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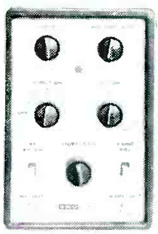

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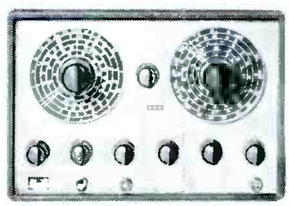

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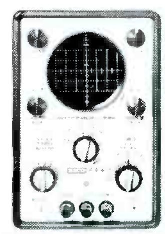

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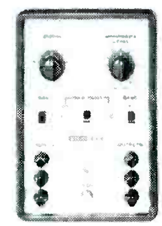

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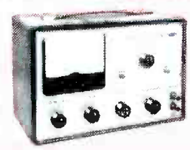

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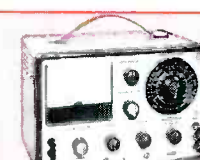

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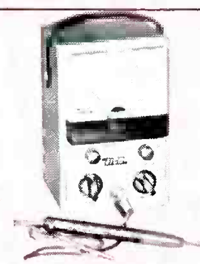

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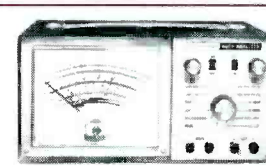

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INTERMODULATION

and

HARMONIC DISTORTION

by Howard M. Tremaine

Nonlinear distortion in a sound system affects the reproduction by introducing frequency components that were not present in the original program material. These added components are an annoyance to the listener due to the masking and interference effects superimposed on the original components of the signal.

In the most commonly accepted method of measuring harmonic distortion, a single sine-wave frequency is applied to the device under test and the internally generated harmonics are measured at the output. A distortion factor meter or a harmonic wave analyzer may be used, and the harmonic distortion read in percent of the fundamental frequency. Although this single-frequency method of measuring harmonic distortion has been in use for many years, it does not present a complete picture of the distortion characteristics of a given device. It is not uncommon for a listener to observe an objectionable quality in the sound reproduction of a transmission system in which a low percentage of harmonic distortion is measured. Amplifiers of the same design, manufacture, and harmonic distortion characteristics often present different qualities in reproduction. This variation in identical amplifiers is usually due to the percent of intermodulation distortion generated within the amplifiers.

Material for this article was adapted from the Howard W. Sams Book Intermodulation and Harmonic Distortion *by Howard M. Tremaine.*

Intermodulation distortion may be defined as "the production, in a nonlinear circuit element, of frequencies corresponding to the sum and differences of the fundamentals and harmonics of the two or more frequencies that are transmitted through the element." Measuring the distortion characteristics by the intermodulation method more than by any other form of measurement approaches the manner in which the human ear responds. It not only presents a more realistic determination of distortion characteristics, but it is also several times more sensitive than the conventional single-frequency harmonic measurement.

In a system where the upper frequency is generally limited to 8 kHz, measuring the harmonic distortion at 5,000 Hz would be meaningless since the second harmonic occurring at 10 kHz would be unmeasurable due to the 8,000 Hz cutoff. However, an intermodulation test signal, consisting of 40 and 7 kHz will often reveal distortion which would seriously affect the reproduction.

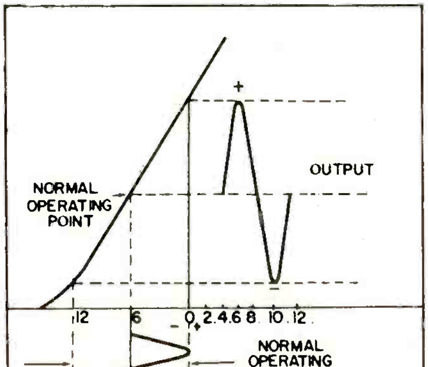

Fig. 1. Class-A operation curve.

In a complete recording and reproducing system distortion may be caused by amplifiers, filters, equalizers, compressors, cutting heads, light modulators, magnetic recorders or reproducers, monitor speakers, or a combination within the system. Distortion within the amplifiers may be caused by tubes operating on the nonlinear portion of the plate-current characteristic curve, improper load termination, poor power-supply regulation, unbalance in the push-pull stages, saturation of the transformer core materials, and faulty components. Many times after an overall distortion measurement is made, the difficulty can be traced to one component in the system.

While 40 Hz is generally used as the low-frequency component for transmission systems using a bandwidth of 40 to 8 kHz, an intermodulation test signal of 60 to 100 Hz in combination with 2 kHz can suffice. Distortion of a transmission system can be observed on a cathode-ray oscilloscope, however, it is rather difficult to determine small percentages of waveform distortion, even with a 5-inch screen. As a rule, 2 or 3% distortion can be observed for the higher order harmonics.

Generation of Harmonic Distortion

Harmonic distortion in an amplifier

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stage is caused by the nonlinear action of the vacuum tube. If a pure sine wave is applied to the control grid of a vacuum tube operating with correct voltages and load impedance, and the amplitude of the sine wave is such that it does not overdrive the control grid, a pure sine wave can be expected at the output of the tube. The only departure from the original waveform of the input will be an increase in its amplitude and a phase reversal of 180° between the input and output circuits. To illustrate how nonlinear distortion is generated within a vacuum tube, a plot of the control-grid voltage versus the plate current for a general-purpose triode biased for Class-A operation is shown in Fig. 1. The tube selected for this illustration normally requires a negative grid bias of 6 volts. This point is indicated as the normal operating point on the plate current characteristic curve.

Operating under the aforementioned conditions, if a sine wave is applied to the control grid, a sine wave will be reproduced in the plate circuit. However, this will be true only if the signal voltage at the control grid does not exceed the normal operating boundaries. These boundaries are the straight-line portion of the curve, starting at the minus 12-volt bias point and continuing up to the zero-voltage bias point. If the peak signal voltage does not exceed these limits, a sine wave will be developed in the plate circuit, and distortion of the input waveform will not occur. The peak value is determined by multiplying the DC bias voltage by 1.414; hence, in this example, it is 8.5 volts.

Fig. 2 shows what happens when the bias is too large. Here, the negative bias has been increased until the operating point (value of plate current) has shifted downward toward the toe or bend in the lower portion of the plate current characteristic at the minus 12-volt point. Under this condition if a sine wave is applied to the control grid, a greater amount of plate current will flow on the positive half of the grid swing than for the negative half and an unsymmetrical waveform will result in the plate circuit. Likewise, if the bias voltage is reduced to a value of minus 2 volts, the operating point is shifted upward. If the control grid swings positive, the amplitude of the positive half of the plate-current waveform will be less than the negative half, since the tube is being driven into the saturation region of the plate-current characteristic.

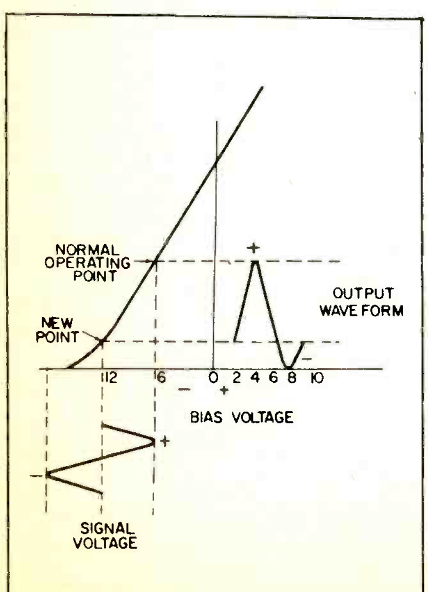

Fig. 2. Overbiasing causes distortion.

Thus, it becomes apparent that the bias voltage on the control grid and the amplitude of the applied signal voltage are the controlling factors in the generation of harmonic distortion within a vacuum tube.

Harmonic distortion can also be generated within a vacuum tube that is correctly biased (Fig. 3). The signal voltage applied to the control grid is so large that it extends into both the toe and knee (saturation) areas of the plate-current characteristic. In the saturation region the peak of the output waveform is flattened since the tube cannot supply further plate current. In the negative region the flow of the plate current is reduced to a near cutoff value. Thus, both the positive and negative peaks of the plate current waveform are distorted, and both odd and even harmonics are generated. The generation of harmonics within a vacuum tube is an inherent characteristic, since the plate resistance is not always uniform and the so-called straight-line portion of the plate current characteristic is not actually straight.

To the human ear the most objectionable harmonics are the second, third, fifth, and seventh; they are usually of higher amplitude and fall within the band of audible frequencies. To further illustrate the generation of harmonics, two superimposed sine waves are shown in Fig. 4. F_1 is the fundamental frequency, and F_2 is the second harmonic. Adding the second harmonic to the fundamental frequency algebraically results in a new frequency, indicated as the resultant. This new frequency is the same as the fundamental frequency, except that the amplitude of the negative peak is increased while the amplitude of the positive peak is reduced. The second harmonic will predominate and is similar to a condition where the bias voltage is too low.

In Fig. 4 a horizontal line has been added (in dashed lines) to indicate the shifted operating point. This line represents a DC component, caused by self-rectification within the tube. Self rectification shifts the operating point in the plate-current characteristic. Depending on the circumstances under which the tube is functioning at the moment, it may move either up or down.

When distortion results in the flattening-off of only one peak in the output waveform, the principal distortion is second harmonic. This is accompanied by a change in the average plate current and is referred to as self rectification. Whenever both peaks of the output waveform are flattened, third-harmonic

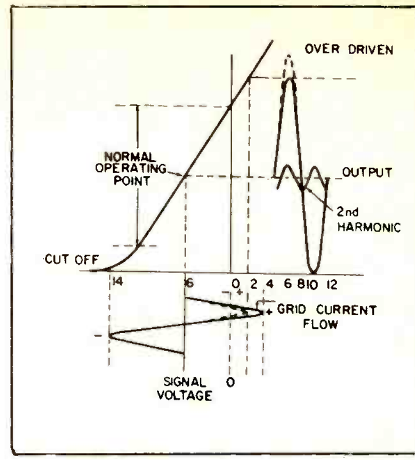

Fig. 3. Overdriving causes distortion.

distortion will predominate. If considerable flattening occurs, a fourth-order harmonic will also be generated, particularly if the control grid is driven positive.

When a triode tube is overloaded, second-order harmonics are created, while a pentode generates third-order harmonics. Even order harmonics may be eliminated or reduced to a negligible amplitude by the use of push-pull circuits. Odd order harmonics generated by a pentode are reduced by the use of push-pull circuitry and the selection of the proper load impedance. Negative feedback will also reduce odd harmonics to a negligible value. However, negative feedback should not be added to an amplifier to reduce its harmonic distortion until the distortion in the amplifier without negative feedback has been reduced to its lowest point.

Beat-Frequency Oscillators

Oscillators used for audio-frequency measurement purposes must have low-harmonic distortion. As a rule, such oscillators have less than 0.25% distortion and many are in the order of 0.1%. The lower the oscillator distortion, the lower is the amount of harmonic distortion that can be measured in a system. As an example, an amplifier having a total of 0.30% harmonic distortion cannot be measured with an oscillator having 1% harmonic distortion. Oscillator distortion cannot be directly subtracted from the measured distortion, however, it is possible to use an oscillator of 1% distortion or even higher for such measurements, if a bandpass filter is connected between the output of the oscillator and the input of the device under test. Since this

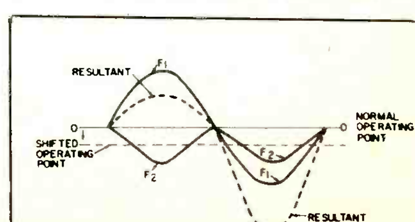

Fig. 4. The fundamental frequency and its second harmonic produce a new frequency.

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requires a filter for each frequency of interest, it becomes impractical.

Audio oscillators are generally one of two types, either a beat frequency or Wien bridge, sometimes referred to as a resistance-tuned oscillator. The beat-frequency oscillator (Fig. 5) employs two radio-frequency oscillators, one operating at a fixed frequency and a second one which is variable and beat with the fixed oscillator. The variable oscillator tuning capacitor (C-1) is mechanically connected to a dial on the front panel and is calibrated in terms of audio frequency. In operation the two oscillator signals are combined internally to produce a beat frequency which will fall within the audio-frequency spectrum. Thus, a continuously variable audio signal is generated. As the dial of the radio-frequency oscillator is rotated the frequency of the oscillator circuit is changed, thereby changing the beat frequency produced by the two oscillators. One of the principal advantages of a beat frequency oscillator is that a single sweep of the dial permits the instrument to be tuned across the entire audio spectrum. As an example of beat-frequency oscillator design, the fixed-frequency oscillator could be operated at 100 kHz with the variable-frequency oscillator capable of covering a frequency range of 80 to 100 kHz. This will generate audio frequencies from zero to 20 kHz.

To produce an audio-frequency signal devoid of harmonics the generated beat frequency is fed through a lowpass filter to remove the harmonics. Low-

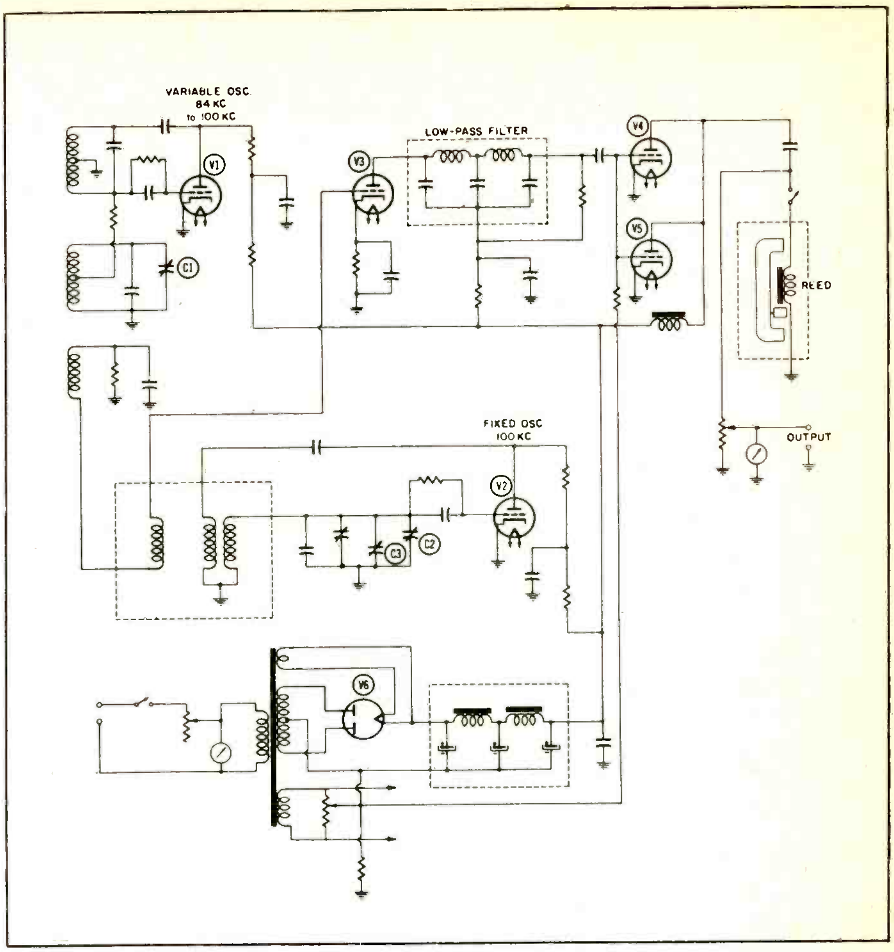
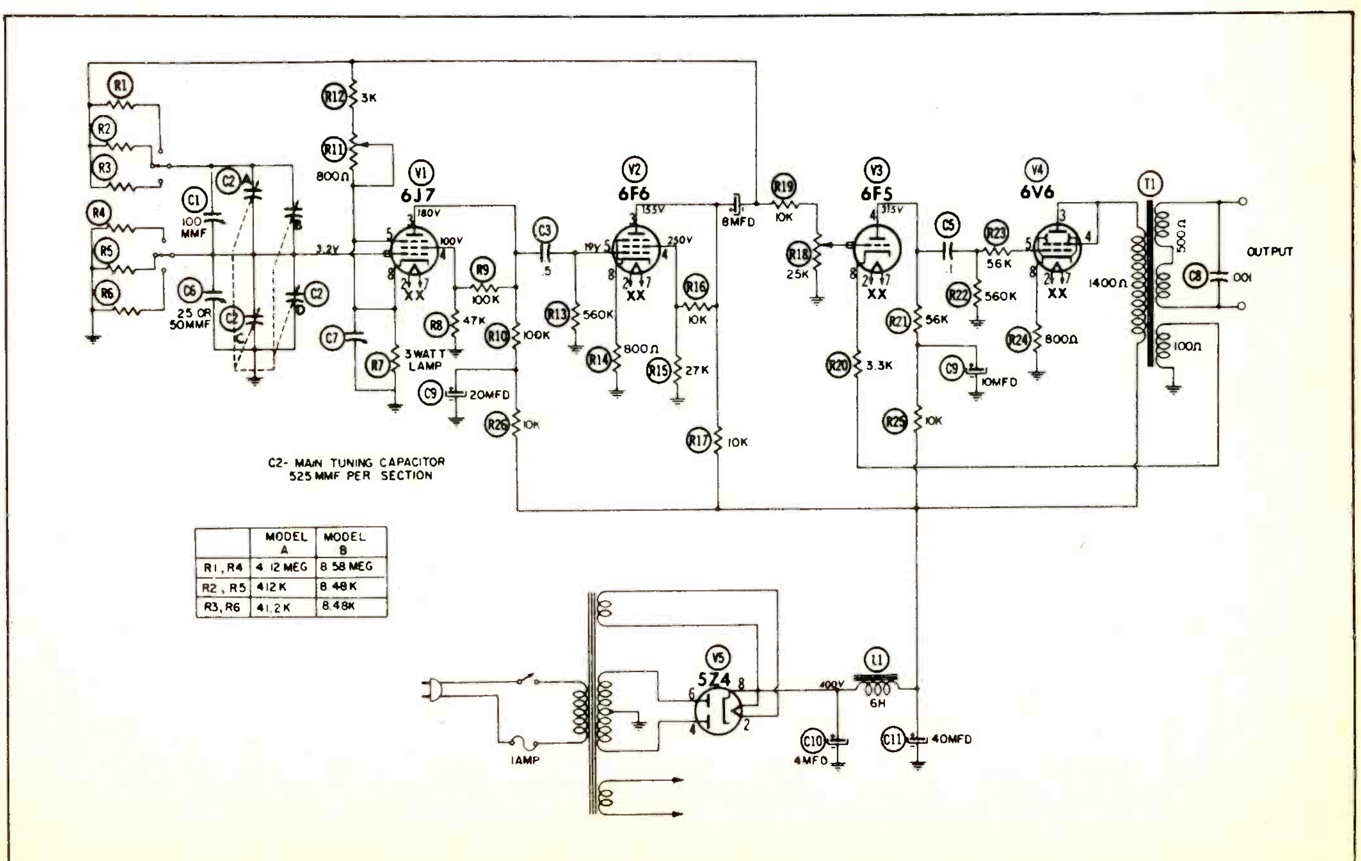


Fig. 5. Schematic of a beat-frequency oscillator.



	MODEL A	MODEL B
R1, R4	4.12 MEG	8.58 MEG
R2, R5	412 K	8.48K
R3, R6	41.2 K	8.48K

Fig. 6. Schematic of a Wien-bridge audio oscillator.

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harmonic distortion can also be achieved by the use of push-pull amplifiers. Beat-frequency oscillators designed for laboratory use generally have a total harmonic distortion in the order of 0.25% or less.

The advantage of a beat-frequency oscillator lies in the fact that it can be used to make sweep-frequency checks of a system or individual components, such as filters, equalizers, or other devices, without resorting to decade switching as used with the resistance-tuned oscillator.

Resistance-Tuned Oscillators

Resistance-tuned oscillators (also called Wien-bridge or negative-feedback oscillators) consist of a bridge circuit composed of resistance and capacitance, as shown in Fig. 6. The oscillator section consists of two tubes V1 and V2. In reality, such oscillators consist of a two-stage resistance-coupled amplifier, which is caused to oscillate by the use of positive feedback network R1, R2, R3, R4, R5, R6, C1 and C2.

This network is frequency selective and controls the frequency of oscillation by the use of a large variable capacitor (C2), which is connected to a dial on the front panel and calibrated in cycles per second. By this method it is possible to tune the oscillator over a wide range of frequencies by switching in different values of resistance in the frequency-selective network. Oscillators of this type may be designed to generate frequencies from a fraction of a cycle to over several megacycles. Negative feedback is employed in the oscillator section to reduce the harmonic distortion to a minimum and to obtain a high degree of stability. The amount of negative feedback is automatically determined by resistive network R7, R11, and R12. The 120-volt, 3-watt pilot light (R7) used as one leg of the bridge, is a nonlinear resistance. The amplitude of the negative feedback is controlled by the lamp in accordance with the amplitude of oscillation. Thus, it maintains the proper operating point for the system. A driver stage (V3) and power amplifier (V4) follow the oscillator section. V4 is transformer-coupled to the output circuit. Here again, negative feedback is used to reduce the harmonic distortion and provide a uniform frequency response at the output.

The output stage will deliver 1 watt of power into a load impedance of 600 ohms. Looking back into the output, the internal-output impedance is approximately 100 ohms. With such a low internal-output impedance, the output voltage is little affected by the external-load impedance. The power supply is conventional, except for its low ripple content. The power transformer does not induce magnetic coupling to the oscillator circuitry.

The principal advantage of the Wien-bridge oscillator is that it requires only a short warm-up period and is ready for almost immediate use after power is applied. Generally harmonic distortion for this type oscillator is less than 0.5%. In models employing push-pull stages it is 0.25% or less. Some Wien-bridge oscillators are designed to cover a range of 20 to 20,000 Hz in a single sweep—similar to the beat-frequency oscillator discussed previously.

Other type audio oscillators employ phase-shifting networks, and inductively tuned circuits. The principal features essential for an acceptable audio oscillator are: accuracy of calibration, low harmonic distortion, consistency of output, low internal noise, and a low value of frequency drift relative to line voltage variations.

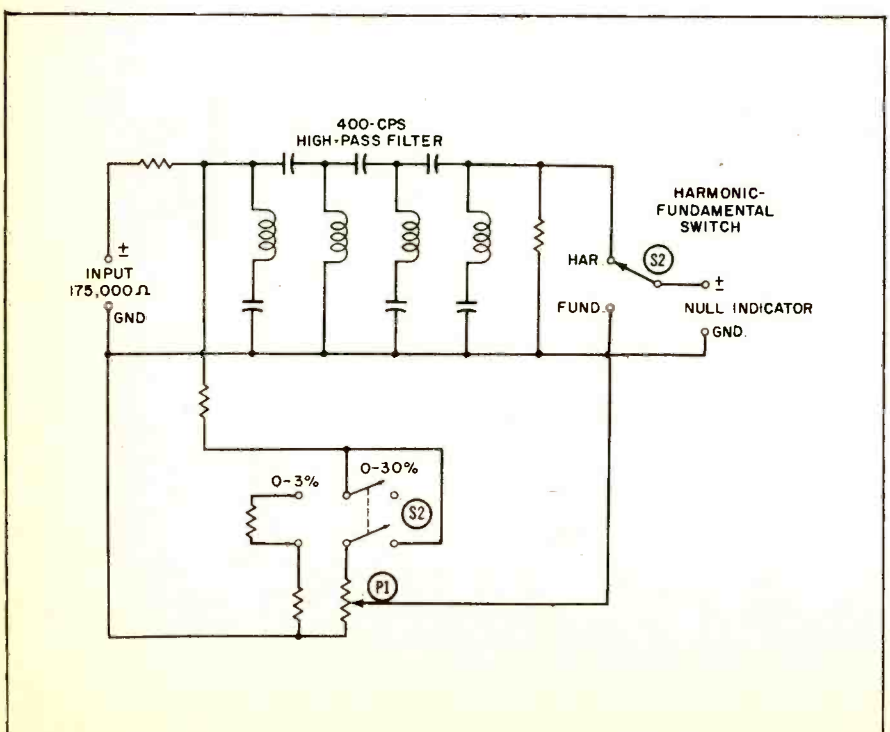

Fig. 7. 400-Hz high-pass filter-type distortion measuring set.

Distortion Sets

The single-filter type of distortion set is the most commonly employed for measuring harmonic distortion. A single sine-wave frequency is applied to the input of a device or transmission system under test. A given output level is set for the device or system, and the amplitude of the generated harmonics measured in percent of fundamental frequency. A distortion set, distortion-factor meter, or harmonic-wave analyzer may be used for this purpose. Distortion-sets and distortion-factor meters measure the total rms harmonic distortion generated within the device under test by lumping all the harmonics present together. The harmonic-wave analyzer measures only the amplitude of the fundamental frequency or the amplitude of the individual harmonic voltages. Information obtained by the use of a harmonic-wave analyzer can be used to compute the total harmonic distortion or to state the amplitude of a given harmonic in relation to the fundamental frequency.

There are several different types of distortion meters. They either employ a high-pass or bandpass filter, or a group of band-rejection filters. Some designs may be continuously tuned over the complete audio spectrum. Sometimes, the instrument will contain an internal null-indicator, while others require the use of an external one.

The schematic diagram of a single, high-pass, filter-type, distortion meter is shown in Fig. 7. Since this device does not contain an amplifier or an indicating meter, one must be supplied externally. The circuit of this instrument centers around the use of a 400-Hz, high-pass filter of extremely sharp attenuation characteristics. With the filter in the circuit the fundamental frequency of 400 Hz is suppressed approximately 75 db. This permits distortion components of less than 0.10% to be measured.

A resistive network and a potentiometer (P1) are connected ahead of the filter for the purpose of comparing the voltage at the output of the filter with the voltage applied to the input. A dial calibrated from zero to 3% and to 30% is mounted on the shaft of potentiometer P1. When making a distortion measurement, the potentiometer is rotated until the same output voltage is obtained for either of the two positions of switch S2, which inserts or removes the filter from the circuit. The measurement is (S2 to Har. position) and the amplitude (S2 to Har. position) and the amplitude of the harmonics is read on an external null-indicator (VTVM). The filter is then removed by means of switch S2 (set to Fund.) and the dial (P1) rotated for an equal indication on the external meter. With S2 in this position, the amplitude of the fundamental and its harmonics is read. When a balance has been obtained between the two positions of this switch, the percent harmonic distortion is read directly from the dial.

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The characteristics of the filter (Fig. 8) are such that all harmonics of 400 Hz—up to and including the fifteenth (6 kHz)—are passed. The sensitivity of this type of measuring device depends primarily on the sensitivity of the external null indicator and the degree of internal and external noise. Distortion sets such as this one measure the total rms harmonic distortion. No indication is given of the amplitude of the individual harmonics as they are measured as a whole. If the individual harmonic voltages must be known, they may be measured with a harmonic-wave analyzer.

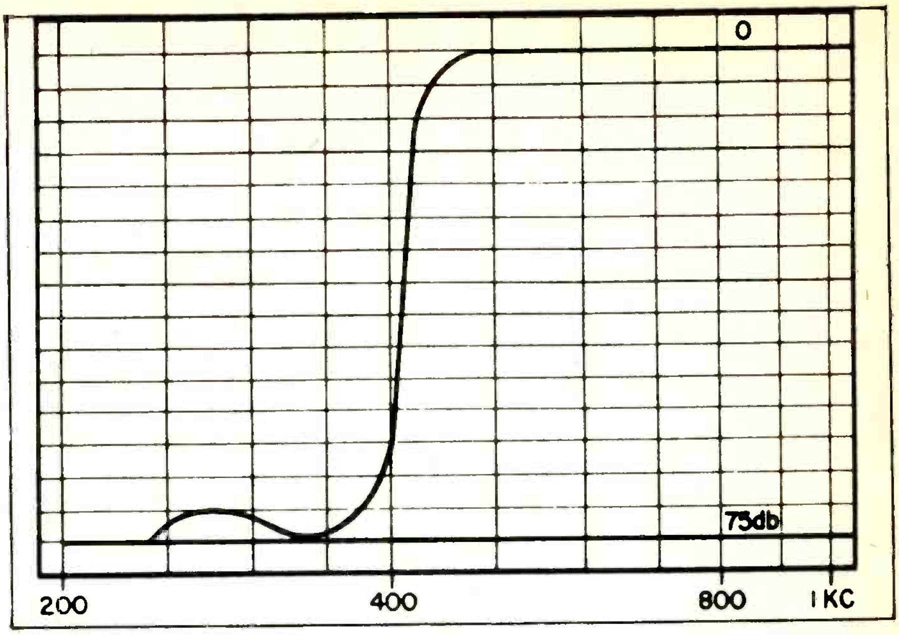

Fig. 8. Frequency characteristic of a 400-Hz high-pass filter.

Continuously Variable Types

Several different types of completely self-contained instruments for measuring harmonic distortion throughout the audio spectrum have been developed. The basic schematic diagram for one such instrument appears in Fig. 9.

Basically, this instrument consists of a high-gain amplifier with an RC-interstage coupling unit that can be balanced to a sharp null and a calibrated attenuator for adjusting the sensitivity of a vacuum-tube voltmeter. Degeneration is employed to maintain the stability of the amplifier gain and to provide a flat transmission characteristic. The null frequency is continuously variable and is used to eliminate the fundamental frequency of the test signal, leaving only the distortion products generated within the device under test. The percentage of harmonic distortion may be read directly from the scale of the VTVM.

When making hum and noise measurements, the null network is switched out of the circuit. The instrument then functions as a sensitive VTVM with a wide frequency response. Two input circuits are provided—a transformer for bridging a line of 600-ohm impedance, and a direct connection to a 100,000-ohm input control. Frequencies up to 55 kHz are passed by the amplifier without discrimination for distortion measurements using an 18 kHz fundamental frequency. The VTVM provides a full-scale deflection for distortion measurements of 0.3, 1.0, 3.0, 10, and 30% distortion. Hum and noise may be measured down to —80 dbm. This instrument will measure the total rms harmonic distortion for any frequency between 50 and 18 kHz, including the harmonics up to 30 kHz, using the input transformer. Harmonics up to 55 kHz may be measured with the 100,000-ohm input potentiometer.

An oscillator with low harmonic distortion (0.20% or less) is connected to the input of the device to be tested through a suitable network. The output is terminated in its normal impedance by a resistive load. The distortion meter is connected in parallel with the load resistance. The signal to the device under test is increased to develop the desired output power. Measurements are

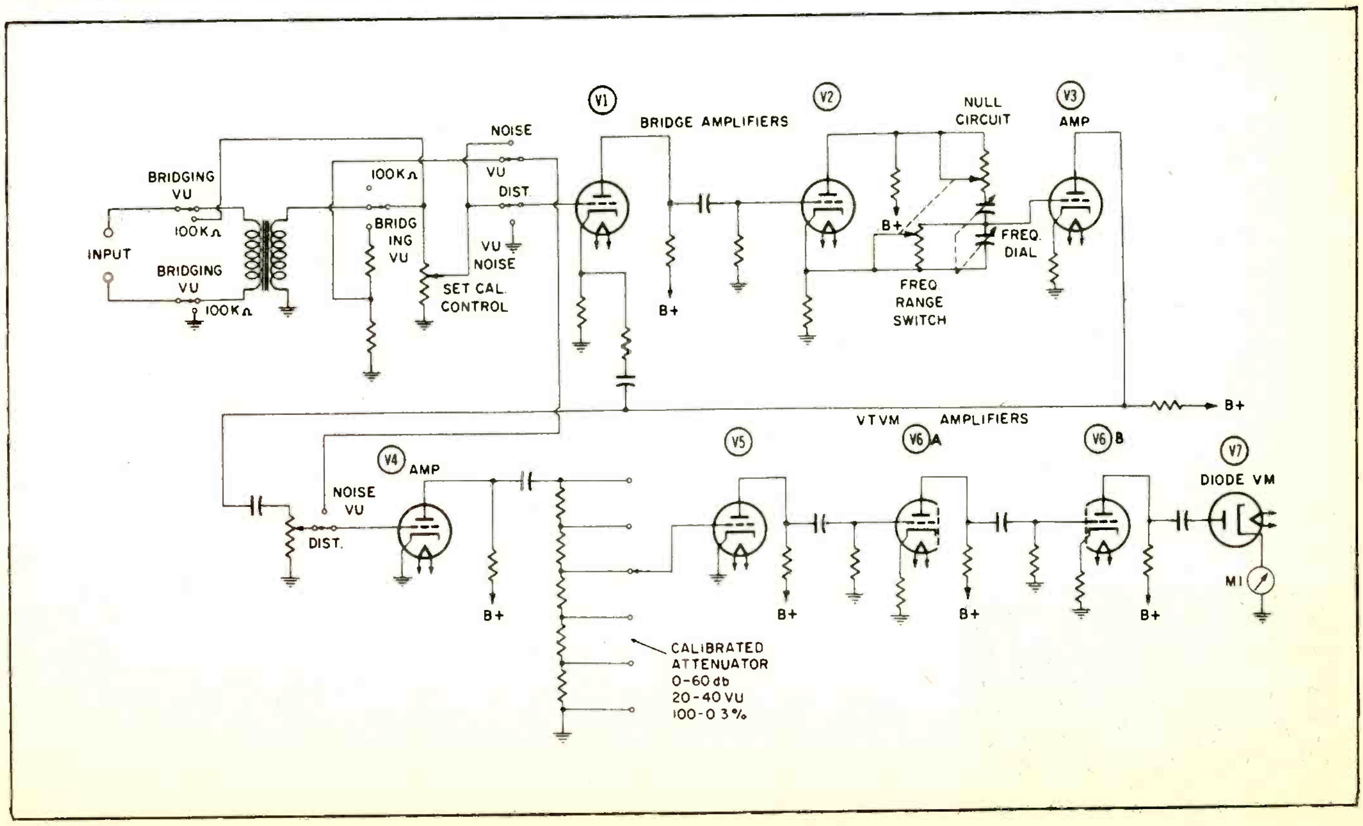

Fig. 9. Schematic of a continuously variable distortion meter.

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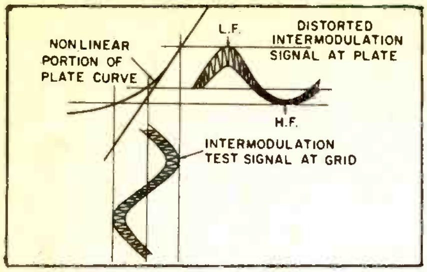

Fig. 10. Intermodulation distortion caused by operating on the non-linear portion of the curve.

made at several different power levels and then plotted as power output versus harmonic distortion.

Harmonic Wave Analyzers

A wave analyzer is used to measure the individual amplitudes of harmonic frequencies contained in a complex waveform. The instrument consists of a variable local oscillator, selective amplifier, and indicating meter. The local oscillator modulates the unknown frequency to produce a constant difference frequency. This frequency is applied to a selective amplifier (also called an intermediate amplifier) whose output is proportional to the magnitude of the unknown voltage.

A wave analyzer is in reality a frequency-selective vacuum-tube voltmeter that uses the heterodyne principle employed in radio receivers, only in this instance it operates at audio frequencies. The beat frequency may be either the sum or difference of the two frequencies. This basic principle is used in most wave analyzers.

The local oscillator of the wave analyzer beats with the frequency under observation; the resulting beat frequency is then applied to the selective amplifier. The amplitude of the beat frequency is measured at the output of the selective amplifier with a calibrated VTVM.

The advantage of variable selectivity in an analyzer over the fixed-selectivity type is apparent where a harmonic analysis is being made of a device that has mechanical motion, such as a disc, tape, or film reproducer. In such devices a certain amount of flutter is encountered, and if the intermediate-amplifier selectivity is too great, the signal passes in and out of the selective-amplifier pass-band, making the measurement of low amplitudes difficult. A selective amplifier with variable bandwidth can be adjusted for a bandwidth suitable for a given measurement. If a steady signal source, such as from an oscillator, is being measured, either type of analyzer is satisfactory.

The local oscillator of the analyzer that produces the beat frequency must be of stable design. The variable capacitor of the local oscillator is mechanically connected to a large dial which is calibrated in terms of audio frequency. Although calibrated in audio frequency, the actual frequency of the oscillator varies somewhat between zero and 50 kHz, depending on the incoming frequency. The frequency of the local oscillator is equal to the frequency difference between the selective-amplifier frequency and the frequency under observation.

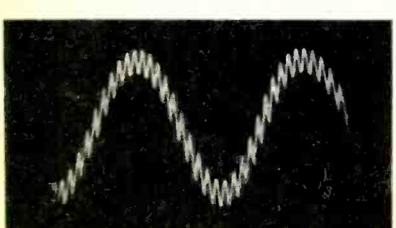

Fig. 11. Undistorted IM test signal.

The intermediate frequency of wave analyzers employing negative feedback in the selective amplifier is usually 20 kHz, while those using a crystal employ a frequency of 50 kHz. As an example assume that the analyzer uses a tuned amplifier of 50 kHz and the signal under measurement is 400 Hz. The local oscillator must be tuned to a frequency of 49.6 kHz. This frequency will produce a beat frequency between the incoming signal and the local oscillator of 50 kHz (400 + 49,600). As another example, if the incoming frequency is 16 kHz the local oscillator must be set to a frequency of 34 kHz. The beat frequency will also be 50 kHz (16,000 + 34,000).

Generation of Intermodulation Distortion

If a test signal consisting of a high and a low frequency is applied simultaneously to the input of a nonlinear transmission system, modulation of the high-frequency component of the test signal will occur at the rate, or multiple of the rate, of the low-frequency component as the test signal swings over the nonlinear portion of the transmission-system transfer characteristic. The resulting distortion generated by this action is termed intermodulation distortion and may be defined as the percent amplitude modulation of the high-frequency signal by the low-frequency signal.

Using a test-signal ratio of 4:1 (low frequency four times the amplitude of the high frequency, 12-db differential), the distortion measured by the intermodulation method is roughly four times that measured by the conventional single-frequency method previously discussed. If the ratio between the two test signals is reduced to 6 db, the measurement will be approximately 2.7 times that of a single-frequency measurement. However, it should be understood that there is no simple mathematical procedure for expressing the relationship between a single-frequency harmonic distortion measurement and an intermodulation measurement. The generated intermodulation products are proportional to the harmonics measured by a single frequency —but only under set conditions.

In practice it may be found that the value of the intermodulation products in percent may be greater or less than the harmonics, depending on the order of the harmonics and the design of the device being tested. Therefore a direct comparison of the harmonics and intermodulation products cannot be made, unless the conditions are specified. As a guide to what may be expected in radio and commercial recording and reproducing equipment, the following figures are typical:

- Frequency-modulated transmitters
  - 100% modulation—5 to 7%
  - 80% modulation—2 to 3%
- Disc-recording systems
  - record/playback—2.5 to 4%
- Audio amplifiers
  - High quality—0.10 to 1%
  - Medium quality—2 to 5%
- Magnetic recorders and reproducers
  - record/playback—2 to 4%

For the purpose of illustration, the intermodulation distortion of a single-ended triode amplifier stage operating Class-A with normal load impedance and operating voltages will be investigated. The transfer characteristics for such a tube are shown in Fig. 10. Two test frequencies of 40 and 2,000 Hz (Fig. 11) are mixed in a ratio of 4:1 and applied to the control grid. The ratio of 4:1 for the test signal is obtained by setting the high-frequency component 12 db lower in amplitude than that of the low-frequency component. It is assumed that the combined test signal is of sufficient amplitude to drive the plate-circuit signal into the toe region of the plate-current characteristic. Because of the curvature at the lower end of the transfer characteristic, the symmetrical test-signal waveform will be distorted at the output. Since the low-frequency component of the test signal is of greater amplitude than the high-frequency component, it is distorted to a greater extent due to the deviation in the slope of the transfer characteristic. Thus, the high-frequency component is modulated by the low-frequency component at 40 Hz. If distortion is present in the amplifier, modulating the high-frequency component by the low-frequency component causes a flattening off of the high-frequency peaks at the output (Fig. 12), generating sum and difference frequencies.

The percent of intermodulation distortion may be defined as the ratio of the average deviation of the amplitude of the higher frequency signal above and below the mean value to a mean value expressed in percentage. Any mathematical relationship between readings of

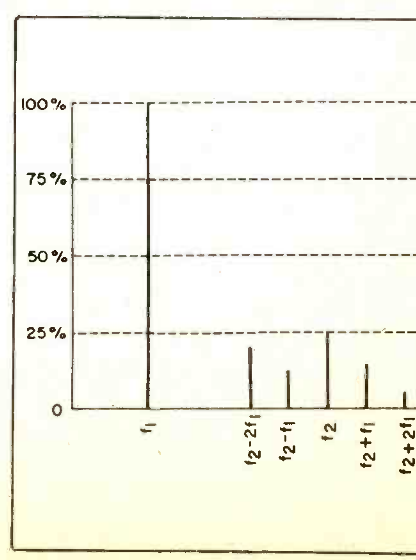

Fig. 13. SMPTE input spectrum.

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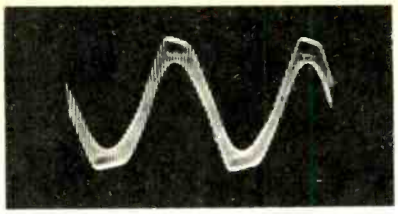

Fig. 12. Distorted SMPTE signal.

percentage intermodulation and percentage harmonic distortion must be made to only second harmonic or only the third harmonic.

Measuring Intermodulation Distortion

There are three methods of measuring intermodulation distortion. Each has its own advantages and disadvantages. The SMPTE method, adopted by the Society of Motion Picture and Television Engineers, is extensively used. The CCIF method, recommended by the International Telephonic Consultative Committee, offers certain advantages in some applications. The notch method is a simplified method of measurement and does not require an intermodulation analyzer.

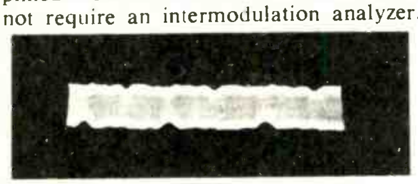

Fig. 14. Distorted high-frequency at the filter output.

SMPTE Method

Basically, the complete analyzer consists of two units—a signal generator and an analyzer unit. The signal generator generates two signals that are applied simultaneously to the input of the device under test. The analyzer portion is connected across the output load impedance of the device being tested and measures the intermodulation distortion percent being generated in the device. In the SMPTE method of measuring, the test signal consists of a low and high frequency mixed at a ratio of 4:1. The low frequency may be anywhere between 40 and 100 Hz and the high frequency between 2 and 12 kHz. The choice of frequencies will depend on the frequency characteristic of the device under test. As a guide, the following frequencies may be employed:

- Wide-band amplifiers—40 and 7,000 Hz (sometimes 12,000 Hz)
- Medium-band amplifiers—60 and 2,000 Hz
- Limited-band amplifiers—100 and 2,000 Hz

If the composite test signal is applied to the input of an amplifier, any nonlinearity in the amplifier will cause sum and difference frequencies to be generated. A portion of the frequency spectrum as it would appear to the input of the analyzer is shown in Fig. 13. Frequencies f_1 and f_2 are the fundamental frequencies of the test signal. Other frequencies shown are the sum and difference frequencies generated within the amplifier. The amplitude of frequency f_1 is taken as the reference frequency, and is indicated as 100%. All other frequencies are plotted with reference to this frequency. It should be noted that frequency f_2 is 12 db lower in amplitude than f_1, which corresponds to a ratio of 4:1. The amplitude of the sum and difference frequencies in the output are dependent on the amount of intermodulation distortion generated within the amplifier.

If a frequency of 100 Hz is selected for f_1 and 5 kHz for f_2, sum and difference frequencies appear at intervals of 100 Hz. Other frequencies above and below f_2 also appear, but they are omitted in Fig. 13 for the sake of clarity.

The signal generator generates two frequencies, one high and one low. The two signals are applied to a mixing circuit set for a 4:1 ratio, and then they are applied through an attenuator to the device under test. The analyzer portion connected across the output of the device contains an input attenuator, high-pass filter, amplifiers, rectifiers, low-pass filter, and a vacuum-tube voltmeter for indicating the percent of intermodulation distortion.

To illustrate how the analyzer functions, assume that an amplifier is to be measured. The composite signal from the generator section is attenuated to the proper input level for the device under test and then applied to the input of the amplifier. The output of the amplifier is terminated in a resistive load equal to its normal operating load impedance. Because of the nonlinearity of the amplifier transfer characteristics, sum and difference frequencies are generated within the amplifier. The distorted waveform at the output of the amplifier appears as in Fig. 12. Both the positive and negative peaks are flattened off.

It should be noted for this particular amplifier that the output waveform is compressed on both the positive and negative peaks. That is, the high-frequency signal peaks are flattened off at the peaks of the analyzer and passed through a distorted signal is applied to the input of the analyzer and passed through a high-pass filter which removes the low-frequency component, leaving only the modulated or distorted high-frequency signal as shown in Fig. 14. The notches in the waveform correspond to the compressed high-frequency peaks. Leaving the

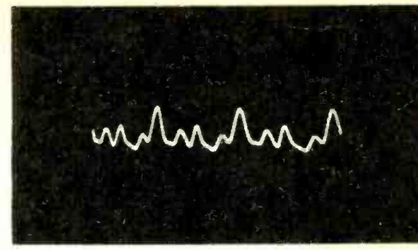

Fig. 15. The resulting new signal.

high-pass filter, the distorted high-frequency component is amplified and applied to a full-wave rectifier and then to a 600-Hz low-pass filter that removes the high-frequency component, leaving only the modulated envelope or a pulsating direct current (Fig. 15) at the output. This pulsating direct current is the measure of intermodulation distortion of the high-frequency component caused by the modulation effect of the amplifier's low-frequency component.

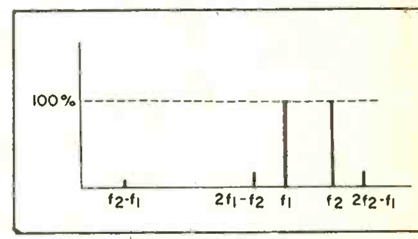

Fig. 16. CCIF input spectrum.

CCIF Method

A second method of measuring intermodulation distortion, known as the CCIF method, is recommended by the International Telephonic Consultative Committee. It also employs two frequencies (f_1 and f_2), but they are of equal amplitude. The two frequencies differ by an amount ranging from 30 to 1,000 Hz. These frequencies are kept at a fixed ratio and moved up and down the frequency spectrum, producing a constant beat frequency along with the distortion products of the device under test. The appearance of the frequency spectrum for the CCIF method is shown in Fig. 16. The intermodulation distortion products are measured at the output of the device under test with a harmonic wave analyzer. The total intermodulation distortion measured by the CCIF method may be computed in reading the wave analyzer:

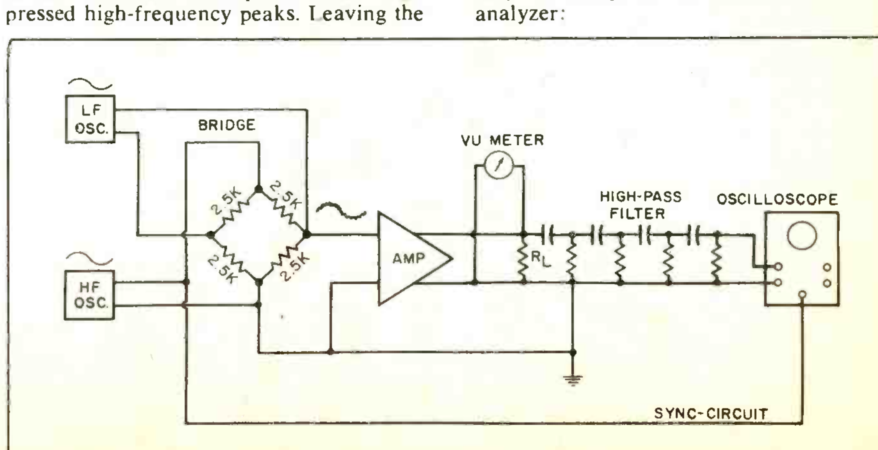

Fig. 17. Connections for measuring IM distortion using notch method.

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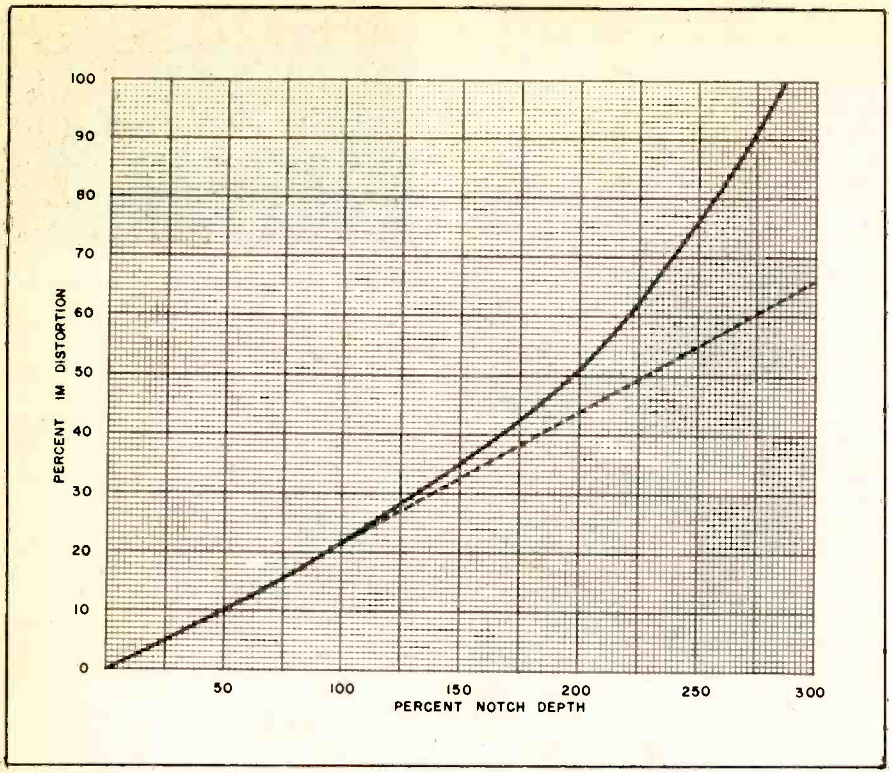

Fig. 18. Relationship between notch depth and intermodulation distortion.

$$\text{IM Distortion} = \frac{\text{difference-frequency amplitude}}{\text{sum of high frequency test signals}}$$

It is felt by some investigators that the CCIF method offers some advantages over the SMPTE and single-frequency harmonic methods of measuring distortion. This is particularly true if the device under test has a limited frequency response, such as might be found in a hearing aid, noise suppressor, or low-pass filter. For such a device a single-frequency distortion measurement could be misleading, because of the limited frequency response. The SMPTE method might also be misleading, because of the 4:1 ratio between the low- and high-frequency components of the test signal. It would appear that the CCIF method would be most satisfactory for such conditions because the component frequencies of the test signal are of equal amplitude and permit a better measurement of high frequencies up to the cutoff.

The principal difference between the two systems of measurement is that the CCIF method measures the low-frequency distortion due to the distortion of the higher frequencies, while the SMPTE method measures the effect of low-frequency distortion superimposed on the high frequency.

Notch Method

Intermodulation distortion may be measured by the notch method without the use of an intermodulation analyzer. While this method is not very accurate, it is satisfactory for practical purposes.

The notch method employs two oscillators, a resistive bridge network for combining the output signals of the two oscillators, a high-pass filter, and a cathode-ray oscilloscope connected as shown in Fig. 17. The oscillator signals, which may be of any desired ratio, are fed into a resistive bridge network that affords isolation of the two signals, preventing the generation of intermodulation between the oscillators while permitting them to be combined into a composite signal. One leg of the bridge circuit feeds the input of the device being tested. The output of the device under test is terminated in its normal load impedance by resistive termination R_L. A high-pass filter is bridged across the load termination with the oscilloscope connected to the output of the filter network. The filter is designed to have a steep cutoff characteristic and may be of an LC or RC configuration. Its cutoff frequency must be at least twice that of the low-frequency component of the test signal, since its purpose is to remove the low-frequency component and leave only the high-frequency component with the modulation envelope of the low-frequency signal.

An amplifier under test is shown in Fig. 17. First, the oscillator signal voltage is set by means of a VTVM connected across the arms of the bridge circuit associated with the oscillators. After setting the ratio between the oscillators, the gain of the amplifier is adjusted for a given output level. The amplifier output signal is passed through the high-pass filter (removing the low-frequency component) and displayed on an oscilloscope. The sweep-circuit control of the oscilloscope is adjusted to display an image of one cycle. This can be easily accomplished by connecting the external sync terminal of the oscilloscope to the plus-minus terminal of the low-frequency oscillator.

Under normal operating conditions a notch will appear at the upper and lower edges of the image. An experimental relationship has been determined between the depth of the notch and the percent of intermodulation distortion, using a commercial intermodulation analyzer. The relationship is shown graphically in Fig. 18. Percent intermodulation may be computed as shown in Fig. 19. Below a value of 10% intermodulation (50% notch depth) the relationship is fairly linear, making it practical to attach a scale to the face of the oscilloscope tube to read in percent intermodulation distortion.

If more than one notch appears in an image, the total notch depth is the arithmetical sum of the individual notches on both the upper and lower edges of the image. If the image displays a peak rather than a notch, it is an indication of oscillation in the amplifier and is generally found to occur between 5 and 40 Hz. Typical images that may be expected are shown in Fig. 20. For a single-ended two-stage amplifier, two sets of four notches will be displayed for one cycle; four notches are normal for a push-pull stage. When notches appear on both edges, it is an indication that the distortion is occurring on both peaks of the signal.

For certain types of intermodulation testing it may be desirable to use a signal ratio other than the 4:1 conventional method of measurement. If the distortion appears in the lower frequencies, it may be determined by the use of 40, 60, or 100 Hz in combination with 5,000 Hz mixed in a 4:1 ratio. As little distortion will occur at 5,000 Hz, this frequency may be used as an indicator of low-frequency distortion. High-frequency distortion may be measured by 100 Hz in combination with 7,000 or 12000Hz set to a ratio of 1:1. ▲

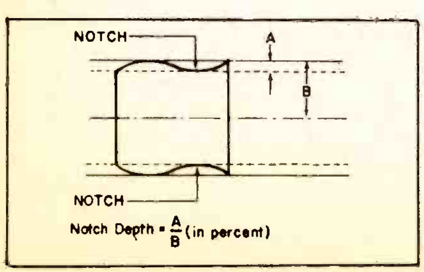

Fig. 19. Determining notch depth.

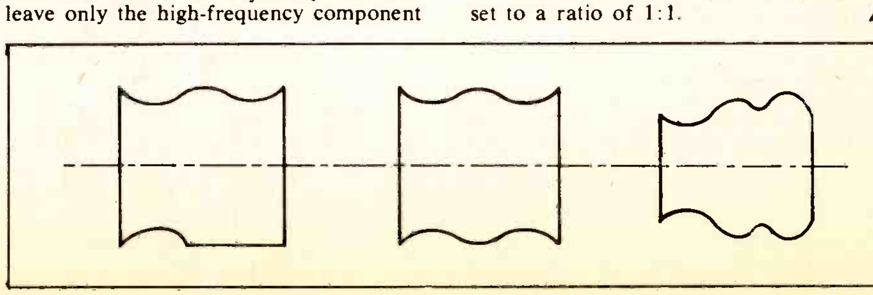

Fig. 20. Typical notch images.

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PF Reporter™

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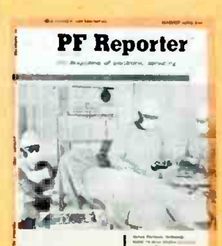
the magazine of electronic servicing

VOLUME 16, No. 8 AUGUST, 1966

CONTENTS

About the Cover

Modern medicine relies heavily on electronics. In doctor's offices, clinics, hospitals, and laboratories, electronic equipment is playing a major role in research, diagnostic, and operative and post-operative monitoring functions. Our cover photo, which shows the operating room of a large hospital, illustrates the application of electronics to medicine. An article beginning on page 18 of this issue describes a variety of medical electronic instruments and their uses in terms familiar to the technician.



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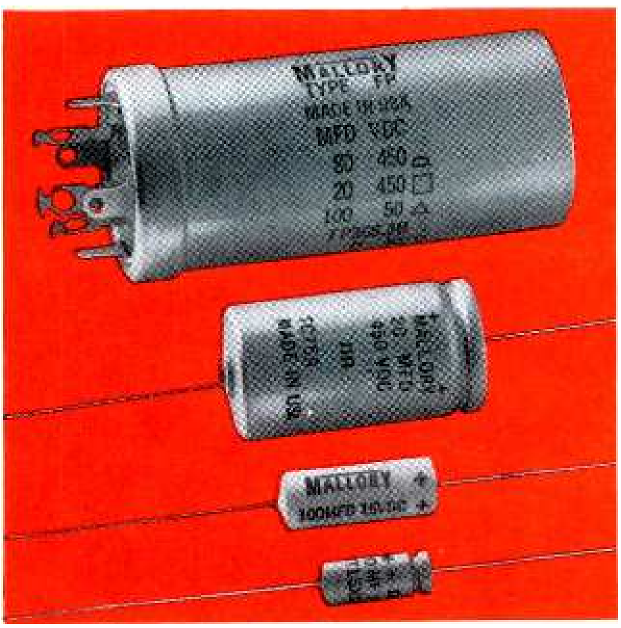

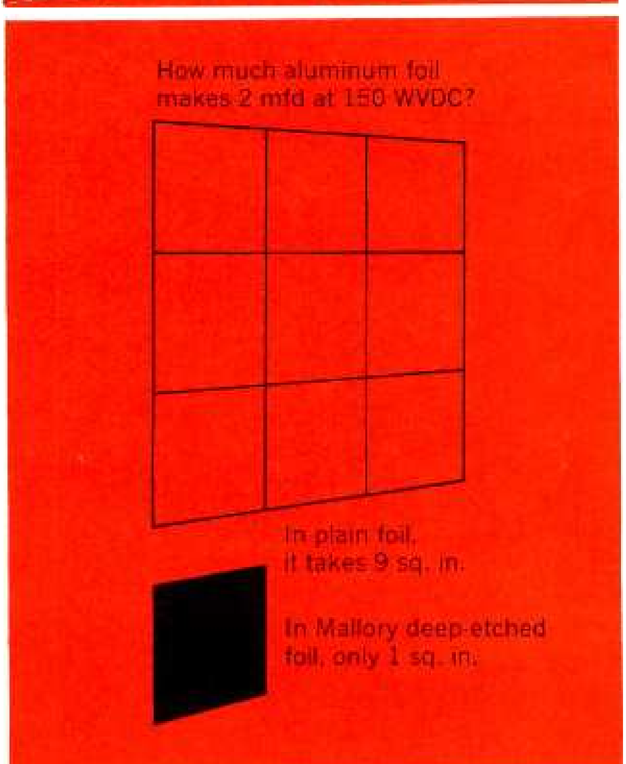

Finding the right electrolytic capacitor for a replacement job often becomes a matter of juggling three factors: what the circuit originally called for, what you can get quickly from a distributor, and what you have on hand in your shop. Here are a few hints that may help to make your life easier.

The important parameters about an electrolytic are voltage rating, capacitance, temperature rating and size. You have a certain amount of leeway on all four of these . . . and knowing how far you can stretch safely may save you a lot of shoe leather looking for the exact replacement.

Let's take voltage first. You can *always* substitute a capacitor with *higher* voltage rating than that originally required, with absolutely no harmful effects (except maybe on your pocketbook, because you may pay for extra capability that you don't need). But you should *never* replace with a voltage rating *lower* than the original.

How about capacitance? Our advice—don't go too far from −10% +50% of the original value. You've probably heard that standard industry specs allow tolerances of 10% low and up to 150% high. Actual manufacturing practice at Mallory, is to make capacitors to considerably tighter tolerances . . . because most radio and TV manufacturers won't tolerate the wider variations. Too small capacitance is apt to raise hum levels. Too high capacitance may lead to surge damage to silicon rectifiers.

On the temperature score, you don't have to worry if you use a Mallory FP-WP, TC, TT, or MTA type, because they're all rated for 85°C (except for three odd-ball TC's), and that's plenty for home instruments or industrial electronics. Our wax-filled cardboard tubulars are rated 65°C. The few cents extra that you might spend for a Mallory capacitor, compared to the cheapest ones you could buy, will assure you of *several* times longer service life.

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One final tip. Our new Capacitor Replacement Guide makes it a cinch to find the exact part number to specify, to replace just about any electrolytic you may encounter. Ask your Mallory Distributor for a copy, or write Mallory Distributor Products Company, a division of P. R. Mallory & Co. Inc., P. O. Box 1558, Indianapolis, Indiana 46206.

50th ANNIVERSARY

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The Electronic Scanner

news of the servicing industry

Mergers

It was announced by President W. R. Triplett that **Triplett Electrical Instrument Company** has purchased the assets of **Electronic Medical Specialties, Inc.,** producer of medical electronic equipment for hospitals, laboratories and research. The purchase price was not disclosed.

Marvin Buffington, former president of EMS, will be general manager of the new Triplett division to be known as EMS-Buffington Division. The division will remain at the original facility location, 5939 Mayfield Road, Cleveland, Ohio.

Gulf & Western Industries, Inc. has agreed to acquire all the net assets of **Muntz Stereo-Pak, Inc.**

The acquisition, announced by David N. Judelson, executive vice president of Gulf & Western and Earl W. Muntz, founder and president of Muntz Stereo-Pak, is subject to compliance with the regulations of the California Corporations Act and approval of the boards of both companies.

It is contemplated that all of the operations and assets of Muntz Stereo will be placed into a wholly-owned subsidiary of Gulf & Western and that present management of Muntz Stereo will continue to direct the operations of the new subsidiary subject to Gulf & Western.

Muntz is currently producing about 10,000 stereo tape cartridges daily. The company was formed in 1963 and presently has 1,500 accounts throughout the United States. Its sales for fiscal 1966 are estimated at $20 million. Gulf & Western is a mining, chemical, manufacturing, automotive parts distribution, and aerospace company. The New York-Houston based company reported sales for the six months ending January 31, 1966 of $149,888,000.

International Telephone and Telegraph Corporation stockholders overwhelmingly approved the merger of ITT and **American Broadcasting Companies, Inc.**

At a special stockholders' meeting held recently in Baltimore, ITT stockholders voted in favor of the merger plan which previously had received approval by the boards of directors of both companies.

Before the merger becomes final, approval must be obtained from the Federal Communications Commission and other appropriate government agencies. A favorable tax ruling with respect to the merger was obtained from the Internal Revenue Service on April 18.

NATESA Awards

The **NATESA** Spring Directors Conference was the scene of presentation of plaques symbolic of the 1965 Friends of Service Management Awards which were voted to a number of companies at the NATESA Convention last August. This award is for activities to improve public relations and acceptance of the contributions of independent service toward better service and performance of home electric devices.

The recipients were—The Finney Co., General Electric Tube Division, Philco Parts & Service Operations, RCA

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Remember; 45¢ buys you more than a quarter of a million man/hours of experience, plus true devotion to our business . . . our only business . . . overhauling your television tuners the best way we know how. And in over ten years we sure know how!

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Not the cheapest — just the best.

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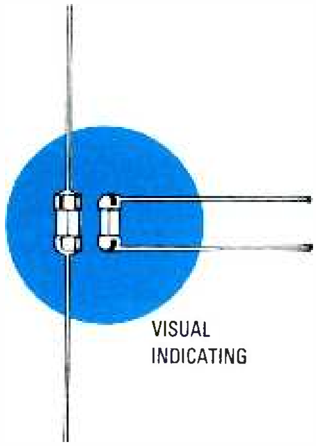

For use on miniaturized devices, or on gigantic space tight multi-circuit electronic devices.

Glass tube construction permits visual inspection of element.

Smallest fuses available with wide ampere range. Twenty-three ampere sizes from 1/100 thru 15 amps.

Hermetically sealed for potting without danger of sealing material affecting operation. Extremely high resistance to shock or vibration. Operate without exterior venting.

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BUSS: The Complete Line of Fuses and . . . . .

Electronic Components and Devices, RCA Sales Corp., Raytheon Tube Division, Sylvania Tube Division, and Zenith Radio Corp.

Previously, plaques were awarded to the Howard W. Sams & Co., Inc., and Tung-Sol Electric, Inc., in special presentations.

Money Matters

The highest quarterly sales in **Admiral Corporation** history, a sharp increase in earnings, and the declaration of the company's first cash dividend since December 1956 were recently announced.

Vincent Barreca, president, said that consolidated sales in the first quarter were $101,405,845, compared with $67,464,682 in 1965.

The substantial increase in sales was attributable to the company's three major divisions—appliances, consumer electronics, and government electronics—with the largest gain a 151-percent increase in factory sales of color television receivers.

Collins Radio Company reported earnings of $5,357,-000, or $2.37 per share on the average number of shares outstanding, for the nine months ended April 29, 1966. Sales were $272,062,000.

Comparative nine-month results for the previous year were earnings of $2,913,000, or $1.31 per share, on sales of $197,080,000.

Backlog at April 29, 1966, was $337 million, compared to $261 million a year ago and $430 million at January 28, 1966.

General Instrument Corporation broke all records for sales, profits, and backlog in the fiscal year ended February 28, 1966.

Sales for the year ended February 28, 1966, of $111,-760,265—topping the $100 million mark for the first time—were up 16 percent over the previous year. Record backlog at fiscal year-end was $63 million (vs. $37 million a year earlier), with the larger portion for commercial business, due particularly to "heavy demand for color-television and computer components."

The Jerrold Corporation's sales and profits continued at record levels during the fourth quarter of the fiscal year ended February 28, 1966.

Jerrold operations continued to move at a record pace in the first two months of the new fiscal year. Sales for March and April were nearly $8 million, up over 30 percent from the comparable months a year ago, and the firm's backlog remains in excess of $14 million.

Results of CATV systems in which Jerrold has an ownership interest are not consolidated in the Company's operating statement.

Consolidated net income of **Oak Electro/Netics Corp.** in the first quarter increased 53 percent on a 12-percent sales gain over the similar 1965 quarter.

Sales amounted to $14,623,822, compared with $13,-048,970 in 1965.

Increased sales in the quarter resulted from strong demand for the company's major component products, particularly rotary and push-button switches, television tuners, indicator lights, and quartz crystals and filters.

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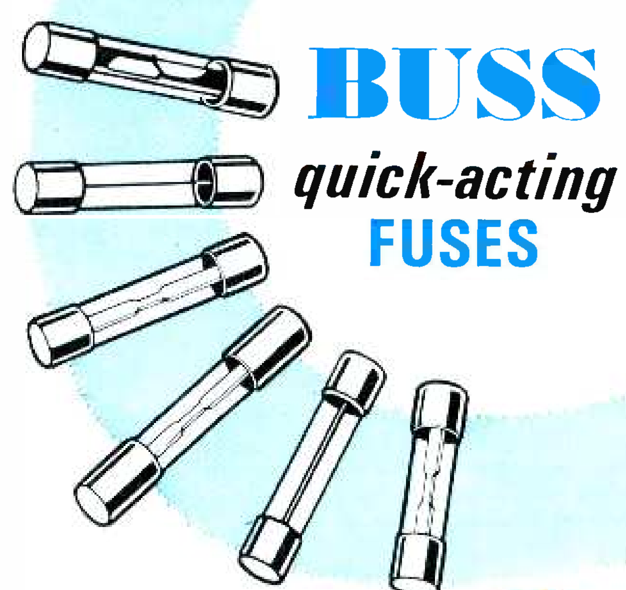

"Quick-Acting" fuses for protection of sensitive instruments or delicate apparatus;—or normal acting fuses for protection where circuit is not subject to current transients or surges.

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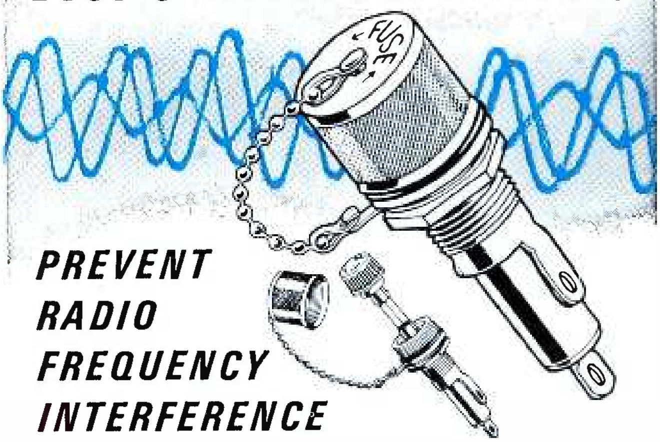

For use where fuse and fuseholder could pick up radio frequency radiation which interferes with circuit containing fuseholder —or other nearby circuits.

Fuseholder accomplishes both shielding and grounding.

Available to take two sizes of fuses—¼ x 1¼" and ¼ x 1" fuses.

Meet all requirements of both MIL-I-6181D and MIL-F-19207A.

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. . Fuseholders of Unquestioned High Quality

Record high earnings for the year to date, forecasts of new highs in sales and earnings for the year as a whole, and stockholder approval of the acquisition of D. C. Heath and Company, textbook publishers, highlighted the recent **Raytheon Company** annual meeting.

Thomas L. Phillips, president, told stockholders "this year we expect Raytheon's sales volume to exceed $600 million, more than $100 million higher than last year and the highest in any year to date."

"Looking ahead," Phillips told stockholders "we are well on our way to achieving the goals announced a year ago." At the 1965 annual meeting, plans were described to double sales and more than triple total earnings by 1970.

Reeves Industries, Inc. had record net earnings of $106,-900 in the first quarter of 1966, or 3 cents per share, compared to an adjusted net loss of $153,100 for the same period last year, H. W. Clapper, company president told the shareholders' annual meeting. First quarter sales were $2,624,000 compared to $1,943,000 in the comparable period in 1965.

Reeves Industries is a large supplier through its Soundcraft Division of magnetic tape for the broadcasting industry, the growing home-recording market, and the data-processing field.

The Entertainment Products Division of **Sylvania Electric Products, Inc.** reported that accelerating demand for 1966 product lines boosted division sales in the first four months of this year by more than 100 percent over the comparable 1965 period.

John T. Morgan, president of Sylvania Entertainment Products Corp., marketing subsidiary of the Division, said sales were aided by growing demand for color television. Sales of color-TV sets in the four-month period were more than double the sales during the first third of 1965.

Mr. Morgan noted that consumers have become increasingly alert to console performance specifications of high fidelity stereo and high quality furniture. Consequently, he said, demand for quality equipment has been strong.

Apprentice Training

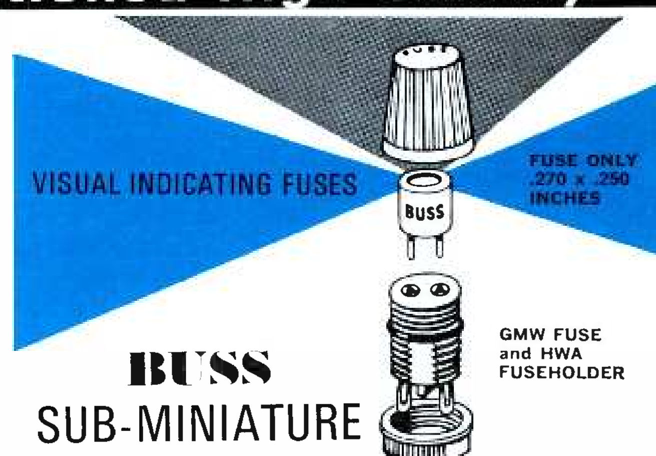
Co-operating with the Labor Department's Bureau of Apprenticeship and Training, the **National Electronic Associations, Inc.,** is solidifying a program for the training of radio-television repairmen. Fulfilling a dual need, the program is designed to ease both unemployment and the critical shortage of technicians. Training in the four-year apprentice program involves both classroom work and on-the-job training.

Expansions

The Bendix Corporation is planning to expand its avionics production with the construction of a new facility at the Fort Lauderdale Executive Airport, Fla. E. K. Foster, Bendix vice-president and group executive, stated:

"The new facility is necessary because of the continuing growth of the commercial and general aviation market and Bendix' increasing share of this market.

The avionics products of the Radio division include radio communications, navigation equipment and systems, automatic direction finders, and weather and Doppler radar systems.



For space-tight applications. Fuse has window for inspection of element. Fuse may be used with or without holder.

Fuse held tight in holder by beryllium copper contacts assuring low resistance.

Holder can be used with or without knob. Knob makes holder water-proof from front of panel.

Military type fuse FM01 meets all requirements of MIL-F-23419. Military type holder FHN42W meets all military requirements of MIL-F-19207A.

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EDITOR'S NOTE:

Within the last several years, a new branch of electronics has rapidly developed: *Medical Electronics*. Many of the innovations in this area are by-products of aerospace research; others have resulted from application of electronic data-processing techniques to medical statistics. As the frontiers of the state-of-the-art recede, the medical-electronics field constantly expands, utilizing new devices and new techniques. For example, lasers are now being used almost routinely in many surgical operations. And the electroencephalograph (shown at the right) is a device used for measuring the brain's activity. With these innovations and their effect upon the electronics industry in mind, PF REPORTER presents this medical-electronics feature.

Medical Electronics Terminology

Some of the terms you might encounter.

by Ed Bukstein

The technician who sets out to explore the field of medical electronics can expect to encounter much familiar terminology. Such awe-inspiring names as *ballistocardiography*, *electromyography* and *cardiac defibrillator* may frighten the technician who does not realize that the instruments bearing these impressive names contain familiar circuits. The *electroencephalograph*, for example, consists of a low-frequency amplifier and a pen-type recorder; a *cardiac pacemaker* is a blocking oscillator; and a *phonocardiograph* is a microphone-amplifier-oscilloscope combination for displaying heart sounds. These instruments, and others, are described below in the familiar terminology of the electronics technician.

Ballistocardiograph (bah lis tō kar' dē o graf): Each time the heart muscle contracts, it squeezes blood through the circulatory system of the body. Like the ballistic recoil of a rifle when the bullet is ejected, the ejection of blood from the heart produces a movement of the body along the head-foot axis. A person standing on a sensitive scale can sometimes observe this effect by noting the slight deflection of the scale pointer during each heartbeat. The ballistocardiograph (BCG) is an instrument that records these body movements.

Recordings of the ballistocardiograph are accomplished with the patient reclining on a specially constructed table. The table top is mounted on springs or rollers so that it is free to move along the head-foot axis. Ballistic motion of the patient's body is therefore imparted to the table top, and a sensing device such as a phototube, strain gauge, magnetic pickup coil, or movable-core inductor responds to this motion. Output of the sensing element is amplified and fed to an oscilloscope or a pen-type recorder. The resulting waveform, known as a ballistocardiogram, can be evaluated by trained personnel to reveal information about the heart and circulatory system.

Cardiotachometer (kar" de o tah kom' e ter): The cardiotachometer (Fig. 1) is a form of frequency meter used to indicate the heartbeat rate. The sensing element may be a microphone responding to heart sounds, a pressure transducer responding to the pulse, or metal electrodes picking up the voltage produced by the heart. In any case, the output of the sensing element is amplified and applied to a pulse-shaping circuit. These standardized

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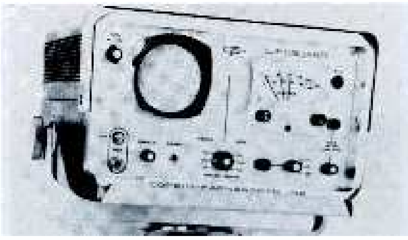

Fig. 1. Cardiotachometer.

pulses, one for each heartbeat, are then applied to a metering circuit to indicate the rate of heartbeat.

Defibrillator (de fib″ ri la′ tor): Fibrillation is a condition in which the muscle fibers of the heart contract in a random, un-coordinated sequence. The heart therefore loses its effectiveness as a pump, and the condition is fatal within a few minutes if normal heartbeat is not restored. By shocking the heart electrically, the defibrillator causes simultaneous contraction of all muscle fibers. This produces a condition of cardiac standstill from which the heart often recovers spontaneously, resuming a normal beat.

The output of the defibrillator is often a 60-Hz sine wave obtained through a transformer from the power lines. Voltage is adjustable in the range of 50 to 200 volts. Contact with the patient is established by means of two metal electrodes placed on the chest, and the duration of the shock, .1 to .3 second, is controlled by a time-delay circuit.

High-voltage DC may also be used. Capacitance-discharge defibrillators (see Fig. 2 for an example) supply a 2000 to 2500-volt pulse for time durations of less than 20 msec. In addition, defibrillators have been synchronized with electrocardiographs for treatment of fibrillation—the device is then similar to the pacemaker.

Diathermy (di′ ah ther″ mē): Diathermy employs RF energy to produce heat in the deep tissues of the body. Eqiupment consists of a high-power RF oscillator whose output is applied to a pair of metal electrodes (insulated to prevent electric shock to the patient). These electrodes, known as applicators, are positioned on the patient's body so that the tissues to be heated are between the applicators; the patient thus becomes the dielectric of a capacitor. Proper choice of size and position of the applicators permits heating of a selected region of the body. Typical frequencies of operation are in the 13-, 27-, and 40-MHz bands, but some units operate in the microwave region around 900 or 2300 MHz.

Fig. 2. DC defibrillator.

Electrocardiograph (e lek″ tro kar′ de o graf): The electrocardiograph (EKG), see Fig. 3) records the voltage produced by the heart as it alternately contracts and relaxes. This voltage is picked up by means of metal electrodes strapped to the arms, legs, and chest of the patient. At the electrodes, the voltage is approximately 1 millivolt peak and must be amplified to a level sufficient to drive a recording pen which writes on a paper chart. The amplifier must have excellent low-frequency response because the input pulses from the electrodes have a basic frequency of approximately 1 Hz (the heartbeat rate). For this reason, EKG amplifiers generally employ either direct or capacitive coupling with relatively large values of capacitance—2 to 10 mfd.

Although the low-frequency response of the EKG amplifier must extend below 1 Hz, high-frequency response is not critical. Few electrocardiographs (including the pen mechanism) will respond above 100 Hz, and response may be deliberately limited to less than 60 Hz to attenuate stray pickup from the power lines.

The recording mechanism is essentially a D'Arsonval movement fitted with a light-weight pen instead of the usual pointer. The pen writes on a long paper chart pulled through the machine by a constant-speed motor.

Electroencephalograph (e lek″ tro en sef′ ah lo graf): The electroencephalograph (EEG) records the electrical activity of the brain.

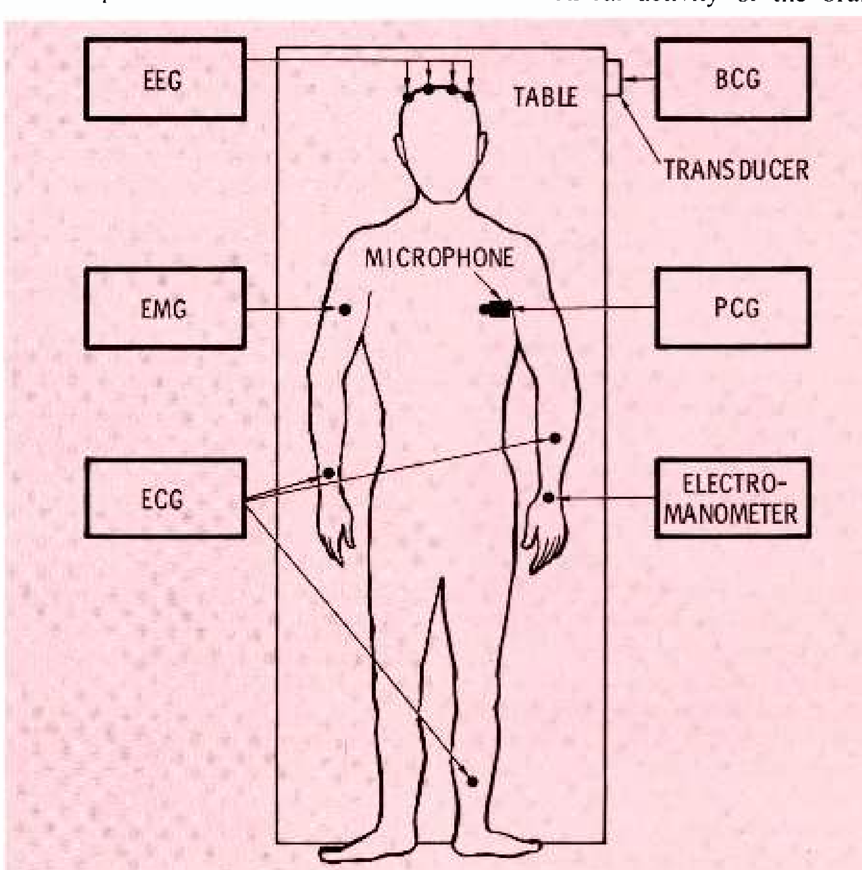

Fig. B. Typical examples of medical instrumentation: EEG records brain voltage, EMG records muscle voltage, ECG records heart voltage, BCG records movement of body when blood is ejected from heart, PCG records waveform of heart sounds, and electromanometer records blood-pressure waveform.

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Fig. C. Oscilloscope designed for medical applications.

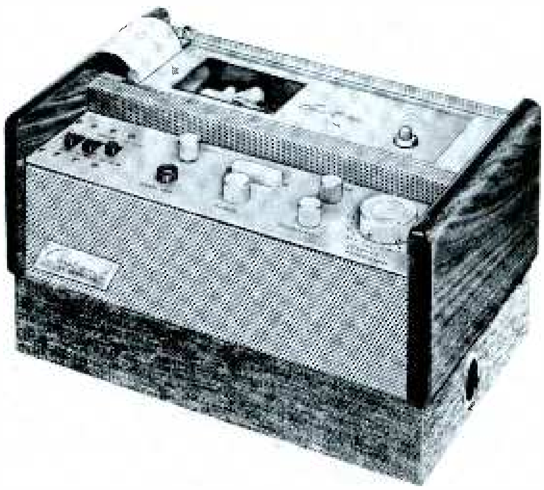

Fig. 3. EKG records electrical activity of the heart.

Like the electrocardiograph, this instrument consists of a high-gain amplifier and a pen-type recorder. The brain-generated voltage is picked up by small metal electrodes on the surface of the scalp. The waveform is roughly sinusoidal and the amplitude at the electrodes is in the μ volt region. The dominant frequency component, known as the *alpha* rhythm, is approximately 8 to 12 Hz.

Research and clinical electroencephalographs are multichannel instruments to permit simultaneous recording from different areas of the scalp. Typically, the instrument consists of eight identical amplifiers feeding eight recording pens. All pens write on the same (wide) chart so that the waveforms are recorded in correct time relationship.

Electromanometer (e lek″ tro man om′ e ter): The electromanometer is a pressure-recording device. A typical instrument employs a transducer such as a strain gauge for sensing variations of pressure. The transducer is mounted in a hypodermic syringe which is inserted into the blood vessel whose pressure is to be monitored. The strain gauge varies in resistance according to pressure changes and is connected in a bridge circuit. The degree of unbalance of the bridge then varies according to pressure changes. Output of the bridge is amplified, and the resulting waveform is either displayed on an oscilloscope or applied to a pen-type recorder. Some electromanometers employ surface-type transducers such as condenser microphones for measuring pulse pressure.

Electromyograph (e lek″ tro mi′ o graf): The electromyograph (EMG) records the electrical activity of muscle. A needle-shaped electrode is inserted into the muscle to be studied and picks up the voltage pulses produced when the muscle fibers contract; these pulses are amplified and displayed on an oscilloscope. (Pen-type recorders do not have the frequency response generally required for electromyography. Most electromyographs include an audio amplifier and loudspeaker to make the muscle pulses audible. To the trained diagnostician, these sounds are as meaningful as waveforms on the oscilloscope.

Oximeter (ok sim′ e ter): The oximeter is a device for measuring the oxygenation of the blood. The blood sample is placed between a light source and a photocell, and the light transmitted through the sample is a measure of the oxygen content. Output of the photocell is amplified and displayed on a meter. Some oximeters employ an ear-clip so that measurement can be performed without drawing a sample of blood. The ear-clip contains a miniature light bulb and photocell to measure light transmission through the ear lobe.

Pacemaker (pās mak er): The pacemaker is a pulse generator used for restarting the heart after a condition of standstill (cardiac arrest) has occurred. By means of electrodes placed on the chest, or directly on the heart during surgery, pulses of current are passed through the heart at regular intervals. Each pulse causes the heart muscle to contract, restoring normal heartbeat. The pulses are 1 to 2 milliseconds in duration and are variable in repetition rate from approximately 20 to 200 pulses per minute. A few heart patients require continual electrical stimulation, and miniaturized pacemakers are implanted surgically in their bodies.

Phonocardiograph (fo″ no kar′ de o graf): The phonocardiograph (PCG) records the waveforms corresponding to the sounds produced by the heart. The sounds are picked up by a microphone held against the chest, and the signal is fed to a high-gain, low-noise amplifier. Amplifier output is either displayed on an oscilloscope or is applied to a pen-type recorder. A headset or loudspeaker is also included for aural monitoring of heart sounds.

The waveforms recorded by the phonocardiograph convey diagnostically useful data not attainable by use of the ordinary stethoscope. The acoustical stethoscope (and the doctor's ears) does not respond to many important heart sounds, which are low in both frequency and intensity.

Crystal and condenser microphones are often employed in phonocardiography. In a variation of the basic technique, a subminiature microphone can be pushed through a blood vessel until it is inside the heart. This permits monitoring of sounds within the chambers of the heart, and these sounds can be interpreted in terms of blood flow, valve action, leakage, or other desired information. ▲

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Maintaining Vibration Test Equipment

High-power audio equipment in the laboratory.

by Wayne Tustin

Ambitious electronic technicians can render a valuable service to nearby aerospace firms which use vibration test equipment, and can be well paid for occasional trouble-shooting and assistance. This article will briefly describe vibration test systems and tell how they are used. Finally, it suggests ways to go after this lucrative business.

A few old "shakers" are driven mechanically, somewhat like oscillating paint mixers. We will discuss more modern electromagnetic systems which are used quite commonly by aerospace firms, military and government research labs, etc.

Electromagnetic Shaker Systems

A system for vibration testing usually consists of three major elements:

(1) An electromagnetic shaker, or vibration exciter, such as shown in Fig. 1. This is really an overgrown loudspeaker. As shown in Fig. 2, DC flows in a field winding which is connected to a table. The table (and the item to be tested) vibrate at the frequency of the AC; the most common frequency range is 5 to 2,000 Hz. Maximum stroke is usually 1 inch.

(2) A power amplifier which can deliver enough AC voltage and current to drive the shaker. Amplifiers range from 1 to 150 kilowatts or greater, though most encountered are relatively small—1 to 10 kw. For maximum fidelity, combined with reasonable cost and efficiency, these amplifiers are usually Class AB_1 or AB_2. Most of them use forced-air or water-cooled vacuum tubes, but a few of the latest use large water-cooled transistors.

(3) Signal sources and system con-

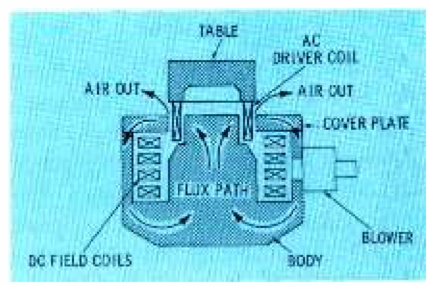

Fig. 2. Cutaway view of a shaker.


Fig. 1. Shaker attached through floor of temperature chamber.

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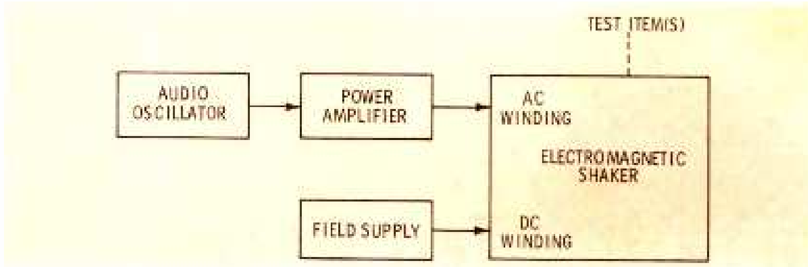

Fig. 3. A typical shaker system.

trols. These may be located on the power amplifier or in a separate console. The type of signal source used depends upon the type of vibration testing required. Most vibration testing calls for sinusoidal motion of the shaker and test item. However, a growing number of vibration test specifications call for "random" vibration.

Fig. 3 is a block diagram of a basic shaker system.

System Uses

Do not be surprised if you have not heard much about vibration testing previously. It is a new field of testing, one which is of tremendous importance in America's defense efforts and in the "Space Race." As recently as 10 years ago, very little vibration testing was being performed.

Most vibration testing is done to increase the reliability of aircraft, missiles, and rockets, It really began during World War II, when military aircraft missions often were aborted because the vibration from the engines affected delicate electronic and electromechanical systems and interfered with their operation. Often the culprit was a "noisy" vacuum tube or a "chattering" relay. Such faults had not previously caused trouble because prewar engines were less powerful and airborne systems were much simpler (or did not exist at all).

Most vibration testing is a form of environmental testing. Such tests are performed to find out if a particular component or assembly will operate satisfactorily while being subjected to vibration. Will a tube produce noise? Will a relay chatter? Will a circuit function correctly? Attach the test item to a shaker and find out!

Test Specs

Test specifications dictate the type of motion, frequency range, severity of vibration, and length of time the test will continue. An early test specification called for sweeping the frequency range from 10 to 500 Hz and back to 10 in 15 minutes. This sweep was to be repeated 8 times, with the test item oriented in each of three directions. Up to 74 Hz, the "crossover" frequency, the stroke was to be held at 0.036″ (peak-to-peak). Above 74 Hz, the acceleration was to be controlled at ±10 "g" or "gravitational constants." Such a test specification is shown graphically in Fig. 4. Newer specifications may call for sweeping up to 2,000 Hz or even higher, for strokes up to 1″, and for accelerations up to ±100g. The motion is to be sinusoidal; the output of a motion pickup, called an accelerometer, should resemble Fig. 5 when it is viewed on an oscilloscope. The signal which drives the power amplifier, which in turn drives the shaker, originates in an audio oscillator.

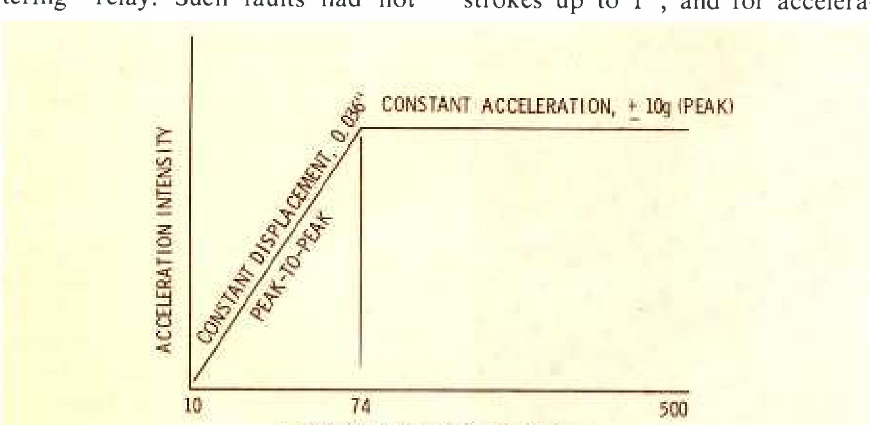

Fig. 4. Early test specification.

The vibrations just described are an attempt to simulate the kind of vibration that occurs in ships, autos, and piston-engined, propeller-driven airplanes. It usually is caused by "dynamic unbalance"—the rotation of parts which are not perfectly balanced. (A simple example is the vibration you feel in your car when a wheel is unbalanced.)

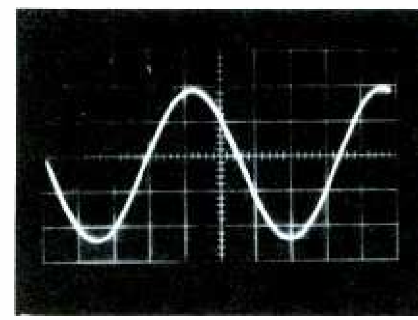
Fig. 5. Motion generator output.

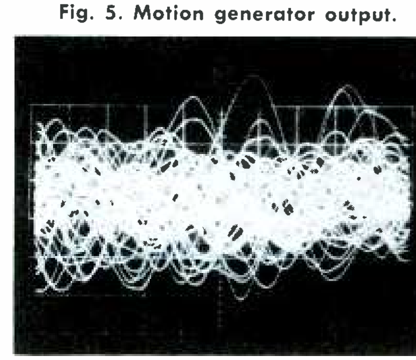
Fig. 6. Noise generator output.

More and more test specifications now call for "random" motion, which is much harder to describe than the sinusoidal vibration just discussed. Random vibration usually contains a spectrum of frequencies; that is, all frequencies in a continuous band (such as 20 to 2,000 Hz) are present at once. Signals for such tests originate in a noise generator, and the motion will definitely not be sinusoidal. The output of a motion generator attached to the shaker may look like Fig. 6 when viewed on an oscilloscope.

Controlling the Test

As we mentioned earlier, the

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controls may be located on the power amplifier. In larger, more elaborate systems, operating controls will be found on a separate console. The console may be located in a soundproof room, as big shakers create much noise when they vibrate. The power amplifier may even be located outside the test lab. This is especially true if it is a large, air-cooled unit; these units make a lot of blower noise and may dump much hot air from their exhausts.

For sinusoidal vibration tests, as suggested by Fig. 5, the two essential operating controls are these:

1. the frequency of the oscillator;

2. the setting of a gain control, which may be marked "Force Control."

For random vibration tests, the operating controls are much more complex. Elements known as equalizers, clippers, analyzers, and with other strange-sounding names will be encountered. At first these may be difficult to understand (both what they do and how they work), but eventually you will be able to service them as well as the simpler parts of the system.

The great majority of vibration testing laboratories are equipped to do only sinusoidal vibration testing. Only a very few labs are equipped for random testing.

Getting Started

There is a great deal more you need to know, both to understand the functions of the system and of its parts, and to know how to troubleshoot a shaker system. Remember, though, that they closely resemble a hi-fi system. Shaker motion should merely duplicate the input electrical signal.

A great deal of information may be found in the instruction manuals that are originally provided with every system. You should borrow these and study them. Unfortunately, they usually have two shortcomings:

1. They are badly compartmented. That is, one section will deal with the shaker, another will describe the power amplifier, etc. Manuals seldom give the reader an overall look at how the entire system works. They assume that the reader already knows a great deal about vibration testing.
2. Manuals may contain a lot of "boilerplate" material; that is, they carry much more-or-less standardized printed material that applies to all of that manufacturer's systems. You will have to search to find the specific information that applies to the shaker, amplifier, etc., that you are trying to service.

Home-study courses are available, offering a great deal of generalized information both for the operator of shaker systems and for people who must maintain them. As you absorb the general information in those courses, the specific information found in the shaker system manuals will become clear and understandable.

Soliciting Business

Most users of vibration test equipment will welcome your offer to maintain their shaker systems in good running order. Usually you should talk to someone whose title might be Head, Vibration Test Laboratory; or Head, Environmental Test Laboratory; or Manager, Test Department.

Explain that you are soliciting the business of keeping their shaker equipment in "like new" condition. Emphasize that you know how important it is to the test lab that the shaker system not break down on the day of an important test. Such breakdowns often have dire consequences, since vibration tests are usually the final step before shipment of a firm's product. Tell them you understand the basic operation of their systems but that you will need to study their manuals. Point out that you believe in preventive maintenance to find and correct minor imperfections before they become major catastrophes. Explain also that you are available, in case of emergency, at night or on weekends (at higher rates).

The managers of these laboratories are often mechanical engineers. Their knowledge of electronics may be somewhat limited. Don't try to "snow" them, of course; quietly affirm that you are competent to do the job. In many cases, you will be welcomed.

Of course, the initial answer may be, "No." The firm may already have a good electronics technician who operates and maintains the vibration test system. Leave your card, anyway; that man may leave or be reassigned to another job. His successor may not be as competent, and you could be asked to take over maintenance.

You will note that most of the suppliers in Table I are either on the East or West Coast, close to most aerospace centers. But many government and military laboratories, and many of the firms that manufacture aerospace products, are located some distance away. If one of these users of vibration equipment (located in Missouri, for example) needs a serviceman, that man must fly a long distance, at considerable expense and with serious delays, to vital test programs.

There will be times, of course,

• *Please turn to page 61*

Table I

Major Sources of Vibration Test Equipment and Auxiliary Equipment

Electromagnetic Shaker Systems	
AGAC-Derritron Corp.	Alexandria, Virginia
Ling Electronics	Anaheim, California
MB Electronics	New Haven, Connecticut
Unholtz-Dickie Corp	Hamden, Connecticut
Vibration Measuring Systems	
Endevco Corp.	Pasadena, California
Gulton Corp.	Metuchen, New York
Kistler Instruments Corp.	Clarence, New York
Vibration Analysis Systems	
Honneywell	Denver, Colorado
Spectral Dynamics Corp.	San Diego, California
Technical Products Corp.	Hollywood, California

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Milestones of TV

A short history of early television.

by T. T. Jones

Many discoveries and inventions were accidental. For instance, lightning struck a tree and man discovered fire. However, television wasn't discovered that easily. It was the result of many years of work by many people. Most of these people were caught up with the idea of long-distance communication. Morses's telegraph was the first breakthrough; others soon followed.

Within months of the invention of the telegraph, Alexander Bain invented a system for sending images over wire. The device employed a wire brush to scan words made of metal type, and the receiver reproduced the words on chemically treated paper. Some of Bain's basic principles are still in use in the facsimile and wire-photo networks.

The first actual transmission of a picture by electricity came in 1862, when outline drawings were sent over wires by a device called the Pantelegraph. The system, invented by Abbe Caselli, was in use between Paris and Amiens from 1865 to 1869. A similar system was observed in use just ten years ago. This device, called the Telautograph, reproduced handwriting as it was written. It was used between floors of a large midwestern hospital.

In 1875, G. R. Carey conceived the TV system shown in Fig. 1. The basic idea was ingenious, but there were many practical problems. The system failed primarily because the selenium cells of the day did not develop sufficient current to light the bulbs. It was another 30 years before DeForest invented the vacuum tube which could amplify the current from the cells. Another problem was the tremendous number of circuits needed to carry the picture.

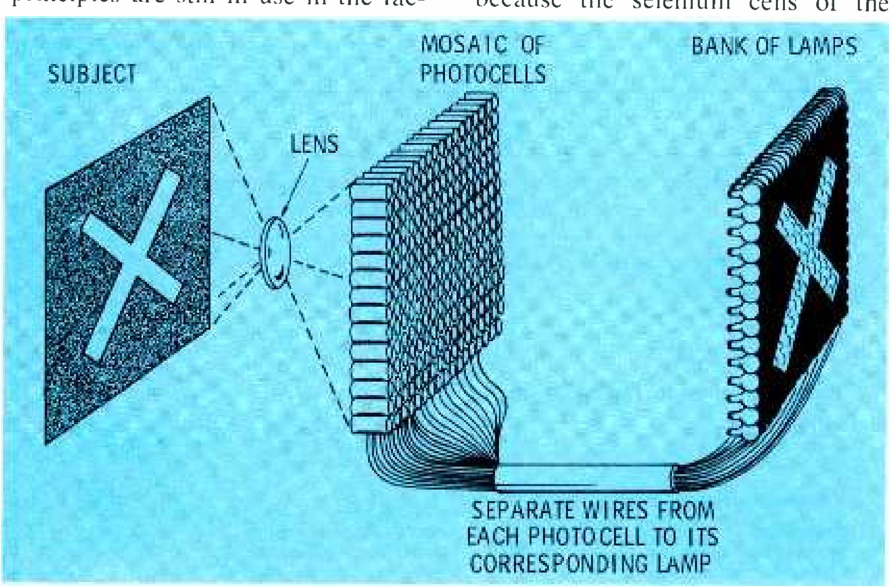

Fig. 1. 1875 photocell TV system.

The most significant advance in the early quest for TV came in 1884 when Paul Nipkow invented the scanning disc. The disc shown in Fig. 2 scans 24 lines per frame. Later developments increased the scan to 240 lines. The scan is effected by rotating the disc. As each hole reaches the end of the line the following hole starts across, slightly lower, to scan the next line. At the end of one revolution, hole number one is in position to start the next frame. The scanning disc solved one of Carey's problems, since only one circuit could carry the picture.

There was little TV activity during the next few years, since many of the best minds of the day turned their attention to radio. However, in 1907 Boris Rosing patented a TV system using the cathode-ray tube as a receiving device. At this time the CRT was a crude and fragile laboratory toy. Rosing worked at the St. Petersburg Technological Institute and had a young student named V. K. Zworykin. Zworykin's experiences in St. Petersburg were the foundation for his brilliant career in television.

The following year, Campbell-Swinton in Great Britain proposed

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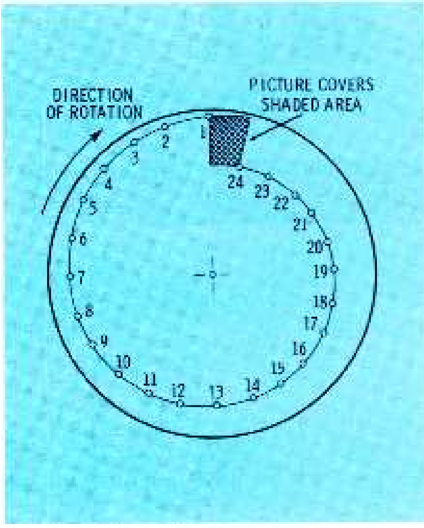

Fig. 2. Nipkow's 1884 scanning disc.

a system using a CRT as a camera device, but somehow nothing came of it.

By this time, all the ingredients of a TV system had been discovered. The problem was the consolidation of the existing ideas. However, World War I halted most of the TV experimentation, and it was not until 1923 that further significant work was done. In that year J. L. Baird, in London, and C. F. Jenkins, in New York, sent silhouettes over wire with a scanning-disc system similar to that in Fig. 3.

By 1925, Jenkins and Baird were using moving pictures in their experiments. During the same year, Mr. Jenkins broadcast movies over station NOF in Washington, thus establishing the enduring tradition of old movies on the late show.

In 1927, A.T. & T. tried a TV-telephone experiment between Washington and New York, using 50-line scan. The experiment was reasonably successful, but no attempt was made at the time to commercialize it. In the late 30's, however, a commercial phone-TV link was in operation between Berlin and Nuremburg, Germany, with toll charges twice the regular long-distance phone rate. More recently, a high quality phone-TV system was in use between the New York World's Fair and the Chicago Museum of Science and Industry.

England and America were linked by TV Feb. 8, 1928. Baird transmitted a picture of Mrs. Mia Howe in London to a receiver in Hartsdale, N. Y. The event received considerable publicity in the New York Times, which called it a "milestone of epochal importance." Some thirty-five years later Telstar duplicated the feat, with much improved picture quality.

The year 1928 produced many "firsts" in television. In August, Mr. Baird demonstrated a crude color TV system, and a 3D stereoscopic TV. In May, WGY in Schenectady became the first station to have a regular TV schedule, 3 afternoons a week. Movies were broadcast on a regular schedule in Washington, starting July 2, and WGY broadcast the first live drama show on Sept. 11. At the same time, Philo Farnsworth was quietly working on a receiver which used a CRT instead of a scanning disc.

TV sprang up in several nations the next year. BBC began broadcasting in England on an experimental basis, and Germany soon followed. These two nations had stations on the air more or less regularly until World War II began. At least fifteen other countries had some activity.

Germany and Russia were quick to realize the value of TV to their propaganda machines. Receivers were installed in many public places so that the state news agencies could be seen and heard.

Bell Labs held a public demonstration of a color-TV system in 1929; however, with so many problems still to be solved in black-and-white, color received little attention.

By 1931, however, the TV industry was booming. Fifteen stations in the U. S. had regular transmission schedules. All were using scanning discs, and most of them used 48-line pictures, 15 per second. W9XR in Chicago had only 24 lines, but W2XBS scanned 72 lines per frame. The transmission channels were about 100 kHz wide,

Fig. 4. TV receiver of 1932 vintage.

in the band from 2000 to 2900 kHz. A typical receiver of the period is shown in Fig. 4.

The English Derby was televised live in 1931. This was a major event, because the cameras of the day were very insensitive to light. Most programs were performed under carbon-arc lights. This same year, Allen Dumont began operation of his factory which was to bring the CRT out of the laboratory and into homes.

Two years later the boom collapsed. The 48-line scan did not give good quality pictures, and even when scanning discs were improved to 120 lines, the definition was poor. CBS suspended broadcasts after 2500 hours on the air.

Research went on, however, as RCA was experimenting with the iconoscope, and Farnsworth was perfecting the image-dissector tube. The answer to scanning problems was at hand.

The year 1935 ushered in a new series of experimental broadcasts.

• *Continued on page 62*

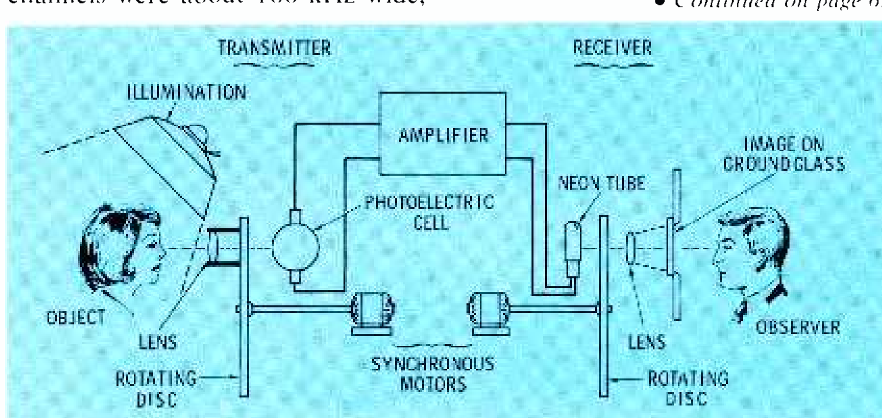

Fig. 3. 1923 scanning system sent silhouette images.

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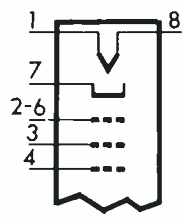
TUBE and TRANSISTOR DATA

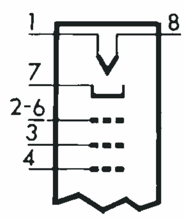
CATHODE-RAY TUBES

16CHP4
Protection—tension band
Deflection—114°
Filament—6.3V @ 0.45A (11 sec)
Grid 2—30V



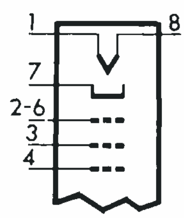
8HR

16CMP4
Protection—tension band
Deflection—114°
Filament—6.3V @ 0.45A (11 sec)
Grid 2—400V



8HR

17EMP4
Protection—tension band
Deflection—114°
Filament—6.3V @ 0.45A (11 sec)
Grid 2—50V



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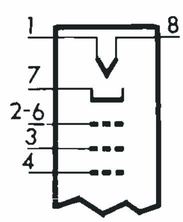
19ESP4
Protection—tension band
Deflection—114°
Filament—6.3V @ 0.6A (11 sec)
Grid 2—50V



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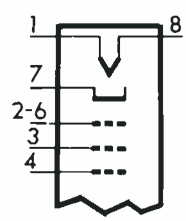
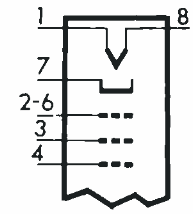
19FEP4
Protection—tension band
Deflection—114°
Filament—6.3V @ 0.45A (11 sec)
Grid 2—30V



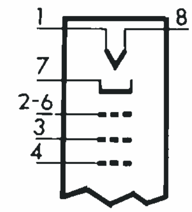
8HR

19FNP4
Protection—tension band
Deflection—114°
Filament—6.3V @ 0.6A (11 sec)
Grid 2—300V



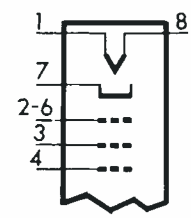
8HR

21FXP4
Protection—filled rim
Deflection—114°
Filament—6.3V @ 0.45A (11 sec)
Grid 2—400V



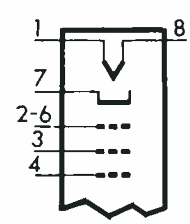
8HR

23GTP4
Protection—tension band
Deflection—110°
Filament—6.3V @ 0.6A (11 sec)
Grid 2—300V



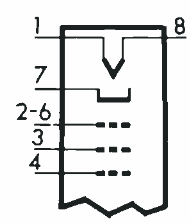
8HR

23HGP4
Protection—tension band
Deflection—110°
Filament—6.3V @ 0.45A (11 sec)
Grid 2—300V



8HR

23HKP4
Protection—filled rim
Deflection—110°
Filament—6.3V @ 0.6A (11 sec)
Grid 2—150V



8HR

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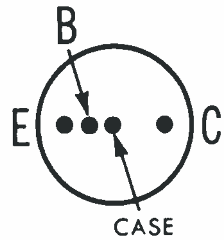
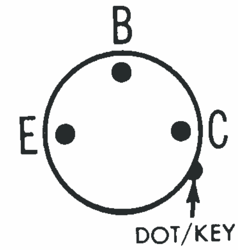
TRANSISTORS

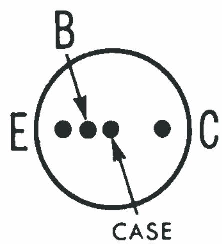
2N1180
FM-IF Amplifier
PNP—Germanium



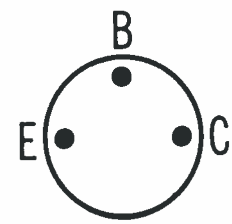
2SA103
IF Amplifier
PNP—Germanium



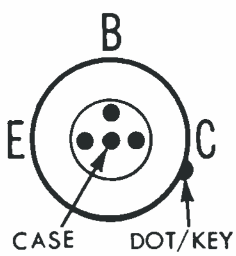
2N2009
FM Oscillator
PNP—Germanium



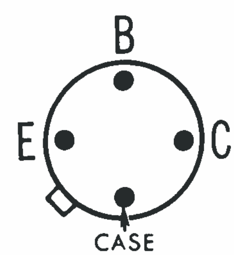
2SA103CA
IF Amplifier
PNP—Germanium



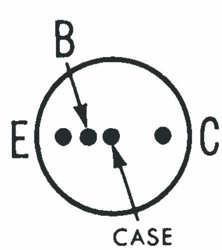
2SA60
Video Amplifier
PNP—Germanium



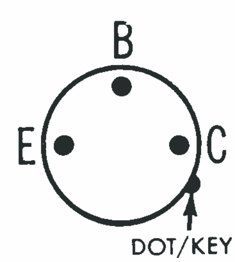
2SA127
Video Amplifier
PNP—Germanium



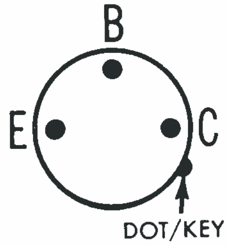
2SA70MA
IF Amplifier
PNP—Germanium



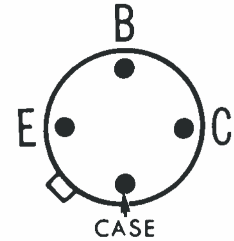
2SA141
AM IF Amplifier
PNP—Germanium



2SA71B
IF Amplifier
PNP—Germanium



2SA235C
Video IF Amplifier
PNP—Germanium



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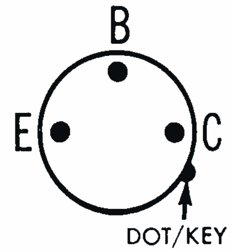
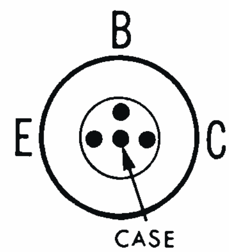
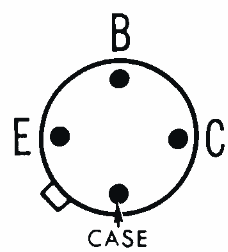
2SA385
Noise Inverter
PNP—Silicon



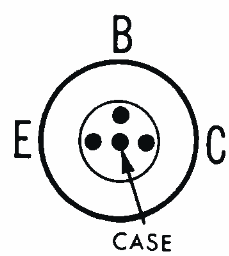
2SA437
Video IF Amplifier
PNP—Germanium



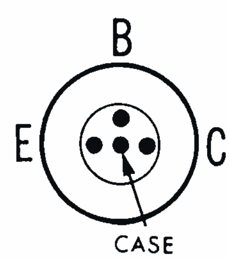
2SA448
UHF Oscillator
PNP—Silicon



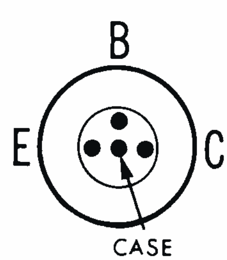
2SA454
IF Amplifier
PNP—Germanium



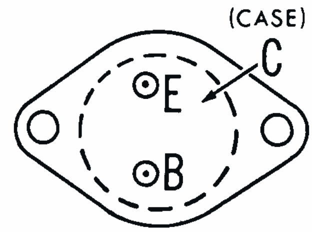
2SA455
IF Amplifier
PNP—Germanium



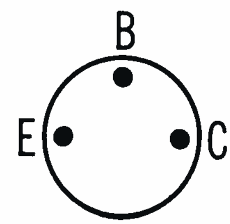
2SA456
IF Amplifier
PNP—Germanium



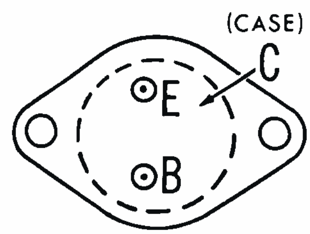
2SB62
Vertical Output
PNP—Germanium



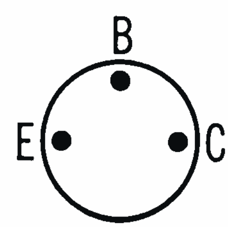
2SB94
Horizontal Oscillator
PNP—Germanium



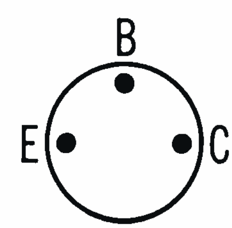
2SB128
Vertical Output
PNP—Germanium



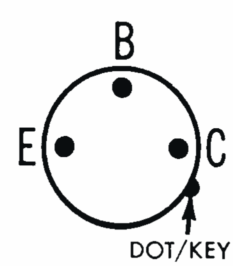
2SB169
AF Amplifier
PNP—Germanium



2SB172A
AF Amplifier
PNP—Germanium



2SB172F
Horizontal Oscillator
PNP—Germanium



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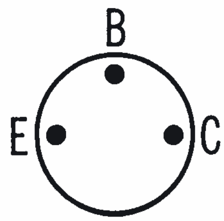
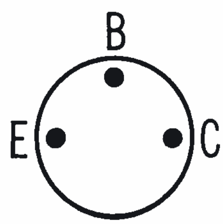
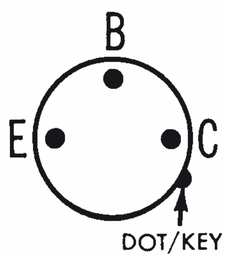
2SB173B
AF Amplifier
PNP—Germanium



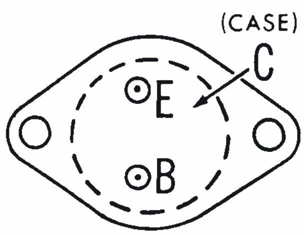
2SB175A
AF Amplifier
PNP—Germanium



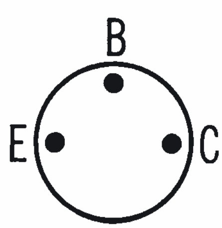
2SB178A
AF Amplifier
PNP—Germanium



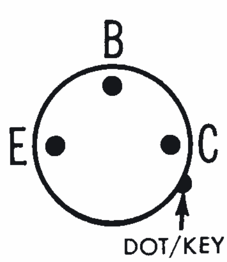
2SB232
Horizontal Driver
PNP—Germanium



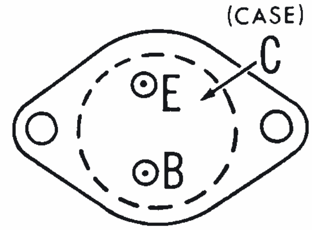
2SB263
AF Amplifier
PNP—Germanium



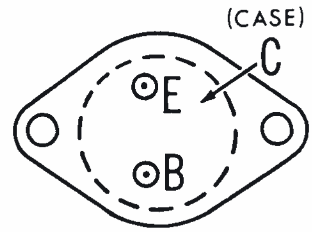
2SB324
Voltage Regulator
NPN—Germanium



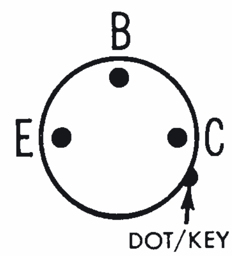
2SB432
Horizontal Output
PNP—Germanium



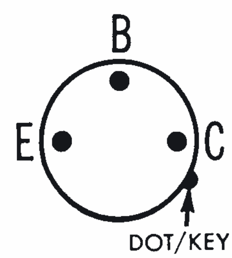
2SB448
Horizontal Driver
PNP—Germanium



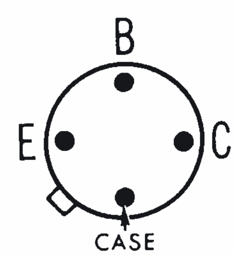
2SC58A
Video Amplifier
NPN—Silicon



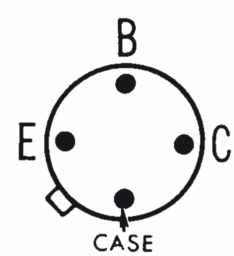
2SC281
AGC Keying
PNP—Germanium



2SC526
Video Amplifier
NPN—Silicon



2SC538
Vertical Driver
NPN—Silicon



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Testing FM-Stereo Adapters Dynamically

by Robert G. Middleton

The beginner is often uncertain as to how to proceed in a dynamic test of an FM-stereo adapter. His uncertainty results from an incomplete knowledge of how the adapter works, and how to evaluate the test data. Therefore, we will take the reader step-by-step through the signal characteristics and signal-circuit actions of FM -stereo adapters. This review will show normal and abnormal signals, and the adjustments required for peak performance. Knowledge of signal processing and circuit action will enable one to pinpoint a faulty component.

The Stereo Signal

Basically an FM-stereo signal consists of two audio-frequency signals that occupy the same FM channel. These separate audio signals provide stereophonic sound reproduction. The individual audio signals are identified as "Left" (L), and "Right" (R). These correspond to the outputs from a pair of microphones at a sound studio, as seen in Fig. 1. The audio signal from the L microphone is different from that of the R microphone; therefore, the stereo signal consists of two audio waveforms which vary independently in frequency and amplitude. At the receiver, the L and R signals are fed to separate speakers. The speakers are placed some distance apart to simulate the distance between transmitting microphones.

Multiplexing

Beginners might suppose that an FM radio channel could be divided into two equal parts for transmission of the L and R signals on individual carrier waves. However, this is not feasible for two reasons. First, one audio signal requires nearly all the available bandwidth in an FM channel. Fig. 2 shows the bandwidth relations. Note that the maximum available frequency swing in each channel is ±75 kHz.

This frequency swing of ±75 kHz corresponds to 100% modulation of the FM carrier. Hi-fi reproduction comprises audio frequencies up to 15 kHz. In an AM signal, this corresponds to a frequency range of ±15 kHz, or a bandwidth of 30 kHz. However, in FM sidebands, the width has little relationship to the audio frequency of the modulating

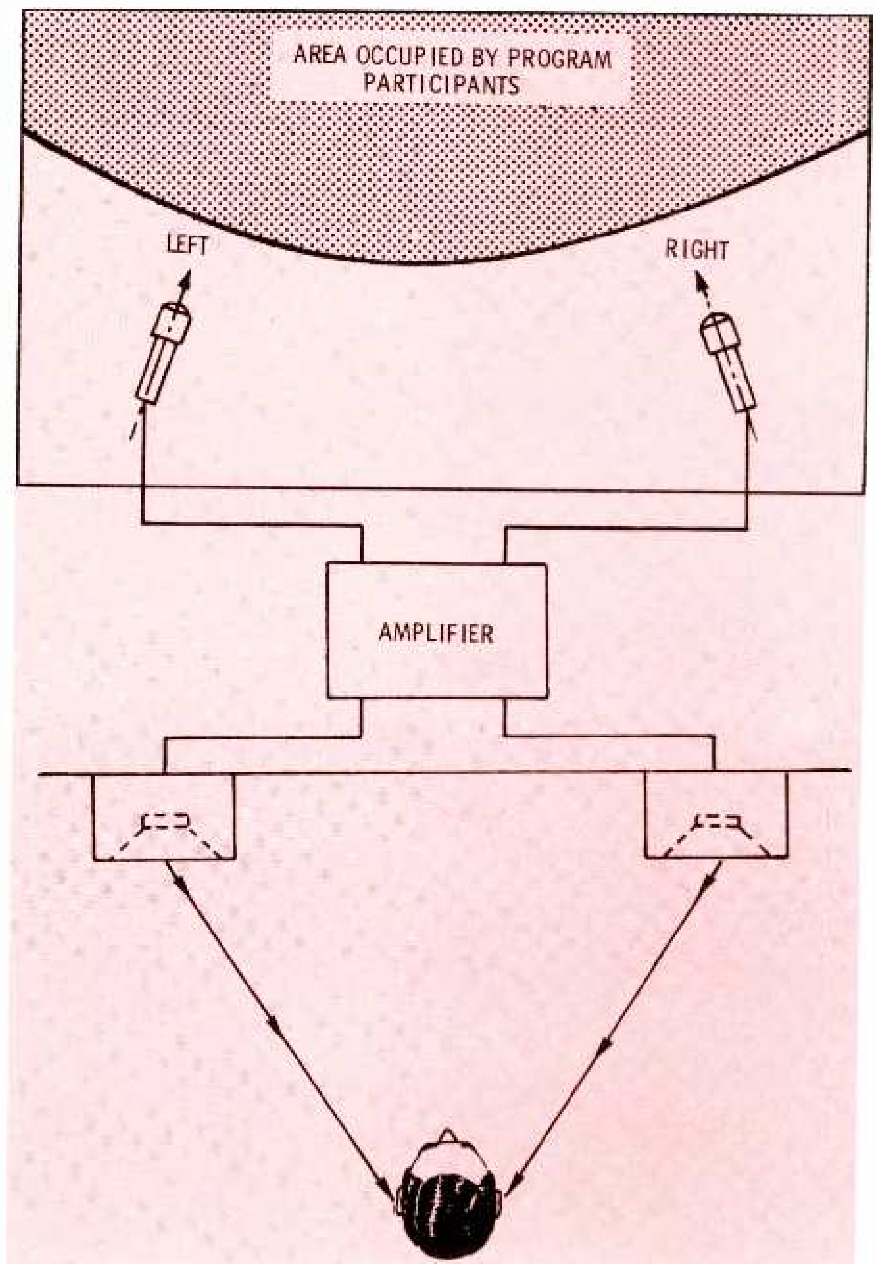

Fig. 1. One system—two signals.

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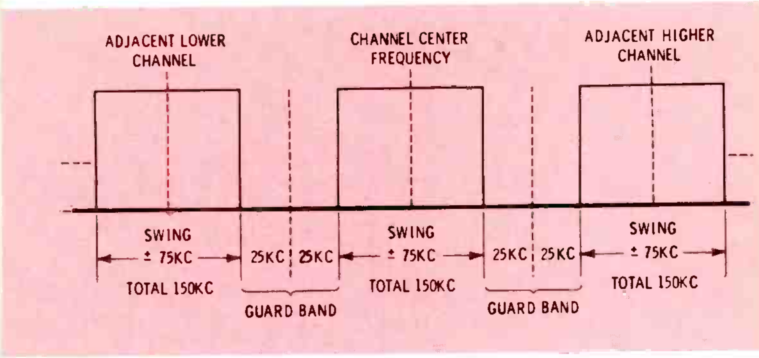


Fig. 2. Maximum deviation is 75 kHz.

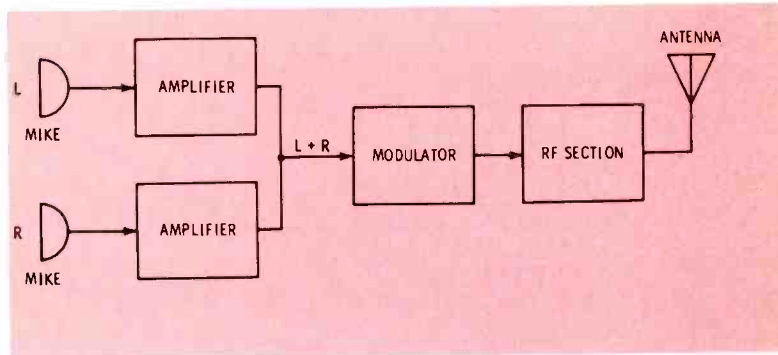


Fig. 3. Mixing signals produces mono.

signal. Since all the available bandwidth of an FM channel is required to transmit 100% modulation of a single audio signal, cutting this bandwidth in half in order to transmit a second audio signal would result in reduced audio level.

Therefore, we must consider how two signals can be multiplexed so that each signal occupies all of the available bandwidth in the channel. The basic requirement of multiplexing is that each signal be transmitted without distortion and without interference to the other signal. Each signal must also have an electrical characteristic that permits "clean" separation from the combined signal at the receiver.

As in color television, we also have a compatibility requirement. In other words, the multiplex transmission must "look like" an ordinary FM signal to a conventional receiver, but it must also "look like" separable L and R signals to a stereo-multiplex receiver. The FCC-approved method is comparatively simple. Let us analyze this system step-by-step.

It starts with the familiar monaural audio signal. The mono signal is the arithmetic sum of the L and R signals. Hence, the first step in the FCC-approved method is to employ two microphones as if they were one. When we mix the L and R signals as shown in Fig. 3, we obtain a mono (L & R) signal. If this L + R signal is modulated on the FM carrier, the result is the same as if one microphone were used.

Insofar as ordinary FM receivers are concerned, only this monophonic audio signal is being transmitted. Actually, we shall see that addititonal information, to which an ordinary FM receiver is unresponsive, is also being transmitted.

Formation of the Multiplexed Signal

Suppose that we add a 38-kHz carrier to an audio program, and modulate both signals on the RF carrier, as depicted in Fig. 4A. Evidently, only the audio L + R signal can be reproduced at the receiver. The 38-kHz carrier is far out of the range of audibility. Furthermore, if we modulate the 38-kHz carrier, this modulated signal is inaudible on an ordinary FM receiver. For example, if we modulate the 38-kHz carrier with a 15-kHz audio signal, the lower sideband has a frequency of 23 kHz and the upper sideband has a frequency of 53 kHz (Fig. 4B). Nobody can hear either a 23-kHz or a 53-kHz tone.

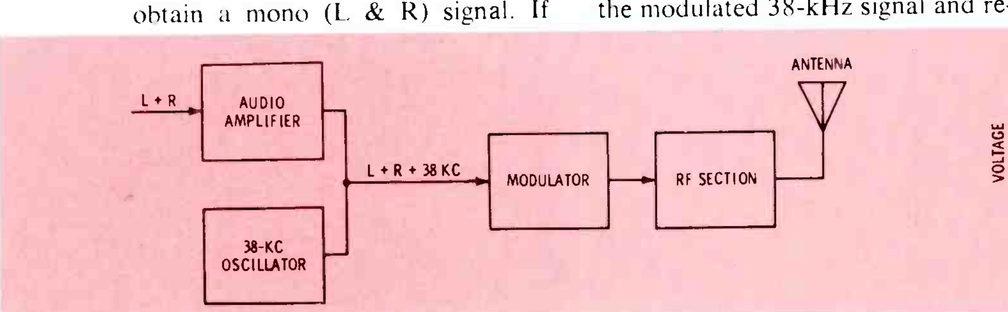
Let us see how the upper and lower sidebands in Fig. 4B can be recovered and fed to another speaker. Fig. 5 shows the basic arrangement. This method employs a 23- to 53-kHz bandpass circuit that picks out the modulated 38-kHz signal and rejects the mono signal. In turn, the output from the bandpass circuit is fed to a detector. Accordingly, the audio signal which modulated the 38-kHz carrier is developed and fed to the second speaker. Thus, the encoded signal, which was rejected by the first speaker, has been made audible from the second speaker. This is the fundamental principle of multiplex operation from transmitter to receiver.

The beginner may be confused at this point, unless it is stressed that the signals charted in Fig. 4B occupy the audio and ultrasonic range. Note carefully that the output from the discriminator in Fig. 5 is an ordinary audio signal accompanied by a super-audio or ultrasonic signal comprising the modulated 38-kHz carrier. This modulated 38-kHz carrier from the discriminator can be truly regarded as an audio signal modulated on a very-low-frequency RF carrier.

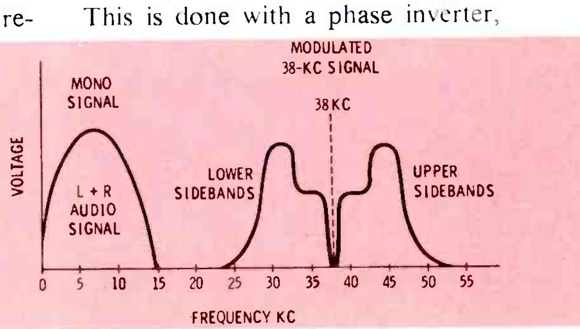
The L-R Signal

Although the simple arrangement shown in Fig. 5 reproduces the two independent signals shown in Fig. 4B, the arrangement must be elaborated slightly to obtain an R signal from one speaker and an L signal from the other speaker, to meet our goal of stereo reproduction. Let us see what is necessary.

First, we form an L-R signal. This is done with a phase inverter,



(A) Block diagram.



(B) Spectrum analysis.

Fig. 4. Adding the 38 kHz signal.

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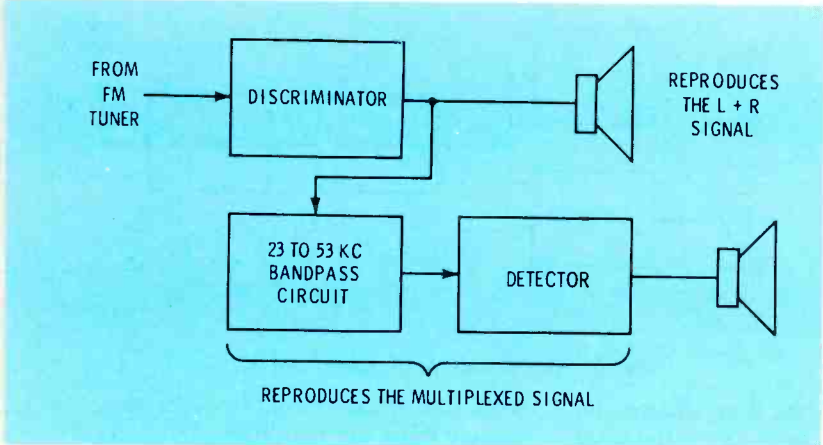

Fig. 5. Detecting the 38 kHz signal.

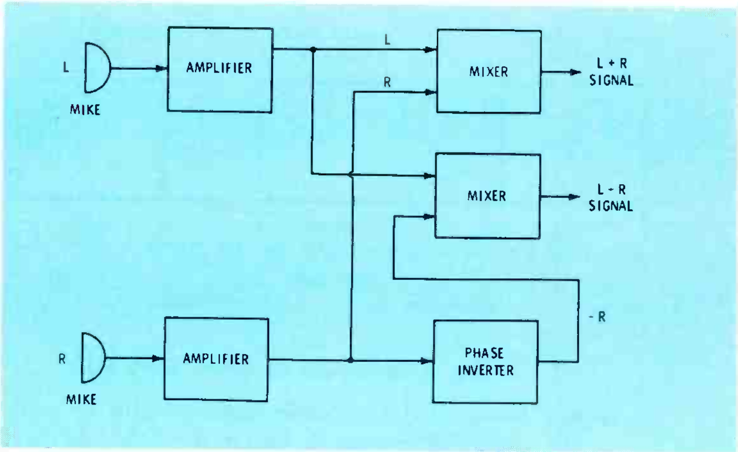

Fig. 6. Forming L + R and L − R.

as in Fig. 6. By inverting the polarity of the R signal and adding it to the L signal, we get an L-R signal.

This gives us both L + R and L — R signals to work with. If we add L + R to L — R, we get 2L. If we subtract L — R from L + R, we get 2R. Then, we can feed 2L to one speaker and 2R to the other. This gives us stereo reproduction. Now that we have L + R and L — R signals, the multiplex transmission is made as shown in Fig. 7. To obtain stereo reproduction at the receiver, we add and subtract the L + R and L — R signals in mixers, as seen in Fig. 8. Accordingly, one speaker reproduces the R signal, while the other reproduces the L signal. Stereo reproduction thus results from multiplexing the L + R and L — R signals when suitable receiving equipment is used.

Subcarrier Suppression

Although the 38-kHz subcarrier could be transmitted in theory, it is suppressed to permit the upper and lower sidebands to be transmitted at a higher level, improving the signal-to-noise ratio. The subcarrier must be reinserted with the sidebands at the FM receiver. Reinsertion must be accomplished not only at the exact frequency of 38 kHz, but also in the correct phase, if distortion is to be avoided. How can this be done? The practical answer is to transmit a 19-kHz pilot subcarrier. You will see from Fig. 4B that 19 kHz falls in an empty space between the L + R signal and the lower sidebands of the L — R signal. This insures clean reception of the pilot subcarrier without any interference.

At the transmitter, the 38-kHz subcarrier is actually generated, though it is not broadcast. Instead, a 19-kHz oscillator is locked to the 38-kHz subcarrier generator and thereby maintained in correct phase. This 19-kHz pilot subcarrier is broadcast in place of the 38-kHz subcarrier, which is suppressed. In turn, the FM receiver reproduces the 19-kHz pilot subcarrier. Next, the receiver generates the second harmonic of the 19-kHz pilot subcarrier. This second harmonic is a synchronized 38-kHz carrier wave that is reinserted with the upper and lower sidebands of the L — R signal. The end result is the same as if the 38-kHz subcarrier had been broadcast with the L — R signal.

Stereo Multiplex Signal Generator

Dynamic tests of FM stereo adapters are made with a stereo multiplex signal generator. These generators must supply an L + R signal, an L — R signal, and a 19-kHz pilot signal, just as an FM transmitter does. Most stereo multiplex generators supply a choice of modulated RF or unmodulated (audio) output. The modulated RF output is provided by an RF oscillator with a frequency near 100 MHz. The L + R and L — R signals have a typical audio frequency of 1 kHz.

A typical FM stereo-multiplex signal generator provides a total of 12 test signals, as follows:

1. Left monophonic output.
2. Right monophonic output.
3. Sidebands of L without 19-kHz pilot.

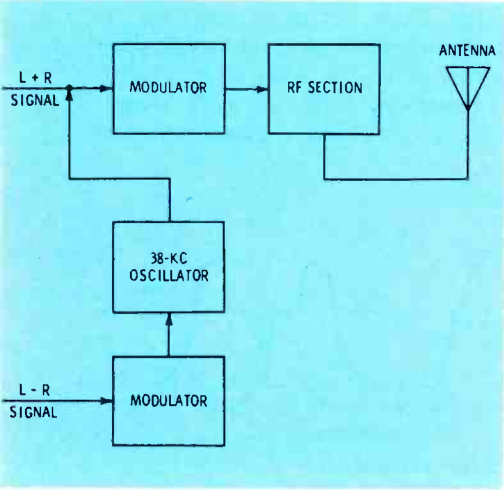

Fig. 7. Forming composite signal.

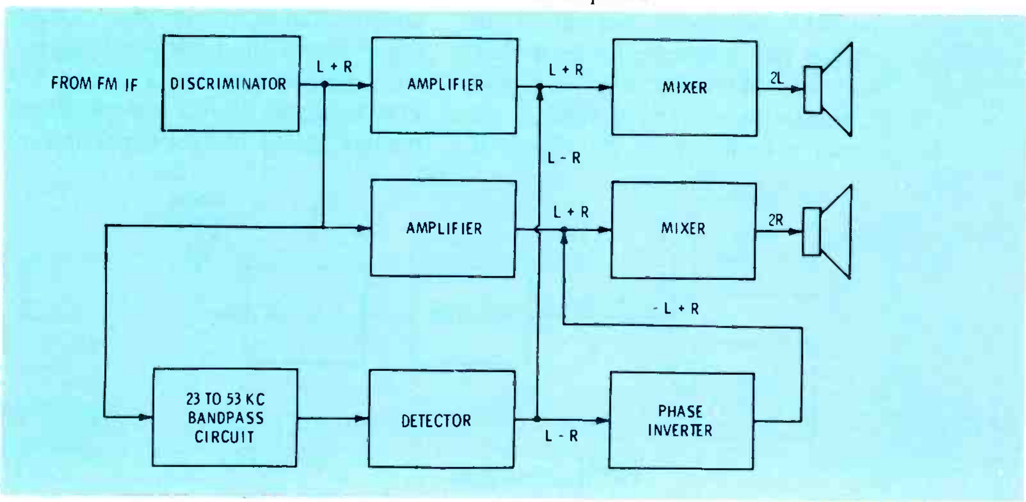

Fig. 8. Functional block diagram of the multiplex adapter.

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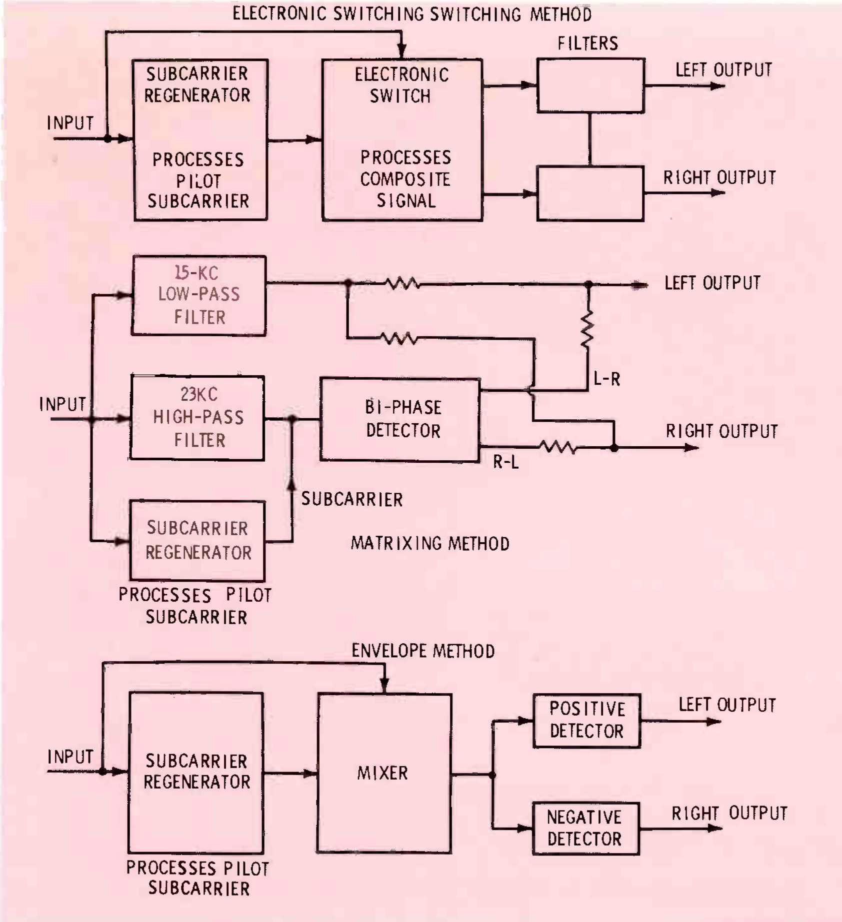

4. Sidebands of R without 19-kHz pilot.
5. Sidebands of L with 19-kHz pilot.
6. Sidebands of R with 19-kHz pilot.
7. L-channel composite signal without 19-kHz pilot.
8. R-channel composite signal with 19-kHz pilot.
9. L-channel complete composite signal.
10. R-channel complete composite signal.
11. 19-kHz sine wave.
12. 38-kHz sine wave.

The applications of these various signals will be explained after a brief description of FM stereo adapters.

FM Stereo-Multiplex Adapters

An FM stereo-multiplex adapter is connected between the FM tuner and a pair of audio amplifiers. The output from the FM tuner is an audio signal (L + R signal), a 19-kHz pilot subcarrier, and sidebands of the modulated 38-kHz suppressed subcarrier. These are L — R sidebands. The adapter has one input and two outputs. Adapter circuits fall into three chief categories, shown in Fig. 9. Thus, a particular adapter might employ an electronic switching system, a matrixing system, or an envelope system of multiplex detection. At this point, we merely note that the end result is the same no matter which system is utilized.

Plan of Test

Fig. 10 shows the general test setup. The stero-multiplex generator is connected to the input of the adapter. A scope or a VTVM can be used to monitor the left-channel and right-channel outputs. It is more convenient to use a pair of VTVM's or scopes so that we do not have to transfer connections back and forth. However, this is a matter of shop facilities and personal preference. Note that if the adapter is being tested without an FM tuner, we use the audio output from the generator and feed it to the adapter input connector. On the other hand, if the adapter is being tested with its companion FM tuner, we use the modulated-RF output from the generator and feed it into the antenna-input terminals of the FM tuner. To avoid objectionable noise, the left and separation for R-channel and L-channel signals.
right audio amplifiers may be disconnected from the adapter.

It is highly advisable to test the adapter without the FM tuner so that any defects present in the tuner will not be falsely attributed to the adapter. Our first test is made for separation. This is the most basic function of an adapter.

Figs. 11A and 11B show the results of a test when an adapter performs ideally. The generator is set for R channel audio output. When the probe is applied to the right-output lead, we observe a 1-kHz sine wave. On the other hand, when the probe is applied to the left-output lead, we see only a horizontal trace. This is complete or 100% separation of the L and R signals by the adapter. Of course, you will not expect to find complete separation. Instead, the left output signal is likely to look like the waveform in Fig. 11C. This is called crosstalk. The separation control on the adapter is used to minimize crosstalk (or to peak separation).

After you have checked the adapter for separation with an R channel composite audio signal, switch the generator to L channel output and again observe the waveforms at left output and right output leads. You may find that the separation control must be readjusted slightly for best separation. In this event, leave the control set midway between the points of best

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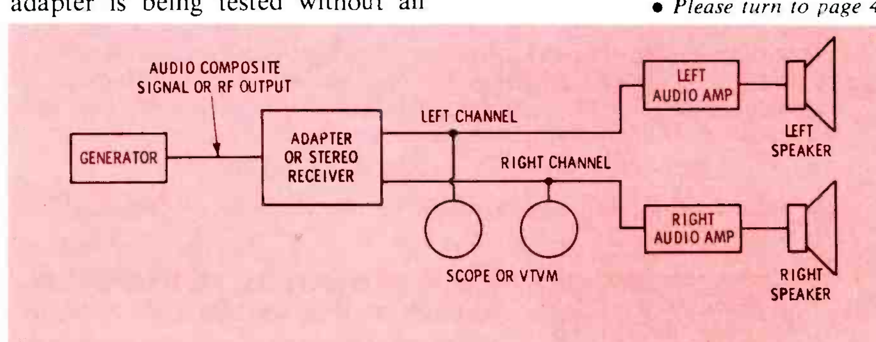

Fig. 10. Separation measurement.

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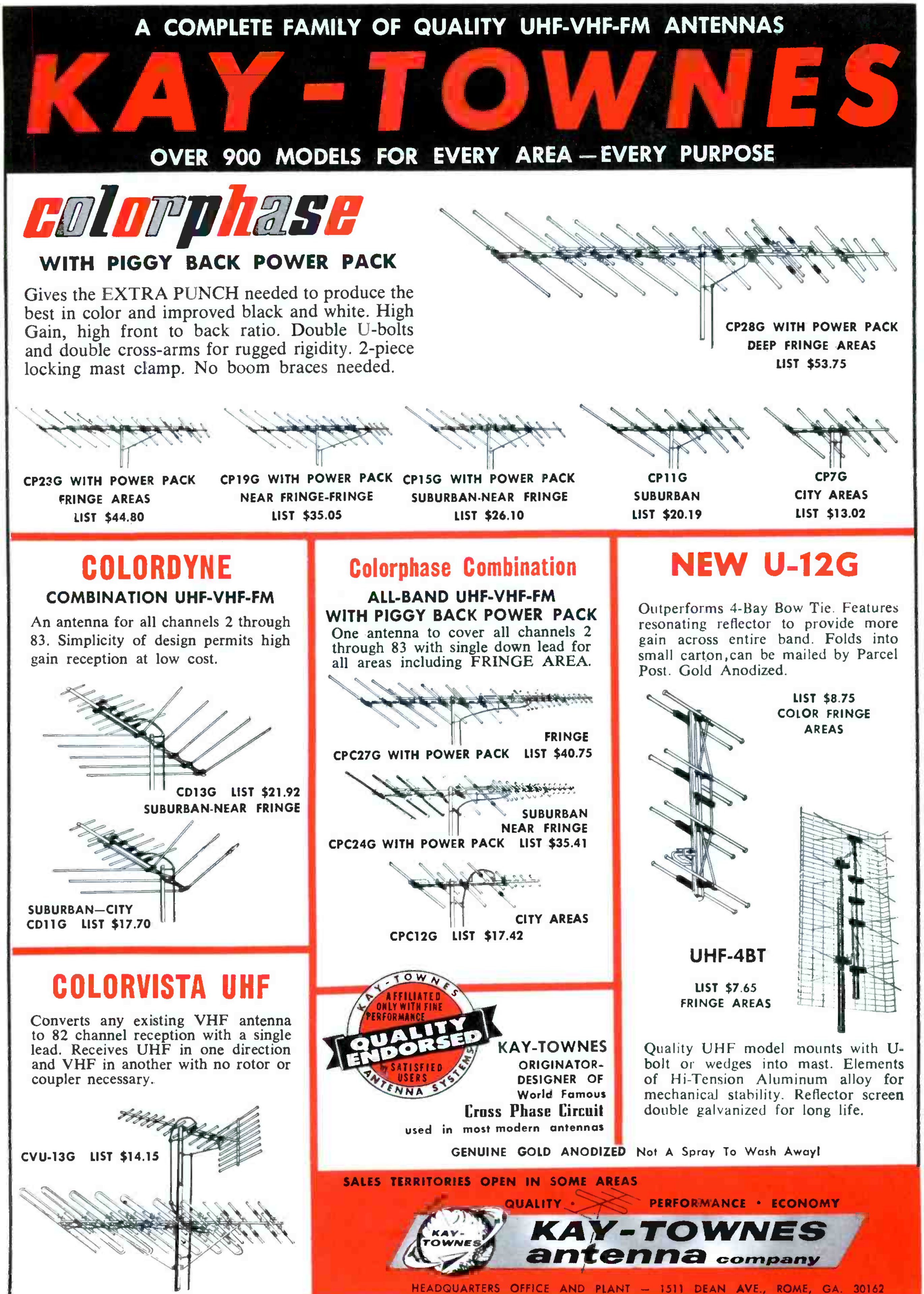

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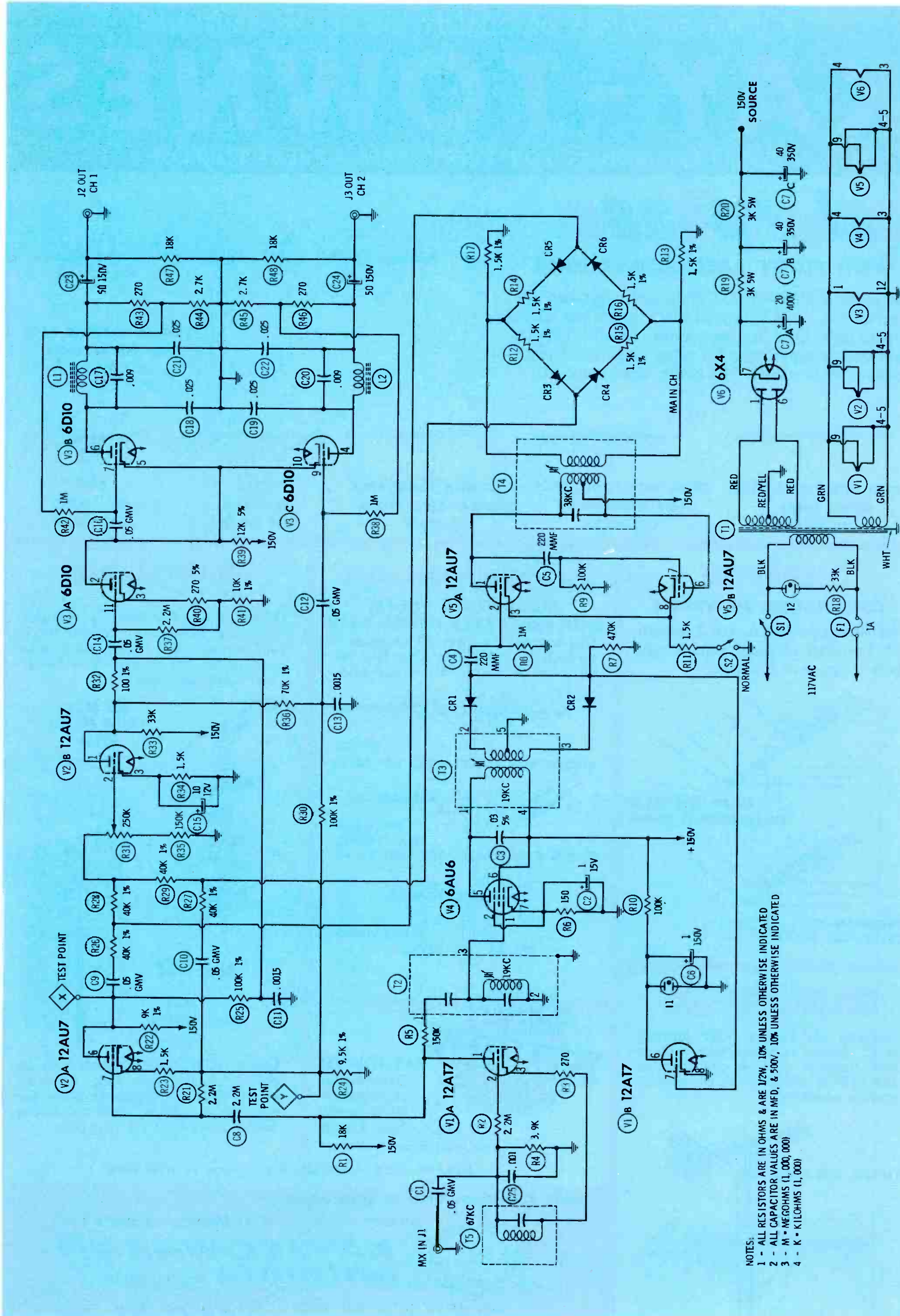

Fig. 12. Typical MPX adapter—EICO.

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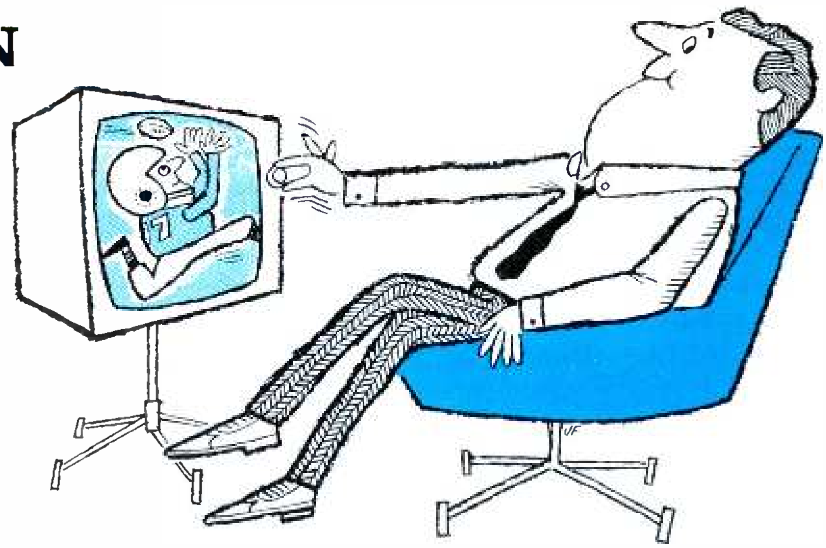


Until the introduction of Belden 8290 Shielded Permohm TV lead-in cable, there were serious limitations in the effectiveness of the various lead-in cables available, whether twin lead or coaxial.

Here Robert E. Sharp, electronic engineer of the Belden Manufacturing Company, discusses the problems and the reasons why Belden 8290 Shielded Permohm is the all-purpose answer for 82-channel and color TV reception.

Q. *What problems have been experienced in using twin lead cables other than 8290?*

A. Most installers have found out that using flat ribbon or tubular 300 ohm line for UHF and color installations is unsatisfactory. When these lines encounter dirt, rain, snow, salt, smog, fog, or industrial deposits, the impedance drops abruptly, the attenuation soars and the picture is lost.

To overcome this problem, Belden developed its 8285 Permohm line which encapsulates the flat twin lead in a low loss cellular polyethylene jacket. This keeps all of the surface deposits out of the critical signal areas—regardless of weather conditions.

Although this was a major improvement, there still remained the problem of electrical interference signals from automotive ignition systems, reflected TV signals and extreme electrical radiation which could be picked up by the lead-in to create ghosts and static lines in the picture.

Q. *Then, is this why many people recommend coaxial cable as TV lead-in?*

A. Yes. Because of the incorporation of a shield, coaxial cable has an advantage over unshielded twin lead.

Q. *Then, why isn't coaxial the total answer?*

A. Coaxial cable has much higher db losses per hundred feet than twin lead. Although the shield in coaxial cable does reduce lead-in pick-up of interference signals, it is not as effective as a 100% Beldfoil* shield.

Another way to put this is that 8290 delivers approximately 50% of the antenna signal through 100 feet of transmission line at UHF while coaxial cable can deliver only 15% to 20%, frequently not enough for a good picture. Even at VHF, the higher losses of a coaxial cable may be intolerable, depending on the signal strength and the length of the lead-in.

The following chart spells this out conclusively. We have compared RG 59/U Coax to the new Belden 8290 Shielded Permohm. All 300 ohm twin leads, under ideal weather conditions, have db losses similar to 8290.

CHANNEL	MC	db LOSS/100' 8290	db LOSS/100' COAX (RG 59 Type)
2	57	1.7	2.8
6	85	2.1	3.5
7	177	3.2	5.2
13	213	3.5	5.9
14	473	5.4	9.2
47	671	6.6	11.0
83	887	7.7	13.5

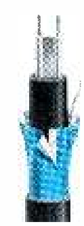
Capacitance: 8290—7.8 mmf/ft. between conductors
Coax—21 mmf/ft.
Velocity of Propagation: 8290—69.8%
Coax—65.9%

Q. *Won't the use of matching transformers improve the efficiency of a coaxial cable system?*

A. No! The efficiency is further reduced. Tests show that a pair of matching transformers typically contribute an additional loss of two db, or 20% over the band of frequency for which they are designed to operate. Incidentally, transformer losses are not considered in the chart.

Q. *How does 8290 Shielded Permohm overcome the limitations of other lead-ins?*

A. 8290 is a twin lead with impedance, capacitance, velocity of propagation and db losses which closely resemble the encapsulated Permohm twin lead so that a strong signal is delivered to the picture tube. At the same time, 8290 has a 100% Beldfoil shield which prevents line pick-up of spurious interference signals. In short, 8290 combines the better features of twin lead and coaxial cable into one lead-in.



Q. *What about cost?*

A. In most cases, 8290 is less expensive than coax since matching transformers are not required. The length of the lead-in is also a factor in the price difference. The cost of coaxial cable installations can vary tremendously, depending upon the type and quality of matching transformers used. If UHF reception is desired, very high priced transformers are required.

Q. *Is 8290 Shielded Permohm easy to install?*

A. Yes! Very! It can be stripped and prepared for termination in a manner similar to 300 ohm line without the use of expensive connectors. It also can be taped to masts, gutters or downspouts, thus reducing the use of standoffs. There is no need to twist 8290 as the shield eliminates interference problems. It is available from your Belden electronic distributor in 50, 75, and 100 foot lengths, already prepared for installation, or 500' spools.

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Fuse blows with V6 out of socket.	Short in T1	Replace
Fuse blows only with V6 in socket.	Defective V6, short C7	Replace
Filament not lit.	Open heater in tube Open green lead for T1 or leads to filaments. 6.3V winding of T1 open	Replace tube Replace T1
POWER bulb doesn't light	Defective R18, I2	Replace
MX stereo bulb doesn't light when stereo program is in progress	Defective R10,T2,T3,I1,C6, CR1, CR2	Replace
MX stereo bulb lights only with V1 out of socket	Misaligned T2 and T3	Realign
DC voltage at V6 cathode (pin 7) is incorrect as specified below:		
a) No voltage	Defective V6 C7 shorted internally or externally Connection to center top of h.v. secondary winding of T1 open	Replace Repair or replace Repair or replace
b) High voltage	Lead from C7C, R19, or R20 open	Repair or Replace
c) Low voltage	T4 shorted to ground C7A open or shorted V6 defective	Replace Replace Replace
Excess hum	C7 open	Replace
Sustained microphonics	V1 defective	Replace
Distorted Stereo	T2,T3,T4 out of alignment	Realign
Lack of separation	V2,R31,R33,R34,R35,CR1,CR2, CR3,CR4,CR5,CR6	Replace
High-pitched whistle on certain FM stereo stations	67kc (SCA sub-carrier) trap T5 misaligned or defective	Realign by adjusting coil slug for inaudibility of whistle. If defective, replace.

Fig. 13. Trouble shooting chart for the EICO MPX adapter.

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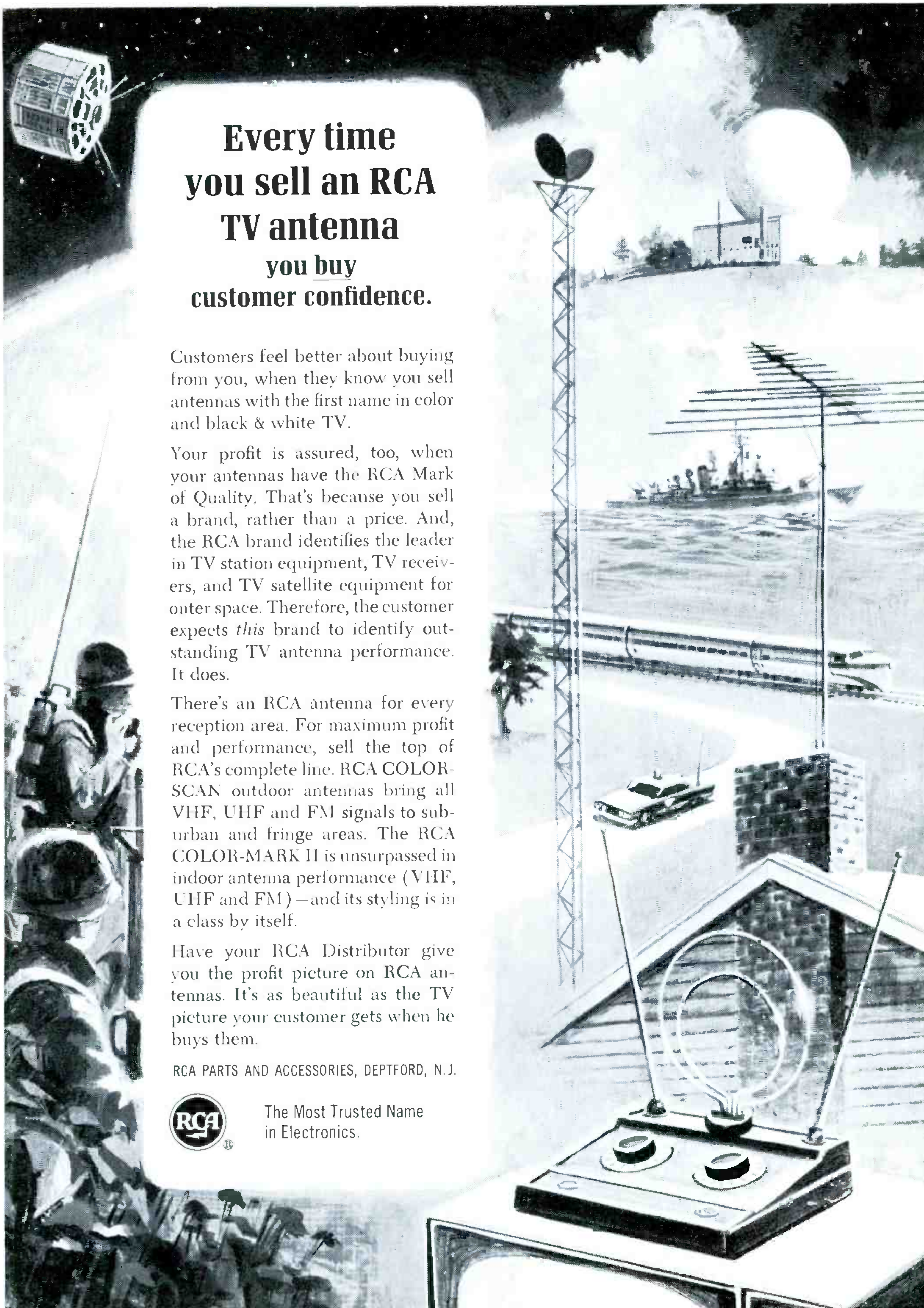

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Testing FM

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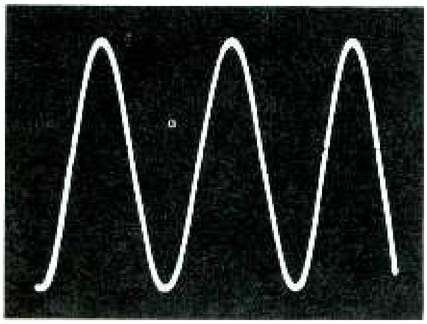
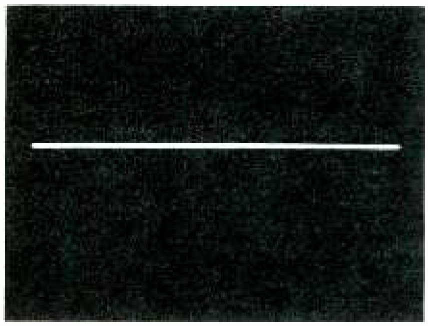
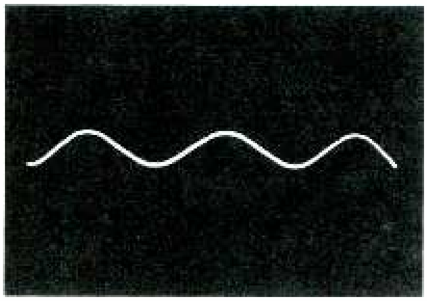


(A) Normal right output.



(B) Ideal left output.



(C) Normal left output.

Fig. 11. Input to right channel.

Evaluation of Separation

Adapters are rated for separation in decibels. When making the separation test, we measure the difference between the two wave-form amplitudes in db units. Check your measured db value against the manufacturer's rating on separation for the adapter. If your measured value is less, there is troubleshooting to be done. Tubes are the most common troublemakers, followed by capacitors, semi-conductor diodes, and resistors. Tuned-circuit alignment is checked last, as it is seldom the culprit. Transistorized adapters may develop a defect in a transistor, but this is much less likely than capacitor trouble.

Adapter Trouble Symptoms

Let us review some typical adapter trouble symptoms. The circuit diagram for a widely-used adapter is shown in Fig. 12. If we should find unsatisfactory separation, we check V2, R31, R33, R34, R35, CR1, DR2, CR3, CR4, CR5, and CR6. Other trouble symptoms might be fuse blowing, dark multiplex stereo bulb, hum, microphonics, distorted stereo output waveform, or whistles. The components to check in case of such trouble symptoms are charted in Fig. 13. It was noted previously that the configuration shown in Fig. 12 is only one of the three basic systems used in multiplex adapters. However, the general principles of multiplex operation serve as a guide to pinpointing defective components in any type of adapter.

Adapter Operation With FM Tuner

After you have checked out the operation of an adapter, the next consideration is performance in combination with the companion tuner. The test setup is made as indicated in Fig. 14. In the ideal situation, performance will be the same as when composite audio is fed directly to the adapter. In practice, however, we will find at least a slight difference in performance. One of the most common trouble symptoms is waveform distortion, which may or may not be accompanied by reduced separation. In other words, we might not see a true sine wave as illustrated in Fig. 11, but a waveform with clipped peaks, or possibly even a dip in

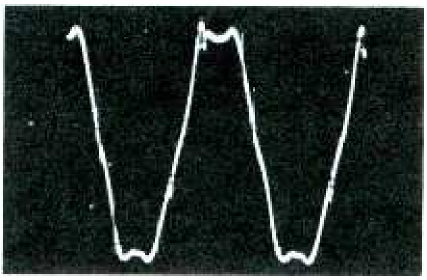


Fig. 15. Distorted peaks caused by poor FM tuner alignment.

the peaks (Fig. 15). In such cases, we should use a sweep generator to check the RF, IF, and discriminator alignment. Most technicians are familiar with sweep alignment of FM tuners. It should be stressed that an alignment job that "gets by" in mono reception will probably be inadequate for good stereo-multiplex reception. You can use test signals from an FM stereo-multiplex generator for touch-ups, but this will result only in a rough alignment, and must usually be supplemented by complete alignment with a sweep and marker generator.

Conclusion

We have covered the basic points of importance for dynamic tests of FM-stereo adapters. These explanations will get the beginner "off the ground", but there are numerous details yet to be learned to qualify as an experienced stereo technician. Remember too, that your evaluations of adapter and tuner performance cannot be more accurate than your test equipment. Efficiency at the bench also requires a good understanding of the circuit action utilized in the three basic adapter systems. ▲

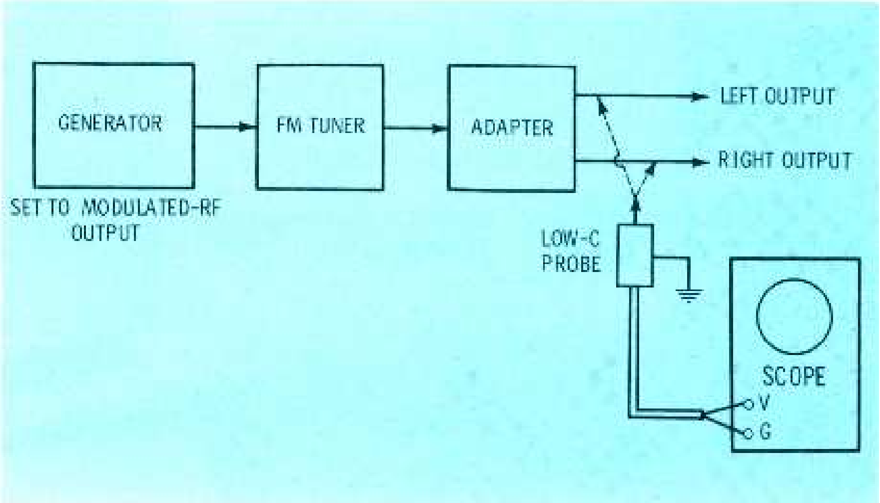


Fig. 14. Test set-up with FM tuner.

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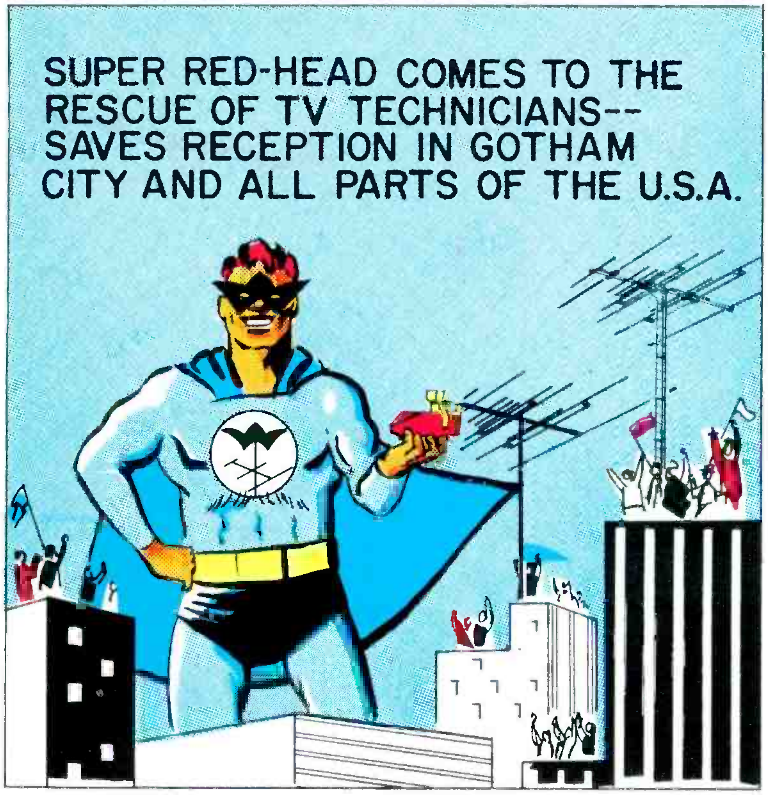

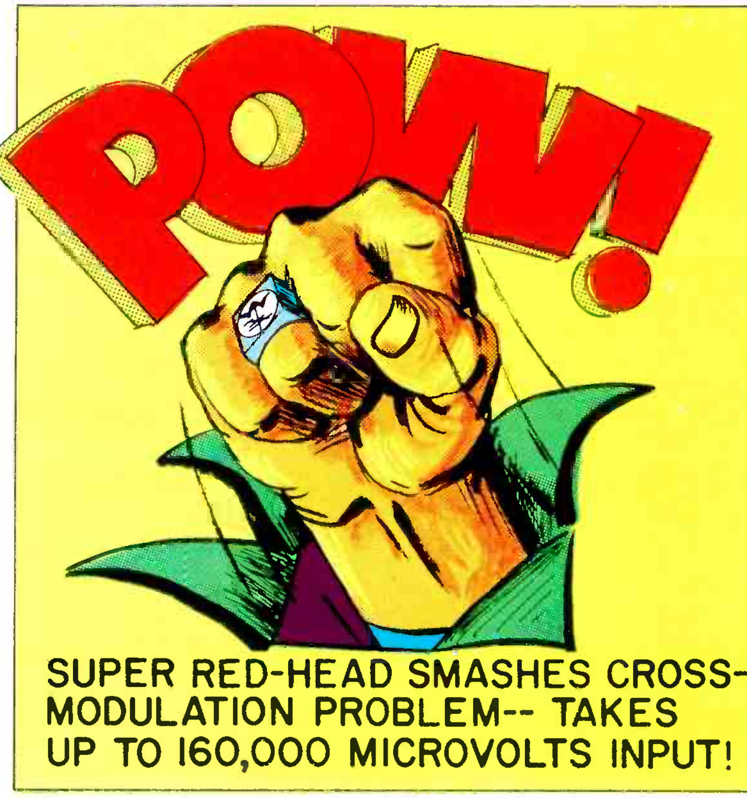

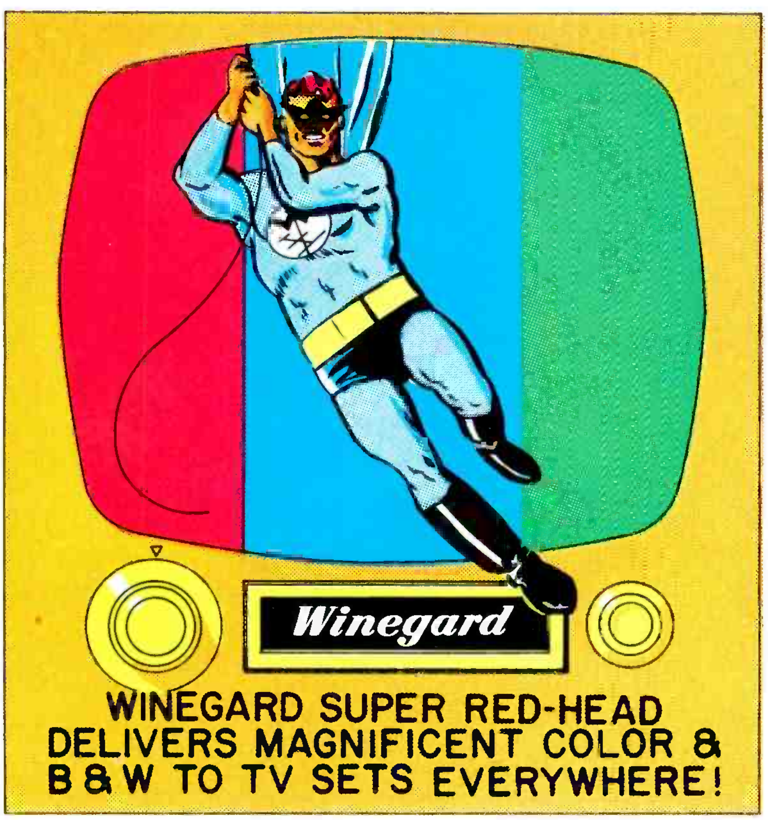

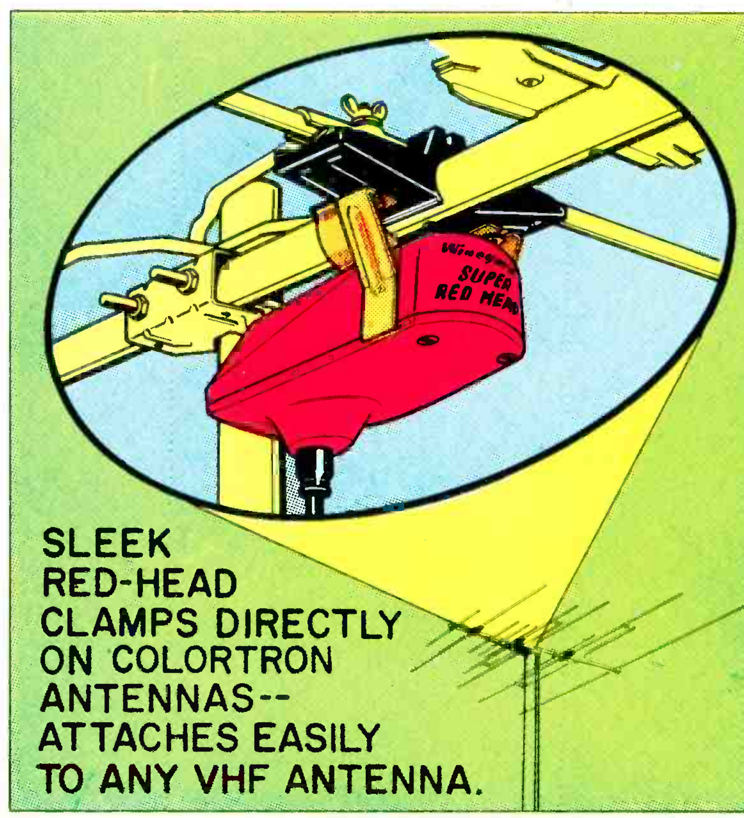

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Notes on Test Equipment

analysis of test instruments . . . operation . . . applications

by T. T. Jones

Radio Analyst

Carrying on the tradition of the earlier analysts, the new **B&K Model 970 Radio Analyst** is a multipurpose instrument which by itself enables the technician to repair most radios. Included in this one cabinet is a power supply for battery radios, an AM and FM signal generator, and a VOM. There are many additional conveniences which make short work of radio repair.

The instrument supplies power for the set under test from a transformer supply. This supply has a ten-position switch which enables the operator to select any voltage from 1.5 to 15 volts in 1.5-volt steps. The output is rectified by a full-wave bridge and filtered through a swinging choke and a 20,000-mfd capacitor. The output terminals have a 200-ohm potentiometer in parallel, and the arm is connected to the bias-output terminal. Thus, in addition to the step-selected voltage, any voltage in between may be selected for use with a receiver which requires a tapped supply. See Fig. 2.

The VOM uses a conventional circuit with a 100-ma meter. The meter is protected against overload by a pair of diodes, and sensitivity on the volt scales is 5.5K ohms per volt. A six-inch patch cord is provided so that the meter can be used to monitor the current supplied by the power supply.

Fig. 1. Performs many functions.

There are several transistor tests built into the 970. The first is an in-circuit test. If the device under test is hooked to the 970 power supply, a single probe is touched to the base of the transistor in the circuit. The meter will read up-scale if the transistor is capable of amplifying.

A more sensitive check is the beta test. This must be performed with

B&K Model 970 Specifications

Power Supply

Output: DC Power;. 1.5, 3, 4.5, 6, 7.5, 9, 10.5, 12, 15 volts calibrated at 1 amp, capacity 5 amp. 6, 12 volt Auto calibrated at 5 amp, capacity 5 amp. Switch selected.
Bias; continuously variable 0-100% of DC Power selection.
Ripple: less than 5%.
Fuse: 3 amp on primary of power transformer, 5 amp protects power supply diodes.

VOM

Sensitivity: 5.5K ohms/volt
DC volts: 2, 20, 200, 500 volts @ 5% full-scale accuracy.
DC current: 20, 200 ma. 2.5 amp. @ 7% full-scale accuracy.
Resistance: R × 1, 10, 100 @ 20% full-scale accuracy.

Signal Generator

Frequency: Band A 250 kHz-750 kHz AM
Band B 750 kHz-2 MHz AM
BandC 10MHz-11.4 MHz AM or FM
Band D 88 MHz-108 MHz FM
Accuracy: 2% at 455 kHz, 1600 kHz and all frequencies in Band D.
All other frequencies 5%.
RF level: Minimum .025 volt rms on Bands A, B & C. Minimum .01 volt rms on Band D
Modulation: 400 Hz. Supplies a minimum of 30% modulation on AM and 70-kHz deviation on FM.
Audio output: 400 Hz. Minimum 50mv rms into a 3-ohm load. 1.25V rms into a 72-ohm load.

Transistor Tester

In-circuit: Good/bad.
Out-of-circuit: Beta; 0-300. Leakage; good/bad.

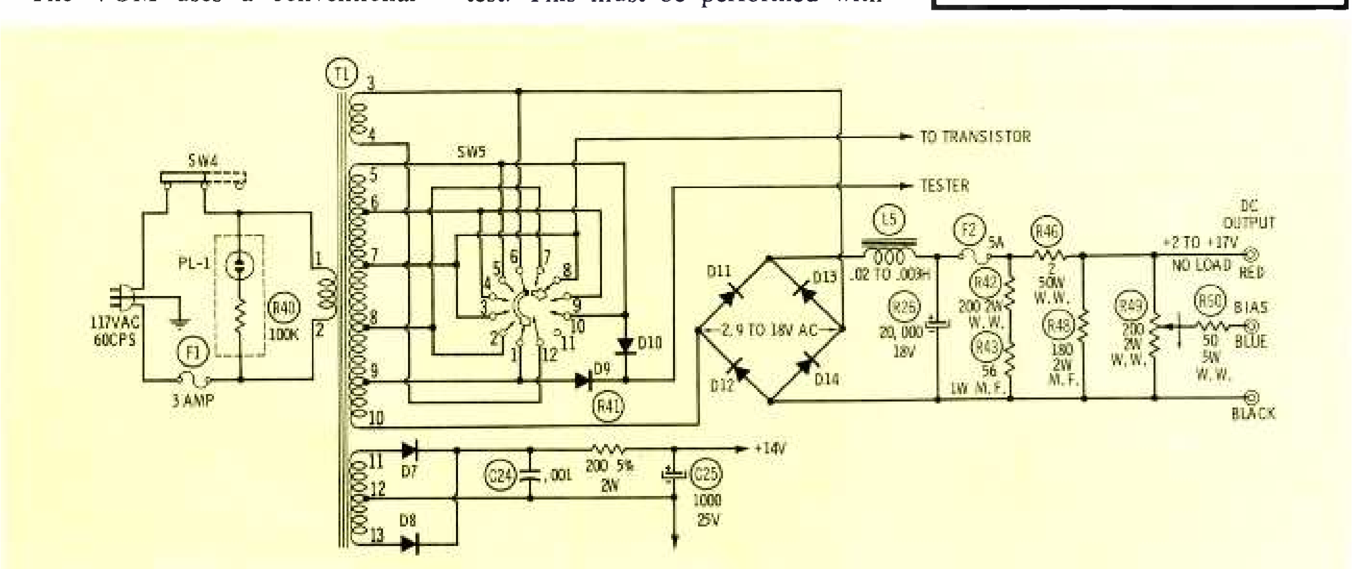

Fig. 2. Power-supply schematic.

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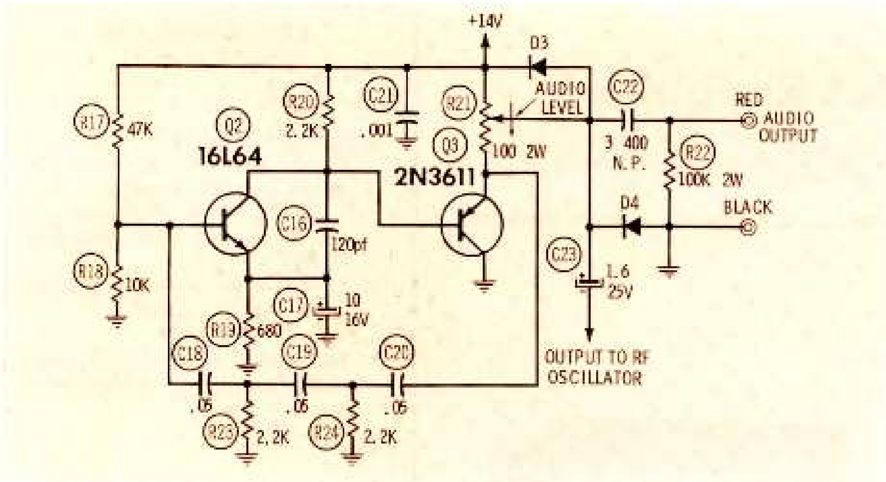

Fig. 3. Phase-shift oscillator.

the transistor out of the circuit, as shunt resistances can make the test meaningless. Beta is read on a scale calibrated 0-300. Provisions are made for greatly increased current capacity, to test the beta of power transistors. In addition to the beta test, there is a collector-to-emitter leakage test.

The signal generator consists of two sections. The first section is a two-stage, phase-shift oscillator, shown in Fig. 3. Feedback is through the network C18, C19, C20, R23 and R24. These components shift the phase 180 degrees at only one frequency—400Hz. Phase shift is more or less than 180 degrees at any other frequency, and will not sustain oscillation. Therefore, the oscillator is very stable and accurate at 400 Hz.

The RF oscillator is a capacitor-tuned, modified Hartley circuit. Modulation of the RF carrier is accomplished by feeding the audio signal to the collector for AM and switching it to a varactor diode across the tank coil for FM. Calibration accuracy was very good on the unit we tested.

The unit is housed in a heavy-gauge wrinkle-finish case. In general appearance it is a miniature of the famous TV analyst, and should make a welcome companion for that unit.

For further information, circle 62 on literature card

Audio Generator

The increasing sales of stereo radio and record players have been paced by the improvements in fidelity. Today's $100 portable record player sounds as good or better than the finest consoles of 15 years ago. Records and tapes are constantly improving.

The end result is that the consumer—your customer—demands better fidelity. His ear is trained to notice those slight distortions and roll-offs that would have been acceptable a few years ago. The days are past when repairing a record player means putting on a platter and seeing if you can hear sound.

Now you need a calibrated, low-distortion audio generator to produce a signal. **EICO** has just such an instrument, pictured in Fig. 4. The output frequency is selected by switches which insure highly repeatable readings. The voltage output is measured on an accurate voltmeter, also providing repeatable tests, in addition to the obvious convenience. The harmonic distortion on the unit we tested was found to be less than .05% across the en-

EICO Model 378 Specifications

Frequency Range:

1Hz—110kHz, switch slected, two significant figures and multiplier.

Frequency Accuracy:

±5%

Output Level Ranges:

0-3, 10-volts rms into a high-impedance load (10KΩ minimum). 0-.003, .01, .03, .1, .3, 1 volt rms into 600Ω 3-volt range;

Source Impedance:

10-volt range; varies between 0 and 1000Ω.
3-volt range; varies between 800 and 1000Ω
1-volt range and below, 600Ω external load, 290Ω internal load.

Db Ranges:

−70 to + 22db, in 10-db steps (0dbm 1mw in 600Ω)

Meter Accuracy:

2% full scale.

Output Distortion:

less than .1% 20Hz-20kHz.

Power Requirements:

105-125 VAC,
50-60Hz, 40 watts.

Size (HWD):

8½" × 12½" × 7½"

Weight:

13 pounds

Price:

$49.95 kit, $69.95 wired.

Fig. 4. Low-distortion generator.

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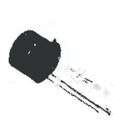	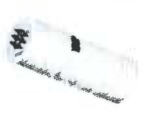		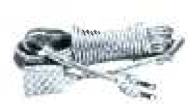
Transistor EA15X25	Spindle EA97X174	Knob ET43X299	Polarized Extension Cord ET90X32

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GENERAL ELECTRIC

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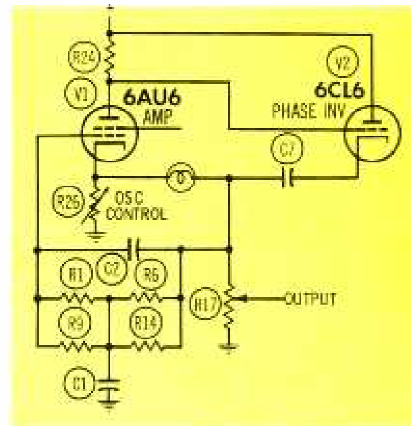

Fig. 5. Oscillator circuit.

tire audible portion of the output.

The oscillator circuit (Fig. 5) uses a voltage amplifier directly coupled to a phase inverter, which in turn is coupled back to the cathode of the amplifier through C7 and R27. At the same time, negative feedback is accomplished by coupling through C7 and the capacitor-shunted "T" network.

Frequency is determined by switching R1 and R6 at the decade level and R9 and R14 for units. C2 and C1 are switched by the multiplier control and change the ranges by a power of 10.

An interesting feature of the circuit is R27, which is actually a 3-watt lamp. Its function is similar to a thermistor. As the positive feedback through C7 and R27 builds up, the oscillator would soon "run away." However, increased current through R27 results in an increase of resistance, stabilizing the circuit at a constant amplitude. R26 is used to set this level at a point below distortion. The signal from the oscillator is passed through an attenuator. This has a variable control (Output/Fine) and an 8-step switch with 10-db steps. There is a 600-Ω load which is automatically switched out in the 3- and 10-volt levels, and may be manually switched out at lower levels. The meter is connected in the attenuator and automatically reads the voltage present at the output terminals, if the generator is terminated properly. It is also calibrated in db and referenced to 0 dbm (1mv in 600Ω).

We put the unit through its paces in the lab and found it to be well within specifications on all functions. Since initial tests it has been used quite extensively in the lab and has stood up quite well. ▲

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Book Review

Fundamentals of Transistors, A Programmed Text; RCA Service Company; Prentice-Hall, Inc., Englewood Cliffs, N.J., 1965; 223 pages, 9¼" x 6½", hard cover; $10.00.

The foundations of transistor technology and circuit behavior are imparted to the reader through a teaching technique called programmed instruction. Progression from the relatively easy concepts of conductivity, conductors, and insulators to the more difficult areas of junction theory and transistor behavior is accomplished in small, comprehensive steps.

The text material is organized into 68 separate sections, each section conveying a particular idea, specific application, or behavorial aspect of semiconductor devices. Section 1 through 10 cover semiconductor physics. Junction theory and diodes are the subjects of sections 11 through 17. Sections 18 through 24 are concerned with PNP and NPN transistor theory, including symbology and the effects of collector-voltage and emitter-current changes. Sections 25 through 37 deal with the configuration and characteristics of the common-base amplifier. Similar information concerning common-emitter amplifiers is covered in sections 38 through 45, with additional information on the graphical relationships of current, voltage, and power gain. Sections 46 through 53 discuss the common-collector amplifier. A self test of the three transistor configurations is contained in Section 54. A comparison of transistor and vacuum-tube amplifiers is made in Section 55. Sections 56 through 62 contain information on biasing methods. The effects of temperature on semiconductors and related circuits are dealt with in Sections 63 through 66. The remaining sections discuss zener diodes and transistor electronic switching.

Although programmed instruction has been applied to many subject areas of electronics, the reader will find it particularly effective in learning the basics of transistor theory and application. Comprehension and retainability should be high using this type of self-instruction. ▲

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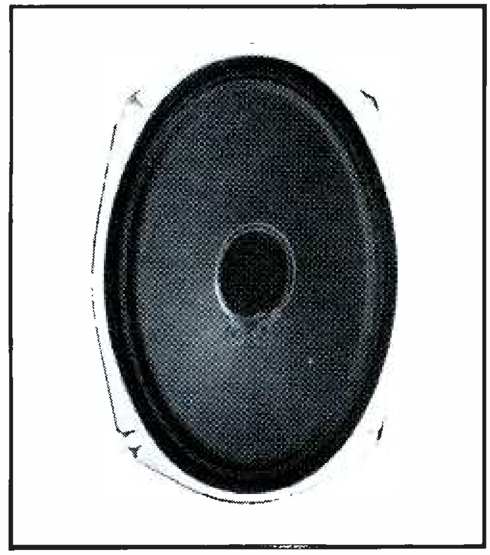

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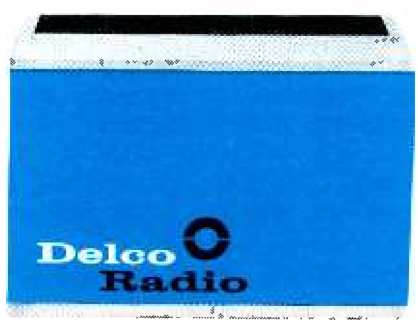

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BRIDGE Circuits in Industry

by Edwin Walker

In industrial electronics, as in other lines of instrumentation, the secret of good performance and reliability lies as much in the design of the units as in the materials and methods of construction. A complete system for industrial measurements must include not only a transducer to convert the sensed quantity to an electrical one, but also a suitable electronic circuit to utilize the resulting signals. The circuit required for a particular application will depend upon the type of transducer employed and the function to be performed by the system output.

Many types of transducers, including those in which a mechanical input produces a change in impedance or electrical coupling, must be supplied with a suitable excitation signal if a useful output is to be produced. Other types require the application of a biasing or polarizing voltage. Weak output signals must be amplified to a level sufficient to drive other instruments or for transmission to a remote location without serious losses caused by noise pickup along the way.

Modulation techniques are often used to facilitate transmission of the signals, and they permit use of simpler and more dependable amplifiers. In turn, the signal must be demodulated to recover the original information. Auxiliary circuits may include a means of compensating for changes in transducer or system characteristics that may result from variations in operating conditions. Other facilities which may be required in particular applications include filters to restrict the bandwidth of the system and linear networks that modify the shape of the transfer characteristics.

One of the most versatile circuits for measuring electrical quantities is the bridge. By using an appropriate configuration, resistance, inductance, capacitance, frequency, or voltage may be measured. Measurements thus made are extremely accurate, since the value of the known parameter is expressed in terms of bridge elements that can be precisely calibrated.

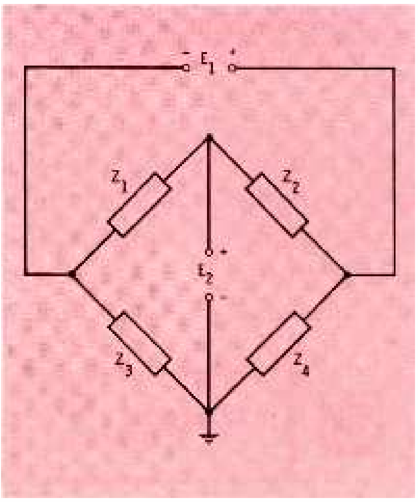

Fig. 1. Basic bridge circuit.

For some purposes, bridges are used strictly for comparisons—the bridge is balanced or nulled and the value of the unknown arm is calculated by a simple ratio equation. In other cases, the bridge serves as a means for obtaining a voltage roughly proportional to the deviation from a null condition.

Impedance Measurements

Fig. 1 illustrates the basic bridge circuit for measuring impedance. The unknown impedance may be placed in any one of the four arms. The remaining three arms consist of suitable fixed or calibrated impedances. An excitation voltage, E_1, of suitable frequency, is applied to the input terminals while a null detector is connected across the output voltage, E_2. One or more of the three calibrated impedances are adjusted to reduce the output voltage to zero. For this bridge circuit, the impedance relationship necessary for a null condition is expressed by the equation $Z_1/Z_2 = Z_3/Z_4$.

When an electromechanical transducer is connected as the unknown impedance in a bridge circuit, a measurement of the mechanical input to the system is accomplished first by adjusting the bridge for balance, then by reading the value from a calibrated dial. In applications where manual balancing can-

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not be used, the signal from the bridge can be applied to a servo amplifier that drives a motor connected to the adjustable bridge member. The transducer output is then read from a pointer affixed to the motor shaft. If remote indication is required, a signal proportional to the transducer output can be generated by a potentiometer driven from the motor shaft.

Resistance Measurements

Fig. 2. illustrates the circuit of a Wheatstone bridge, the most commonly used bridge for resistance measurements. Either AC or DC excitation may be employed, provided that the frequency is kept sufficiently low to insure that the bridge impedances are kept free from reactive components. This usually is true at frequencies up to a few kHz. The condition for balance of this bridge is expressed by this equation: $R_x = (R_1/R_2)R_3$.

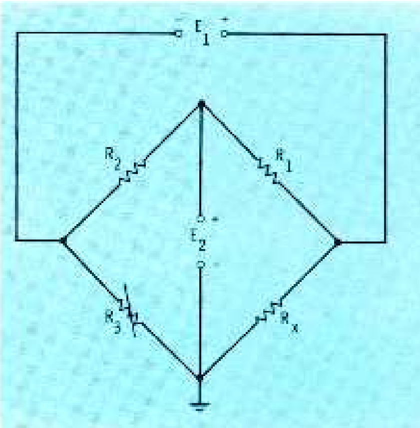

Fig. 2. Wheatstone Bridge.

While all three of the calibrated bridge resistors could be made variable, it is usually more convenient to make R_1 and R_2 fixed, and to achieve balance by adjusting R_3. If a wide range of resistances are to be measured, the bridge ratio R_1/R_2 is usually set at a convenient power of 10 by switching appropriate fixed resistances into these two arms. With such an arrangement, the value of the unknown resistance may be read directly from a dial on R_3.

In the bridge circuit shown in Fig. 2, the position of the excitation source and detector may be interchanged without affecting conditions under which a null is obtained. For any given application, choice of source and detector positions will be determined largely by impedance levels at the two sets of terminals.

Measuring Reactive Impedances

When building AC bridges for measuring reactive impedances, several factors limit the choice of elements for use in the bridge arms. Precision inductors are expensive and tend to be quite bulky. Furthermore, the presence of unavoidable resistance and core losses limits the Q that can be realized. In addition, the range of inductance variations is rather limited, because variations in inductance are accompanied by changes in Q.

Calibrated variable capacitors are also subject to serious limitations. They are available only in very small values of capacitance, and because of their small values, stray circuit capacitances often impair the accuracy of calibration.

Because of the foregoing factors, the use of either fixed or variable inductors in bridge arms should be avoided. Where capacitors are required, the circuit should be so ar-

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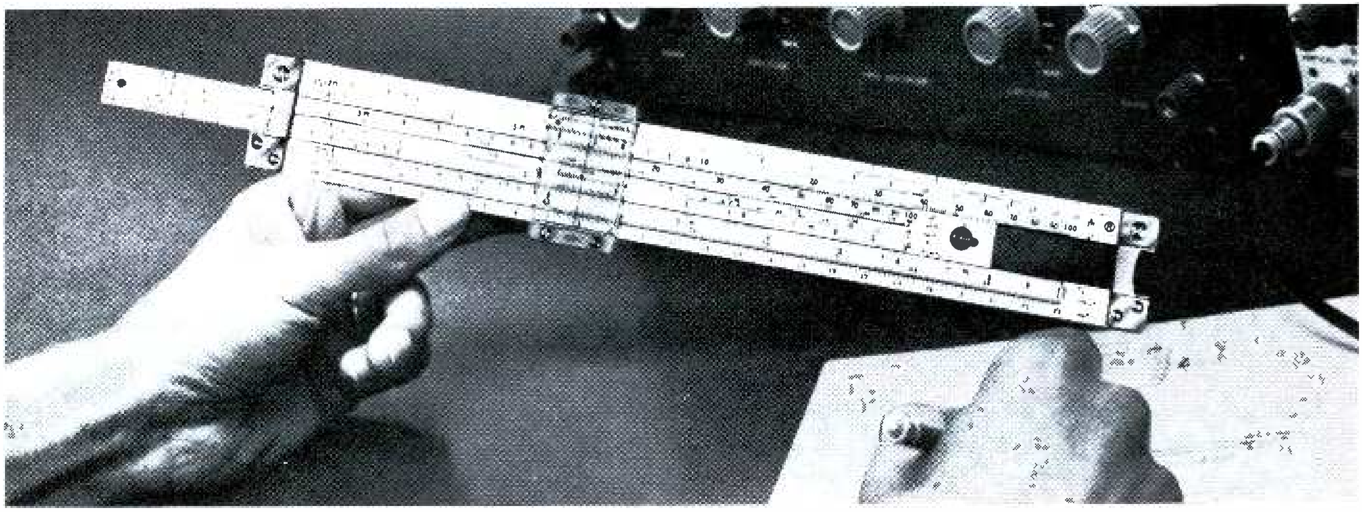

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ranged that fixed capacitors can be used. If necessary, various values of fixed capacitance can be switched into the circuit to permit operation over a wide range of impedances or frequencies.

If the foregoing conditions are met, all the continuously variable bridge elements will be resistors. In general, two calibrated variable resistors will be required in an AC bridge because of the need to balance the real and active components simultaneously. For bridges used to measure small changes in reactance from a nominal value, however, it is often possible to arrange the circuit so that once the bridge has been balanced for the nominal value of impedance, only one resistance need be reset to restore balance after a small impedance change.

Capacitance Measurements

The circuit of a Wien Bridge, the most commonly used type for measuring capacitance. can be seen in

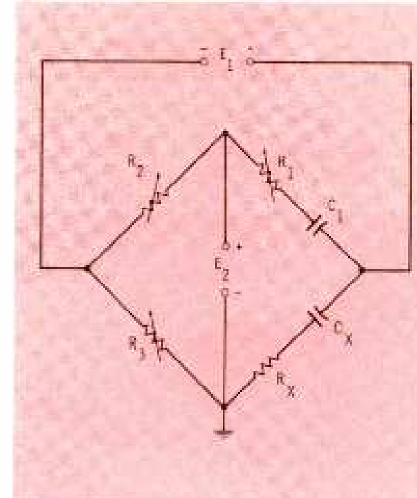

Fig. 3. Wien capacitance bridge.

Fig. 3. Capacitor C_1 is usually a fixed capacitor with provision for switching in different values if a wide range of capacitance is to be measured. Resistors R_1 and either R_2 or R_3 are continuously variable; R_2 or R_3 can be calibrated directly in capacitance, and if a fixed excitation frequency is employed, R_1 will provide a direct indication of dissipation factor.

The Wien Bridge is essentially a symmetrical circuit; two of the calibrated arms are pure resistance, while the third contains the same type of impedance as is present in the unknown. Balance is achieved by adjusting the variable elements so that all three pairs of corresponding elements are in the same ratio.

Inductance Measurements

The same technique used for measuring capacitance can be employed for measuring inductance. Because precision inductors suffer from the limitations already described, it is preferable to utilize a capacitor as the reactive bridge element. To make it possible to balance a bridge containing both a single inductor and single capacitor, it is necessary that the two reactive elements be located either in the same arm or in arms diametrically opposite each other. Location of the two reactive elements in the same arm is usually undesirable, since it would necessitate use of a variable capacitor. As a result, most inductance bridges employ a fixed capacitor in the arm opposite the unknown reactance. With this arrangement, balance is achieved by adjusting the two resistive elements. The range of such a bridge can be set by switching the

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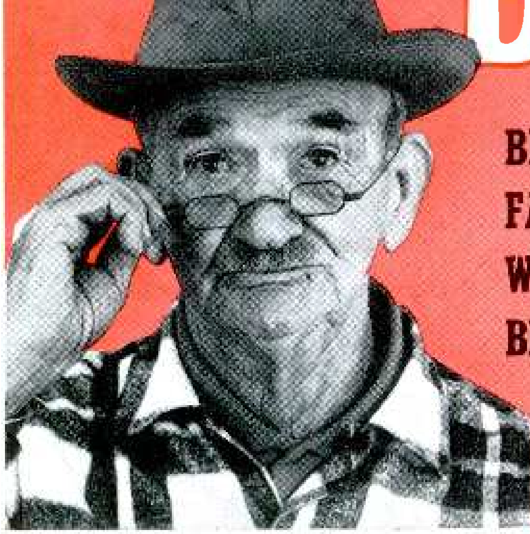

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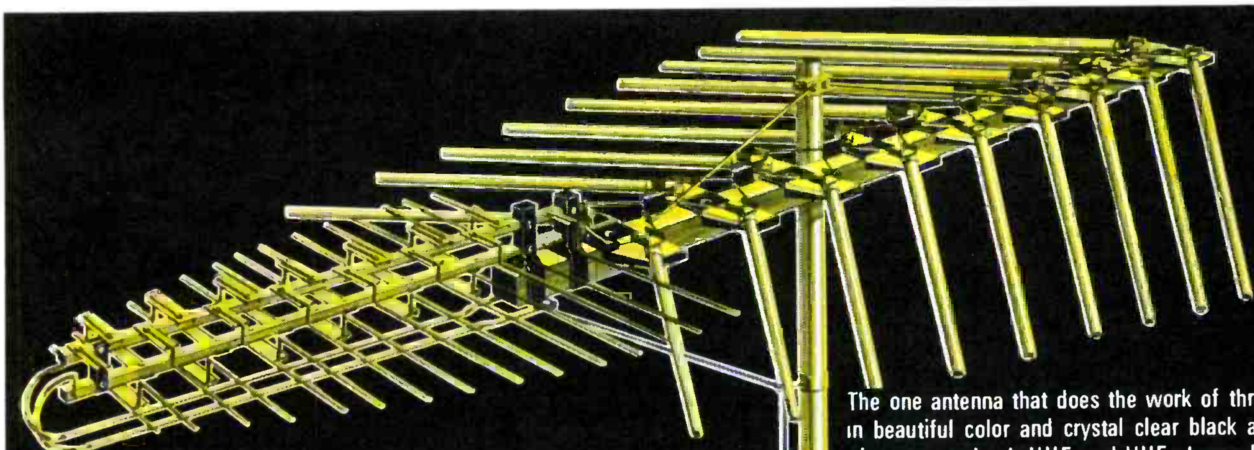

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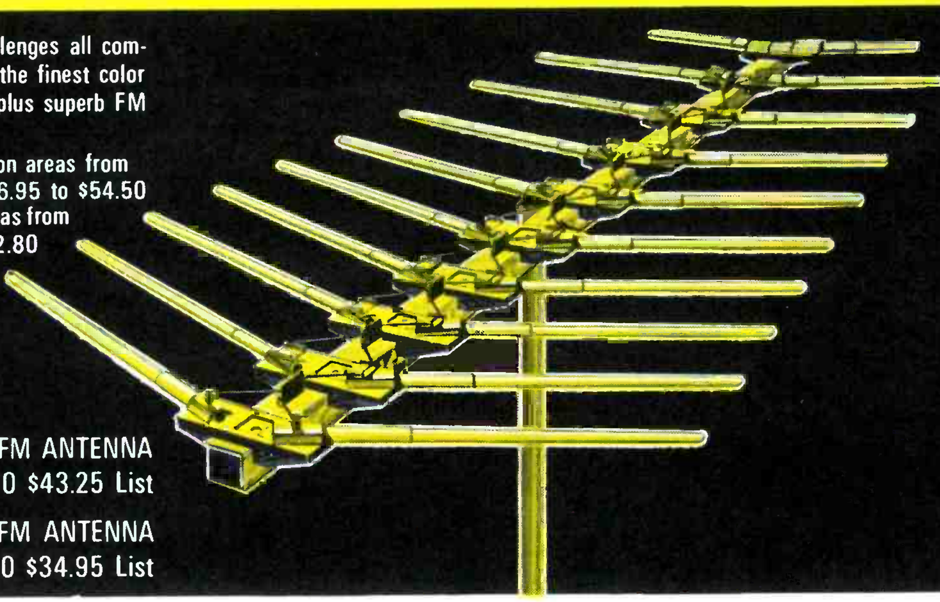

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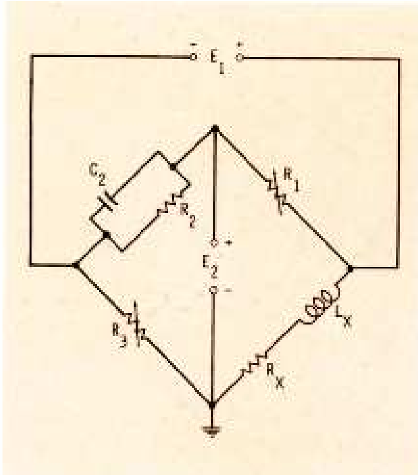

Fig. 4. Maxwell inductance bridge.

value of the third resistive arm, or capacitor, usually in cascade steps.

A bridge circuit of this type is illustrated in Fig. 4. Either R_1 or R_3 may be calibrated to read inductance directly, while quality is indicated by the R_2 value needed for balance.

When using Maxwell's inductance bridge for measuring inductors having high values of Q, it is necessary that R_2 be capable of assuming very large values. It is sometimes difficult to obtain calibrated variable resistors having the necessary range, thus Hay's inductance bridge (Fig. 5) can be used instead. In this circuit, the resistor is placed in series with the capacitor, instead of in the parallel arrangement utilized in the Maxwell circuit. This permits an inductor with a high Q to be balanced by a relatively low value of R_2.

Frequency Measurements

In addition to measuring impedance, bridge circuits are also employed for measuring the frequency of an applied signal. A bridge circuit used for this purpose is arranged so that its balance is largely dependent upon frequency.

A Wien bridge circuit for measuring frequency is shown in Fig. 6. This circuit differs from the Wien capacitance bridge in that C_4 is shunted with a low value of resistance to minimize the frequency-dependency of the null.

If all resistors are made variable, use of this bridge becomes very

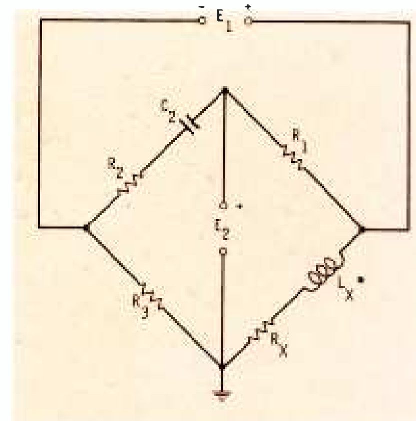

Fig. 5. Hay inductance bridge.

complicated. To simplify the operation, it is customary to fix the ratios R_3/R_4 and C_4/C_3. A common arrangement employs equal capacitance values for C_3 and C_4, while R_3 and R_4 are maintained at equal values by utilizing two variable resistors on a common shaft, with R_2 being equal to twice R_1.

To permit the obtaining of a sharp null, despite slight inaccuracies in component values, a low-resistance potentiometer is often inserted between R_1 and R_2. This in-

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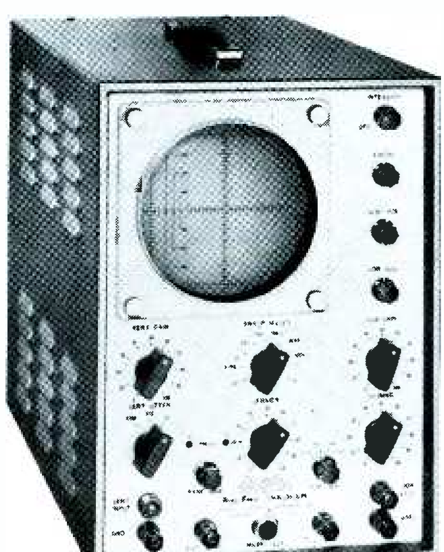

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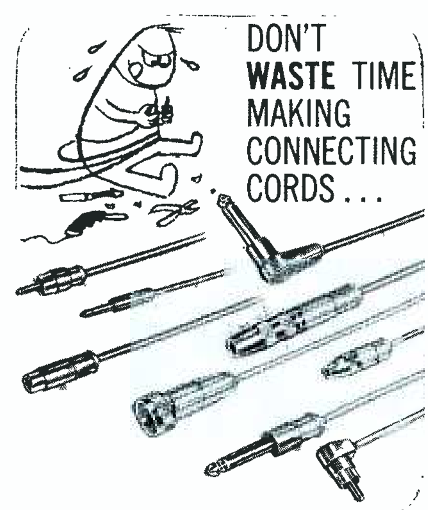

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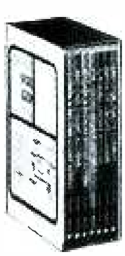

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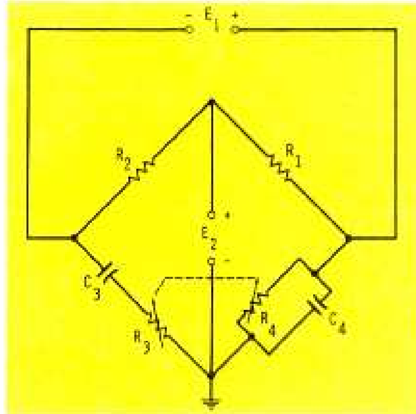

Fig. 6. Wien frequency bridge.

sures sharp frequency discrimination without introducing appreciable error. Where a wide range of frequencies must be measured, the range of the bridge may be extended by simultaneously switching the values of C_3 and C_4.

Comparing Voltage

A half-bridge circuit is useful for the comparison of two voltages. This circuit (Fig. 7) is often used in conjunction with balanced transducers which, in their normal state, have equal voltages developed across their two sections. In such an application, use of the bridge cancels out the quiescent component of the signal.

The application of a mechanical input to the transducer causes voltages to change in opposite directions, with the difference between them appearing at the output terminals. Alternately, the balance of the system can be restored by changing one or both resistors, while the value of input is determined from the amount of change required to restore the null condition. When this technique is used, the two resistors are replaced by a calibrated potentiometer from whose wiper the output is taken. ▲

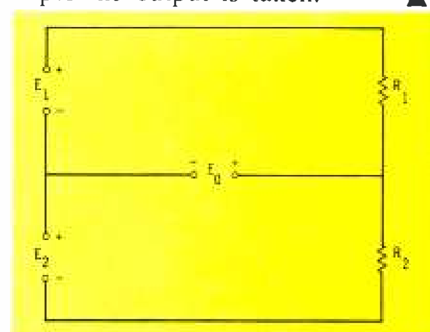

Fig. 7. Half-bridge circuit.

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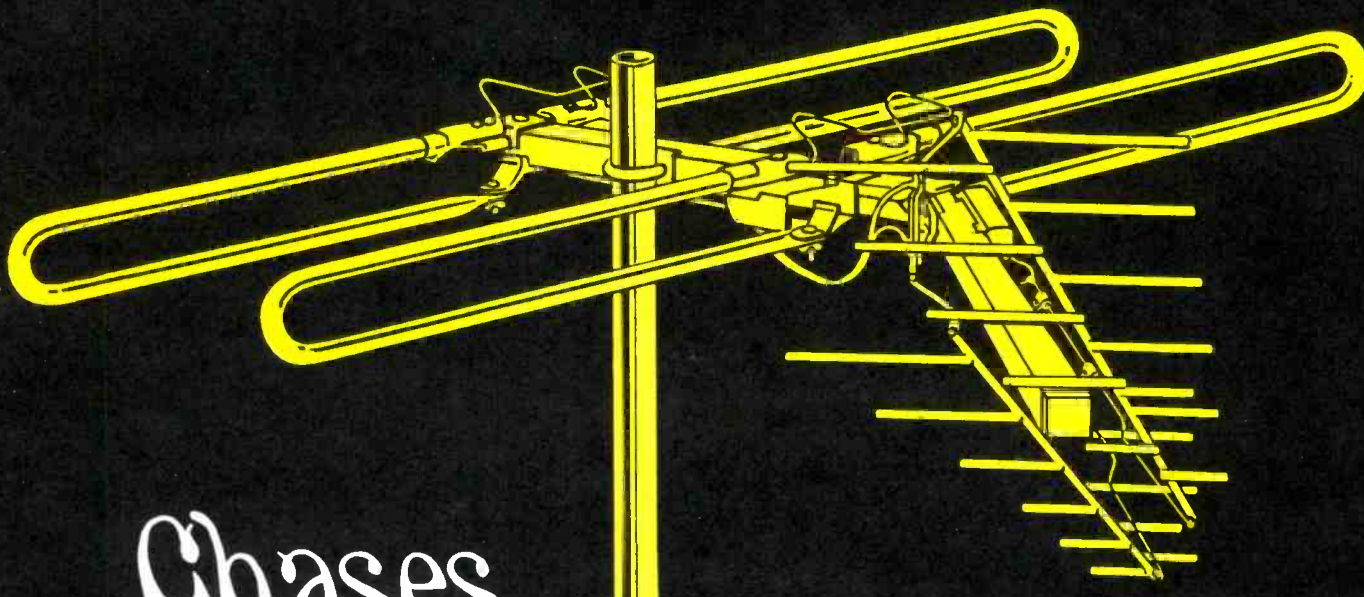

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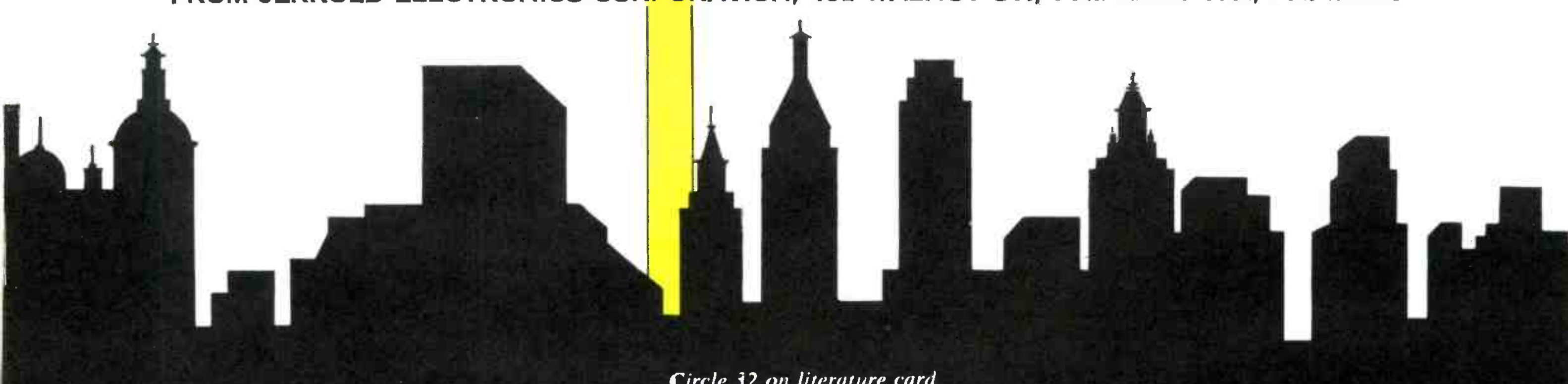

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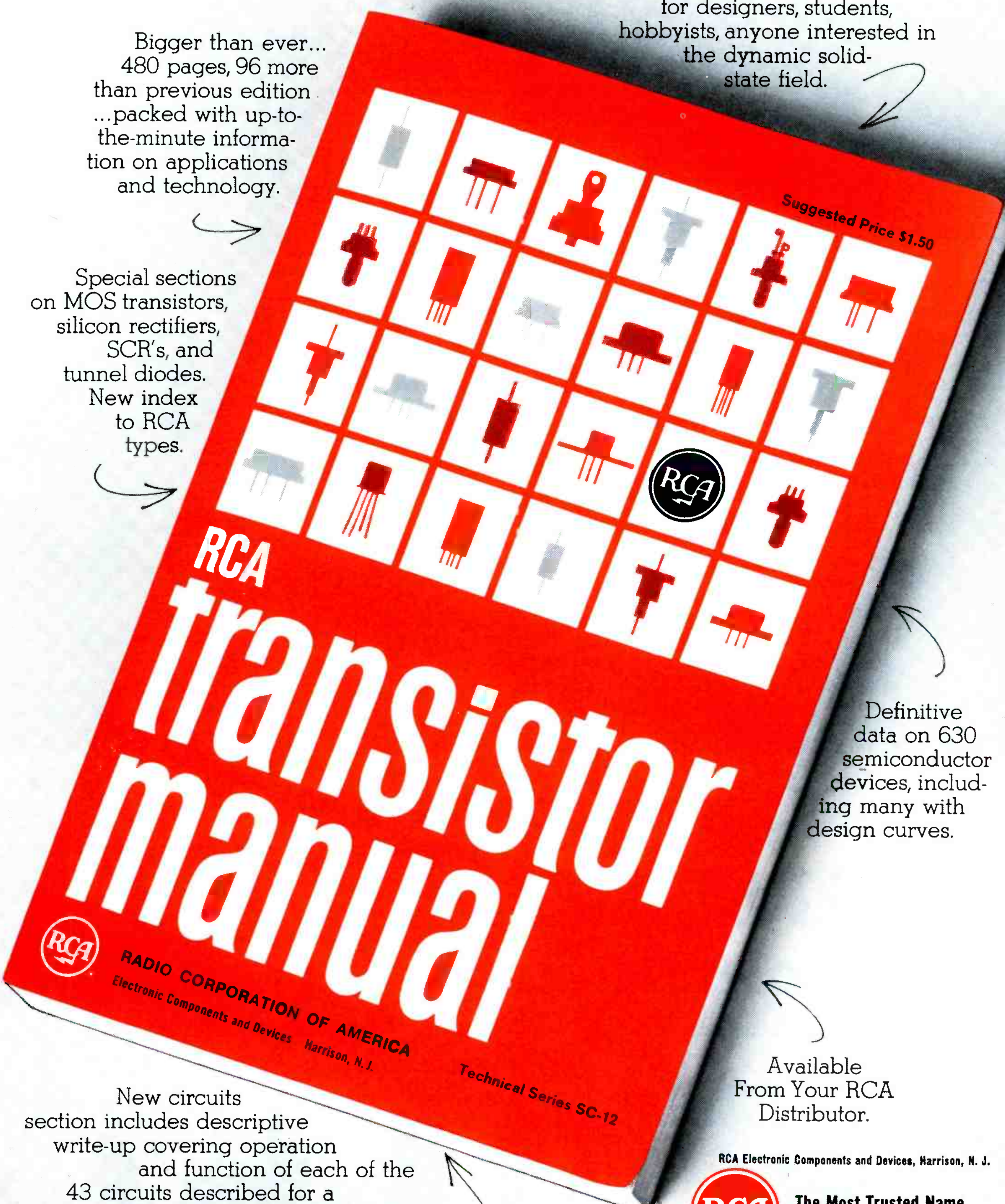

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Maintaining Vibration

(Continued from page 23)

when you will be "stuck." At those times, you should plan to telephone the service department of the equipment manufacturer for assistance in locating and fixing the difficulty; this help will be cheerfully given. Once in a great while, your customer will have to arrange for a field service man to come and bail you out; but these events will be rare. If you were not taking care of their equipment, your customer would have to pay for many more such trips.

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There is danger both in undercharging and in overcharging. If you undercharge, you will not be adequately paid for your time. If you overcharge, you may not make a sale. Shaker manufacturers charge around $100 per day for their field engineers, plus travel and living expenses. A relatively minor repair on a shaker system in a smaller town, remote from a major airport and from the shaker manufacturer, can cost $500 plus parts. Here is your main advantage—you are already nearby. The customer's tests are not delayed several days waiting for the field man to arrive.

You can do quite well at $10 to $12 per hour. You should ask for at least a 6-month contract that will guarantee you at least $100 per month. This will compensate you for the time required to familiarize yourself with their particular system, in the unlikely event that no troubles occur.

You should agree on what parts will be stocked, and by whom. You should also agree as to which of you will order special parts as required (output tubes, for example, can run $800 apiece).

Conclusion

A competent electronics technician can quite easily understand the functioning of an electromagnetic shaker system and its associated instrumentation. He can materially help nearby aerospace firms and laboratories by assisting with the maintenance of this equipment, and can add considerably to his income at the same time. ▲

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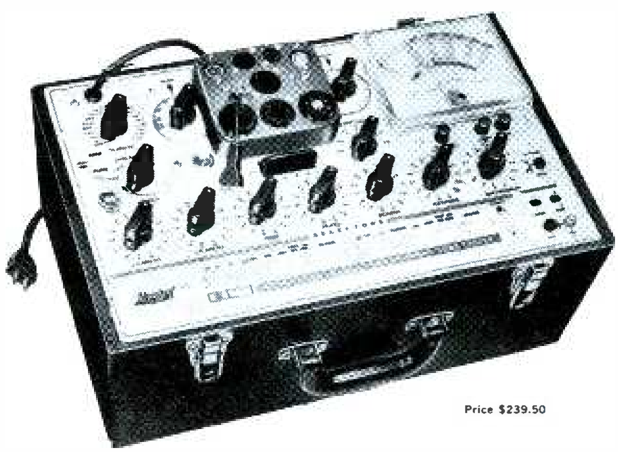

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Milestones

(Continued from page 25)

Fig. 5. Andrea TV receiver of 1938.

RCA went on the air in New York with electronically scanned transmission. Philadelphia and Los Angeles soon followed. The Don Lee Broadcasting Company started a daily schedule of broadcasts using 300-line, 24-frame pictures.

In 1936, BBC in London commenced a regular schedule with a 405-line scan, the same system in use today on its VHF channels. TV was better accepted in London than in America. People started building and buying receivers, and the industry was highly developed at the start of World War II. There were over 20,000 receivers in use by September 1939. BBC suspended operations at the start of the war, but was soon back in business following the end of hostilities.

By the end of 1936, several TV proposals were before the FCC. The broadcasters wanted a frequency spectrum from about 35 to 85 MHz, and amateur radio operators became concerned over the possibility of losing their 5-meter band. The band was later moved down from 56 MHz to 50 MHz, but the hams did retain the full 4-MHz bandwidth.

Surveys were made to determine whether the public actually wanted TV, and one survey concluded that the average person would watch less than 12 minutes a day. The surveyor thought, however, that if some really good programs were broadcast, the viewer might watch for as long as a half-hour.

Some hams built receivers to watch the experimental broadcasts, and at least one company offered receivers in kit form. RCA published a 3-page advertisement in a 1938 edition of a ham journal discussing the problems of TV development. The ad invited hams to help develop the industry, as they had helped radio, and offered kinescopes for sale. The 5" Model 1801 CRT was priced at $40. This was at a time when the average service technician earned $30 a week.

The set shown in Fig. 5 is one of the first commercial receivers of 1938. An interesting feature is the lack of vertical and horizontal controls on the front, although the set does have a focus control on the front panel. Incidentally, the set is still operating.

In April 1939, RCA started a regular schedule of TV broadcasts. The opening was marked by an address by David Sarnoff from the New York World's Fair. On August 26 of the same year TV viewers saw the Brooklyn Dodgers play the Cincinnati Reds in the first televised pro baseball game.

CBS demonstrated a working color-TV system the next year, and even did some experimental color broadcasts over W2XAX in New York. Another New York station, WCBW, ran daily broadcasts using

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this system in 1941. Baird then demonstrated a 3-D color-TV system. It was developed to the point where the viewer did not need special glasses to view the stereoscopic effect. Commercial telecasting was finally given the green light July 1, 1941. WNBT, New York, was the first commercially licensed station on the air.

The scanning standard was raised from 441 lines to 525, and the sound changed to FM. Hundreds of receivers were returned to factories for modification to the new standards, and in many cases this was done free of charge. Typical receivers of the day had 7- to 10-inch screens. One manufacturer shipped CRT's in a separate carton to minimize possibility of breakage.

The outbreak of WW II brought curtailment to most TV activity. CRT production converted to radar sets. Most experimental work with TV was directed toward remotely controlled bombers. However, six stations stayed on the air during the war, most of them broadcasting only four hours weekly. Telecasts were used in instruct air-raid wardens and the Red Cross workers, and to conduct War Bond drives. Nevertheless, some sports and entertainment programs were still broadcast, and receivers were donated to military hospitals in the viewing area.

After the war, activity resumed quickly, with 30 station-construction permits in 1946 and 66 in 1947. In 1947 the viewing audience topped one million for the first time when the Louis-Walcott bout was televised. By 1950, 47 stations were on the air, and 109 more were authorized.

The networks were expanding over the country and finally reached coast to coast in 1951. President Truman opened the cross-country link speaking from San Francisco.

The same year, the FCC approved the field-sequential color system. CBS started colorcasting on a regular schedule June 25, 1951. Some receivers were built and sold for this system, but material shortages caused by the Korean war forced suspension of color transmission on Oct. 5, 1951. The FCC approved the present color system Dec. 17, 1953, and regular broadcasts in compatible color began the following January.

The space age has brought new TV milestones at a fast pace. Communications satellites have linked continents, and weather satellites have sent back remarkable photos of the earth. Pictures from the Moon and Mars, sent back via TV, have added much to man's knowledge of space.

Proposals have been made recently for stereo sound in TV. The Russians have announced a 3-D TV system using one picture tube; but there are moving parts involved in the picture display, and evidently the viewer will have to wear special glasses.

A more promising system is the laser display device currently undergoing development. Known as the wave-front-reconstruction method, the system is still in early laboratory stages. However, we can expect to see and hear our TV programs in three dimensions in the not-too-distant future. ▲

just in time for the fm and uhf boom! an all transistorized field strength meter.

THE ALL NEW SENCORE FS134 FIELD STRENGTH METER

Once again, you can turn to the roof tops for a fast dollar in antenna installations. But this time, you can do it the easy way. No more running up and down ladders, locating cumbersome AC extension cords, lugging heavy tube operated field strength meters on the roof, or worse yet, getting the shock of your life from the AC line as you hold onto a soil pipe. Here is a new portable field strength meter to fill your every need in VHF, UHF or FM antenna installations. Many customers want all antennas on one mast thus creating interaction. Here is where the FS134 goes to work. You can optimize antenna location and orientation in seconds. Just connect the antenna, tune in the station and adjust. Self-contained speaker blasts forth the sound from the TV or FM station to insure that you have the exact signal that you are looking for. The FS134 is so light weight (only 9 lbs.) that you can take it with you up the chimney if necessary. Get rid of the assistant at the other end of the transmission line and the needless "yelling" back and forth. Get the FS134 today . . . only **$199.50**

COMPARE TO ANY OTHER FIELD STRENGTH METER AT TWICE THE MONEY

• Sensitivity . . . 30 microvolts ±3 DB on VHF-FM and 30 microvolts ±6 DB on UHF • Sound system sensitive to 5 microvolts for locating and identifying weak stations • Input impedance . . . 300 ohms or 75 ohms • 500 KC band width • Powered by easy to get "C" cells • 4" meter with 2% accuracy calibrated in DB and microvolts.

professional quality — that's the difference!

SENCORE

426 SOUTH WESTGATE DRIVE • ADDISON, ILLINOIS

Circle 37 on literature card

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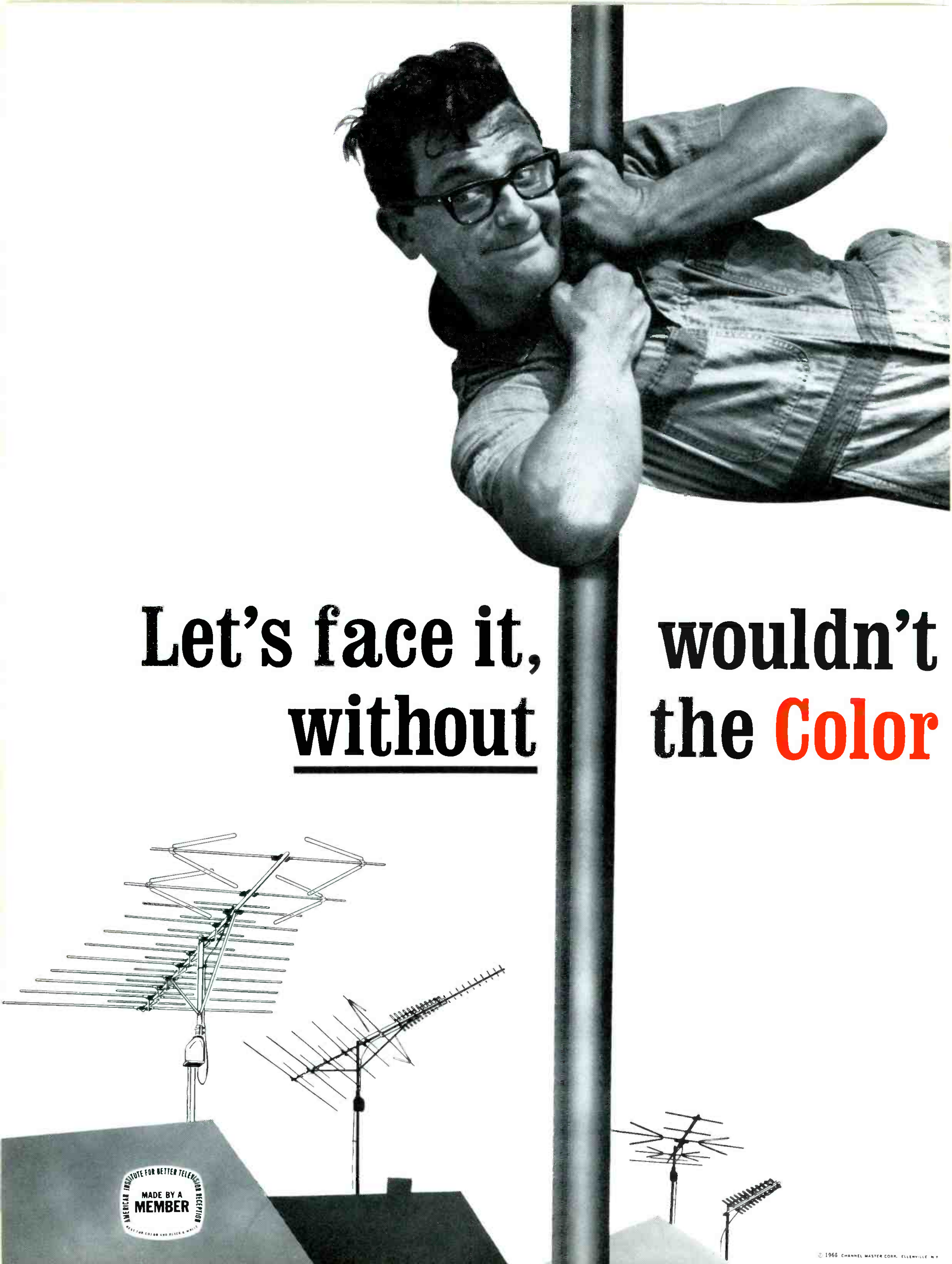

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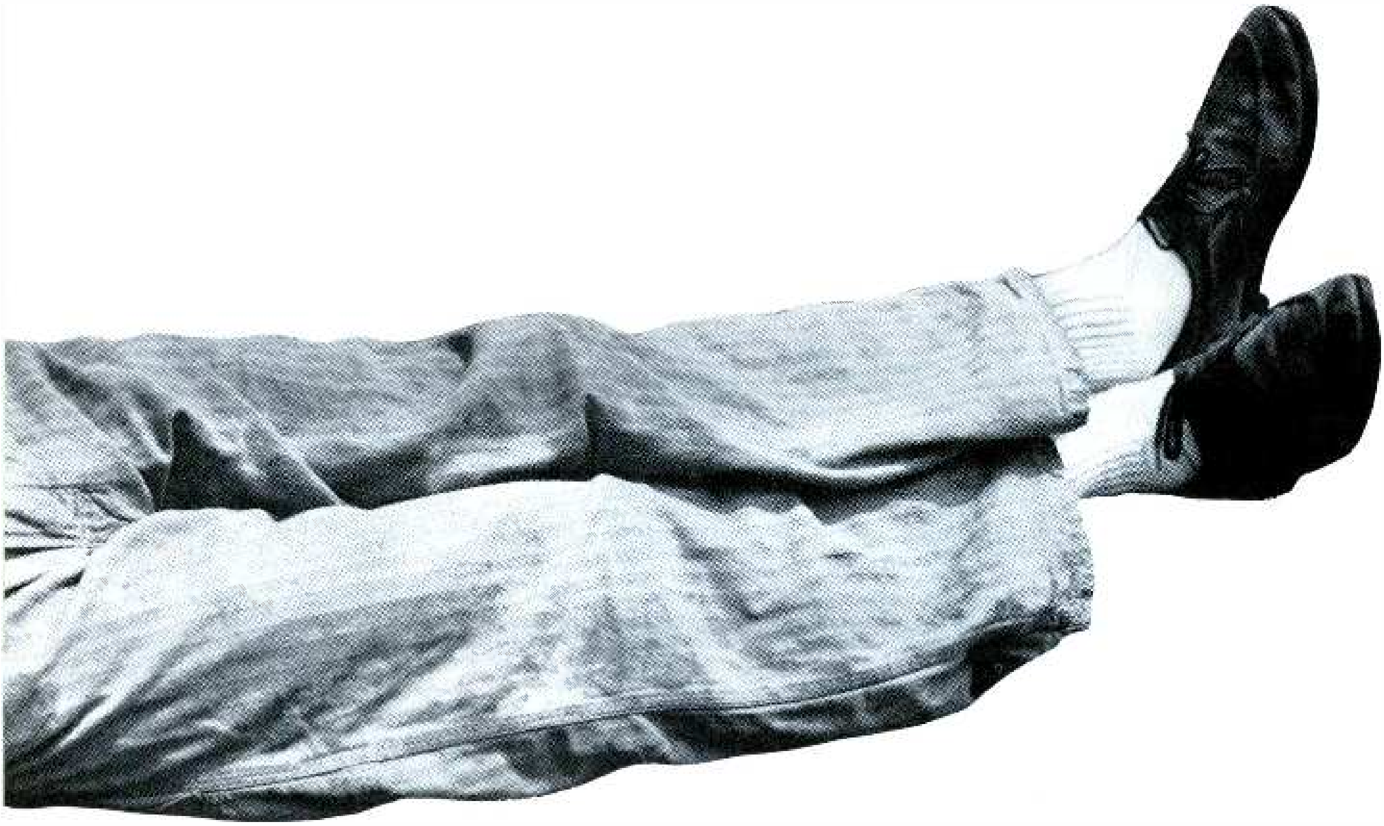


you look silly up there
Breakthrough Antenna?

(Especially when it costs no more)

Channel Master didn't invent color. What we have done is to bring out the best in it. On both the VHF and UHF bands.

We're so much deeper than anybody else in top-calibre color antennas, you'd think we had a patent on the product. We do. 3 patents, in fact, and 2 patents pending.

What it adds up to is a grand total of 20 topline antennas with design so advanced—that they're better than anything anyone has ever made before. Anyone else has to be No. 2 at best—in quality (and sales). And hardly likely to become No. 1—even if they do try harder.

It's our principles that keep us on top. (Our proven Crossfire VHF Proportional Energy Absorption Principle — our proven Coloray Power Equalizer Principle—and our equally proven Ultradyne UHF Principle. To name three.)

What's your area—what's your need? Channel Master meets it with a model from one of three series:

Color Crossfire Series.* The best selling VHF/FM color antennas in history. Top gain and highest possible front-to-back ratio from metropolis to suburbs to deep fringe. Need we say more!

Coloray Series.* The antennas that don't believe in ghosts. They combine the high gain characteristics of the Crossfire with up to 30 to 1 front-to-back ratios.

Ultradyne Series.* Includes Ultradyne Crossfires — the most powerful 82-channel/FM antennas yet developed . . . with 15:1 front-to-back ratio across the entire UHF band. Ultradyne "UHF only" antennas require no coupler when used with any 300 ohm VHF antenna (such as the Crossfire).

All twenty "Color Breakthrough" antennas are built extra-rugged and protected against corrosion by our famous EPC Golden Overcoat.

So while you're up there, mister, make sure you don't let your customer (and yourself) down. Install a Channel Master—and it's 20 to 1 you've picked the right antenna. And when, like us, you get to sell more antennas than anybody else, you can bet it won't be by accident. It has to be by design.

CHANNEL MASTER **The Color Breakthrough Antennas**

Circle 38 on literature card

www.americanradiohistory.com

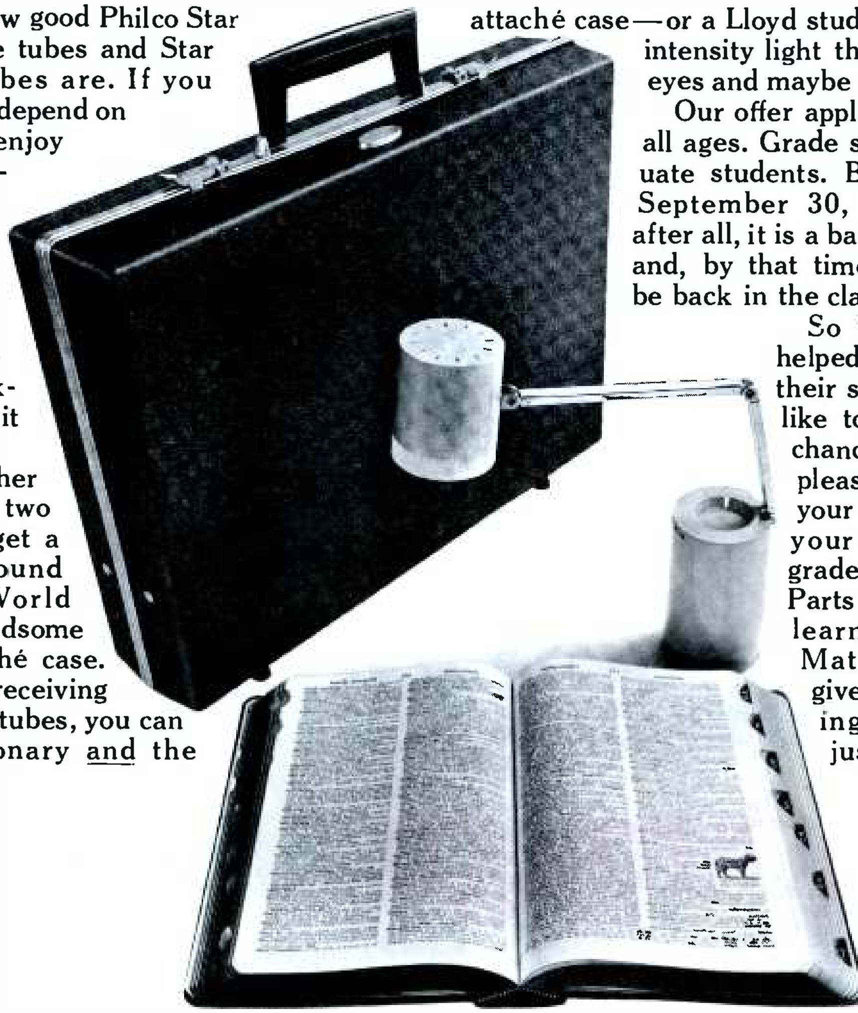
Buy Philco tubes and send your kids back to school brighter.

You already know how good Philco Star Bright 20/20 Picture tubes and Star Light Receiving tubes are. If you didn't, you wouldn't depend on them as you do. And enjoy such outstanding customer satisfaction.

But now, Philco has a way for you to shed some light on another area. Your kids and their schooling. It's a special back-to-school offer, and it works like this.

When you buy either 55 receiving tubes or two picture tubes, you get a free, beautifully bound Webster's New World Dictionary. Or a handsome executive-type attaché case.

If you buy 110 receiving tubes or four picture tubes, you can get both the dictionary <u>and</u> the attaché case—or a Lloyd student lamp, a high-intensity light that's good for the eyes and maybe the grades.



Our offer applies to students of all ages. Grade schoolers or graduate students. But it expires on September 30, 1966, because, after all, it is a back-to-school deal and, by that time, everybody will be back in the classrooms.

So if you've never helped your kids with their studies, and you'd like to, now's your big chance. It'll give you pleasure to know that your business helped your kids make the grades. See your Philco Parts Distributor and learn all the details. Matter of fact, he'll give you a great-looking ball-point pen just for stopping by.

PHILCO®

A SUBSIDIARY OF *Ford Motor Company*

Circle 39 on literature card

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The Troubleshooter

answers your servicing problems

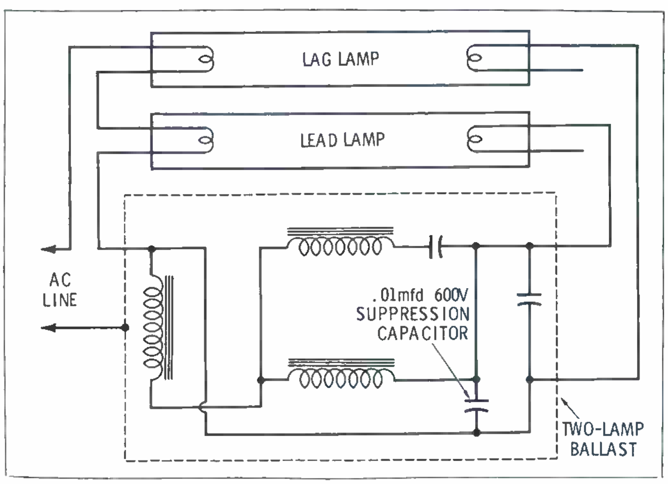
Neon Interference

I am having a problem with interference from the neon lights installed in my shop. They seem to affect car radios in particular. Can you tell me how to reduce or eliminate this interference?

V. K. Glazier

Cedar City, Utah

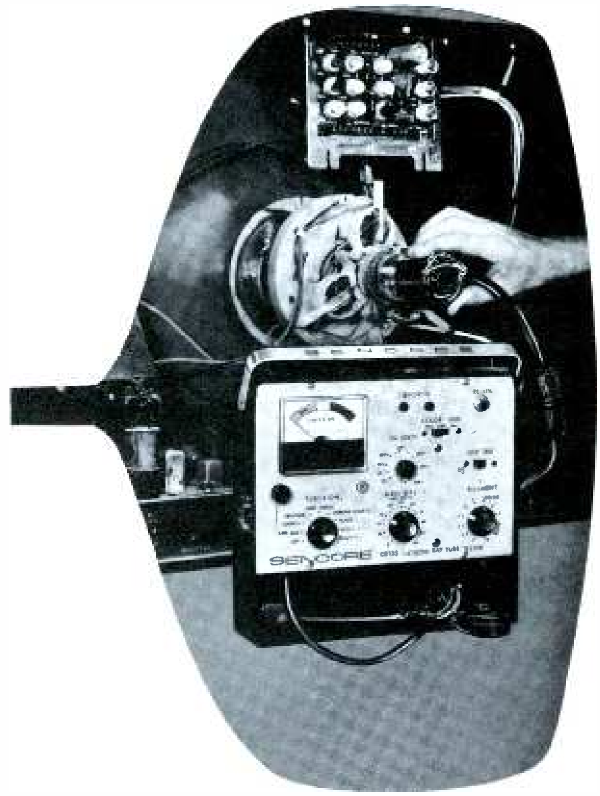
The only positive method of eliminating the random or transient type of interference caused by neon or fluorescent lighting is to replace the neon or fluorescent type with incandescent lighting. Suppression of direct lamp radiation is impractical because adequate shielding would seriously interfere with the normal lighting function of the lamp. However, if the interference is primarily a result of radiation from the lamp's power leads, a 01-mfd, 600-volt feedthrough or bypass capacitor will eliminate or reduce most of the interference. In fluorescent installations employing a starter, the capacitor is placed across the starter leads. For starterless systems, the capacitor is installed in the ballast as illustrated. Additional information on eliminating this and other types of RF interfernce can be found in an article titled "Finding and Curing RF Interference" in the July 65' issue of PF Reporter.



Mica Arcing

I would like to pass on to other technicians my experience with a supposedly impossible situation on a "tough-dog" transistorized auto radio. A Mopar Model 214 (Sams Photofact Auto Radio Series, Volume 19) was brought in because of intermittent operation and static. Checking voltages, I found that the voltages on the RF-amplifier transistor (XI) increased when the radio cut off. Other voltages also varied from normal when the radio cut off. There appeared to be no logical explanation for the voltage variations. Suspecting a bad transistor, I tried substitution, but the trouble persisted. Changing components in what I thought was the affected area proved futile. Checking the output with a scope, I found a large amount of noise riding on the modulated signal. By breaking the circuit to each stage, I isolated the source of the trouble to the oscillator stage. I then began checking components.

top money maker in the service business



NEW IMPROVED SENCORE CR133 CRT CHECKER & REJUVENATOR

The new, improved CR133 CRT Checker is designed to test all present picture tubes — and it's ready for future tubes too! Two plug-in replaceable cables contain all sockets required. The compact, 10 lb., CR133 checks CRT emission, inter-element shorts, control grid cut-off capabilities, gas and expected life. Checks all tubes: conventional B&W, new low drive B&W, round color tubes and new rectangular color picture tubes. Exclusive variable G2 Volts from 25 to 325 Volts insures non-obsolescence when testing newly announced "semi-low" G2 CRT tubes. New Line Voltage Adjustment insures the most accurate tests possible. Uses well-filtered DC for all checks to avoid tube damage and reading errors. Color guns are individually tested as recommended by manufacturers. Exclusive automatically controlled rejuvenator applies rejuvenation (ACR) voltage as required by individual tube condition; precisely timed to prevent over-rejuvenation or tube damage. The ACR feature is most useful for color tube current equalization to insure proper tracking. Hand-wired and steel-encased for protection of meter and panel in truck or shop, the new improved CR133 is only . . . **$89.95**

The famous CR128 CRT Checker and Rejuvenator is similar to above, but with a three position G2 slide switch and without Line Voltage Adjustment at $69.95

professional quality — that's the difference!

SENCORE

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Circle 40 on literature card

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Getting a hernia and not getting paid for it?

Switch to Elmenco dipped Mylar®-paper capacitors and you won't have to worry about call-backs, lost profits, broken reputations or broken anything else.

The only ordinary thing about them is their price.

You get capacitors that meet the requirements of high-reliability computer and missile systems. You get capacitors that hold their rating at 125°C continuous operation. Yet you get them at TV set prices.

Elmenco dipped Mylar-paper capacitors come in just about any value you need from .001 mfd to 1.0 mfd. And just about any TV rated voltage you need, too, from 100V through 1600V.

Ask your Authorized Arco Distributor to put them on your next order. Without fail.

Tell him you're counting on his support.

(While you're at it, ask about other Elmenco types: padders and trimmers; high voltage dipped micas.)

Arco Electronics

A Division of Loral Corporation
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Dallas, Texas, Pasadena, California,
Menlo Park, California.

® DU PONT TRADEMARK

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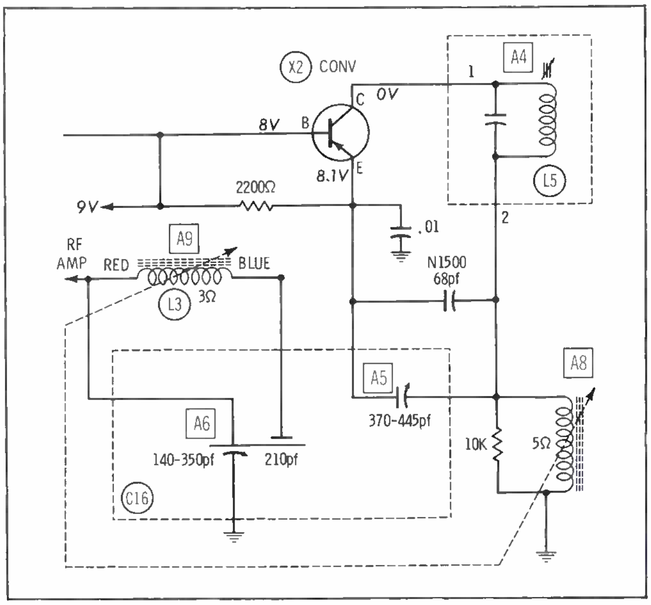
After removing the oscillator adjustment capacitor, dual-section trimmer C16, I discovered that the 8.1 volts on the capacitor had been arcing across the mica, causing the intermittent operation and static. I'm sure that this proves that low voltages will arc just as well as higher voltages, under certain conditions.

GLEN DEIBERT

Burton, S. C.

We can't argue against actual experience. However, you'll have to admit that this is a very unusual situation and was probably the result of a combination of contributing factors that normally are not present in any one circuit at the same time. Such a combination could have been dirt, moisture, and one or two other factors which could have concentrated enough charge on a small area to cause the arc.



Good or Bad Capacitors

I have two triple-section electrolytics (40-30-20 mfd) and one dual-electrolytic (40-40 mfd) that do not show any value at all on a capacitor tester. However, when I checked them with an ohmmeter, they all checked good—meter deflected and came right back. I suspected the capacitor tester at first, but other capacitors of the same type and value as those above provide an accurate indication on it. Based on the foregoing facts, do you think the electrolytics under question are suitable for circuit use.

R. FEOLICH

Canton, Ohio

What you have proven thus far is that the electrolytics are not open. If the ohmmeter returned to a stable reading of 50K ohms or more after deflection, it can be assumed that the electrolytic had a normal amount of leakage when the relative low voltage of the ohmmeter was applied to it. However, when the much higher voltage of a capacitor tester or B+ circuit is applied to the capacitor, the leakage might be much higher, or even excessive. In your case, the capacitor tester is providing a more accurate indication of the condition of the capacitors.

A two-part article in the May and June '66 issues of PF REPORTER *titled "Leave Those Parts in the Circuit" provides some interesting and valuable information on testing capacitors.* ▲

FAMOUS ZENITH QUALITY TUBES for greater reliability, longer life

TV Picture Tubes

A complete line of more than 200 top-quality tubes. For color, black-and-white, or special purposes.

"Royal Crest" Circuit Tubes

A full line of more than 875 tubes . . . the same quality tubes as original Zenith equipment. Your assurance of the world's finest performance.

Zenith black & white replacement picture tubes are made only from new parts and materials except for the glass envelope in some tubes which, prior to reuse, is inspected and tested to the same high standards as a new envelope. In Color tubes the screen, aperture mask assembly and envelope are inspected and tested to meet Zenith's high quality standards prior to reuse. *All* electron guns are new.

Order all genuine Zenith replacement parts and accessories from your Zenith distributor.

BUILT TO THE QUALITY STANDARDS OF ZENITH ORIGINAL PARTS

ZENITH®

The quality goes in before the name goes on®

Circle 42 on literature card

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at last...
instant color patterns
at your finger tips...
zero warm-up time

THE ALL NEW SENCORE CG135 DELUXE TRANSISTORIZED COLOR GENERATOR

The big push is on in Color TV. Equip yourself now with the new, solid state Sencore CG135 and cash in on the zooming volume of new service business as Color-TV booms! Instant, service-ready RCA standard color bars, cross-hatch, white dots and individual vertical and horizontal bars enable you to set up or trouble-shoot more Color TV sets per day; earn top money in this fast growing service field. It's an analyzer too: Color gun interruptors, unmodulated video for chroma circuit trouble isolation and unmodulated sync pulses to keep Zenith receivers in sync for this test, make color trouble shooting a snap. Sturdy all-steel contruction for rugged, heavy duty in the field or shop. Another Best Buy in profit-building service instruments from Sencore at **$149.95**

COMPARE THESE FEATURES: SEE WHY THE CG135 IS IN A CLASS BY ITSELF

• Solid state construction employs high priced GE "Unijunctions" to develop six "jump out proof counters" that guarantee stable patterns at all times with no warm-up • Standard RCA licensed patterns as shown on schematics throughout the industry • Handy universal color gun interruptors on front panel • Lead piercing clips insure non-obsolescence • CRT adaptors optional • Crystal-Controlled 4.5mc Sound Carrier Analyzing Signal to insure correct setting of fine tuning control • RF output on Channel 4 adjustable to Channel 3 or 5 from front of generator when Channel 4 is being used • No batteries to run down; uses 115 V AC • Less than one foot square, weighs only 8 lbs.

professional quality — that's the difference!

SENCORE

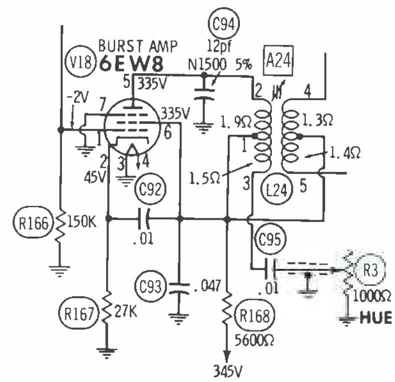
426 SOUTH WESTGATE DRIVE • ADDISON, ILLINOIS

Circle 43 on literature card

COLOR COUNTERMEASURES

Symptoms and tips from actual shop experience.

Chassis: Zenith 25MC36 (most Zenith color chassis)
Symptom: Color sync weak or lost altogether.
Tip: Check for intermittent C92 and C93 in screen grid circuit of burst amplifier.



Chassis: Zenith 25" using yoke No. 95-2286
Symptom: Ringing, especially in red field.
Tip: Check connection of heavy orange wire where it enters the yoke plug.

Chassis: General Electric Chassis CB
Symptom: Tint control has insufficient range.
Tip: Replace tint control trimmer capacitor with a 5K potentiometer. For 21" chassis use GE part ET 45X599. For 25", use GE part ET 49X600. Peak subcarrier circuits.

Symptoms: Circuit breaker kicks out instantly. Usual B+ circuit check OK.
Tip: Check heater circuits on Damper and HV regulator for short to ground. B+ is applied here to help prevent flash-over.

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get with it!

YOU CAN'T SOLVE TODAY'S COMPLEX ALL-CHANNEL COLOR & BLACK/ WHITE TV RECEPTION PROBLEMS...

SNOW

SMEARING

INTERFERENCE

WITH YESTERDAY'S AMPLIFIERS.

YOU NEED THE: • ADVANCED ELECTRONIC DESIGN • SOLID STATE RELIABILITY • COLOR CAPABILITY • SEALED PRINTED CIRCUITRY • SIGNAL SPLITTING VERSATILITY OF THE SPACE AGE DESIGNED **JFD COLOR-TELE-AMP**

Buy 2 get 1 Free!

JFD® COLORTELE-AMP AMPLIFIER DEAL

NO—we haven't flipped our lid.
We just want to prove to you that JFD ColorTele-Amps are the best amplifiers you can use.

That's why we're giving away FREE **one** ColorTele-Amp with every **two** you buy from your distributor.

We know that when you see the amazing on-the-job performance our ColorTele-Amps deliver, you'll be coming back for more.

So clip out the coupon below, fill it out and take it to your favorite JFD distributor to get your FREE ColorTele-Amp. He has a wide selection of indoor and outdoor ColorTele-Amps to suit any and all of your reception requirements.

available in two models for

1. Outdoor installation on any antenna where highest possible noise-free gain is the primary need.
2. Indoor use anywhere in the home where convenience of single self-contained amplifier/power supply/signal splitter is preferred.

No. 1

Outdoor Amplifiers

VUT-3, VUT-3TF, VN-2, VT-2, VT-275, VT-1, UHT-2, FT-1, FT-175

No. 2

Indoor Amplifiers

HVU-3, HV-2, HV-1, HU-2, HF-1, EV-1, EF-1

TAKE ME TO YOUR DISTRIBUTOR FOR FREE COLORTELE-AMP AMPLIFIER!

Attention: ColorTele-Amp Dept.

JFD Electronics Co.
15 Avenue at 62nd Street
Brooklyn, New York 11219

JFD® COLORTELE-AMP CERTIFICATE

GOOD ONLY AUGUST 1—SEPTEMBER 30, 1966

THIS SPACE MUST BE FILLED IN BY SERVICE-DEALER.

Store Name ....

Street ....

City .... Zip Code ....

State ....

Service-Dealer Signature

....

Distributor Counter-signature

....

NOTE TO SERVICE-DEALER

1. Fill in (please print) your name and address in space provided.
2. Present this certificate to your **JFD** distributor at time of purchase of two ColorTele-Amps—and get one **FREE** (of the same model).
3. Only one certificate may be applied to each purchase. Void where prohibited, taxed or otherwise restricted.

NOTE TO DISTRIBUTOR

TAKE ADVANTAGE OF OUR SPECIAL "ONE-FREE FOR TWO" COLORTELE-AMP OFFER TO DISTRIBUTORS.

1. Be sure you've got ColorTele-Amps in stock. Order 48 or more of any one or two of the models listed above and get **24 FREE.** Call your **JFD** representative or write us direct for immediate delivery.
2. Countersign the filled out certificate when redeemed by your dealer and mail to us so we can pay you 50 cents for handling.
3. Offer ends September 30, 1966.

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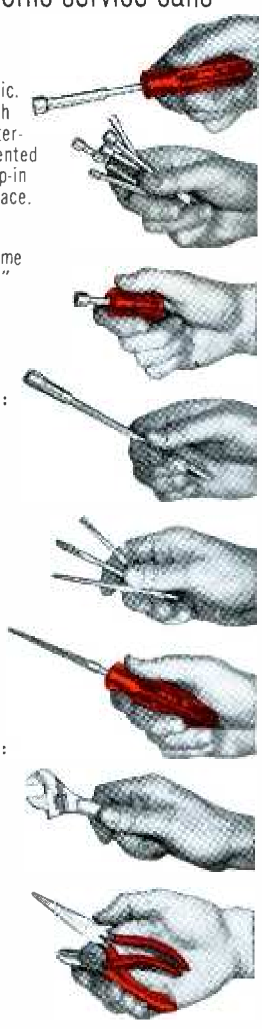
SERVICE MASTER...

EVERY TOOL YOU NEED 99% OF THE TIME

complete 23-piece kit for radio, TV, and electronic service calls



2 HANDLES: shockproof plastic. Regular 4" length . . . 2" Stubby. Interchangeable. Patented spring holds snap-in tools firmly in place.

9 NUTDRIVERS: High Nickel chrome finish, 3/16" to 1/2"

3 STUBBY NUTDRIVERS: 1/4", 5/16", 3/8"

EXTENSION BLADE: Adds 7". Fits both handles.

3 SCREWDRIVERS: Two slotted . . . 3/16", 9/32" #1 Phillips

2 REAMERS: 1/8-3/8", 1/4-1/2"

ADJUSTABLE WRENCH: 6" thin pattern, 1" opening

LONG NOSE PLIER: "Cushion Grip", 2 1/4" nose

DIAGONAL PLIER: "Cushion Grip" hand-honed cutting edges

ROLL UP KIT: Durable, plastic-coated canvas. Compact, easy-to-carry.

Ask your distributor to show you kit 99 SM

XCELITE

XCELITE, INC., 18 Bank St., Orchard Park, N. Y. 14127

Circle 46 on literature card

Product Report

For further information on any of the following items, circle the associated number on the Catalog & Literature Card.

Digital Voltmeter

(135)

A transistorized digital voltmeter, reading from .001 to 999 volts DC and accurate within .1% of reading (± 1 digit), is announced by **Simpson.** It is equipped with a high-brightness, seven-bar, numerical display and can be used as a readout device or analog-to-digital converter for a broad range of electrical transducers. Optional features include an AC input converter and a binary output. Price of the basic unit is $500.

Audio Amplifier

(136)

A new solid-state audio amplifier, designed especially for broadcasting, commercial sound, high fidelity, and other low-power applications, is now available from **Round Hill Associates, Inc.** Seven transistors and one thermistor are used in Model AA-200. Other circuit features include a shielded input transformer which permits use with 50- to 150-ohm, low-impedance microphones, and an output transformer with 8-ohm and 500-ohm windings capable of delivering 200 mw of undistorted audio power.

The unit has a frequency response of ± 1 db, 20 to 20,000 hertz and harmonic distortion of less than 1%. A gain of over 80 db makes the unit suitable for use with low-level microphones or other low-level pickups, such as surveillance devices and telephone pickups. The output of the amplifier can also be used to drive a larger power amplifier in applications in which many loudspeakers are needed. The unit draws approximately 100 ma under full load and can be operated from any 9-volt DC source. Power supply Model PS-220 is offered as an accessory and can be used to operate two AA-200 amplifiers.

Housed in a brown enamel steel case, the amplifier measures 9" x 2 3/4" x 3 1/4" and weighs 28 ounces. A locking-type volume control is mounted on the case. A barrier strip is used for all connections. The unit is priced at $34.50.

Portable Amplifier Modules

(137)

A portable electronics line called Irectronics has been developed by **International Rectifier.** The line includes a

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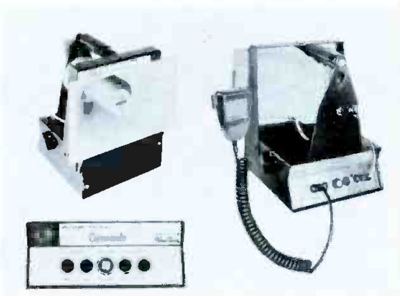
portable guitar amplifier, public-address amplifier, remote photoflash slave, transistorized boat/signal horn, loud-hailer/electronic megaphone, and danger blinker beacon.

Each of these portable modules snaps onto a universal battery adapter that serves as a housing for either a 6-volt lantern battery or four "D" cell batteries—as well as serving as a carrying-case and cabinet for the system. Only one universal battery adapter is needed for all six portable projects.

The portable electronics line also includes a complete selection of accessories for completing the various projects. Prices range from $5.95 to $9.95.

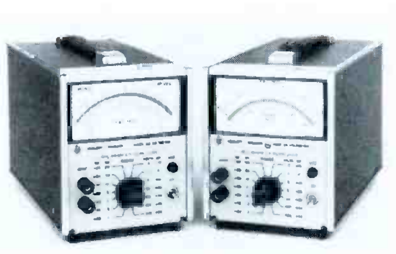


Solid-State Megaphone

(138)

This new 25-watt, solid-state megaphone provides clear intelligible sound up to half a mile away. The Commando is a complete battery-operated, portable public-address system. Included in the **Perma-Power** unit are an all-transistor amplifier, a weatherproof horn speaker, a noise-cancelling hand-held microphone, and a hand grip and shoulder strap. The megaphone weighs 16 lbs. with batteries, and uses ordinary "D" flashlight cells. The battery pack of 10 "D" cells will normally provide a full year of service. Alkaline batteries will last even longer.

Designed especially for outdoor applications, the weather-resistant unit can be used for many training, communications, and recreational purposes. The hand-held microphone is detachable from the horn, allowing the megaphone to be used without blocking the user's field of vision. Price of the unit is $129.95.



Voltmeters

(139)

These two voltmeters, Models 400F and 400 FL, are the newest of **Hewlett-Packard's** 400 series of AC voltmeters. Both models have 100-uv full-

3 more features —all new

Here is RCA's new WR-50B RF Signal Generator—wired or kit. It looks just like the old WR-50A, but the resemblance ends there. It has all the features you liked in the older model...plus 3 new ones you'll find in red below:

- Wide frequency range from 85kHz to 40MHz in 6 overlapping ranges plus harmonics for higher frequencies
- Built-in crystal calibrating oscillator circuit with front panel crystal socket
- Internal 400 Hz audio oscillator
- *NEW—Sweep output at 10.7 MHz with return trace blanking for sweep alignment of FM receivers*
- *NEW—Sweep output at 455 kHz with return trace blanking for sweep alignment of new transistorized AM radios*
- Individual inductance and capacitance adjustments for each range
- Modulation level control
- Two-step RF attenuator switch plus a continuously-variable attenuator control
- *NEW—additional switch for further attenuation of crystal oscillator output*
- The Optional Distributor Resale Price is only $65.00. Kit Form, $45.00, includes pre-assembled range switch with pre-aligned coils and trimmers. See the RCA WR-50B at your authorized RCA Test Equipment Distributor.

RCA ELECTRONIC COMPONENTS AND DEVICES, HARRISON, N. J.

RCA®

The Most Trusted Name in Electronics

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CDE's Ten Series Rotor Helps Give The Truest Urban/Suburban Color TV Reception!

Green sky, purple people and brown water...help your customers avoid these with CDE's 10 series rotor. The 10 is the most rugged lightweight on the market...the first rotor system designed specifically for metro-suburban areas.

It's *dependable*...because of a weatherproof die-cast housing. *Better-performing*...because of a high-torque motor with heavy wormgear drive. *Longer-lasting*...because of heavier-than-average construction throughout.

And see the built-in antenna mounting mast? It's there to prevent mistakes: the 10 series can *only* be fitted to antennas it can control.

Available in both automatic and manual forms, the 10 series rotor means the very best in color and black and white TV reception. Goes great with FM rigs, too!

CDE CORNELL-DUBILIER

Don't forget to ask them: What Else Needs Fixing?

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scale ranges and 10-megohm input impedance. An AC output produces 1 volt rms for full-scale deflection, regardless of range and use; on the 100-uv range, the amplifier has 80-db gain with less than 5-uv noise. The frequency range of the instruments is 20 Hz to 4 MHz. The accuracy of the 400F is ±0.5% of full scale ±0.5% of the reading. The 400FL accuracy is ± 0.5% of full-scale ±1% of the reading. Model 400F presents a linear voltage scale on the uppermost portion of the meter, while the Model 400FL presents a linear db scale on the uppermost portion of its meter.

Both instruments are capable of measuring voltage gains up to 144 db over five decades of frequency range. Internal noise, referred to the input, with a 100-kHz bandwidth, is typically 3 uv.; thus, signals as low as 10 uv can be measured with 10% accuracy. A front-panel control engages a 100-kHz low-pass filter to eliminate the error-producing effects of high-frequency voltages when low-frequency measurements are being made.

The gain of the built-in amplifier and the sensitivity of the instrument make it useful as a calibrated high-gain preamplifier for oscilloscopes, bridge detectors, and other devices. The unit's sensitivity also makes it possible to connect a calibrated microphone directly to the input terminals when making acoustical measurements. Models 400F and 400FL are priced at $275.00 and $285.00, respectively.

Switch Modules
(140)

New miniature and subminiature switch modules with contacts rated at up to 15 amperes have been announced by **Switchcraft.** Called "Piggy-Back" Snap-Switch Modules, these high-current switches can be used for controlling electric motors and solenoids, and as primary power control switches in a wide variety of test equipment, control panels, and industrial devices. Six types of modules are available for use with series 35000, 36000, and 37000 "Multi-Switches."

The miniature modules (rated at 15 amps, ½ hp, 125/250 VAC) have a single-pole switching action and can be mounted singly or in pairs on each multi-switch. Single miniature module, part No. 83SA, can be used for all switching functions except push-to-lock/push-to-release. Part No. 803SA can be used on multi-switches with push-to-lock/push-to-release switching functions.

Subminiature modules (rated at 10 amps, ¼ hp, 125 VAC) are available with either single-pole or double-pole switching actions. As many as four units may be used on each multi-switch station. Single module, part No. 83SC, can be used for all switching functions except push-to-lock/push-to-release. Part No. 803SC is designed for push-to-lock/push-to-release functions only. Part No. 83SD and 803SD serve the same functions as Part No. 83SC and 803SC, respectively, except 83SD and 803SD are double modules.

Part No. 83SA and 803SA are priced at $2.50 each, 83SC and 803SC are $4.50 each, and 83SD and 803SD are $8.00 each.

Public Address Amplifiers
(141)

The 30-watt amplifier shown here is one of a series of six solid-state, public-address amplifiers announced by **Bogen Communications.** The MTA series offers amplifiers ranging from 10 to 100 watts. Silicon transistors, low-impedance microphone inputs requiring no transformer, built-in protection against shorted or

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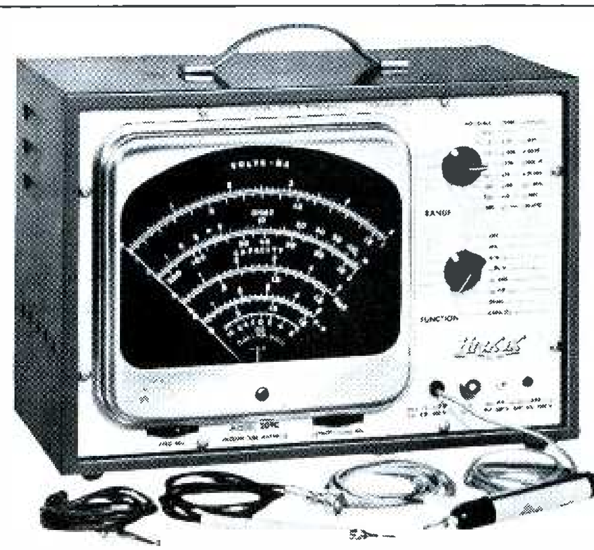

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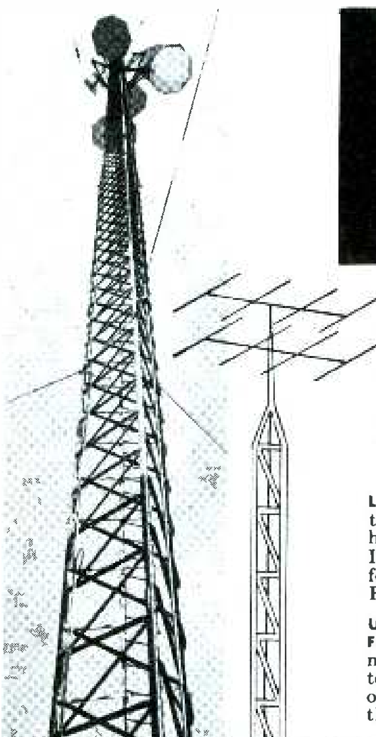

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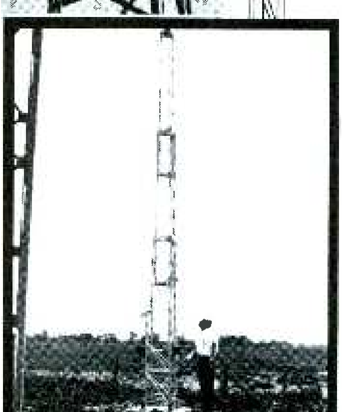

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open speaker lines, and a complete accessory line are features of the series. Other features include plug-in circuit board, and chimney-type heat sinks and heat-sensing "thermoguards" which permit safe and continuous operaton up to 158°F. The MTA30 (shown here) and MTA60 amplifiers, as well as the MTM mixer-preamplifier, have provisions for multiple microphone inputs. The volume of the inputs can be remotely controlled.

Accessories for the MTA series include manual phonograph tops, carrying cases, plug-in transformers and magnetic cartridge modules, rack panel kits, control-guard locking plate, stand-by controllers, remote volume controllers, and a plug-in component for microphone precedence. A plug-in limiter for the mixer-premaplifier is also available. Model MTA10 (10 watts) is priced at $124.90; Model MTA30 (30 watts), $199.85; Model MTA60 (60 watts), $249.90; MBT60 (60-watt booster amplifier), $187.35; MT100 (100-watt booster amplifier), $349.90.

Portable VOM
(142)

A new portable volt-ohm-milliammeter, Model 630-APLK, with a transistorized switching circuit, guards against accidental burn-outs and provides comprehensive overload protection. It virtually eliminates bent pointers and burned out resistors, shunts, and coils—and changes in accuracy due to overheating.

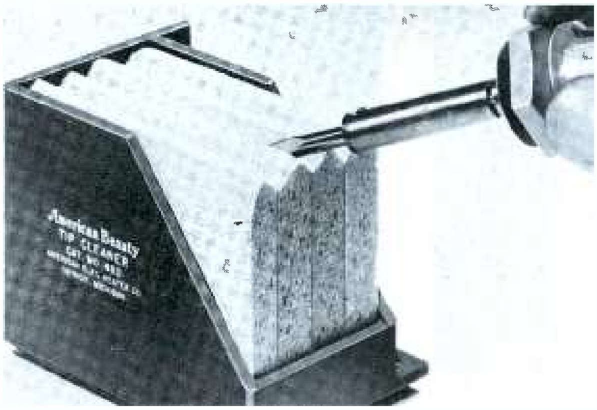
Featuring a sensitivity of 20,000 ohms-per-volt DC and 5,000 ohms-per-volt AC, the **Triplett** VOM has an accuracy of ±1½% DC and ±3% AC guaranteed in horizontal position. The unit is usable with frequencies through 500 kHz. A single, easy-to-read selector switch minimizes chances of error when changing ranges, and a mirror-backed scale insures accuracy by eliminating parallax.

The meter, equipped with a polarity-reversing switch, is protected from stray magnetic fields by a patented self-shielded, Bar-ring magnet movement design. A special diode network across the meter protects the meter movement against instantaneous transient voltages.

A 0-50 microampere meter movement provides consistently reliable meter readings. The transistorized switching-circuit battery, with extremely long life, is easily checked by using the X100-ohms range. The VOM also features flushmounted controls, jacks, and meter, and a special meter shorting feature or "OFF" position for high damping when the tester is in transit.

Weighing 5 lbs., the meter is encased in durable, black molded plastic with a clear, unbreakable plastic scale window and measures 3 11/32" × 5½" × 7½". The VOM comes with batteries, leather carrying handle, 50" banana-type leads, and test prods with removable alligator clips.

A variety of leather carrying cases and an accessory AC ammeter adapter with a long-lead attachment are available for the unit. Price is $95.00.



Tip Cleaner
(143)

A new instrument for the quick cleaning of soldering-iron tips is now being marketed by **American Beauty.** Enabling a one-pass cleaning of the entire tip as it is slipped between wet cellulose sponges, the device (catalog No. 480) serves to eliminate the problems of linting, stray pellets, and tip-plate damage.

The instrument, equipped with a high-impact styrene holder, features a ¾"-deep water well which keeps sponges wet all day.

Measuring 2⅓" × 2¾" × 3½", it has a non-slip rubberized base, bored for bench mounting. Price is $3.00.

Color Generators
(144)

The CG10 LO-BOY is completely solid state and battery operated with a new case design giving the serviceman a portable standard color generator for set-up and convergence work in the field. The timer circuits have been simplified and brought out on the front panel as simple operator's controls. The new timers are adjusted just like the horizontal and vertical hold controls on a TV set. If the timers should ever jump time, they can be touched up right on the TV receiver, rather than returning the generator to the factory for simple timer adjustments.

The new **SENCORE** color generator provides the five basic patterns used in convergence; ten standard type color bars, individual horizontal and vertical lines, crosshatch, and adjustable white dots. A variable interlace control allows for the correction of the interlace on some TV sets thus forming a complete dot for better and faster convergence. The LO-BOY is powered by C cells that are replaceable from the outside of the unit. The battery voltage is regulated to provide maximum stability over the entire life of the batteries. The generator is housed in a laminated-vinyl steel case and is priced at $89.95.

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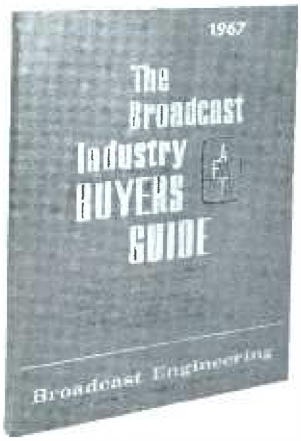

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Broadcast Engineering

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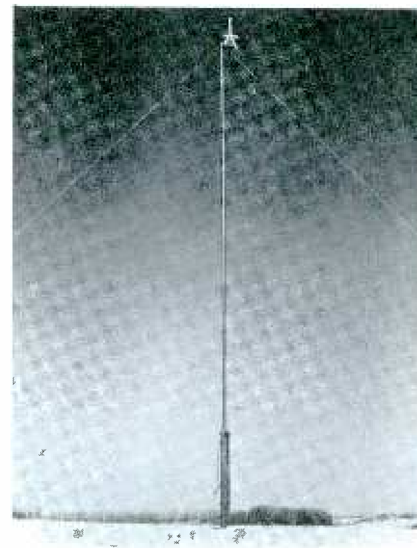
Coil Cross-Reference Catalog
(145)

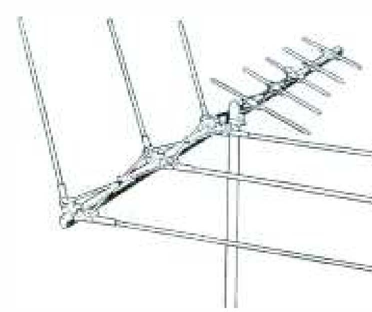
A new cross reference of coil and transformer part numbers used by all manufacturers to **Workman** part numbers is now available. RF chokes and coils, balun coils, antenna coils, oscillator coils, peaking coils, and sound discriminators are listed in catalog No. 103. Also included are horizontal, width, and linearity coils, and IF transformers designed for 44 mHz, 21 mHz, 10.7 mHz, 4.5 mHz, 455 kHz and 262 kHz. There is no charge for the catalog, which is available, upon request, to all radio and TV servicemen.



Transportable Mast
(146)

A lightweight aluminum mast provides rapid installation and support of antennas having a maximum projected area of 16 square feet. The mast consists of a manually operated launcher assembly, 5 foot tube sections to provide a required height up to 50 feet and guying elements.

The **Andrew** masts are available in 35 and 50 foot models and may be completely installed with antenna and RF cable by two men. Weight of the 50 foot mast assembly is 150 pounds.



Urban Antenna
(147)

This compact, log periodic antenna provides uniform directional pickup and is designed for color, b-w, and FM or FM stereo reception in the VHF and UHF frequency ranges. The Model LPV-VU5 antenna is 45" long and has three driven V dipoles to cover both VHF bands. Three active dipoles, plus three directors, provide the stepped-up gain needed for UHF. The frequency response of the **JFD Electronics** unit is flat within ±.5 db on any channel, providing good color registration. A sharp forward lobe in the polar pattern assures unidirectional pickup and a high front-to-back ratio on all channels.

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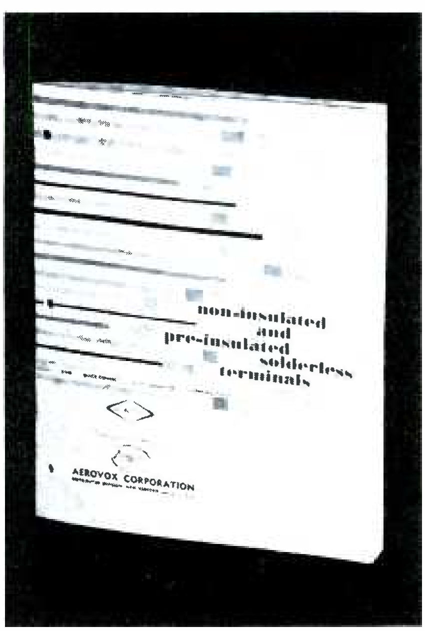
Soldering-Iron Stand

(148)

A new safety-engineered soldering-iron stand has been introduced by **American Beauty.** Especially suited for use with "Little Dandy" and other miniature irons, the new stand features a gravity-controlled receptacle which opens and closes automatically, safeguarding against accidental burns.

The stand, which holds the iron in an aerated basket, is made of cadmium-plated, heavy-gauge steel and may be permanently mounted on the work-bench. Weighing 8 oz., it measures 6" long, 2" wide, and stands 4" high. Price is $4.00.



Solderless Terminals Catalog

(149)

A 28-page, illustrated catalog covering noninsulated and preinsulated solderless terminals is now available from Aerovox. The new catalog contains specifications for flanged, square-spade, ring, and quick-connect type terminals.

Also included in the catalog is a buying guide to help in selecting the terminal best suited for particular applications, a description of electric and manual presses for terminal attachment, and information on quick-connect adaptors as well as butt and line connectors.

Snap Rings and Pliers

(151)

The development of a complete line of retaining ring pliers and snap rings has been announced by **Vaco Products Company.** The new line features both internal and external snap rings, each available in ten sizes ranging from 3/8" to 1". The snap rings are made of oil-dipped, carbon spring steel and are reusable.

Both internal and external retaining pliers are available in three tip styles: straight tip, 45°-angled tip, and 90°-angled tip. The pliers are also available with a spring in the handle.

The retaining pliers and snap rings also come in service kits, for internal and external applications. The kit includes a supply of each of the ten sizes of snap rings and one set of pliers in a compartmented, plastic case. The snap rings are also available in plastic packs and are priced at $2.00. ▲

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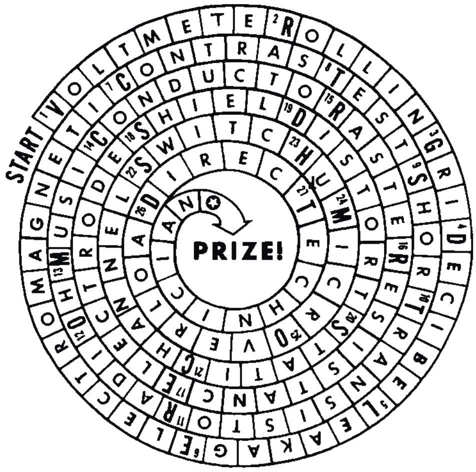

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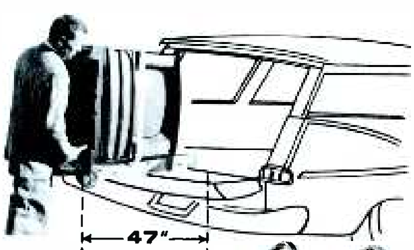

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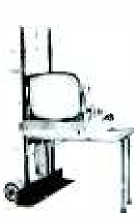

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66. *AMPHENOL CORPORATION* — New 28-page catalog aids selection of RF connectors and coaxial cable. Specifications are detailed for nearly 1400 items.
67. *ANTENNACRAFT* — Four-color catalog sheet about the new "*Big-Shot-8*" VHF-UHF-FM antenna designed for city and suburban use.
68. *BLONDER-TONGUE* — New products catalog, featuring all channel UHF-VHF-FM amplifiers, couplers, converters, etc.
69. *CORNELL-DUBLIER* — 8-page pamphlet "All Channel Reception with Antenna Rotor System" explains advantages of rotor systems.*
70. *FINNEY*—Form 20-353 about the *Finco-Axial* 75 ohm antenna system for UHF-VHF and FM.*
71. *JFD* — New 1966 dealer catalog covering complete line of log-periodic outdoor antennas, indoor antennas, rotators, converters, amplifiers, masting, splitter-couplers/combiners, matching transformers, lightning arrestors, antenna mounts, and hardware.*
72. *PARKER METAL GOODS CO.*—Catalog sheet illustrating rachet type chimney mount.
73. *WINEGARD* — Interesting and colorful brochure about the RS 230 and RS 275 *Super Red Head* antenna preamplifier.*
74. *ZENITH* — Information bulletin on antennas, rotors, batteries, tubes, power converters, record changers, picture tubes, wire, and cable.*

AUDIO & HI-FI

75. *ADMIRAL* — Folders describing line of equipment; includes black-and-white TV, color TV, radio, and stereo hi-fi.
76. *ATLAS SOUND* — Catalog 566-67 illustrates and describes many new models of public address loudspeakers, microphone stands and accessories for commercial sound applications.
77. *COMPONENTS SPECIALTIES, INC.*—Two flyer sheets announcing new line of high-compliance speakers, and test equipment.
78. *GROMMES PRECISION* — Brochures about S-line and Custom-line high fidelity amplifiers, receivers, speakers, and accessories.
79. *JENSEN* — Multicolored 24-page catalog No. 165-L featuring speakers and headphones. Also, 22-page catalog No. 6801 supplying phono-cartridge list and cross-reference.
80. *KARG LABORATORIES, INC.* — Data sheet on low-cost Model X-5 silicon transistor phonograph amplifier which mounts in the base of any standard record changer, converting it to a compact stereo phonograph.
81. *NUTONE*—16-page full-color booklet illustrating built-in stereo music system and intercom radio systems. Includes specifications, installing ideas and prices.
82. *OAKTRON* — "The Blueprint to Better Sound," an 8-page catalog of loudspeakers and baffles giving detailed specifications and list prices.
83. OXFORD TRANSDUCER — 4-page catalog describing three lines of phonographs, tape recorders, and consoles.
84. PERMA-POWER — Catalog sheet about a new 25-watt solid state megaphone.
85. *SEMITRONICS* — Flyer sheet describing the *Dart M-100* microphone.
86. *SONOTONE* — New spec sheet SAH-107 about new dynamic cardioid mikes.
87. *TURNER* — Bulletin 1075 on the new Model 600 microphone.
88. *WATERS CONLEY CO., INC.* — Colorful brochure describes the full line of *Phonola* tape machines and phonographs.

COMMUNICATIONS

89. *KRECKMAN* — Catalog #68 describes a full line of communications antennas and accessories.
90. *MOSLEY ELECTRONICS* — Catalog covering complete 1966 line of citizens-band equipment.
91. *MOTOROLA* — Booklet describing new high power walkie-talkies and handy-talkies for business bands.
92. *PEARCE-SIMPSON* — Specification brochure on IBC 301 business-band two-way radio, *Companion II, Director, Escort II, Guardian 23,* and *Sentry* citizens-band transceivers. "The Modern Approach to Business Communications" concerning land mobile radio service for businessman.
93. *SONAR*—Brochures on new CB, business band transceivers, and on FM wireless mike.

COMPONENTS

94. *BUSSMAN* — 24-page catalog giving detailed information on the complete line of *Buss* and *Fusetron* small dimension fuses and fuseholders — the ones most used for protecting electronic equipment. Ask for Buss bulletin SFB.*
95. *ELECTRO-VOICE*—Two new guide booklets describe E-V's solid state stereo components and high fidelity product lines. Ask for forms #1104 and #1112.
96. *LITTELFUSE* — TV circuit-breaker application cross-reference by set manufacturers.
97. *OAK* — Catalog and supplement describes Oak line of rotary and lever switches.
98. *QUAM-NICHOLS* — General Catalog 66 listing public address, sound systems, high fidelity, automotive, radio-TV replacement.
99. *SPRAGUE* — Catalog K-508 is a large 64-page replacement manual cross-referencing electrolytic capacitors from manufacturers part number to Sprague number. Covers TV, tape recorders, radios, etc. Includes list prices.*
100. *SWITCHCRAFT*—New Product Bulletin 161 describes new high quality cradle switch. Switch holds standard WE and other telephone industry headsets.*

SERVICE AIDS

101. *BAY PRODUCTS* — New 40-page steel shop equipment catalog featuring all new *Converto-Bench.*
102. *CASTLE*—How to get fast overhaul service on all makes and models of television tuners is described in leaflet. Shipping instructions, labels, and tags are also included.*
103. *CHEM-SPRAY AEROSOLS, INC.* Bulletin about *Plytex* PCA tuner cleaner.
104. CLEVELAND INSTITUTE OF ELEC-*TRONICS* — New pocket-sized, plastic "Electronics Data Guide" of formulas and tables, including frequency and wavelength, db formulas and table, antenna lengths, and color code.*
105. *ELECTRONIC CHEMICAL* — Brochure of aerosol chemicals for controls, tuners, and tape heads.
106. *GEM CITY TUNER SERVICE*—Shipping labels, tags and literature explaining our fast tuner service as seen in 1966 Photofacts Index, page 65.
107. *LAFAYETTE RADIO ELECTRONICS* —1967 Catalog, No. 670—featuring two-way radios, stereo hi-fi, tape recorders, test equipment and components.
108. *MID-STATE TUNER*—Informative flyer and shipping labels on 24-hour service for all makes TV tuners.
109. *PRECISION TUNER*—Literature supplying information on complete low-cost repair and alignment service for any TV tuner.
110. *YEATS*—The new "back-saving" appliance dolly Model 7 is featured in a four-page booklet describing featherweight aluminum construction.*

SPECIAL EQUIPMENT

111. *CLEVELAND ELECTRONICS INC.*—3 multi-color flyer sheets describing *Babe* reverberation kit, and *Cathedral-Sonic* self-contained reverberation kit.
112. *GIBBS*—Brochure describing complete line of low priced automobile reverberation amplifiers.
113. *SOUND SENTINEL* — Commercial-residential security alarm designed specifically for the small business and the homeowner.

TECHNICAL PUBLICATIONS

114. *HAYDEN*—New, 64-page catalog listing books published by the Hayden Book Company, Inc. and John F. Rider Publisher, Inc. for the electronics service technician, student, and hobbyist.
115. *RCA INSTITUTES, INC.* — New 1966 Career Book, "Your Career in a World of Electronics," describes programs and courses in television, telecommunications, automation and industrial electronics, drafting, and computer programming.
116. *HOWARD W. SAMS*—Literature describing popular and informative publications on radio and TV servicing, communications, audio, hi-fi, and industrial electronics, including special new 1966 catalog of technical books on every phase of electronics.*

TEST EQUIPMENT

117. *B & K*—New 1966 catalog featuring test equipment for color TV, auto radio, and transistor radio servicing, including tube testers designed for testing latest receiving tube types.
118. *EICO*—1966 short-form catalog is 48-pages long. Describes a complete line of test instruments, CB and ham equipment, hi-fi components, and miscellaneous electronic equipment.*
119. *HICKOK*—New flyer detailing selected items of service test equipment.*
120. *JACKSON*—New catalog of "Service Engineered" test equipment.
121. *MERCURY*—All new test-equipment catalog featuring time saving "Service-Man" equipment, and brochure on a new color bar generator.
122. *RCA*—Flyer sheet on the WR-50B RF signal generator, available in kit form. Unit has sweep output at IF frequencies.*
123. *SECO*—Form SS 4 about the new model 240 SCR analyzer and model 260 transistor tester.
124. *SENCORE*—Latest 4-color catalog plus other information on new developments in the *Econoline* series of test equipment.*
125. *SIMPSON*—Flyer giving specifications of Model 604 Multicorder for measuring and recording volts, amps, milliamps, and microamps.
126. *TRIPLETT*—All new catalog 49-T covering the full line of VOM's, VTVM's Tube & transistor analyzers, signal generators, and featuring the new laboratory accurate, overload-protected VOM model 630-APLK.

TOOLS

127. *ARROW* — Fly sheet illustrating three staple guns and showing uses.
128. *BERNS*—Data on unique 3-in-1 picture-tube repair tools, on Audio Pin-Plug Crimper that enables technician to make solderless plug and ground connections also for color and other picture tubes. Model AV-2 for RCA type phono plugs, along with C rings for shielded braided wire ground connections and LC-3 for 5/32" pin diameter.
129. *ENTERPRISE DEVELOPMENT*—Time saving techniques in brochure from Endeco demonstrates improved desoldering and resoldering techniques for speeding and simplifying operations on PC boards.*
130. *VACO*—Catalog No. SD-119 on interchangeable-blade snap driver kits and components.

TUBES & TRANSISTORS

131. *GC ELECTRONICS* — New transistor cross-reference gives seven replacement numbers for substitution of over 4000 transistor types. Diodes and rectifiers are also included. Form #IR-6018-G.
132. *INTERNATIONAL RECTIFIER* — Catalog F-66 features a new line of transistors, color TV replacement crystals, and printed circuit selenium rectifiers. New semiconductor cross-reference guide is also offered.
133. *RCA*—Form ID1226A is a new pocket guide to picture tube interchangeability.*
134. *WORKMAN*—Transistor cross-reference for use with *Miracle Five* transistor line that replaces 2,977 entertainment-type transistors.

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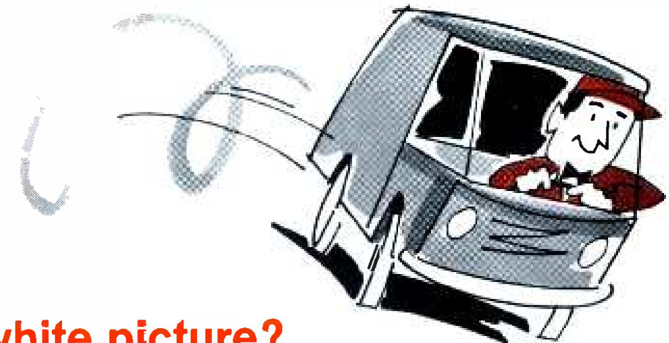
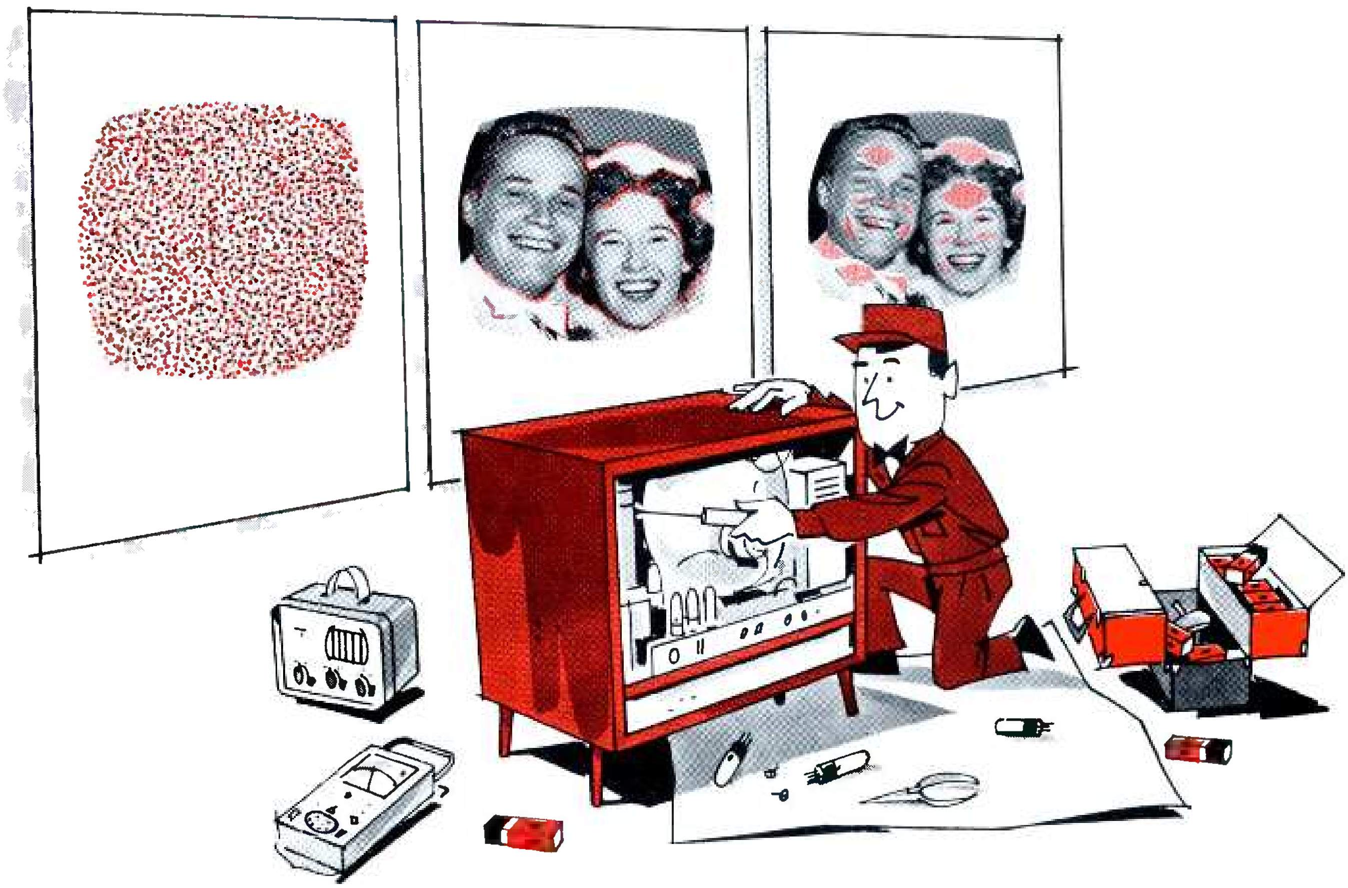
RCA's COLOR TV FASTCHECK #4



Color in a black and white picture?



First, determine the exact nature of the undesired color...

One of the best performance indicators of a color TV receiver is the quality of its black and white picture. It should be free of all color fringing and tinted areas. Because undesired color effects can be due to several causes, the exact nature of the unwanted color should be determined before adjustments are attempted.

Make sure that rf interference is not present. Then, follow these steps in order:

1. Tune in a black and white picture, adjusting fine-tuning correctly.
2. Check for color fringing (misconvergence) around picture elements, and for tinted patches. If fringing is evident, use an RCA WR-64B Color-Bar/Dot/Crosshatch Generator and readjust convergence. Eliminate tinted raster areas by degaussing the picture tube and resetting purity if required.
3. Tune to an unused channel and look for colored snow. If colored snow is present, adjust the color-killer threshold control to the point where color disappears from the snow.
4. Tune in a black and white picture. Set controls for normal brightness and contrast. The highlights should be white and the lowlights should be gray. If highlights and/or lowlights are tinted, adjust gray-scale tracking.
5. If proper gray-scale tracking cannot be achieved, check tubes and components in the chroma amplifier stages.
6. If these checks fail to correct the trouble, use an RCA WT-115A Color Picture Tube Tester to check emission of the three electron guns of the picture tube.

This is another in a series of color TV service hints from RCA. For more satisfied customers always replace with top quality RCA receiving tubes. Your local RCA tube distributor can supply all your tube needs for color TV, black and white TV, radio and hi-fi.

RCA ELECTRONIC COMPONENTS AND DEVICES, HARRISON, N. J.

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CIRCUIT BREAKER CADDIES

CADDY #094077

10 circuit breakers, trip ratings: 2.25, 2.5, 2.75, 3, 3.25, 4, 4.5, 5, 6, and 7 amps.

CADDY #094076

8 circuit breakers, trip ratings: 2.25, 2.75, 3, 3.25, 4, 4.5, 5, and 7 amps.

30 Popular Fuses: 5 each — N 3/10, N 7/10, N 1, C 3/10, C 1/2, C 3-1/2.

Circuit breakers and fuses at your finger tips for instant servicing in field and shop. For color and black/white TV sets.

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