2 BASIC TROUBLESHOOTING TECHNIQUES

Most techs don't use a logical approach to CB repairs. Many of these people wouldn't know a vacuum tube from a vacuum cleaner. They looked in a radio once or twice and now they're experts! Instead they try the methods usually reserved for amateurs, which you probably know as "shotgunning," "hit and miss," and of course, "guess." Occasionally such methods are lucky but to be professional and successful you must develop a <u>systematic</u> approach.

USE OF LOGICAL METHODS

The CB transceiver is an electronic system, and a very sophisticated one at that. Starting from scratch you'll be overwhelmed by everything going on inside unless you fully understand each function.

The functions are best understood by viewing each as a block or "black box" for the moment. When you connect all the blocks together you have a "block diagram." Later we'll break the blocks down into stages, stages into circuits, and circuits into component parts. The block diagram phase is so important to developing a logical troubleshooting approach that you'll never succeed without it. Therefore your first task should be to <u>memorize</u> the functional block diagrams shown. Memorize them and understand them to the point where you can easily draw them yourself.

Figure 2-1 shows block diagrams of typical AM and FM CB transceivers. (SSB is covered in CHAPTER 6.) I strongly suggest you spend some time studying them, especially if you're a relative newcomer to CB servicing. Once you understand a block diagram, the logical sequence is to find the faulty block, then the faulty stage, then the faulty circuit, and finally the faulty part within the circuit. To follow this sequence you need certain basic knowledge:

1. What the overall system does in normal operation.
2. What the functions are, and how adjustments affect them.
3. What each component part does to affect the circuit operation.

PHYSICAL FEEDBACK

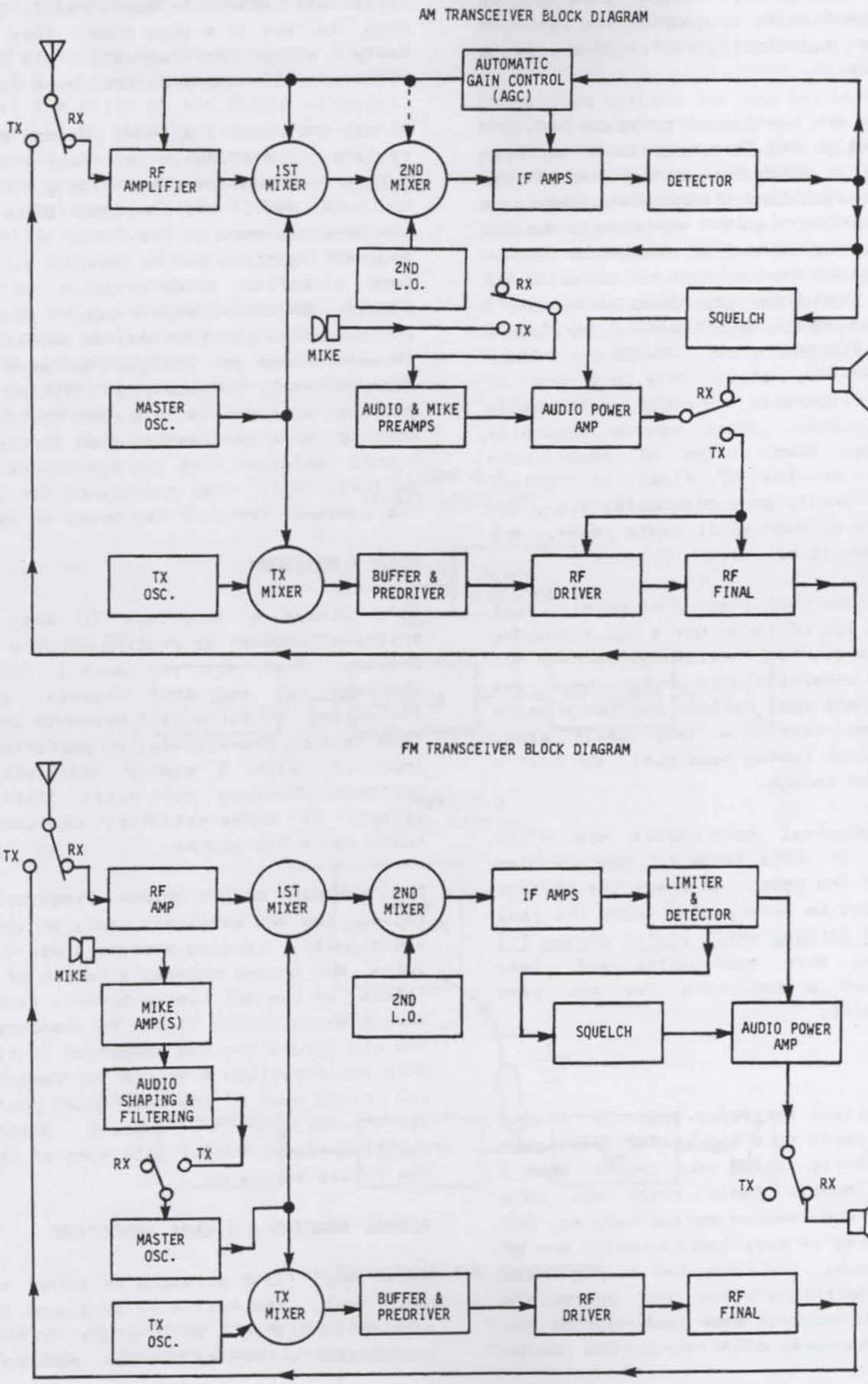
A basic way to locate blocks which aren't working right is to figure out which ones <u>are</u> working right. One of the best ways to get such feedback is to simply look at the radio's various indicating devices like SWR Meter, Modulation Meter, S-Meter, RF Meter, tube filaments, dial lamps, fuses, LED channel display, etc. You can use sight, smell, hearing and touch a lot more than you realize.

For example, you can see a broken wire or component lead, broken PC foil trace, smell a burned resistor, feel a power transistor or IC that's overheating or not heating normally. A speaker hum or buzz might tell you the audio section is working OK. Generous use of your senses will often lead to a fast and profitable fix.

Physical checks are a logical first step, especially with intermittents. Intermittents are the bane of most technicians and will drive you crazy if you let them. The first question in such cases is, "What conditions cause the intermittent problem?" Does it happen when you tap on the frame or push on the PC board? Does it happen only when the set is warm (or cold)? These are all clues which form a pattern when you understand each circuit function and how they relate to each other.

Example: Suppose the receiver volume pops up and down when tapping on the chassis. A finger on the VOLUME control causes a hum which doesn't change. This tells you the audio section is working right. You can hear an on-the-air signal or the one from your generator, and the S-Meter needle remains constant during the tapping, which eliminates the RF circuits. That narrows it down to the IF or detector sections, so from that point it's a matter of finding the part that's loose, poorly soldered, etc. Beginning to see how this works?

FIGURE 2-1
AM & FM TRANSCEIVERS



So much for mechanical intermittents. "Thermal" intermittents are also very troublesome. You key the mike, the transmitter is fine for a few seconds, then suddenly quits. Once you've confirmed that flexing or tapping the case or PC board has no effect, you're down to a thermal problem.

Semiconductors are greatly affected by heat and cold, and can go bad from excesses of either. You need a way to check both conditions. Maybe the RF power amplifier transistor opens a junction or internal lead contacts when it heats, but acts normally otherwise. Power devices especially have a habit of doing this. How do you test this? By using some stuff called "Freeze Spray" or "Chill Spray." (GC Electronics #10-8668 or 10-702, Miller-Stephenson #MS-240, etc.) This is a can of Freon which evaporates so quickly it cools whatever it touches. Since you've logically narrowed things down to the RF amps, some freeze spray on the RF Final or Driver transistor may verify your diagnosis; i.e., the radio transmits as soon as it cools down, but stops again when it reheats.

Sometimes you need heat instead of cold to test a component. A lot of techs use a hot soldering iron but you've got to be extremely careful not to damage an otherwise good part! There are commercial thermal spot testers available which concentrate the heat in a very small area. Don't use a shrink tubing heat gun; the heat's not concentrated enough.

Summing up, physical spot checks are often justified and if this leads to the problem you're ahead of the game. So check the obvious things first, but be sure you've found the real problem. Assume nothing until you've proven it! There's nothing more aggravating and less profitable than a call-back for the same customer complaint.

ATTITUDE

Almost as important as proper logic is proper attitude. You can't be a successful repairman if you're constantly losing your temper. When I was at G.E. Mobile Radio there was this oldtimer, Al, who worked exclusively on the hand-helds. If you've ever looked inside one of those $1500 toys, you know what a nightmare they can be. Hair-fine wires and incredible parts density. Anyway, each tech had his own little room; the walls of Al's room had large chunks of plaster missing from where he'd thrown the radios at the wall whenever he got disgusted with them. The reason he never got fired was because he was a really great tech, when he was in a good mood. They needed him badly enough to tolerate his occasional outbursts. However your customers may not!

Al was the exception. And CBs don't cost $1500 so it's not profitable to invest a lot of time unless you can fix them. I'm guilty of temper tantrums myself and sometimes think of CBs as the Japanese revenge for Hiroshima. If you find yourself getting mad or running out of ideas, take a coffee break or go on to an easier repair. An easier repair psychs you up, since it convinces you that you're not as stupid or incompetent as you thought you were. Besides, temper really clouds your thinking and makes you miss what should have been obvious. There's nothing more embarassing than finding a very simple solution that you overlooked two hours earlier. Will your conscience let you charge the customer for your two hours of steam?

KEEP A NOTEBOOK

It's always a good idea to keep notes of anything unusual or routine about a particular chassis. That way you save a lot of time whenever you see that chassis again. If installing an extra part prevents another one from failing prematurely, or performance can be improved with a simple modification, the customer deserves this extra little bit of effort. It makes satisfied customers, which makes you a bit richer.

For example on the Uniden President Jackson radio, the AGC overloads badly on very strong SSB signals, causing extreme audio distortion. Turns out Uniden changed a couple of resistor values in the AGC timing circuit from previous models which worked fine. By changing back to the old values the SSB reception is fine again. Once you establish a system for remembering how you fixed some of the old "dogs" you'll save a lot of time when they reappear. After a while you'll collect a real gold mine of information for future reference.

SIGNAL TRACING & SIGNAL INJECTION

When your first attempts to solve a problem don't work, the next step is signal tracing or signal injection. With signal injection you substitute a signal from an external source like a signal generator or another radio. If you get the right signal output with the test injection, the circuits between the injection point and the output point are probably OK.

Let's say the problem is "No Receiver Audio." See Figure 2-2. Inject a signal from an audio generator at the wiper of the VOLUME control. If you heard it in the speaker, the audio amplifier could be ruled out as the problem. This means the problem must be somewhere before the audio amplifier stages. But if the injection still produced no speaker output, you'd have to consider the audio chain as the problem area. This method can be used throughout the radio including Transmit. If you suspected a dead oscillator or mixer, inject the correct signal from an external RF generator at the proper point to see if operation is restored.

Signal tracing involves the connection of some other indicating device like a 'scope, signal tracer, frequency counter, or VOM/RF probe to see if the signal is reaching a particular circuit point. Figure 2-3 shows this idea applied to the "No Receiver Audio" problem.

These two methods let you quickly localize the circuit area to determine the problem more exactly. Some techs like to inject signals at the front and follow them until lost. Others work backwards from the output end until the proper signal is found. I've done both at various times and there's no preferred choice. The point is not to start in the middle without a clear idea of which direction to proceed. Unless of course there's a logical reason to believe the middle is the faulty area.

FIGURE 2-2
SIGNAL INJECTION

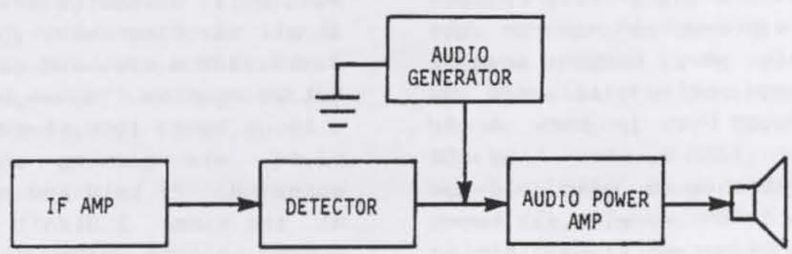
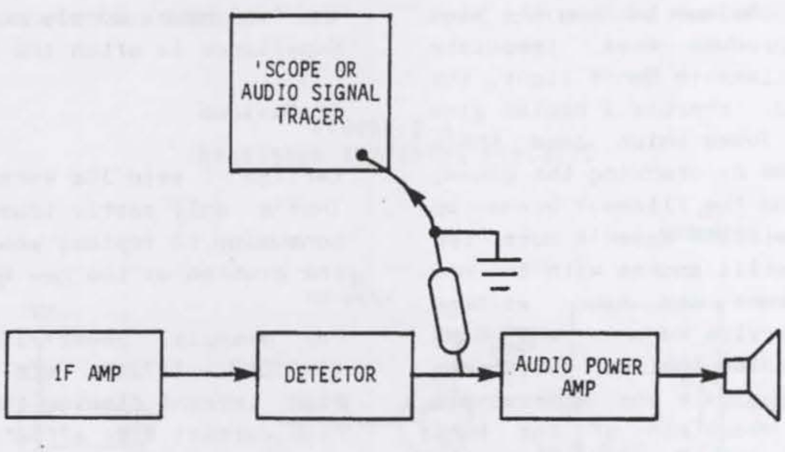


FIGURE 2-3
SIGNAL TRACING



INTERPRETING THE DC BIASES

After isolating the problem to a particular circuit or stage, the next logical step is to make some voltage measurements of the active devices; i.e., the tubes, transistors, or ICs.

The service manual should specify the voltages at each terminal and the operating conditions that produced them. (You <u>do</u> have the service manual, right?)

Your interpretation also requires an understanding of the various amplifier operating "classes" used (A, B, AB_1, C), since voltage changes might be a lot more subtle than outright shorts and opens. For example, distortion in a Class A audio amplifier might be due to a resistor change that effectively changes its bias to another operating class. Amplifier classes are defined by the amount of forward bias relative to the input signal. Bias affects amplifier efficiency (the output level for a given input) and the purity of the amplified signal. Amplifier classes are described in more detail later.

Tubes

Tubes are relatively easy to check by direct substitution. A tube tester isn't always reliable, since it runs them at greatly reduced operating voltages to prevent injury to the operator. Tubes aren't very common anymore except for a few vintage radios still used by some oldtimers. (Browning Mark 3, Mark 4/4A, Tram D201, Dak X, Robyn T240-D, etc.) Like old cars, tubes can function even with old-age problems. It's common to find many or all tubes testing less than "GOOD" but still maintaining the radio up to specs. At the low levels used in CB circuits, there's often a tremendous reserve gain that's not even being used.

Most tube problems are obvious because the high operating voltages produce more immediate physical signs. The filaments don't light, the plate glows cherry red, there's a bluish glow when gassy or leaky. Tubes which lose their vacuum rapidly, such as by cracking the glass, turn a milky color and the filament burns up immediately. If a substitute doesn't cure the problem or the radio still smokes with the new tube, unplug the tube and make voltage measurements. Most service manuals and SAMS Fotofacts for tube radios include resistance measurements. These indicate the approximate ohms-to-ground across each pin of the tube socket. This is a great troubleshooting aid, so use it when available.

Because of the heat generated, components like resistors and capacitors eventually break down. Aside from tube filaments burning out, these component breakdowns represent about 90% of tube equipment repairs. You'll occasionally find some exotic problem like a transformer impedance changing from shorted turns, but this is rare.

Tube substitution is the fastest way to test faulty stages, unless an obvious physical symptom (like smoke!) is present. When tube substitution doesn't work, pull the tube and measure the voltages (or resistance-to-ground) on the socket pins for clues to the problem.

If small parts like resistors, coils, or capacitors burn open, the circuit simply doesn't work. But if they short, other symptoms appear that make the tube look bad when the real problem is the part connected to the tube.

Here's a personal example, Lou Franklin age 12: I was building a high-level plate modulator for my old Heathkit DX-40 Ham rig. (It used screen modulation, cheap but without the real punch of high-level AM.) Anyway, I built this Class B push-pull modulator with a pair of 6L6s, got it all wired correctly, and turned on the rig. I keyed the mike and got a normal RF carrier. But as soon as I spoke into the mike, there was a large bang, lots of smoke, and the 6146 Final plate was glowing cherry red. My father screamed, "I told you so!" What happened? Well at the time, I didn't realize that the Final plate voltage with high-level AM at 100% modulation can theoretically swing to <u>double</u> the resting plate voltage. The existing plate bypass capacitor was naturally underrated and blew up in my face, shorting out and passing the full power supply current through the tube! Experience is often the best teacher...

IC Devices

Earlier I said ICs were easy to troubleshoot. That's only partly true. Since an IC is time-consuming to replace you must be very sure it's the problem or the new one may also burn out.

For example, power ICs like audio outputs (TA7205P, TA7222, etc.) often fail due to the high current flowing through them. This same high current also affects shunt components like the bypass capacitors connected to them. If they were bad and you didn't notice, the new IC might smoke too.

IC diagnosis is limited to measuring the listed voltages and looking for the input and output signals. If the signals are present and at their indicated levels, you can be 99% sure the IC is good. Using a 'scope to check for inputs and outputs is the first thing I do. If the signals are missing, greatly reduced, or distorted, then I measure the pin voltages. If all or some of the voltages are grossly different than specified, then I temporarily assume the IC is bad. After removing it, I recheck the voltages at the empty pin foil traces again, and try to interpret which differences are normal and which might mean a problem external to the IC. With no IC in the board I 'scope the input trace again to confirm that a normal input signal is present. With these precautions I'm reasonably sure the new device will fix the problem. When in doubt, always proceed slowly!

TRANSISTOR BASICS

Most active devices in modern CBs are discrete bipolar NPN transistors. PNP types are used when polarity differences are advantageous, like in DC switching and voltage regulator circuits. FETs (Field Effect Transistors) are also found, but are limited to receiver or mixer stages. There are lots of ICs throughout the transceiver, but they're easy to troubleshoot since there's nothing you can do about fixing them internally anyway.

The tricky part for most repairmen is the plain old bipolar transistor, so we'll briefly review some things about them. If you don't understand how transistors work in the first place, go back to the suggested reading list in CHAPTER 1 and study that material first.

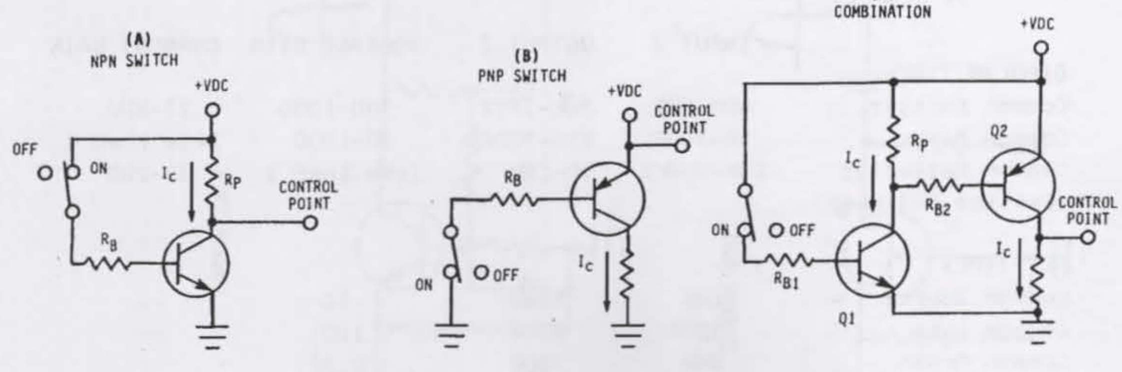
TRANSISTORS AS SWITCHES

Many CB circuits use transistor switches, mostly to control various T/R voltages and signal paths, or to control mode functions which are different among the AM, FM, USB or LSB (or both SSB) modes. The base of the NPN or PNP device controls current flow through its emitter and collector. With no base current flow there's no collector current, and the transistor is cut off. As more base current is applied, the collector current also increases until at some point further base current no longer increases the collector current. This is the "saturation" point. Between the extremes of cutoff and saturation is the linear operating region. Most amplifiers work in the linear region to prevent distortion, but switches generally must avoid this region.

Figure 2-4A shows a basic NPN switch of the type common to CBs. In the "ON" state, a voltage applied to R_b causes current to flow in the base-emitter junction. This causes a much bigger current to flow from collector to emitter. Because heavy collector current flows its voltage drops very low, near ground potential. In the "OFF" state, no base voltage is applied and the transistor remains cut off. Its collector voltage is pulled up near V_{cc} by R_p.

A PNP switch, Figure 2-4B, is commonly used when control is needed in the high-to-low base

FIGURE 2-4
TRANSISTOR SWITCHING CIRCUITS



voltage direction rather than the low-to-high NPN condition. In this case when the base voltage falls to about 0.6 V less than the collector, the transistor turns on and its collector is pulled down near zero volts again.

CBs also use combinations of NPN and PNP devices, Figure 2-4C. This has the advantages of more gain and no signal inversion between input and output. As Q1 turns on its collector is pulled lower and turns on Q2. This complementary-pair arrangement is very common to amplified squelch and AGC circuits, and to voltage regulators and AM modulators in the newer AM/SSB radios. In such circuits they function more like variable resistors than hard ON-OFF switches.

TRANSISTOR AMPLIFIER CIRCUITS

Refer to Figure 2-5 and the following table. Bipolar transistor circuits are classified as Common Emitter, Common Base, and Common Collector. The "common" element is the one shared by both the input and output circuits. FETs can also be defined by their common elements and are included here too. Each type has different characteristics, and each can be found throughout a CB transceiver. Values are approximate and will depend upon operating voltages, currents, external load values, and input signal levels.

Note from Figure 2-5 that only the Common Emitter and Common Source have in/out signal relationships 180° out of phase; all others are in phase.

The Common Emitter is the most widely used configuration for CB circuits like RF, IF, and audio amplifiers, and for DC amplifiers and switches. (The FET equivalent is the Common Source, which has high input and medium-to-high output impedance and is usually chosen for that reason.) The input signal is applied between base and emitter, and the output is taken between emitter and collector. It has the highest power gain of all classes, up to 40 dB.

The Common Base circuit is used for voltage regulation of the "series-pass" type, functioning as a variable resistor where the amount of base current controls the amount of output current. It's often used for the RF amplifier stage in the receiver front end, where the low input impedance makes a good coupling match for a standard 50Ω antenna with better linearity than the Common Emitter. The Common Base also has a higher cutoff frequency, but less power gain. The power gain, which is up to 30 dB, is due to the high ratio of input/output impedances. Since input/output signals are in phase, it oscillates easily and is often used for just this purpose.

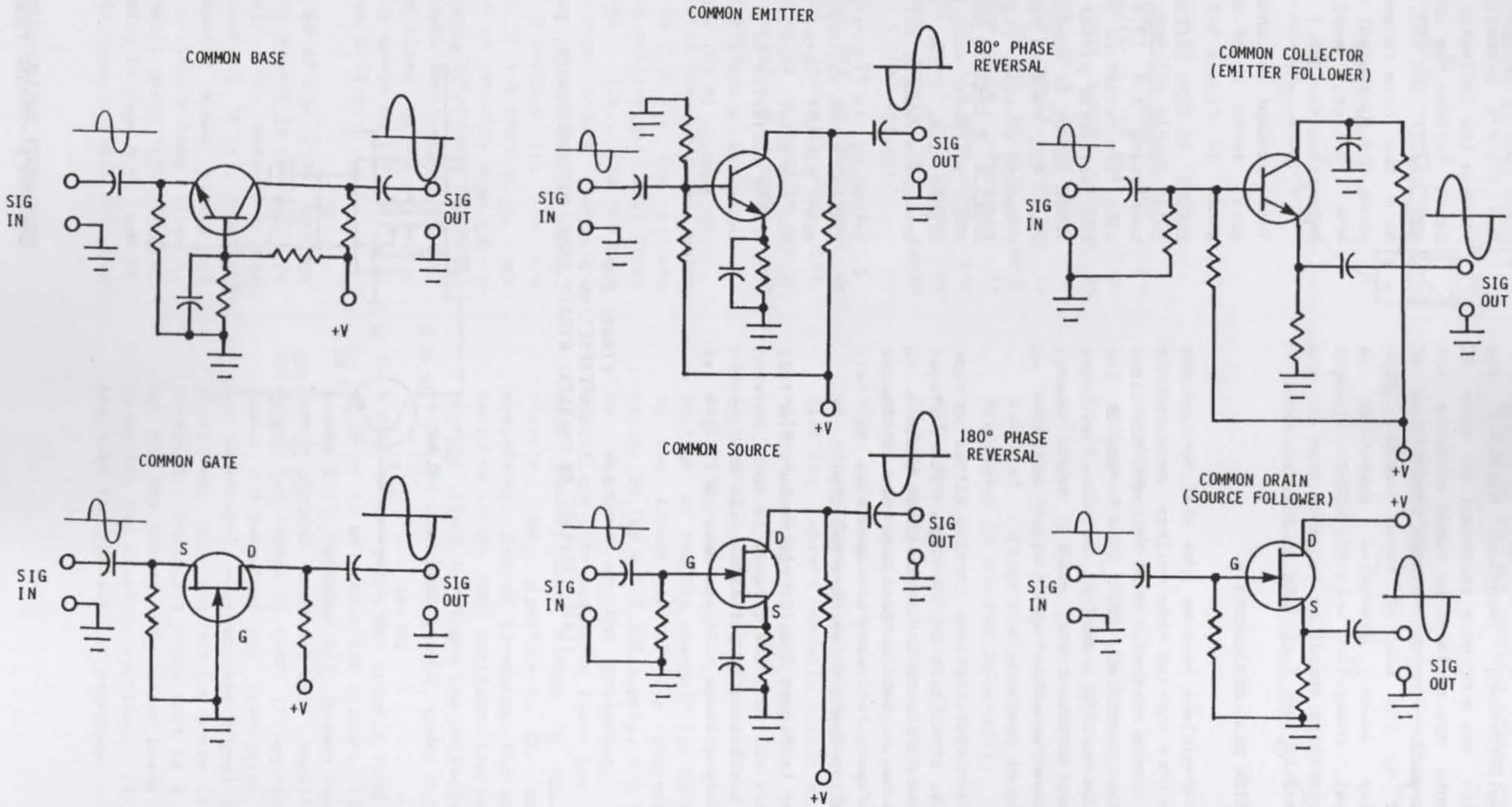
The Common Collector or "Emitter Follower" is rarely used in CBs. The main purpose is for impedance matching, high input to low output. It might be applied in a mike input circuit, where a high-impedance ceramic or crystal mike is being matched to a low-impedance preamp input. It's also found in most Uniden AM/SSB IF strips to DC-couple between IF stages. It has some power gain, up to about 16 dB.

All three circuits may be found in the NPN or PNP configuration, and the only difference is the polarity of the supply voltages. Learn the differences. Memorize them! Whenever you get confused about which way current flows, just follow the arrows; they always point in the direction of <u>conventional</u> (not electron) current flow. "Conventional" means from the more positive to the more negative terminal.

The circuits shown in Figure 2-5 used only resistors and capacitors, which is normal for

	INPUT Z	OUTPUT Z	VOLTAGE GAIN	CURRENT GAIN
BIPOLAR TYPE:				
Common Emitter	400-5KΩ	30K-75KΩ	300-1000	25-200
Common Base	50-300Ω	20K-500KΩ	50-1500	less than 1
Common Collector (Emitter Follower)	20K-500KΩ	50-1KΩ	less than 1	25-200
FET TYPE:				
Common Source	1MΩ	15KΩ	50	--
Common Gate	300Ω	35KΩ	100	--
Common Drain (Source Follower)	2MΩ	300Ω	0.95	--

FIGURE 2-5
BASIC TRANSISTOR AMPLIFIERS



audio, DC, or switching purposes. However for RF amplification, impedance matching and stability are much more important so many RC components are replaced by tuned circuits and transformers. You can always identify an RF circuit by its use of tuned rather than resistive loads. Otherwise operation is identical. Understand what the proper voltages and polarities should be for each type so you know what to look for. This is covered next.

TRANSISTOR BIAS MEASUREMENTS

Many technicians have no idea what conclusions to draw once they've made voltage measurements on the active devices. When voltages are close to those specified, it's safe to assume the stage is working properly. But when voltages are very different they scratch their heads. They know "somethin' ain't right" but have no idea how to proceed.

Most transistor problems involve either an open or short, especially in the higher power stages since manufacturers underrate power devices to save money. Leakage problems tend to happen less often. Following are some tips to help you analyze the problem more exactly.

1. Refer to Figure 2-6. If you measure the full supply voltage, the circuit is open between the two measuring points because no current is being drawn. If you measure 12.71 V at the collector of Q12, Q12 isn't turned on and there's probably an open component between the collector and ground. The only parts between the collector and ground are Q12 itself and R43, so check them first. Note the base-to-emitter voltage drop of about 0.6 V, typical of all properly working NPN transistor amplifiers. (Reverse the polarities for PNP.)

   This concept of shorts and opens seems to give techs a lot of trouble though. As shown in Figure 2-7, <u>any time you read across an open circuit, you will read the full supply voltage.</u> Try this yourself by connecting the 13.8 VDC supply in series with two resistors of any value. Connect the voltmeter probes as shown. Many techs would expect to measure something less than 13.8 VDC because resistors are voltage-dropping devices, right? Yes, <u>but only when there's a load to consume power.</u> If R2 and the voltmeter were reconnected as shown in Figure 2-8, then you would expect to measure a reduced voltage.

2. Returning to Figure 2-6, if you measured little or no voltage, there's probably an open circuit between the measuring points and the power supply, or a short to ground. If the collector of Q12 measures 0 V, this indicates a short to ground or an open to the supply. If C71 shorts it would pull the

FIGURE 2-6
INTERPRETING BIASES
(LATE CYBERNET AM CHASSIS: HYGAIN 2702, MIDLAND 77-888, ETC.)

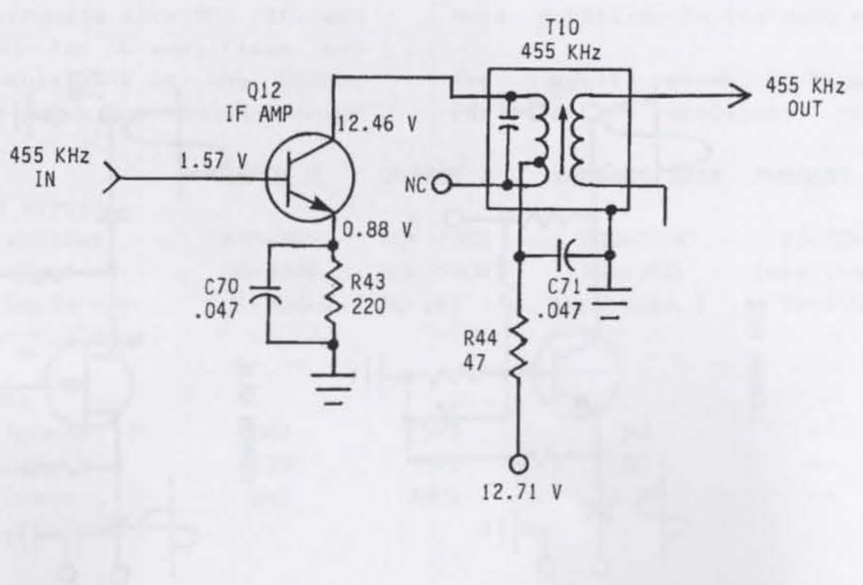


FIGURE 2-7
MEASURING VOLTAGE ACROSS AN OPEN CIRCUIT

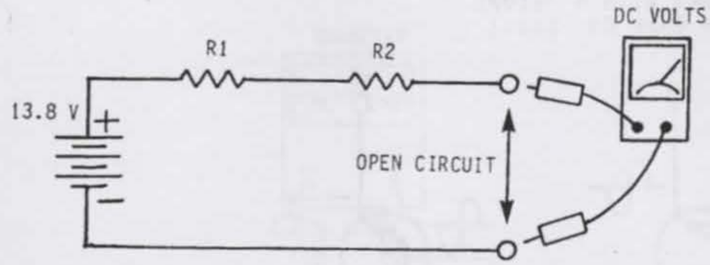
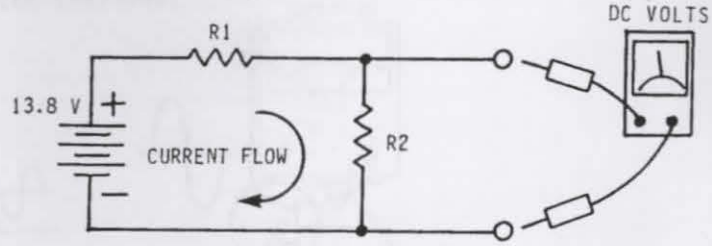


FIGURE 2-8
MEASURING VOLTAGE ACROSS A LOADED CIRCUIT



top end of R44 down to ground and Q12's collector along with it. If R44 is high enough it will limit supply current so nothing as obvious as a blown fuse or burned resistor would result, and this is the usual case. If R44 weren't present you'd definitely see smoke somewhere! If R44 or the primary of T10 were open, the collector of Q12 would no longer be connected to the power supply, so it would then read 0 V. Wasn't that logical?

3. If you find either R43 or R44 open or burned, you should logically check Q12, C70, and C71 for shorts; a short in any of them would pass excessive current and probably smoke the part.

4. Check the base-emitter bias voltage, which should be 0.6 VDC to 0.75 VDC for silicon transistors used as small-signal amplifiers or saturated switches. (I.e., the NPN base should read this much higher than the emitter, regardless of absolute voltages.) When less than 0.5 V replace it; the b-e junction is leaky. If the reading is near 1.0 V, the junction is probably open. There are minor base voltage differences depending on circuit functions; a small-signal type of amplifier will read close to 0.6 V, while saturated switches or power amplifiers will often read as high as 0.75 V.

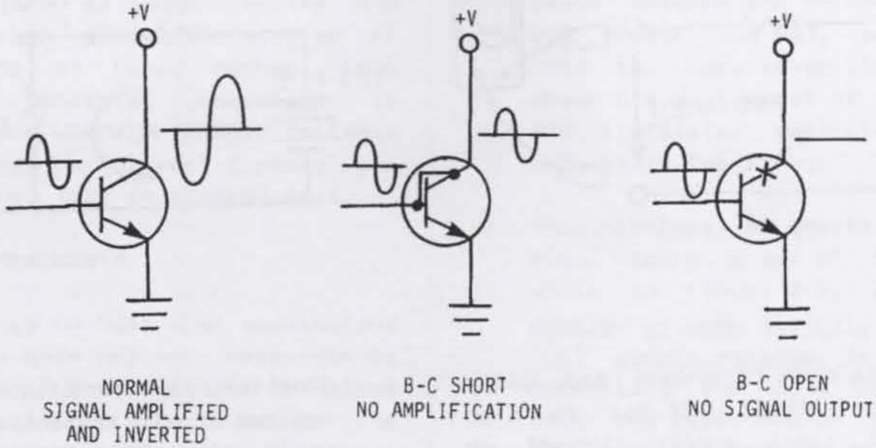
   The most common cause of low bias voltage (assuming the power source is correct) is the transistor itself. Try measuring the collector-emitter junction. If it's equal to V_{CC} but the schematic shows plenty of resistance in the collector-base circuit, the junction is probably open. (Like Step #1 above.) If the reading is near 0 V, use an insulated-hook clip lead to short the b-e junction, which kills the bias. The c-e voltage should instantly rise. Likewise, you could also clip-lead a 10KΩ resistor from collector to base, which should bias it on and pull the collector voltage down. If the expected voltage changes don't happen, the transistor is shorted internally.

   NOTE: The preceeding step is only useful for Class A amplifiers. These tests won't work where there's either no bias or reverse-bias, like oscillators, clipping circuits, or other Class B or C stages. In those circuits there's normally little or no bias without a driving signal present.

5. In general, small-signal amplifiers with a collector load resistor operate with a c-e voltage of roughly one-half V_{CC} to keep it in the linear part of its characteristic curve. So for a 9.0 VDC supply, 4-5 VDC will be measured at the collector. For RF amplifiers with inductive loads the voltage will measure much closer to V_{CC}, since there's no significant DC collector resistance, just AC impedance. For saturated switches in the "ON" position, the base will measure about 0.7 V and the collector will be pulled down near ground, under 0.5 V.

6. A dual-trace 'scope can quickly find shorts or opens in an amplifier circuit. Refer to Figure 2-9. Remember all Common Emitter or Common Source amps not only amplify, but <u>invert</u> the signal by 180°. If you 'scope the input and output of the transistor you'll see immediately whether the signal is being amplified, and whether the phase is being inverted. Obviously there must be a signal up to the tested stage which means signal injection for receiver problems, or keying the mike for transmitter problems.

FIGURE 2-9
TESTING TRANSISTORS WITH A 'SCOPE
(Courtesy Hayden Book Co. Inc.)



Summary Of Transistor Failure Conditions
(Courtesy Heinemann-Newnes Books)

1. Base-Collector short: Base and collector voltage measure the same. Base-emitter junction is still good, giving normal 0.6 V difference reading. Supply voltage falls slightly due to higher current draw.

2. Base-Emitter short: Both terminals read the same, and lower than normal. Collector voltage rises near V_{CC}, since no collector current is flowing.

3. Collector-Emitter short: Both terminals read the same. Device turned off, since emitter rises higher than the base. Supply voltage falls due to excess current draw. Fuse may blow, especially in power circuits.

4. All junctions shorted: All terminals read the same. Supply voltage falls due to excess current draw.

5. Base-Emitter open: Base rises well above normal difference of 0.6 V. Collector rises near V_{CC}, and emitter falls near ground.

6. Collector-Base open: Collector rises near V_{CC}. Emitter falls near ground. Base still reads normal 0.6 V difference, since b-e junction is still good.

TESTING SEMICONDUCTORS WITH THE OHMMETER

Since most faulty semiconductor devices in a CB will be either open or shorted, you can follow bias measurements with simple VOM checks using the resistance scales. This section describes how to make such tests.

Testing Diodes

A diode is a simple switch. When the polarity of the applied voltage forward-biases it, the diode turns on and current flows. "Forward bias" means the anode is at least 0.6 V more positive than the cathode for silicon devices, and 0.2 V for germanium devices. In CB circuits silicon diodes are used almost exclusively; germanium diodes are used only for AM detection, S/RF metering, AGC, and RF overload protection where the lower conduction voltage is desirable. When the semiconductor junction is reverse-biased, no current flows so the switch is effectively turned off. Most VOMs on the resistance scale use a 1.5 V battery, more than enough to turn on a diode junction.

As shown in Figure 2-10, if the negative lead of the meter is connected to the cathode and the positive lead to the anode, the diode will be forward-biased. When this happens there's very little resistance, indicated by a low resistance reading. For silicon devices this reading is typically about 500-600Ω (200-300Ω for germanium) using the Rx100 scale.

If you then switch the meter leads as shown in

FIGURE 2-10
FORWARD BIAS DIODE TEST

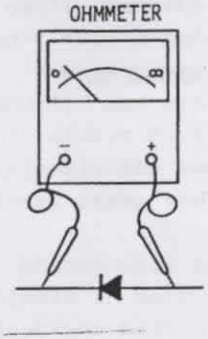
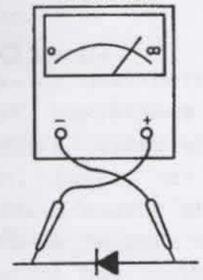


FIGURE 2-11
REVERSE BIAS DIODE TEST



(Courtesy McGraw-Hill Book Co.)

Figure 2-11, the diode is now reverse-biased so very little current flows. The small current that does flow results from the high "back" resistance which causes either a very high resistance reading or none at all, depending upon the scale used. So to test a diode, attach ohmmeter leads first one way and then the other. In one direction you'll read very high resistance and in the other very low resistance. But note the following precautions, which also apply to testing transistors:

1. The actual ohms reading is different from meter to meter and for different range scales. To increase the accuracy of your readings, compare them to a known good device of the same type.

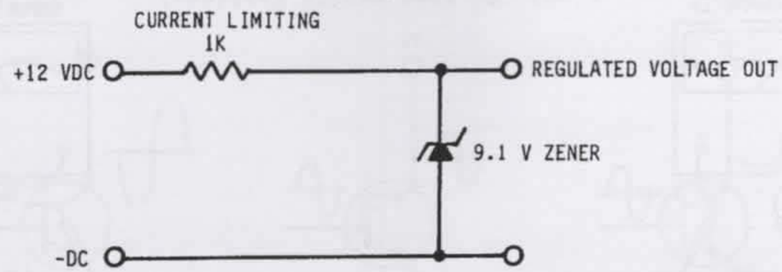
2. You'll generally have to disconnect one device lead before measurements. In-circuit tests can be very misleading, since there may be low-resistance components in parallel with the diode which make it appear shorted. For example, relay coils have shunt diodes to protect against voltage spikes as the relay switches. You couldn't test this diode without unsoldering one lead, because it would have a low resistance reading both ways. How often have you been fooled into thinking you found a bad diode, only to discover upon lifting a lead that it tests good?

   When testing transistors the ohmmeter battery often has enough voltage to turn on the junction, giving a false reading. Electrolytic capacitors of the type used in CBs can also provide low resistance paths when accidentally reverse-polarized with an ohmmeter. A VOM that uses several volts to operate can damage a junction if the reverse breakdown voltage is exceeded. For these reasons, play it safe by using a VOM powered only by a 1.5 V battery, and limit current by using the Rx100 or higher scale. Many meters have a special "LOW OHMS" scale to measure resistances without turning on the junctions, a good feature to consider.

3. Make sure you know which meter lead is positive and which is negative, especially when testing transistors. Yes, I'm serious! <u>The BLACK lead on many VOMs may only be negative for voltage measurements, not necessarily for resistance readings!</u> Many people don't realize this. It's easily checked by testing some known good diodes out of circuit; if placing the BLACK lead on the cathode (the banded end) and the RED lead on the anode reads a high rather than low resistance, the meter polarity is reversed. (BLACK is [+], RED is [-].) This doesn't mean the meter's bad; it's just the way they designed it. My little Radio Shack 22-201A multimeter works this way, and yours may too.

To test for leakage or shorts, switch to a higher resistance scale like Rx1000 and connect the leads in the reverse-bias order. With a low resistance this way you have a shorted or leaky diode, assuming you removed one lead from the circuit first. Silicon diodes show reverse resistances greater than 1MΩ. Germanium diodes have higher leakages, about 100KΩ to 1MΩ. Some diodes may function OK in certain applications even with lower leakage resistances. For example, rectifiers have physically larger junctions and may show higher leakage currents.

FIGURE 2-12
TESTING ZENER DIODES

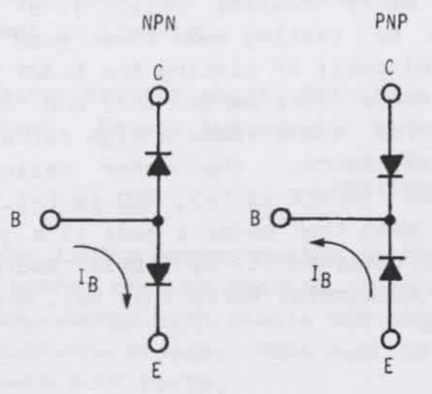


You can check Zeners like any other diode for opens, shorts, or leakage. But that doesn't tell you if it's regulating at the specified value. Check them as shown in Figure 2-12 by applying a DC voltage at least 2 volts higher than the Zener voltage through a series limiting resistor.

Testing Transistors With An Ohmmeter

Transistors can be checked like diodes but need a bit more caution. Think of a bipolar transistor as two back-to-back diode junctions like those shown in Figure 2-13.

FIGURE 2-13
BIPOLAR TRANSISTOR EQUIVALENTS



The common element is the base. By connecting a VOM as shown back in Figure 2-10 and 2-11, the junctions will be forward-biased one way and reverse-biased the other way. Like diodes, there's very little current flow with reverse bias so you get a high resistance reading. With forward bias current flows so the resistance reading is low. You can check PNP and NPN transistors exactly the same way, except that polarities are reversed so the meter leads must also be reversed for readings to make sense.

NPN or PNP?

The NPN/PNP subject confuses many techs, so let's try to clear this up. First of all, about 95% of the discrete transistors in a CB are NPN types. The only reason PNP types ever appear is when it's convenient to take advantage of their opposite polarities. Examples are DC switching, voltage regulation, and squelch circuits. For almost every other function, the NPN is used.

How do you figure out which one is which? If you have a schematic, just look which way the arrow points on the emitter lead. Here's a simple memory trick I was taught:

"NPN = No Point In"
"PNP = Point In Please"

Sounds corny but does make you remember! Now assume you don't have a schematic, or the schematic is printed wrong, which does occasionally happen. Check the voltage relationship between the collector and emitter. If the collector voltage is more positive than the emitter, it's an NPN device; if the collector voltage is negative with respect to the emitter, it's a PNP transistor. An easy trick to remember collector polarity is:

NP positive N
PN negative P

If you can't remember any of this, just follow the arrows; the arrows <u>always</u> point in the direction of conventional (not electron) current flow, from the more positive terminal to the less positive terminal. This is also true for diodes.

Identifying The Leads

Now suppose you can't read the number on the case and you don't have a schematic, even a misprinted one. Suppose you don't have a Japanese spec manual, and you know American replacements don't always have the same basing even though electrically the same. How can you identify the emitter, base, and collector?

Simple ohmmeter checks will tell you. Check each pair of terminals in both directions. Two of the six combinations will give low forward resistance readings. Of those two combinations, one lead will be common to making the other two leads read low resistance. This common lead is the base. If the positive meter lead on the base gave the low readings, it's an NPN type; if the negative lead it's a PNP type. The meter polarities are the <u>true</u> ones, regardless of RED or BLACK color. With the base known, you can figure out the others by studying their connections within the circuit.

Leakage Tests

Transistors when reverse-biased with an ohmmeter should show very high resistance readings. For silicon transistors, forward bias will read under 500Ω on the Rx1000 or Rx10K scale. When reverse-biased they probably won't register at all. I just tried both a small signal and power type and couldn't get a twitch even on the 10M scale of two different meters. Germanium transistors are non-existent in CB radios these days so don't worry about them unless you're fixing some ancient rig from the early 1960's. (Germanium tests much higher leakages than silicon, so don't be too quick to decide it's faulty.)

Testing FETs

You can also use a VOM for FETS, but you must be more careful. Use only a VOM with a "LOW OHMS" scale as previously mentioned. MOSFETs in particular are easily damaged by static, so always keep them in a conductive carrier and use a grounded soldering iron.

The plain old JFET (2SK19, 2SK49, MPF102, etc.) can be tested like a bipolar transistor. Use the Rx100 or Rx1K scale for forward resistance readings. Only N-channel FET types are used in CBs, so connect the (true) positive meter lead to the gate and the negative lead to the drain or source. Typical JFET forward resistances are 200-1KΩ. When reverse-biased there should be almost infinite back resistance; otherwise it's leaky or shorted.

For the single- or dual-gate MOSFET, use the meter's highest resistance scale to minimize the current. MOSFET gates are insulated by an incredibly thin layer, so tests between the gate(s) and drain/source should show almost infinite resistance in both directions. If not, the gate insulation has broken down.

Understanding Device Markings

Here's a brief lesson in understanding the EIAJ (Electronic Industries Association of Japan) markings on diodes and transistors. The first number ("1," "2," or "3") is the number of electrical connections, minus one. Thus diodes all start with the number "1," bipolar transistors with "2," and dual-gate MOSFET transistors with "3." The next item is a letter "G" or "S". The "G" means germanium material, the "S" means silicon. Next is a letter "A," "B," "C," or "D" for bipolar transistors or "J" or "K" for FETs, which identifies the polarity and application. The "J" means a P-channel FET, the "K" means an N-channel FET. The "A," "B," "C," and "D" for bipolar transistors are grouped as follows:

A = PNP, high frequency
B = PNP, low frequency
C = NPN, high frequency
D = NPN, low frequency

The next number group is the actual registered device number, such as 2SA<u>733</u>. Suffix letters (2SC1674<u>L</u>) after the device number refer to an improved production version of that device. (An "A" suffix means the first improvement, "B" is the second improvement, and so on.) Unless you're using an exact replacement this makes no difference, since SK or ECG subs don't differentiate that precisely. For exact replacement you can always use an improved device for its earlier version, but the reverse isn't necessarily true for every circuit.

If you think about where you've seen all these device numbers on a CB schematic, it starts to make some sense, right? The following examples help clarify this numbering system.

BIPOLAR TRANSISTOR APPLICATION EXAMPLES:

2SC945	=	NPN silicon high frequency (low power)
2SC1307	=	NPN silicon high frequency (high power)
2SB525	=	PNP silicon low frequency (medium power)
2SA733	=	PNP silicon high frequency (low power)
2SD325	=	NPN silicon low frequency (high power)
2SK19	=	N-Channel JFET
3SK45	=	N-Channel dual-gate (MOS)FET

In CB applications "low frequency" generally means audio, switching, or voltage regulation uses. "High frequency" means everything else, like RF and IF amplifiers and mixers. There are always a few exceptions. For example the 2SA733 and 2SC945 are often used in switching or squelch circuits where cheap, low power PNP or NPN devices are needed. You can use a high-frequency transistor for a low-frequency application, but not the other way around.

Transistors have standard industry markings and you can't necessarily tell who made it unless the package is physically large enough to have the manufacturer's logo on it. The "TO" prefix which defines its physical case (TO-220, TO-92, etc.) means "Transistor Outline." ICs are usually identifiable by their markings, which are read, left to right: manufacturer, generic family (digital or linear), registered device number, package material, and special factors like reliability or temperature range.

Each manufacturer has its own letter prefix. Full details are found in the IC MASTER yearly catalog. (Available from Hearst Business Communications, 50 Charles Lindbergh Bl. #100, Uniondale NY 11553. TEL: 516-227-1300.) However before you spend a bunch of money on that, you should know there's a free download at: **http://ptf.com.**

Use their Web search box and just type "IC Master."

Sometimes proprietary or "in house" numbers are assigned to transistors and ICs, making replacement more difficult. Following is a brief prefix ID summary for the companies whose chips you're most likely to find in CB radios.

The IC suffix letter is especially important, because it refers to some physical package characteristic which you'll probably need to know for exact replacement. This may refer to the package material like plastic or ceramic, or the lead configuration. Many manufacturers use the letter "P" for plastic (MC145106<u>P</u>), but not always. NEC uses a "C," as in µPD2824<u>C</u>. A common dual op-amp is the 4558D or 4558S. The "D" means dual-in-line pins, the "S" means single-in-line. Obviously they're not going to be interchangeable!

COMMON CB MANUFACTURERS' IC PREFIXES:

AN, MN	=	Panasonic (Matsushita)
BA	=	Rohm
CA, CD	=	RCA
HA, HD	=	Hitachi
LA, LB, LC	=	Sanyo
LM, MM	=	National Semiconductor
M	=	Mitsubishi Electric
MB	=	Fujitsu
MC, MRF	=	Motorola
NE	=	Signetics
NJM	=	New Japan Radio Co. Ltd.
SN	=	Texas Instruments
TA, TC	=	Toshiba
TDA	=	European Association: SGS, Siemens, Telefunken, etc. May be second-sourced from some others on this list.
µPC, µPD	=	NEC Electron

Many ICs use the same device number with only the manufacturer's prefix being unique, like <u>NJM</u>4558, <u>µPC</u>4558, etc. They're the same. Sometimes you'll find a bunch of other numbers often mistaken for the device number. Usually these are control or batch numbers so the manufacturer can trace a production problem on a run of bad ICs. For example, the chip may have markings like "LM324N" and "8307" on it. We smart technicians of course recognize the "LM-324-N" as National Semiconductor's linear monolithic device #324 in molded DIP epoxy package. The "8307" means "the 7th week of 1983," when it was made.

YOUR BUILT-IN TESTERS
(EYES, EARS, NOSE, FINGERS)

You'll discover a lot of CB repairs don't require fancy test equipment. When you learn to be observant and logical, ask the right questions, and use your own senses, the cause of many common problems will jump right out at you. On the next page is a brief summary of some cause and effect problems that can be analyzed by using sight, sound, smell and touch, and good old common sense.

LIGHTS & LED DISPLAYS:

1. Doesn't light up = burned out bulb(s), bad power connections, faulty power source, burned out fuse.
2. Lights dimly = power supply problem, wrong lamp previously installed.
3. Lights too brightly = power supply problem, wrong lamp previously installed.
4. LED segment(s) out = poor solder connection of LED pin(s) or associated pull-up resistor(s), bad 7-segment display block.

RESISTORS:

1. Burned, charred, blistered, cracked, or smoking = excessive current.
2. Cold or cooler than normal = open, broken lead, lower than normal current, resistance value increased.
3. Hot, hotter than normal = excessive current.

CAPACITORS:

1. Bulging, discolored, charred, hotter than normal = leakage.
2. Loose connection(s), noisy output = intermittent or complete circuit failure, defective part, frequency shift.

CHOKES & TRANSFORMERS:

1. Burned, charred, arcing, smoking, hotter than normal, smell of tar = high current, faulty shunt component, turns shorted.
2. Cold to touch = open transformer, no input voltage, no load connected to output.
3. Buzzing sound = laminations or windings loose, excess current.
4. Output changes = intermittent part or connection.
5. Smell of ozone = internal arcing.

SPEAKER:

1. Distortion, buzzing, rattle = broken cone, voice coil rubbing, loose mounting, faulty audio amp.
2. Loud hum or buzz with signal = poor power supply filtering.
3. No signal sound, buzzes or hums = open voice coil, open coupling from amplifier, open connection.
4. Buzz or hum but no signal sound = open signal path to speaker.

S/RF METERING:

1. No deflection = open signal path, faulty meter, bad sampling diode.
2. Too much or too litte deflection = improper adjustment.

TUBES:

1. Doesn't light up = bad tube, filament voltage missing.
2. Glows red hot = bad tube, incorrect bias or short, no drive, shorted shunt component on socket.
3. Arcing = faulty tube.
4. Filament dimmer than normal = filament voltage problem, bad tube, wrong tube type.
5. Noisy or intermittent output, arcing, or microphonic when tapped = bad tube, loose connection in socket, elements shorting.
6. Cold to touch (except gas voltage regulators) = bad tube, low filament voltage.
7. Visible purple haze = gassy tube (except voltage regulator types which are supposed to glow when conducting).
8. Milky color = vacuum missing due to cracked glass.

TRANSISTORS:

1. Smoking, arcing, split, cracked, feels hotter than normal = junction shorted, excessive current, voltage or bias.
2. Output intermittent when tapped = bad device, bad connection.
3. Cold or cooler than normal = junction open, no current draw, improper bias, supply voltage missing or low.

PC BOARDS, CONNECTORS:

1. Output change when flexed or pulled = intermittent connection, poor solder joint, cracked PC trace.
2. Warm or hot = dirty connection, high current, shorted.
3. Burned, smoking, open PC trace = shorted series device, resistive connection, high current.

(List courtesy McGraw-Hill Book Co.)

NOTES