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TROUBLE SHOOTING

"Tough" Sets or "Dogs"

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Experienced technicians can find the trouble quickly in about 90 per cent. of the receivers that require service. But it may take several hours or even days of exasperating effort to find the trouble in the remaining 10 per cent. The latter sets are commonly, and mildly, described as "dogs", because too often they cause a loss which overcomes profits made on other sets.

In service organisations where most of the sets are repaired in the home by experienced field men, it is only natural to expect that a larger percentage of the sets brought into the shop may be dogs.

The time spent on dogs is not wasted if it produces gradual improvement in trouble-shooting methods. A review of past experience with dogs reveals two important facts relating to trouble-shooting methods:

1. *When the trouble is eventually found, it is usually in a component that had been checked repeatedly.* Often, in the course of working on a dog, a technician will say "I know that the trouble is right in this particular section. I've checked everything in this section. I've tried new tubes, I've replaced several parts. Everything checks OK, but the trouble is still there." Yet, in many cases when the trouble is found, it is in one of the components that had been checked, double checked, and triple checked. Obviously, in such cases there must be something wrong with the method of checking.

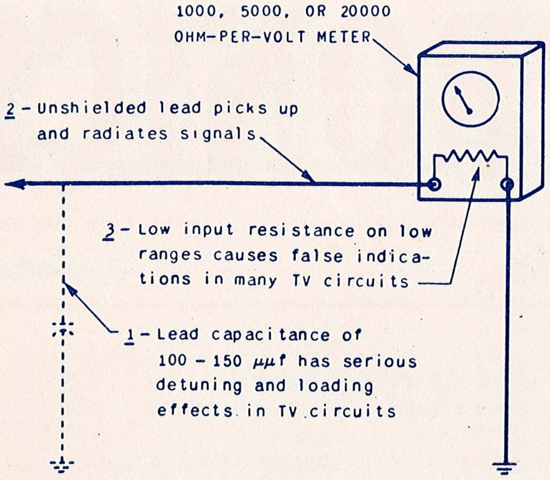
2. *The trouble almost always turns out to be something "simple",* like a capacitor, transformer, coil, resistor, or tube. After all, there is little else in a television receiver. The trouble may be due to slight leakage in a coupling capacitor, shorted turns in a transformer that checks OK for dc resistance, change in value of a resistor that appears perfectly normal, a defect in a tube that presumably had been checked, a stray lump of solder causing a ground or short circuit in a hard-to-see spot, or some intermittently defective part that checks okay when cold.

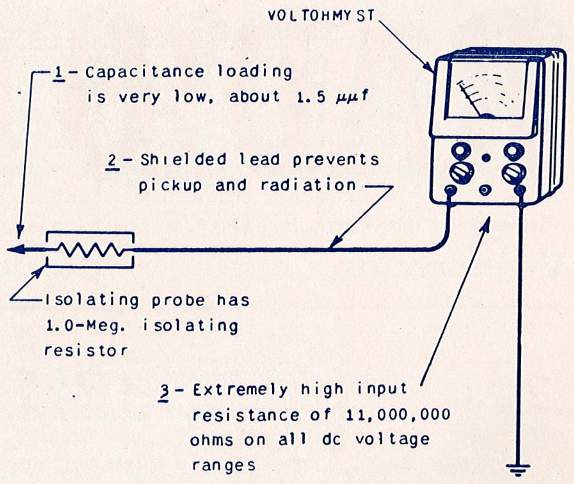
The trouble in many dogs is not so simple. For instance, it may be a combination of two different troubles in the same section of the receiver. Or, if a set has been worked on for several days, or by several technicians, new and weird troubles may have been added to complicate the original condition: Several leads may have been snipped open for checking purposes, and never resoldered. Worse still, the leads may have been resoldered on the wrong contacts. When a technician falls heir to such a set, he is likely to be inheriting a major headache that only patience, perseverance, and painstaking effort can remedy.

Some technicians create their own dogs by refusing to believe the plain and honest statement that, in many cases of obscure trouble, it pays to check the over-all rf-if alignment. If someone has tampered with the alignment adjustments, or if trouble has developed in an rf or if tuned circuit, the technician may waste many hours checking components and voltages before he realizes that the receiver requires realignment. Unstable sync, incomplete blanking, weak picture or sound, distorted sound, poor picture quality, hum, buzz, snow, and interference, are some of the troubles caused by poor alignment. If the technician has a convenient set up of *good* alignment equipment, it takes about five minutes to connect the equipment to the receiver and to determine definitely whether the alignment is good or bad. Five minutes spent in checking the alignment may save five hours of fruitless trouble-shooting effort.

In all cases where the trouble is eventually found in a component that had previously been checked as OK, the technician should immediately question his method of checking. Why didn't the fault show up when the component was first checked? Is there something wrong with the method used in checking the particular component?

The purpose of this article is to point out, with complete frankness, the common deficiencies and limitations in the methods and equipment used for checking. This article also contains helpful information and suggestions for checking transformers, coils, resistors, and capacitors; checks which are the foundation of all trouble-shooting work.





There are three basic reasons why conventional voltmeters of 1000, 5000, or 20,000 ohms per volt are NOT satisfactory for checking tube voltages in TV receivers:

(1) *The capacitance loading* of approximately 100-150 μμf completely detunes any rf or if circuit, thus greatly reducing the signal voltage and altering the agc voltage and the plate voltages in the rf-if amplifiers. In video, sync, and deflection circuits, the capacitance loading reduces the signal amplitude and affects the waveform. In rf, horizontal, and vertical oscillators, the capacitance loading reduces the frequency, amplitude, and activity of the oscillator.

(2) *The unshielded lead* picks up and radiates rf, if, and other stray signals, and may cause regeneration and misleading voltage indications.

(3) *The resistance loading* greatly reduces the voltage in all high resistance circuits. On the 5-volt range of a 20,000 ohm-per-volt meter, the input resistance is only 100,000 ohms, which causes completely false indications in all circuits of more than about 50,000 ohms. The combination of capacitance and resistance loading results in false, unreliable, and misleading indications in most of the tube circuits of a TV receiver.

In sharp contrast to the misleading indications of conventional voltmeters, the RCA VoltOhmyst gives the technician the greatest possible aid in TV troubleshooting:

(1) *The input capacitance is extremely low,* about 1.5 μμf, and therefore has minimum effect in rf and if signals, and negligible effect in all other circuits.

(2) *The input lead is shielded,* eliminating signal pickup, radiation, and the possibility of regeneration due to the feedback that is present on unshielded leads.

(3) *The input resistance is extremely high* (11,000,000 ohms) on all dc voltages ranges, even the lowest. The high input resistance insures correct indication of actual circuit voltages.

In addition to these essential electrical features, the RCA VoltOhmyst provides direct-reading peak-to-peak voltage ranges, the convenience of a single zero-adjustment setting for all "ohms" scales, and protection from meter damage on dc voltage measurements.

Limitations in Methods

1. *DC-Resistance checks do NOT prove that a transformer or coil is OK.* Even if the measured dc resistance agrees exactly with the values shown in the service data, the transformer or coil may have shorted turns, or other troubles, that seriously affect its operation. Leakage between windings may not show up on an ohmmeter, but may be detected by connecting the coils between a source of high voltage and a high-impedance voltmeter. *In most cases, the only reliable method available for checking transformers and coils is the substitution of a new transformer or coil.* In many difficult service jobs, the trouble is eventually corrected by installing a new transformer or coil, despite the fact that the original unit checks OK on an ohmmeter.

2. *Ohmmeter checks for leakage in a capacitor do NOT always reveal leakage that occurs when normal operating voltage is applied to the capacitor.* The voltage applied to a capacitor during ohmmeter check is very low, and necessarily so; otherwise the ohmmeter battery would burn out low resistance elements being tested, such as the filaments of the battery-operated tubes. The voltage across the capacitor in the receiver may be many hundreds of volts. A capacitor that checks OK on an ohmmeter may break down or exhibit leakage under normal operating voltage in the receiver. *Leakage, particularly leakage in coupling capacitors, is responsible for the trouble in a high percentage of difficult service jobs.*

3. *The colour code on a resistor does NOT prove that the resistance value is correct.* Resistors can increase or decrease greatly in resistance value, or become opened, *with no outward change in appearance.* An appreciable percentage of obscure troubles are eventually traced to change in the value of a resistor that "looks" OK and has the correct colour code.

4. *"Sparking tests" for high voltage do NOT prove that the voltage is sufficient.* Sparks can be drawn between the high-voltage lead and the high-voltage electrode of the picture tube, even when the voltage is less than half of normal. Spark tests can mislead the technician into believing that lack of brightness is caused by a perfectly good picture tube. There is no need to guess about the high voltage when it can be measured easily and quickly: An inexpensive RCA WG-289 high-voltage probe enables the owner of any RCA VoltOhmyst to measure dc voltages up to 50,000 volts. (The WG-290 probe is available for voltohmmeters that have phone-tip connectors.)

Limitations in Equipment

Even if the technician avoids the four pitfalls listed above, he may still be hampered and misled by serious limitations and deficiencies in his testing equipment. Most technicians, being honest and modest, blame themselves for any confusion or misleading indications that occur while using test equipment, particularly alignment equipment. In too many cases, the confusion and wrong indications are a direct result of shortcomings in the test equipment itself. It will pay the technician to stop and ask himself —"Is this instrument designed to give me the greatest amount of help in my work, or does it have serious shortcomings that will confuse and mislead me?"

Here, briefly, are some of the things to watch out for:

1. *Ordinary voltohmmeters* (1,000, 5,000 *and* 20,000 *ohms-per-volt) are NOT satisfactory for voltage measurements in the high-resistance, high-impedance, and high-frequency circuits of television receivers.* The effects of capacitance loading, resistance loading, stray pickup, regenerative feedback, and radiation from the leads result in false voltage readings that often mislead the technician into believing that trouble exists in circuits where there is no trouble, and vice versa. The voltages indicated by an ordinary voltohmmeter in many of the circuits *in a perfectly normal TV receiver* are hopelessly different from the actual operating voltages in the set, and also from those specified in the receiver service data. Those technicians who depend on ordinary voltohmmeters are needlessly handicapping their own trouble-shooting ability. It is in the technician's best interests to use a good vacuum-tube voltmeter such as the RCA VoltOhmyst. The VoltOhmyst, with its low-capacitance isolating probe, shielded input cable, and extremely high (11-megohm) input resistance on all dc voltage ranges, has minimum loading and detuning effects on the circuit being tested and, therefore, indicates the true operating voltages.

2. *A CRO that is not designed for use with a low-capacitance probe is NOT satisfactory for checking waveform troubles in the sync separator and deflection circuits.* An unshielded input lead on a CRO picks up stray pulse voltages, and hum voltages, that obscure and alter the desired waveform. It is not satisfactory simply to use a shielded input lead, because the high capacitance of the shielded lead, plus the input capacitance of the CRO (which may total 150-200 $\mu\mu$f), severely reduces the amplitude and waveform of the signal at the test point in the receiver. The resulting pattern on the CRO is incorrect and misleading.

In order to localize a trouble to a particular stage in the video amplifier, sync separator, or deflection circuits, it is essential that the CRO have the following features:

(a) *A frequency-compensated isolating probe and shielded input cable.* The input capacitance of the probe should not exceed about 10 or 15 $\mu\mu$f.

(b) *Voltage calibration for the vertical amplifier.* Calibration is required in order to determine the voltage amplitude at any point in the waveform of the input signal. The amplitude is just as important as the shape.

(c) *Adequate frequency and phase response for observation of horizontal sync pulses.* If the CRO is designed for use with a low-capacitance probe, a frequency response flat to 0.5 Mc, and trailing off to 2 Mc or more, is more than satisfactory, provided the phase response is good. Beware of claims for wide-band frequency response measured *at the input terminals posts* on a CRO. Such claims are meaningless and misleading, because the addition of an input lead (a CRO cannot be used without an input lead) *drastically* cuts down the "rated" frequency response.

3. *Alignment equipment that is built to sell on "price appeal", and that fails to meet any of the minimum requirements listed below, is NOT a good investment at any price.*

(a) *The rf and if output voltage of the sweep generator must be "flat" over every swept range, and must remain flat at all settings of the output attenuator.* "Peaks and dips" in the sweep output voltage mislead the technician into believing that well-aligned receivers need realignment. When a receiver is aligned with such a sweep, the response curve appears correct, but is actually wrong. There is no satisfactory method, except laboratory analysis, to determine the flatness of output voltage. The purchaser must depend on the manufacturers' claims. In this connection, it is a significant fact that *the RCA sweep generator is the only service-type sweep in general use on TV production lines, in TV development laboratories, and in the laboratories of industrial and educational institutions.*

(b) *The sweep generator and marker oscillator must not produce unwanted and confusing response curves and unwanted multiplicity of markers.* In using alignment equipment that has excessive output of harmonics or spurious signals, it is extremely difficult, and often impossible, to determine the correct response curve and the correct marker. Such equipment is a useless investment at any price.

(c) *The sweep generator and the marker oscillator must have adequate shielding and proper cable termination.* Radiation from the equipment or cable produces — (1) spurious response curves, (2) unwanted and misleading markers, and (3) general instability and variations in the amplitude and shape of the response curve due to hand-capacitance effects. This point should be given careful consideration, particularly if the test equipment manufacturer suggests the use of "a metal top on the bench and bonding of the equipment" to reduce the effects of the undesired radiation. Adequately shielded and properly terminated alignment equipment does NOT require such artificial (and usually ineffective) aids.

(d) *The marker oscillator must have built-in crystals and built-in means for setting the variable oscillator to the crystal harmonics.* The mere fact that a marker oscillator has one or two built-in crystals, or "provision for plug-in crystals", is no assurance that the crystals are fully usable. Some marker oscillators have only one crystal that provides check points at wide intervals, such as 5 Mc, and the misleading claim is made for them that the dial can be set accurately between these check points by "interpolation". The catch in this case is that even if the *dial* is set precisely by interpolation, the oscillator *frequency* may still be off by an excessive amount. Frequent crystal check points are essential for accurate setting of the variable oscillator. The feature of "external plug-in crystals" has a misleading appeal; the technician should first check on the number and cost of the crystals that he will have to purchase to accommodate all of the different intermediate frequencies now in use, with more to come. The RCA WR-39C Crystal Calibrator has three built-in crystals and a built-in heterodyne detector, amplifier, and speaker. The method of using the crystals provides calibration at every $\frac{1}{4}$-Mc point throughout the rf and if ranges. A 4.5-Mc crystal provides the accuracy necessary for alignment of sound-if amplifiers and discriminators in all intercarrier sets. The 4.5-Mc crystal may also be used at will to modulate the variable oscillator, thus providing *both* picture and sound markers simultaneously: This feature is extremely valuable in checking and aligning rf tuners. In brief, the RCA Sweep Generator and Marker Oscillator are designed to aid the user, not to confuse or mislead him.

Hundreds of technicians have learned the hard way, through bitter and expensive experience, that the above information on requirements for testing equipment is NOT "sales talk". Many of these technicians, who spent hard-earned money on equipment that they later found by experience to be inadequate, confusing, and misleading, have asked the writer to bring out the real facts as plainly as possible. This we have now done.

SUGGESTED CHECKING METHODS

This section contains practical information and suggestions for checking transformers, coils, resistors, and capacitors. ,

Checking Coils and Transformers

Shorted turns in a coil or transformer winding may be regarded as equivalent to a short-circuited secondary winding of the same number of turns. Shorted turns may or may not cause trouble, depending on the function of the coil, the circuit in which it is used, and other factors. Even one short-circuited turn in the coil of an rf or if tuned circuit may make it impossible to peak the circuit at the specified frequency. On the other hand, a short circuit across all of the turns in a video peaking coil is unlikely to have any noticeable effect. Shorted turns in a deflection-circuit transformer may seriously affect the operation of the circuit.

Unfortunately, it is impossible to detect the presence of a small percentage of shorted turns by checking the dc resistance of the winding. The fault must usually be found in a round-about fashion. The usual method is first to eliminate all other possibilities of trouble in the particular section of the receiver by checking the tubes, components, voltages, and wiring. Then, even though the dc resistance of the particular coil or transformer checks exactly with the values specified in the service data, it is necessary to try a new coil or transformer. If the trouble disappears when the new unit is installed, it can be assumed that the original coil or transformer was faulty, possibly due to shorted turns.

There are several reasons why dc resistance checks fail to reveal a short circuit across a small percentage of the turns in a coil: (1) There is a manufacturing tolerance in the impedance and consequently in the number of turns on most windings, with a corresponding tolerance in the dc resistance. (2) The resistance values specified for coils and transformer windings in the manufacturer's service data are frequently taken from a single sample of the receiver: Any of the coils and transformers in the sample receiver may be on the low edge, or the high edge of the tolerance range. (3) There is a normal amount of error in the ohmmeter used in compiling the service data, and also in the ohmmeter used by the technician. The combination of these factors makes it virtually impossible to detect a small percentage of shorted turns by means of dc-resistance checks.

It is important to remember that dc-resistance checks do NOT prove that a coil or transformer is OK. Resistance checks are valuable in revealing open coils, completely shorted coils, shorts across more than about 20 per cent of the turns, leakage and shorts between coils, leakage and shorts from a coil to the core, leakage and shorts from a coil to the outer container or to the chassis, and similar defects.

Ohmmeter checks also fail to reveal leakage or breakdown (across coils, from coil to coil, from coil to core, etc.) that may occur only when normal operating voltages are applied to the coil or transformer in the receiver. When there is reason to suspect leakage or breakdown from a coil to the core or to the chassis, a check can be made by temporarily insulating the unit from the chassis.

Checking RF and IF Coils, Transformers and Traps

If an rf or if tuned circuit can be peaked at its specified frequency, it can be assumed that the coil is OK.

Shorted turns reduce the inductance of a coil and increase the resonant frequency of the circuit. When a circuit cannot be tuned low enough in frequency, inspect the coil for shorted turns. If the coil appears normal, and if there is a fixed or adjustable capacitor in the tuned circuit, check the capacitor for open circuit and for capacitance value. If a satisfactory checker is not available for measuring low-value capacitors, try a new capacitor. Capacitors used in rf and if tuned circuits are critical (in value, and often in construction); hence it is advisable, and frequently essential, to use exact replacements.

When the inductance or capacitance of a tuned circuit is too low, it is possible to be misled by a false peak in response which occurs when the iron core in the coil is moved through the maximum-inductance position at the centre of the coil. If the core can be moved from one end of the coil to the other, there should be two different positions (one on each side of the centre of the coil) at which the circuit can be resonated to the correct frequency. In some tuned-circuit transformers, and in some tuned coils that have a coupled wave trap, it is necessary to use a particular one of these two settings in order to obtain the correct coupling between windings. The correct setting is usually specified in the service data.

When it is impossible to peak a tuned circuit or trap at the specified frequency, check the dc resistance of the coil. If it is opened or shorted, inspect the coil, the leads from the coil, and the terminal connections. If necessary, temporarily disconnect and check the associated tuning, coupling, and by-pass capacitors, and any shunt damping resistor. If these parts check OK, try a new coil.

Coils that are wound with spaced turns of bare wire can be checked visually: Look for shorts between adjacent turns, and for splashes of solder across the turns. If there is a tap on the coil, or a capacitor mounted on the coil, make certain that the connecting bus leads are not shorting against the coil.

Video Peaking Coils

Video peaking coils are used to "hold up" the high-frequency response, from about 2 to 4 Mc, in the second detector and video amplifier. A shorted peaking coil reduces the definition of the picture slightly. An open peaking coil may result in complete loss of picture, or serious loss of picture quality. The effects of open and short circuits may be summarized as follows:

(a) A complete short circuit, or shorted turns, in one peaking coil usually causes only a minor loss in the definition ("sharpness", or fine detail) of the picture.

(b) If the peaking coil has a damping resistor connected across it, an open circuit in the coil leaves the damping resistor in the circuit; consequently, there is seldom complete loss of picture, but there is usually a noticeable loss of picture quality and, in some cases, poor sync action.

(c) If the peaking coil does not have a damping resistor connected across it, an open circuit in the coil is likely to result in complete loss of picture. For instance, if the coil is in series with a video plate circuit, an open coil creates an open plate circuit, with resulting loss of picture.

When the visible symptoms indicate that the trouble is in the video amplifier, it is advisable to check the dc resistance of the peaking coils. The resistance ranges from about 2 to 10 ohms, depending on the size of the wire and the inductance of the coil. If a coil is found to be opened or shorted, it should be replaced.

As mentioned above, a shorted peaking coil has little effect. This fact can be used to advantage when it is found that loss of picture, or poor picture quality, is caused by an open peaking coil: *To make a temporary or emergency repair on an open peaking coil, simply connect a short circuit across it.*

If the damping resistor across a peaking coil becomes opened, there is seldom any visible effect in the picture. Lack of damping can, however, cause "ringing" in the particular circuit. Ringing may produce multiple images on all stations. The images are uniformly spaced and progressively weaker. (When multiple images are caused by external signal reflections from several surrounding objects, the images are not uniformly spaced, not progressively weaker, and are seldom identical on all stations.) Video ringing can also occur in a circuit consisting of a peaking coil connected in series with a load resistor, if the resistor is shorted out.

In order to check the dc resistance of a shunt damping resistor, it is necessary to disconnect one end of the peaking coil from the resistor. In some receivers each of the peaking coils is mounted on, and connected to, a small tubular resistor. The resistor may or may not be used to provide damping across the coil. If the resistor is intended to provide damping, it usually has a value under about 25,000 ohms. If the resistor is used solely as a convenient means for mounting the coil, it has a much higher resistance, usually one megohm or more, and, in this case, the resistor has no effect on the action of the circuit.

Width and Linearity Coils

If the raster is visible on the picture tube, adjust the iron core in the width coil, and in the linearity coil, from the maximum-inductance position (core at centre of coil), to the minimum-inductance position (core out of coil). If the resulting change in width and linearity appears normal for the particular receiver, it may be assumed that the coil is OK. If adjustment of the core has little or no effect, or if this check cannot be made due to absence of the raster, disconnect one end of the coil and check the dc resistance. If the coil is definitely opened or shorted, it should be repaired or replaced. If the coil appears to be OK, check the associated circuits and components.

Horizontal and Vertical Transformers and Deflecting Coils

When the visible symptoms indicate that the trouble is in the horizontal or vertical section of the receiver, considerable time and effort can be saved by first localizing the fault to one half of the section. This step can be accomplished by checking the waveform and the peak-to-peak voltage at the output of the discharge circuit, and comparing the observed readings with the values specified in the service data. The writer recommends the RCA WO-56A 7-inch oscilloscope for this purpose. If a suitable oscilloscope is not available, measure the peak-to-peak voltage at the discharge circuit with an RCA WV-97A Senior VoltOhmyst, which has direct-reading peak-to-peak voltage scales.

Check the tubes, components, voltages, and wiring in the suspected portion of the section. Check the dc resistance of the transformers and deflection coils. Check for leakage in the grid capacitors of the oscillator, discharge, and output tubes, using the method suggested later in this section. If careful check of each component fails to reveal the trouble try a new transformer. An open or short circuit in the deflection coils usually results in a keystone-shape raster, as depicted in the RCA-Pict-O-Guide, Vol. II, HD-10.

If the fuse in the horizontal output circuit is found to be opened, it is a good practice to inspect the horizontal output transformer for evidence of high-voltage arc-over. If there is a burnt or charred spot on one of the windings, it is generally advisable to replace the transformer. If there is no visible evidence of trouble in the transformer, install a new horizontal output tube. Also check the filament winding for the damper tube which may be shorted to ground. In either case, replace the fuse and observe the horizontal output transformer when power is applied to the receiver. If the transformer starts to arc-over or smoke, immediately turn off the power. In this case, it is generally necessary to replace the output transformer. It is also advisable to check all other components in the horizontal output circuit.

Filter Choke

When there are noticeable 120-cycle hum symptoms in the picture, in the sound, or in both, check the electrolytic filter capacitors, and the dc resistance of the filter choke. If the hum is not caused by the electrolytic filter capacitors, try a new choke.

Power Transformers

When a power transformer operates considerably hotter than usual, the trouble may be caused by external over-load in one of the secondary circuits or by internal over-load due to shorted turns in the primary or in one of the secondary windings. As mentioned previously, shorted turns in a winding are equivalent to a separate secondary (of the same number of turns), which is short circuited. The current that can flow in the shorted turns is limited by the size of the wire and other factors. There is usually higher current and higher power loss in a shorted turn on a "heater" winding than on a B-supply winding.

A power transformer can be checked for excessive power loss, due to shorted turns or other internal fault, by disconnecting all of the secondary circuits and operating the transformer until it attains maximum temperature. If the transformer becomes excessively warm or hot on this "no load" check it is a definite sign of internal trouble.

An *external* short circuit or over-load can be localized to a particular secondary circuit by the following method:

1. Remove the power plug and disconnect all of the secondary windings.
2. Remove all of the tubes from the receiver. Remove the socket from the picture tube.
3. Connect one of the heater circuits.
4. Apply power to the transformer. Look for signs of overloading. If the particular heater circuit does not cause over-load, insert the tubes that are operated from this heater winding. Look for signs of over-load as each of these tubes is inserted. If there is no evidence of over-load, it may be assumed that this particular heater circuit is OK.
5. Turn off the power, connect the next heater winding, and proceed as in item 4.
6. Check all of the heater circuits, and, finally, the B-supply secondary.

Checking Tubular Resistors

On most service jobs, the tubular resistors can be checked simply by visual inspection. If a resistor is not discoloured, darkened, charred, swollen, cracked, or broken, and if the colour code agrees with the resistance specified in the schematic diagram on the receiver, it may be assumed that the resistor is *probably* OK. But, if a thorough check of the tubes, components, voltages and wiring in the suspected section of the receiver fails to reveal the fault, *it is then definitely advisable to measure the actual resistance of each resistor* in the defective section of the set. Resistors can increase or decrease in resistance value, and also become opened, without the slightest alteration in external appearance. In addition, there is always a remote possibility that the colour coding on a resistor may be incorrect, and that certain colours such as orange and yellow, or bluish-green and greenish-blue, may be mistaken. For these reasons it is a good rule, particularly when working on difficult jobs, not to accept the resistors at "face value", but instead, to measure the resistance of each resistor.

A resistor rarely becomes overloaded through any fault of its own. Over-load is almost always caused by an external short circuit or ground in one of the associated components. Hence, *when a resistor shows visible signs of over-load, it is not sufficient merely to replace the resistor.* It is essential to check for possibility of short circuit and grounding in the associated circuit components and wiring. Resistor over-load is frequently caused by excessive leakage or short circuit in an associated by-pass capacitor, but it may also be caused by a defective tube, incorrect voltages on a tube, leakage in a coupling capacitor, grounding in an associated coil or transformer, or similar defects.

If the reason for the over-load cannot be determined, it is advisable to install a new resistor, and to operate the receiver for sufficient time to see if the condition recurs. If the resistor becomes excessively hot, quickly check the voltages in the resistor circuit to determine the point at which the short circuit or grounding is taking place. It may be necessary to snip open any associated by-pass capacitor, or other component, to determine whether it is responsible for the over-load.

Many technicians have asked how much change can be tolerated in resistance values. It is impossible to give a general answer to this question because some circuits are more critical than others. For example, a change of 10 per cent in the value of a grid-bias resistor for a video stage may cause trouble, while a change of 50 per cent in the grid-leak resistor of the same stage may have little if any effect. Circuit constants are selected by the design engineers to provide the best possible performance over the range of operating conditions, including high and low line voltage, high-and-low-limit tubes, high-and-low-tolerance limits in other components, high and low room temperature, etc. If a resistance value appears to be unimportant for a particular set of operating conditions, it may possibly be important for a different set of conditions. It is therefore sensible to adhere to the specified values as closely as possible. When a defective resistor is replaced, it is good practice to replace it with a unit of equal or better tolerance, or measure the replacement with an ohmmeter.

The task of checking all of the resistors, and the dc resistance of all other components in the suspected section of a receiver, can be simplified and speeded up by the use of the RCA VoltOhmyst. Ordinary voltohmmeters, and many vacuum-tube voltohmmeters impose the continual nuisance and distraction of resetting the zero adjustment every time that the meter is switched to a different "ohms" scale. *This nuisance is eliminated in the RCA VoltOhmyst, because one setting of the zero adjustment holds good for all scales,* unless the "Ohms" battery is exhausted.

The following two points, in connection with resistance checks, are well known but can stand emphasis (1) It is necessary in many cases to disconnect one end of the resistor, coil, capacitor, or other component that is being checked, in order to eliminate any effect from other circuit elements. (2) It is often necessary to allow time for the tubes to become cold before checking resistance in grid circuits. Depending on the polarity of the ohmmeter leads, there may be grid current, and resulting error in meter reading, if measurements are made while the tubes are still warm.

Checking Capacitors

Continual improvements in the design and construction of all types of capacitors have reduced the rate of capacitor failure to a very low level, but in view of the fact that *there are more than 150 capacitors in the average television receiver,* it is not surprising to find that capacitors are responsible for the trouble in a high percentage of all TV service jobs.

Capacitors may become opened, partially opened, shorted, partially shorted, or leaky, or may develop internal series resistance. Leakage is equivalent to having a dc resistance connected internally across the capacitor. Leakage as high as 1,000,000,000 ohms can cause trouble in certain circuits, while leakage as low as 1000 ohms has no noticeable effect in other circuits. When the leakage resistance is low, a few ohms or less, the capacitor is said to be "completely shorted", or to have a "dead short". Somewhat higher resistance is described as a "partial short." Leakage may be caused by imperfections or conducting particles in the dielectric, by carbonization of the dielectric due to internal arc-over, and by other reasons. Capacitors may develop internal series resistance, usually due to poor internal contact, which makes the capacitor less effective for certain applications, particularly in rf and if circuits. "Opened" capacitors are usually the result of internal disconnection of one of the leads. Cracking or breaking of the dielectric and silver-film plates in ceramic-type capacitors usually causes a complete open circuit or a great reduction in capacitance. Occasionally a capacitor becomes partially opened (capacitance drops to a fraction of the original value), due to internal disconnection of a portion of the plate area.

To check a capacitor for capacitance, leakage, and other factors, it is necessary to disconnect the capacitor from the circuit, and measure it on laboratory-type equipment. While this method is excellent for engineering purposes, it is too slow, and generally unnecessary, for routine service work, where it is frequently necessary to make rapid checks on a dozen or more capacitors in the suspected section of the receiver. It is usually easier and quicker to try a new capacitor, if necessary, than to disconnect and measure the suspected capacitor. In actual service practice, capacitors are checked by various indirect methods, and by substitution, as follows:

1. *Shorted bypass capacitors* are usually detected during the process of *measuring dc voltages* in the suspected section of the receiver. In any plate, screen, cathode, or grid-return circuit that requires a bypass capacitor, there is normally some dc voltage across the capacitor. (The correct voltage may be specified in the service data for the receiver, or it may be estimated from other specified voltages in the same circuit.) If there is no voltage across the capacitor, or if the voltage is considerably lower than it should be, it indicates that the capacitor *may* be shorted. This possibility can be checked quickly by simply disconnecting one end of the capacitor. If the voltage in the circuit returns to normal when the capacitor is disconnected, it indicates that the capacitor is shorted. If the voltage does not return to normal, check for other faults in the same circuit, such as an open filter resistor, a ground in another component, or a defective tube. See Fig. 1.

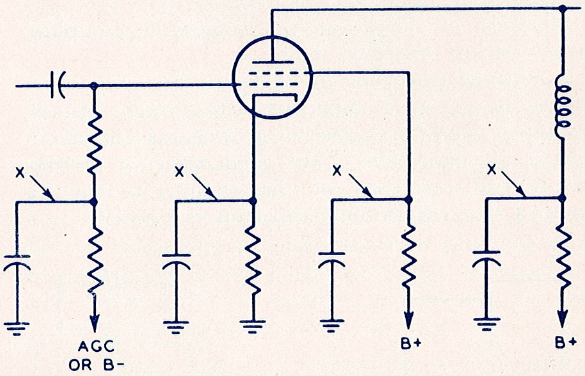


Fig. 1. The following simple method is often used to check for possibility of short circuit in a bypass capacitor: When the B+, B— and agc voltages are approximately correct, but the dc voltage at any of the points marked "X" is zero, or appreciably lower than the normal value, temporarily disconnect the capacitor at this point. If the voltage at the particular point returns to normal, it indicates that the bypass capacitor is shorted. The voltage on one tube element usually affects other tube voltages. For instance, if the cathode voltage is low, the plate and screen voltages may also be low; or if the screen voltage is low, the plate voltage may be high.

When a *plate- or screen-circuit bypass capacitor* becomes shorted, it usually causes excessive current flow through any associated filter (or dropping) resistor. As a result, the resistor may become burned open, or it may change considerably in resistance value. Whenever a plate- or screen-circuit bypass capacitor becomes shorted, it is always advisable to check the associated filter resistor and any other components that may have been overloaded as a result of the shorted capacitor.

When a suspected bypass capacitor is disconnected (in checking for possibility of short circuit), the absence of the bypass capacitance may affect the normal operation and voltages in the circuit. In such cases, the voltages will not return to normal until a new bypass capacitor is connected in the circuit.

2. *Shorted or leaky coupling capacitors* are usually detected by *dc voltage measurements.* If the grid-bias voltage in a particular stage is considerably less than normal, or if it is positive, the coupling capacitor should be checked for possibility of leakage, as described later, or a new capacitor should be temporarily substituted for the suspected capacitor to see if it remedies the trouble.

In oscillator circuits (rf, horizontal and vertical) the normal negative grid-bias voltage is produced by grid current that flows during positive peaks of the oscillator signal. If the grid-bias voltage is very low, or considerably less than normal, it is necessary to check all of the components in the oscillator circuit, including the grid capacitor.

In circuits such as the horizontal discharge, horizontal output, or some sync-separator stages, where the normal grid-bias voltage is obtained entirely or in part as a result of grid current on positive peaks of the applied signal, low bias voltage is often due to insufficient input-signal voltage.

Methods of checking for leakage in coupling capacitors are described later.

3. *Opened capacitors* are detected by temporarily connecting a good capacitor across each of the suspected capacitors, one at a time, as shown in Fig. 2. If connection of the good capacitor restores the normal operation of the circuit, it may be assumed that the original capacitor is opened.

Fig. 2. On difficult service jobs it is a good practice to check all of the bypass and coupling capacitors in the suspected section of the receiver for possibility of open circuit: Temporarily connect a good capacitor across each of the suspected capacitors in turn. If connection of the good capacitor restores normal operation it may be assumed that the original capacitor is opened.

Good capacitors in certain circuits may be connected or disconnected with no apparent effect on the performance of the receiver. There are several possible explanations in such cases: (1) There may actually be a slight effect which the observer fails to notice. (2) The effect may be apparent only under certain operating conditions. (3) The particular capacitor may not be essential, but may have been incorporated as a precautionary measure. For instance, in many receivers extra capacitors and resistors are used in the intermediate-frequency plate, screen and grid decoupling networks as an additional safeguard against possibility of regeneration.

4. *Any faulty capacitor in any circuit* can be detected by the "substitution" method, as shown in Fig. 3. Disconnect the "high" end of the suspected capacitor. Temporarily connect a good capacitor in the circuit. If the trouble is still present, after the new capacitor is connected, it may be assumed that the original capacitor is OK. If the trouble disappears when the new capacitor is connected, it may be assumed that the original capacitor is defective. Obviously, in the latter case, a new capacitor should be installed permanently. The new capacitor should have the correct capacitance and the correct voltage rating, or a higher rating. The new capacitor should be of the same type (paper, mica, ceramic, etc.) as the original, and it should have the same temperature coefficient, if the original capacitor has temperature compensation.

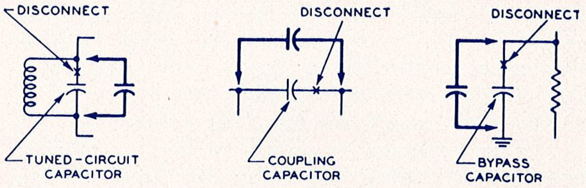


Fig. 3. Faulty capacitors can be detected by the substitution method: Disconnect one or both ends of the suspected capacitor. Temporarily connect a good capacitor in the circuit. If the new capacitor remedies the trouble it may be assumed that the original capacitor is defective. See text for additional details.

When the substitution method is used for checking *bypass and coupling* capacitors, the capacitance of the testing capacitor is not critical in most circuits. Ordinarily, the testing capacitor may have a value anywhere in the range of from $\frac{1}{2}$ up to 2 times that of the original capacitor. Even a value of from $\frac{1}{4}$ to 10 times that of the original capacitor is likely to be satisfactory for the purpose of revealing defects in the original capacitor.

However, when *deflection circuits* are checked for the cause of poor linearity, and when *deflection oscillator and discharge circuits* are checked, the rated capacitance of the testing capacitor should be the same as that specified for the original capacitor.

In *rf and if tuned circuits* the testing capacitor should be an exact duplicate of the original capacitor. In *rf tuned circuits* even the lead lengths on the testing capacitor should be the same as on the original.

Many technicians keep a selected assortment of capacitors solely for use in substation checks. The larger capacitors, such as electrolytics, may be equipped with leads and clips for convenience in connection.

Even in circuits where the capacitance value appears to be unimportant, the replacement capacitor (the capacitor that is permanently installed in place of the defective one) should be an electrical duplicate of the original. In rf and if tuned circuits the replacement capacitor should duplicate the original both electrically and physically.

In high-frequency rf and if circuits it is NOT good practice to parallel two or more capacitors in order to obtain the desired capacitance value: a dip or a peak may be produced in the response band of the amplifier at the resonant frequency of the paralleled capacitors, if this frequency happens to fall within the band.

Some tubular capacitors have a dark line printed around one end of the label with the words "ground", or "outer foil" to indicate that the pig-tail on this end is connected to the metal-foil plate that is on the outside of the rolled-up assembly. It is a good general practice to connect the outer-foil end of the capacitor to the grounded or low-impedance side of the circuit. When the outer-foil plate of the capacitor is grounded, it forms an electrostatic shield around the capacitor, thus reducing the amount of stray coupling to and from other nearby components and wiring.

Checks for Leakage

No resistance limits have been established in television service practice for classifying a capacitor as "leaky" or "not leaky" because the effects of leakage depend on the particular circuit in which the capacitor is used, as shown in the following examples:

(a) A partial short-circuit (low-resistance leakage) of 1,000 ohms in a capacitor connected across a 100-ohm cathode resistor has very little effect on the operation of the circuit. Such leakage is likely to pass unnoticed unless the technician happens to disconnect the capacitor and check it for leakage. A leakage of 1,000 ohms in a plate- or screen-circuit bypass capacitor, or in a plate-to-grid coupling capacitor seriously affects the voltages and the operation of the circuit.

(b) A leakage of one megohm in a plate or cathode bypass capacitor ordinarily has negligible effect on the operation of the circuit, but the same leakage in a plate-to-grid coupling capacitor is practically equivalent to a short circuit in most cases, and will definitely affect the operation of the circuit.

(c) A leakage of even 100 megohms (100,000,000 ohms) in a plate-to-grid coupling capacitor is likely to cause trouble if there is a high-value resistance in the grid circuit. Consider the following conditions:

Plate voltage = 300 volts
Normal grid bias = —8 volts
Grid resistance = 2.0 megohms
Leakage in coupling capacitor = 100 megohms

In this example the voltage drop across the grid resistor due to leakage in the coupling capacitor is almost 6 volts (2/102 x 300). This voltage bucks the normal grid bias, reducing it from —8 to —2 volts. Such a large percentage of change in grid-bias voltage is very likely to cause trouble.

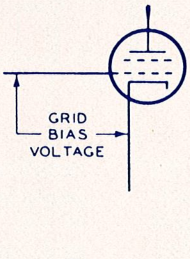


Fig. 4

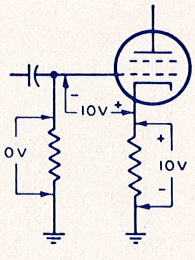


Fig. 5

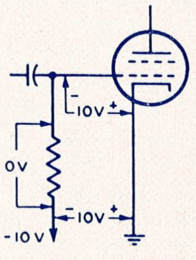


Fig. 6

(d) Even a leakage of 1,000 megohms (1,000,000,000) may cause trouble, as in the following case:

Plate voltage = 300 volts
Normal grid bias = —2 volts
Grid resistance = 2.0 megohms
Leakage in coupling capacitor = 1,000 megohms

The drop across the grid resistor due to leakage in this case is approximately 0.6 volts (2/1002 x 300), which reduces the grid bias from —2 to —1.4 volts. If this condition existed in a video amplifier it might result in sync clipping and unstable sync action.

In many cases of obscure trouble, the fault is eventually corrected by replacing a coupling capacitor that "checks OK" on an ohmmeter. When a faulty capacitor, or any other faulty component, appears to check OK, the technician is likely to spend many hours of exasperating effort checking other components before he finally decides to try a new capacitor. Obviously it is senseless to depend on checks that fail to reveal the fault:

For *practical* purposes the best way to check for leakage in coupling capacitors is by measuring the "leakage voltage" across the grid resistor while the receiver is in operation and while normal operating voltage is being applied to the capacitor. For a thorough understanding of this method, it is necessary to understand the different ways in which grid-bias voltage is obtained, and how it can be measured. This entire subject is covered, as briefly as possible, in the following illustrations and text.

The actual grid-bias voltage is *the dc voltage between the grid and cathode,* as indicated in Fig. 4. Voltages shown in service data are usually measured with respect to the chassis, but in many circuits the voltage from grid to chassis is not the actual grid-bias voltage.

In Fig. 5 the voltage from grid to chassis is zero, but the actual grid-bias voltage, obtained by the voltage drop across the cathode resistor, is 10 volts.

In Fig. 6, the actual grid-bias voltage is —10 volts, measured either with respect to the chassis or with respect to the cathode, because the cathode is connected directly to the chassis.

In Fig. 7 the actual grid-bias voltage is —10 volts, obtained by the drop across the top resistor in the cathode circuit. The grid-to-chassis voltage is the same as the voltage across the bottom resistor in the cathode circuit.

In Fig. 8 the actual grid-bias voltage is —10 volts, obtain by the drop across the cathode resistor. Grid-to-chassis voltage is —100 volts. Voltage measurements from grid to chassis, or from cathode to chassis, are likely to be misleading in circuits like Figs. 7 and 8. Refer also to Fig. 9.

Fig. 9 is the same as Fig. 8 except that a partially-shorted cathode bypass capacitor has reduced the voltage across the cathode resistor, and also the grid-bias voltage by 50%, from 10 volts to 5 volts. If the technician measures the grid-to-chassis voltage, which is still —100 volts, and the cathode-to-chassis voltage, which is 95 volts instead of 90 volts, *he is very likely to assume that there is no trouble in the circuit,* since he is aware that the negative supply voltage (—100 volts in this example) is frequently 10% high or low. In circuits of this type, it is best to measure the voltage across the cathode resistor, and also the voltage from grid to cathode. Refer to Fig. 10.

The service data for the receiver may not show the voltage across the cathode-resistor, but it may give the voltage at each end of the resistor, measured with respect to the chassis as shown in Fig. 10. The voltage across the cathode resistor is the difference between these two voltages. (12 volts in this example.)

The required grid-bias voltage for a tube is sometimes obtained by using two grid resistors to divide the voltage from an available negative-supply tap, as shown at left in Fig. 11 and in an equivalent form at the right in Fig. 11. In this particular example the resistors are equal in value, and they divide the total voltage in half, but any other fraction of the voltage may be obtained by changing the ratio of the two resistors. The effective grid resistance is equal to the value of the two resistors in parallel, or 0.5 megohm in this example.

NOTE: In conventional rf and if amplifiers, and in most video amplifiers, there is no grid current and (if there is no leakage in the coupling capacitor), there is *no dc voltage across the grid resistor.* (An exception may occur in a stage in which the cathode-resistor bias is less than 1.5 volts and the grid resistor has a value of more than about one megohm. Then, current due to "contact potential" may produce a slight negative voltage across the resistor.) This condition of zero dc voltage across the grid resistor is shown in examples given in Figures 5 to 9 inclusive. There is, of course, ac-signal voltage across the resistor and ac-signal current through the grid resistor. There is grid current in oscillators and in certain amplifiers, and this current produces dc voltage across the grid resistor, as shown in Figures 12 to 15 inclusive. If the grid coupling capacitor is shorted or leaky, the leakage current produces a dc voltage across the grid resistor, as shown in Figures 18 and 23.

Grid-bias voltage in oscillators is obtained (entirely or in part) as a result of electron flow from cathode to grid during the peaks of the positive half-cycles of oscillator voltage on the grid. The electrons charge the grid capacitor, making it negative on the grid side. In the time between positive peaks, the capacitor discharges through the grid resistor, thus producing a voltage across the resistor as indicated in Fig. 12. This voltage is termed the "developed" grid-bias voltage, and it is a measure of the oscillator activity. *If the developed bias voltage is lower than normal, it indicates trouble or misadjustment.* If oscillation ceases, the developed bias voltage drops to zero, and the plate or screen current may become excessive: A resistor may be used in the cathode circuit to provide protective bias voltage and to prevent tube damage in the event that the circuit stops oscillating.

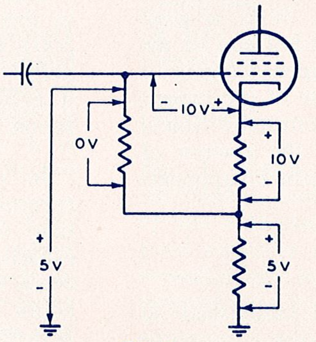


Fig. 7

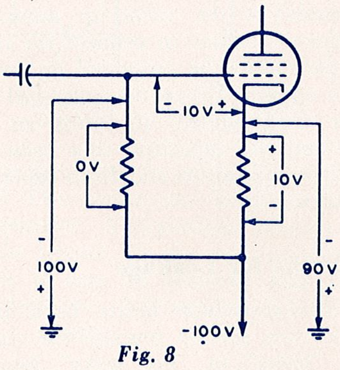


Fig. 8

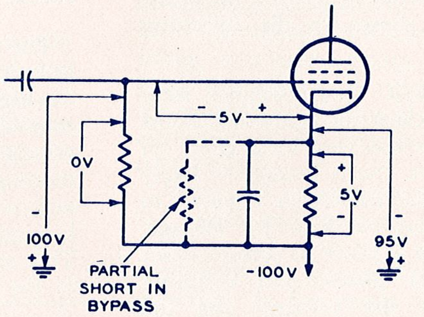


Fig. 9

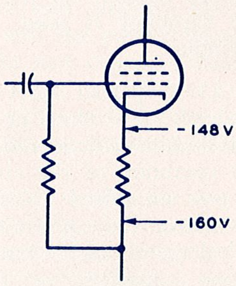


Fig. 10

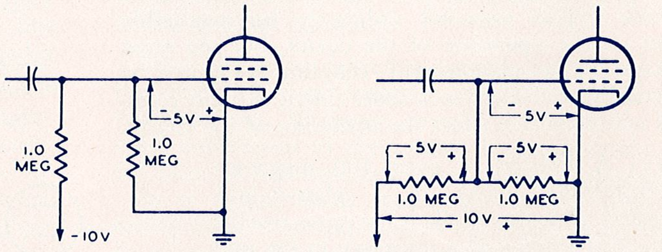


Fig. 11

In certain amplifiers and limiters the grid-bias voltage is produced as a result of cathode-to-grid electron flow during the peaks of the positive half-cycles of the *applied input signal.* The developed grid voltage (Fig. 13) is a measure of the amplitude of the applied signal. If the developed grid voltage is appreciably less than normal, it indicates either that the amplitude of the applied signal is below normal, or that there is trouble in the circuit, including the possibility of leakage in the coupling capacitor. A resistor may be used in the cathode circuit to provide bias voltage and to prevent tube damage in the event that the input signal fails, or becomes too weak.

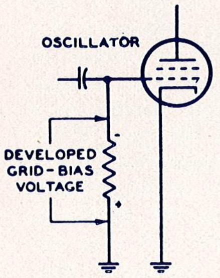


Fig. 12

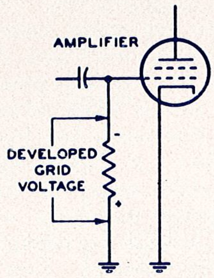


Fig. 13

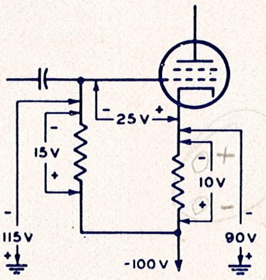


Fig. 14

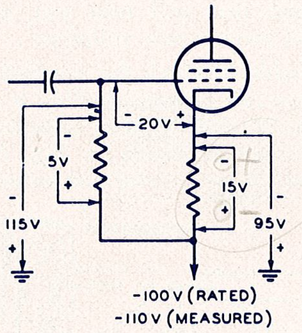


Fig. 15

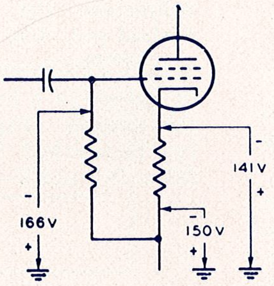


Fig. 16

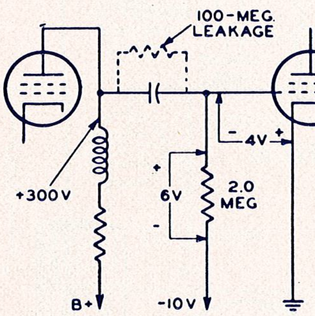


Fig. 17 18

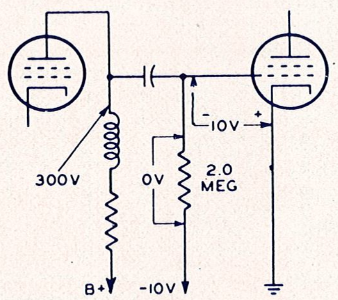


Fig. 18 17

In Fig. 14, which shows the circuit of a typical horizontal-output amplifier, the grid-bias voltage is —25 volts, of which —10 volts is obtained by the drop across the cathode resistor, and —15 volts is produced as a result of cathode-to-grid electron flow during the peaks of the positive half-cycles of the input signal. The developed voltage across the grid resistor is a measure of the amplitude of the applied signal. If the developed voltage is appreciably less than normal, it indicates either that the amplitude of the applied signal is below normal, or that there is trouble in the circuit, including the possibility of leakage in the coupling capacitor.

In circuits where the cathode is returned to a relatively high negative voltage point in the B-supply circuit, as shown in Fig. 15, *it is important to realise that voltage measurements made from grid to chassis are very likely to be misleading.*

The voltages in the power supply are often 10% higher or lower than the values specified in the service data. Therefore, if the grid-to-chassis and the cathode-to-chassis voltages check within ± 10% of the specified values, the technician is likely to assume that everything is OK. Actually, such checks do NOT reveal troublesome changes in developed voltage across the grid resistor, nor in the voltage across the cathode resistor.

? diagram errors

Assume that the voltages shown in Fig. 14 are correct, and that in Fig. 15 certain trouble has changed the developed voltage from —15 volts to —5 volts, and has changed the voltage across the cathode resistor from 10 volts to 15 volts. Also assume that the —100 volt supply actually measures —110 volts. Note that, despite the trouble, the grid-to-chassis voltage is the same in both cases. Note that there is only 5% change in the cathode-to-chassis voltage. In circuits of this type it is best to measure the developed voltage across the grid resistor, the voltage across the cathode resistor, and the voltage from grid to cathode. Measurements of this kind require the use of a high-impedance electronic voltmeter having a shielded input cable and isolating probe, such as the RCA VoltOhmyst.

?

The service data for the receiver may not show the developed voltage across the grid resistor, nor the voltage across the cathode resistor, but may show the grid-to-chassis voltage, the cathode-to-chassis voltage, and the measured or the "rated" voltage of the negative-supply point to which the cathode is returned, as shown in Fig. 16. The voltage across each resistor may be determinated from these other voltages. In the example shown, the voltage across the grid resistor is 16 volts (166 — 150), and the voltage across the cathode resistor is 9 volts (150 — 141). The service data *should* give the exact measured value of the negative supply voltage, but in many cases because only the rated voltage is given, considerable percentage of error may result when the voltage across the resistors is computed. Owing to the difficulty of reading within a few volts on the higher-voltage scales of a voltmeter, the

? ?
Errors in diagrams

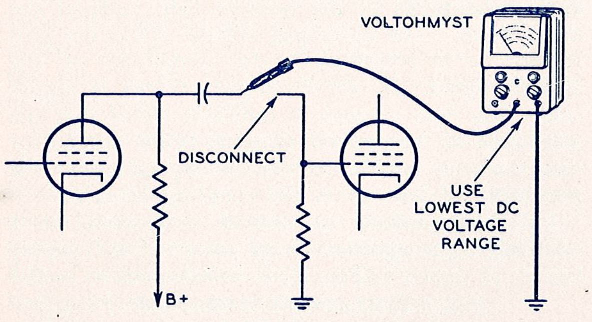


Fig. 19

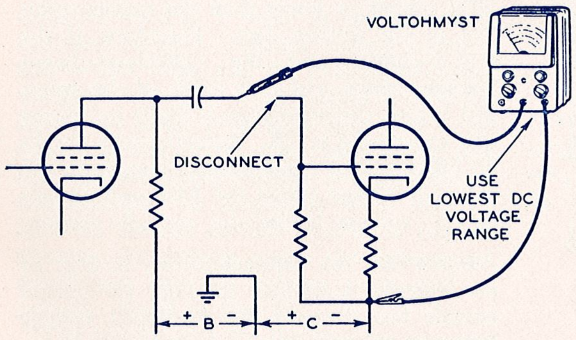


Fig. 20

service data *should* show the developed voltage *across* the grid resistor, and the voltage *across* the cathode resistor.

In Fig. 17 the grid-bias voltage on the second tube is —10 volts. If there is any leakage in the coupling capacitor, it will cause a voltage across the grid resistor that "bucks" the normal bias voltage, as shown in Fig. 18.

In Fig. 18 leakage of 100 megohms (100,000,000 ohms) causes a voltage drop of +6 volts cross the grid resistor. This voltage bucks the normal grid-bias voltage, reducing it from the correct value of —10 volts to a troublesome low value of —4 volts.

Ohmmeter checks often mislead the technician into believing that a leaky coupling capacitor is OK. The low testing voltage in ohmmeters is often inadequate to reveal high-resistance leakage, and it fails to reveal leakage that may exist when normal operating voltage is applied to the capacitor. Both of these failings can be overcome by checking the "leakage voltage", as shown in Figs. 19, 20, 21, 22. The check is made with the receiver turned on and with normal circuit voltage applied to the capacitor. The instant the probe is touched to the capacitor, the meter pointer will be deflected, but if the capacitor is OK, the pointer should return to zero.

If the grid circuit is returned to a negative voltage point (such as —50, —100, —150 volts) the operating voltage applied to the capacitor is equal to the plate voltage plus the "C" voltage. The full voltage is used in checking the capacitor for leakage by connecting the VoltOhmyst as shown in Fig. 20.

The voltage produced *across the grid resistor,* as a result of any leakage in the coupling capacitor, can be measured as in Figs. 21 and 22.

In circuits where the grid-return is not connected directly to chassis, connect the VoltOhmyst across the resistor, as shown in Fig 22, to measure the leakage voltage across the grid resistor.

An ordinary voltmeter (1,000, 5,000 *or* 20,000 *ohms per volt*) *gives completely wrong and misleading indications of leakage voltage,* as proved in the examples shown in Fig. 23. In the first example, the reading on a 20,000 ohm-per-volt meter misleads the technician into believing that the leakage is only 0.3 volt, whereas the actual leakage voltage is 6.0 volts, a value which will cause definite trouble in most cases. In the second example, the leakage voltage of 0.6 volt is likely to cause trouble in a video amplifier that has a low bias voltage (in the order of 2 volts). A 20,000 ohm-per-volt meter indicates only 0.03 volts for this same leakage, thereby leading the technician into the erroneous belief that the leakage is negligible and that the capacitor is OK. (Moral: Don't handicap your trouble-shooting ability, and don't run the risk of turning simple service jobs into difficult dogs, by depending on the misleading indication of ordinary voltmeters. Use a meter that will help you, not mislead you. Use a good vacuum-tube voltmeter .

It is sometimes advisable to check for possibility of leakage in a new capacitor before installing it in the receiver. Paper, mica and ceramic capacitors can be checked for leakage as shown in Fig. 24. Select B+ and B— points in the receiver that provide

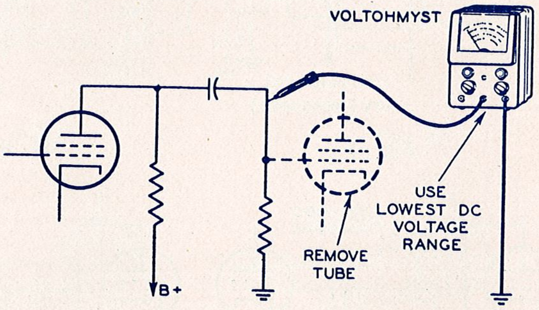


Fig. 21

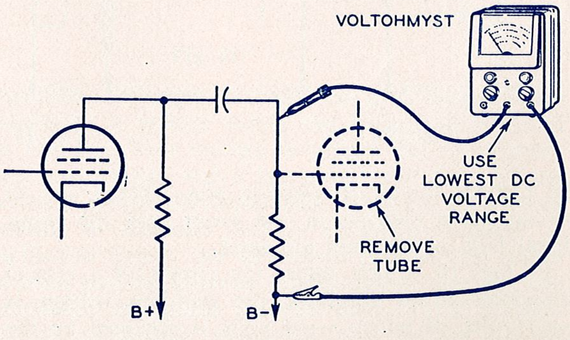


Fig. 22

a voltage approximately equal to the rated voltage of the capacitor. Use a low dc-voltage range on the VoltOhmyst.

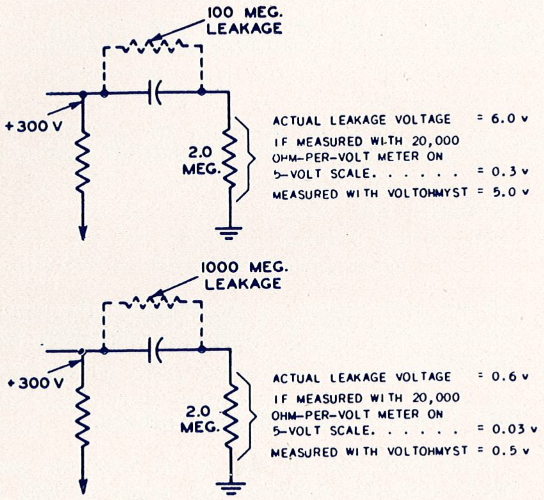


Fig. 23

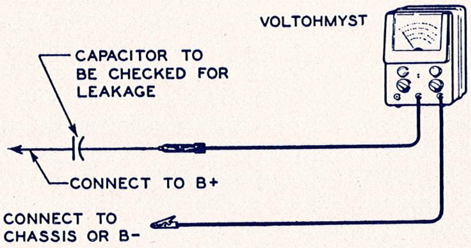


Fig. 24

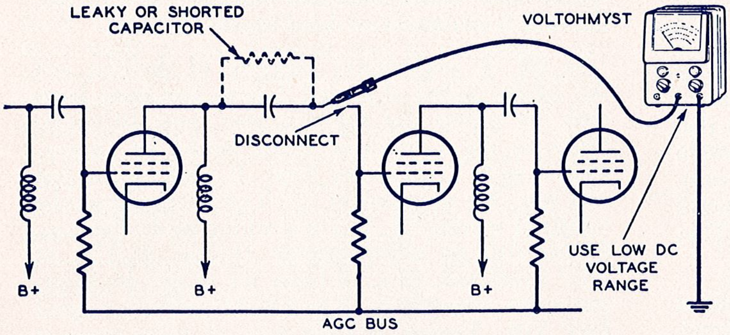


Fig. 25

A shorted or leaky coupling capacitor in an agc-controlled if amplifier affects the voltage on the agc bus and at the grid of each of the controlled tubes. Disconnect one coupling capacitor at a time and check it for leakage voltage as in Fig. 25.

THE PSEUDO-STEREOPHONIC EFFECT

This effect has been briefly described in the Radiotron Designer's Handbook, page 866, and two loudspeakers are used so that one is at least 4 feet further from the listener than the other. One of the readers of the Handbook has inferred that the invention was attributed to Haas, from the reference given in the test. This was not intended, since the effect has been known for many years. The earliest published reference known to the writer is by "Cathode Ray" under the title "Making the most of a dual loudspeaker" in Wireless World 35.20 (November 16th), 1934.

The writer had a dual loudspeaker arrangement working in his home for several years, some considerable time ago, and by suitable control of the relative volumes, or by suitable positioning of the listener, quite effective results were obtained. In this case the direct line between the two speakers was about 14 feet.

It was Haas who first made actual measurements from which the design of any installation can be made without recourse to experiment.

CALCULATING IMPEDANCE ON THE SLIDE RULE

A method for calculating the impedance of R and X in series is given in the Radiotron Designer's Handbook, page 258. However, Mr. M. G. Scroggie has drawn our attention to a slightly easier method described in a letter by R. Pollard to the Wireless World, February, 1950, page 76.

This is based on the expression $1 + \tan^2 \theta = \sec^2 \theta$.

To calculate an impedance value, take the smaller value of either resistance or reactance and set it on the "C" scale to the left-hand index of the slide rule. Slide the cursor along to the larger value on the "C" scale. Read off on the "A" scale and add 1, sliding the cursor to this value. The resultant impedance is then indicated on the "C" scale.

The method may be proved by referring to the familiar 3, 4, 5, right-angled triangle. If 3 on the "C" scale is set to the left-hand index, and the cursor is moved along to 4, we get $4/3 = 1.33$, which is $\tan \theta$ on the "D" scale and $\tan^2 \theta = 1.778$ on the "A" scale. To this value 1 is added to give $\sec^2 \theta = 2.778$ on "A" and $\sec \theta = 1.667$ on "D". Without further movement of the slide or cursor,, $\sec \theta$ is automatically multiplied by 3, which gives the resultant impedance $3 \times 1.667 = 5$ under the hair line on the "C" scale.

THE TRANSISTOR

—OR 25 MILES ON A HUNK OF GERMANIUM

Some background on the Tiny Devices that may revolutionize the Electronic Art

By George M. Rose

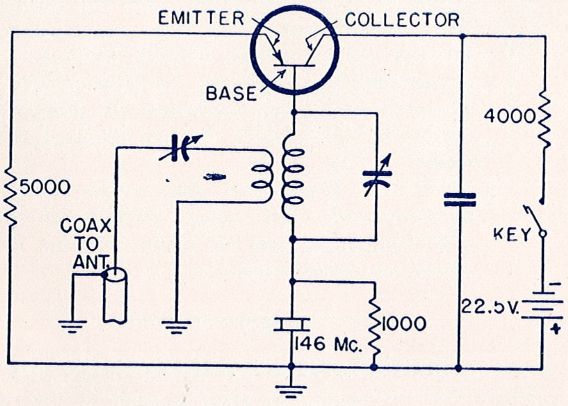


Fig. 1 — **Schematic diagram of the transistor crystal oscillator used on 146 Mc. by K2AH. The only unfamiliar element is the symbol for the transistor itself. Values in the tuned circuits are dependent on the frequency used, but this general circuit works with crystals of much lower frequency as well.**

While engaged in semiconductor research at the Bell Telephone Laboratories, Messrs. Bardeen and Brattain observed that if two cat whiskers were placed very near each other on a piece of germanium and current was made to flow between each cat whisker and the germanium, the two currents would react on each other. The remarkable thing was that a small change in current through one whisker would make a larger change in current through the other. This is amplification, and any electronic device which will amplify is of more than passing interest. Thus the transistor was born.

Further research showed that power amplifications of 100 times or more could be readily achieved. From this point it takes little imagination to visualise the usefulness of such a simple device; no hot cathode, very small size, and apparently nothing to wear out or get used up.

In the short space of five years the amount of scientific effort and the number of dollars spent on the transistor family has ballooned to millions of man-hours and of dollars. Even more fantastic is the fact that most of this investment is still in development rather than in production. Both industry and the government are gambling on the future of the transistor, but it looks like the odds are all favourable.

The Lowest-Powered Transmitter.

Now what has all this to do with the average ham? Actually nothing very much at this time, except that being a person possessing more than average scientific curiosity and ability he likes to anticipate his next-after-next project.

The writer, being fortunately situated with respect to transistor availability, was able not only to anticipate but also to carry out a pet ham project of many months' standing. This was to generate rf power, no matter how small, on two meters and see if the resulting signal could be heard beyond the confines of the shack. The two-meter band was chosen for two reasons. First K2AH has a decent antenna (12-element beam) on two meters. Second, transistors were not supposed to work at frequencies as high as 146 megacycles. Ordinary transistors do not, but we in RCA had managed to put together some special ones which oscillated not only at 146 Mc. but which continued to do so above 300 Mc.

A bit of arithmetical juggling of decibles and the known output of several 2-meter rigs came forth with the answer that anything over about 10 microwatts in the 12-element beam would be "gravy" over a path 15-20 miles long. It worked out just that way. We were sure of 30-50 microwatts from the transistor transmitter, so it was with considerable confidence that we asked Tommy Thomas, W2UK, of New Brunswick, N.J., to listen for us at 146 megacycles. He promptly came back and reported the signal RST 559. Tommy is a bit over 25 miles away as the signal flies. We then had contacts with W2KNI, Mountainside, N.J., and with W2DPB in East Orange, N.J., both of whom are about 15 miles away. Our own QTH is Mountain Lakes, N.J.

The transistor transmitter itself was simply a keyed crystal-controlled oscillator using about the same number of incidental components as one would find in the usual tube oscillator. The circuit is shown in Fig. 1. It will seem unfamiliar because the symbol for a triode transistor is different from that of a triode vacuum tube. However, in principle the circuit is a relative of the well-known Colpitts. Another feature which is perhaps also unfamiliar is the use of the quartz crystal as an rf bypassing element. Crystals can be made to operate as either high-impedance or low-impedance circuit elements at closely adjacent frequencies. In this case the low-impedance mode was used so that the series resistor in the transistor base lead would be bypassed and oscillation would occur only at the crystal frequency. Next to making the transistor work at 2 meters, the pleasantest surprise came in finding it was possible to get solid frequency control at the 9th overtone of a 16-Mc. crystal which was originally maximized for 5th overtone. Control was so tight that there was no noticeable keying chirp.

Power was supplied from a hearing-aid type $22\frac{1}{2}$-volt "B" battery. The series dropping resistor reduced this potential to about 10 volts at the transistor so that the total power to the oscillator was about 30 milliwatts.

We have not had the time at this writing to replace the series dropping resistor in the transistor collector circuit with a modulating transistor, but this is possible and will be done in time.

Types of Transistors.

The kind used in the 2-meter ham rig is a "point-contact" transistor in development by RCA consisting of two phosphor-bronze "cat whiskers" touching a small piece of germanium at points less than a thousandth of an inch apart. Germanium is a basic element and, like silicon, galena, and certain other materials, is in the class of semiconductors. These are peculiar materials in that they are neither good insulators nor good conductors. They have another property which is both interesting and useful. Any metallic contact which is made to them with fairly light pressure will be found to carry current more easily in one direction than in the other, and is thus rectifying. There is as yet no good explanation but the effect seems to be a combination of electrochemical and mechanical action which disturbs the atoms of the semi-conductor in the region of the contact. Well-soldered contacts do not exhibit this rectifying effect. This "disturbed" region of the semiconductor is called a "barrier" and can be thought of as a swinging door having a stiff spring on one side and a light spring on the other.

The point-contact transistor then consists of two of these rectifying contacts closely adjacent to each other on a piece of germanium. Typical construction is shown in Fig. 2. Of all the various semi-conducting materials explored so far germanium seems to work best, so most transistor development centres around its use.

One of these contacts, called the collector, is biased several volts (sometimes as high as 30 or 40 v.) in the direction of poor conduction, so that only a small amount of current flows. Figuratively, we are trying to open the door against the stiff spring. The other contact, called the emitter, is biased a few tenths of a volt in its direction of good conduction. As this emitter bias is applied, the collector current will be observed to increase substantially and will increase 2 or 3 times as rapidly as the emitter current increases. The emitter current, therefore, reduces the effectiveness of the "barrier" at the collector contact, or in effect reduces the stiffness of the spring in our door analogy. We, in effect, get a "current gain" of at least 2 or 3 times. This in itself is not very impressive, but now let us measure two other electrical properties. The input or emitter circuit resistance is found to be about 500 ohms, and the output or collector circuit resistance about 20,000 ohms. A bit of arithmetic, using Ohm's law, shows we have a power amplification of about 100, which, of course, "ain't hay".

So much for the point-contact transistor, except to point out something you might have overlooked. The transistor is a current-controlled device in contrast with the vacuum tube which is a voltage-controlled device. This means that transistor circuity will be different in many respects from the familiar tube circuitry. It also means that direct performance analogies between vacuum tubes and transistors can lead to considerable confusion and should be avoided.

These remarks apply almost equally well to another type of transistor which is receiving about the same amount of technical attention as the point-contact transistor. This one is known as the "junction" transistor. It appears to be even more promising than the point-contact type, particularly at low and medium frequencies. Power gains as high as 100,000 in a single stage have already been measured. Physically the junction transistor is quite unlike the point-contact type, as can be seen from Fig. 2, although there is some similarity in principle. It, too, has two "barriers" but these are located opposite each other on or within a piece of germanium crystal. One technique for creating these barriers, or junctions, is to diffuse another material, such as the metal indium, into two sides of a small slab of germanium. Electrical connections are made as shown in Fig. 2 to each of these junctions. The third contact in both types of transistor is a non-rectifying contact soldered to the body of the germanium piece and is called the "base".

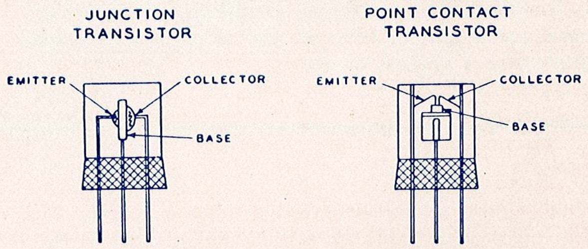


Fig. 2 — Basic details of junction and point-contact transistors.

The explanation for the occurrence of power amplification in the junction transistors is somewhat less complicated than is the case with the point-contact transistor, but is still too abstruse to attempt here except to again say that the two junction areas interact. A more thorough explanation calls for the use of the concept of conduction by "holes" in addition to conduction by electrons. Holes are places in the germanium crystal atomic structure where electrons could be but are not. Although this sounds ridiculous it has considerable foundation in fact. These holes do enter into the conduction process and behave as if they were positive electrons. There is no analogous effect in vacuum tubes.

It is quite possible to make transistors in which either electron or hole conduction is predominant. One can therefore make transistors which have almost identical electrical characteristics except that the applied battery potentials are exactly reversed in polarity. It would be just as if we could make positron tubes as well as electron tubes. This is particularly intriguing to circuit specialists because it makes certain types of circuitry possible with transistors which are either impractical or perhaps impossible with tubes.

They Have Shortcomings, Too.

Transistors in their present stage of development have many shortcomings such as temperature dependence, certain types of instability, excess noise, and power as well as frequency limitations. The encouraging thing, however, is the fact that no one has yet been able to prove that these defects cannot be overcome in time.

The main purpose of this article is not so much to explain transistors as it is to acquaint you with the fact that there is a new member of the electronics family which is already extremely important and about which you are certain to hear more and more. Unfortunately you will probably find it virtually impossible to lay hands on transistors suitable for v.h.f. experimentation. Be patient, because the day will certainly come when you can obtain them with ease.

New RCA Releases

RCA-6AT8 is a multiunit tube of the 9-pin miniature type containing a medium-mu triode and a sharp-cutoff pentode in one envelope. It is designed primarily for use as a combined oscillator and mixer tube in television receivers utilizing an intermediate frequency in the order of 40 Mc.

The 6AT8 has the same electrode structure as the 6X8 but employs a different basing arrangement which makes possible shorter connections to the coils in certain designs of turret tuners. Except for a very slight change in some of the inter-electrode capacitances, the characteristics and ratings of the 6AT8 are the same as those of the 6X8.

RCA-6BZ7 is a medium-mu twin triode of the 9-pin miniature type having high gain and low noise. It is designed for use as an rf amplifier tube in tuners of vhf television receivers and as a low-noise pre-amplifier tube in uhf television receivers employing a crystal mixer.

RCA-6BC4 is a short medium-mu triode of the 9-pin miniature type designed for use as a cathode-driven rf amplifier in UHF-TV tuners covering the frequency range from 470 to 890 Mc. Having a transconductance value of 10,000 micromhos, the 6BC4 facilitates circuit design to provide high gain and reduced equivalent noise resistance.

Other design features of the 6BC4 include silver-plated base pins to reduce losses due to skin effect at ultra-high frequencies, four grid terminals to permit reduced lead inductance and resistance in circuit arrangement, an electrode structure permitting good isolation between the load circuit and the input circuit, and low inter-electrode capacitances.

RCA-6BK7-A is a twin triode of the 9-pin miniature type. It is used as an rf amplifier tube in vhf television tuners or as the if pre-amplifier in uhf tuners.

RCA-12AV7 is a twin triode of the 9-pin miniature type used as an amplifier or frequency converter in the FM and vhf television broadcast bands.

Editor .. .. D. Cunliffe-Jones

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