CRYSTAL DIODE

Circuit Kinks

MORE NEW USES FOR GERMANIUM DIODES
INTRODUCTION

In this booklet, we present 40 germanium diode applications, tried and proven, which did not appear in the several crystal booklets published previously by our Company. We believe the engineer, service technician, transmitting radio amateur, and hobbyist all will find items of interest in this new collection of circuits and data. It is believed further that the items contained in this booklet will provoke further thought and experimentation on the part of readers—activity which will lead to development of even more applications of the already prolific germanium diode.

In recent years, the crystal voltmeter and miscellaneous crystal meters have attained an identity of their own. For this reason, a separate chapter has been devoted to meters. Increasing acceptance of the germanium diode in TV reception likewise has occurred, and a description of successful circuits in this category appear in Chapter 3.

This booklet is offered with the earnest wish that it will bring practical ideas to radio-television technicians everywhere.

SYLVANIA ELECTRIC PRODUCTS, INC.
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CHAPTER 1
CRYSTAL METERS AND METER ACCESSORIES

1.1 LINEAR VOLTOMETER FOR
BUILT-IN INSTRUMENTATION

A small, wide-frequency voltmeter is useful on the panel of another instrument, such as a radio-frequency or audio-frequency oscillator, for continuous monitoring of signal output. A built-in meter of this type eliminates necessity for an external voltmeter.

The simple series-diode crystal voltmeter circuit of Figure 1-1 is suitable for such built-in instrumentation. The 0-1 d. c. milliammeter indicates 0-10 volts r. m. s. directly. This voltage range is satisfactory for most audio oscillator applications. If the output circuit of the oscillator is reasonably low impedance, response of the voltmeter circuit will be perfectly linear down to 0.1 volt (1/100 of full-scale deflection of the milliammeter).

The voltmeter input leads may be connected directly across the oscillator output terminals when the output voltage will not exceed a maximum of 10 volts r. m. s. For higher output values, the resistance of the calibration control potentiometer may be increased as required. At lower full-scale voltages than 10, the meter will not be linear, therefore the builder must not aim for low full-scale deflections unless he is willing to draw a special scale for the meter. In r. f. signal generators and in audio oscillators, the voltmeter also may be connected to the input terminals of the output attenuator in the instrument. This will permit standardization of the signal to a prescribed value at the attenuator input.

The d. c. return necessary for proper operation of the crystal diode must be completed by the output circuit of the instrument to which the voltmeter is attached. Ordinarily this return will be obtained through the secondary winding of the output transformer. No d. c. component must be present in the instrument output, otherwise the meter

Figure 1-1. Series-type Linear Voltmeter for Built-in Instrumentation.
Figure 1.2. Shunt-type Linear Voltmeter for Built-in Instrumentation.

A single-point calibration of the voltmeter will suffice, since response is linear. The full-scale point is the most desirable. Apply a known 10-volt r.m.s. signal to the input leads of the meter circuit (the power-line frequency will be satisfactory) and output the calibration control potentiometer to bring the pointer exactly to the 1-milliampere point on the meter scale.

1.2 TUBE-DRIVEN LINEAR CRYSTAL VOLTMETERS

Sensitive a. c. voltmeters combine a high-gain, wide-band signal amplifier with a rectifier-type meter indicator circuit. Such meters are widely used in laboratories for the measurement of audio signal levels down to millivolt ranges. The experimenter may construct a simple, sensitive a. f. voltmeter of this type by connecting a high-gain audio amplifier ahead of a suitable linear crystal voltmeter. Linearity within the amplifier may be improved by means of suitable negative feedback. The sensitivity of this arrangement is a function of the overall gain of the amplifier. The crystal voltmeter circuit is operated at a voltage high enough to insure good linearity. This latter feature allows use of a common meter, such as a 0-1 d. e. milliammeter, without a special scale.

Figure 1.3 and 1.4 show test circuits for amplifier-rectifier-type meters. In each case, the full-wave crystal voltmeter circuit is capacitance-coupled to the amplifier output stage. A full-bridge circuit (4 diodes) is employed in Figure 1.3, and a half-bridge circuit (2 diodes) in Figure 1.4. The full bridge meter has a sensitivity of only 1/4 the sensitivity of the half-bridge; however, it requires four diodes which form a bridge (for balanced conditions) and should have matched characteristics. A Type 1N35 dual diode may be used in the half bridge (Figure 1.4) with two matched 100-ohm resistors.

The output stage of the power tube normally employed in the amplifier. In most amplifiers built especially for audio use, however, the output tube is a triode-type (6AK5 or 6AP5) in a coupled push-pull or triode-connected 341 in battery-operated models.

In each circuit (Figures 1.3 and 1.4), the electrolytic condenser shown in parallel with the meter may be used to improve the meter response. A 47-ohm, 0.1-megohm resistor should be added in series with the meter for exceptional accuracy and to reduce drift.

To calibrate a tube-driven crystal voltmeter, apply an accurately known a. c. voltage to the amplifier input and set the amplifier gain control for desired meter deflection. For example, a 10-millivolt signal may be applied to the amplifier, and the gain set for full scale deflection of the 0.1 milliammeter. The meter will read 0.10 millivolt. The procedure then is repeated for each desired range of the meter. To switch ranges at will, range switches are installed which correspond in value to the resistance settings of the gain control then determined.
1.3 HIGH-RESISTANCE CRYSTAL VOLTMETER

A common objection to the ordinary crystal-type a. c. voltmeter is its relatively low input resistance. This characteristic limits the instrument to measurements in low-impedance circuits if calibration accuracy is to be maintained.

![Figure 1-5. High-Resistance Crystal Voltmeter.](image)

The instrument resistance can be increased advantageously by use of a low-range current meter. The most sensitive microammeter obtainable in the conventional panel-type case has a range of 0.10 microamperes (Marion 503BN). This meter permits a voltmeter sensitivity of approximately 100,000 ohms per volt. Figure 1-3(A) shows the circuit of a crystal voltmeter with such a desirable high-input resistance characteristic. Two high-handling-current diodes (Type 1N54) are connected in series to provide the high order of reverse resistance required when high-resistance multiplier resistors are to be used in a voltmeter circuit. The basic circuit, as shown in the sketch, gives full-scale deflection of the microammeter with 15 volt r. m. s. input. Because of the unusually low current density, response of the circuit is not linear and a special meter scale or calibration chart must be prepared. The multiplier resistors required for various voltage ranges must be worked out experimentally by the builder, since their exact values will depend upon the individual germanium diodes used. The multiplier for the 1 volt range will be close to 20,000 ohms; 925 ohms for 10 volts; 4.9 megohms for 50 volts; 9.9 megohms for 100 volts; 21.9 megohms for 250 volts; and 49.9 megohms for 500 volts. Because of the extremely high values of multiplier resistors required beyond 500 volts, it is not advisable to extend the instrument range beyond that full-scale voltage. In a multi-range instrument, the multipliers may be switched in the conventional manner successively into the circuit, as shown in Figure 1-3(B).

The high-resistance voltmeter may be used at radio frequencies, as well as at audio and power-line frequencies. The voltage source under test must supply a d. c. return for the voltmeter circuit to allow the flow of d. c. current through the meter.

1.4 SQUARE-LAW D. C. VOLTMETER

Square-law a. c. voltmeters have been available for some time. Similar instruments for experimental d. c. operation are not readily obtainable. A square-law d. c. voltmeter, in which meter deflection varies approximately as the square of the applied voltage, is useful for taking accurately small voltage changes on a single meter scale. Voltage changes, of important interest in certain types of experimental work, thus become more readable than on the common linear d. c. voltmeter scale.

The non-linear response of a germanium diode at low current densities may be utilized in the development of a square-law d. c. voltmeter by employing the diode as a series resistor in a simple meter circuit. The diode is connected to pass current in the forward direction. Type 1N54 gives approximately square-law response in the forward voltage range 0.1 to 0.2 volt. It is necessary, therefore, to bias the diode positively to 0.3 volt and then to apply the unknown d. c. voltage in series with this bias. The response curve may be corrected to square-law by means of a low value of linear series resistance. Figure 1-4 is the circuit of a complete square-law d. c. voltmeter. The 1N54 is biased to 0.1 volt positive, the point at which square-law operation starts, by means of the voltage divider R1-R2. Close adjustment of this voltage is obtained by means of the BIAS CONTROL rheostat, R1. In order to keep the circuit resistance low, so as not to reduce the steepness of the diode response curve, the 0.1 volt bias is developed across a 1-ohm resistor, R2. Also in order to keep the circuit resistance low, a low-resistance indicating microammeter is necessary (100 ohms or less internal resistance). Since the 1N54 curve is somewhat steeper than square law in the 0.100 microampere operating range, a small amount of series corrective resistance is provided in the circuit by the CURVE CONTROL rheostat, R1.

The circuit is adjusted in the following manner: (1) Short-circuit temporarily the D. C. INPUT terminals. (2) Set rheostat R1 to zero ohms. (3) Connect a low-range d. c. vacuum-tube voltmeter or a 20,000 ohms-per-volt d. c. voltmeter across resistor R2. (4) Set rheostat R1 for a 0.1 volt deflection of the test voltmeter. (5) The microammeter will indicate approximately 20 microamperes at this point. This is the "false zero" of the crystal voltmeter. (6) Remove the short circuit and apply an accurately-known 0.1 volt d. c. potential to the D. C. INPUT terminals. Observe the correct polarity. (7) Note the meter deflection. If this reading is not 20 microamperes (four times the false-zero reading), increase the resistance setting of rheostat R1; if short-circuit the D. C. INPUT terminals and reset rheostat R1 for 0.1 volt deflection of the test voltmeter. Note new false-zero reading.
1.5 BALLISTIC METER FOR SINGLE TRANSIENTS

Figure 1.7 shows the circuit of a simple rectifier-storage capacitor "front end" for use ahead of a d.c. vacuum-tube voltmeter, such as the Sylvania Polyometer, to catch rapid, one-shot transients. The arrangement shown will indicate approximately the peak value of positive, non-repetitive pulses. Negative pulses can be checked by reversing the polarities of both the germanium diode and the electrolytic capacitor.

Note that fast, non-repetitive pulses charge the 2000-microfarad capacitor approximately to the pulse peak voltage. The large capacitor holds the charge due to this voltage for an interval long enough to enable the operator to read the meter. After the reading is made, the short-circuiting switch is closed momentarily to discharge the capacitor and return the meter to zero. The instrument may be calibrated for fast transients initially by means of an oscilloscope having a voltage-scaling screen.

1.6 SIMPLE A.C. MILLIVOLTMETER

A simple a.c. millivoltmeter circuit for n, f, and c f., measurements is shown in Figure 1.8. The lower range of this circuit is 0-110 millivolts m. s., and a special feature of the circuit is its linearity. This sensitive range may be extended by means of suitable multiplier resistances connected in series with the negative terminal of the microammeter. Multiplier resistance values must be worked out experimentally, since their exact values will depend upon individual germanium diodes.

Figure 1.8. Series-type A.C. Millivoltmeter.

Audio-frequency millivolts may be measured in low-impedance circuits with the millivoltmeter circuit shown in Figure 1.9. This arrangement employs the high turns ratio of a line-to-push-pull grid transformer to step the low voltages up to values high enough to operate the diode and milliammeter. A standard, panel-mounting 0-50 d. c. milliammeter is used. Type IN56 germanium diode provides maximum rectified current for a given signal input voltage.

Full-scale deflection of the meter is obtained with an input signal of 10 to 15 millivolts m. s. An individual calibration must be made. The response is not linear although it is very nearly so. The transformer must be a high-quality audio component having wide-frequency response if the instrument calibration is to hold throughout the audio spectrum.

The basic range of the instrument (10 to 35 mV, full-scale) may be extended by means of appropriate multipliers connected in series with the negative terminal of the meter. The resistance values of these multipliers must be worked out experimentally for the particular diode and meter used.

Use of the transformer-coupled millivoltmeter shown here will be restricted to low-impedance voltage sources (50 ohms or less). When high-impedance input is required, the millivoltmeter circuit may be preceded by a simple cathode follower.

1.7 TRANSFORMER-COUPLED A.F. MILLIVOLTMETER

Figure 1.9. Transformer-coupled A.F. Millivoltmeter.
1.8 AUDIO-FREQUENCY MICROVOLTER

Figure 1-10. Audio-frequency Microvolter, Simplified Circuit

This instrument is used to obtain known output voltages from an audio oscillator and is useful for checking gain and other characteristics of amplifiers and associated equipment. A COARSE CONTROL, rotary switch, selects either of four output ranges: 0.1 millivolt, 0.10 mv, 0.100 mv, or 0.1 volt. A FINE CONTROL, potentiometer, allows smooth, continuous variation of the output in any of the selected ranges. The microvolter calibration is standardized by feeding a 1 volt signal into the A F. INPUT terminals. This 1 volt reference level is indicated by a bridge-type crystal voltmeter.

The crystal voltmeter consists of a 0.1 d. c. milliammeter, four matched IN54 diodes (or two IN53 diode diodes), and a screw-driven-adjusted meter calibration resistor. To adjust the microvolter initially: (1) Feed a 1000-cycle signal into the A F. INPUT terminals. (2) Set the FINE CONTROL potentiometer to its top (high-resistance) position. (3) Connect a high-resistance, a. c. vacuum-tube voltmeter between circuit points X and Y. (4) Adjust the output of the 1000-cycle source for a 1 volt deflection of the v. t. voltmeter. (5) Adjust the VOLTMETER CALIBRATION CONTROL, (therefore for exact center-scale deflection of the milliammeter. (6) Mark the FINE CONTROL dial 1 at this point. (7) Reduce the setting of the FINE CONTROL until the v. t. voltmeter reads 0.9 volt. (8) Mark this point 0.9 on the FINE CONTROL dial. (9) Repeat the procedure at each lower 1/10 volt step down to 0.1 volt deflection of the v. t. voltmeter, and mark each dial point accordingly. (10) Remove the v. t. voltmeter from the circuit.

To use the microvolter, feed the test signal into the A F. INPUT terminals and adjust the output of the signal source for center-scale deflection of the milliammeter in the microvolter. A desired output signal level then may be obtained by proper settings of the COARSE and FINE controls. For example, 1 millivolt output is obtained by setting the FINE CONTROL to 0.5 and the COARSE control to 6 000. (This corresponds to 0.5 of 001 of 1 volt or 0005 v., which is 0.1 volt.)

1.9 B. C. METER COMPRESSOR

The simple compression circuit shown in Figure 1-11 alters the normally linear response curve of a d. c. milliammeter in such a way that a small applied current produces a relatively large change in meter deflection, while larger currents produce progressively smaller differences in deflection. One application of a compressed meter of this type is as the null detector in a d. c. resistance bridge. In this application, the meter sensitivity to changes in current level increases as the null point is approached—a desirable feature in bridge balancing. The "slowing down" of the meter response curve at high current levels also protects the meter against slamming when the bridge is unbalanced.

The response curve in Figure 1-11 illustrates circuit behavior with a typical IN54 diode and 0.1 d. c. milliammeter. Response of more sensitive current meters, such as d. c. microammeters, may be compressed in the same manner. However, the meter series resistor (shown as 500 ohms for the 0.1 milliammeter in Figure 1-11) must be determined experimentally for the particular microammeter used. The value of this resistor must be such that exact full-scale deflection of the meter is obtained at the maximum current input which will be encountered.

1.10 PEAK-TO-PEAK TELEVISION VOLTOMETER PROBE

Figure 1-12. Peak-to-peak Television Voltmeter Probe

The amplitude of the complex waveforms found in television receivers may be checked successfully with a voltmeter only when the meter response corresponds to and indicates peak-to-peak voltages.

Figure 1-12 shows a typical crystal probe which can be connected ahead of a d. c. vacuum-tube voltmeter, such as the Sylvania Polyvolt. With this probe, peak-to-peak values are indicated by the d. c. scale of the meter.
All values above 5 volts peak-to-peak may be read directly from the meter. Below 5 volts p-p, however, a special calibration must be made, since low-voltage non-linearity of the crystal diodes in this circuit causes the indications to be somewhat lower than true peak-to-peak values.

The probe circuit consists of two shorts-type peak rectifiers with their inputs in parallel. One rectifier responds to the positive half-cycle of the applied voltage; the other to the negative half-cycle. The d. c. output of each is equal to the peak value of the corresponding half-cycle. The d. c. output circuits of the two rectifiers are in series and thus are additive. Type IN58

1.11 FULL-WAVE CURRENT METERS

Crystal-type a. c. milliammeters and microammeters, like crystal voltmeters, have the advantage of wide frequency response. Full wave current meters give the greatest sensitivity, since they utilize both cycles of the measured current wave. Several circuit arrangements are available for basic full-wave current meters. Figure 1-13 shows the four most satisfactory circuits; full bridge, 3/4 bridge, 1/2 bridge, and 1/3 bridge. Response of each of these circuits is non-linear, requiring a special meter scale or calibration chart. A brief description of each circuit follows.

Full Bridge. This circuit appears in Figure 1-13(A). At full-scale deflection of the meter, the a. c. input current is approximately 1.11 times the current value indicated by the d. c. meter. For best results, the four diodes must have matched characteristics, such as IN7.

3/4 Bridge. See Figure 1-13(B). At full-scale deflection of the meter, the a. c. input current is approximately 1.19 times the current value indicated by the meter. For best results, the three diodes must have matched characteristics. In the absence of perfect matching of diodes, however, resistance R may be adjusted for equal-amplitude pulses, as viewed on the screen of an oscilloscope connected across the d. c. meter terminals.

1/2 Bridge. See Figure 1-13(C). At full-scale deflection of the meter, the a. c. input current is approximately 1.29 times the current value indicated by the meter. For best results, the two diodes must have matched characteristics; although, in the absence of perfect diode matching, one of the resistors may be adjusted for equal-amplitude pulses, as viewed on the screen of an oscilloscope connected across the d. c. meter terminals.

1/3 Bridge. See Figure 1-13(D). At full-scale deflection of the meter, the a. c. input current is approximately 1.39 times the current value indicated by the meter. For best results, the two diodes must have matched characteristics; although, in the absence of perfect diode matching, one of the resistors may be adjusted for equal-amplitude pulses, as viewed on the screen of an oscilloscope connected across the d. c. meter terminals.

Resistors. The resistors used are specified in Figure 1-14 for an ohmic value of 10,000 ohms. This value is less than the maximum impedance of the oscilloscope, and is adequate for all practical purposes.

Multiplying Ranges. Higher ranges may be provided for the crystal-type current meters by connecting an appropriate shunt resistor for each desired range across the a. c. input terminals. The resistance of the shunt must be such that the current flowing through it will be the difference between the total current to be measured and the a. c. current normally flowing into the crystal meter circuit.
In simple, half-wave a. c. voltmeters, for all voltages higher than 50 v. r. m. s., it is advisable to connect two germanium diodes in series for rectification (See Figure 1-18). There are two reasons for this. First, high-voltage multipliers have high resistance values, and when this resistance is comparable to the back resistance of a single diode in a voltmeter circuit, rectification efficiency is reduced. Second, the two diodes in series are better able to withstand the high peak inverse voltages encountered. In a series-diode circuit, such as Figure 1-14, the increased forward resistance due to the second diode is negligible compared to the high resistance of the multiplier, and does not detract from the advantages of increased back resistance. The 1 megohm resistor (shown in dotted lines) may be used to provide a better return path for the meter circuit when the multiplier resistor is an extremely high value for measuring high a. c. voltages.

Type IN5 is a special high-back-resistance diode. This type has a resistance of at least 1 megohm at -10 v. and is especially suitable for the circuit of Figure 1-14. Each diode in the Type IN5 dual unit likewise has at least 1 megohm resistance at -10 v. and this type provides both diodes for the series connection.

**GERMANIUM DIODE INSTALLATION HINTS**

1. Use the type of diode specified in the circuit diagrams. These types have been selected carefully to withstand circuit voltages and other operating conditions.

2. When soldering the diode to the circuit, hold the pilot leads with a pair of long-nosed pliers. This will prevent heat from the soldering iron from entering and possibly damaging the semiconductor.

3. In all installations, use as much of the pilot lead length as is practical. The cathode terminal is properly marked with the abbreviation "CATCH" and with a wide band.

4. While the Germanium Diode is a rugged component, the user is cautioned against deliberately dropping the diode to the floor, tapping it on, or otherwise handling it in a rough manner so as to expose it unnecessarily to mechanical shock.

5. Mount the crystal diode so that it is reasonably free from severe mechanical vibration.

6. Keep the crystal diodes as far as possible from heated objects.

7. Observe the diode polarity shown in the circuit diagrams. The cathode terminal is properly marked with the abbreviation "CATCH" and with a wide band.

**CHAPTER II
COMMUNICATION APPLICATIONS**

**2.1 IMPROVED LOW-LEVEL FREQUENCY MULTIPLIER**

Several germanium diode radio-frequency multiplier circuits have been published in previous literature. Figure 2-1 shows an improved arrangement for multiplication at low-power levels. In this circuit, two germanium diodes are connected in parallel with their reversed polarity to pass current on both halves of an unmodulated r. f. cycle, and are tapped down the input and output tank coils for improved impedance matching. This circuit utilizes the fullest advantage of the nonlinear (distorting) characteristic of the diode to produce harmonics of the input frequency. The input tank, L1C1, is tuned to the desired harmonic. The diodes are tapped from 1/2 to 1/3 the way up from the ground end of each tank coil. A radio-frequency milliammeter may be inserted across the meter jack to check current through the diodes. This current must not exceed twice the average anode current recommended for the type of diode used. This current value, for example, would be 100 ma. for two Type IN5's, 120 ma. for IN50's, etc. Maximum frequency multiplying efficiency will be obtained at low current levels (meter readings of 1/4 milliam- pere and under), the region in which diode non-linearity is greatest. The two diodes need not be matched; in fact multiplying action is enhanced somewhat by mismatch.

While the germanium diode frequency multiplier is a low-power device, it nevertheless will find application in high-sensitivity transmitter exciters and in other experimental equipment where frequency multiplication can be carried out at low power levels ahead of high-power preamplifiers or linear power amplifiers.
2.2 HARMONIC ACCENTUATOR FOR EXCITERS

Figure 2-2 shows how a pair of germanium diodes may be connected in the grid circuit of a frequency multiplier stage in a transmitter to raise harmonic output. By distorting the grid current fluctuations and thus emphasizing harmonics in the r.f. excitation voltage, the effectiveness of the multiplier stage is increased. This arrangement is particularly favorable to odd harmonics (3rd, 5th, etc.). Grid resistor bias is shown in Figure 2-2, but the scheme may be employed also in multiplier stages which employ bias-voltage supplied cathode resistor bias.

2.3 SIMPLE CUEING RECEIVER

Figure 2-3. Simple Cuing Receiver.

Where the surrounding noise level is not excessive, a stage manager or program director on the studio floor with a portable s, b, f. r. microphone trans- mitter can "cue" actors or announcers through simple personal receivers of the type shown in Figure 2-3. The receiver may be carried in a pocket or hidden in some convenient part of a costume, need not be any larger than a book of safety matches, and the two short lengths of flexible insulated wire which comprise the "dipole" antenna may be stretched conveniently into the costume. The antenna length is not particularly critical; a useful amount of energy being picked up by brute force from the nearby transmitter. A foot or so at length in each section usually will suffice. The number of turns in the : f. c. chokes will depend upon the transmitter frequency. A rule of the thumb is to measure off (for each choke) 1/4 wavelength of No. 30 cotton-covered wire and wind two or three windings on insulated solder or sticks about the same diameter as the germanium diode.

At noisy locations, output of the crystal cueing receiver may be fed into a conventional hearing aid as a boost-er audio amplifier.

2.4 AMPLIFIER PROTECTIVE RELAY

Figure 2-4. Amplifier Protective Relay.

The scheme shown in Figure 2-4 protects a grid resistor-biased beam power amplifier in a transmitter against damage due to loss of bias when excitation fails or drops to a low level. Since the protective circuit is operated by r.f. energy from the exciter, it is controlled directly by excitation level. This arrangement allows the advantage of a small amount of resistor bias to be utilized with complete protection.

A small amount of r.f. energy is picked up by the coupling coil mounted rigidly near the driver plate tank coil. This energy is rectified by the 1N43 diode and the resultant d.c. used to hold the resistance of the relay. 2X-1. The setting of the 10,000-ohm potentiometer and the coupling coil spacing both are adjusted by trial so that the relay 2X-1 opens when the amplifier grid bias drops to the minimum permissible voltage level. Relay 2X-1 in turn controls a 115-volt a.c. relay, 2X-2, which removes plate and screen voltage from the amplifier whenever excitation fails to the level corresponding to minimum permissible grid bias. Both of the relays are normally open. Although a single-ended amplifier capacitance-coupled to the driver is shown in Figure 2-3, the protective relay scheme may be applied as well to pushpull amplifiers, and to other methods of inter-stage coupling.
2.5 CARRIER-OPERATED RECEIVER MUTING SYSTEM

Figure 2-5. Transmitter (Carrier) Operated Receiver Muting System.

In Figure 2-5, the transmitter carrier is rectified by a 1N34 diode and the resultant d.c. applied to a sensitive relay. When the relay closes as a result of the carrier coming on, one pair of its contacts short-circuits the antenna input terminals of the receiver, while the other pair short-circuits the loudspeaker voice coil. This scheme eliminates the usually heavy-duty transmit-receive switch or relay system, and is particularly applicable to a receiver which must be located at some distance from the transmitter. Since this arrangement permits the receiver to operate continuously at its normal voltage, standby drift is eliminated. When the transmitted carrier is interrupted, the receiver automatically is recommissioned. Modulation does not affect the relay.

Coff L and capacitor C are chosen to resonate at the carrier frequency. In the neighborhood of a transmitter of reasonable power, sufficient energy may be picked up without an antenna. Farther away, a small pickup antenna will be required. This may be a random length of insulated wire or a short vertical rod.

2.6 VOICE (MODULATION) CONTROLLED RELAY

Figure 2-6. (Voice Modulation) Controlled Relay.

Voice-controlled system, depend upon control action obtained with the modulation component of energy picked up from a modulated transmitter. Such systems operate only while modulation is present and release in the absence of modulation. Presence of the carrier component has no effect. Typical applications are voice-controlled receivers, instruments, switching devices, etc., associated with the transmitting station.

Figure 2-6 shows a simple voice control receiver which is small enough to be built into an inconspicuous box. The coil-capacitor combination, L, C, is tuned to the transmitter carrier frequency. The 1N35 acts as a detector or modulator. The modulation component obtained by means of the 1N35 is passed by the coupling transformer to the IN54 which acts as a modulation rectifier. D, C, output of the IN56 is applied to a 1- or 2-milliampere 4-c. relay which is accordingly picked up as a result of presence of modulation.

The length of time the relay is held in after modulation ceases may be controlled by the 5000-ohm potential and 1000-microfarad electrolytic capacitor shunting the relay coil. The less resistance cut to the circuit by the potentiometer, the faster will be the relay dropout, and vice versa. Thus, the potentiometer may be set at one extreme to drop the relay out after each ordinary spoken word, or at the other extreme so that the relay holds-in for several seconds after speech modulation ceases.

2.7 MONITOR RECEIVER FOR BROADCAST TRANSMITTER LOCATION

Figure 2-7. Monitoring Receiver for Broadcast Transmitter Location.

For continuous aural monitoring (via loudspeaker) of a broadcast station straight from the air, a simple crystal "front end" may be coupled to a small audio amplifier. Details of this arrangement are shown in Figure 2-7.

A short pickup antenna, consisting of a vertical rod or a random length of insulated wire, is all that is required with the receiver to deliver a handy audio signal to the amplifier input terminals. The 1-4 coupling combination specified in Figure 2-7 is designed to cover the 500-1600 kc. range. Tuning capacitor C can be a miniature air trimmer pre-set to the transmitter frequency. If frequencies higher than 1600 kc. must be reached, a few turns may be removed from the 1-milliampere c. l. choke, L, to obtain resonance. The audio amplifier need not be bulky nor complicated, since the a. l. output
3.4 TUNED CRYSTAL-TYPE SIGNAL TRACER

Signal tracers are justifiably popular for tracking down trouble in radio receivers. An amplitude-modulated test signal is used in the signal tracing operation. Most simple signal tracers consist of a crystal-type demodulator probe connected to the input circuit of a high-gain audio voltage amplifier. An output indicator, such as an a. c. voltmeter, headphones, or magic eye tube, shows relative signal strength (or absence of signal) at various test points. Worthwhile improvement is obtained when the signal tracer can be tuned to the carrier frequency of the test signal, but conventional tuned signal tracers (channel analyzers) contain many tubes and are both complicated and expensive.

Figure 3-3 shows a simplified, tuned signal tracer. The input stage embodies a simple tuned circuit and IN14 detector. This, in effect, a crystal receiver. The exploring test prod is connected to the tuned circuit through a 2-ufd capacitor which serves to isolate the instrument from the circuit under test and from the operator’s fingers, thereby preventing detuning of tested circuit. Output of the diode detector is fed into a high-gain audio amplifier terminated by an output meter. For a.c. operation, the amplifier may consist of a resistance-coupled 6AF6-6AG5 combination. For full-convertible battery operation, a 1U4-2S4 resistance-coupled lineup may be used.

Tuning of the signal tracer is accomplished by means of a dual 365-ufd, grid-tuned variable capacitor with its two sections connected in parallel. The complete tuning range is 400 kc. to 50 Mc. in four ranges: 400-1200 kc, 1100-3500 kc, 2-10 Mc, and 2-50 Mc. This range includes all i, r, l, and well.
3.5 TELEVISION VIDEO DETECTOR

The lower dynamic impedance and increased efficiency of the germanium diode recommend use of this component in a number of circuits in place of the usual diode tubes. Other advantages obtained at the same time are compactness, low cost, operation, low shunt capacitance, simple wiring, and elimination of filament. A typical application is the germanium diode video detector for television receivers.

Figure 3.4. High-efficiency Video Detector.

In Figure 3.4, a video detector circuit is designed around the Type IN66 which is a special video detector diode. Circuit constants are given for 4-megacycle bandwidth.

Improved receiver performance has been reported by service technicians and by experimenters who have incorporated this video detector into t.v. receivers.

TO OBTAIN ALL TYPES OF SYLVANIA GERMANIUM DIODES SEE THE SYLVANIA RADIO TUBE DISTRIBUTOR NEAREST YOU. YOU WILL FIND HIM LISTED IN THE YELLOW PAGES OF YOUR TELEPHONE DIRECTORY UNDER "RADIO SUPPLIES AND PARTS.”

3.6 F.M. — T. V. DISCRIMINATOR

The improved forward and reverse characteristics of the two matched diodes in the Type IN65 dual diode unit are exploited fully in the simplified discriminator circuit shown in Figure 3.5. The increased reverse resistance of the IN65 allows the use of the high (100,000-ohm) load resistors for best circuit efficiency and without any input providing.

This discriminator may be employed in regular F.M. receivers, as well as in sound channels in television receivers. If a pair of matched 100,000-ohm resistors is used, no adjustments will be required beyond the usual alignment of the input transformer.

3.7 F. M. DYNAMIC LIMITER

Figure 3.6 shows a germanium-type dynamic limiter which has many of the complexity of tube-type stages of the same type. This circuit may be applied in F,M. receivers and t.v. sound channels. The threshold level is variable and reaches low signal levels. Interchannel background noise, as well as radio buzz in intercarrier-type television receivers, is quieted by this limiter circuit.

Chief feature of the limiter is the all-barrel Type IN66 high-conduction diode which is connected in parallel with the primary of the detector input transformer (ratio detector or discriminator). Diode bias is developed across the 10,000-ohm diode series resistor. The shunting capacitor is a 10-microfarad electrolytic. The time constant of this R-C combination is satisfactory for rejection of amplitude-modulated multipath interference components, 60-cycle blanking pulses, and similar phenomena.
3.8 T. V. CASCADE SYNC CLIPPER

A high-level sync clipper is shown in Figure 3-7. The two cascaded IN34's in this circuit are supplied with fixed bias partially derived from the plate load resistor of the last video amplifier. The biasing network for each diode has a long time constant. The high-frequency compensation of the video output stage is unaffected by shunting the clipper circuit across this output, because of the low diode capacitance. Striping action of the two diodes is cumulative, since the clipping level of the second diode is determined by the partially separated sync pulse output of the first diode. Separation is sharp, and sync pulse output of the clipper is completely free of video information.

3.9 A. G. C. PEAK DETECTOR

In the circuit of Figure 3-8, a IN34, direct-coupled to the plate output of the last video amplifier, is used as an A. G. C. detector. This diode conducts only during the sync interval because of the lengthened discharge time constant of its load circuit. The positive d.c. voltage output of the diode detector is R.C. filtered and presented to the control grid of the A. G. C. amplifier tube.

The control rate of the circuit takes care of all but very fast fading; however the receiver gain does not alter appreciably during vertical blanking periods, as vertical sync pulses are not "pushed down."

3.10 T. V. VERTICAL PULSE SEPARATOR

A biased IN54 diode in the circuit shown in Figure 3-9 follows a 2-stage differentiating network, and clips horizontal components from the applied sync signal. The negative vertical pulses in the diode output then are applied to the grid of a triode which amplifies, squares, and inverts them. The output pulses are steep-fronted, of high amplitude, and positive in polarity. This circuit affords stable vertical sync minus interlace jitter and line pairing. The low interelectrode capacitance of the IN54 improves pulse discrimination.

GERMANIUM DIODE INSTALLATION HINTS

1. Use the type of diode specified in the circuit diagrams. These types have been selected carefully to withstand circuit voltage and other operating conditions.

2. Before inserting the diode, hold the leads with a pair of long-nosed pliers. This will prevent the leads from deflecting upon insertion and possibly damaging the reverse unit.

3. In all installations, use as much of the printed lead length as possible.

4. While the Germanium diode is a very fragile component, the user is cautioned against deliberately dropping the diode to the floor, tapping on it, or otherwise handling it in a rough manner so as to expose it unnecessarily to mechanical shock.

5. Mount the crystal diode so that it is completely free from severe mechanical vibration.

6. Keep the crystal diode as far as possible from heated objects.

7. Observe the diode polarity shown in the diagrams. The cathode terminal is plainly marked with the designations "CATH" and with a wide band.
CHAPTER IV
EXPERIMENTAL APPLICATIONS

4.1 AMPLITUDE MODULATOR

A simple amplitude modulator with a host of applications in test instruments and electronic control gear is shown in Figure 4.1. With a minimum of components, this circuit utilizes the ability of a non-linear component such as the 1N34 germanium diode to accomplish modulation. In a typical application, unmodulated r.f. from an oscillator or signal generator is fed into one pair of input terminals, and an audio modulating signal into the second pair of input terminals. Amplitude-modulated r.f. is then available at the output terminals. The wide frequency range afforded by the germanium diode also permits the modulation of one r.f. signal by another r.f. signal, or modulation of one audio signal by another audio signal.

The diode modulator may be employed for externally modulating a signal generator, for producing amplitude modulation at low power levels in radio and carrier-current transmitters, tone-modulating received signals (by inserting the modulator in the i.f. amplifier of a receiver), and for producing a modulating ("two-tone") audio signal for special amplifier checking. Since no coupling transformer is present in the modulation input circuit, high modulating frequencies extending far into the r.f. spectrum may be used with ease. The diode modulator can be operated at ultrasonic frequencies, if desired.

The information in this book is based without assuming any obligations.

4.2 BRIDGED-T PHASE MODULATOR

Figure 4.2 shows an ingenious bridged-T circuit in which a pair of germanium diodes replaces the usual resistance arm of the conventional bridged T network. The resistance of the diodes, and therefore the network transmission characteristic, is varied by means of a control voltage applied to the diodes. This circuit was developed by Dr. M. L. Galloian of the U.S. Navy Bureau of Standards.

An important property of this circuit is its ability to give an appreciable phase shift between input and output voltages, with negligible amplitude attenuation. 90-degree phase shifts have been obtained. Another important property is ability of the circuit to function as a simple phase modulator. For this application, the modulator may be inserted in the coaxial line between two low-level stages of a phase-modulated transmitter.

Circuit constants for Figure 4.2 are those given by Dr. Pavley for 7250 kc operation with 50-ohm input and output impedances. Constants for operation at other frequencies, audio and radio, may be obtained by means of standard bridged-T calculations.
4.3 SPIKE GENERATOR

A somewhat simpler sharp pulse generator is shown in Figure 4.4. This circuit resembles a low-pass R-C filter in which germanium diodes take the place of the usual resistors. Unlike the arrangement described in Section 4.3, this circuit gives a pulse repetition rate equal to the frequency of the applied sine wave. The circuit may be used throughout the audio spectrum with the component values shown. At radio frequencies, smaller capacitors and shielding between components will be required.

The 2-megohm rheostat is adjusted to give the best pulse shape, as viewed with a wide-band oscilloscope. Negative pulses may be obtained by reversing the polarity of each of the diodes.

4.5 SAWTOOTH GENERATOR

The circuit of Figure 4.5 converts a sine-wave input signal into a sawtooth wave. At 10 volts r.m.s. input, this sawtooth waveform was found to be linear enough for use as an oscilloscope sweep up to 50 kc.

With the diode polarity shown in Figure 4.5, positive-going sawteeth are obtained. Reverse the polarity of each diode to obtain negative-going sawteeth.

4.6 GERMANIUM TROIDE POWER SUPPLY

Figure 4.6. Germanium Triode Power Supply.
Germanium crystal triodes (transistors) are small-sized components. Often, the power supply components, for furnishing d.c. operating voltages to germanium triode amplifiers and oscillators are many times the size of the germanium triodes themselves. Even selenium rectifiers, used for this purpose, are enormous in comparison with germanium triodes.

The ideal miniaturization afforded by the germanium triode can be pursued by using a high-back-voltage germanium diode as the rectifier in the low-current germanium triode d.c. power supply. Figure 4.6 shows a power supply of this type, in conjunction with a single-stage germanium triode amplifier. With a 30-volt-output miniature (10 to 20 ma.) power transformer and 1NS diode, potentiometer R₂ allows a positive voltage of approximately 0.2 v. to be selected directly for the emitter ("grid") electrode of the germanium triode, while potentiometer R₃ allows close selection of a negative voltage of approximately 30 v. for the collector ("plate") electrode. Note the apparent backward connection of the diode and of the miniature electrolytic filter capacitors. These polaritys are very important since, unlike vacuum tubes, the germanium triode "grid bias" must be positive and its "plate voltage" negative.

### 4.7 MINIATURE LIGHT-INTENSITY METER

In the circuit shown in Figure 4.7, a 1N77 subminiature germanium photodiode is employed as the light-sensitive pickup device and a 1NS diode as the power supply rectifier. This instrument may be used to examine the brightness of small illuminated areas, such as sections of photographic negatives, illuminated charts, etc. The 1N77 photodiode is tiny enough to be mounted in the tip of a thin pencil-type exploring probe. The 1N77 is especially sensitive to red and infra-red illumination.

The light-intensity meter has good sensitivity and may be calibrated with the aid of a foot-candle meter or other brightness standards. To prepare the meter for use, simply dial in the 1N77, and adjust the ZERO-SET rheostat for zero reading of the microammeter.

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**Figure 4.7. Miniature Light-Intensity Meter.**

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**Figure 4.8. Indicating Audio Frequency Meter.**

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**Figure 4.9. Calibration Data for the Audio Frequency Meter.**

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**4.8 INDICATING AUDIO FREQUENCY METER**

When conditions do not warrant or permit use of a more complicated electronic audio frequency meter, satisfactory frequency indications may be obtained with a simple circuit making use of the varying reactance of a capacitor. This scheme has been employed in the design of the instrument circuit shown in Figure 4.8. This arrangement is no more complicated than a rectifier-type 1/2-voltmeter circuit.

The instrument has two overlapping frequency ranges: 20 to 500 cycles, and 100 to 3000 cycles. Scale calibration charts are given in Figure 4.9. From the charts, it will be seen that the frequency curves are neither linear nor uniform. This requires the preparation of a calibration chart or the drawing of a special meter scale. The input signal voltage must be maintained constant at 10 volts r.m.s. but in most instances, this requirement will impose little hardship. The 0.1- and 0.01-microvolt capacitors must have exact specified values and should be of good quality.

The frequency meter may be calibrated with an audio oscillator. Set the oscillator to 500 cycles, and the frequency meter to its low-frequency range. Adjust the signal input voltage to 10 volts r.m.s. and set the 20,000-ohm CALIBRATION CONTROL rheostat to bring the meter pointer exactly to full scale. If the two capacitors have exact values, no further adjustment of the control will be necessary. The meter then may be calibrated at as many frequency points as desired, being careful each time the frequency is changed to keep the input voltage at 10 v.

Signal voltages higher than 10 v. can be accomplished by stepping them down to 10 v. either through a transformer or with a resistance-type voltage divider.

---

**A. Low-Frequency Range**

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**B. High-Frequency Range**

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4.9 VOLTAGE-SELECTIVE CIRCUIT

![Figure 4-10. Voltage-selective Circuit.](image)

It is convenient in a number of electrical control operations to have a control voltage rise to some peak value as an applied voltage increases in value, and then fall back to zero as the applied voltage continues to increase. Few circuits have been available for this purpose.

Figure 4.10 shows a simple germanium diode circuit in which d.e. output voltage rises from zero to approximately 79 millivolts as the input voltage rises from zero to approximately 50 volts, and then decreases as the input voltage increases further, eventually again reaching zero when the applied voltage has risen to 150 volts. Action of this circuit, which is a diode bridge, is based upon the fact that one bridge arm (the germanium diode) is a non-linear element. The bridge therefore can be balanced as only one input voltage value, and imbalances in one direction or the other depending upon the level of applied voltage.

While the slope of the output voltage curve is relatively blunt, it is sufficiently "selectivity" to pick up a sensitive meter-type d.e. relay at 0.5 volt input and to drop the relay out at points slightly higher and lower than 0.5 volts. Where higher output voltage is required, the output may be fed into a d.c. amplifier.

The 1000-ohm potentiometer is set at about half-range (500 ohms each side), but its exact setting will depend upon forward current characteristics of the individual diode used. When this circuit is set correctly, the output voltage (as read with a 100 or 200-milli-ohm 200-ohm or higher meter, the 100 microammeter, and range of a Simpson Model 260 volt-ohm-milliammeter will suffice), the output voltage will fall to zero but will never go negative as the input voltage is varied.

4.10 GERMANIUM DIODES AS CURVE STRAIGHTENERS

In a circuit in which direct current flow is non-linear with respect to voltage variation, a germanium diode often may be employed to straighten-out or linearize the current curve. The diode simply is connected in the current-carrying arm of the circuit with its anode connected to positive. Best success is obtained when the curve to be corrected is somewhat less than linearity. The circuit current must not exceed the average continuous forward current rating of the diode used.

In some instances, a variable resistance must be connected either in series or parallel with the diode to obtain the desired amount of current correction.

**RATINGS AND CHARACTERISTICS OF SYLVANIA GERMANIUM CRYSTAL DIODES**

Sylvania's line of germanium crystal components includes four types of diode, a dual-diode and four variator networks. All are lightweight, compact, rugged circuit elements having low shunt capacity, no contact potential and require no heater supply or mounting hardware. They have exceptional electrical stability and are strongly resistant to thermal shock.

Among the 14 germanium diodes are types designed to withstand working voltages up to 50, 150, 300 or 500 volts in the reverse direction, to exhibit exceptionally high back resistance or to possess a high forward conduction characteristic.

Six types are now available in either the ceramic or glass construction type. The glass types are made moisture proof by the unique hermetically sealed glass cartridge. They are smaller and lighter than the ceramic types and have been designed with terminals smaller in diameter than the glass body to eliminate risk of accidental contact in side-by-side mounting.

The dual-diode Type IN36 is a matched pair of IN34 diodes carefully matched for use in balanced circuits, for full-wave rectification, modulation or demodulation.

Sylvania Variator Types IN40, IN41, IN42 and IN71 are networks of four carefully selected and matched diodes especially designed for use as ring modulators in carrier suppression or carrier transmission circuits. In the plug-in units, Types IN40, IN42 and IN71, the crystals are mounted in a compact metal radio value shell. In Type IN71, the crystals are assembled in a rectangular metal can equipped with eight soldering lugs and adapted for top or sub-panel mounting.

All Sylvania Germanium Diodes have a nominal short capacitance of 1 pF, indicate an ambient temperature range of -50° to +70° C and have an average life of more than 10,000 hours.

The principal electrical ratings for each diode and the diode-diode and variator types are shown in the accompanying table.
### Sylvania Germanium Diodes

#### Ratings and Characteristics

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<th>Reverse Voltage Breakdown (volts Max.)</th>
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<td>Low Impedance Varistor</td>
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</table>

*Units are matched in the forward direction at 1/4 watt to the current ratings through the lower resistance and 1/2 within 10% of that in the higher resistance unit. Ratings shown are for each diode.

*Conduct of heat quickly spread and matched germanium diodes, whose resistances are balanced within ± 2.5%, in the forward direction at 7.5 volts. For additional balance, the forward resistance of each pair of matching units are balanced within ± 2.5%. Ratings shown are for each diode.

*Units are matched in the reverse direction at 0.15 volts max. at 60 ma. 70% modulated at 400 volts. Demodulated output across a 4700 ohm resistance is for a 0.5mA current in a maximum of 0.2 volts peak to peak.
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