7 POWER SUPPLIES & T/R SWITCHING

All modern CB equipment operates from a 12 VDC main power supply input. In mobiles this comes directly from the vehicle battery and charging system. The CB is normally connected to a fused vehicle circuit rather than directly to the battery; otherwise the operator must remember to turn the radio on and off each time. The automotive charging system normally outputs about 13.8 VDC to maintain the battery, which is why this figure is commonly specified.

Transistorized base radios operate on exactly the same 13.8 VDC as mobiles, but they include additional circuits to change the AC mains of 110/220 VAC to 13.8 VDC. This extra circuitry is normally located on a small PC board on the frame of the main chassis. Most manufacturers use exactly the same main chassis for their base and mobile models having similar features.

Tube-type radios require various positive and negative DC voltages, as well as filament voltages to light the tubes. These voltages come from a transformer-based AC power supply connected to the 110/220 VAC mains. Some radios use hybrid circuits combining both tubes and transistors, and will require a number of low and high DC output voltages.

Since there are still many repairable tube CBs (at least in the U.S.), you should understand their operation too. Judging by the requests I get, tube rigs will be around for a long time. It's especially hard for those whose only electronics experience is with solid-state equipment. For one thing, a different way of thinking and a lot more caution is needed. Secondly, there are very few remaining electronics textbooks or references to help the newcomer with vacuum tube theory. Not to mention schematics or SAMS Fotofacts!

Regardless of what's used for the main DC supply, it will be further divided into a number of branch circuits that power specific functions in the radio. These branches may be simple or complex, depending upon factors like the degree of regulation, 23- vs. 40-channel, or AM vs. multimode. In this chapter we'll explore how these various operating voltages are generated in tube and transistorized CBs. In addition T/R control circuits are also analyzed, since problems often occur in only one mode and are usually related to specific branch circuits. I'm grateful to the Howard W. Sams Publishing Co. for permission to reprint some of their more complicated schematics here.

THE MOBILE DC POWER SUPPLY

The simplest DC power supply is found in AM and FM radios. The radio ties to the main 13.8 VDC vehicle supply through a pair of wires, usually colored RED and BLACK to indicate positive and negative inputs, respectively. The RED wire is usually fused at 2.0 amps using an in-line or chassis-mounted fuseholder. (SSB and export models are often fused at 3.0 A or more.) Most radios use a plug & socket arrangement for the DC power, although some cheaper models have the wires entering the frame directly through a plastic strain relief with no socket.

Positive Vs. Negative Grounds

Some large trucks and foreign cars use a positive-ground electrical system, which means the vehicle frame is the [+] connection and the [-] is the hot side. Partly because of this, most CBs have a "floating" chassis which is electrically insulated from the metal frame to work with either system. You'll notice the PC board mounting screws don't actually touch any foil on the main board; they pass through holes having either no pads, or isolated foil pads. On floating chassis the frame is <u>not</u> the ground return for DC or signals; the ground return is the chassis common tie point. This is the large foil area running all around the PC board. The large foil surface forms a ground plane to help break up stray ground loops, and offers a low impedance at CB frequencies and higher.

In positive-ground systems, the BLACK [-] wire should always be fused to protect the radio! Most people don't even realize this, since manufacturers didn't bother with the extra expense of fusing both power leads for such a relatively small percentage of vehicles. You can't connect a negative-ground radio to a positive-ground vehicle without using a special inverter. (Radio Shack still sells these, Cat. #22-129.) The odds of seeing such radios are small though. Some 23-channel models like the Johnson Messenger 123B had a polarity-reversing switch for the RED and BLACK DC input wires.

Ground Loops

If the frame ground is at one DC potential and the chassis common point at another, sparks may fly with careless handling of tools and test probes. The radio is also more likely to show self-oscillation or increased TVI/RFI problems. These are the result of "ground loops," which are small currents generated when physically grounding a circuit at more than one place. That's why you see two separate ground symbols on the schematics: the little fork symbol means frame ground, and the symbol with the tapering horizontal lines means signal/DC ground.

Refer to the following sketch. "A" shows three circuits that each have different wire lengths running to the ground point. The boxes can represent separate circuits within one radio, or separate pieces of station equipment. The ground of Circuit #3 is tied to the ground of Circuit #2, which is tied to the ground of Circuit #1. The problem is that real wire lengths may have slightly different impedances, indicated by Z1, Z2, Z3. As shown by R1, R2, R3 and the arrows, these may create unequal ground currents, especially where RF is circulating. They're known as "common mode" currents.

An arrangement that improves this situation is shown in "B" and is called a "star" ground. This is the usual CB chassis grounding method. Note Circuit #1, #2, and #3 are tied only to a single common ground connection, and don't rely on each other for grounding. One advantage of printed circuit boards is that the large common foil surface allows a single short, direct ground connection to be used for every circuit. Ground loops in CBs can be caused by open bypass capacitors that normally tie the frame to the common PC foil. Or in base stations, by using more than one grounding point for all the various station accessories.

Because of ground loops, you can't make meaningful DC voltage measurements from any ground reference except the common circuit tie point. On older tube-type equipment this was the same as the metal frame; newer tube radios using PC boards have the same circuit common points as transistorized chassis. Never assume the signal/DC ground and the cabinet ground are the same; they may not be! On radios having floating chassis (virtually all modern radios), they're different. Only a few older solid-state CBs used the same ground for chassis and frame, generally the negative-ground-only models.

Since the metal shields of tuning coils and transformers are always soldered to the common circuit ground, you can use them for a [-] voltmeter reference when unsure. For 'scope or relative RF measurements the probe's ground can be clipped to the frame though, because it's AC-coupled in numerous places to the circuit common point via capacitors. These bridging capacitors prevent ground loops and unwanted oscillations, particularly from stray RF.

GENERATING GROUND LOOPS
(Courtesy Gernsback Publications Inc.)

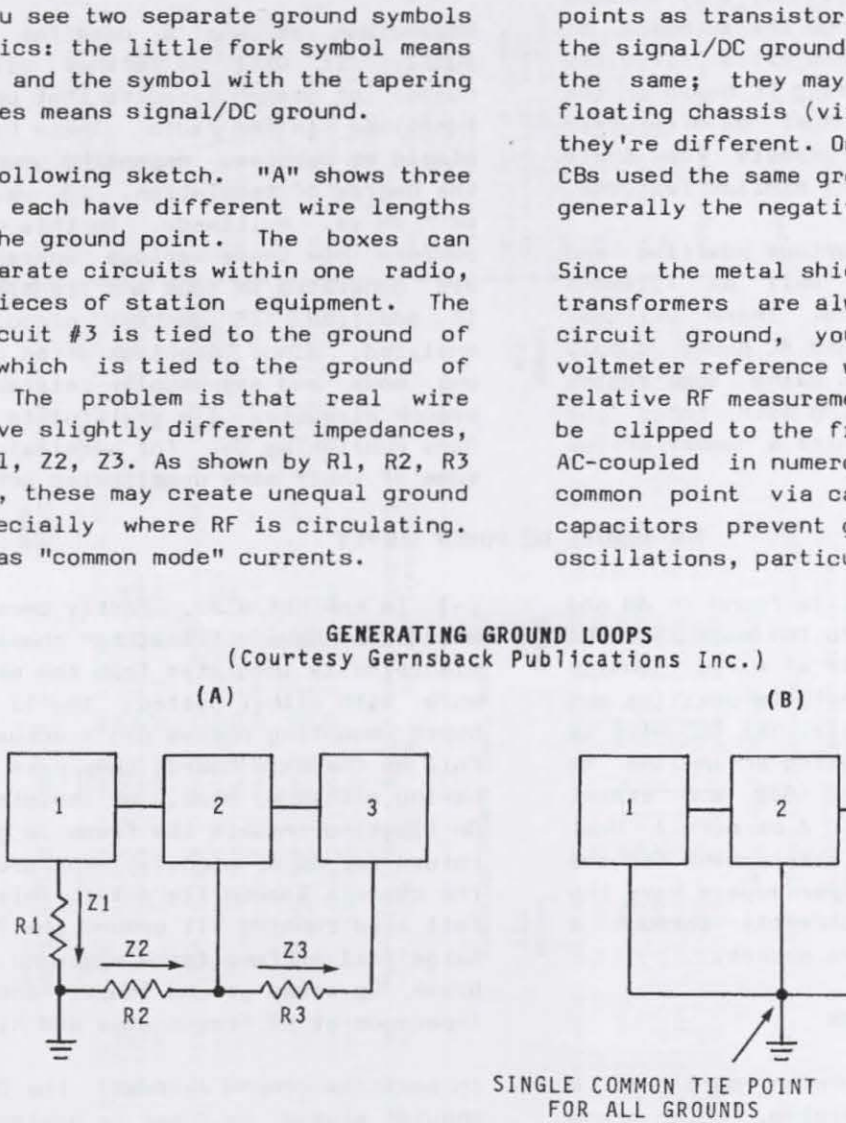


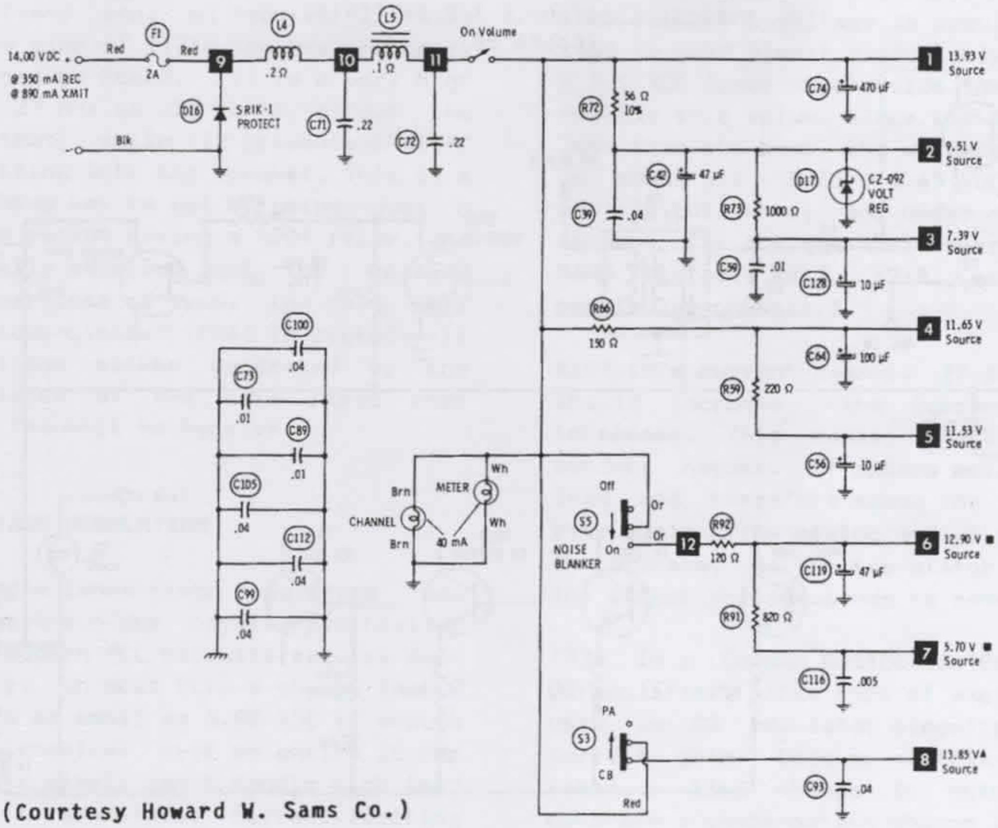
Figure 7-1 shows the simplest 13.8 VDC power system. D16 protects against accidental reverse-polarity connections, and when shorted is the <u>most common cause</u> for the "Blows Fuses" symptom. If the positive supply were connected to the BLACK wire and the return to the RED, the diode would conduct. With no series resistance to limit current flow, the fuse would theoretically blow. I say "theoretically" because more often than not the diode blows first! And CB operators also have a bad habit of replacing the correct fuse with something huge, like 10 A! Once the diode does short, a new fuse will blow every time the radio is reconnected to the DC source and turned on.

This diode should always be replaced with one having a forward current rating greater than the fuse, or it will blow again if the leads are accidentally reversed. Unfortunately even the manufacturers tend to use a 1 A diode here, which is why it's such a common failure. If a 2 A fuse is normal, use the heavier 2.5 A or 3.0 A replacement diode like an ECG125/SK3081 or ECG156/SK3051. <u>Never</u> use a 1N4001/ECG116 type here, since they're only rated at 1 A. (Note that SAMS Fotofacts almost always lists them as replacements though; they simply copied what the manufacturer specified on the original schematic, which was also wrong!)

After replacing a shorted diode, inspect the 13.8 VDC PC foil too; the excess current may have split it with a hairline crack, or done something more obvious like curling the foil right off the board. A few older radios don't even have the protection diode; if you see this on your bench, do the customer a favor and put one across the DC power entry point.

L4, L5, C71 and C72 in Figure 7-1 are for RF and spike suppression. Any ignition noise (which is broadband RF) is filtered before it can enter the radio via the power line. L5 is an iron core choke, which prevents voltage spikes from damaging other components. After the 13.8 VDC passes the ON/OFF switch part of the VOLUME control, it branches off into eight different directions. Source #1 is always used to supply the RF power amps via the modulation

FIGURE 7-1
EARLY MOBILE DC DISTRIBUTION SYSTEM
(Cobra 29)



(Courtesy Howard W. Sams Co.)

transformer, and the audio power amp stage. Note there's virtually nothing to limit current on this source except the series resistance of the coil windings. Thus a shorted RF Driver, RF Final, or push-pull audio power transistor can easily (and very often does) cause the "Dead Radio" or "Blows Fuses" symptom.

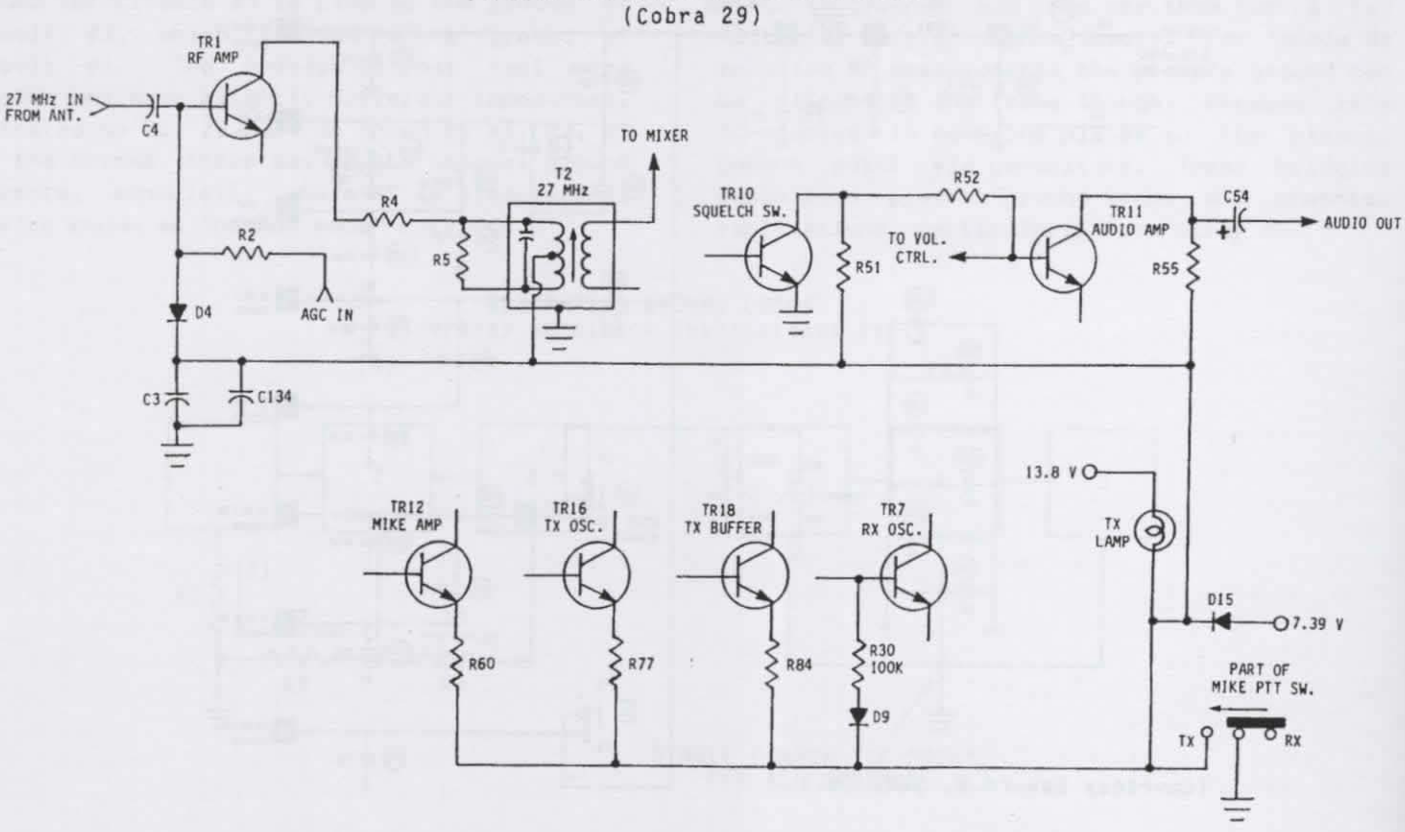
Each branch circuit is established using series resistors and shunt filter capacitors. R72 limits current to Source #2, R73 to Source #3, etc. Source #2 is the only one with fixed regulation from Zener diode D17 because it powers the oscillators, where better stability is needed. Sources #6 and #7 power the optional Noise Blanker circuit. Source #8 is a constant Transmit voltage used to power the entire transmitter oscillator/RF amplifier chain. It's disconnected in the "PA" position so only the mike and audio chain will function.

Electronic T/R Switching

The power supply in Figure 7-1 was an example of "electronic" T/R switching, in contrast to "relay" switching. The names refer to how the various T/R supply voltages and signal paths are controlled; i.e., by conduction of active devices, or by hard make/break relay contacts. Electronic switching is much more common and gives many techs difficulty due to the large number of functions being controlled. But it's easy to understand when you consider each switched stage individually. In Figure 7-2, the required switching in this particular radio is summarized.

When the PTT button is pushed, eight different changes occur. The emitters of Mike Amp TR12, Transmit Oscillator TR16 and Transmit Buffer TR18 are grounded so they'll operate. Source #3 from Figure 7-1 is pulled down to ground by D15, effectively shorting it out. This voltage has enough series resistance (not shown) to limit the short-circuit current to a safe value. D15 also isolates Source #3 from the 13.8 VDC which will simultaneously light the Transmit lamp. Grounding Source #3 removes the collector supply to Squelch Switch TR10, Audio Preamp TR11, and Receive RF Amp TR1 to disable the receiver. It also kills the base bias on Receive Oscillator TR7 when D9 switches. The high RF impedance of R30 insures T/R isolation.

FIGURE 7-2
TYPICAL ELECTRONIC T/R SWITCHING
(Cobra 29)



Grounding Source #3 also makes D4 conduct, which kills TR1's base voltage too. This extra function is needed to make absolutely sure the b-e junction of front-end amp TR1 is protected from transmitted RF. Like all electronically-switched CBs, the receiver input is connected directly to the RF power amps on Transmit, since they share a common antenna coupling network; there's no hard T/R antenna routing like that used in relay switching.

Relay T/R Switching

Since relays are much more expensive than diodes, they were limited to a handful of older CB models. The relay may be a DPDT or 4PDT type, depending upon how many T/R voltages and signals are switched on a set of poles. One set is always used to switch the antenna between the receiver front end and the transmitter RF power amps. The coil works on 13.8 VDC from the main input; a standard 12 VDC relay is used.

In Figure 7-3 a DPDT relay is used. One set of poles supplies Sources #5, #6, and #7 on Receive, and Sources #8, #9 and #10 on Transmit. The other set switches the antenna and speaker. Besides routing the antenna between the transmitter RF power amp and the receiver front-end amp, on Receive it also grounds the low side of T17's speaker secondary via L13 so it can be heard. L13 is a very high impedance to 27 MHz so it won't affect the transmitter output, while L12 prevents that RF output from getting into the speaker. This is a simple and cheap way to get by using just a DPDT relay. (In radios having a 4PDT relay, one pole is normally reserved just for speaker grounding.) Regardless of type, the relay coil is normally diode-clamped (CR6) to protect it from high-voltage spikes generated by the inductive collapse of the coil field when switching from Transmit to Receive.

TRANSISTOR VOLTAGE REGULATION

The use of simple Zener diode regulators was good enough for the older crystal-synthesized CB radios, but modern PLL circuits require much better stability. In most PLLs a change in VCO control voltage as small as 0.02 VDC is enough to shift the synthesizer over an entire 10 KHz channel! A Zener simply can't handle high load currents, and its associated current-limiting resistor is wasteful.

Instead, electronic voltage regulation offers superior stability by using one or more transistors. A transistor is connected as a variable resistance in series between the supply and the load, and feedback from the load side adjusts this resistance to keep the output voltage steady. The advantage is that the transistor handles all the load current, with a Zener diode used only as a low-current voltage reference in the transistor's base circuit.

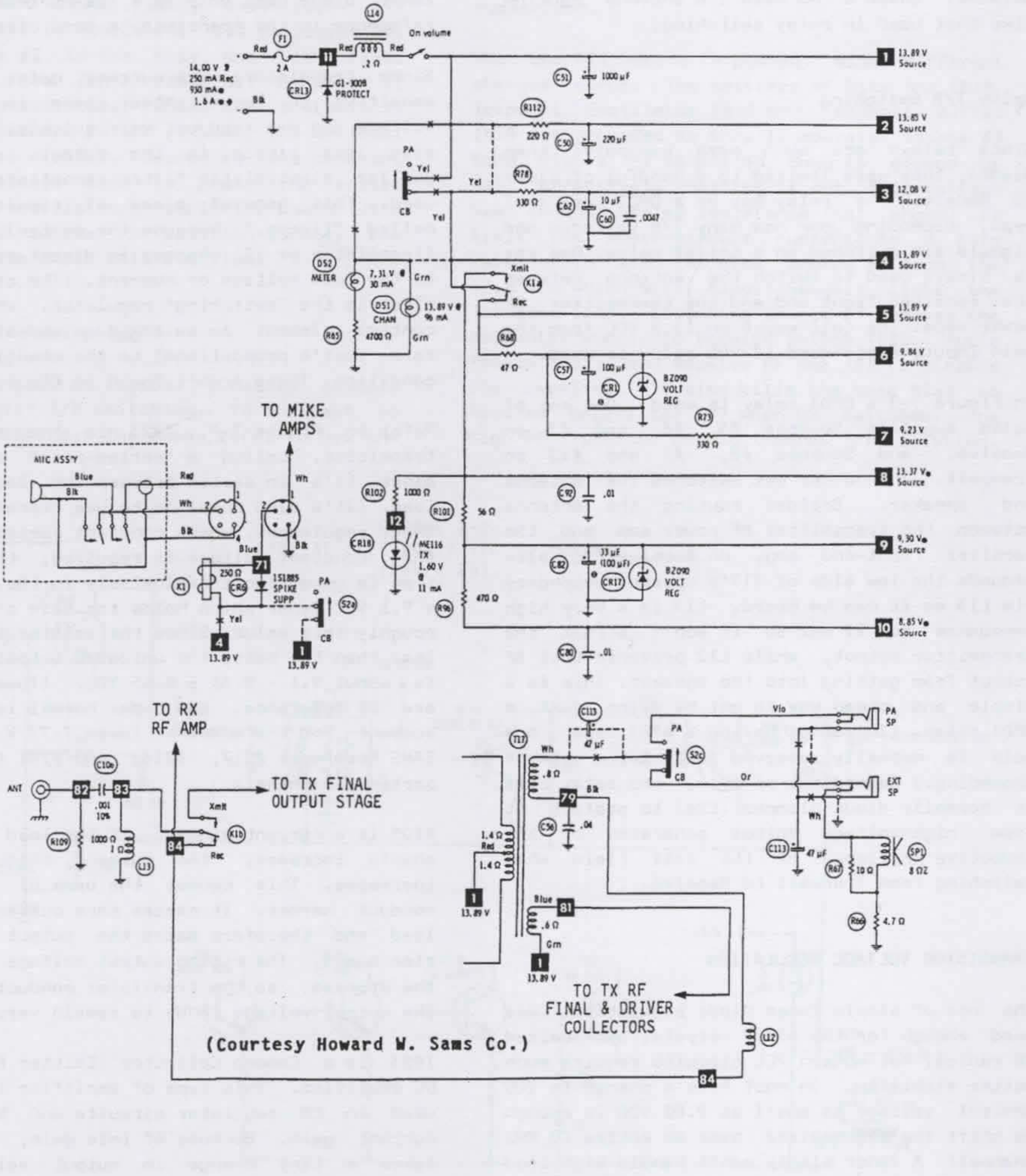
Since transistors have current gain, they're sensitive to the slightest change in output voltage and can readjust very quickly. There's also less ripple in the output, allowing smaller electrolytic filter capacitors to be used. This general class of regulators is called "linear," because the control element (transistor or IC) changes in direct proportion to the load voltage or current. (The other main class is the "switching" regulator, where the control element is switched on and off at a rate that's proportional to the changing load condition. These aren't found in CBs.)

Refer to Figure 7-4. TR23 is the regulator transistor, called a "series-pass" regulator since it's in series between the source and load. (It's also possible to use transistors as shunt regulators, where constant <u>current</u> rather than constant voltage is required; the series type is used almost exclusively in CBs.) D22 is a 9.1 VDC Zener which holds the base of TR23 at roughly this value. Since the emitter is 0.65 V less than the base, the unloaded output voltage is about 9.1 - 0.65 = 8.45 VDC. (These Zeners are 5% tolerance, and under normal load will account for the somewhat lower 7.79 V shown in SAMS Fotofacts #217, #218, and #281 for this particular chassis.)

R105 is a current sensor. If the load current should increase, the current through R105 increases. This causes the base of TR23 to conduct harder. It passes more current to the load and therefore makes the output voltage rise again. The rising output voltage reverses the process, so the transistor conducts less. The output voltage tends to remain very steady.

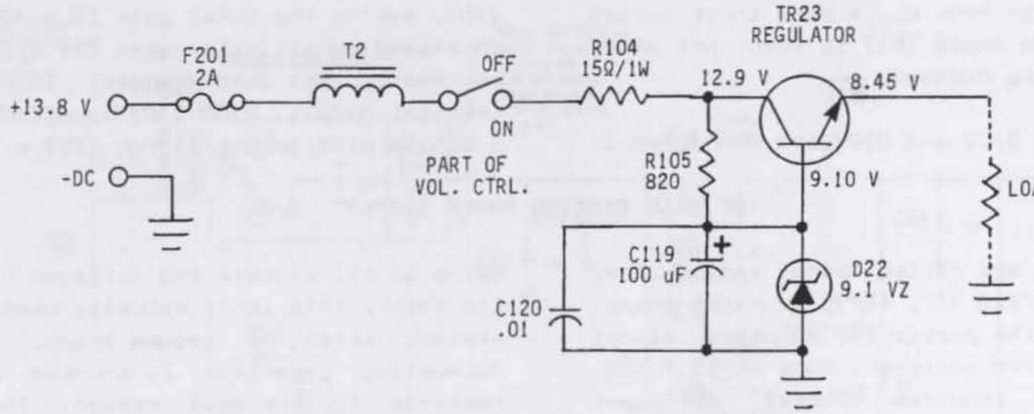
TR23 is a Common Collector (Emitter Follower) DC amplifier. This type of amplifier is widely used in CB regulator circuits and has high current gain. Because of this gain, it only takes a tiny change in output voltage to generate a compensating change in base current and maintain the regulation.

FIGURE 7-3
TYPICAL RELAY T/R SWITCHING
(Pace CB144)



(Courtesy Howard W. Sams Co.)

FIGURE 7-4
SERIES-PASS VOLTAGE REGULATION
Cobra 29GTL, 29LTD, etc.)



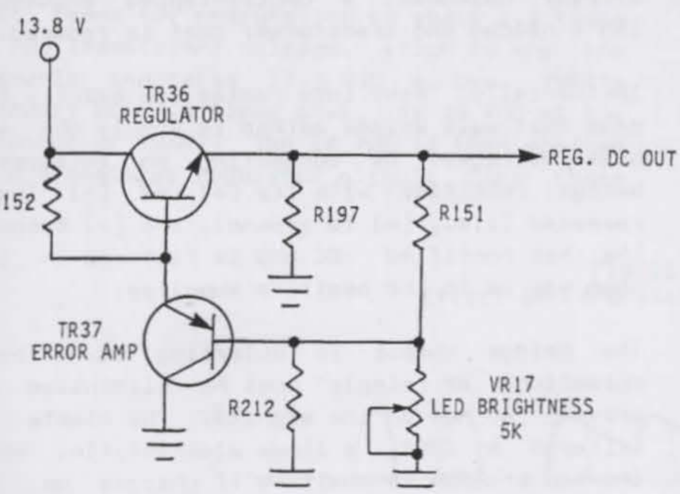
Depending upon its normal current demand the pass transistor may be heat-sinked, although nowadays most are the plastic TO-220 types standing up vertically on the PC board. The main disadvantage of this circuit is its lack of short-circuit protection. With a short across the load, the fuse wouldn't blow fast enough to protect TR23. This limitation results in another common CB power supply failure, and can be solved by current limiting circuits.

Improved Regulator Circuits

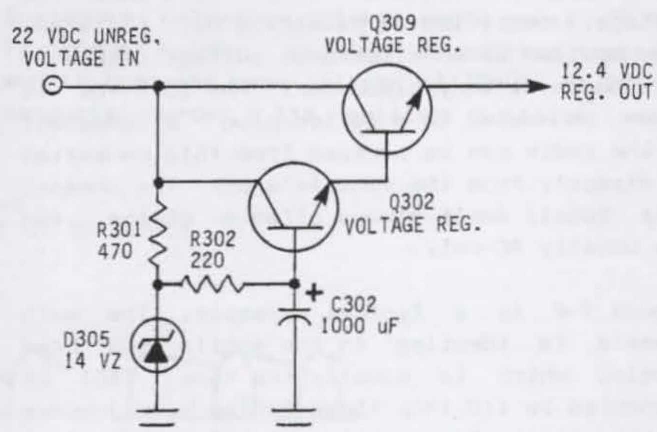
The basic series-pass regulator can be improved by adding an amplified feedback loop on the load side of the pass transistor. This not only increases its sensitivity to changes in output, but adds a current-limiting safety factor. Figure 7-5A shows how a second transistor, TR37, is used to control the conduction of pass transistor TR36 which drives the LED display.

FIGURE 7-5
ELECTRONIC VOLTAGE REGULATION

(A)
IMPROVED SERIES-PASS REGULATOR WITH ERROR AMP.
(Realistic TRC457, etc.)



(B)
DARLINGTON SERIES-PASS REGULATOR
(Dak Mark X)



As the current demand to the load increases, less base current is available at TR37 from R151/VR17/R212, lowering its conduction and raising its emitter voltage. This makes TR36 conduct more, passing more current and raising the output voltage back up. A dead short across the output would cause TR37 to turn off TR36 before it could be damaged.

In Figure 7-5B, Q302 and Q309 are connected in a Darlington circuit. This is similar to the basic regulator of Figure 7-4, except current gain is now the product of both transistor gains and is therefore much higher. Typical gains (H_{fe}) are about 20 for Q309 and 40 for Q302, making the total gain 20 x 40 = 800. This increased sensitivity makes the circuit respond to the tiniest load changes. In many similar Cybernet models, Q302/Q309 is often replaced by a single plastic Darlington like a 2SD837.

THE BASE STATION POWER SUPPLY

CBs for home use are called "base" radios. They operate from 110/220 VAC, 60/50 Hz mains power, depending upon the particular country. Almost all transistorized equipment runs on 13.8 VDC. Tube equipment requires several different voltages: high-voltage DC of 200-450 VDC for the plates and screens, 6.3 VAC for the tube filaments, and a negative grid bias voltage for various amplifier functions. The purpose of any base power supply is to convert the 110/220 VAC mains to all these required operating voltages.

THE AC/DC SOLID-STATE POWER SUPPLY

The modern base radio consists of a main transceiver chassis that's virtually identical to its mobile cousin, and a mains power supply. Because the base radio is physically large and has plenty of room on its frame, the mains supply is contained on a separate PC board on the frame. The power transformer is also bolted to the frame, as well as any optional goodies like a clock, frequency counter, scanner, etc.

The mains power supply has exactly the same kind of circuitry as the AC-to-DC converters or "power packs" commonly used to operate mobiles as base stations in a building. The 110/220 VAC input is first transformed down to a lower AC voltage, rectified to pulsating DC, filtered, and applied to an electronic voltage regulator like those already discussed. The 13.8 VDC is often connected to a switch/plug arrangement so the radio can be powered from this converter or directly from the vehicle's DC. The cheaper base models don't always offer a choice, and are usually AC-only.

Figure 7-6 is a typical example. The main chassis is identical in the mobile and base models, which is usually the case. T401 is connected to 110 VAC. (Some radios have jumpers on the primary for a choice of 110 or 220 VAC.) R424 provides a DC ground reference for the AC mains so all signals and voltages have a common tie point; this isn't actually needed but helps prevent potential ground loops. Sometimes a decoupling capacitor is shunted across this resistor for the same reason. The secondary output is about 18 VAC. C412 and C413 are for voltage spike suppression. In this particular model the secondary is fused, but primary fusing is used equally.

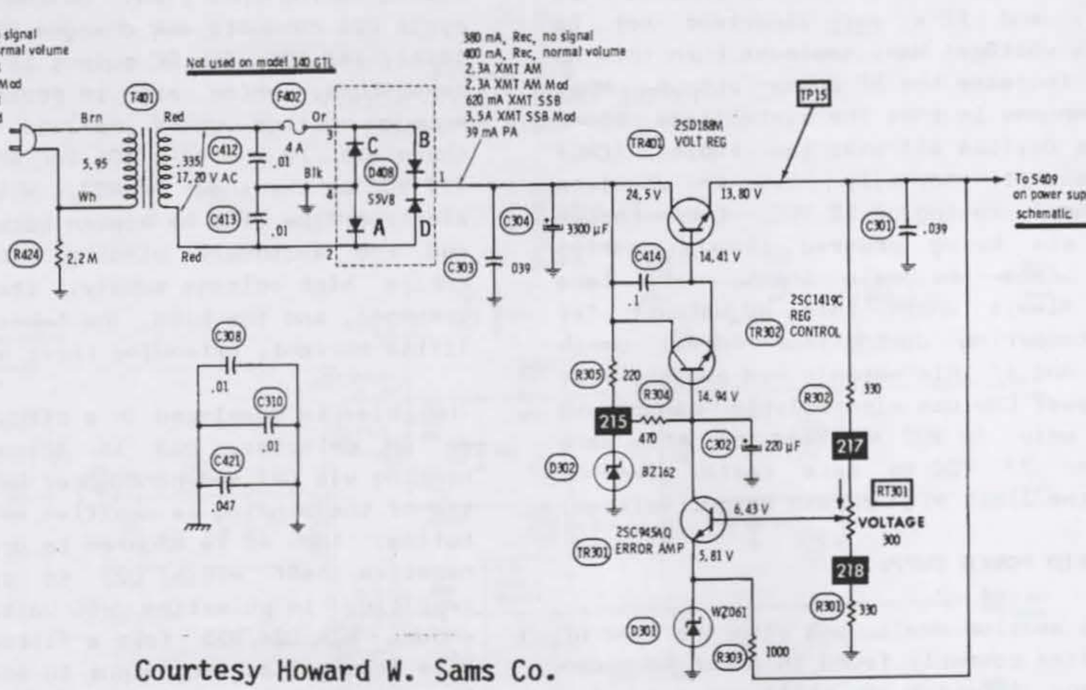
The 18 VAC secondary goes to a full-wave bridge rectifier. The bridge may consist of four discrete diodes of the 1N4006 type, or a single integrated 4-lead device. In either case they must have suitable current ratings: discrete diodes are at least 2 A, integrated bridges at least 8 A. Like the reverse-polarity diodes, they're often underrated and common failures.

The bridge rectifier consists of a pair of diodes operating on alternate halves of the AC input cycle. In this circuit, when the top of T401's secondary is positive with respect to the bottom, diodes "A" and "B" conduct; on the next half of the input cycle, diodes "C" and "D" conduct. Because a full-wave bridge is already balanced, a center-tapped secondary isn't needed and transformer cost is reduced.

Incidentally, many tube radios use exactly the same full-wave bridge method to supply the -DC bias voltages. By connecting an integrated bridge rectifier with its [+] and [-] leads reversed (i.e., [+] to ground), the [-] becomes the hot rectified -DC and is filtered in the same way as in the positive supplies.

The bridge output is pulsating DC. These pulsations or "ripple" must be eliminated to prevent AC hum on the signals. The ripple is filtered by C304, a large electrolytic. When the top of C304 is positive it charges up. On the negative half cycle the current can't force itself back through the rectifier so the

FIGURE 7-6
BASIC AC-TO-DC POWER CIRCUIT
(Cobra 142GTL, Realistic TRC490, Uniden Washington)



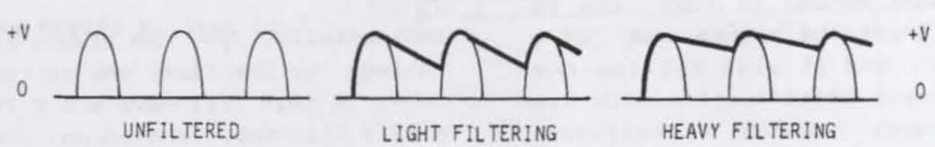
Courtesy Howard W. Sams Co.

capacitor, if large enough, retains most of its charge. Some current however will start discharging through the load resistance, but another positive half cycle will come along and recharge it before it has a chance to fully discharge. This is illustrated graphically in Figure 7-7. It shows voltage amplitude vs. time for two different capacitances; note how the larger value has the greater smoothing effect.

Rectifiers using silicon diodes always have capacitive input filters. In such filters the input capacitor charges up to about 1.4 times the RMS transformer voltage, which is why the schematic indicates 17.2 VAC across T401's secondary but 1.4 times that, or 24 VDC at the collector of TR401. The 24 VDC is then applied to a transistor regulator circuit like those described earlier; three transistors are used here for greater current gain and sensitivity. The output has now been made adjustable too.

Again feedback controls the conduction of pass transistor TR401. This time the error amp, TR301, compares the feedback of R301/R302/RT301 with a fixed reference voltage from Zener D301. Any difference is fed to another DC error amp, TR302, which also has a fixed base reference via Zener D302. Suppose a heavy load caused the output voltage to drop. This would cause the base voltage of TR301 to drop, turning it off more and raising its collector voltage. This increased collector voltage would cause TR302 to conduct harder, raising its emitter voltage and in turn the base voltage of TR401. As TR401 conducts harder, its emitter supplies more

FIGURE 7-7
EFFECT OF CAPACITANCE ON DC RIPPLE



current so the output voltage rises. A lighter load will cause just the reverse to happen.

RT301 adjusts the regulated output to exactly 13.8 VDC. All similar base models include this adjustment, and it's very important not to exceed this voltage! Many amateurs turn this up trying to increase the RF power output. What usually happens is that the overvoltage blows out active devices all over the radio! (CMOS ICs for example normally have an absolute maximum supply rating of 12 VDC. Even though such ICs are being powered through series resistance from the main input, why take chances?) Always check this adjustment for previous tampering during your normal bench alignment. And if this weren't bad enough, most of the newer CBs use electrolytic capacitors rated at only 16 VDC instead of the more conservative 25 VDC to save costs. They're pushed to the limit with excess output voltage.

TUBE & HYBRID POWER SUPPLIES

(NOTE: This section deals just with the type of power supplies commonly found in older American models, many of which are still very popular here. Technicians and foreign readers expecting to service only the transistor CB equipment may want to skip over this material.)

Tubes need high DC operating voltages, which are normally supplied by a step-up AC power transformer. The high-voltage pulsating DC that results is filtered and applied to the tubes. Separate secondary windings supply the negative bias voltages and AC filament voltages. In the case of hybrid tube/transistor equipment (Eg., Tram D201/201A, Browning Mark 4/4A, Dak Mark X, etc.), an additional low-voltage AC winding is included to power the solid-state circuits using methods already discussed. Many tube-type mobiles from the early CB days used switching oscillators to produce the high-voltage DC.

Figure 7-8 shows a typical base power supply for an older 23-channel hybrid transceiver. C31 and C32 are for transient suppression. The top secondary of T1 supplies 106 VAC which is used for both the high-voltage and bias supplies. D26 and D27 form a voltage doubler. This is a very common method in tube CBs to get high voltage without the higher cost of a bigger transformer. And it also retains the advantages of full-wave rectification with its higher ripple frequency compared to half-wave rectifiers; smaller electrolytics can be used.

Assume "STANDY" switch S4-1 is closed. On the positive half of the AC cycle D27 conducts and charges C28 to 1.4 times the RMS secondary voltage, or about 148 VDC. D26 is reverse-biased during this time. On the negative half cycle D26 conducts and charges C29c to the same level, 148 VDC. The DC output is across the two capacitors, which are in series. The total output voltage under no-load conditions is therefore (2 x 1.4) x 106 VAC RMS, or roughly 297 VDC at the input to R27. With S4-1 opened, electron flow will be broken between C28, C29c and the secondary winding. This kills the entire high voltage supply, its various load branches, and the bias. The tubes idle and draw little current, extending their useful lives.

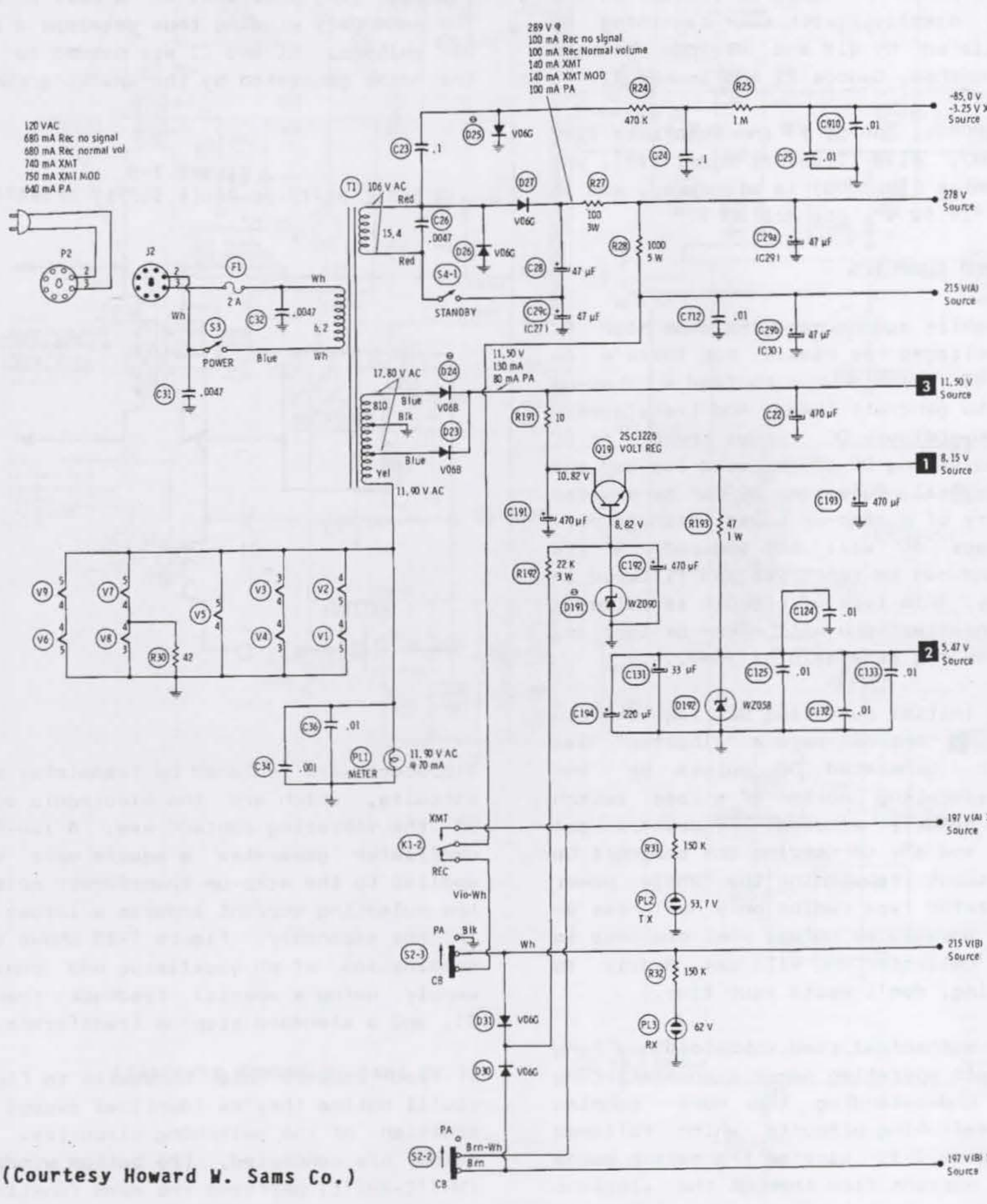
The bias is developed in a circuit similar to an AM detector. D25 is AC-coupled to the winding via C23 and configured so that when the top of the winding is positive relative to the bottom, the AC is shunted to ground. On the negative half cycle D25 is reverse-biased, resulting in pulsating -DC voltage at D25's anode. R24/C24/R25 form a filter with a long time constant so the output is essentially pure DC. C25 and C910 are for transient suppression and RF filtering. In some radios an integrated bridge rectifier supplies the -DC bias instead of discrete diodes, but is otherwise the same.

The lower secondary winding also serves a dual function. It's tapped at the 11.90 VAC point to provide the filament voltages, and center-tapped to supply 17.80 VAC for the low-voltage transistor supply. Since all the tubes in this radio use indirectly-heated cathodes (i.e., cathode and filament are electrically separate but thermally close to each other), AC hum pickup isn't a problem and the simpler AC power can be used to heat the filaments.

Note all tube filaments except V5 are part of a series pair. V5 is a 12 V filament tube, but all the others are 6 V types. (Actually, 6.3 V and 12.6 V.) Two series-connected filaments across a 12 V supply drop 6 volts across each; V5 is across the full 12 V winding. This is a standard method used in tube power supplies. When only 6 V filaments are used, the power transformer has a winding just for them.

Incidentally, you can always tell the filament voltage by the first one or two numbers of the tube: a 6BQ5 will have a 6 V filament, a 12AX7 a 12 V filament, and so on. This goes back to the old days of radio when batteries powered

FIGURE 7-8
TYPICAL HYBRID POWER SUPPLY
(Teaberry Model "T")



(Courtesy Howard W. Sams Co.)

everything; if a radio required say, a 90 V "B" battery, it would choose tubes such that their total series filament voltage drops equal 90 V.

This radio's transistor DC power is supplied by the full-wave rectifier D23/D24. This works like the full-wave bridge described earlier, except that only two diodes and a grounded center-tap are needed. C22 is the filter capacitor. The 15.5 VDC (Source #3) drives the LED channel display, with the remaining DC output regulated by Q19 and divided between two other branches, Source #1 and Source #2.

NOTE SAMS ERRORS: Source #3 in Fotofacts #187 (Robyn T-240D), #198 (Teaberry Model "T"), and #202 (Gemtronics GTX-5000) is mismarked, and it should read "15.50 V", not "11.50 V."

DC-TO-DC POWER SUPPLIES

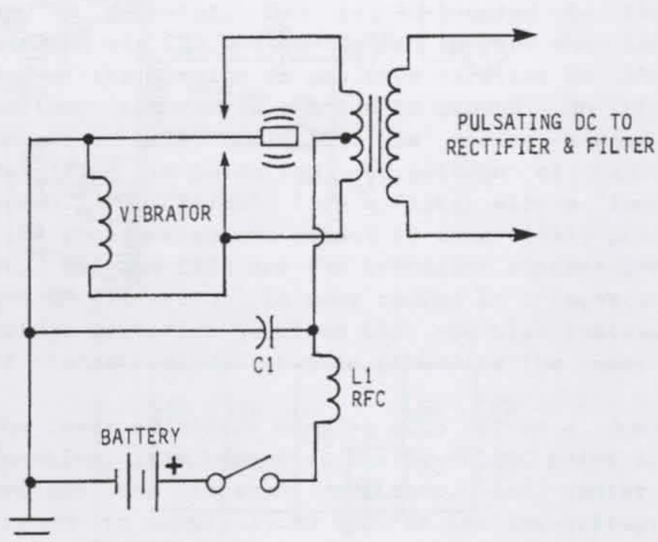
Tube-type mobile radios need the same high DC operating voltages as bases, but there's no convenient AC mains source to feed a step-up transformer to generate them. And transformers won't work on ordinary DC. Since there's no AC available, pulsating DC can be used instead and works just as well. Pulsating DC can be applied to the primary of a step-up power transformer. A high-voltage AC will be induced in its secondary, and can be rectified and filtered in the usual way. This type of circuit is called a "DC-to-DC Converter" and will often be labelled "POWER OSC" on the schematic or SAMS.

To get the initial pulsating DC requires an oscillator. In the old days a "vibrator" was used, which generated DC pulses by the mechanical vibrating action of a reed switch across the primary winding. Vibrators are extinct now, and any CB needing one couldn't be repaired without rebuilding the whole power supply. Vibrator type radios only had three or six channels anyway, so unless your customer is an antique collector who will pay dearly to keep it working, don't waste your time.

Although the mechanical reed vibrators are long obsolete, their operation makes a good starting point for understanding the more complex electronic switching circuits which followed them. In Figure 7-9, closing the switch makes DC battery current flow through the vibrator coil, pulling the center contact down. Once it hits the bottom contact, the coil is shorted out and a surge of DC current flows through the bottom half of the transformer's primary. This induces a voltage in its secondary winding.

The center contact is springy and with no more coil voltage to hold it down, it springs back and hits the upper contact. This feeds a DC pulse to the top half of the primary now, inducing an equal but opposite-phase voltage in the secondary. This combination of mechanical and electromagnetic action makes it continue to vibrate, just like that of a bell or a buzzer. The secondary winding thus develops a pulsating DC voltage. L1 and C1 are needed to suppress the noise generated by the sparking contacts.

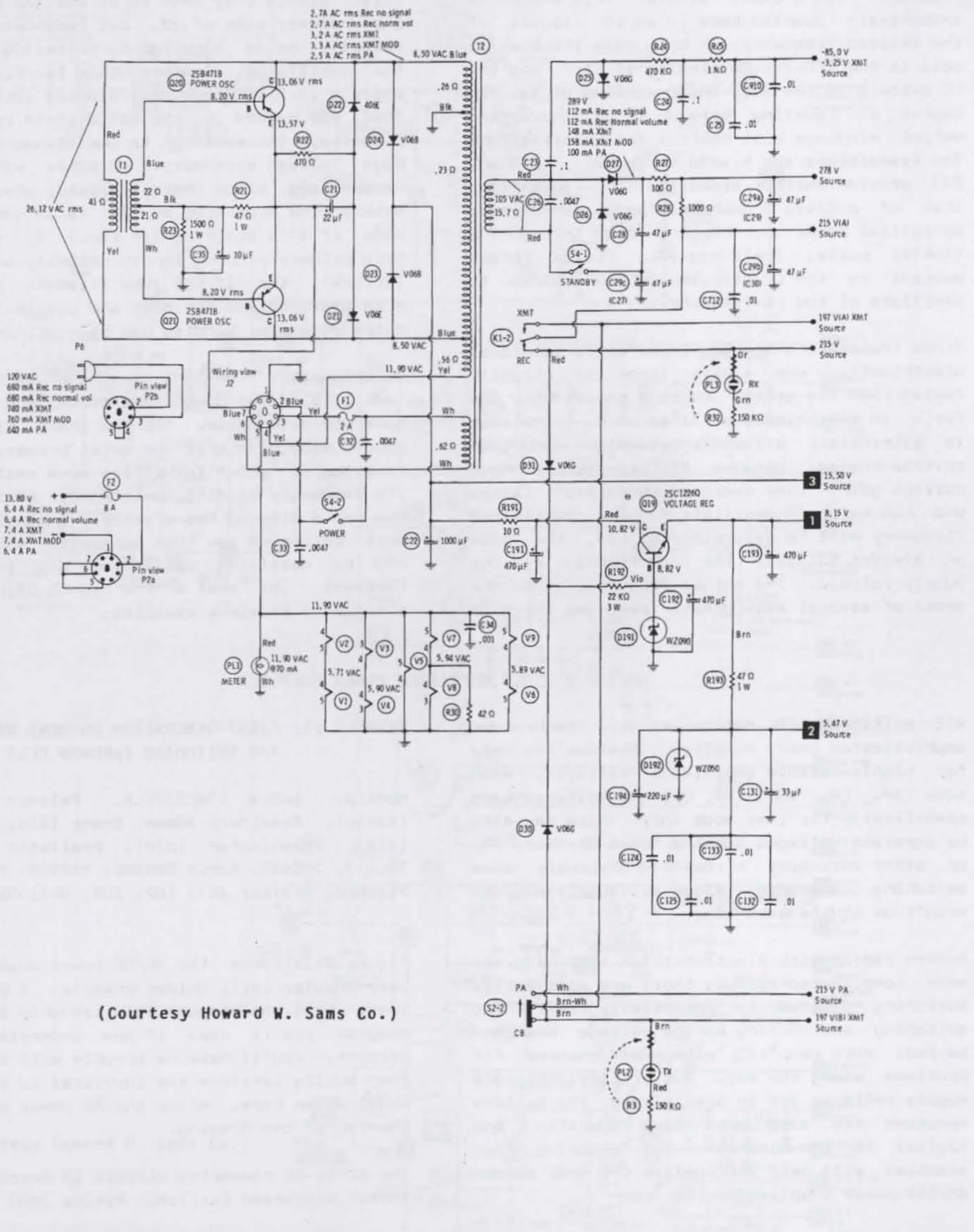
FIGURE 7-9
BASIC DC-TO-DC POWER SUPPLY OPERATION



Vibrators were replaced by transistor switching circuits, which are the electronic equivalent of the vibrating contact arm. A low-frequency oscillator generates a square wave which is applied to the step-up transformer primary, and the pulsating current induces a larger voltage in the secondary. Figure 7-10 shows a clever combination of an oscillator and conventional supply using a special feedback transformer, T1, and a standard step-up transformer, T2.

If you compare this schematic to Figure 7-8, you'll notice they're identical except for the addition of the switching circuitry. When AC mains are connected, the bottom winding here (WHITE-WHITE) performs the same function as the primary winding (WHITE-WHITE) did back in Figure 7-8. The main chassis are all identical under various brand names (Gemtronics, Robyn, Teaberry); some use the combo supply, some the

FIGURE 7-10
DC-TO-DC POWER SUPPLY USING TRANSISTOR OSCILLATORS
(Gemtronics GTX-5000, Robyn T-240D)



(Courtesy Howard W. Sams Co.)

straight AC supply. Separate 8-pin octal plugs connect either the AC or DC main primary input.

Q20 and Q21 form a push-pull "Armstrong" type oscillator. The Armstrong oscillator gets its feedback from a small "tickler" coil which is inductively coupled back to an LC circuit of the desired frequency. In this case the tickler coil is the RED-YELLOW winding of T1, and the LC circuit is the BLUE-WHITE winding of T1. The degree of coupling between T1's input and output windings will control the oscillation. The transistors are biased on by R21. C35 and R23 provide emitter stabilization, just like that of a Class B push-pull audio power amp. On initial power-up, current flows through the tickler coils. Their magnetic fields induce current in the LC circuit, which starts to oscillate at the LC frequency.

Since transistors are never perfectly identical electrically, one always turns on slightly faster than the other. Current pulses back and forth in the primary of T1 as each transistor is alternately driven to saturation and then reverse-biased. Because all transistors have current gain, they overcome the circuit losses and can maintain oscillation. The oscillator frequency will be determined by C35, the bias of divider R21/R23, the inductances, and the supply voltage. The actual frequency is on the order of several KHz, greatly reducing the size and cost of the electrolytic filter capacitors when compared to those in a 60 Hz mains input.

D21-D24 form a full-wave bridge rectifier and are AC-coupled from the oscillators by C21. At first glance they seem to be out of place on the primary side of T2, but remember they're actually being supplied by pulsating DC from the oscillator. Compare this to Figure 7-8, where a 17.8 VAC secondary winding (BLUE-BLACK-BLUE) was needed for the solid-state regulation circuits, in addition to the standard RED-RED high voltage secondary. No extra winding is needed here, since there's already about 17 VAC between the BLUE-BLUE of T2. (8.50 VAC on each side of T2's BLACK center tap.) By extending this primary winding length slightly on one end (YELLOW), the 12 VAC tube filament power is also provided. So the cost and complexity of an extra secondary winding has been eliminated.

Unfortunately the SAMS drawing of T2 makes it look like a step-<u>down</u> transformer, and that was done to save space. But the sharp technician should recognize that the total primary winding resistances shown for T2 are much smaller than its secondary winding resistance, as it would be for a step-up transformer. I mention this only to remind you that schematic appearances can be deceiving until you dig into them further! The rest of the branch circuitry is similar to previous examples.

AM/SSB & OTHER MULTIMODE POWER SUPPLIES

All multimode CB radios require much more sophisticated power supplies. Besides the need for highly stable oscillator voltages, each mode (AM, FM, USB, LSB, CW) has voltages used specifically for that mode only. There may also be separate voltages for the Noise Blanker, PA, or other accessory circuits. Obviously some switching is needed, since all supply sources aren't on at the same time.

Modern radios with electronic T/R switching are more complicated because there are more active switching devices to potentially fail. The switching and routing of the various branches becomes more complex, with more chances for problems along the way. But precisely because supply voltages are so specialized, the failure symptoms are also much more specific and logical to troubleshoot. The following four examples will help you analyze the most common AM/SSB power supply circuits.

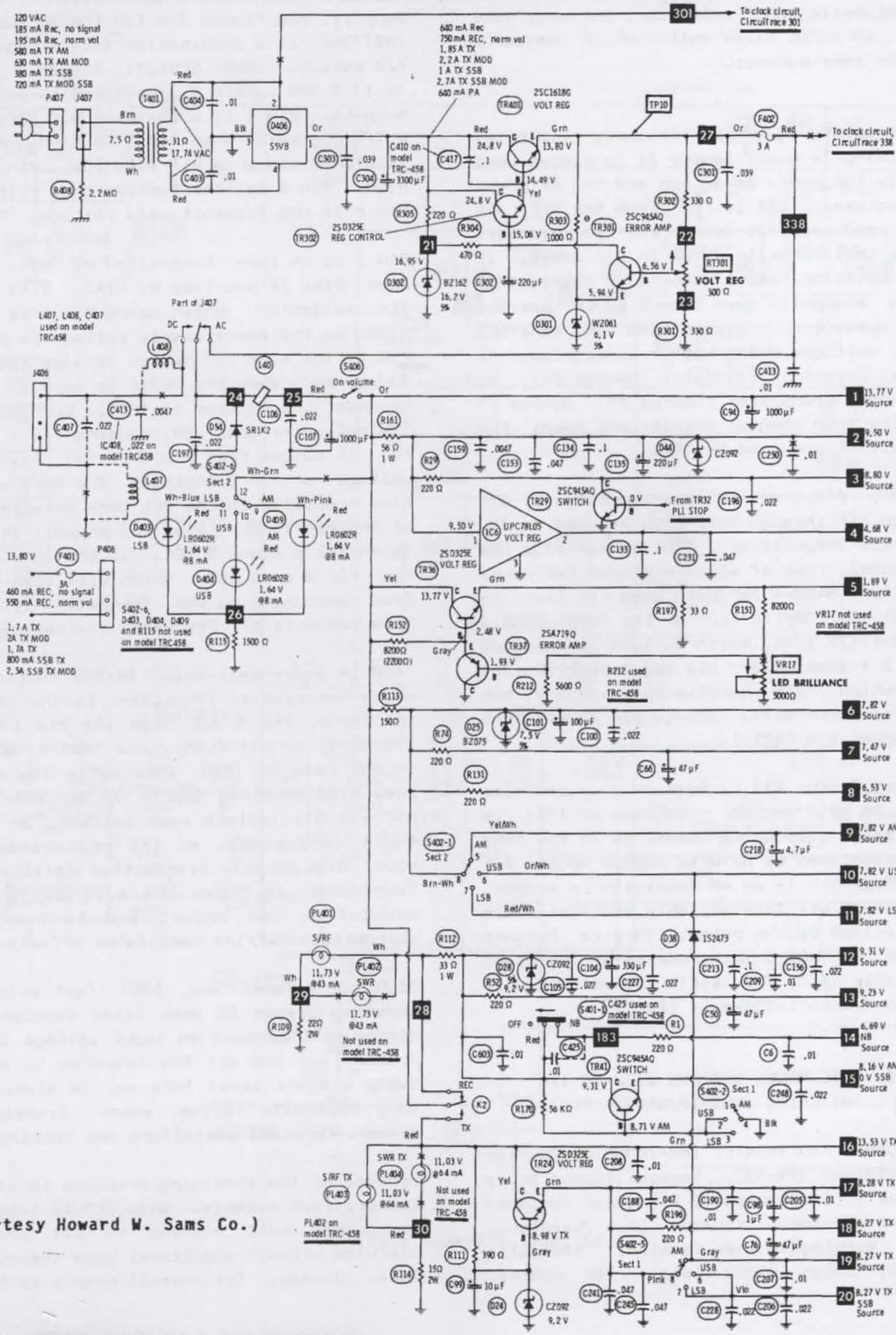
EXAMPLE #1: FIRST-GENERATION UNIDENS WITH RELAY T/R SWITCHING (μPD858 PLL)

Models: Cobra 138/139XLR, Palomar SSB500A (early), President Adams, Grant (old), Madison (old), Washington (old), Realistic TRC449, TRC457, TRC458, Robyn SB510D, SB520D, Stag 357, Teaberry Stalker 101, 102, 202, WKS1001.

Figure 7-11 shows the AC/DC power supply for a very popular early Uniden chassis. I purposely chose this one because it's probably the most complex you'll see; if you understand this circuit, you'll have no trouble with the rest! The mobile versions are identical to the base model shown here, minus the AC power supply at the top of the drawing.

The AC-to-DC converter circuit is exactly like those discussed earlier. Notice J407 includes

FIGURE 7-11
EARLY AM/SSB POWER SUPPLY WITH RELAY T/R SWITCHING
(Cobra 139XLR, Realistic TRC457/458, old President Washington, etc.)



(Courtesy Howard W. Sams Co.)

shorting contacts which route the main 13.8 VDC input from either J406 in mobile use, or from the mains-converted DC at Circuitrace #338. This particular jack is spring-loaded and allows automatic input selection, but many base CBs use an AC/DC slide switch which manually serves the same purpose.

There are twenty DC supply branches, and relay T/R switching is used. Source #1 is always used to supply the audio power amp and the RF power amp collectors. TR29 is fed from the PLL Lock Detector and controls Source #3, which powers an IF amp that normally works in all modes. If the Lock Detector output should go HIGH, TR29 saturates and pulls down Source #3 to prevent unlocked operation. Sources #2-8 are constant regulated voltages using either Zener diodes, a 3-terminal 5-volt IC regulator (Source #4), or a series-pass transistor (Source #5). Source #5 powers the LED channel display and needs the higher current provided by TR36.

Sources #9, #10, and #11 are regulated by D25 and branch off through S402-1 to be used on AM, USB, or LSB respectively. MODE switch S402 has six sections, four of which are used for power distribution. S402-6 is just used for lighting individual AM/USB/LSB LEDs on the front panel. S402-2 controls TR41, which in turn is supplied by the 9.2 V Zener D28. D28 regulates Sources #12-15, which are Receive-only via one set (K2) of relay contacts. Source #14 powers the Noise Blanker via S401-1.

Notice that Source #15 is Receive-only and also AM-only. On USB or LSB, the base of TR41 is grounded so no current can pass. On AM the base is forward-biased by R170 to supply Source #15 with 8 VDC, which is an AM-Receive-only source. Sources #16-20 are Transmit-only voltages which are controlled by the relay. They're further subdivided by S402-5 into sources of constant Transmit-only (#16, #17, #18), Transmit-AM-only (#19), and Transmit-SSB-only (#20).

EXAMPLE #2: LATE-MODEL UNIDENS WITH IC T/R SWITCHING (MB8719/MB8734 PLL)

Models: Cobra 140/142GTL, 148/2000GTL, Courier Galaxy, Midland 79-900, Pearce-Simpson Super Bengal Mark II (Australian), President (Uniden) Grant (new version), Madison (new version), McKinley, Washington (new version), Realistic TRC450/490, Robyn SB505D (late), SBE LCBS-8, LCMS-8, Stalker XX (export), Teaberry Stalker IX, XV, XX, Tram D80, D300.

Figure 7-12 shows the DC section of this power supply; see Figure 7-6 for the AC supply. IC5 (MB3756) is a combination 8-volt regulator and T/R switch. (Sub: ECG1271, SK7789.) The input is 13.8 VDC on Pin 2. There are three regulated outputs. Pin 1 is a constant 8.0 VDC. Pin 5 is a T/R control: when Pin 5 is HIGH, Pin 6 will be HIGH, and when Pin 5 is LOW, Pin 8 will be HIGH. Pin 6 is the Receive-only voltage, and Pin 8 is the Transmit-only voltage.

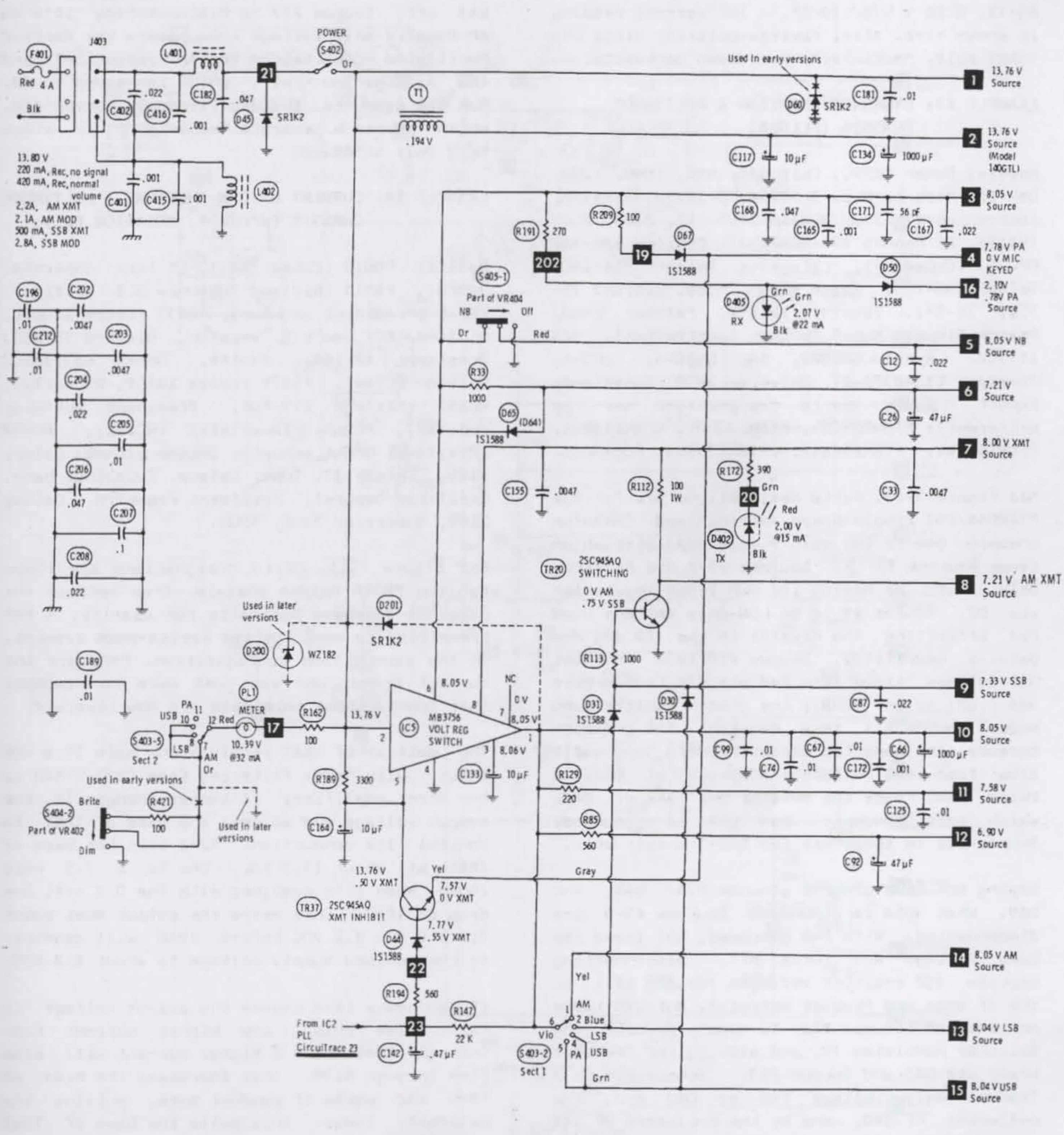
Pin 5 is in turn controlled by TR37. A small base bias is provided by R147. R189 pulls up its collector, which means Pin 5 is normally HIGH so the Receive-only voltage is present on Pin 6. The mike PTT button is also connected to Source #4. When the mike is keyed, Source #4 grounds the emitter of TR37, turning it on. Its collector goes LOW, causing Pin 5 to switch the IC output from Pin 6 to the Transmit-only voltage at Pin 8 instead. The base of TR37 is also connected to the PLL Lock Detector. (Pin 6 of the MB8719 PLL chip, not shown.) This LD pin is normally about 8 VDC. If the loop unlocks, PLL Pin 6 goes LOW, which will also keep TR37 from switching to the Transmit-only voltage. This prevents off-frequency transmission.

TR20 is a Transmit-only, AM/SSB control switch which has several functions. In the LSB or USB positions, the 8 VDC from IC5 Pin 1 turns on D30 (USB) or D31 (LSB) via S403-2, which turn on the base of TR20. This pulls its collector LOW, disconnecting Source #8 on SSB-Transmit. D30 and D31 isolate each voltage. On AM, TR20 isn't conducting, so the collector remains HIGH. This AM-only transmitter voltage has two functions: to close the mike audio path so modulation can occur, and to control the appropriate Carrier Oscillator offsets.

D200 (18 V Zener) and D201 (fast switch) were added as clamps in some later versions; these diodes will conduct on input voltage spikes to protect IC5 and all the branches it supplies. Using a shunt Zener this way is always a good idea in mobile radios, where transients are common. Consider installing one routinely.

Control of the remaining branches is similar to the previous example. Note IC5 is large enough to supply full current to all the branch circuits without additional pass transistors or Zener diodes. The overall result is that the

FIGURE 7-12
UNIDEN AM/SSB POWER SUPPLY WITH IC T/R SWITCHING
(Cobra 140/142GTL, Realistic TRC490, Uniden Washington, etc.)



(Courtesy Howard W. Sams Co.)

MODE switch now has fewer poles and the T/R relay has been eliminated, lowering costs.

NOTE SAMS ERRORS: Source #8 is just present for AM-Transmit-only; it should have said, "7.20 V AM-TX, 0.20 V USB/LSB-TX." The correct reading is shown here. Also, reverse-polarity diode D45 (SAMS #219, "McKinley") was drawn backwards.

EXAMPLE #3: CYBERNET AMERICAN & MULTIMODE CHASSIS (PLL02A)

Models: Boman CB950, Colt 480, 485, 1000, 1200, Dak SSB Mark X, G.E. 3-5825A, 3-5825B, 3-5875A, Gemtronics GTX-77, HyGain 2705 (V), 2785, 3108 (VIII), JC Penney 981-6247, JIL Citizen SSB-M6, MPL-5 (Canadian), Lafayette Telsat SSB-140, Telsat SSB-120, Major M360, M588, Midland 78-574, 78-891, 78-999, 79-892, Palomar 2900, Pearce-Simpson Super Panther (Australian), RCA 14T302, Rystl CB4082, SBE LCBS-4, LCMS-4, Truetone CYJ4837A-87, Universe 5600 (Canadian). Export Chassis (parts designations may be different): PTBM059C0X, PTBM121D4X, PTBM122D0X, PTBM125A4X, PTBM131A4X, PTBM133A4X, PCMA001S.

See Figure 7-13. Parts designations are for the PTBM048/058 single-board American and Canadian chassis. Q44 is the main 9-volt regulator which feeds Sources #5-18. Sources #5-8 are Receive-only, with #6 having its own Zener regulation via D2. Source #9 is an LSB-only voltage used for offsetting the crystal in the 10.692 MHz Carrier Oscillator. Source #10 is a constant SSB voltage, since it's fed via S2a from either D46 (LSB) or D47 (USB); the diodes isolate each mode. Source #11 is a constant SSB voltage because the same two diodes feeding Source #10 also feed the collector and base of Q41. A third path feeds the emitter and base of Q40, which only conducts when D48 is grounded; Source #12 is therefore for SSB-Transmit-only.

Keying the mike grounds grounds D54, D48, and D49. When D54 is grounded, Sources #5-8 are disconnected. With D48 grounded, Q41 loses its base voltage and turns off, disconnecting certain SSB receiver voltages (Source #11) to the IF amps and Product Detector. But Q40 turns on instead (Source #12) to supply power to the Balanced Modulator IC, and also to the Transmit Mixer via D45 and Source #13. Source #13 is a Transmit-only voltage fed by D45 and the collector of Q40, and by the collector of Q42 and D52/D44. Two series diodes are used for greater isolation between Sources #14 and #16, since high-level RF from the power stages is present. Along with D45 they isolate Q40 from Q42. Chokes L4 and L5 further decouple this RF.

D49 also conducts on Transmit, turning Q43 off and Q42 on like the previous NPN/PNP pair. With Q43 off, Source #17 is disconnected; it's an AM-Receive-only voltage and powers the Carrier Oscillator (not needed for AM reception) and the 455 KHz 2nd Mixer, which is needed on AM. Now Q42 conducts instead to supply Source #16, which powers a separate Transmit Mixer stage used only on AM.

EXAMPLE #4: CURRENT UNIDEN AMERICAN & MULTIMODE CHASSIS (µPD2824, MC145106 PLL)

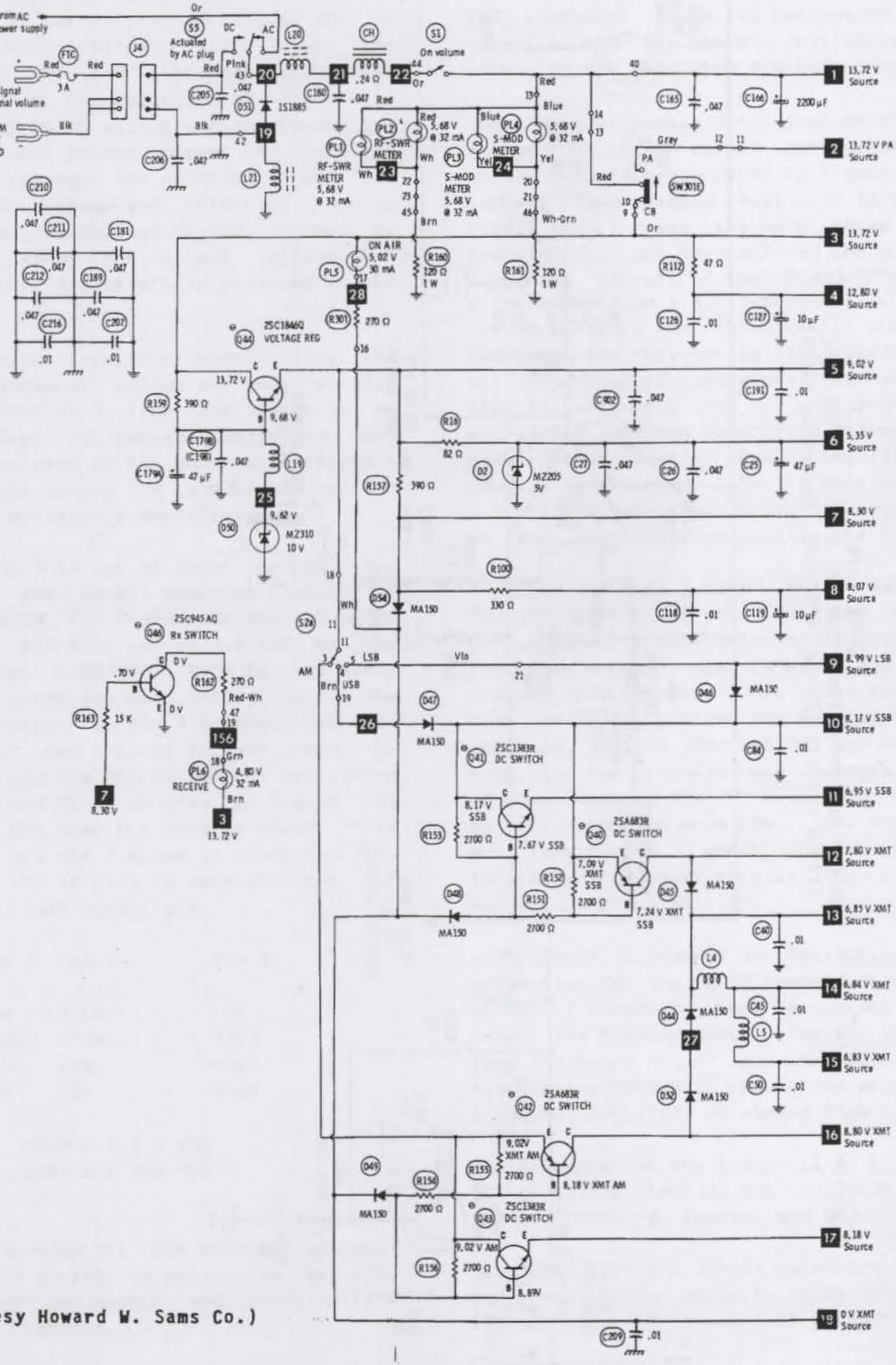
Models: PB010 (Cobra 148GTL-DX late, Superstar 360FM), PB015 (Midland 7001 new U.S. version), PB042 (President Jackson), PC833 (Cobra 146GTL, Midland 6001 new U.S. version, Midland 79-260, President AR-144, AX-144, Sears 663.3810, Uniden PC244), PC879 (Cobra 148GTL-DX early), PC893 (Stalker ST9-FDX, President McKinley export), PC965 (Realistic TRC451), PC999 (President Grant export). Uniden clones: Galaxy 2100, Galaxy II, Super Galaxy, Excalibur base, Excalibur Samurai, President Franklin, Galaxy 2100, Superstar 3600, 3900.

See Figure 7-14. Parts designations are those for the PB010 Uniden chassis. I've redrawn the original Japanese schematic for clarity. A PNP transistor is used for the series-pass element, in the common base configuration. PNPs are the current trend, and you just have to remember that input/output terminals are now reversed.

The emitter of TR41 receives the main 13.8 VDC input, with heavy filtering from C227. TR40 is the error amplifier; it senses changes in the output voltage and adjusts the base of TR41 to control its conduction. R241 sets the base of TR41 at about 13.0 VDC. D88 is a 7.5 volt Zener. When it's combined with the 0.7 volt b-e drop of TR40, this means the output must reach 7.5 + 0.7 = 8.2 VDC before TR40 will conduct. So the no-load supply voltage is about 8.2 VDC.

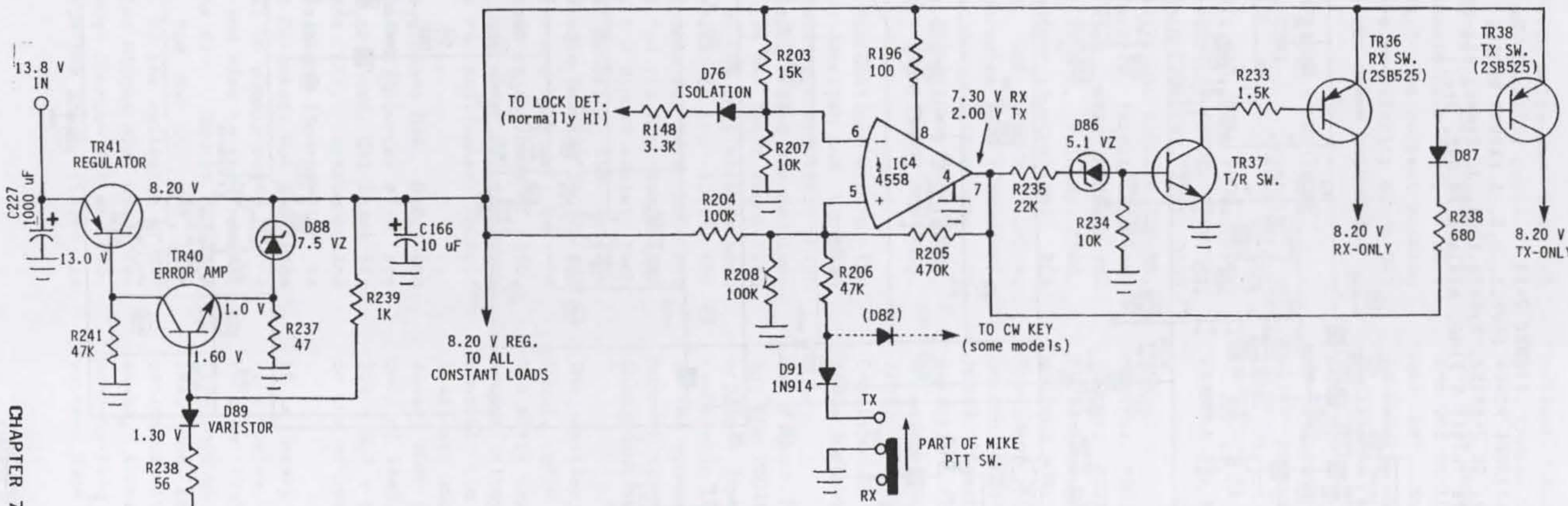
If a heavy load causes the output voltage to fall below this, the higher current flow through TR41 means a higher current will also flow through R239. This increases the bias on TR40 and makes it conduct more, pulling its collector lower. This pulls the base of TR41 lower, turning it on harder and passing more compensating current, which raises the output voltage back up to its correct level.

FIGURE 7-13
CYBERNET MULTIMODE POWER SUPPLY, U.S. & EXPORT MODELS
(PTBM048 chassis: GE 3-5825A, HyGain 2705, JC Penney 981-6247, Lafayette Telsat SSB140, Midland 79-892, etc.)



(Courtesy Howard W. Sams Co.)

FIGURE 7-14
UNIDEN MULTIMODE POWER SUPPLY, U.S. & EXPORT MODELS
(PB010 chassis: Cobra 148GTL-DX, Superstar 360FM)



The second part of this regulator is a simple overvoltage protector. D89 is a voltage-sensitive varistor, which means its resistance decreases as the voltage applied to it (and therefore the current flowing through it) increases. It's biased by R238 and R239 so the base of TR40 is normally at about 1.60 VDC. A rise in output voltage will lower the resistance of D89 and therefore the base voltage of TR40. The collector of TR40 will pull up higher, which will lower the conduction of TR41 to prevent excess current and therefore excess output voltage. The addition of D89 can be considered a cheap and effective back-up safety system. The voltage divider formed by R239/R238/D89 keeps the output voltage of series regulator TR41 carefully balanced at the desired level.

The T/R switching circuits of models using the 4558 IC are somewhat unique and were briefly mentioned in CHAPTER 5. (The 4558 IC may be an 8-pin DIP or 9-pin SIL package, depending upon model. It's not used in the American versions.) One half of dual op-amp IC4 is a simple voltage comparator or difference amplifier.

On Receive, Pin 5 is set at about one-half V_{CC} (4.0 VDC) by the equal resistor values of divider R204/R208. Pin 5 drops to about 2.0 VDC on Transmit. Pin 6 is set at 3.2 VDC by the unequal divider R203/R207. R205 is the loop feedback and gives IC4 some voltage gain. The Receive mode output at Pin 7 is about 7.3 VDC. The comparator can only be tripped when the mike is keyed <u>and</u> the PLL is locked; i.e., when Pin 6 is HIGH and Pin 5 is LOW. Pin 5 goes LOW by grounding D91 when the mike is keyed. This triggers IC4, and Pin 7 drops to about 2.0 VDC. Summarizing, the IC bias is carefully set for the following truth conditions:

Pin 5	Pin 6	Pin 7
LOW	HIGH	LOW
HIGH	HIGH	HIGH
HIGH	LOW	HIGH
LOW	LOW	HIGH

HIGH = > 3.2 VDC
LOW = < 3.2 VDC

If the normally-HIGH PLL Lock Detector circuit goes LOW, Pin 6 will be pulled low by D76, which triggers the switch and inhibits the changeover to Transmit.

With IC4 Pin 7 normally at about 7.3 VDC, this makes the 5.1 V Zener D86 conduct and turn on TR37. TR37 conducting turns on TR36, so current flows from its collector to the receiver circuits. On Transmit Pin 7 goes LOW, turning off D86 and the Receive-only voltage. Instead D87 conducts, since its cathode is now more negative than its anode. This turns on TR38, supplying the regulated Transmit-only voltage.

The American models don't include the 4558 IC, instead choosing direct control of the T/R supply transistors. Refer to Figure 7-15. The compact PB062 chassis (Realistic TRC453, Uniden PC122, etc.) uses the same three switching transistors, but has replaced the discrete 8 V regulator circuit of the PC833/PC965 chassis with a standard 1 A, 3-terminal IC regulator. The IC contains the equivalent of the amplified feedback and current-limiting circuits. Like all 3-terminal IC regulators, it has an input (Pin 1), an output (Pin 3), and ground (Pin 2), and always includes capacitive filtering (C118, C119). The plastic TO-220 regulator IC is usually heat-sinked. You'll occasionally find a 5-volt, 8-volt, or 12-volt IC regulator used in other CB models, especially the newer ones.

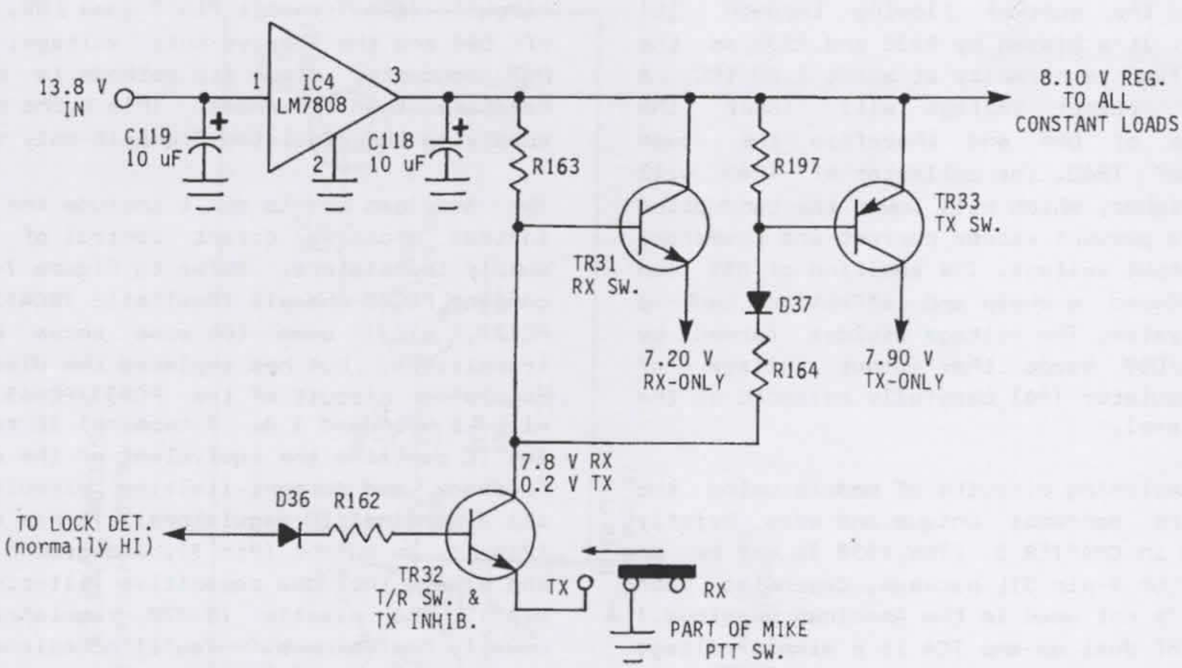
TR32 has the dual function of T/R switching and Transmit Inhibit for out-of-lock conditions. The µPD2824 PLL Lock Detector is normally HIGH; therefore when the mike is keyed <u>and</u> the PLL is locked, TR32 conducts. This pulls down the base bias on TR31, killing the Receive-only supply voltages. Instead TR33 and D37 can now conduct, supplying the Transmit-only voltages. The use of complementary NPN/PNP switching transistors is very common in many CBs. They increase gain and sensitivity, don't invert input/output levels, and in power supplies they increase the current-handling ability.

NOTE SCHEMATIC ERRORS: The Realistic and Uniden schematics for the PB062 chassis show IC4 Pin 1 and Pin 3 reversed; they're correct as shown here! The factory manuals for the Uniden "PRO" line and Cobra "Plus" line are also mismarked. All similar TO-220 IC regulators are: 1-INPUT, 2-GROUND, 3-OUTPUT, as viewed from the front.

Replacements for the 8-volt (1 A) type positive IC regulator include the HA17808W, µPC78M8, LM7808, LM340T-8, ECG964, and SK3630.

SERVICING TIP: The 2SB525 switching transistors in these Uniden circuits (like TR36/TR38 and TR33 in Figure 7-14 and 7-15 respectively) are

FIGURE 7-15
SIMPLIFIED UNIDEN AM/SSB POWER SUPPLY USING IC REGULATOR
(PB062 chassis: Realistic TRC453, Uniden PC122, etc.)



very common failures. They're underrated and can't handle the heavy current demand. This is one of the first things you should check with a symptom of "No Receive" or "No Transmit" when the other mode is working normally. Replace a bad one with a heavier PNP audio-type device such as an ECG294, or even a TO-220 transistor like the ECG292/SK3441 or TIP30.

TROUBLESHOOTING THE POWER SUPPLY

Power supply failures usually give little or no warning, especially in solid-state circuits. A device can open and kill the associated supply voltage. A short circuit can cause excessive current to flow; by the time you see the smoke the damage is done. Or something less than a complete short could pull a supply voltage down so low that the circuit(s) being powered by it doesn't work. But power supply circuits are among the easiest to troubleshoot, because they can be logically analyzed by what they power.

Symptoms of power supply problems include:

1. Blows fuses. (DC input, AC input, or both where applicable.)
2. Stuck on Transmit (or Receive) all the time; won't switch properly.
3. No Receive, Transmit normal.
4. No Transmit, Receive normal.
5. No Transmit or Receive, meter lights only.
6. Base radio operates from its 12 VDC input but not the AC mains input.
7. No Receive, No Transmit, or both, one mode only. (AM/FM/USB/LSB or both SSB.)
8. USB or LSB off frequency.
9. No AM modulation present with normal RF carrier output, but SSB-Transmit normal.
10. Excess hum or "motorboating."

Blown Fuses

A voltmeter and ohmmeter are the only tools usually needed for power supply problems. A 'scope can be used to measure the effectiveness of filter capacitors on ripple reduction, although usually it's easier just to bridge a good capacitor across a suspicious one and note any change. Fuses sometimes blow just from old age; always see if a new fuse blows too. If not, don't worry about it. If the new one blows, then start looking for a short across the load. The most common causes of blown fuses are a shorted reverse-polarity diode, shorted audio power transistor or IC, or shorted RF Driver or Final transistor. These are all directly across the main 13.8 VDC bus and are therefore independent of operating modes.

The first test with the "Blows Fuses" problem is an ohmmeter check directly across the DC power input wires or socket. With the VOLUME control or power switch turned "ON," you should measure a definite resistance which changes when you reverse the test leads. A reading near zero ohms both ways indicates a short. Any power supply feeding semiconductor devices will always measure higher resistance one way than the other, and this applies to branch circuits as well as the main 13.8 VDC input. If a short is indicated, isolate the appropriate load from its source to determine which one is the cause.

Completely Dead Radio

In the case of radios that don't even light up, start by looking outside the radio. The in-line fuseholders sometimes fail to make contact internally, so there's no measurable voltage on the radio side and the fuse itself checks good. You can stretch the fuseholder springs a bit to cure this. Slide mounts are another major source of missing supply voltages, if contact between the mating halves is poor or open. The copper contacts can usually be bent up higher by slipping a screwdriver underneath them and twisting. With the flat type of slide mount contact, apply some extra solder to make them thicker so the sections will mate more tightly.

Never overlook a poor vehicle ground as a problem source either. I've had cases where a mobile unit worked fine on Receive, but the higher current drain on Transmit dropped so much DC voltage it couldn't function. If you consider that a solid-state transmitter will typically draw about 1.5 A or more, a dirty contact having only a few ohms of resistance could drop several volts! The grounding question can be logically answered by seeing if the radio works normally on a bench DC supply.

Replacement DC power cables are available from Radio Shack (#21-550), Dick Smith Electronics (#D-9001), and GC Electronics (#18-508) in the standard 3-pin versions. GC carries the 2-pin, coaxial, and direct cables to fit many of the older mobile models too. Gold Line also sells the standard 2-pin (#1147) and 3-pin (#1148) CB power cords.

Mikes and T/R Switching Problems

Bad mikes are a major source of problems that first appear to be internal to the radio. A Transmit keyline that doesn't change states because of a bad switch, cable, or plug will obviously cause problems in one mode only. With electronic T/R switching several things must happen at once and if the Transmit keyline doesn't ground, the radio stays in the Receive mode. Likewise if any of the associated T/R switching diodes were to short, the radio could remain stuck on Transmit all the time. (Or stuck on Receive, depending on the specific diode function.) Faulty T/R diodes can also cause some strange squeals or oscillations, because circuits which should only be powered in one mode are turned on all the time. In some circuits one main transistor switch controls several other T/R devices further downstream; if the main transistor isn't switching the other devices sure won't either.

In relay T/R circuits, one side of the relay coil normally grounds on Transmit. If you don't hear a click or see the contacts move, first assume it's a mike problem. You should measure about 13 VDC on both sides of the relay coil on Receive; if one side shows no voltage, measure the coil for DC continuity, which is typically 150-300Ω. Relay coils do go bad occasionally. You can also check the relay by jumpering a 13.8 VDC source to the hot side of its coil while pushing the mike button; if the coil and mike wiring are both good, the relay will energize. Mikes can be easily checked for continuity and T/R switching with an ohmmeter.

AC/DC Base Problems

In base radios the AC supply is often the problem, with the radio working normally on DC power. This is the first thing to check with the "Dead Radio" symptom. Assuming it works normally on DC, the problem will usually be found in the rectifier, filter capacitors, or regulator transistor/IC. The active devices are the most likely failures. If shorted, they blow the fuse. If open, the fuse will be OK but there's no output voltage. In full-wave bridge circuits using discrete diodes, all four diodes should be replaced when a shorted one is found; the excess current usually weakens the others, which may fail too at just the wrong time!

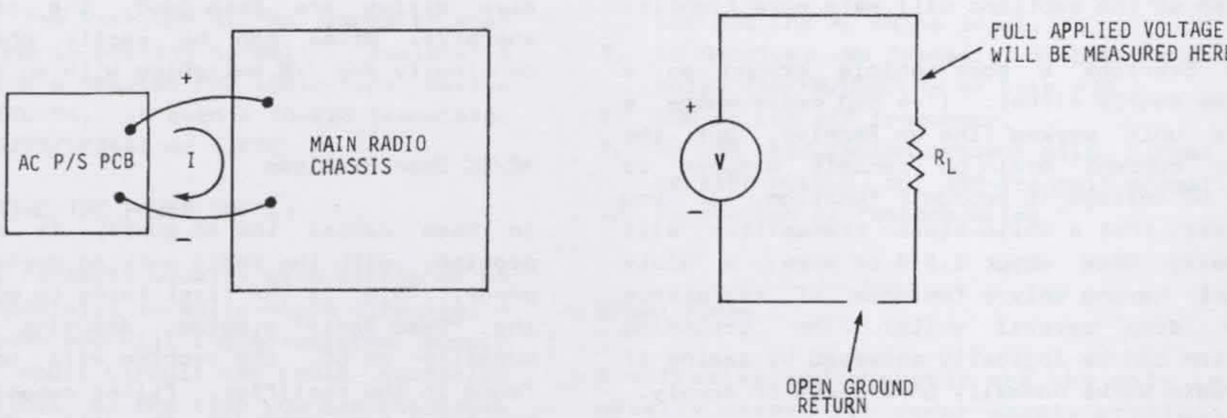
An electrolytic filter capacitor that's shorted or leaky can burn out the bridge and blow fuses too. When voltage arcs across the dielectric, it carbonizes and creates a low resistance path which allows heavy current to flow. In such cases the shorted bridge is easily found but the shunt capacitor(s) that caused it isn't so obvious, so always check them too.

Large capacitors of 0.1 µF or more can be checked for leakage with an ohmmeter, and will produce a needle kick when first touched with the test leads. One capacitor lead must be removed from the circuit first, which in the case of PC types means wicking off the solder from one pad and wiggling the lead to break its connection to the foil. Use a high scale like x1K. A good electrolytic will initially read a low resistance, gradually rising to 100KΩ or more as it charges. If the ohmmeter leads are reversed, it normally reads a different value. The old tube radios often used paper dielectric capacitors in high-voltage locations; these should read 10MΩ or more after a few seconds.

Power transformers occasionally fail. Turns may short together if the insulation breaks down, causing a heavy primary current flow regardless of which side had the breakdown. The fuse will likely blow and there may also be smoke and/or the smell of burning tar. Isolate the secondary from its load and if the transformer continues to smoke, replace it. In older tube models having a center-tapped secondary, shorted secondary turns or an open center-tap return cause reduced voltage, because the circuit functions more like a half-wave than a full-wave supply. An open diode in a voltage doubler would also cut the output voltage in half.

An open ground return wire between the AC power supply board and the main PC board will cause the radio to remain dead, but all branch circuits will read 13.8 VDC. Figure 7-16 shows how this can happen. The AC-to-DC board is always tied to the main radio PC board by both [+] and [-] wires to complete the DC loop. If one side of the radio load (R_L) is open a voltmeter will read the full applied voltage, since there's no load to pull it down. Check these wires and the applicable foil traces for potential open circuits.

FIGURE 7-16
EFFECT OF OPEN GROUND BETWEEN AC POWER SUPPLY & MAIN CHASSIS



Hum Problems

Hum or "motorboating" is caused by bad filter capacitors. In the simpler radios with shared audio power circuits, hum may show up on both the received signals and the transmitted audio. This problem is much more common to AC-powered base units and all tube radios in general. Electrolytic filter capacitors dry out with age, and given the age of most tube radios and the heat they radiate, it's almost guaranteed. Electrolytics can also fail when a radio has been sitting around unused for a couple of years. Bridging a new electrolytic across a suspicious one will quickly answer this question. Tube CBs are still extremely popular and common among American radio oldtimers.

The Branch Power Circuits

A radio which lights up but is otherwise dead will be found to have one or more (or all) of its branch voltage supplies missing, assuming the synthesizer itself is running. For example, suppose the meter lights work but the LED channel display is dead. The display is usually driven from a regulated branch source, but the metering lights are powered directly from the 13.8 VDC input before any branch circuits, so they wouldn't be affected. Think logically!

In simple regulation circuits without current limiting, an emitter-to-collector short in the series-pass transistor would supply the full unregulated input voltage to the load. This can be disastrous, since it may zap transistors and ICs all over the place! Likewise, an open Zener reference on the series-pass transistor will heavily forward-bias the transistor, possibly burning it out and causing load damage too.

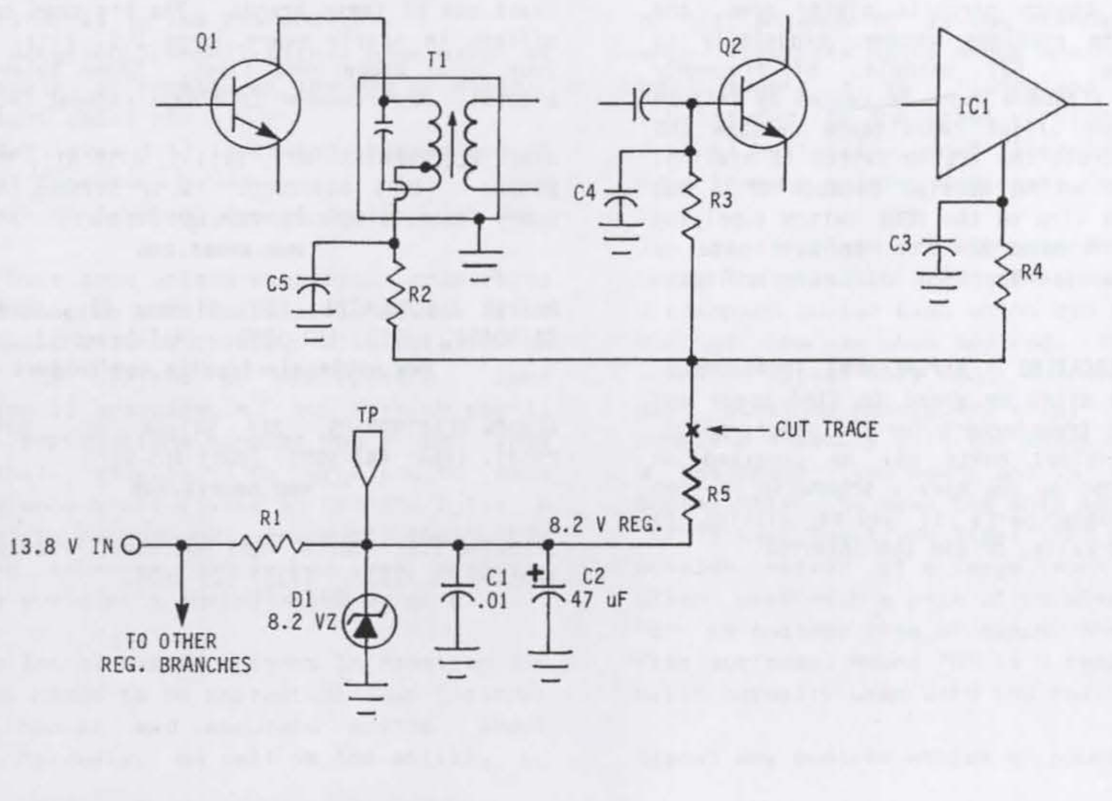
IC voltage regulators have very high gain and can oscillate when not properly filtered. Normally the input and output pins are heavily decoupled, and these electrolytic and/or disc capacitors should always be checked whenever an IC regulator fails. A common failure with the MB3756 Uniden regulator is caused by improper Clarifier modifications: when attempting to increase varactor control voltage, the series resistance is often jumped out at the Clarifier pot's cold end; this leaves nothing to limit the current when the Clarifier is turned to its minimum resistance knob position.

Isolating Source vs. Load Problems

Sometimes a short in the load circuit causes the same symptoms as a short in the power supply itself. To determine which is faulty, they must be isolated from each other. This may be as easy as unsoldering one lead somewhere, but often it's more complicated because the source voltage is powering several circuits. Figure 7-17 shows one troubleshooting approach you can easily use in such cases.

Q1, Q2, and IC1 are all being powered from a Zener-regulated 8.2 VDC source. Suppose the voltage on this bus (TP) is way low, only a few volts. Excessive current draw somewhere must be pulling it down. The components shunted across this supply bus are C1-C5, Q1, Q2, and IC1, any one of which could cause the problem if shorted or leaky. If an active device were shorted but had enough series resistance connected to it, there probably wouldn't be anything as obvious as a blown fuse. Once the current divides down

FIGURE 7-17
PROBLEM ISOLATION IN BRANCH CIRCUITS



into the various branch circuits, the failure is often more subtle, and results from an abnormally low voltage instead of an outright short.

By disconnecting the Zener circuit from the three active devices, you'd know immediately in which half the problem lies. In this particular example, you could isolate each half by lifting one end of R2, R3, and R4. (Assume R5 isn't present.) If the voltage at TP doesn't rise to normal, the problem can only be D1, C1, or C2. I'd start with the electrolytic and the Zener, since ceramic disc capacitors don't seem to fail nearly as often. Apply the same logic if the Zener had been replaced by a series-pass transistor of similar ratings.

Assume the voltage rises to normal after disconnecting the three loads. This means one or more of the three branch circuits is the problem. But which one? Replace each component lead one at a time, until the problem reoccurs; you'll then know which specific load circuit is the cause and must be investigated further. There's very often some series resistance (R5) between the Zener and the load, in which case you'd then only have to lift R5 instead of three individual load resistors.

In this example isolation was relatively easy. But sometimes a regulated branch feeds so many different circuits all over the radio that it's easier to cut the main PC trace that separates the source from the load (Point "X"), instead of unsoldering numerous parts. Just don't forget to bridge your cut with a bare jumper wire again once the problem is fixed!

The further the branch circuits divide down, the more specific the problems become, especially in multimode radios. For example, off-frequency operation on one sideband might be caused by failure to switch in some offset capacitance because the voltage that controls the active switch is missing. Or maybe there's no FM Receive because of a bad contact or broken wire on the MODE switch supplying voltage to the FM detector IC. In each case, a logical and systematic approach will quickly locate the problem area.

SERVICING TIP: LOCATING A REPLACEMENT TRANSFORMER. Many people have asked me where to find power and audio replacement transformers for the older radios. Although the original parts may be unmarked or unreadable, as long as you have a schematic you can still find suitable parts if you're willing to write, make phone calls, or use the Internet.

You really don't need an exact replacement if the voltage winding tap(s) and current ratings (for power types) and input/output impedances (for audio types) are somewhere close in value. And you may need to physically remount the new transformer on the chassis, usually by just drilling one new hole in the chassis to match the replacement to the new mounting bracket hole spacing.

So, where to find a replacement transformer these days? You can start by checking the two antique radio parts sources on Page 25. If you strike out, then contact the manufacturers or distributors on this page. The best-known American manufacturers of old CB power and audio transformers from the tube era are all still actively in business:

STANCOR PRODUCTS, Arizona: (602) 275-3800.
www.stancor.com

THORDARSON-MEISSNER INC.
11969 Hwy. 1, Mt. Carmel IL 62863. (618) 262-5121. (800) 712-3000. The link below has a huge list of distributors to find the one closest to you:
www.thordarsonmagnetics.com/contacts.php

TRIAD MAGNETICS, 22520-B Temescal Canyon Rd., Corona CA 92883. (951) 277-0757.
www.triadmagnetics.com

They probably won't sell to you directly, but they will give you the name(s) of their distributors. It might even be faster to go directly to a major electronics parts distributor like those listed in Chapter 1. Most of those guys will always carry at least one of these brands. The big ones have sales offices in nearly every large U.S. city, so check your local phone book first. Shown below are the biggest. And remember to always request catalogs!

AVNET ELECTRONICS INC., 2211 S. 47th St., Phoenix AZ 85034. (480) 643-2000. U.S. offices in nearly every state, plus many foreign offices.
www.avnet.com

MASTER ELECTRONICS, 1301 Olympic Bl., Santa Monica CA 90404. (310) 452-1229. (All brands.)
www.masterelectronics.com/contact

NEWARK ELECTRONICS, 217 Wilcox Av., Gaffney SC 29341. (864) 487-1900, (800) 463-9275.
www.newark.com

STERLING ELECTRONICS, 4201 Southwest Freeway, Houston TX 77027. (713) 623-6600.