Universal TEST INSTRUMENT

By

McMURDO SILVER

This versatile instrument enables service technicians to measure every voltage in AM, FM, and television receivers.

Fig. 1. This new improved v.t.v.m. provides fifty-one total ranges of d.c. and a.c. volts to above 100 mc., ohms through 2000 megohms, current from 1.2 ma. through 12 amperes, db. from —10 through +50.

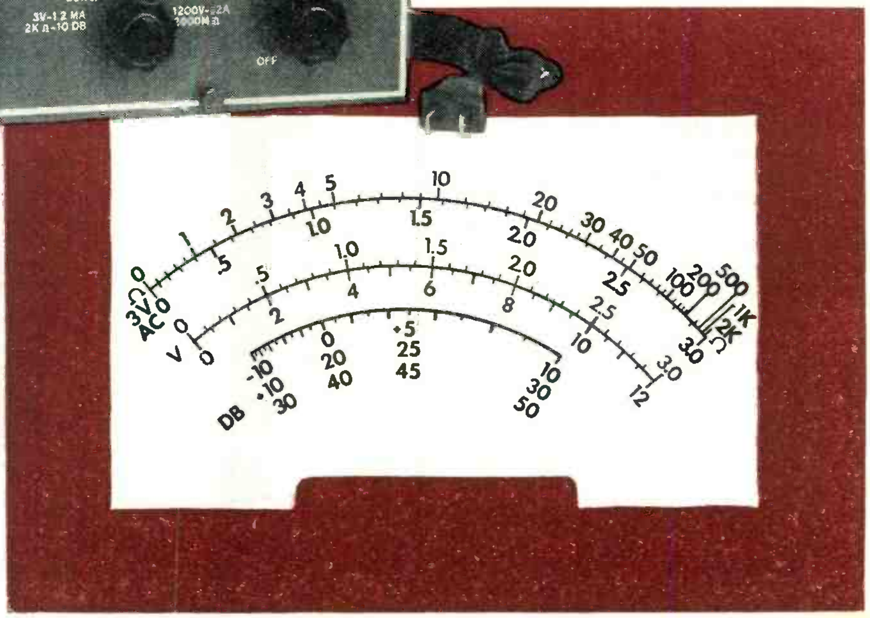


Fig. 2. These basic meter scales cover 39 of 51 possible ranges. The remaining 12 high-voltage d.c. ranges are read by multiplying center scales by 2.5.

THE known history of mankind reveals his increasing mastery of the elements. The price of such increasing mastery has been an accompanying increase in complexity of life. Radio receivers alone illustrate this point effectively. Thirty years ago the best imaginable receiver consisted of a one-tube regenerative detector followed by two stages of audio frequency amplification. The components were so few, their functions so free of interactive effects, that trouble shooting in such a receiver was simple. Replacement of dry "B" and recharging of storage "A" batteries, substitution of new tubes for old, and a cursory knowledge of operation of a few simple circuits was all the service technician needed to set up shop.

Receivers of immediately prewar vintage were a far cry from such simplicity, not to mention the even more marked simplicity of precedent "one-slide tuning coil and crystal detector" days. A typical high-quality 1940/1 broadcast receiver might include one or more stages of r.f. amplification, a first detector or mixer, a heterodyne oscillator, one or more stages of i.f. amplification, an a.v.c. system linking most of the above circuits, a second or audio detector, one or more stages of a.f. voltage amplification, a push-pull a.f. power amplifier, a power supply rectifier and filter system, and a dynamic loudspeaker with separate signal and field-energization circuits. Ten or more substantially different yet closely inter-linked and inter-related circuits, each with a multiplicity of coils, condensers, resistors, switches, and tubes confronted the service technician. An FM receiver might include, in addition, limiter, discriminator, and de-emphasis circuits — while a.f.c., amplified a.v.c., and volume-expander circuits were not infrequently encountered. Television receivers were, and will be, even more complex.

It seems safe to state that with the increasing complexity in receiver construction necessary to yield the improvements in performance expected in postwar receivers, be they AM, FM, television, facsimile, or combinations thereof, prewar service techniques and instruments will be inadequate. The old methods of interchanging tubes, measuring a few power-supply and heater voltages, possibly checking alignment, must of necessity give place to a thorough understanding of circuit conformation, interlinkage and functioning, and test instruments adequate to localize troubles, reveal their character, and so permit repair.

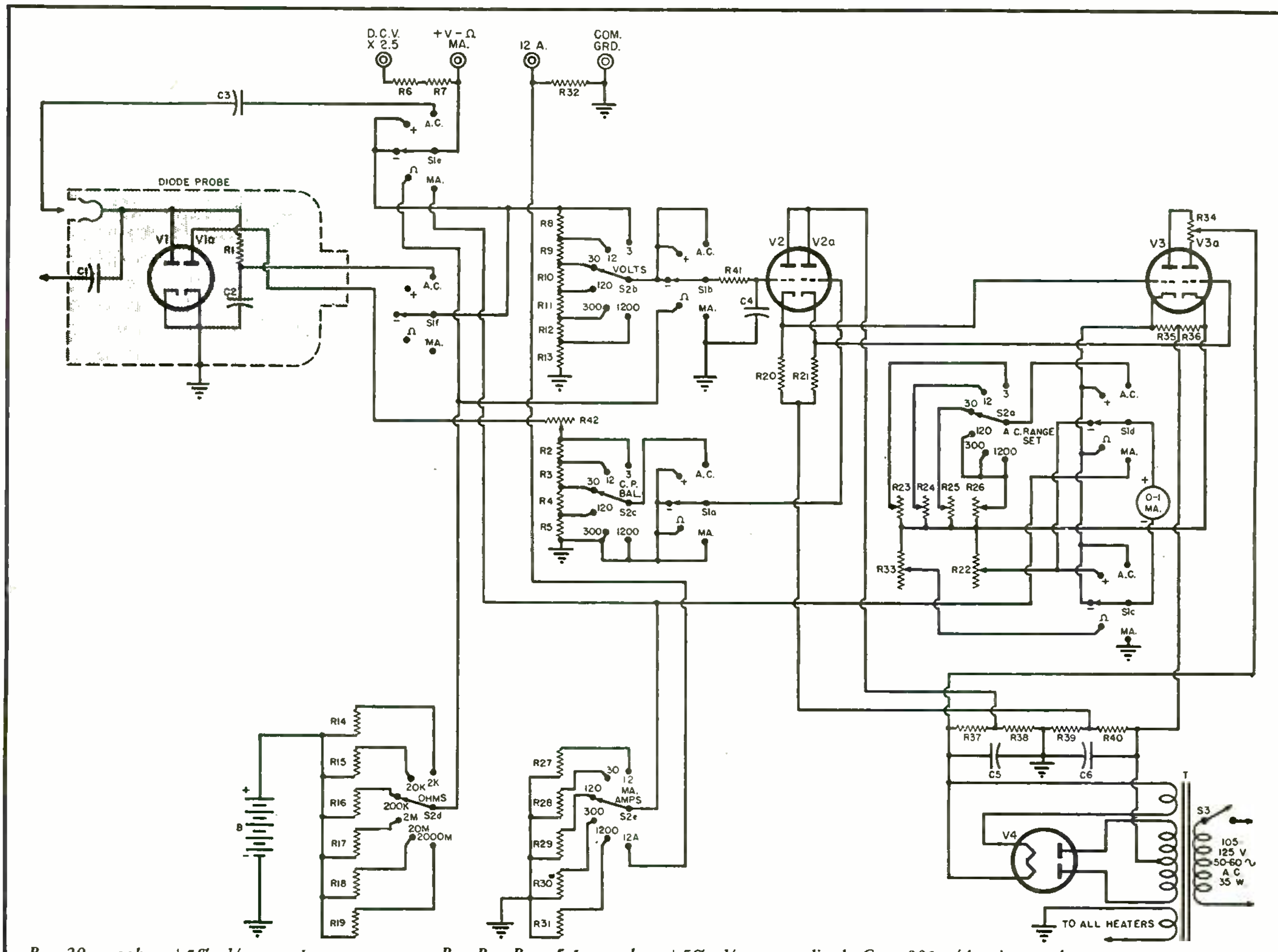
Specializing in receiver design and production since the crystal detector days of long ago, the writer has watched the progressive development of more and more complex receivers with horrified fascination at the increasing burden such development has placed upon the service technician and his equipment. Long ago he recognized the inadequacy of available test equipment and techniques to cope with the situation in a logical manner. In the design laboratory, where cost of equipment is of quite secondary importance and time was not invariably of the essence, techniques direct and effective when applied by skilled engineers possessed of long training were developed and successfully applied. These involved investigation of the behavior of each individual circuit making up one of many cascaded and inter-linked sections in a receiver. Equipment necessary to such analysis was costly, complicated, and difficult of operation due to inherent instability which had to be compensated for by frequent check and calibration of the test equipment itself against even more costly and complicated fundamental equipment standards.

The signal is the common denominator of the majority of circuits in every radio receiver. Signal voltage should appear in amplified form in each successive circuit of a properly functioning receiver. Detectors do not usually amplify the signal, but rather convert it to a new frequency. They may be checked by observing the amplitude of the converted signal in terms of gain or loss at their output. It is apparent that if the service technician could apply the laboratory technique of measuring signal voltages, plus every other voltage present in a receiver, he would be provided with a rapid and almost infallible system of servicing. Resistance, and occasionally capacitance, measurements would also be necessary, plus alignment of ganged or cascaded tuned circuits. Alignment is possible using a signal generator and output meter. It is also possible to obtain alignment by employing signals at today's broadcast stations which are, in many cases, even more stable in frequency than the usual signal generator. The matter of providing for *complete measurement of every significant voltage* found in radio receivers has proved much more difficult of practical, everyday solution. Yet, if servicing and maintenance of complex multi-circuit receivers is to be rapid, simple, and modern, it must presuppose as a fundamental requirement the ability to measure every type and magnitude of voltage encountered in postwar receivers.

In the course of over six years devoted to direction and supervision of design, development, and production of a wide variety of military radio equipments, the writer was early driven face-to-face with this basic need of accurate and complete voltage measurements.

Ordinary volt-ohm-milliammeters leave much to be desired. Their d.c. input resistance can seldom practically exceed 20,000 ohms/volt, while the usual practice of employing copper-oxide rectifiers to convert a.c. voltages into d.c. for actuation of the usual d.c. meter movement results in even lower meter resistance. Such low meter resistances automatically eliminate any possibility of measuring signal voltages, or even d.c. vacuum tube operating voltages directly, since such voltages are almost invariably applied to tube elements through high resistance circuits. Copper-oxide rectifiers are practically useless above relatively low audio frequencies, and become in-

Fig. 3. Employing only four tubes, this instrument in its entirety has been based on latest commercial design principles.



R_1—20 megohm, ±5%, ¼ w. carbon res.
**R_2, R_9—7.5 megohm, ½ w. metalized res.*
**R_3—1.5 megohm, ½ w. metalized res.*
**R_4, R_{11}—750,000 ohm, ½ w. metalized res.*
**R_5—250,000 ohm, ½ w. metalized res.*
**R_6, R_7, R_8—37.5 megohm, ½ w. metalized res.*
**R_{10}—3.75 megohms, ½ w. metalized res.*
**R_{12}—375,000 ohm, ½ w. metalized res.*
R_{13}—125,000 ohm, ½ w. metalized res.
R_{14}—10 ohm, ±1%, ½ w., w.w. res.
**R_{15}—100 ohm, ½ w. metalized res.*
**R_{16}—1000 ohm, ½ w. metalized res.*
**R_{17}—10,000 ohm, ½ w. metalized res.*
**R_{18}—100,000 ohm, ½ w. metalized res.*
R_{19}—10 megohm, ½ w. metalized res.
R_{20}, R_{21}, R_{41}—5.1 megohm, ±5%, ½ w. metalized res.
R_{22}, R_{23}, R_{24}, R_{25}, R_{26}—3000 ohm w.w. pot.
R_{27}—258.4 ohm, ±1% w.w. res.
R_{28}—1.758 ohm, ±1% w.w. res.
R_{29}—.423 ohm, ±1% w.w. res.
R_{30}—.161 ohm, ±1% w.w. res.
R_{31}—.028 ohm, ±1% w.w. res.
R_{32}—Set experimentally to give 12 ampere range
R_{33}—10,000 ohm, w.w. pot with s.p.s.t. sw.
R_{34}—3000 ohm w.w. pot.
R_{35}, R_{36}, R_{37}, R_{40}—43,000 ohm, ±5%, 2 w. metalized res.
R_{38}, R_{39}—4300 ohm, ±5%, ½ w. metalized res.
R_{42}—10 megohm pot.
C_1—.0005 μfd, silver-mica cond.
C_2—.001 μfd. mica cond.
C_3—.03 μfd. 3000 v. tub. oil cond.
C_4—.005 μfd. mica cond.
C_5, C_6—8 μfd. 350 v. elec. cond.
S_1—5 pos., 6 circuit, 3 section ceramic sw.
S_2—5 circuit, 6 pos., 5 section ceramic sw. (front section shorting)
S_3—S.p.s.t. sw. on R_{33}.
T—Power trans; 115 v. primary, 5 v.; 2 amp; 6.3 v.; 1.6 amp; 650 v.. 40 ma.
V_1, V_1a—6AL5 dual diode
V_2-V_2a, V_3-V_3a—6SN7GT dual triodes
V_4—5Y3GT rectifier (or optionally 5W4GT or 5Z4)
M—0-1 d.c. ma.
*(*Pairs of res. matched in series to give specified values)*

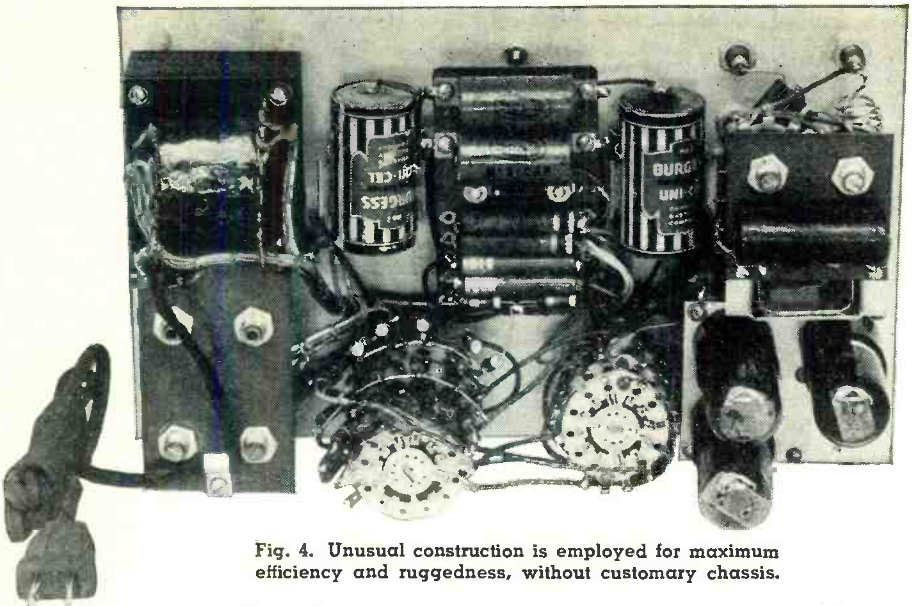


Fig. 4. Unusual construction is employed for maximum efficiency and ruggedness, without customary chassis.

creasingly inaccurate as frequency is raised above usual power line values.

The use of vacuum tubes as coupling agents between a.c., d.c., or r.f. voltages present in high resistance circuits and low resistance power consuming meter movements is an obvious solution at first glance. Yet, anyone familiar with the instability, undependability, and general untrustworthiness of vacuum-tube voltmeters, heretofore available, has shunned all but the most expensive laboratory types or had to be content with an approximation of desired performance. All were of decidedly limited utility in their inability to provide accurately all required voltage measurements. The unsolved problem, as it appeared to the writer, was the inability to produce a universal test instrument capable of high accuracy and truly negligible circuit loading when functioning as a voltmeter over the *full range of voltage and frequency* essential to modern receiver design and servicing, as well as ability to function accurately as a power output meter, milliammeter, and ammeter (as for auto radio input currents) and to provide accurate resistance measurements over the great range required in postwar radio servicing.

It is believed that the instrument herein described and illustrated fully satisfies these heretofore unsatisfied requirements. It is a perfected vacuum-tube volt-ohm-db.-ma.-ammeter possessing practically the absolute stability and dependability of the meter movement and associated multiplier/shunt resistors. Product of years of research and development, in it has been accomplished that end so essential to universal satisfaction—the practically complete divorcement of the inescapable vagaries of vacuum tubes from affecting operational accuracy. This has been accomplished not at the expense of meter resistance but with what is believed to be the highest effective meter resistance, d.c., a.c., and *signal tracing* r.f. yet obtained in any stable instrument.

Stemming out of the laboratory type of v.t.v.m. described in the September, 1943 issue of RADIO NEWS, this new instrument goes far beyond predecessor types to provide some 51 ranges and functions—more than heretofore available in any equally compact meter, and of truly extraordinary dependability and accuracy. Six d.c. voltage ranges of 3, 12, 30, 120, 300, and 1200 volts are provided at 50 megohms input resistance, plus the same six in reverse polarity at the turn of a knob. Six more dc. ranges at 125 megohms input resistance, of 7.5, 30, 75, 300, 750, and 3000 volts full-scale, are also doubled by the polarity reversing switch. Six a.c. ranges at 6.6 megohms effective input resistance are had at 3, 12, 30, 120, 300, and 1200 volts full scale. Withdrawing the r.f. diode probe from the instrument panel, as for direct contacting without intervening connecting leads to r.f./i.f. circuits for voltage measurement up through over 100 megacycles, gives the same ranges in r.f. at 6.6 megohms effective input loading shunted by approximately 8 $\mu\mu$fd. (The detuning due to this shunt capacitance is eliminated in r.f./i.f. voltage measurements by momentary retuning of the circuit under measurement.) Three of the a.c. ranges are calibrated in decibels (0 db. = 1 milliwatt in 600 ohms). Six direct-reading, zero-left vacuum-tube resistance ranges have full-scale values of 2000, 20,000, 200,000 ohms and 2, 20, and 2000 megohms. Six direct current ranges of 1.2, 30, 120, 300, 1200 ma., and 12 amperes complete a total of 51 useful ranges—enough to service almost any conceivable type of radio receiver in terms of every voltage from antenna input right on through the heretofore almost-impossible-of-accurate-measurement a.v.c., a.f.c., limiter, discriminator, and plate and grid voltages in resistance-coupled amplifier stages, on through power output and even a.c. power input.

The effects of variation in the a.c. line voltage used to power the instrument are almost completely washed out by balanced circuit design. The variation in the behavior of any one vacuum tube due to line voltage variation is balanced out by an equal and opposite effect produced by its complementary balancing tube. The effects of diode contact potential (generated within a diode when its cathode is heated for electron emission) are balanced out by a companion diode and new circuit arrangement. The usual diode meter reading error at low frequencies is eliminated by automatic substitution of an input capacitor large enough to prevent low-frequency attenuation. This capacitor is replaced by a low-inductance, silver-mica unit for r.f. usage equally automatically. The effects of change in vacuum tube characteristics with aging and use is washed out practically 100% by degeneration in each circuit so heavy as to actually permit exchange of an old tube for a new tube with negligible effect upon meter calibration! Burn out of meter through 1000-times overload is eliminated in all but current ranges. The meter is completely protected by so designing its actuating circuits that total meter current in the presence of overload is limited to a value insufficient to burn out the meter movement.

Grid and Gas Current Errors Eliminated

Grid current, the besetting sin of practically all v.t.v.m.'s, is completely eliminated. The importance of this feature cannot be overlooked. It is what causes the usual v.t.v.m. to read higher than zero when its input jacks are *open,* fall to zero when they are short-circuited—as the instructions almost invariably require the operator to do to set zero. This is all right *if* the voltage source to be measured is of low resistance. If it is of high resistance, the *usual* case in radio receivers for all except power circuit measurements, then removal of the input short-circuit lets the meter read above zero once again when a not easily predictable amount of this error will add to the voltage to be measured if it is present in the usual high resistance grid, plate, or a.v.c. circuit.

The importance of the complete elimination of grid current effects (caused with ordinary vacuum tubes whenever the grid circuit resistance is high, hence the manufacturers' specifications of maximum permissible grid resistance for tube types which may be damaged thereby) cannot be emphasized too much. It is the source of error and inaccuracy invalidating any attempt at precise measurements with any v.t.v.m. which will not hold the same zero reading with input *either open* or *short-circuited.* It is the limitation upon the maximum value of input resistance which may be attained; and the only reason for using vacuum tubes is to obtain an input resistance so high as not to affect circuits which must be measured. Only when grid current effects, plus the

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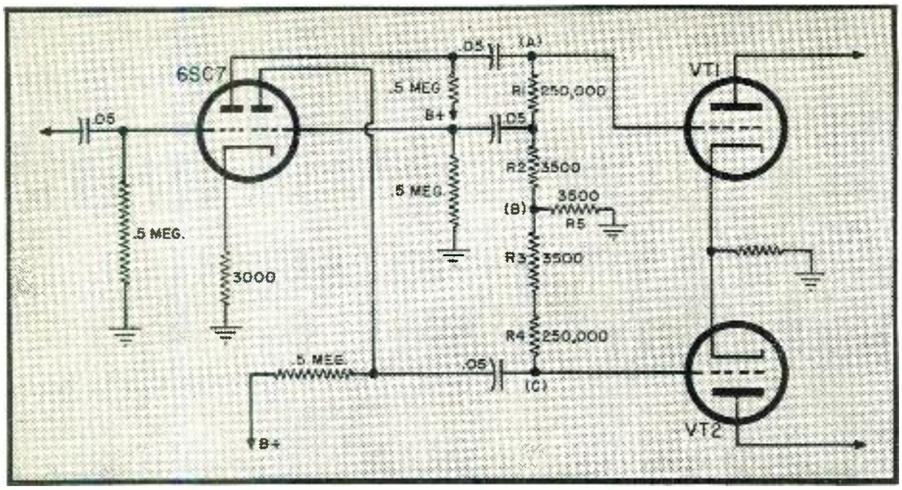


Fig. 8. Modified arrangement of Fig. 6. This circuit compensates for part of the unbalance that might otherwise occur.

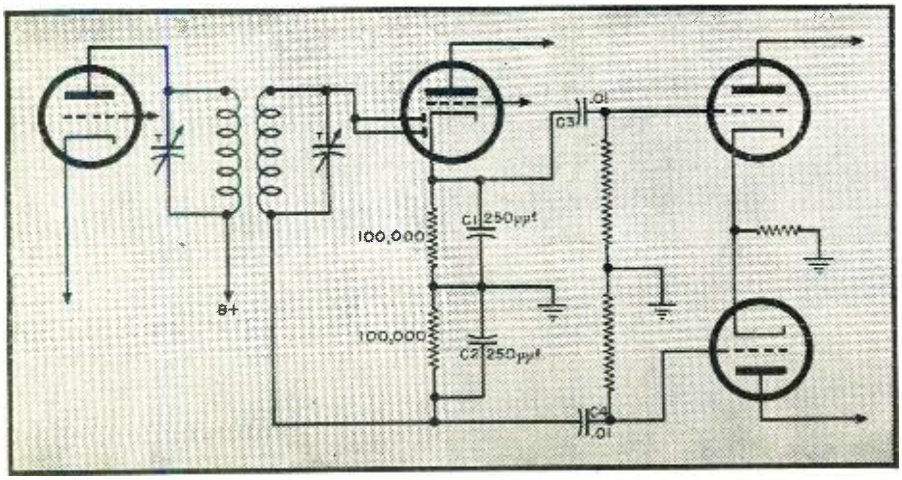
enough to provide approximately two volts at the driver grids.

This about covers the assortment of phase inverters that are very useful at present. A few facts to remember about phase inverters are, never bypass the cathode resistor unless specified. The system usually is necessarily designed in such a manner that the output would be highly distorted were it not for the degeneration that takes place when the cathode is left unbypassed. Other than for the bypass condenser, the inverter is usually designed like a regular class-A amplifier. Ordinarily, the resistor values used are the same as they would be in the case of an ordinary class-A amplifier stage and are split up accordingly in the voltage dividers. Remember, the audio voltage will divide itself across a resistor in the same manner d.c. voltage does. Whenever designing or servicing a phase inverter system, where two tubes are used or if a dual triode is used, make sure they both have identical emissive characteristics or are as close to being identical as it is possible to get them.

Although a good tube tester and an ohmmeter is all the equipment that is necessary when designing and servicing phase inverters, a signal tracing unit such as a chanalyst is desirable, since it is possible to measure the actual balance of voltages. An oscilloscope, of course, can be used for the same purpose and with it, you can also observe the phase relationships of the voltages. The balance of the voltages is always dependent on the resistors, the values of the coupling condensers, and tube characteristics. As long as the resistor values are chosen correctly, the coupling condensers are identical and the tube characteristics are identical, the operation of the two sides of the amplifier will be identical. Distortion in a phase inverter can usually be traced to unbalance caused by one or more of those parts changing value enough to impair operation. The resistors have a tendency to change value as some of them have a rather high audio voltage across them and run rather hot.

The phase inverter is a handy system for the serviceman in these days of shortages, since one can be hooked up in the average shop in a few minutes. As the fidelity is high, the customer is well pleased and the serviceman can make a neat profit on a job that he otherwise would have to refuse because of unavailability of parts or tubes. —30—

Fig. 9. Circuit diagram of a phase inverter which is somewhat unusual. Phase inversion takes place in the second detector stage of receiver.



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other points set forth above, are completely eliminated, may really dependable, stable and continuingly accurate results be had.

The instrument possessing these vitally required features is illustrated in Figs. 1, 3 and 4, while its pleasingly open and non-confusing meter scale appears in Fig. 2. This latter is worth serious consideration, for in routine design and service work it is only too easy to confuse the selected meter scale when the meter face is crowded with many scales, thus making serious errors. The ability to reduce so many different functions to so few scales provides assurance of functional uniformity and identicality, in themselves most important. It will be noted in Fig. 2 that all voltage ranges, a.c., d.c., and r.f. are read upon but two scales, that the slope of all is identical except for the 3-volt a.c. range. Here the unavoidable slope in diode operation at low input voltages necessitates a separate scale. Had the lowest range been made approximately 5 volts, this non-linearity would have been swamped out, exactly as it is on all but this one range. Yet, a 3-volt range is more useful in r.f., i.f., and a.f. amplifier work than is one of almost twice its magnitude, since it permits measurement of much smaller signal voltages and signal tracing is one of the features which postwar service technicians simply cannot be without. It will be noted that the six resistance ranges require but one scale, the range switch simply indicating the number of zeros to be added to the observed resistance reading. The two center scales, differing only in figures above and below the line, take care of all voltage ranges but the 3-volt a.c. range, again by adding zeros to the observed reading as indicated by the range switch (or by multiplying by 2.5 and adding appropriate zeros for the 12 d.c. ranges at 125 megohms input resistance). The three db. ranges require but one scale, with three sets of range figures in the ample space below the db. scale. There is little point in detailing here the work required to simplify the meter scale to this degree, tying back as it does to complex circuit behavior, but only to hope that it may prove a welcome relief to overworked technicians.

One Zero Setting for 51 Ranges

Another important operating point is the simplicity of zeroing this instrument. One zero knob, and one single adjustment thereof, sets zero at start of operation for every voltage-db. range. One single *ohms adjust* knob sets each resistance range to full scale at start of measurement with but a single adjustment. Zero does not shift about when ranges are changed but is set once and for all by one adjustment, as it should be in any properly de-

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signed instrument. All this, despite the ability to perceive less than a 1/10th per-cent change in zero on the large, open-faced 4⅝″ Alnico-magnet meter. The meter itself is of 0-1 ma. range, sturdy and rugged as microammeters seldom are, yet, in this new v.t.v.m., only 3 volts across 50 megohms—miniscule power and infinitesimal circuit loading—drives the meter to full-scale 1 ma. deflection.

The simplicity of operating controls, all located upon the 12″ long and 7″ high panel of 3/32″ thick reverse-etched aluminum, is clearly illustrated in Fig. 1. At the lower left is the *set zero* knob, adjusted but once to set meter zero for all functions and ranges. Immediately above it is the removable shielded diode r.f. probe. This is the *signal tracing* probe with which signal voltages may be followed from antenna right through every signal circuit to speaker voice-coil by contacting the probe tip and shell to successive grid and plate circuits and ground. Its construction is such as to require no connecting leads worthy of the name either within the probe itself or between it and the circuit to be measured—the reason, among others, why the instrument is usable well above 100 megacycles, at which frequency it is still highly accurate. For low-frequency measurements, test leads with special prods are inserted into the two insulated jacks immediately above the probe, the probe inserted in its socket as illustrated, and measurements made in the usual manner. The same test leads in the same two jacks serve for a.c. and d.c. volts, ohms, decibels in output meter operation, and milliamperes/amperes. There is no need to shift test leads about for different functions or for reversal of d.c. polarity, except for the 12 ampere current range and for the 3000 volt d.c. range (the upper right jack together with the *com.-gnd.* jack, provides all twelve of the x2 5 d.c. voltage ranges). The reasons for not handling the 3000 volt and 12 ampere ranges through the two basic input jacks is because of the extra insulation required for high voltages, and to keep the heavy current of the 12 ampere range out of the *range* switch contacts, both desirable precautions in conservative design.

Special Construction

The panel arrangement of Fig. 1 is so self-explanatory as to require little special mention. The rear view of Fig. 4 is a different matter, as is the schematic diagram of Fig. 3. The construction of Fig. 4 is distinctly military/commercial, in contrast to usual test instruments. The usual chassis has been dispensed with entirely in favor of the more substantial and efficient location of every component part directly upon the back of the heavy panel itself, exactly as in the Navy low-frequency transmitter described in the May, 1944 issue of RADIO NEWS. At the upper left of Fig. 4 is the power transformer, *T*, of Fig. 3, through which all operating voltages are provided for plates, grids, and heaters. Below it is a linen bakelite panel carrying the four factory-adjusted, wire-wound a.c. range set resistors R_{23}, R_{24}, R_{25}, and R_{26}, one for each of the three lowest voltage a.c. ranges, and a fourth for the three higher voltage a.c. ranges. Immediately to the lower right is the 5-gang ceramic *range* switch directly carrying the many 1% matched pair metalized and wire-wound current multiplier resistors. To its right is the *function* switch, 6-circuit, 5-position ceramic also. These ceramic switches, as well as the special construction employed, are essential to preserve constant the very high meter resistance now available throughout wide variations in temperature and humidity. At top center is the meter itself, its terminals carrying a stable linen—in contrast to usual paper—base phenolic panel which supports the power supply voltage divider resistors, degenerative cathode resistors R_{35} and R_{36}, and the two electrolytic filter capacitors C_5 and C_6. These are metal-cased, hermetically sealed units of high quality and ample voltage rating.

At the extreme lower right of Fig. 4 is the socket plate carrying the three vacuum tubes V_2, V_3, and V_4—but more of these later. This sub-panel is mounted sufficiently behind the front panel on plated brass studs to give easy access to *zero* adjusting potentiometer R_{34}, exactly as its companion a.c. range resistor plate at the extreme lower left is similarly supported behind *ohms adjust* rheostat R_{33}. To right and left of the meter panel are the two ohmmeter dry batteries. Dry batteries are employed as a voltage source for resistance measurements simply because of their low cost, long life, and convenience. In this function, constancy of voltage is most important. Any attempt to draw such voltage from the main power supply would entail excessive cost for special voltage regulators, while such good regulation for other meter functions is obtained directly through the balanced circuit design.

At upper right of Fig. 4 is visible the linen-phenolic panel carrying the d.c. range set and the a.c. diode contact-potential balance rheostats R_{22} and R_{12} respectively. This panel is mounted upon the rear of the r.f. diode probe socket and carries low-frequency a.c. input capacitor C_3, as well as socket pin, through which it is directly connected, to the measurement plate of the 6AL5 (V_1) dual u.h.f. diode

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JOHN H. ROBERTS

mounted in the plug-in probe shield. Immediately above this assembly are visible the four input jacks, with the two 1% matched pair high d.c. voltage multiplier resistors as well as the heavy, coil-type 12 ampere direct current shunt visible between them.

New Circuits Explain Improved Results

The secrets of the extraordinarily high input resistance, extreme frequency range, and absolute stability of this new instrument lie not alone in the mechanical construction and unusually high quality of parts above described, but in the new and advanced circuit of Fig. 3. A detailed analysis of its development would be excessively lengthy, and detract emphasis from the essential points of practical usefulness of the finished instrument which it has been sought to bring out herein. For easy understanding tubes V_1, V_2, and V_3 may be thought of as the actual measurement channel, with V_{1a}, V_{2a}, V_{3a} as the complementary balancing channel. V_4 is, of course, the power supply rectifier. Starting with V_1, which with its associated components is housed in the removable aluminum-shielded, ceramic-headed r.f. probe, V_1 is the a.c. measurement rectifier. For r.f. and high a.f. operation it employs the 500 $\mu\mu$fd. silver-mica insulating capacitor C_1 housed in its shield. Capacitor C_3, .03 μfd., is automatically substituted when the probe is in its socket. Resistor R_1 and capacitor C_2 are the filter, removing a.c. ripple from the rectified a.c. which actuates the meter. Since V_1 delivers d.c. output in close proportion to the peak value of any a.c. voltage to be measured, R_1 is made 20 megohms so that only 100/140 of the rectified d.c. (1.41 x r.m.s. value) is applied to the d.c. load R_8 through R_{13} of 50 megohms total (to yield r.m.s. a.c. meter indication). *Function* switches S_{1e} and S_{1f} cut the diode a.c. rectifier into or out of the circuit as required.

As soon as V_1 is heated, its cathode emits electrons which impinge upon its plate. A self-generated d.c. voltage results. This must be balanced out. This has been a problem defying really satisfactory solution when the range-establishing voltage-divider follows the diode—as it must if any of the usefully wide a.c. voltage/frequency range is to be covered. So a second, or balancing, diode V_{1a} is brought into play having in its output circuit load resistors R_2 through R_5. Across these resistors is developed a second contact-potential, regulated to exactly equal that generated within V_1 by rheostat R_{12}. This voltage, usually around 1 volt, must, as a.c. ranges are changed, be divided down in step with that generated by V_1, hence, the tapping of its load resistors by switch S_{2e}. (All S_1- and S_2- switches are ganged, S_1- being *function*, S_2- *range*. By this new technique, the problem of contact-potential is nicely solved, and the instrument stays zeroed without adjustment over all a.c. ranges. Contact-potential compensation is required individually only for the four a.c. voltage ranges of 120 volts and below, since a possible 1-volt error on 300 and 1200 volt ranges is insignificant in percentage.

V_3 and V_{3a} are the voltmeter tubes proper, in that variations in their grid voltages are what produce changes in meter readings. This portion of the new instrument follows very closely indeed the teachings of the writer's article in the September, 1943 issue of RADIO NEWS. Variations in plate current of measurement triode V_3, due to variations in line voltage and tube aging, are balanced out by equal and opposite changes in V_{3a}. Note that dual tubes are used in each successive circuit as, produced identically, their section uniformity versus voltage and time is believed to be materially better than for the case of separate tubes. V_3 and V_{3a} see an effective plate-cathode voltage of only half the 400 volts generated by the power supply due to the very heavy degeneration and large voltage drop occasioned by their 43 kilohm cathode resistors R_{35} and R_{36}. The other half of the power supply voltage is included in their grid circuits to buck out the heavy negative grid bias developed across R_{35} and R_{36}. The net result is class-A operation with grids approximately 8 volts negative with respect to cathodes, yet with the very heavy degeneration necessary to stability. The meter is connected from cathode-to-cathode to avoid useless voltage drop across unnecessary plate resistors, and in such manner as to limit the total current flow to the meter and so give protection against overload for up to 1000 times rated input voltage. Switches S_{1c} and S_{1d} reverse meter connections to yield the several different polarities required in a.c., d.c., and ohms measurement. *Range* switch section S_{2a} selects the 4 appropriate factory-set a.c. and 1 d.c. range setting resistors—all except R_{33} for *ohms,* which is front-panel adjustable to permit compensation for gradual fall-off in *ohms* battery "B".

New Cathode Follower Eliminates Grid Current

Were voltages to be measured to be applied directly to V_3 grid through a.c. filter R_{41} and C_4 from 50 megohm *range* "stick" and switch S_{2b}, the change in grid resistance so occasioned would result in varying orders of grid current in V_3, and so the unstable zero, usual to vacuum tube voltmeters, plus the error caused by addition of the initial meter reading error to the applied voltage. The only way to escape this most serious drawback is to reduce plate voltage to around 18 volts or less, below which grid and gas current will not show up. But grid current is not bothersome at usual E_p and may be washed out in initial *zero* setting *if the resistance in the grid circuit is held constant.* These requirements conflict, and a new solution had to be created to produce a stable, high-resistance instrument. This new solution is the use of a cathode follower, operated at plate voltage low enough to banish the last traces of grid and gas current effects, located between input voltage divider "stick" and the meter-actuating tube requiring high enough plate voltage to provide a 1 ma. current change for a 3-volt grid bias change.

By this new device, it becomes possible to utilize high enough plate voltage on the actual meter-actuating tube to obtain ample plate current shift for a small grid voltage change to allow employment of a rugged meter carrying no excessive price premium, all without any of the usual deleterious grid and gas current effects. The measurement cathode follower is V_2, its companion balancing tube (in the same single 6SN7GT bulb) is V_{20}. Each tube has a 5.1 megohm cathode resistor, R_{20} and R_{21}, with the excessive grid bias developed thereacross bucked out by the opposing drop across R_{19}, similar to V_3, V_{30}. Here again class-A operation obtains, as is essential if the grid voltage range is to be linear in both positive and negative directions for a voltage greater than the basic 3-volt range. This is necessary to permit d.c. polarity reversal by simple shift of the *function* switch.

The 125 megohm x2.5 d.c. voltage ranges of 7.5 through 3000 volts in six steps are obtained by placing the two 37.5 megohm resistors R_6 and R_7 in series with the 50 megohm meter input provided by the basic voltage range "stick" R_6 through R_{13}. This multiplies the voltage ranges by 2.5 times and provides for an interesting check for absence of grid current. For example, if 3 volts d.c. be applied between *com.-gnd* and *+-Ω-MA* jacks the meter should read 3 volts and its zero should not shift when these jacks are open or short-circuited. But, if grid current is present, applying 3 volts d.c. between *com.-gnd.* and x2.5 jacks will not result in the proper voltage division to yield a meter reading of 1.2 volts, as it should. The fact that it does exactly this in the instrument described is proof positive of the complete elimination of grid and gas current effects.

V.t.v.m. Signal Tracer Is Self-Testing

One very interesting and useful feature is the resemblance of the new instrument to a lathe—reputed to be the only machine tool which can duplicate itself without the aid of other tools in the process. Using the d.c. voltmeter section, every d.c. operating voltage within the instrument itself can be checked! The a.c. input and power transformer a.c. secondary voltages may be checked using the a.c. voltage ranges. Using the resistance ranges the values of range multiplying resistors may be measured. So complete are the tests and checks of the instrument by its own functions, and so independent is it of changes due to minor variations in its own operating voltages, that it may almost be regarded as self-testing. By simple means set forth in the commercial instruction book capacitances of usual values of paper and electrolytic capacitors may be measured with that order of accuracy possible to other than bridge measurements, as may be a.c. and r.f. currents, not to mention insulation resistances ranging up to thousands of megohms.

While the instrument herein described is basically a voltmeter, its extraordinary frequency range and multiple functions make it much more than the usual V-O-M. It is a visual dynamic signal tracer, which, with its other advanced characteristics, at last gives to the service technician in simple usable form the ability to rapidly perform measurements upon receivers impossible without costly and complex laboratory equipment—an essential key to the door of postwar profits.

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As I See It

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technical phase of the industry. Now we are faced with the situation wherein the lack of technical knowledge will tend to throttle the sales capabilities, if not the very existence of the service shop, unless we do something about it.

To do this *something,* we must understand fully another influence which is at work. This is the end of the war. War does many strange things. It produces a victor and a vanquished, but even the victorious nation experiences changes in the habits and thinking of its people. It is true that everybody remains rational, but the general feeling, especially in commerce, is that the end of the war is the equivalent of a rebirth; people can start afresh. This comes about from the condition that the prosecution of war interrupts the normal flow of commodities to the people through the usual channels; therefore, the usual train of commercial actions and ways of thinking are interrupted. The end-product of profitable enterprise is still the aim, but the manner in which this will be accomplished usually is subject to much transformation. This discontinuity is accepted during war, but when it comes time to rejoin the broken threads, the past seldom is the pattern for the future.

New technical development, new manufacturing techniques, and new concerns born during the war, create numerous changes in the commercial life of the nation, especially with respect to competitive effort. The zone of influence of these changes encompasses the radio repair man just as it does many other groups of people. To attempt to swim against the tide is ridiculous; to recognize the truth as it exists makes much more sense.

The Threat by the Set Dealer

Examine the advertisements in the trade papers. You will note that the radio manufacturer of the past is spreading horizontally in the items he