holes in the signal. But it sounds continuous because the gaps are much too fast for human perception. This is like viewing a flourescent light which is actually flashing on and off at

FIGURE 4-27
HOW NOISE BLANKERS WORK



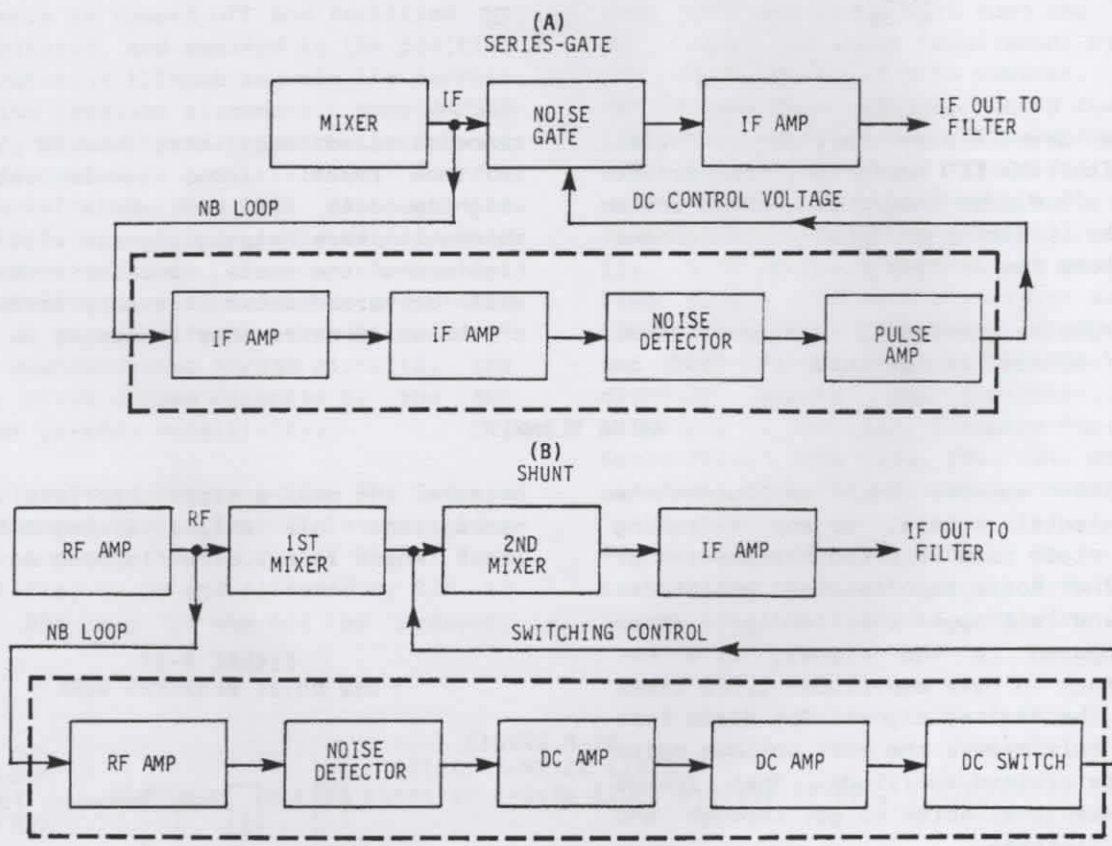
50/60 Hz; you perceive only a constant light, not a blinking light.

Noise Blankers come in many varieties, but the basic idea is always the same: an RF or IF signal is sampled near the receiver's front end and applied to a diode detector. The rectified DC is amplified and applied to a transistor switch control. This control element is then used to open and close the IF path further downstream, at the noise rate. Figure 4-28 shows block diagrams of the two most common blanker types: the Shunt, and the Series Gate.

Note the NB loop is always placed <u>before</u> any highly selective IF devices like a crystal filter, since blanking is actually a form of clipping that produces harmonics which can be attenuated by the filter. Filters also tend to stretch out the pulse length, making them harder to distinguish from the real signals.

The length of a noise pulse also explains why NBs are less effective against relatively long-duration noise, like that from power lines, lightning, and motor brush arcing. Blankers are most effective against noises with short times, like those generated by automobile ignitions and fast make/break switching circuits.

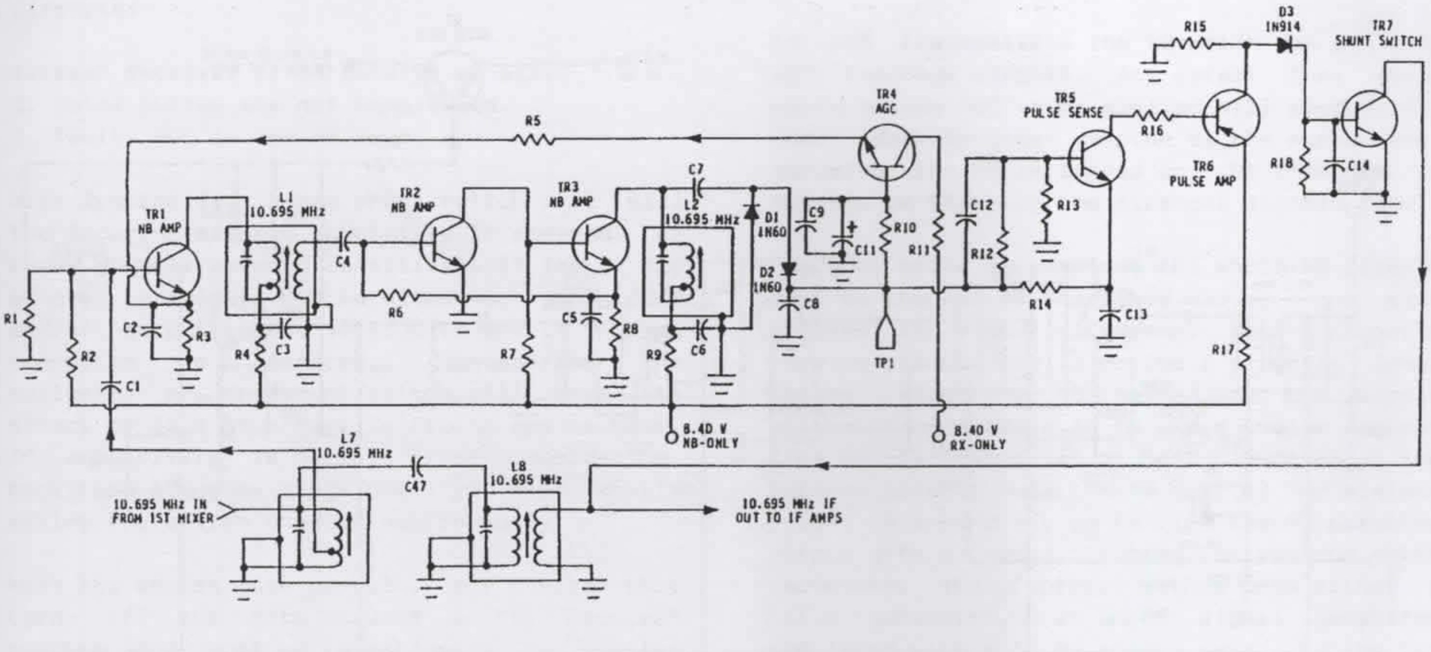
FIGURE 4-28
NOISE BLANKER CIRCUITS
(Courtesy Hayden Book Co.)



Shunt NB Circuit

The Shunt NB is the most common in CB radios. A switching transistor is shunted directly across the IF path and driven by amplifying and shaping circuits. As the switch conducts, it kills the signal path for the length of the noise pulse. In Figure 4-29, a 10.695 MHz IF sample is taken from L7 and amplified by TR1. L1 is adjusted for maximum noise transfer. The noise is further amplified by TR2 and TR3 and peaked by L2. D1/D2 form a voltage doubler which rectifies the noise to positive-going DC. They're germanium diodes for good voltage sensitivity. The DC is further amplified and shaped by TR5 and TR6. When a noise pulse

FIGURE 4-29
SHUNT NB CIRCUIT
(Cobra 146GTL, President AR144, Realistic TRC451, Uniden PC244, etc.)



appears, TR5 conducts and its collector voltage goes lower. This turns on TR6 and its current flow through D3 turns on TR7. TR7 is shunted directly across the IF path, cutting off the input for the duration of the noise pulse.

In all similar Uniden NB circuits, AGC is always included. This prevents extremely strong signals from triggering the NB switch. Otherwise the radio would be blanked by strong signals as well as noise pulses. TR4 is the AGC amp and is wired much like a Series-Pass voltage regulator. C9 and C11 have time constants chosen to separate IF signals from noise pulses. When enough base bias develops at TP1, TR4 conducts and passes current to the emitter of TR1. This raises TR1's emitter voltage, reducing its gain.

Series Gate NB Circuit

A less common circuit found in some Johnson and other radios is the Series Gate type, Figure 4-30. Instead of shunting the noise to ground, a transistor gate is placed in series with the IF path. It's normally conducting but turns off when a noise pulse occurs. Since noise is broadband in nature, the NB circuit can be tuned to any frequency close to 27 MHz, like the 23.5 MHz used here. The signal is sampled at the output of the Mixer but <u>before</u> the 4.3 MHz tuned circuits, so 23 MHz noise is still present there. Any noise at 27 MHz is virtually identical to noise at 23.5 MHz, but by doing it this way the extremely weak 27 MHz signal at the Mixer won't be loaded down by shunting a 27 MHz NB input directly across it.

The noise loop is sampled at the Mixer and amplified by Q13 and Q14. R49, R52 and R56 lower the Q of T11, T12, and T13 respectively since highly-selective tuned circuits are undesirable here. The noise is detected by CR10, filtered by C45/R58, and reamplified by Q15. Note the large value of C47, since the detected noise is now mostly DC. Some final RF filtering is provided by C49 and RF choke L2. Q3 is a PNP noise gate which is connected as a Series-Pass transistor and normally forward-biased by R11/R12/R13. When a noise spike occurs, the collector of Q15 goes LOW, temporarily turning off the base of Q3. This NB includes AGC sampled directly from the normal AGC bus; this negative-going voltage is used to lower the gain of Q13 and Q14.

Phase Inverter NB Circuit

A third NB circuit type is the Phase Inverter, Figure 4-31. The incoming signal is sampled and fed back to the RF or 1st Mixer stage 180° out of phase, effectively cancelling it for the length of the noise pulse. You can identify this circuit from the lack of any detector

FIGURE 4-30
SERIES-GATE NB CIRCUIT
(Johnson Messenger 4170, 4175)

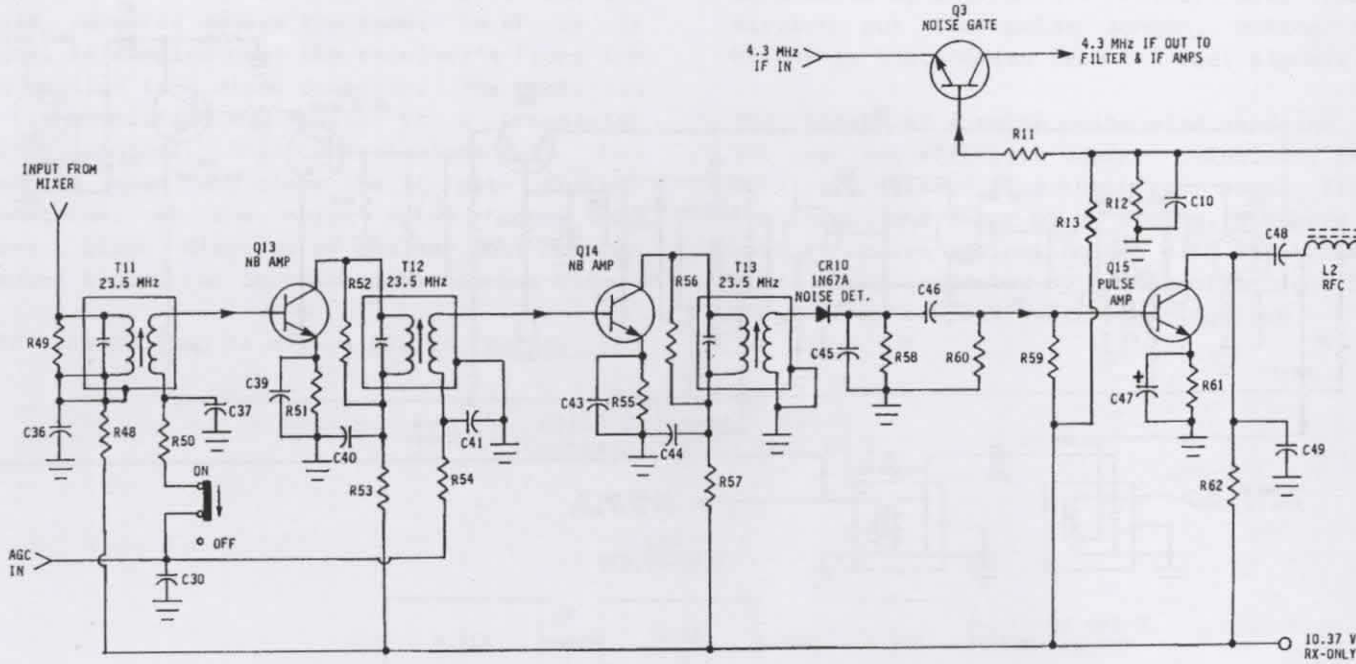
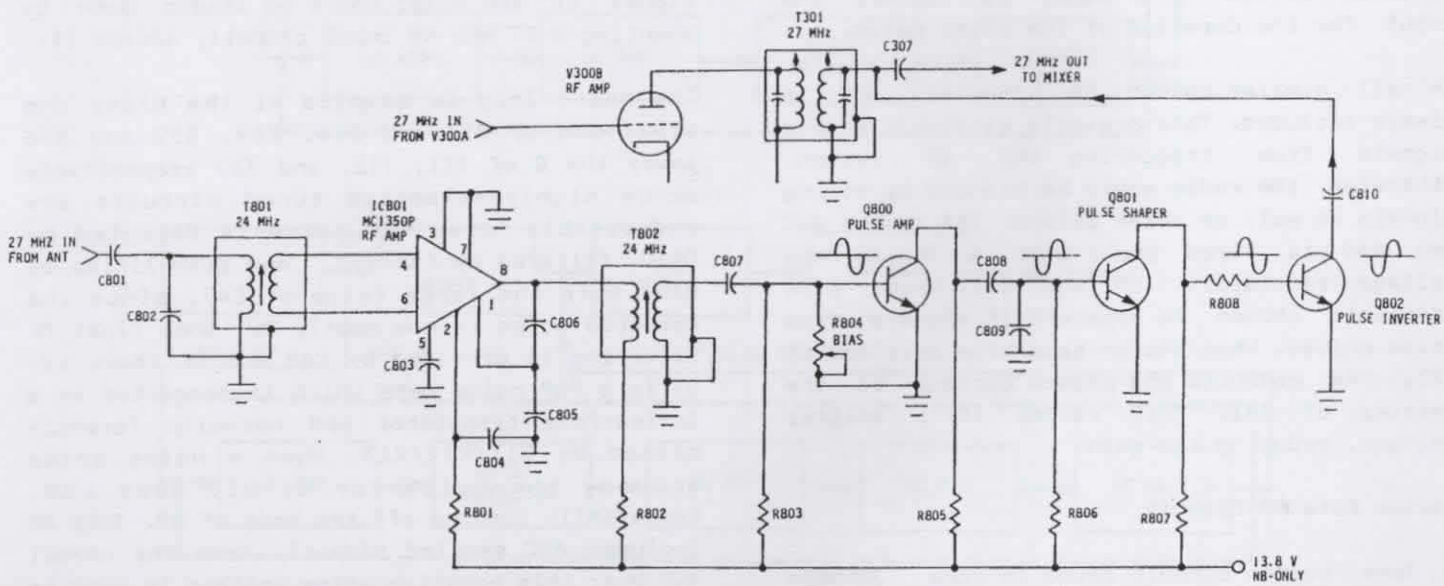


FIGURE 4-31
PHASE INVERTER NB CIRCUIT
(Tram D201/D201A)



diode in the loop. The NB input sample comes directly from the antenna. Again the NB strip is tuned to a slightly lower frequency (24 MHz) by T801 and T802, effectively forming a separate 24 MHz front end.

IC801 amplifies the 24 MHz noise. Three Common Emitter amplifier/shaper stages follow, each having the characteristic 180° phase shift from base to collector. With an odd number of transistors, the amplified output at the collector of Q802 will be inverted 180° from what it was at the antenna. This inverted output is coupled back into T301 to cancel reception for the time of the noise pulse. R804 sets the correct conduction bias level on Q800 relative to the incoming noise voltage. IC801 is a common broadband IF Amp/Detector of the type found in FM receivers and TV sound IF stages. (MC1350 = ECG746/SK3234.)

NOISE BLANKER TROUBLESHOOTING

There are several problems associated with NB circuits:

1. Weak Receive, or no Receive at all.
2. Noise pulses are not suppressed.
3. Faulty AGC in the NB loop.

With Symptom #1, a bad shunt switch will kill the incoming signals completely if shorted, or cause greatly reduced sensitivity if leaky. The general procedure is to disconnect the input and/or output to the NB loop to see if normal reception is restored. Unsoldering the collector of the shunt switch will test its effect or lack of effect in fixing the problem. If sensitivity is normal after unsoldering, backtrack stage by stage until you find what's making the switch conduct continuously.

With the series gate circuit, any problem that turns off the gate causes a "No Receive" symptom and must be investigated by similar backtracking, stage by stage. If the gate is shorted, reception may be normal but noise pulses won't be blanked out.

An internal short in the NB IC of a shunt or phase-inversion circuit will have the same effect as a shorted shunt transistor switch. Check IC voltages and replace it when questionable.

In SSB transceivers the NB often has its own AGC feedback circuit. Any defect that would cause excess AGC to be applied will produce the same "Weak Receive" symptom as the normal AGC, assuming the NB is turned on. Or the lack of AGC may be blanking the stronger signals too.

For poor noise supression, the whole NB circuit must be checked as described above, and also checked for proper alignment. With a properly working circuit you'll notice a slightly lower volume with the NB turned on. A simple alignment procedure is to use a noise source like an electric drill or hair blowdryer at the antenna socket. Tune the NB coil(s) for minimum noise. A second way is to view the NB detector output with a 'scope, tuning for maximum noise reduction. The factory method uses either a noise generator, or an RF signal generator modulated with a 60 Hz square wave, tuning for minimum noise. When a diode detector is used in the NB loop you can probe the diode(s) with a DC voltmeter, tuning for maximum detected DC voltage. In the newer Uniden SSB radios this detector output is conveniently made a Test Point, like "TP1" in Figure 4-29.

THE FM DETECTOR

Many CB radios now use the FM mode, either as part of a multimode export transceiver, or an FM-only radio like those of the British or Dutch services. It's a narrow-band system with about ± 2.5 KHz being the maximum usable FM deviation. There's little difference in operation between the two categories; multimode radios with FM added are mostly re-works of existing AM designs. This is a lot cheaper than starting from scratch with an FM-only design. Because of this, the UK and European (CEPT) CB systems that were specifically designed for FM from the ground up often perform better, particularly the receivers.

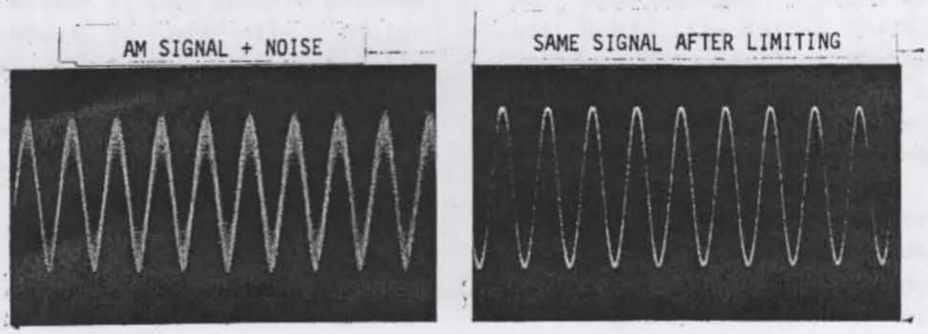
FM receivers don't need AGC. Instead multiple peak clipper stages are used to limit all amplitude-modulated signal components. The limiters are part of the FM Detector IC and have varying time constants to act on different types of incoming noise. Like AGC though, the purpose is to keep the audio level constant over a wide range of input signals. Unlike AGC, with FM it's desirable to run RF and IF stages with as much gain as possible in order to drive the AM peak limiters properly. The limiters are biased so they'll easily overload even on signals as low as 0.5 µV. This sharp reduction in amplitude-modulated noise is what gives FM its superior sensitivity and S+N/N ratio.

Figure 4-32A is a graphic illustration of the effects of amplitude limiting on a sine wave input to remove noise. Figure 4-32B shows how an AM signal is sharply limited in the FM limiter/detector circuit. Note how peak clipping starts even at low input levels; the more the input level increases, the greater the amplitude limiting.

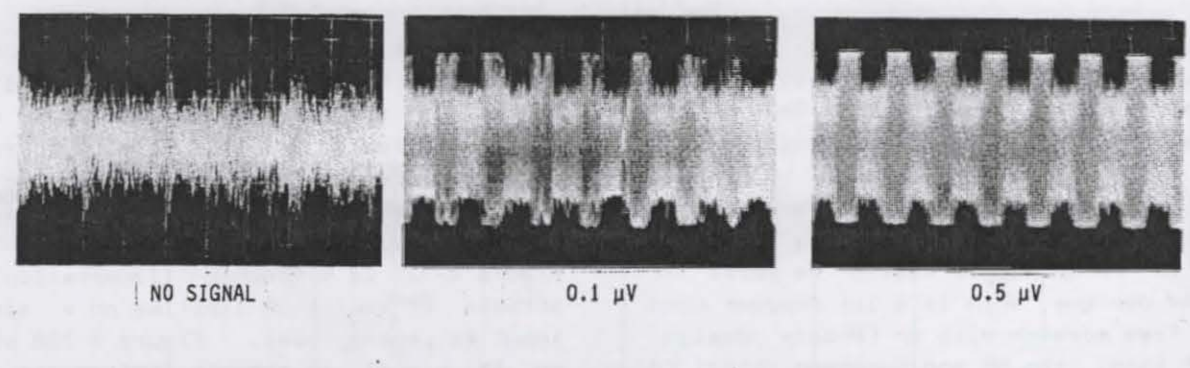
FM receivers also don't need ANL or Noise Blanker circuits, since FM by definition removes amplitude-modulated noise. And of course the FM-only radios don't need the other circuitry required in AM and SSB equipment. In spite of these differences, both FM radio groups use exactly the same methods of FM demodulation and even the same IC chips. The

FIGURE 4-32
EFFECT OF FM LIMITER ON AM SIGNAL

(A)
REMOVING AM NOISE FROM SINE WAVE
(Courtesy ARRL RADIO AMATEUR'S HANDBOOK)



(B)
AM LIMITING VS. INPUT SIGNAL LEVEL
(Courtesy Heinemann-Newnes Books)



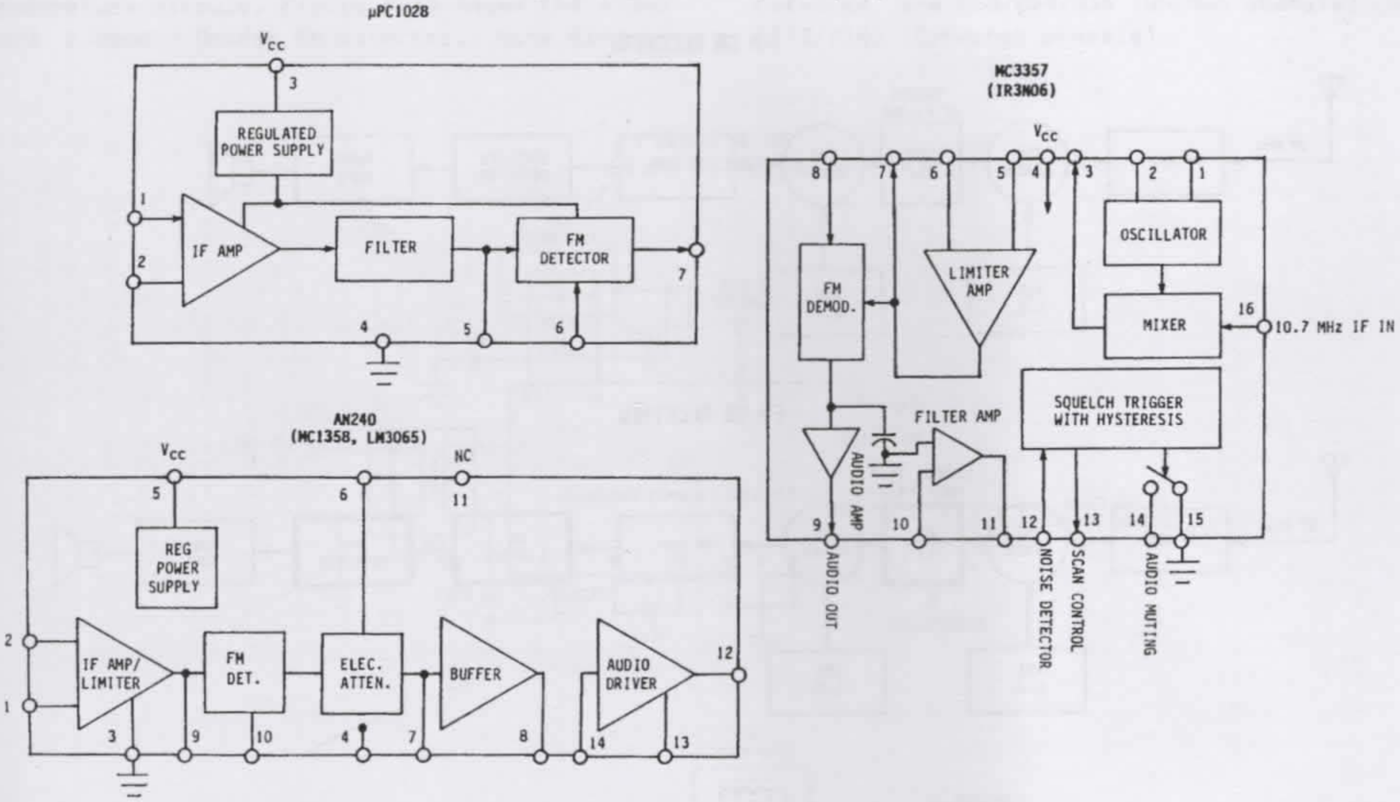


FIGURE 4-33
COMMON CB FM DETECTOR ICs

functional block diagrams of the most common CB-FM ICs are shown in Figure 4-33.

There's little difference in any receiver stages preceeding or following the detector. FM does require limiter stages, but these are included in the same IC that serves as the FM detector. The RF and IF amps, mixers, audio amps and squelch are the same. As shown in Figure 4-34, the most significant difference is the detector circuit and (sometimes) the IF filter. Instead of a simple diode which recovers audio riding on the RF carrier, the FM detector converts frequency variations to amplitude variations, which are then applied to the standard audio amplifier chain. The need for a wider IF filter explains why FM isn't practical in single-conversion AM/SSB radios; they use a very narrow filter which couldn't pass a standard 5 KHz wide FM signal. (Such radios only detect one 2.5 KHz AM sideband.)

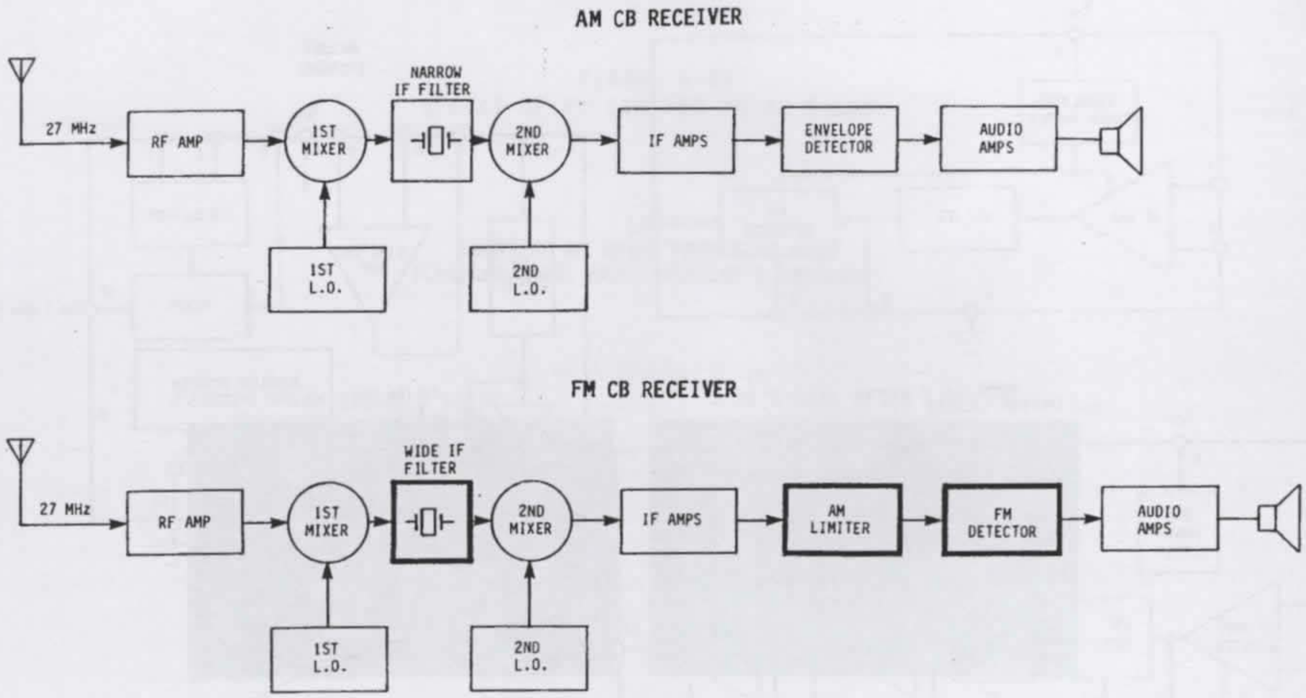
In the Uniden/Uniden clone multimode models, a separate wide FM IF filter is used; the sharper AM filter would chop the fully-deviated FM signal. The Cybernet multimodes don't bother with this, passing both FM and AM through the same 455 KHz IF filter. (Note that the Cybernet chassis which are designed to be FM-only do use the wider IF filters.)

Because an FM demodulator is much more complex than an AM demodulator, ICs are always used for FM detectors. In addition the gain of an FM IF strip ahead of the detector must be fairly high for good AM limiting. Such gain is easily achieved by ICs, which also save space in the radio. The overall gain of a typical FM CB is about 130 dB from antenna jack to speaker. The detector chips are the same ones used for TV audio circuits (TV audio is FM) and scanners. Troubleshooting consists only of checking the detector alignment and measuring voltages and input/output signals on the IC to determine if it's working correctly.

Pre-Emphasis and De-Emphasis

FM requires special audio shaping networks to reduce the amount of thermal noise and loss of

FIGURE 4-34
AM VS. FM RECEPTION



the higher audio frequencies. The higher audio frequencies tend to be of lower amplitude anyway, which means they produce less deviation and poorer noise reduction properties. In the FM transmitter a simple RC network is used to "emphasize" or boost the higher audio frequencies while rolling off the lower ones. An RC time constant of about 50-150 µS results in a more even spread of energy within the communications audio band.

At the receiver end, this effect is converted back or "de-emphasized" to its original modulating form with another RC filter. Since the de-emphasis works equally on both the high-frequency signal and the high-frequency noise, there's no effective change in the S/N ratio. In Figure 4-35, the de-emphasis networks are C178/R165 (AN240) and C28/C29/R36 (µPC1028H). If these parts values changed, the received audio would have more treble or bass, depending upon the direction of change.

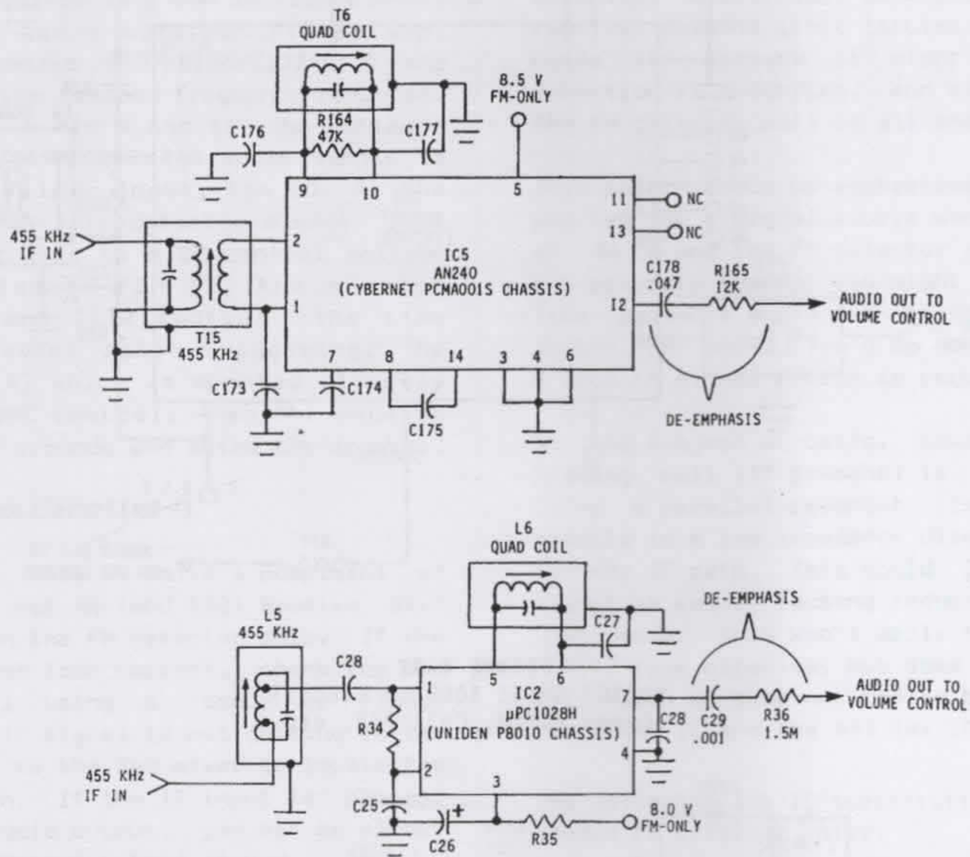
Typical CB FM Circuits

FM reception involves coupling a 455 KHz signal from the last IF stage to the FM Detector IC. A resistive divider or a 455 KHz transformer is used for the coupling. The AN240 circuit in particular uses a tuned input to boost the signal level, while most other FM ICs skip this. In the multimode radios, the audio output from the FM IC is routed through the "FM" part of the MODE switch to the audio amplifier chain. In FM-only transceivers it goes directly to the audio stages.

A single tuning adjustment peaks the detected audio. In the "quadrature" FM detector, it's called the quadrature coil. The name comes from the fact that the tuned circuit produces a 90° (i.e., 1/4-wave) phase shift at the center IF frequency, and the circuit is phase-sensitive. Since the phase shift changes anywhere off the center IF, the detector audio output also changes. Thus the detected audio is a linear reproduction of the incoming phase shifts, which are changing at an audio rate.

Another FM detector is the "differential peak detector" like the popular AN240. In this circuit a balanced set of active peak detectors is combined in a differential amplifier stage; the audio output is the result of changing peak voltage levels instead of the phases. This detector also has a tuned circuit like the quadrature circuit. Figure 4-35 shows the AN240 and a common Uniden FM detector. Note R164 is used in the AN240 circuit to lower the Q of the coil, improving audio response. The de-emphasis networks are C28/C29/R36 (Uniden chassis) and C178/R165 (Cybernet chassis).

FIGURE 4-35
CB FM DETECTORS



MC3357 Multifunction FM IC

Figure 4-36 shows an interesting use of the Motorola MC3357 chip, whose functional block diagram was shown back in Figure 4-33. The IC contains an oscillator and mixer in addition to a five-stage limiter, an FM detector, and a scan control/squelch trigger. The chip was originally designed for scanning type VHF/UHF receivers, which also have a 10.7 MHz high IF and a 455 KHz low IF. The mixer/oscillator combination is used to convert a 10.695 MHz 1st IF down to 455 KHz, where after additional bandpass filtering it's detected and passed to the normal audio chain. This eliminates all the extra parts and room which would otherwise be needed for a second mixer stage.

In the Jackson export model, the 10.695 MHz FM input is broadly shaped and filtered by FT1. The 10.240 MHz PLL Reference Oscillator signal is sampled and applied to Pin 1. Mixing results in 10.695 MHz - 10.240 MHz = 455 KHz, and is filtered again by FT2, then demodulated and the audio output is Pin 9. C25/R31 is the de-emphasis circuit. L4 is the quadrature coil; R28 again broadens its response. The AM/SSB paths are both single-conversion through individual IF filters which are so narrow they'd severely chop the FM audio, but are OK for AM and SSB. By the way, the "IR3N06" number for IC1 on the Jackson schematic is simply an in-house part number for this Motorola device.

Another feature of the MC3357 is its ability to use the superior noise squelch method rather than simple carrier squelch. (See SQUELCH section.) Unfortunately it's not even used in

FIGURE 4-36
MC3357 FM DETECTOR IC
(Uniden Jackson)

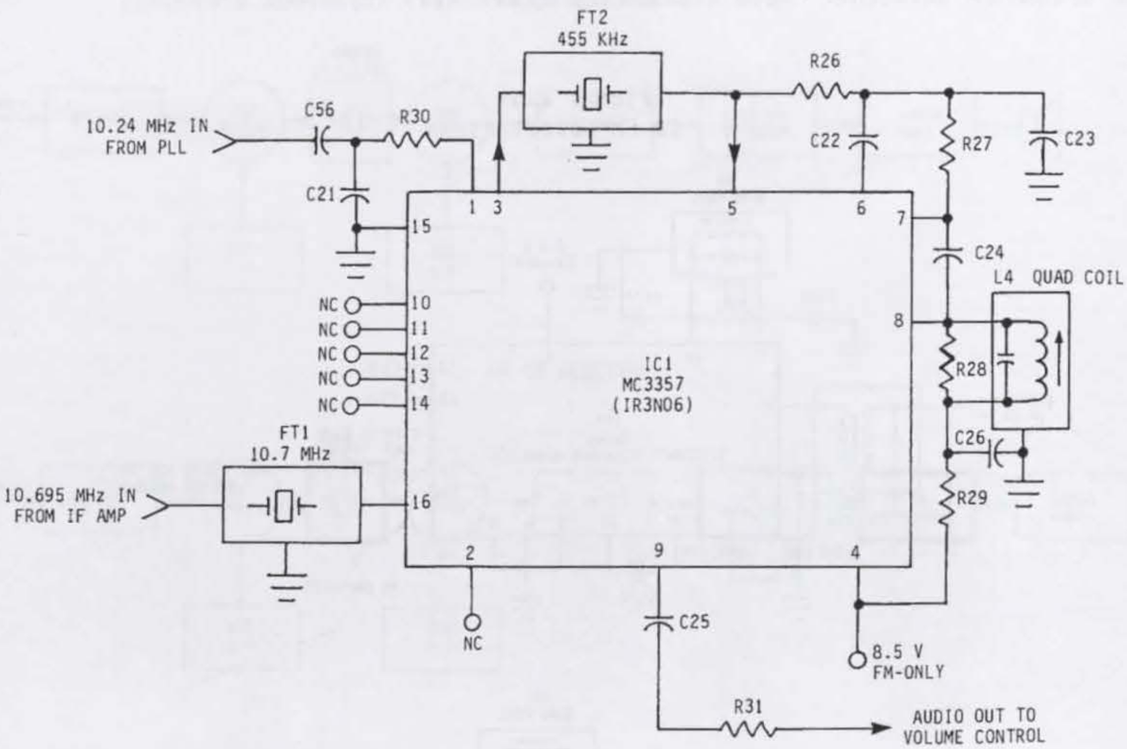
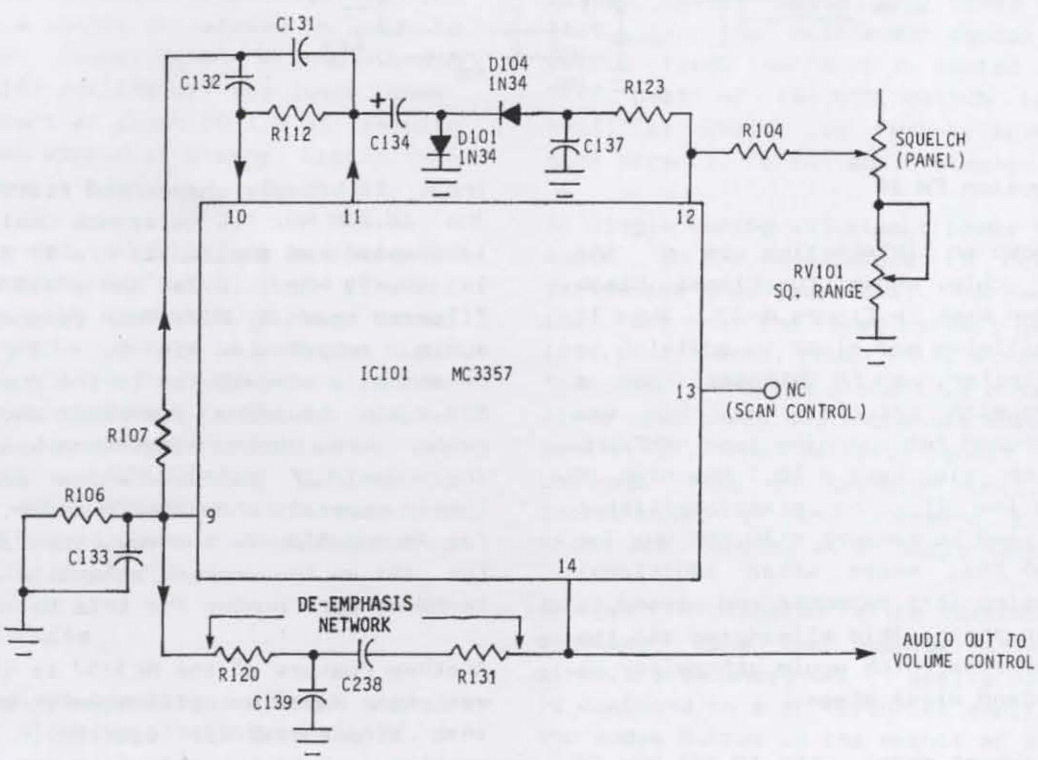


FIGURE 4-37
MC3357 NOISE SQUELCH CIRCUIT
(Cobra 21FXM, Colt 295, etc.)



the Jackson, since that radio must also receive AM and SSB. IC Pins 10-14 are left unconnected. However this feature as well as the scan control are used in many UK and other European FM-only radios. Examples are the Korean-made Maxon chassis (Colt 295, Cobra 21XFM, Midland 4001, etc.) and the DNT LCL-2740FM.

The optional circuitry is shown in Figure 4-37. Since the chip has a built-in filter amp, external RC networks R107/R106/C132/C133 and R112/C131 shape the desired frequency response. Detected audio is Pin 9 and the de-emphasis network is R120/C139/C238. An audio sample is applied to the filter input, Pin 10. At the filter output (Pin 11), detector diodes D101 and D104 convert this to a DC control voltage which is applied to Pin 12, the squelch trigger. R123 and C137 control the time constant to prevent false triggering. The output is Pin 14, which is shunted directly across the VOLUME control; when the squelch operates, Pin 14 grounds and mutes the speaker.

FM RECEIVER TROUBLESHOOTING

It's relatively easy to solve a complaint of "No FM Receive, but AM (and SSB) Receive OK." Check voltages on the FM detector chip. If the specified voltages look correct, check for the IF input signal using a 'scope or signal tracer. If the IF signal is not getting to the chip, backtrack to the 2nd mixer to locate the open signal path. If the IF input is present but there's no audio output, you can be almost positive the FM Detector chip is bad.

Before pulling the IC though, make sure the detector coil is tuned properly and you're checking with a true FM signal source, like a commercial FM generator or a second FM CB. It's very easy to slope-detect an FM signal on an AM receiver. "Slope" detection means receiving an FM signal by tuning slightly off the center carrier frequency with the Delta Tune or Clarifier. With true FM the centered carrier will produce almost no audio output, because FM sidebands cancel each other out in AM detector circuits. Also, slope detection of FM in an AM receiver doesn't limit impulse noise; if such noise is present it might indicate slope detection is occurring, and simple retuning of the FM detector coil is all that's needed.

This point should be emphasized again: if all you had for a signal source was an AM generator or AM CB and the FM detector was defective or not properly tuned, you might hear what sounds like passable audio even though the radio was in the "FM" mode. You'd be hearing AM, not FM. A true FM signal source is required here.

On the subject of coils, make sure the input peaking coil (if present) is properly tuned; being a parallel-resonant circuit, mistuning results in a low impedance directly across the 455 KHz IF path. This could load down the AM signal as well, causing reduced sensitivity in that mode. This won't apply to the µPC1028 or MC3357 type circuits, but does matter in nearly all Maxon or Cybernet radios because they use the AN240 IC and the 455 KHz IF input coil.

The following are IC substitutions for the most common FM detector chips:

AN240	=	MC1358, CA3065E
µPC1028H	=	TA7130P
MC3357	=	See Newtone substitution book
LA1230	=	See Newtone substitution book

SQUELCH CIRCUITS

A receiver's background noise while at full sensitivity is very irritating with no signal present. The purpose of squelch is to silence the speaker when no signal is being received, or when the incoming signal is too weak for good communications. The level at which the squelch "breaks" is adjustable by the operator from the radio's front panel. It could also be adjusted so only signals of a predetermined signal strength will operate the speaker. When the control is set for its maximum effect (full clockwise), it's called "tight" squelch. The squelch range is often specified by the manufacturer, like "0.7 µV to 300 µV." There's normally a second internal adjustment to set the squelch range within the specified limits.

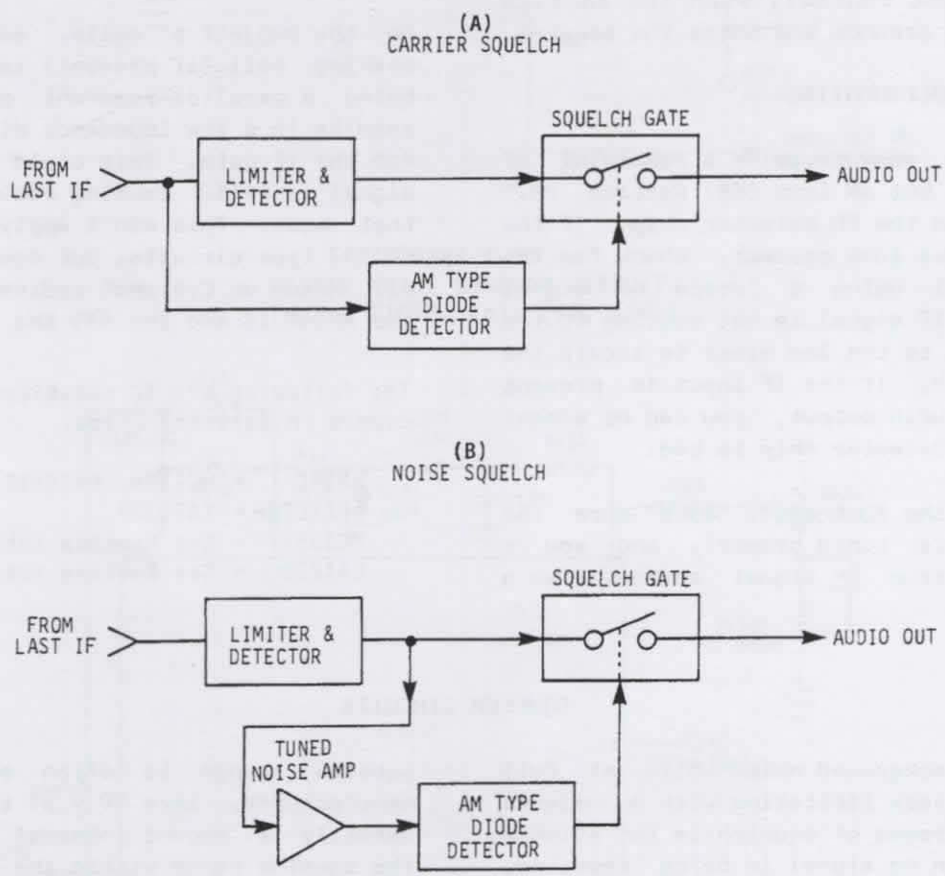
All CB squelch circuits work on the same principle: with no input signal, a transistor switch cuts off the audio amplifier chain by shunting the audio to ground, or because the switch is in series with the detected audio and the audio amplifiers. The circuit may use an IC, a single transistor, or several DC-coupled transistors for greater sensitivity and control. The squelch input is normally taken from the same point as AGC; i.e., right after the detector. In a few 23-channel radios it was sampled at the 27 MHz front end, which wasn't nearly as effective.

Carrier Squelch vs. Noise Squelch

There are two squelch methods common to CBs, "carrier operated squelch" and "noise squelch." Virtually all AM and SSB CBs and FM types with the simpler AN240 or µPC1028H detectors use carrier squelch. In this system, a DC control signal is developed that corresponds to the amplitude of the carrier, similar to AGC.

By contrast, the noise squelch system senses the noise present at the detector output to develop its control signal. Thus the control signal depends directly upon the receiver's S/N ratio. A special tuned noise amplifier in the 5-10 KHz range is used; being above the voice frequency range, it acts only on the noise present. The result is superior sensitivity and immunity to squelching on general background noise or strong bleedover. This method is found in UK-FM equipment using the MC3357 IC. The basic differences are shown in Figure 4-38.

FIGURE 4-38
SQUELCH CIRCUITS
(Courtesy Heinemann-Newnes Books)



Carrier Squelch Methods

Figure 4-39 shows a simple carrier-controlled circuit. Q13 is connected as a saturated ON/OFF switch. VR2 (front panel adjustment) and RV1 (internal adjustment) preset the bias on the base of Q13. Whenever this bias exceeds about 0.6 VDC Q13 turns on, pulling its collector down near 0.0 volts. Since the collector is wired directly across the input to the audio amp at IC4 Pin 5, the audio is shunted to ground and the speaker remains silent. An incoming signal will develop a negative voltage at the anode of detector D9. When this voltage is negative enough to overcome the preset positive bias, Q13 stops conducting and the audio amplifiers work normally. R63/C85 filter audio, and R62/C115 filter any remaining RF so the squelch control voltage is pure DC.

A more sophisticated and effective circuit is shown in Figure 4-40. The main difference is the addition of two DC amplifier stages, TR12 and TR11. TR13 is still the cutoff switch which is shunted across IC4 Pin 4. The forward bias is again preset by VR202 and VR3. At the squelch "threshold" (where it just silences) the base of TR12 is HIGH, turning it on and pulling its collector and the base of TR11 LOW. This pulls the collector of TR11 HIGH through R41, which turns on TR13 to shunt the audio to ground. An incoming signal will develop a negative-going voltage at the anode of AGC diode D6. This cuts off TR12 and reverses the HIGH/LOW bias sequences of TR11 and TR13, allowing the speaker to be heard.

FIGURE 4-39
CARRIER-OPERATED SQUELCH
(Cybernet late AM chassis: HyGain 2702, Midland 77-888, etc.)

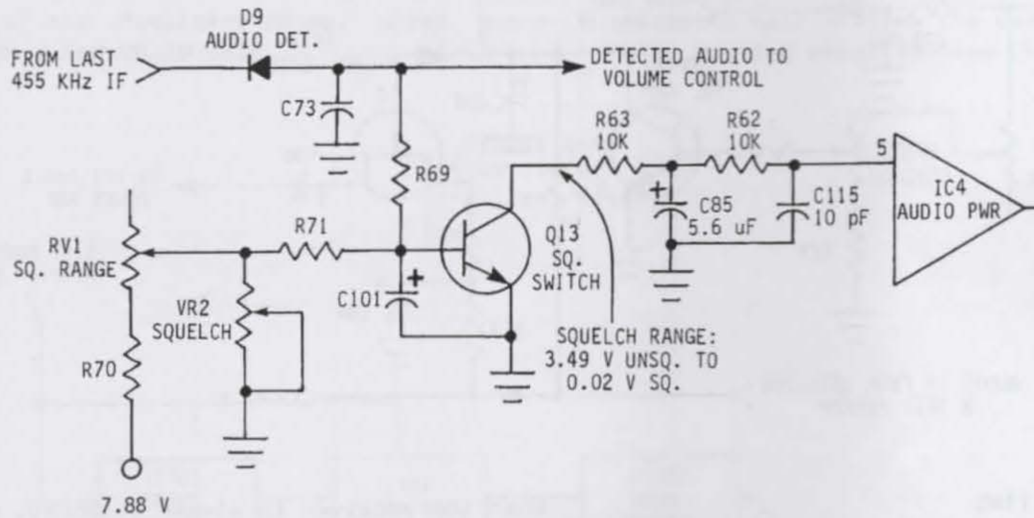


FIGURE 4-40
AMPLIFIED CARRIER SQUELCH
(Cobra 29GTL, 29LTD, etc.)

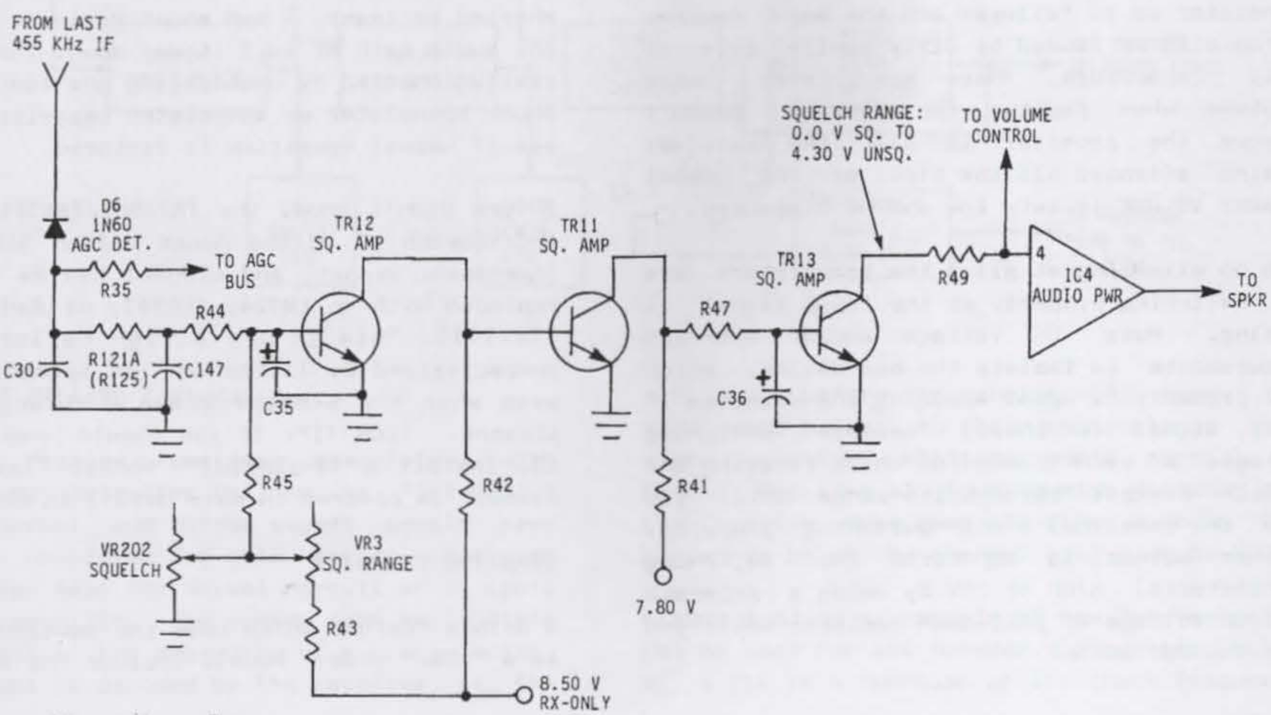
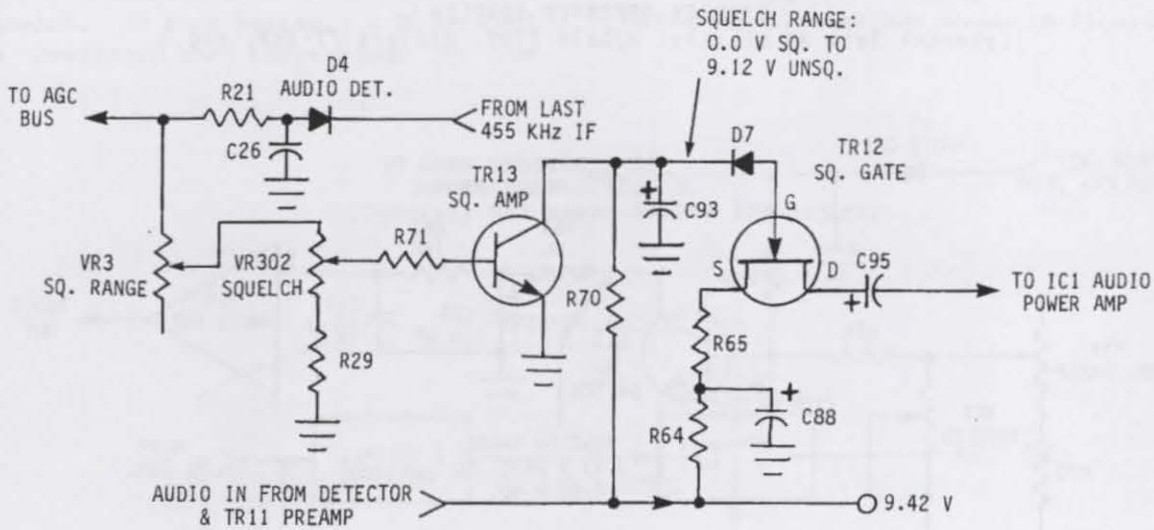


Figure 4-41 shows another type of carrier squelch, the "series gate" circuit. In this circuit the squelch switch, an FET, is in series with the audio path from detector to audio amplifier. The switch must be closed for audio to pass, which it normally will be until the gate of TR12 goes sufficiently negative to pinch off the current flow between source and drain. This pinchoff happens when the collector of TR13 goes LOW. TR13's collector is LOW in the squelched position of VR302. When a large negative-going voltage from a detected signal at the anode of D4 overcomes the preset forward base bias, it stops conducting and its collector goes HIGH, restoring the audio path.

FIGURE 4-41
SERIES-GATE CARRIER SQUELCH
(Cobra 29XLR, 89XLR, etc.)



SQUELCH TROUBLESHOOTING

Squelch problems are relatively easy to isolate once you understand the switching involved. Transistor or IC failures are the main source. A few will be caused by dirty control pots or leaky capacitors. There are three basic symptoms when faulty: the squelch doesn't silence the receiver at all, the receiver remains silenced all the time, or the normal speaker VOLUME is very low and/or distorted.

With no silencing at all, the transistors are not switching properly or the input signal is missing. Make DC voltage and/or ohmmeter measurements to isolate the bad device, which will probably be open. Assuming the detected IF input signal is there, measure switching voltages of each transistor while rotating the SQUELCH control through its range until you find the one that's not switching properly. Another method is to force the switching transistor(s) HIGH or LOW by using a separate pull-up voltage or pull-down resistor until you find the bad switch.

When the receiver is always silenced, distorted or at low volume, and the radio's S-Meter or a signal tracer at the detector shows otherwise normal reception, the active device may be shorted or leaky. A bad shunt device will kill the audio path or pull it way down. This can be easily checked by unsoldering one lead of the shunt transistor or associated capacitor(s) to see if normal operation is restored.

If you didn't know, the TA75902/TA6324/NJM2902 AGC/Squelch IC in the newer Uniden SSB radios (American, export, and clones) can be directly replaced with an LM324, ECG987, or Radio Shack 276-1711. This IC has a high failure rate, characterized by little or no speaker volume even when the S-Meter shows a strong signal present. TECH TIP: If you should replace the IC, install a 14-pin DIP socket first. This circuit is covered in more detail in CHAPTER 6.

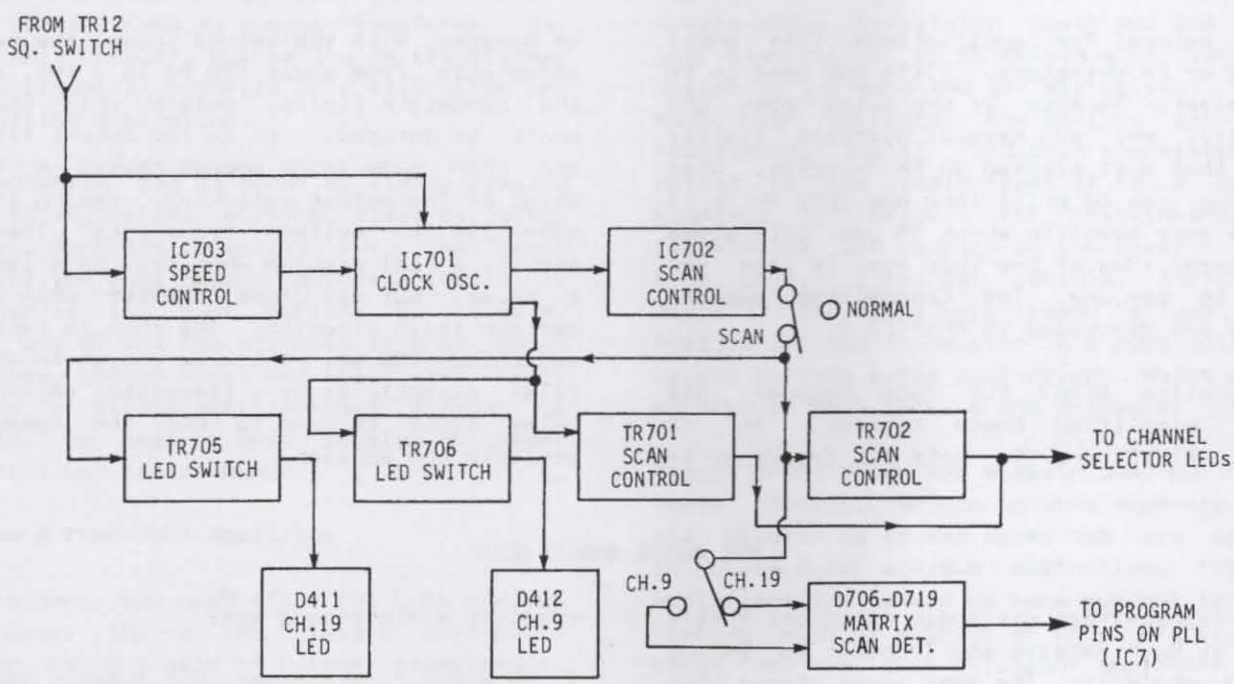
SCANNING CIRCUITS

A deluxe feature which uses the squelch circuit is a "scan" mode. Models include the ARF-2001, President Adams, SBE "Key-Com," Sidebander V, Console V and VI, and Realistic TRC459. In the ARF-2001 and TRC459, a microprocessor allows a choice of programmable frequencies to be scanned and/or memorized; the simpler circuits only scan up and down the CB band, or they scan Ch.9 and Ch.19 only.

This circuit is basically the same as the remote UP/DOWN PLL controller discussed in CHAPTER 3. The main difference here is that the squelch signal controls the scanning, rather than programming within the synthesizer. When a signal appears, the same squelch transistor used for audio muting causes the scan circuit to stop. Figure 4-42 shows a simplified block diagram of the President Adams, which scans between Ch.9 and Ch.19 only.

Standard "4000" series CMOS ICs are used. IC701 and IC703 form a clocking oscillator driven by the squelch transistor. They control IC702, a dual J-K Flip-Flop. This IC simply oscillates back and forth like a multivibrator, but at a speed slow enough so the Ch.9/19 LEDs can be seen flashing. The output of IC702 is disabled in the "NORMAL" mode, but in the "SCAN" mode it controls the PLL lines through a diode switching matrix. The matrix presets the correct BCD program codes for Ch.9 or Ch.19 directly, bypassing the Channel Selector. A signal on Ch.9 or Ch.19 will break the squelch and be heard. IC702 also drives individual transistors for the Ch.9/Ch.19 LEDs. Uniden cleverly planned this scanner so wire jumpers in the matrix allow the user to re-program it for any two other desired channels instead.

FIGURE 4-42
SCAN CIRCUIT
(President Adams)

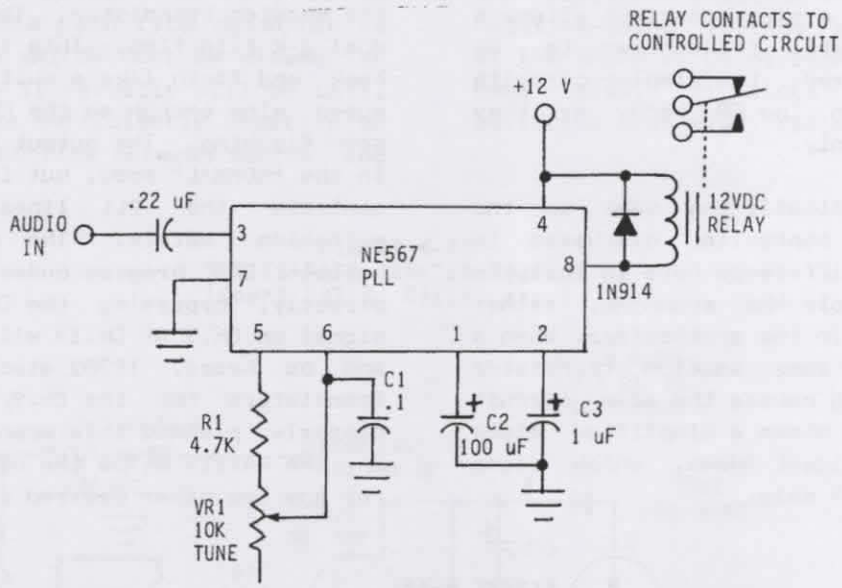


SELECTIVE CALLING (SEL-CALL)

Another feature sometimes associated with squelch is Selective Calling or "Sel-Call." Many Cybernet and Uniden export models have built-in provision for this option, although I've never seen the actual circuit so I can't be more specific. The system adds an audible tone burst at the beginning of a transmission, which must be decoded by the receiver at the other end before the squelch will open. This adds some privacy to the communications link, since undesired stations won't normally be heard. But like all tone squelch systems, once the squelch does open all other signals that happen to be on the channel will also be heard.

Figure 4-43 is an example of how PLL technology can be used for the decoder. Since the output of a PLL is a function of its input frequency,

FIGURE 4-43
PLL TONE DECODER
(Courtesy ARRL RADIO AMATEUR'S HANDBOOK)



it's a natural for applications like audio decoding or FM detectors. (It's not used in FM CB receivers because of the extra cost and complexity; why add several discrete limiter stages that must preceed an FM detector, when everything can be built into one IC?) While I can't be more specific about CB use, this shows the general idea of how they work in case you happen to see one. The transmitter encoder circuits are discussed in CHAPTER 5.

The Signetics NE567 PLL Tone Decoder has greatly simplified these systems. An RC network, R1/VR1 and C1, sets the frequency to be decoded. With the values shown, the range is adjustable from about 670 Hz to 2 KHz. C2 sets the bandwidth limits, outside which the tone won't be decoded. C3 is for output filtering and when made large enough causes a turn-on delay of the output switching, making it less sensitive to voltage transients. Transients aren't a real problem when driving a load like a relay, but may cause "chatter" when driving certain logic circuits. The chip is capable of switching 100 ma, which is enough to drive a relay directly or by a transistor switch. The relay could be used to mute the speaker or activate the squelch.

THE AUDIO AMPLIFIERS

Most CB transceivers use audio circuitry that's shared by both Receive and Transmit to reduce cost and complexity. The same power stages that drive the speaker will often be used for transmitter modulation on AM or FM. The audio path is switched between Receive and Transmit by a relay or diodes and the PTT mike switch. SSB radios have some unique differences, including the current trend towards separate transmitter modulators and receiver audio power amps. The receiver audio stages amplify the detected signal enough to operate a speaker.

Symptoms associated with problems in the receiver audio stages are:

1. No audio from speaker, but S-Meter indicates normal reception otherwise.
2. Low or weak volume.
3. Distortion.
4. Motorboating noises, or hum.
5. Blows fuses.

Dead receiver audio stages are easily diagnosed by touching the wiper of the VOLUME control with your finger or a probe; a normal working amplifier chain will produce a hum in the speaker. Of course this assumes the squelch doesn't have it cut off, since even a properly working stage wouldn't be heard then!

The audio chain usually consists of one to three stages of amplification after the detector and a power amplifier. Many of these are transformer-coupled to the speaker, although the newer IC output stages are usually transformerless. There are three main types of power amplifiers: the single-ended tube or transistor, the push-pull amplifier, and the IC amplifier, in order of evolution.

The single-ended and push-pull types are only found in older American models, since they're considered obsolete technology. (I.e., not cheap enough!) The tube radios always used single-ended audio amps, and so did a few early transistorized radios like the Pace 2300. As production methods improved, the push-pull output came along. Both methods required the use of expensive input and output transformers. The current CB technology uses just a single plastic power IC and no output transformer. Not only is this cheaper, but having no transformer means no potential magnetic core saturation and its resulting distortion.

Troubleshooting can be done by signal tracing or signal injection, working stage by stage until you find the defective one. The power stages are the <u>most</u> common failure point, since they handle the most current or voltage. They're one of the few circuits in a CB radio having heavy enough wires and associated parts to carry a direct short without burning up instantly. So keep a good supply of power transistors and ICs on hand!

The Class B Push-Pull Amplifier

The audio power amp used after the tube era but before power ICs was the "Class B push-pull" amplifier using a pair of output transistors. Push-Pull means two power transistors operate on alternate half cycles of the input signal. This is done by splitting inputs and outputs equally with center-tap transformers to create a balanced circuit. This cancels even-order harmonics (2nd, 4th, etc.) as well as AC hum caused by power supply ripple in base transceivers. The high DC current flowing through a single-ended amplifier can magnetize the transformer core and cause distortion. A further advantage of the push-pull amplifier is that the currents of each tube or transistor are always flowing in opposite directions, which prevents core saturation.

In the Class B amplifier, the transistors are biased at approximately cut-off. Base current flows only when the driving signal is high enough to overcome the existing bias, which for an AC signal means exactly half the time. Because of this, the load on its driving stage is constantly changing from a higher impedance when no current flows to a lower impedance when it does. The driving stage must therefore have good voltage regulation to minimize distortion. You'll generally find the collector supply to the driver transistor heavily filtered by about 100 µF. Since electrolytics tend to dry out and these circuits appear in older models, suspect this capacitor in cases of poor audio quality. Bridge a good one across it to confirm.

Push-pull audio amps weren't used in tube CBs, since a single-ended circuit provides plenty of audio power compared to transistors. But the push-pull circuit is much more efficient than a single-ended transistor power amp and allows the transistors to be driven with very high collector currents and low distortion. To run such high currents, the devices are always heatsinked. You'll find this transistor pair bolted to the radio frame or to a separate aluminum "L" bracket for heatsinking. The transistors are usually in the plastic TO-220 type case, like the 2SC1014, 2SC1096, or 2SC1173, and are a <u>very</u> common failure point. Failure of one transistor in a push-pull pair causes extreme audio distortion, which will be evident on both Receive and Transmit.

Figure 4-44 shows the classic push-pull audio power circuit. Common Emitter amps are used. The stages up to the power amp are operated in Class A for minimum distortion. "Class A" amplifiers are biased so base current is always flowing with or without an input signal. This makes them the least efficient amplifier type, since they only work on the linear part of the input signal waveform. But they have the cleanest output signal. Since they're the least efficient, two stages (TR6, TR7) are needed to increase the level enough to drive the power amp stage. The audio input from the detector goes to the high side of the VOLUME control. It's amplified by TR6 and coupled by C32 to the base of TR7, the Audio Driver stage. The output of TR7 is coupled across T9 to the push-pull power amplifiers TR8 and TR9.

The push-pull power amp, having balanced input

FIGURE 4-44
DISCRETE PUSH-PULL AUDIO POWER CHAIN
(Courier Rebel 23+, Fanon Fanfare 100)

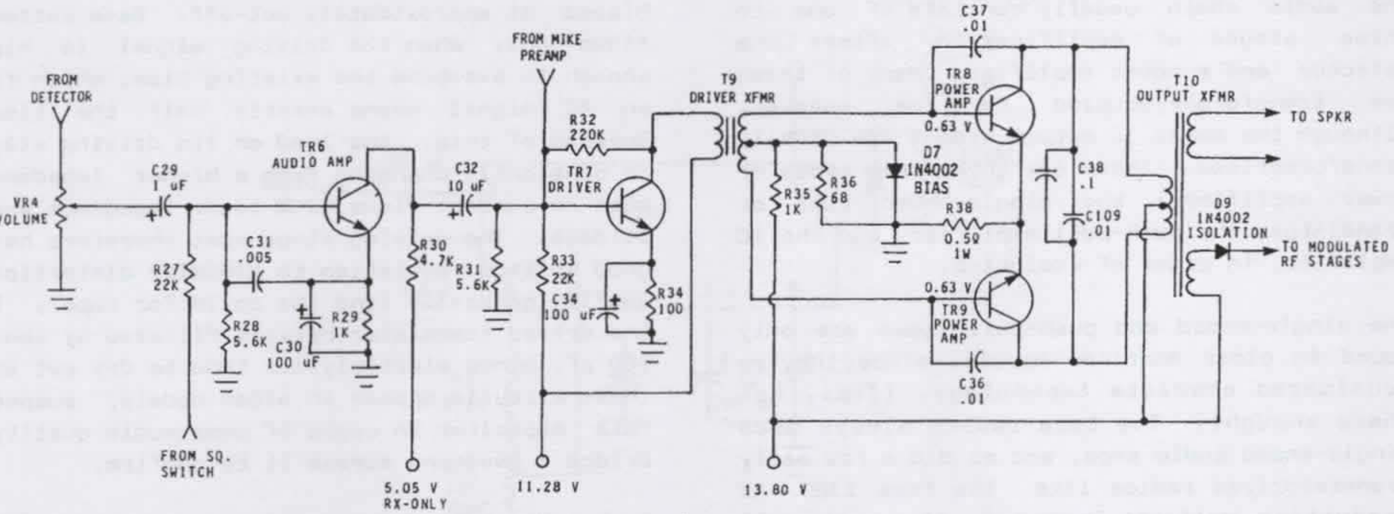
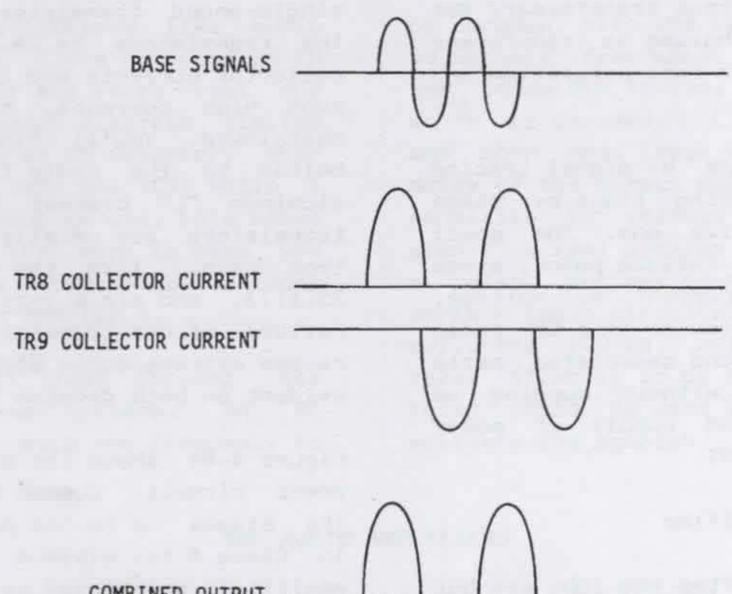


FIGURE 4-45
CLASS B PUSH-PULL AMP OPERATION



and output circuits, means at any given instant each end of T9's secondary will have the opposite polarity with respect to the emitters. One transistor base goes positive at the same time the other goes negative. Their voltages and currents are 180° out-of-phase with each other, since only one transistor conducts at a time. The even order harmonics (2nd, 4th, 6th, etc.) are balanced out, reducing distortion.

Figure 4-45 illustrates how the two halves of the audio cycle will combine to produce a faithful but amplified copy of the original. Class B audio operation always requires a pair of amplifiers working on alternate half cycles. (This operation differs from that of an RF amplifier, which can operate on just a single Class B stage. The flywheel effect restores the complete waveform; see CHAPTER 5.)

Returning to Figure 4-44, C31, C36 and C37 provide some degenerative feedback to stabilize the gain and roll off the higher audio frequencies and harmonics. This maintains a narrow voice bandwidth without splatter to adjacent channels. R38 provides emitter bias stabilizing and current limiting, since a direct ground could cause thermal runaway and destroy the transistors. As the transistor warms up it passes more current and increases the resistor's voltage drop, producing more reverse b-e bias which reduces the current flow. This resistor is usually under 1Ω, with a 1 or 2 watt rating. Sometimes each transistor has its own emitter resistor, a good practice that aids reliability.

R35, R36, and D7 provide the forward bias for Class B operation, since D7 (a silicon diode) is conducting hard. This drops about 0.65 VDC, close to cutoff with no input signal. Such bias is considerably less than Class A amplifiers, which are always conducting and normally run about 1.5-2.5 VDC base bias. Excess bias with Class B causes distortion, which is something to check when troubleshooting that particular symptom. Sometimes you'll see a "thermistor" (thermally-sensitive resistor) in place of D7. The thermistor is a ceramic semiconductor whose resistance changes as its temperature changes. With the negative-coefficient (NTC) type, the more the power transistors (and it) heat up, the lower its resistance and the more voltage it drops away from the bases. This lowers transistor conduction and prevents thermal runaway which could otherwise destroy TR8 and TR9. An open bias diode or thermistor causes severe audio distortion, and the power transistors won't last long either.

C38 and C109 filter some high-frequency audio components and provide some transient spike protection. If either of these is open you may never know it except by out-of-circuit tests. D9 is often called an "isolation" or "limiter" diode and is very important. It helps prevent overmodulation and keeps RF out of the power supply. If it's open there's no Transmit. If shorted, there may be mild distortion, overmodulation, or self-oscillation from RF coupling back into the power supply. Since this diode carries the full transmitter collector current of over 1 A, always replace it with a 2-3 amp device. (1N5400 family, ECG156, etc.) T10 is a dual-secondary output transformer; one winding is for the modulated transmitter audio and the other for the speaker. In newer transceivers this has been further simplified with a single tapped secondary winding.

If either (or both) power transistor shorts, it will most often blow the fuse, since it's directly powered from the 13.8 VDC input. If open, there's extreme distortion, obvious to a listener or on a 'scope. When you find a bad transistor in a push-pull circuit it's smart to replace both; the bad one often weakens the good one. These transistors are very cheap, and may save you potential service callbacks.

IC Audio Power Amplifiers

The current generation of American CBs use IC power amps. Since the UK and European CB services were just getting popular around 1980, they were already past the push-pull technology so their models use ICs too. Figure 4-46 shows typical examples. These ICs are 7-10 pin SIL (single-in-line) devices with a metal surface or tab for heatsinking and bolt directly to the frame or to a separate aluminum "L" bracket. They have up to 5.5 watts output, but most CBs rarely exceed 2 or 3 watts. The high voltage gain (typically about 55 dB) can eliminate the need for a preamplifier stage, but occasionally one transistor driver stage does preceed it.

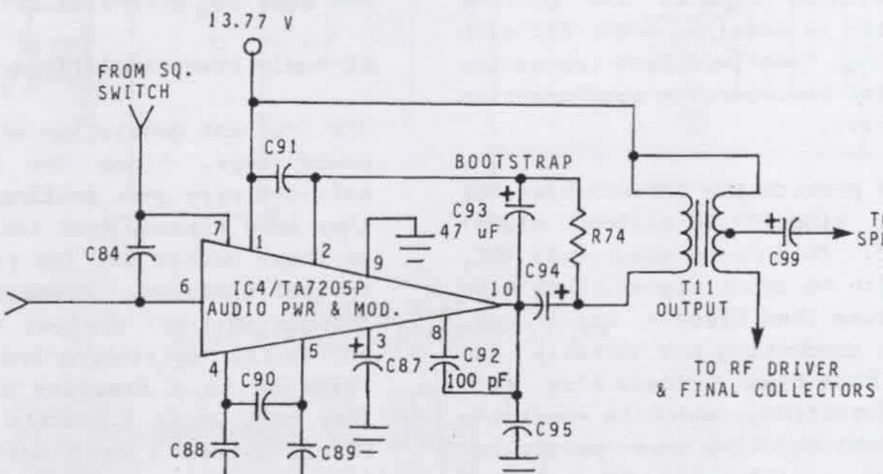
One way to increase gain is through a feedback circuit called a "bootstrap," which is C93 in Figure 4-46A. This couples some of Pin 10's output back to Pin 2, the bootstrap input. The bootstrap used in Figure 4-46B is C114. This capacitor raises the collector load impedance of the driver inside the IC, increasing its voltage gain. One drawback is slightly increased Total Harmonic Distortion, but with the 10% THD typical of CB radios, who'd ever know the difference? C92 of Figure 4-46A adds negative feedback but its value is chosen to reduce the high frequency response. If symptoms of weak audio or changing frequency response occur you should check these capacitors; the electrolytic types do dry out.

Audio power ICs eliminate the need for the input transformer of the push-pull amplifier. The dual-secondary transformer winding has also been replaced with a single center-tapped winding. In Figure 4-46B even the transformer itself has been eliminated. Output coupler C118 is now a very large value, since it's looking directly into a low-impedance speaker circuit. The evolution of ICs has greatly reduced the cost, bulk, and need for audio transformers.

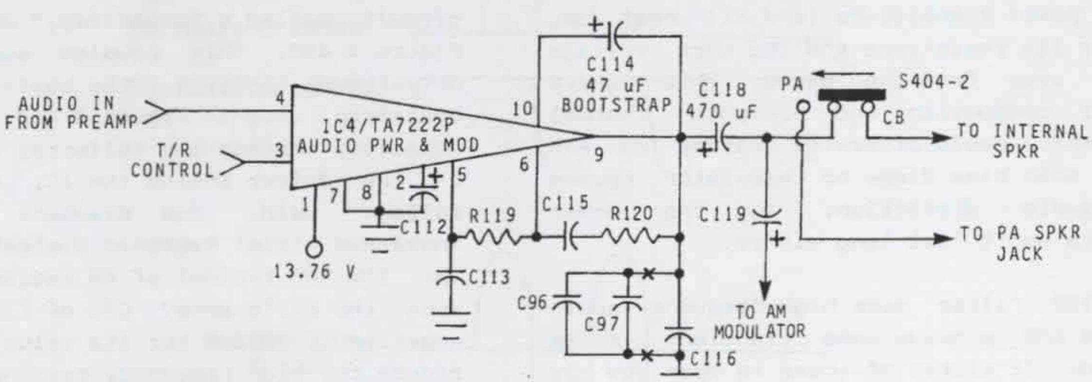
In CBs these ICs are always pushed to their limits, and very often blow out. Note they're almost direct-coupled to the speaker; the wrong speaker impedance or a shorted or open speaker can cause sudden IC failure.

FIGURE 4-46
IC AUDIO POWER AMPS

(A)
EARLY VERSIONS WITH TRANSFORMER OUTPUT
(Cybernet late AM chassis: HyGain 2702, Midland 77-888, etc.)



(B)
LATE TRANSFORMERLESS VERSIONS
(Cobra 140/142GTL, Realistic TRC490, Uniden Washington, etc.)



AUDIO TROUBLESHOOTING

Since almost all Receive audio circuits are shared by Transmit, the tips in this section also apply to modulation problems. The only unique receiver audio circuit is the signal path from the power amp to the speaker itself. This path is switched between the speaker and the RF power stage in AM radios, and the speaker and the FM modulator in multimode radios. So it's a question of audio problems on both Receive and Transmit, or one mode only.

To proceed logically, you must first answer that question. The circuits associated with T/R switching are often the cause when the audio problem only affects one mode. In relay radios, check for continuity of the relay contacts. The speaker jacks are another common fault, particularly in the newer radios that use cheap sub-miniature types. Most are meant to be self-shorting when the plug's removed but may not be making good contact. The jack wires are only #24 or #26 gauge and can break from excess handling or metal fatigue; you may never even know it, since they're hard to spot unless the broken wire moves while you're watching.

Never underestimate mike wiring as the fault. This is especially true with electronic T/R switching, because the speaker is usually grounded only with the mike plugged in and its PTT switch making a complete circuit through the cable. A few 5-pin DIN mike sockets include a self-shorting contact so the speaker can be heard even with the mike unplugged. This contact can open up too. Broken wires inside the mike cable, mike plug, or mike PTT switch are extremely common CB problems.

Assuming the audio problem is common to both the Receive and Transmit modes, you'll have to check the audio amplifier chain itself. Troubleshooting audio amplifiers is very straightforward. In the case of ICs, check voltages and input/output signal pins with a 'scope or signal tracer. If the input is present with no output and specified voltages are off, you can be pretty sure it's bad. It may short or open internally. A short can blow the radio fuse, since the chip is directly powered from the main 13.8VDC supply.

Below are the most common CB audio power ICs and their equivalent American parts. Remember: NewTone now includes the ECG and SK lines, so these parts will say either "NTExxxx" or "TCGxxxx." (Also applies to top of Page 147.)

AN7140	=	ECG1365
BA521	=	ECG1166, SK3827
HA1339	=	ECG1169, SK3708
HA1366WR	=	ECG1261, SK3872
KIA7205P	=	ECG1155, SK3231
KIA7217P	=	ECG1370
MB3712	=	ECG1423, SK7600
MB3713	=	ECG1424, SK7601
TA7205P	=	ECG1155, SK3231
TA7217P	=	ECG1370
TA7222P	=	ECG1278, SK3726
TBA810S	=	ECG1115, SK3917
μPC1156H	=	ECG1194, SK3484
μPC1182H	=	ECG1286, SK3923
μPC1242H	=	contact radio manufacturer, NewTone Electronics, or MCM Electronics. (Addresses on Pages 21 and 24.)

NOTE: The specs on these devices indicate power outputs of about 5.0 to 5.8 watts. But they never run this high in CB radios, since some reserve power is always included to prevent distortion at the lower specified levels.

A shorted push-pull output transistor or IC can draw enough current through a transformer winding to burn it open before the fuse blows. So after you replace the active device, there's still no audio. In older circuits with separate secondary windings for both the speaker and modulated RF stages, one winding could open up while the other still functioned normally.

Transformer problems can be subtle. Windings can short together to change the impedance. This is quite difficult to analyze unless you have very precise DC winding resistance information and a digital VOM to check it. Symptoms include distortion and low volume and/or modulation. Since a transformer is often specially-made, expensive, and hard to replace, save your doubts about it until all other possibilities have been logically eliminated. Power transformer failure is relatively rare.

The speaker itself can cause the "No Receive Audio" problem. The simple way to check is by substitution. I use a cheap PA speaker on my bench, which when plugged into the "EXT SP" jack of the test radio will verify its speaker as good or bad. Speakers do burn open and this can be checked with an ohmmeter; it's quite common when the radio puts out 3 or 4 watts of audio into a speaker often rated at only 1 or 2 watts! Apparently some manufacturers think the full power will never be used. But in locations like an 18-wheeler cab, an airplane, or a boat, the VOLUME may often be up full blast.

Sometimes instead of an open voice coil there's a scratchy VOLUME control, defective capacitor in the power amp stage, or partially shorted or stuck voice coil. In coastal areas, the paper diaphragm may go limp from the humidity. Substitution will confirm the problem. In tube radios a common problem is that the heat eventually dries out electrolytic capacitors. To check this, bridge a good one across the suspected one; it's quick and saves unsoldering if the original wasn't the problem after all.

The symptom of "motorboating" or excessive hum This always caused by poor power supply filtering. Suspect dried out electrolytics here too. The power amps receive their voltage directly from the main input source in tube and solid-state radios. Check the schematic to locate all the audio electrolytics and bridge a good one across any that you suspect. Since electrolytics are also used for interstage coupling and emitter or cathode bypassing, any drastic capacitance change can cause hum as well as low gain or distortion. Hum may also be caused by a broken shield connection in those radios using shielded audio cable. This is especially true in tube radios or ceramic mike circuits, which being high-impedance must always be carefully shielded.

LED CHANNEL DISPLAYS

All CB transceivers having 40 or more channels use a 2-digit, 7-segment LED channel readout display. There's nothing very complicated about its operation when analyzed logically.

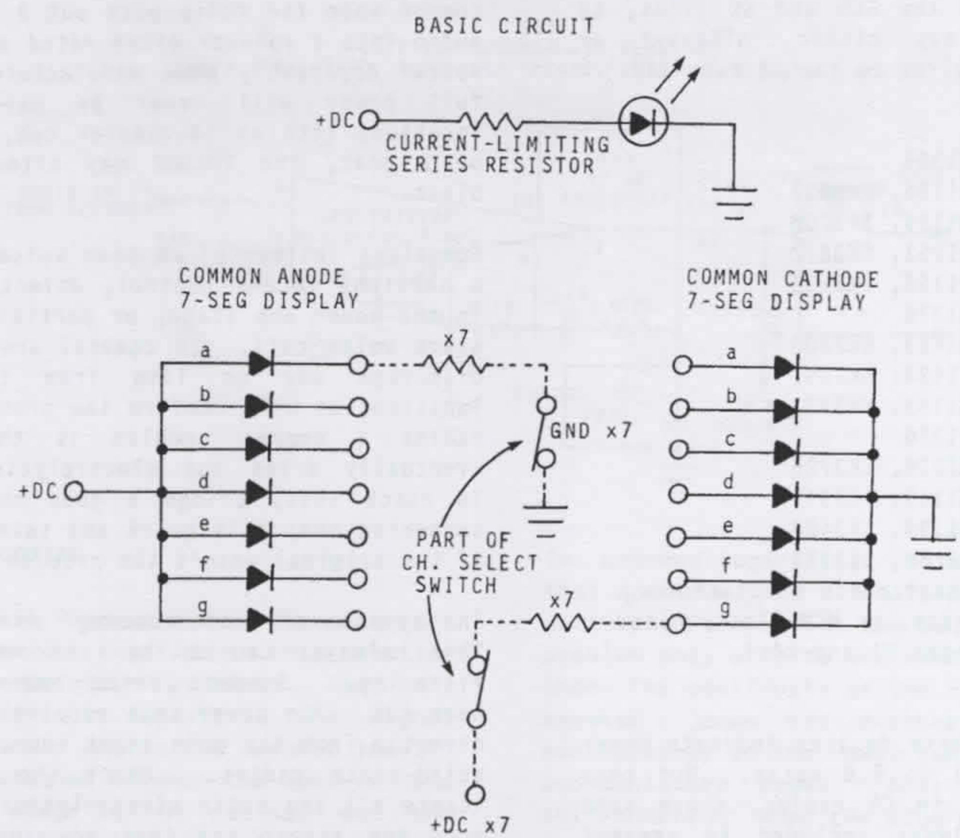
Problems associated with LED channel displays include:

1. Dead or dim segment within a digit.
2. Dead or dim digit.
3. Dead display, both digits.
4. BRITE/DIM control doesn't work.
5. Displays wrong channel number or "garbage."

Figure 4-47 shows the basic LED principle. An LED is a semiconductor using special compounds in the junction that can emit light when forward-biased. Instead of being completely covered like an ordinary diode, the junction is visible through a plastic lens. Different chemicals emit different colors. The higher the forward current, the brighter the light, until saturation occurs. So like all forward-biased diodes, the current must be limited with series resistance or they'll self-destruct.

By placing seven such diodes in a plastic cube, one digit is created. LED displays are either called "common-anode" if the ground returns are switched, or "common-cathode" if the voltage supplies are switched. Both are found in CBs. The limiting resistors may be discrete for each segment, or contained in an IC-type resistor pack on the PC board, like an SIL IC package. They're in series with the voltage or ground side of the segments. By turning the correct

FIGURE 4-47
OPERATION OF 7-SEGMENT LED DISPLAY

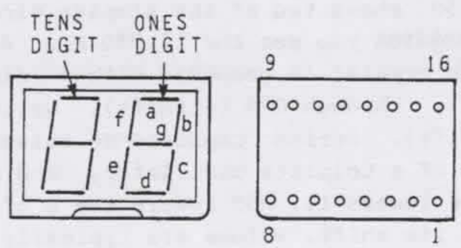


segments on and off, a number is created. The Channel Selector switch usually has an extra wafer to control the LED segments. Radios with scanners or microprocessors use special decoder ICs to control the actual segment switching.

There are two 7-segment blocks for the CB channel display. The left-hand block is the "TENS" digit, and the right-hand block is the "ONES" digit. See Figure 4-48. For the first nine channels, only the right-hand block is needed. For Ch.10 (and up) both blocks will be used: the left for the "1" and the right for the "0." For example to make a "1," segments "b" and "c" must be conducting. The switching continues up to Ch.40. Some export models display directly up to Ch.80. The segment names "a" to "g" are standard among LED manufacturers regardless of the specific device.

Figure 4-48 is the UR202 common-anode display used in many radios. Both digits are contained in a single 16-pin unit. The left-hand "TENS" is defined as Digit 1 and the right-hand "ONES" as Digit 2. Some displays use two separate side-by-side digit blocks. Segments are always labelled "a" through "g." The common-anode type has a regulated voltage applied to the common anode bus (pins 4 and 5), and segments light by grounding the appropriate cathode pins.

FIGURE 4-48
UR202 COMMON-ANODE 2-DIGIT LED DISPLAY



PIN #		PIN #	
1	c-1	9	g-2
2	e-1	10	a-2
3	d-1	11	f-2
4	common-1	12	b-2
5	common-2	13	b-1
6	d-2	14	f-1
7	e-2	15	a-1
8	c-2	16	g-1

For example to display Ch.40, the "4" requires segments "f," "g," "b," and "c" of the left-hand TENS unit, so pins 14, 16, 13, and 1 respectively would be grounded through the Channel Selector switch. For the "0," the switch would ground segments "a," "b," "c," "d," "e," and "f" of the right-hand ONES unit via pins 10, 12, 8, 6, 7, and 11 respectively.

Shown below is a partial logic Truth Chart for this 7-segment display. A "1" indicates a lit segment. Use this idea to troubleshoot any specific segment. First decide which segments should be lit; then backtrack to the switching source of the voltage or ground connections to find the open path.

	TENS	ONES
	a b c d e f g	a'b'c'd'e'f'g'
Ch.1	0 0 0 0 0 0 0	0 1 1 0 0 0 0
Ch.2	0 0 0 0 0 0 0	1 1 0 1 1 0 1
.	.	.
.	.	.
.	.	.
Ch.39	1 1 1 1 0 0 1	1 1 1 0 0 1 1
Ch.40	0 1 1 0 0 1 1	1 1 1 1 1 1 0

Troubleshooting is relatively easy because the segment blocks and resistor packs must be treated like ICs; if one segment is bad you must replace the whole unit. Dead or dim segments must be traced for continuity with a voltmeter from the supply voltage source to ground via the resistor pack and LED pins to find the bad connection. A poor solder joint is a very likely cause for such problems.

The problem of uneven segment brightness within a digit can be caused by a faulty IC resistor pack (or discrete resistors), or a bad solder connection again. Try reheating all solder joints and measure the segment pins to check for unequal supply voltages. If this doesn't indicate or solve the problem, it's internal and you'll have to replace the digit or resistor pack. Some resistor packs are unmarked on the schematic, but you can always jumper discrete resistors across the correct PCB holes in a pinch. Values range from about 680-1.8KΩ. The Channel Selector is unfortunately a special sealed unit and must be replaced if it's bad.

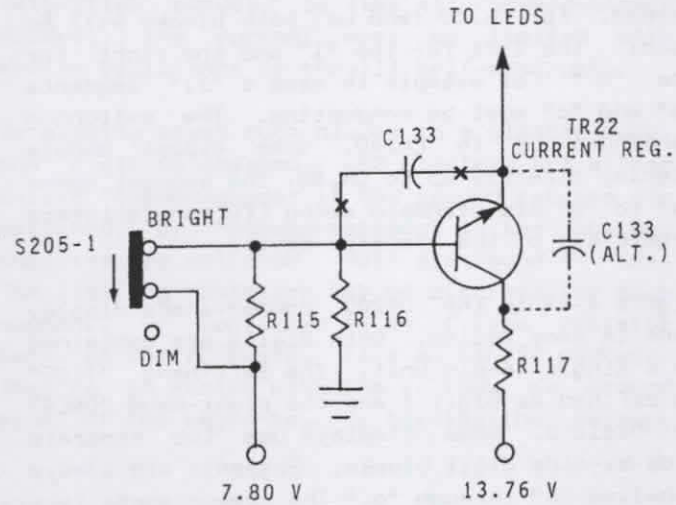
The plastic ribbon cables currently used for interconnections are very delicate; if a trace breaks a segment or a whole digit can be dead. If both digits are dead but the radio works normally otherwise, check the common power source, which is probably missing, or a poor ground to the display common point. Because many newer radios (Cobra "Plus" line, Uniden

"PRO" line, new Midlands and Realistics, etc.) are now substituting LEDs for the meters and other expensive parts, LED problems are also increasing. The greater use of ribbon cables means these problems will ultimately be traced to ribbon breaks or poor soldering of the ribbon cable to the PC board(s) it connects.

Many radios have BRITE/DIM display controls. Figure 4-49 shows a typical circuit. TR22 is a series-pass regulator. Brightness is controlled by changing its bias with the resistive divider R115/R116. The higher the base voltage, the harder it conducts and the more current it passes from the main 13.76 VDC source to the display. Sometimes this regulator is connected to the metering lamps to control them too. If the BRITE/DIM switch or control doesn't work, troubleshoot this regulator circuit.

In radios with scanners, special driver ICs are inserted between the scanner IC and the LED display input. Unlike the previous circuits which are directly driven by a branch of the power supply, the scanner ICs can't source enough current to drive the LEDs directly. The driver IC contains multiple transistor current amplifiers. Obviously with the driver IC in series, it's a potential failure point for the "No LED Channel Display" symptom.

FIGURE 4-49
LED BRIGHTNESS CONTROL CIRCUIT
(Cobra 29GTL, 29LTD, etc.)



DELTA TUNE CIRCUITS

The Delta Tune is an optional receiver feature used to compensate for signals slightly off frequency. It's left over from the days of crystal-controlled synthesizers, when accuracy wasn't always consistent and predictable. With the more accurate PLL synthesizers it's really not even needed, but is still included as an option in many AM and FM radios.

Another reason it's not found as often in newer radios is because improved IF selectivity methods make the skirt response rather flat around the center frequency. If the Delta shift falls within the flat part of the passband, there's nothing to be gained anyway.

The Delta Tune and SSB Clarifier are identical in operation, and circuits range from simple to complex. A front panel control shifts the L.O. frequency slightly. The typical Delta Tune range is $\pm$1 KHz from center knob position. In older radios with individual Receive and Transmit crystal oscillators, it's usually placed right across the Receive crystal bank using capacitors and/or inductors to pull the crystal frequency slightly. Older radios have a fixed 3-position detent knob with [+], [0], and [-] shifts. As varactors appeared they took over the shift function, and the control is now a pot that changes the varactor bias and therefore the shift continuously.

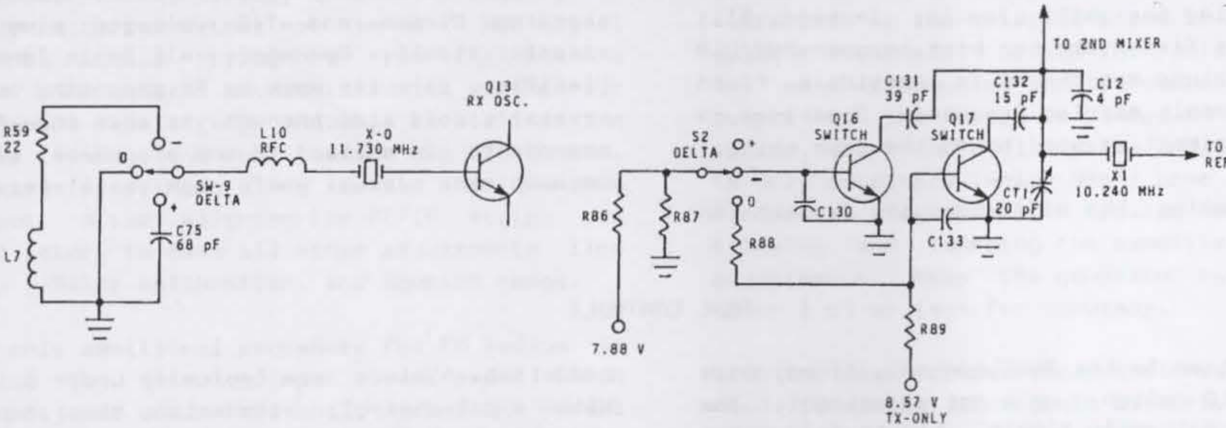
Figure 4-50 shows two of the simpler circuits. In Figure 4-50A you see the 11.730 MHz Receive oscillator crystal is grounded either directly (no shift), through C75 (+ shift), or through L7 (- shift). Series capacitance raises the frequency of a Colpitts oscillator, and series inductance lowers it. R59 lowers the Q of L7 to stabilize its shift. Values are typically under 82 pF or 10 µH. Often this circuit uses three different series capacitors for the same effect.

A more complex method is shown in Figure 4-50B, where individual transistor switches control the amount of shunt capacitance. In the [+] position, the crystal grounds only through C12 and CT1. In the [0] position Q17 turns on, adding the value of C132. In the [-] position Q16 turns on to add the value of C131. Switching from [+] to [0] to [-] will add an increasing parallel capacitance of 4 pF to 15 pF to 39 pF respectively, which lowers the crystal frequency. A Transmit-only voltage turns on Q17 in that mode to maintain just the

FIGURE 4-50
DELTA TUNE CIRCUITS

(A)
DIRECT CAPACITANCE/INDUCTANCE
(Courier Caravelle II, Conqueror II, Fanon Fanfare 880)

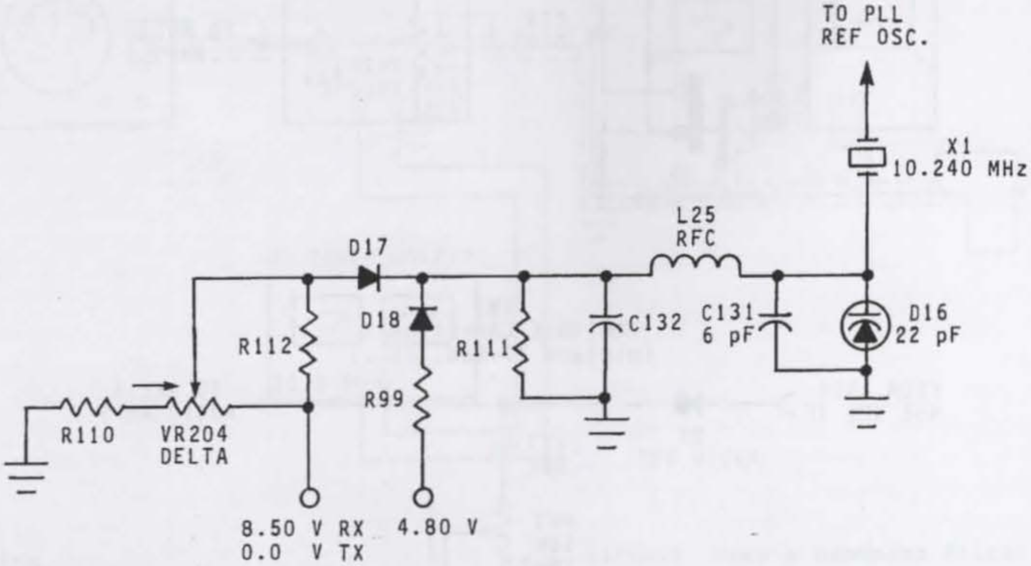
(B)
TRANSISTOR-SWITCHED CAPACITANCE
(Cybernet late AM chassis: Colt 390, Kraco KCB4020, Midland 77-888, etc.)



center frequency via the "0" capacitance of C132; this is required by FCC rules.

Figure 4-51 is the more sophisticated PLL shift control, virtually identical in operation to an SSB Clarifier control. Varactor D16 shifts the frequency of the 10.240 MHz crystal as its bias changes. R110 and R112 form voltage dividers with VR204 to smooth the resistance taper and tuning action. They also provide current limiting for the 8.5 VDC source; without them the current could be excessive with VR204 at its minimum resistance setting. L25 is an RF choke and with C132 keeps oscillator RF out of the power supply. C131 smooths the varactor range and provides temperature compensation by dividing RF currents between both capacitors to reduce heating of any one capacitor. Without C131 the shift range would be greater but less stable. This capacitor should never be removed!

FIGURE 4-51
MODERN DELTA USING VARACTOR TUNING
(Cobra 29GTL, 29LTD, etc.)



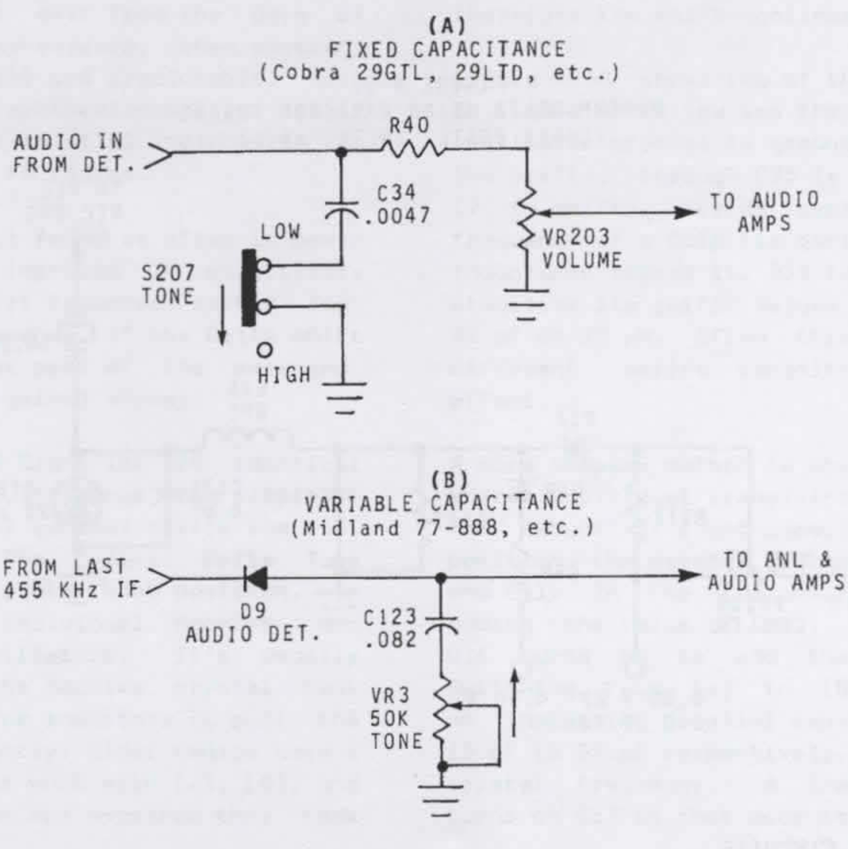
D17 and D18 are steering diodes to disconnect the Delta Tune on Transmit, since this is prohibited by FCC rules. D18 is continuously forward-biased, but D17 is only forward-biased on Receive; on Transmit D17 is reverse-biased, disconnecting the shift circuit. Instead R111 provides a fixed varactor bias through R99/D18 and the values are chosen to provide a fixed center Transmit carrier frequency. Sometimes an internal trimpot is used to do the same thing.

Troubleshooting the older circuits amounts to checking for RF continuity from crystal to ground, looking for open capacitors or inductors, bad switching transistors, missing switching voltages, or bad switch contacts. In the newer circuits you must also consider the steering diodes and T/R voltages plus the varactor itself. Remember, all Delta Tune and Clarifier circuits work by RF grounding on the crystal's cold side through variable and fixed components in series; if any of these should open up, the circuit won't even oscillate.

TONE CONTROLS

Another option is the TONE control. It may be a fixed HI/LO switch, or a pot adjustment. The circuit is extremely simple. Figure 4-52 shows both versions. It always follows the detector stage. A capacitor is shunted across the audio line and when engaged, rolls off some of the higher audio frequencies. Attenuation is determined by the capacitance value; the larger the capacitance, the greater the high-frequency reduction. Values are typically under 0.1 µF. With a pot control, attenuation also depends upon how high the capacitor is above ground at any given setting. That's all there is to it; no amplification or anything complicated. Troubleshooting is a matter of checking circuit continuity from sample point to chassis ground, and possible capacitance value changes.

FIGURE 4-52
TONE CONTROLS



RECEIVER ALIGNMENT PROCEDURES

General Guidelines

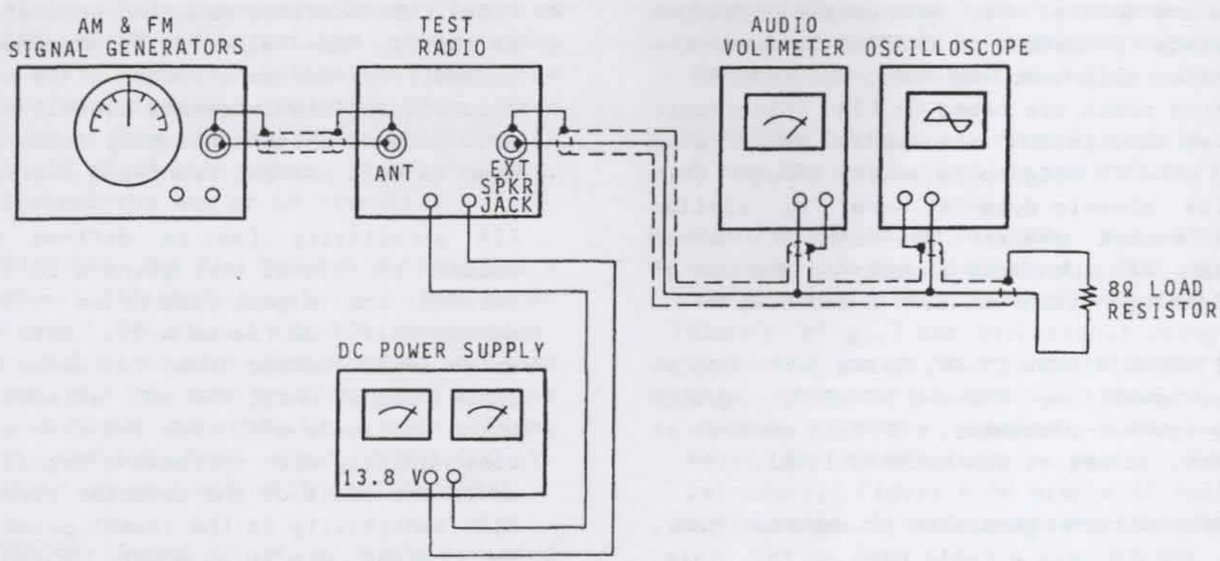
Receiver tuning is easy unless the radio's so badly misaligned that not even a 27 MHz signal can be pushed through it from the antenna jack. The general method (assuming synthesizer alignment was already done) is to start at the last IF stage and work towards the front end, peaking everything along the way for maximum output. After aligning the RF/IF strip, you then return to make all other adjustments like AGC, S-Meter calibration, and Squelch range.

The only additional procedure for FM radios is tuning the detector input transformer (when present) and quadrature coil, after the normal AM RF/IF alignment. The input can easily be tuned by placing a 'scope probe on the IC input pin and tuning for maximum RF voltage. The detector coil itself is tuned by 'scoping the VOLUME control and adjusting it for maximum audio output with minimum distortion. It's a good idea to re-check this with an on-the-air FM signal, adjusting for best audio quality.

You can use any convenient measuring equipment, since all you're looking for are relative signal strenth indications. Figure 4-53 is a review of the test set-up. Use a 'scope or AC voltmeter at the detector diode or across the speaker terminals, or use the radio's S-Meter. The main precaution is to reduce generator output as the radio is peaked to avoid AGC action, which would give false indications. For FM-only receivers (which don't have AGC), this minimizes the chance of driving the IF into limiting and lowering the sensitivity of the adjustments. Keep the generator output under about 1 µV or less for accuracy.

With the receiver extremely mistuned, you might need to inject IF signals directly into the appropriate stages and then work your way towards the front end. For example in a dual-conversion radio, you would inject a modulated 455 KHz signal at the 1st 455 KHz IF amp, peak those stages, then inject the 10.695 MHz (or other) high IF ahead of the 2nd mixer, peak everything downstream from that, and finally inject 27 MHz directly at the antenna jack for the front end RF amp alignment.

FIGURE 4-53
RECEIVER ALIGNMENT TEST SET-UP



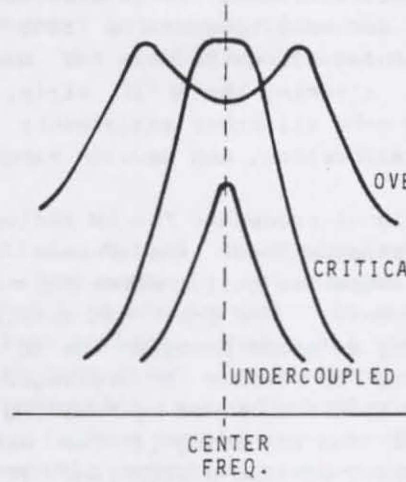
Bandpass Tuning

In the unlikely event sensitivity isn't equal across all 40 (or more) channels and the circuit uses a bandpass filter, try "stagger tuning" the coils. The bandpass filter consists of two or three capacitively-coupled coils, and is found in the 27 MHz and/or high IF stages.

(Review Figure 4-14.) Peak one coil for the low end of the band, one for the high end, and the third (if present) for the middle. Or try increasing the coupling capacitance between the transformers slightly. Remember though, the IF by definition is a fixed frequency regardless of whether the radio has 40 channels or 240 channels; you want the response to be as narrow as possible for good selectivity.

Not all radios use bandpass tuning. Many use a single tuned transformer at each receiver stage. As shown in Figure 4-54, the bandpass circuit gives a much flatter frequency response than a single tuned stage, and a sharper roll-off from the skirt. That's one reason they're used in most export radios and the better American types like the Cobra 140/142GTL or 148/2000GTL chassis. The tuned circuits are capacitively-coupled with a small ceramic disk capacitor of 5 pF or less. The coupling is critical. Under-coupling lowers signal output and sharpens the response too much. (I.e., high Q.) Over-coupling causes passband ripple, although it's sometimes used purposely to broaden the response. Always replace a bad coupling capacitor with another of the same value, unless broadbanding is needed.

FIGURE 4-54
RESPONSE CURVE OF BANDPASS FILTER FOR VARIOUS DEGREES OF COUPLING
(Courtesy Heinemann-Newnes Books)



A SAMPLE ALIGNMENT

The following is a typical alignment procedure for the radio whose layout and schematic are on Pages 144 and 145. This particular chassis (Cybernet PTBM049A0X) is one popular 40-channel PLL02A AM radio, which is marketed under dozens of makes and models. Its synthesizer procedure was already described in CHAPTER 3, and the transmitter alignment appears in CHAPTER 5. Performance specs are based on EIA (Electronic Industries Association) standards. We've also included the FM alignment; even though this particular chassis doesn't have FM, similar Cybernet export chassis do, and all other procedures are identical except for the use of an FM signal generator in Step 6 and Step 8.

1. PRESET CONDITIONS: Ch.19, Delta Tune set at center position, ANL and NB OFF, Squelch fully counter-clockwise, RF Gain control at maximum. Volume at comfortable level.

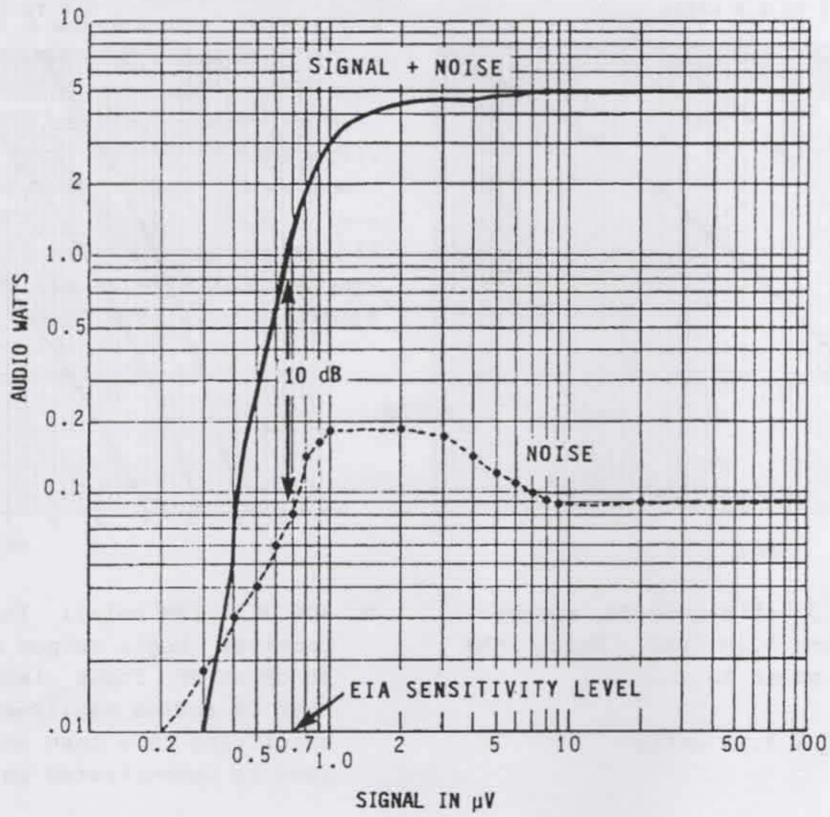
2. LOW IF: Attach generator to antenna jack. (You should have a cable made up for this, with push-on coax connector on one end and suitable connector on the other for the generator output.) Inject Ch.19 (27.185 MHz) 1000 Hz 30% modulated signal. Use minimum signal level to prevent AGC action. Adjust T8, T9, and T10 for maximum output.

3. HIGH IF: Using same or lower signal input to minimize AGC action, peak L14 and T7 for maximum output indication.

4. FRONT END: Continue reducing generator level as above. Peak T5 and T6 for maximum output indication. Now rotate core of T5 one turn clockwise. This increases overall stability and detunes antenna slightly from center of band to help prevent front-end overloading.

   EIA sensitivity (AM) is defined as that amount of signal that gives a 10 dB ratio between the signal-plus-noise (S+N) and noise (N). See Figure 4-55. Note how the noise level (dotted line) increases with the input signal until the AGC attacks, after which it levels off. The S+N then builds up very quickly with increasing signal input, up to the limit of the detector circuit. The EIA sensitivity is the lowest point where the curves are 10 dB apart, which is the same as a power factor of 10. The example shows that at 0.7 µV, when the noise (N) is producing 0.08 watt audio output, the signal plus noise (S+N) produces 0.8 watt output, which is 10 times (10 dB) greater. Thus the rated sensitivity is 0.7 µV.

FIGURE 4-55
TYPICAL EIA RECEIVER SENSITIVITY RESPONSE CURVE
(Courtesy Sencore Inc.)



NOISE LIMITER TEST (AM only): If a noise generator and mixing pad are available, this function can also be checked. Note the rated sensitivity from preceeding step. Turn on the ANL or NB and inject the noise along with the signal. Determine the new sensitivity floor and new noise floor from the chart of Figure 4-55. These should still be with 10 dB of each other. If they're not, troubleshoot the ANL or NB circuit.

5. SQUELCH RANGE: Set the Squelch control fully clockwise. ("Tight" squelch.) Inject an RF signal of 1,000 µV, 1 KHz 30% modulation. Adjust RV1 so squelch just breaks. A good receiver should open squelch close to the rated minimum sensitivity, with tight squelch peaking from about 300-1,000 µV. (Specified upper limit will vary by model.)

6. FM DETECTOR: Inject 10 µV, ±1.5 KHz deviated FM signal at antenna, modulated with 1 KHz audio tone. The AN240 usually has an input coil; peak this for maximum RF voltage with 'scope at Pin 2. Connect 'scope to output of FM Detector IC, audio power IC, or hot side of speaker. Tune detector coil for maximum undistorted audio. (I.e., the biggest and best looking sine wave.) If there's no FM generator available, transmit using another FM CB, tuning for best sounding audio.

7. S-METER: Set the generator output at 100 µV, 1 KHz 30% modulation. Adjust RV3 for "S9".

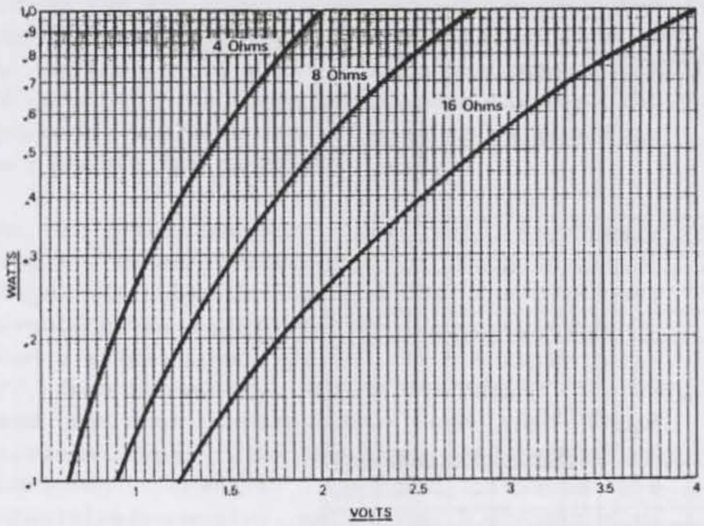
8. AUDIO POWER AND DISTORTION: Set VOLUME to maximum. Inject signal of 1,000 µV, 1 KHz 30% modulation at coax jack. (For FM, inject signal of ±1.5 KHz deviation.) Using audio voltmeter or an "AC" range of a VOM across the speaker terminals, measure audio voltage. Compare measured audio power in watts to manufacturer's spec. For your reference, Figure 4-56 graphs AC volts vs. audio watts at various speaker impedances.

You can also use the formula,

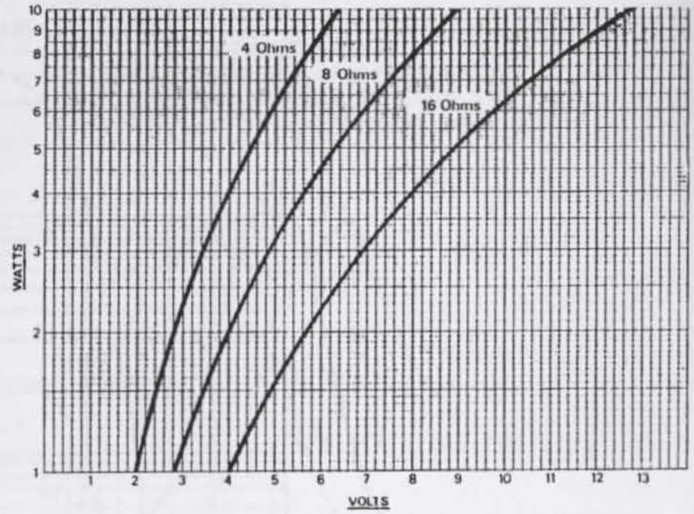
$$P = \frac{E^2}{R}$$

FIGURE 4-56
AUDIO VOLTAGE-TO-POWER CONVERSION CHARTS
(Courtesy B&K Precision)

0.1 to 1.0 WATTS



1.0 TO 10 WATTS



Example: Spec is 3 watts into 8Ω speaker. Suppose you measure 5.10 VAC. Using the formula, the audio power is

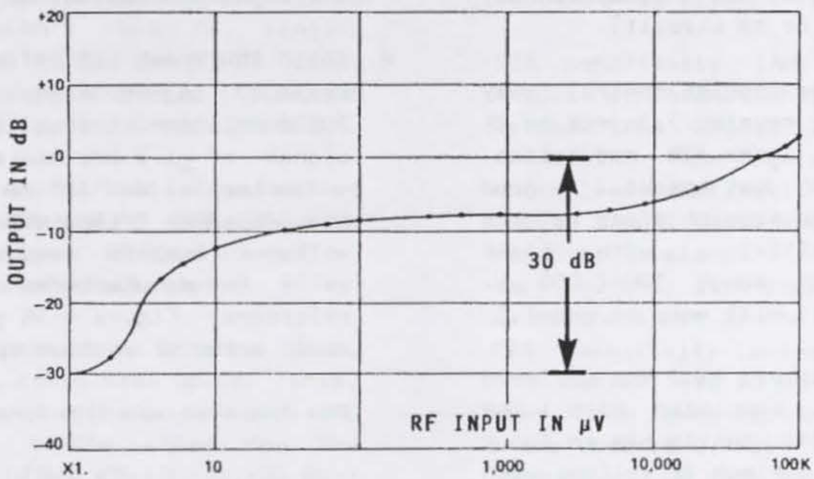
$$\frac{5.10 \times 5.10}{8} = 3.25 \text{ watts}$$

Compare output response at 1 KHz to response using inputs of 400 Hz and 2.5 KHz. Outputs should be within +3 dB @ 400 Hz and -6 dB @ 2.5 KHz. This indicates the receiver's overall ability to pass audio frequencies within the standard transceiver voice band.

9. AGC TEST (AM only): The EIA specifies the receiver audio output should remain within 30 dB at RF input levels from 1-50,000 µV. Most CB radios easily exceed this, typically specifying less than only 10 dB change. This idea is demonstrated in Figure 4-57.

For example, the Cobra 29GTL/29LTD chassis specifies "less than 10 dB audio change for input levels from 10-50,000 µV." (Slightly different input range from the EIA spec.) Using a 50,000 µV RF input signal modulated 30% with a 1 KHz tone, and the VOLUME pot at

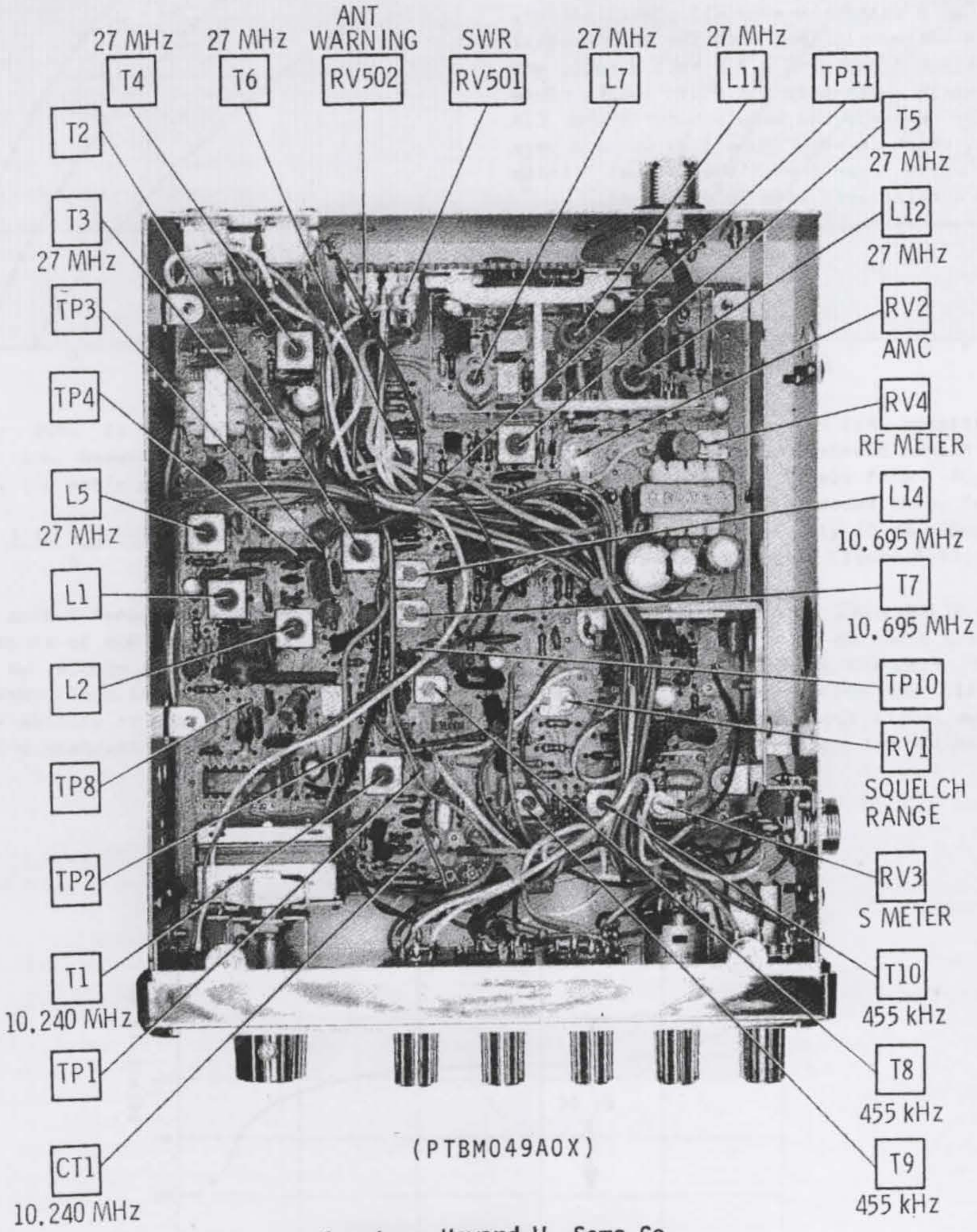
FIGURE 4-57
TYPICAL AM CB RECEIVER AGC RESPONSE
(Courtesy Sencore Inc.)



maximum, I measured about 8.04 VAC across its 16Ω speaker. From Figure 4-56, this converts to about 4 watts audio output. A change less than 10 dB when reduced to 10 µV means the audio output must remain at least 1/10 of 4 watts (10 dB = x10 power ratio), or 0.4 watts. In fact with the VOLUME still at maximum I measured a 3.3 watt output, and 1.9 watts with only a 1.0 µV input. This greatly exceeds the manufacturer's and EIA specs, which is why Figure 4-57 shows a very flat curve even though the actual limits allow a relatively wide 30 dB spread.

NOTES

ALIGNMENT LOCATIONS FOR TRANSCEIVER DESCRIBED IN TEXT



(PTBM049A0X)

Courtesy Howard W. Sams Co.

SCHEMATIC OF TRANSCEIVER WHOSE ALIGNMENT IS DESCRIBED IN THE TEXT