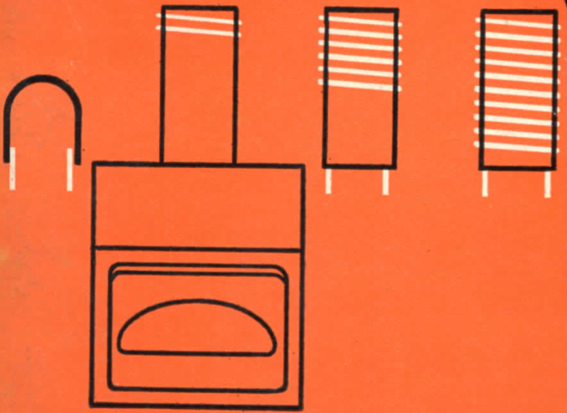
No. 245

HOW TO USE GRID-DIP OSCILLATORS

by Rufus P. Turner



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JOHN F. RIDER PUBLISHER, INC., NEW YORK

Library of Congress Catalog Card No. 60-7594

Printed in the United States of America

PREFACE

The grid-dip oscillator, sometimes called the grid-dip meter or "grid-dipper," is an exceedingly useful test instrument. It was first intended as a simple device for measuring the resonant frequency of a tuned r-f circuit. But, in the hands of ingenious users, it has come to be used for many other purposes. Today, this instrument is employed not only for resonance measurements but also as a signal source, monitor, and field-strength meter, and for checking such characteristics as capacitance, inductance, Q, bandwidth, and the properties of antennas, transmission lines, crystals, and filters.

In spite of the wide utility of the grid-dip oscillator, many technicians fail to receive maximum benefit from use of this instrument. This situation is due in part to ignorance of its capabilities and in part to the fact that technical discussions of the grid-dip oscillator have been scattered throughout the literature. Fuller use of this instrument will save many hours in the shop and laboratory.

The purpose of this book is to bring together in one place complete operating data covering representative uses of the grid-dip oscillator in radio, television, and electronics. We have included only those applications the practical worth of which has been proved by experience. The material is arranged in such a way that it either may be studied consecutively and systematically by the student or consulted handbookwise for specific directions.

The final chapter is devoted to descriptions of commercial grid-dip oscillators. For permission to use this material, the author is indebted to the following concerns: Aerovox Corporation, Barker & Williamson

Inc., Electronic Instrument Co. Inc., Heath Company, Measurements Division of McGraw-Edison Co., and James Millen Manufacturing Co. Inc.

Los Angeles, California RUFUS P. TURNER
January, 1960

SAFETY NOTICE

Use extreme care when checking a live circuit or device with a grid-dip oscillator. *Do not allow any part of the instrument to come into contact with energized equipment.* Such contact may result in electric shock and might cause death.

The power cord of a well-designed GDO contains a third lead which serves for grounding the case of the instrument. This safety lead has been provided for protection against electric shock, should the power line become short-circuited to the case inside the instrument. *Connect this lead to a good earth ground (such as a cold-water pipe) before using the instrument.* If a 3-contact outlet is available, install a 3-prong plug on the end of the power cord and connect the safety lead solidly to the ground prong of this plug.

Be careful and live longer!

CONTENTS

Chapter 1

PRINCIPLES AND CIRCUITS

In the early days of radio, it was first noticed that the d-c grid current of a self-excited radio-frequency (r-f) oscillator is very sensitive to resonance in a nearby tuned circuit. The grid current decreases, or *dips,* as the external circuit is tuned to the frequency of the oscillator, or vice versa.

The important thing about this effect is that the grid-current dip gives a more sensitive indication of resonance than could be obtained with the simple absorption wavemeter which was the principal early radio-frequency-measuring device. It was recognized at once that a tunable r-f oscillator equipped with a grid microammeter could be used advantageously to measure the resonant frequency of "dead" tuned circuits. As with the wavemeter, no direct connection, only inductive coupling, was needed between the oscillator and the circuit under test.

Such tunable oscillators *(grid-dip oscillators* or *GDO's)* were built and used in many laboratories and shops, but the commercial GDO did not appear until many years later.

This chapter explains the basic operation of the GDO. Typical circuits are shown. Future designs undoubtedly will incorporate many novel features, but the underlying principles will remain substantially the same as those explained in the following sections.

1.1 OPERATING PRINCIPLE OF THE GDO

There are many self-excited r-f oscillator circuits. Any one of them might be used as a GDO, but some are better suited to the purpose than others because of simplicity or stability.

For purposes of explanation, a simple tickler-feedback type of circuit is shown in Fig. 1-1. Here, r-f energy fed back from the plate circuit to the grid circuit by inductive coupling between the plate (tickler) coil L_2 and the grid coil L_1 causes oscillation. The oscillation frequency is determined by the capacitance of the grid tuning capacitor (C_1) and the inductance of the grid coil L_1. For wide frequency coverage with a single tuning capacitor C_1, plug-in coils are employed, each coil set consisting of L_1 and L_2 wound on the same plug-in form. The oscillator

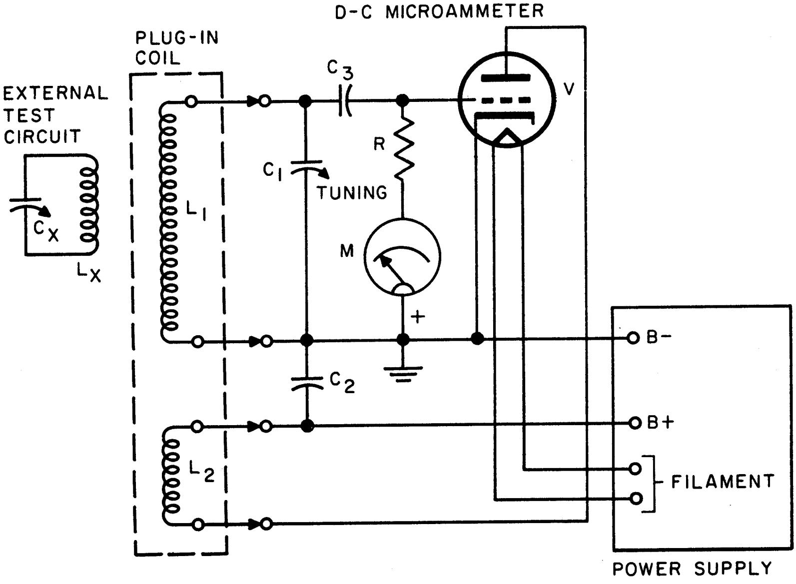


Fig. 1-1. Illustrative GDO circuit.

may be frequency-calibrated and the dial of C_1 graduated to read directly in kilocycles or megacycles. The power supply may be either batteries or a power-line-operated unit.

A d-c microammeter *M* is connected in series with the grid resistor *R*. This meter is deflected as long as the circuit is oscillating. The reason for this is rectification between the grid and cathode of the tube: the r-f voltage induced across L_1 by r-f current flowing in L_2 makes the grid alternately positive and negative with respect to the cathode. A diode is formed, with the grid acting as the plate of the diode. During the half-cycle when the grid is positive, electron current flows through the diode circuit; i.e., from cathode to grid, through resistor *R,* meter *M,* and back to cathode. The meter therefore is deflected. The amount of deflection is proportional to the strength of the r-f oscillation.

Now, if an external tuned circuit L_xC_x is inductively coupled to the grid coil L_1, the deflection of meter *M* will decrease (dip), reaching its lowest point (null) when the external circuit is tuned exactly to the

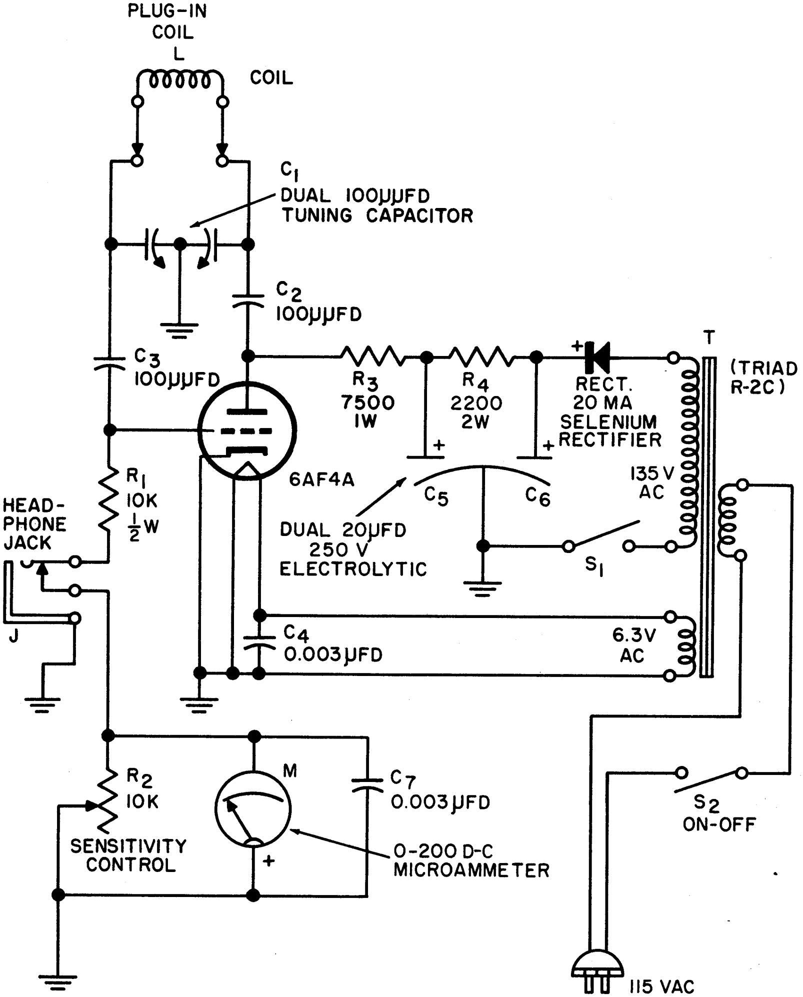


Fig. 1-2. Typical tube-type GDO circuit.

frequency of the oscillator. Conversely, if the external circuit is left fixed and the oscillator is tuned, by varying C_1, null will occur when the oscillator frequency equals that of the external circuit. The frequency is read simply from the null setting of the calibrated dial of tuning capacitor C_1.

The grid current dips because the external test circuit acts as a wave trap, which at resonance absorbs energy from the oscillator tank L_1C_1. This reduction of energy causes the r-f voltage across L_1 to decrease, and this, in turn, causes the grid current to drop. Loose coupling between the test circuit and oscillator coil improves the accuracy of indication by sharpening the tuning.

1.2 TYPICAL TUBE CIRCUIT

Although any self-excited r-f oscillator circuit conceivably might be employed as a GDO, the Colpitts circuit has come into general use. A typical Colpitts-type GDO circuit is shown in Fig. 1-2.

Particular advantages of the Colpitts circuit are: (1) it permits use of a simple 2-terminal coil L, and (2) the blocking capacitors C_2 and C_3 remove dc from the coil and thereby overcome the shock hazard present in some other circuits. However, a 2-section tuning capacitor C_1 is required.

Since self-excited oscillators do not oscillate with uniform intensity for each of the plug-in coils required to cover the total frequency range, or throughout the range of a single coil, the meter deflection will vary with tuning. Sometimes, the pointer will be driven off scale. Some manual adjustment therefore is desirable for setting the pointer to a desirable position on the meter scale prior to tuning for dip. This is the purpose of the SENSITIVITY CONTROL potentiometer R_2. In this circuit, this control functions as a simple meter shunt; in other circuits, the arrangement is different. (See Chapter 10 for examples of circuits.)

D-c plate power for the single 6AF4A tube is provided by a self-contained half-wave power supply consisting of a miniature transformer (T), 20-ma selenium rectifier (RECT), filter resistor (R_4), and dual filter capacitor (C_5-C_6).

The plug-in coils (L) should be designed for the effective maximum C_1 tuning capacitance of 50 μμf. The minimum capacitance (capacitor plus strays) for a midget variable capacitor is of the order of 10 μμf. For this capacitance range of 10–50 μμf, the following coil inductance values will provide the indicated frequency ranges:

COIL INDUCTANCE (microhenries)	TUNING RANGE (megacycles)
400	1.1 - 2.5
100	2.5 - 5
20	5 - 11.5
5	10 - 25
1.25	20 - 45
0.3	40 - 92
0.06	90 -200

Auxiliary functions. A headphone jack (*J*) and d-c switch (S_1) are included in the circuit. When S_1 is closed, plate voltage is applied to the tube, and the circuit oscillates. The instrument then may be used as a conventional GDO. When S_1 is open, however, and S_2 closed, plate voltage is removed from the tube. But since the filament is in operation, the tube will function as a diode detector, and the instrument may be used as a tuned monitor (with magnetic headphones plugged into jack *J*) or as a wavemeter or field-strength meter (without headphones but with the deflection of meter *M* showing the strength of a received signal). Applications of this type are described in Chapter 8 and 9.

1.3 TYPICAL PHYSICAL ARRANGEMENTS OF THE GDO

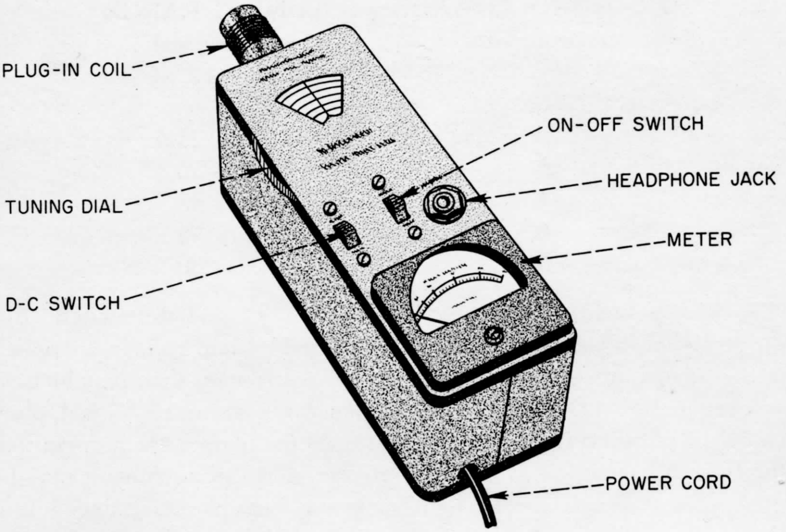
Most grid-dip oscillators are built small so as to be held in the operator's hand and manipulated like a test probe. Some instruments employ a thumb-operated tuning knob and can be both held and tuned with one hand.

There are numerous possible layouts. Figure 1-3 shows two common arrangements. There are many schemes for geared or cord-driven slow-motion tuning dials, and the placement of the dial and tuning knob on the instrument panel depends upon the size and type of this mechanism. See Chapter 10 for views of various commercial instruments.

In the conventional GDO, the coils are wound near the tops of their forms, as in Fig. 1-3, so that they may be placed close to a circuit under test. The coil is plugged into the nose end of the instrument case.

1.4 TYPICAL TRANSISTORIZED CIRCUIT

Battery operation of the tube-type GDO is possible when isolation from the power line is desired. But battery operation of this circuit has two drawbacks: (1) Both A and B batteries are required, and the latter



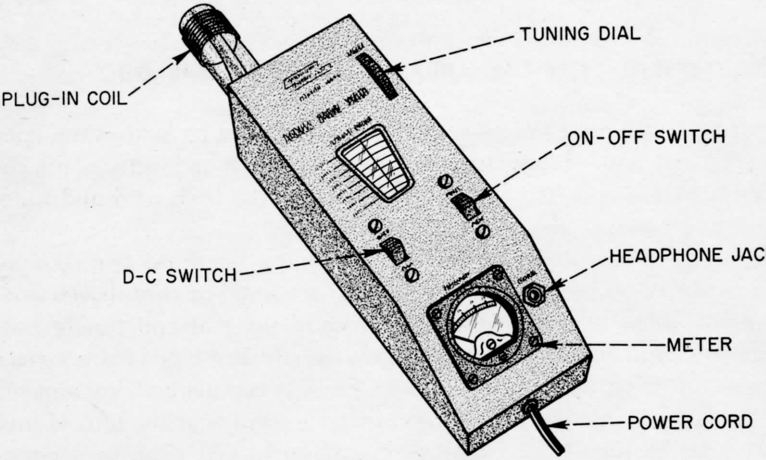


Fig. 1-3. Common GDO layouts.

are relatively expensive; and (2) the large size of the batteries precludes their placement inside the instrument.

These disadvantages are overcome by employing a transistor circuit. The transistorized GDO can be made smaller in size and lighter in weight than the tube version of the instrument, and it can be powered by several inexpensive flashlight cells. Furthermore, the transistor circuit requires no warmup, being ready for instant operation, and it generates no appreciable heat. The only disadvantage of the transistorized instrument, at the time of this writing, is its limited frequency response due to present characteristics of transistors—about 50 mc top frequency for any but very expensive transistors.

Figure 1-4 shows the circuit of a transistorized dip oscillator, properly named since there is no tube and hence no grid. This circuit, which has been adapted from an RCA original, employs a 2N247 drift transistor.

No electrode direct current of the transistor undergoes the dip exhibited by the grid current of a tube, so some other means must be enlisted for deflection of the indicating meter. In this circuit, a portion of the r-f energy in the LC_1 tuned circuit is rectified by a crystal diode *D*, capacitance coupled to the tuned circuit through capacitor C_3, and the resulting dc actuates the microammeter *M*. In conventional GDO operation, the r-f voltage across *L* decreases at resonance and the direct current through the meter dips in accordance.

The meter multiplier rheostat R_5 usually may be preset for deflection in the upper quarter of the scale, and all subsequent adjustment of the meter reading achieved with the SENSITIVITY CONTROL rheostat R_4. But this will differ with individual layouts of the instrument, and some adjustment of the values of the base-bias resistors R_1 and R_2 may be necessary for vigorous oscillation at all frequencies.

The plug-in coils can be wound, according to standard coil charts, for desired frequency bands, taking the range of tuning capacitor C_1 as 10 to 100 μμf. The following inductance values are recommended:

INDUCTANCE (microhenries)	FREQUENCY RANGE (megacycles)
600	0.65– 2
100	1.6 – 5
13	4.4 - 14
1.5	13 - 40

1.5 BUILDING *VS* BUYING A GDO

The question will arise in the mind of an experimenter whether to build or buy a grid-dip oscillator. The technician who is accustomed to building all manner of equipment for himself naturally will consider the feasibility of constructing such an instrument.

Fortunately, the answer is simple. For the technician who enjoys building electronic devices, kit-type GDO's are available. These are described in Sections 10.3 and 10.4 The price of the kit-type GDO is low enough that the private builder cannot build an instrument of comparable quality and appearance at anywhere near the same price.

At this writing, the situation is somewhat different with the transistorized dip oscillator, since commercial models are not available. A transistorized instrument, such as the one described in Section 1.4, may be built at low cost.

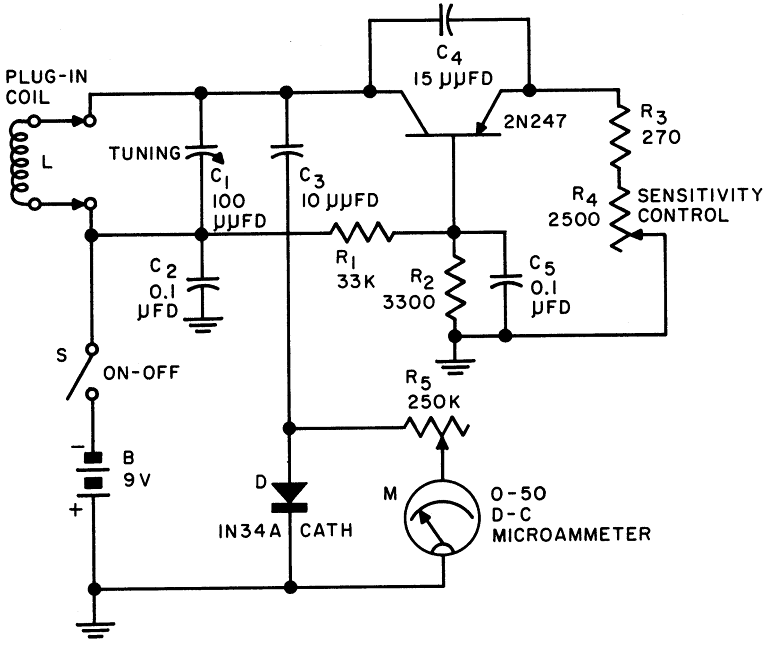


Fig. 1-4. Transistorized dip oscillator circuit.

1.6 SPECIAL INDICATORS

Most GDO's employ d-c microammeters as dip indicators. This is a simple and effective arrangement. A high-impedance r-f voltmeter, instead, might be connected across the oscillator tank, but the added complication is seldom advantageous except in some special laboratory instruments. A high-resistance d-c voltmeter similarly may be connected across the oscillator grid resistor.

A simple and inexpensive type of vacuum-tube voltmeter, which formerly was often used in lieu of a d-c microammeter in home-made GDO's, is the magic-eye tube. Connected across the grid resistor, the eye-tube pattern opens widest to indicate dip. One current commercial GDO employs the magic eye. (See Section 10.1.)

Chapter 2

GRID-DIP ADAPTORS

The *grid-dip adaptor* is a simple device which allows an r-f signal generator to be used as a grid-dip oscillator. The adaptor is connected to the r-f output terminals of the generator and requires no power supply unless it is transistorized. No work is needed inside the generator in order to use the adaptor. All tuning is done with the generator.

The grid-dip adaptor is small, inexpensive, and easy to build. It will appeal especially to engineers and technicians who desire the frequency accuracy and more ample dial scales of a signal generator.

Technical details of two adaptors are given in this chapter. These devices are used, in conjunction with signal generators, in the same way as grid-dip oscillators, and the GDO applications described in succeeding chapters apply to the adaptor as well.

2.1 PRINCIPLE OF THE ADAPTOR

Figure 2-1 shows the basic arrangement of a grid-dip adaptor and signal generator. The adaptor consists essentially of an untuned coil (L), crystal diode (D), and d-c microammeter (M) connected in series and to the output of the r-f signal generator. Resistor R is provided to complete the d-c path of the diode and is required only when there is a blocking capacitor in the output circuit of the generator.

Radio-frequency output from the signal generator is rectified by the diode, and the resulting dc deflects the microammeter. The pointer may be set to any position on the meter scale by adjusting the output control (attenuator) of the signal generator.

The coil L is untuned in the conventional sense. (Actually, it is self-resonant with its own distributed capacitance at a particular frequency which is outside of the range for which the coil is specified.) It serves as an exploring coil in the same way that the coil in a standard GDO functions.

With the meter deflected by the r-f output of the generator, coil *L* is coupled to an external test circuit in the same manner as with a GDO. The meter current will dip when the generator is tuned to the frequency of the circuit under test, or vice versa. The resonant frequency is read from the generator tuning dial. The output control of the generator serves the same purpose as the sensitivity control in a GDO; that is, to position the pointer on the meter scale. The generator may be either modulated or unmodulated. (Modulation contributes nothing to the performance of the adaptor.)

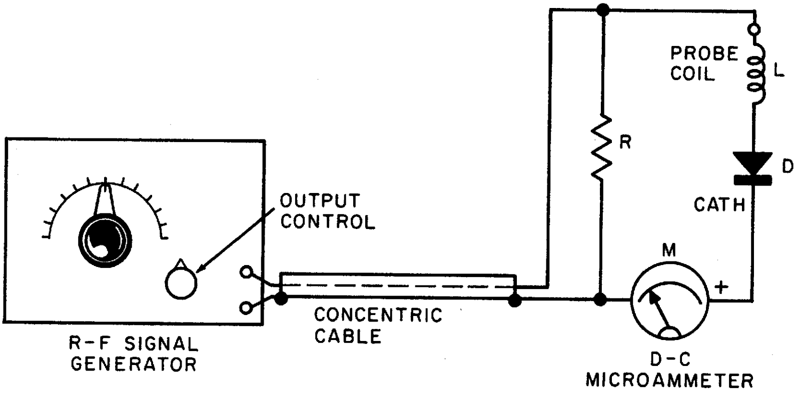


Fig. 2-1. Basic circuit of grid-dip adaptor.

Since coil *L* is aperiodic, it is usable over a wide frequency range. Its useful range is determined by its own inductance. The frequency at which this coil self-resonates with its distributed capacitance must be avoided, since a false response would be obtained at that frequency. To prevent this trouble, the maximum recommended frequency for a given coil is chosen considerably lower than the self-resonant frequency. In the adaptor, as in the GDO, plug-in coils permit wide frequency coverage. Only three adaptor coils will give an instrument range of 100 kc to 300 mc.

The adaptor usually is built in a small metal box or can and connected to the signal generator with a flexible concentric cable. If a miniature meter is employed, the device can be made small enough to be handled conveniently like a test probe.

2.2 DIODE-TYPE ADAPTOR

Figure 2-2 shows the circuit of a practical grid-dip adaptor. This unit can be built into a standard 2-5/16 × 2-1/8 × 1-3/4 inch aluminum chassis box if a 1-1/2-inch microammeter is used. A concentric jack *J* is provided for r-f input. The concentric cable is connected to a mating plug for this jack. If the generator has a coaxial output connection, a plug is attached to the other end of the cable also. Figure 2-3 shows the completed adaptor connected to the signal generator. The lowest-frequency coil is shown plugged in, and the two other coils are standing directly behind the adaptor.

Three plug-in coils are required. These are wound on 3/4-inch-diameter plastic forms according to the specifications given below.

Coil *A*	100 kc–7 mc	145 turns No. 32 enameled wire closewound
Coil *B*	5–40 mc	17 turns No. 22 enameled wire closewound
Coil *C*	35–300 mc	3 turns No. 22 enameled wire closewound

Coil *A* occupies the entire form. Coils *B* and *C* are shorter, however,

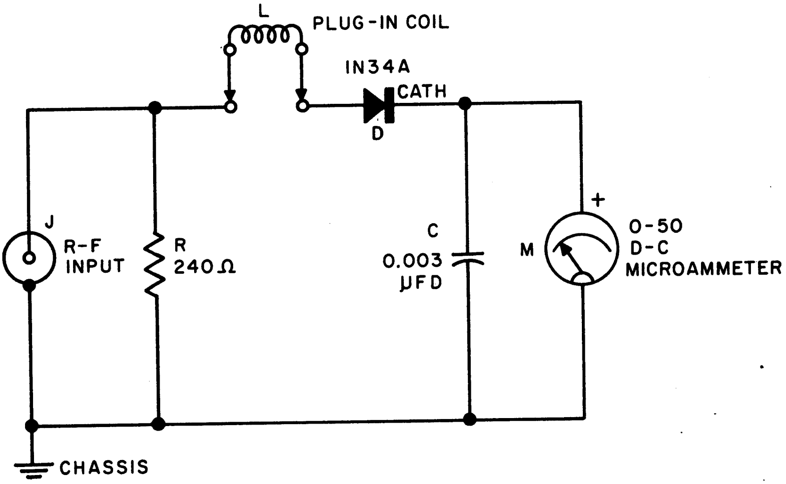


Fig. 2-2. Diode-type grid-dip adaptor circuit.

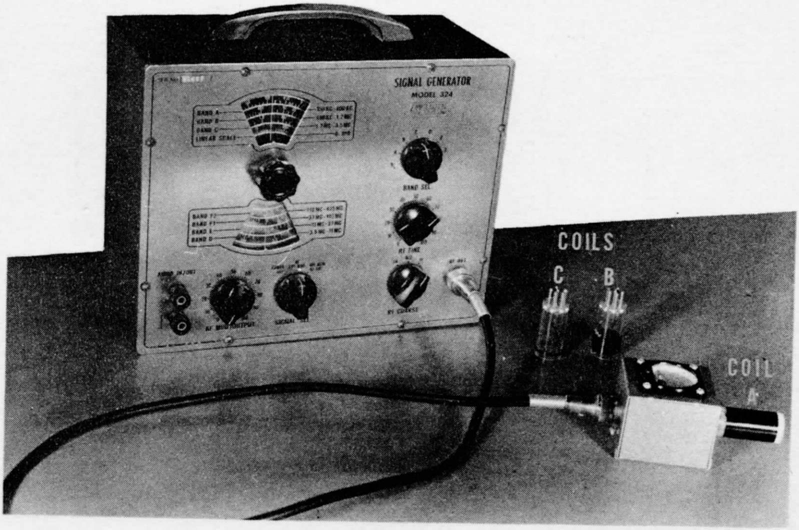


Fig. 2-3. Diode-type grid-dip adaptor connected to signal generator and ready for use. Coil *A* is shown plugged in; coils *B* and *C* are behind the adaptor.

and must be wound near the top ends of their forms (as seen in Fig. 2-3), so that they may be placed close to a circuit under test.

2.3 TRANSISTORIZED GRIP-DIP ADAPTOR

The sensitive d-c microammeter is necessary in the circuit shown in Fig. 2-2 because of the low r-f output voltage delivered by most signal generators. Often, however, use of a less expensive milliammeter may be desired. A 0–1 d-c milliammeter may be used if it is preceded by a transistorized d-c amplifier.

Figure 2-4 shows the circuit of a grid-dip adaptor in which the d-c output of the diode D is amplified by a single-stage amplifier, employing a low-cost general-purpose transistor (2N107) to drive the 0–1 d-c milliammeter M. Full-scale deflection occurs with a diode d-c output of approximately 50 microamperes (μa). The amplifier is powered by two $1\frac{1}{2}$-volt penlight cells B_1 and B_2. Prior to using the adaptor, the meter is set to zero, in the absence of an r-f input signal, by means of the ZERO SET rheostat R_2.

Aside from the transistor amplifier stage, the adaptor circuit is the same as the diode-type unit described in Section 2.2. Note, however,

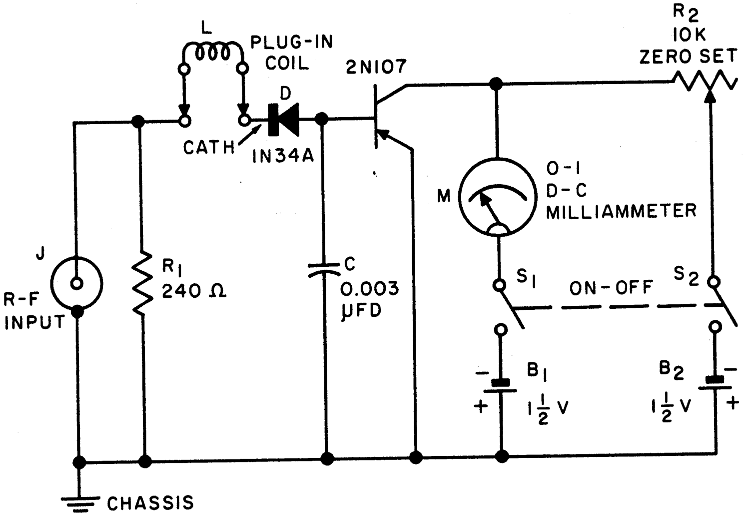


Fig. 2-4. Transistorized grid-dip adaptor circuit.

that the diode *D* in the transistorized circuit is connected in the opposite direction. This is necessary in order that the base of the transistor will receive negative d-c output from the diode. The coils (*L*) are identical with those specified in Section 2.2.

The zero setting of milliammeter *M* will drift with ambient temperature, the pointer moving upscale as the temperature rises. The zero-set rheostat accordingly must be readjusted occasionally, as in a vacuum-tube voltmeter. Whenever setting the meter to zero, connect the adaptor to the generator, plug in a coil, and reduce the r-f signal to zero. The setting of rheostat R_2 is not the same when the coil is removed from the circuit. (Some coil must be plugged in, but it does not matter which one, since a zero setting with one coil will hold for the other two.)

Chapter 3

RESONANT CIRCUIT MEASUREMENTS

The basic application of the grid-dip oscillator is to check the resonant frequency of an r-f tuned circuit. Many other applications are supplementary to this main function. For example, when capacitance or inductance is checked with a GDO, what is really measured is the resonant frequency of a test circuit containing the unknown parameter, and the latter then is determined from this frequency.

Since resonance measurements are the basis of most GDO applications, the technique for these measurements underlies all general uses of the instrument. The student consequently should become thoroughly familiar with the procedures explained in this chapter. They may be used with any standard GDO. The chief advantages of the GDO are realized in most of these measurements; that is, the circuit under test can be completely dead, and no direct connection is needed between the test circuit and instrument. Further applications dealing strictly with resonant circuits are given in Chapters 6 through 9.

Except where noted otherwise in this chapter, the GDO is assumed to operate in an oscillating condition; that is, its DIODE switch must be closed (thrown to its OSCILLATE position).

3.1 PRELIMINARY OPERATING NOTES

The GDO, like other instruments, must be handled properly to obtain satisfactory operation. The following precautions should be observed.

1. Always have a coil plugged in before switching on power to the instrument.

2. After switching on the power, allow a warmup time of at least 10 minutes before using the GDO. This will allow the frequency to stabilize.
3. When holding the GDO during a test, keep hands and fingers near the rear end of the instrument case where they will not be near a coil. Body capacitance can cause false responses.
4. In tests requiring that distance between the GDO coil and circuit under test be held constant, rest the instrument solidly on the table or bench.
5. Keep the line cord and headphone cord as far as possible from the GDO coil and the circuit under test.
6. Remove all extraneous metals and poor-grade dielectric materials from the vicinity of the circuit under test.
7. Prior to making a dip measurement, set the pointer about halfway up the meter scale by adjustment of the SENSITIVITY control. As the GDO is tuned, the deflection will change (dropping as the frequency rises), but it may be restored by readjustment of the control.
8. When searching for a resonant frequency, tune the GDO from its highest frequency downward, except where noted otherwise in the instructions.
9. Always employ the loosest practicable coupling between the GDO and circuit under test. Too tight coupling will cause the GDO frequency to be pulled by the external circuit. This not only gives an inaccurate frequency indication but causes a snap action of the meter instead of a smooth movement of the pointer in and out of the dip "slot."
10. For safety, switch off the oscillator before changing coils. This can be done without extinguishing the tube filament by throwing the DIODE-OSCILLATOR switch to its DIODE position.

These rules apply to all GDO applications and are assembled here for brevity. Otherwise, we would have to repeat many of them in each test procedure subsequently explained.

3.2 BASIC RESONANCE MEASUREMENT

In Fig. 3-1, coil *L* and capacitor *C* form a resonant circuit of unknown frequency f_r. To determine f_r, inductively couple the GDO to coil *L* and tune the GDO for dip. At dip, read f_r from the GDO dial. If there is no clue as to the probable frequency, the GDO should be tuned downward from the highest frequency of its highest range. If dip is not obtained with a given GDO coil, plug in the next lower-frequency coil, retune from the high- to the low-frequency end of its range, and repeat this operation until dip occurs.

Figure 3-1 shows the relationship between the GDO coil and test coil. For maximum inductive coupling, the turns of one coil should be parallel to those of the other. The position shown in Fig. 3-1 (A) will be best for most test coils. However, some coils (because of size, shape, or mounting) are more easily accessible from one end, as in Fig. 3-1 (B). The highest-frequency GDO coil is hairpin-shaped and should be coupled to the test coil in the manner shown in Fig. 3-1 (C). Here also, the turns of both coils are parallel. When the turns of the GDO and test coils are at right angles to each other, inductive coupling is zero or at minimum.

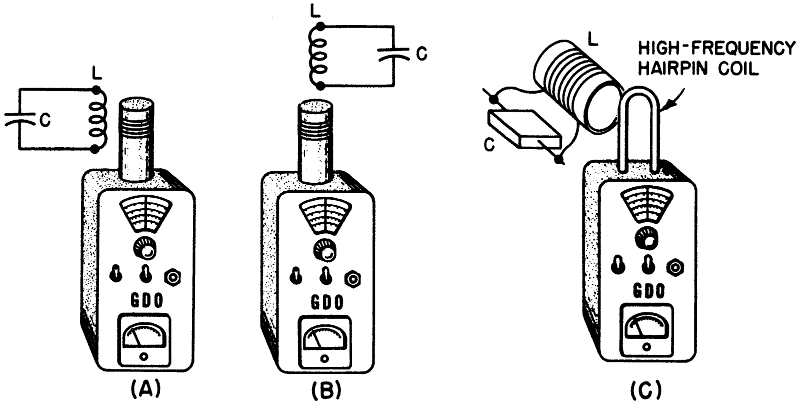


Fig. 3-1. Setups for resonance measurements.

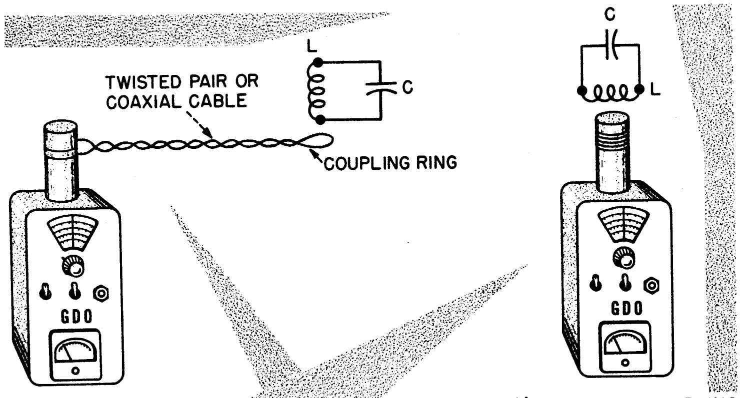
To prevent broad tuning, frequency pulling, or snap action of the meter, the loosest practicable coupling must be employed. This means separating the GDO and test coils as much as possible. As the coupling is loosened, the dip becomes slighter, but the tuning is sharper.

3.3 COUPLING METHODS

The simplest inductive coupling is shown in Fig. 3-1. Whereas this is the type of coupling which will be used in most applications, it is not the only method. Other types will be found preferable for special purposes.

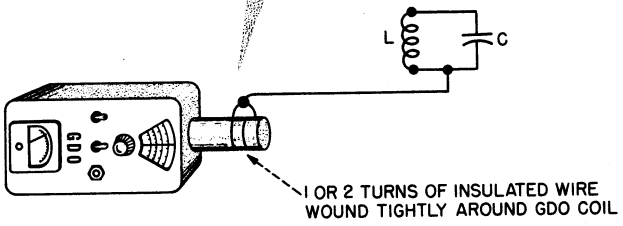
Figure 3-2 shows three additional types of coupling employed in resonant circuit measurements. Link coupling is shown in Fig. 3-2(A). This method is convenient when the geometry or location of coil *L* prevents access to the GDO coil. A pickup coil of 1 or 2 turns of insulated wire is wound tightly around the end of the GDO coil and is connected through a length of twisted pair or coaxial cable to a 1-turn ring which is inductively coupled to the test coil *L*. The plane of the ring must be parallel to the turns of the test coil. The diameter of the ring should be approximately the same as that of the test coil. The distance between the ring and coil *L* determines the tightness of coupling. One commercial GDO employs this type of link coupling exclusively, the ring becoming a test probe. (Section 10.1, Figs. 10-1 and 10-2).

When the turns of the GDO coil and test coil are perpendicular to each other, inductive coupling is zero or minimum, and capacitive



(A) LINK COUPLING

(B) CAPACITIVE COUPLING



(C) CAPACITIVE COUPLING

Fig. 3-2. Additional coupling methods.

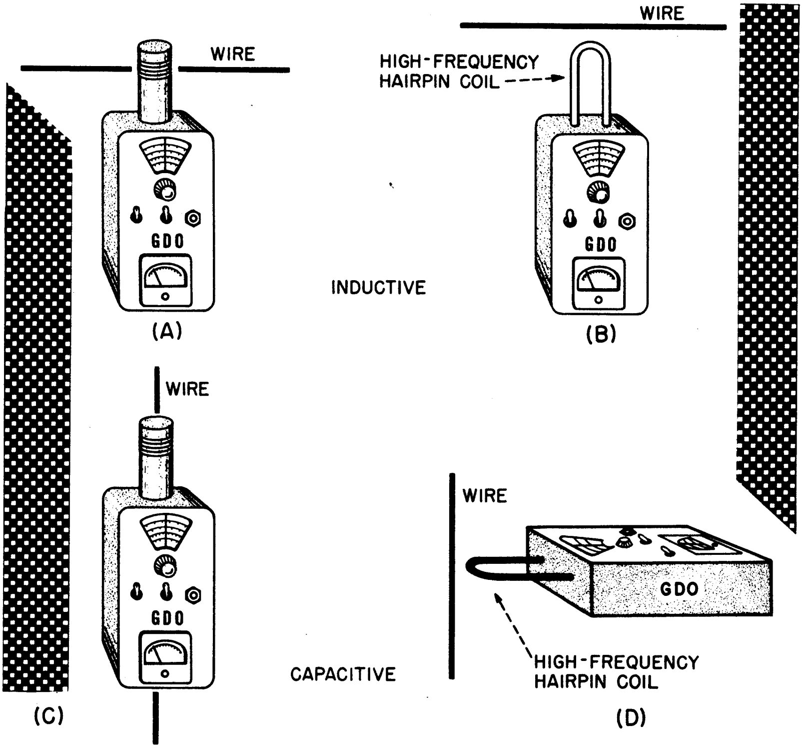


Fig. 3-3. Coupling to single wire.

coupling predominates. This condition is illustrated by Fig. 3-2(B). Capacitive coupling may be obtained with the ring shown in Fig. 3-2(A), when the plane of the ring is perpendicular to the turns of the coil under test. Capacitive coupling is recommended when checking some high-impedance, high-Q circuits and devices, as will be explained later in this and subsequent chapters.

Direct capacitive coupling is shown in Fig. 3-2(C). Here, 1 or 2 turns of insulated wire are wound tightly around the end of the GDO coil and connected by a short, straight lead to the test circuit, *LC*. The capacitance between these turns and the GDO coil is equivalent to connecting a 1- or 2-μμf coupling capacitor between the GDO and test circuit. This method of coupling is mandatory when test coil *L* is shielded or otherwise made inaccessible for inductive coupling. It has the disadvantage, however, that, although the effective coupling capacitance is very small, the calibration of the GDO is temporarily disturbed, the indicated frequency being somewhat lower than the true value.

3.4 COUPLING TO A SINGLE WIRE

When checking for resonances in leads, antennas, and transmission lines, the GDO must be coupled to a single straight wire. This test is invaluable for locating spurious resonances in receiver or transmitter leads to which bypass, or other, capacitors are connected, and for checking resonant frequencies of antennas and feeders.

Figure 3-3 shows how the GDO can be coupled to a single wire in tests of this kind. Figure 3-3(A) shows inductive coupling with a conventional GDO coil; Fig. 3-3(B) illustrates inductive coupling with the high-frequency hairpin coil. In both instances, the coil turns are parallel to the wire for maximum induction. Figure 3-3(C) shows capacitive coupling with a conventional GDO coil; Fig. 3-3(D) shows capacitive coupling with the high-frequency hairpin coil. In the latter two cases, the GDO coil turns are perpendicular to the wire for minimum induction.

Inductive coupling is recommended when the wire is part of a low-impedance (sometimes low-Q) circuit, while capacitive coupling is more satisfactory for high impedance, high Q. When checking an energized transmission line or antenna, inductive coupling is desirable at a current loop, and capacitive coupling at a voltage loop.

The wire is regarded here as the principal inductance of a resonant *LC* circuit. More specific data for checking antennas and transmission lines with the GDO will be found in Chapter 8.

3.5 PRESETTING A TUNED CIRCUIT

Many electronic systems contain fixed-tune circuits which are preset to a single operating frequency during an initial alignment process. These circuits generally consist of simple *LC* arrangements, like those shown in Figs. 3-1 and 3-2, but with either the capacitor or inductor variable. With the aid of a GDO, such circuits may be adjusted while in a passive state; that is, with no voltage applied to the circuit.

To preset a tuned circuit: (1) Switch on the GDO and set it to the desired frequency. (2) Inductively couple the GDO to the coil of the tuned circuit, using one of the arrangements shown in Figs. 3-1 or 3-2(A). (3) Adjust the variable capacitor or the inductive trimmer in the tuned circuit for dip. At the point of exact null, indicated by the GDO meter, the tuned circuit is set to the desired frequency.

If the tuned circuit cannot be reached for inductive coupling, as when a wave trap or tuning coil is shielded, capacitive coupling must be employed. [See Fig. 3-2(C).] However, because of the direct connection, the GDO frequency will not be as accurate as when the coupling is inductive.

3.6 CHECKING AND ADJUSTING WAVE TRAP

To check the frequency to which a wave trap is set, inductively couple the GDO to the coil of the wave trap, using one of the methods shown in Figs. 3-1 or 3-2(A). Then tune the GDO for dip and read the frequency from the GDO dial. If the wave trap is shielded or boxed, so that its coil cannot be reached for inductive coupling, use direct capacitive coupling [as in Fig. 3-2(C)], but remember that the measured frequency will be somewhat lower than the true wave-trap frequency.

To adjust a wave trap to a desired frequency, first set the GDO to that frequency and couple it to the wave trap as explained in the preceding paragraph. Then adjust the variable capacitor or the inductive trimmer in the wave trap for dip.

Because of stray circuit capacitances, a wave trap should be checked in the circuit in which it is to be operated, whenever possible.

3.7 DETERMINING TUNING RANGE OF RESONANT CIRCUIT

In a variable-frequency resonant circuit, either the coil or the capacitor is variable. In a few such circuits, both are variable. The highest frequency to which the circuit may be tuned is reached when the capacitance and/or inductance are adjusted to their minimum values, the lowest frequency when they are adjusted to maximum.

To check the tuning range of the circuit: (1) Couple the GDO to the circuit, using one of the methods shown in Figs. 3-1 and 3-2(A). If the coil of the circuit is not available for inductive coupling, use direct capacitive coupling [Fig. 3-2(C)], remembering that the indicated frequencies will be somewhat lower than true values. (2) Set the resonant circuit for its highest frequency. (3) Tune the GDO for dip and read the high-frequency tuning limit from the GDO dial. (4) Set the resonant circuit for its lowest frequency. (5) Retune the GDO for dip and read the low-frequency limit from the GDO dial. (6) To obtain a tuning curve for the resonant circuit, set the variable element of the circuit successively to as many points as desired, and determine at each setting the corresponding frequency by retuning the GDO for dip. (7) This procedure may be used also for direct calibration of a tuning dial in the resonant-circuit device.

3.8 CALIBRATING ABSORPTION WAVEMETER

A conventional absorption wavemeter consists of a variable capacitor and fixed-inductance coil.

Calibrating a wavemeter consists of determining its tuning range by means of point-by-point frequency measurements: (1) Set the wavemeter to its high-frequency (low-capacitance) limit. (2) Inductively couple the GDO to the wavemeter coil, using one of the methods shown in Figs. 3-1 or 3-2(A). (3) Tune the GDO for dip, read the frequency from the GDO dial, and inscribe this frequency on the wavemeter dial or record it on a calibration chart. (4) Reset the variable capacitor in the wavemeter to the next higher-capacitance point on the dial, and check and record the frequency here in the same way as in Step (3). (5) Repeat at the next succeeding higher-capacitance point on the wavemeter dial. (6) Repeat at as many points as practicable until the low-frequency (high-capacitance) limit of the wavemeter is reached. (7) If the wavemeter has plug-in coils, repeat the entire procedure [Steps (1) to (6)] for each coil.

3.9 CHECKING RESONANCES IN R-F CHOKE

The fundamental frequency at which an r-f choke resonates is a function of the inductance and distributed capacitance of the choke. Thus, an r-f choke having nothing connected to it, and with its leads open, can be regarded as a resonant *LC* circuit. Because of their geometry, some chokes exhibit several resonances other than the fundamental frequency of operation.

The various self-resonances of an r-f choke may be determined readily with a GDO. For this test, the leads of the choke must be free, and the choke should rest on a dry, insulating surface. Figure 3-4 shows suggested methods of coupling a GDO to a choke.

Starting at the high-frequency limit of the highest-frequency plug-in coil, tune the GDO through its total frequency range, changing coils

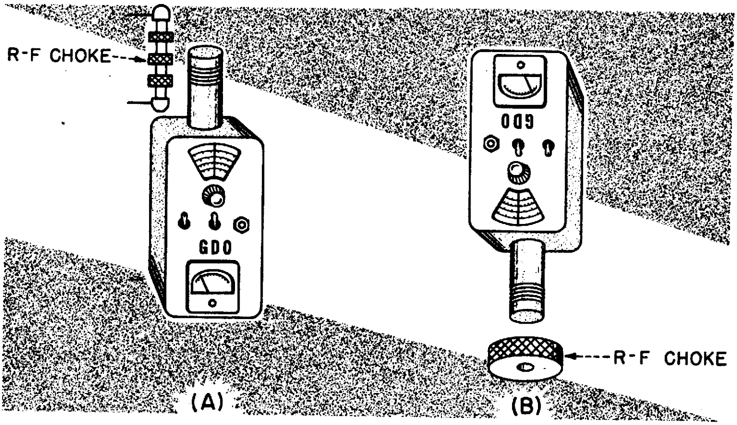


Fig. 3-4. Checking r-f choke.

to shift bands, and note the frequency at which each dip occurs. These are the self-resonances of the choke.

Coupling to some chokes is difficult, and it consequently may be necessary to use link coupling [Fig. 3-2(A)], winding 1 or 2 turns of insulated wire tightly around the choke in place of the coupling ring. Many r-f chokes have relatively low Q, which causes the tuning to be broad and the dip sluggish.

3.10 CHECKING SELF-RESONANCE OF COIL

R-f and i-f (intermediate-frequency) coils resonate at frequencies determined by their inductance and capacitance values. This self-resonance often limits the useful range of a coil. Modern coil-winding techniques are aimed at reducing the distributed capacitance and thereby increasing the self-resonant frequency beyond the top frequency at which the coil must be used.

To use the GDO to measure the self-resonant frequency of a coil: (1) Disconnect the coil from any circuit and spread its leads free of each other and of external conductors. (2) Rest the coil on a dry insulating surface clear of metallic objects. (3) Inductively couple the GDO to the coil, preferably using the method shown in Fig. 3-5(A). When the test coil is much larger or smaller in diameter than the GDO coil, simple inductive coupling may not be possible. In this instance, the link-coupling scheme shown in Fig. 3-5(B) may be employed. One or two turns of insulated wire are wound tightly around the GDO coil and also around the coil under test. The two small coupling coils then are connected together with a short length of twisted pair or coaxial cable. If the test coil is airwound (self-supporting), winding a coupling coil around it may be impossible, and the small coupling coil may simply be rested close to the test coil and parallel to it. If the hairpin coil is used in the GDO, make a coupling coil of 1/2 turn of insulated wire and tape it to the hairpin. (4) Starting at the high-frequency limit of the highest-frequency plug-in coil, tune the GDO through its frequency range, changing coils if necessary, until dip occurs. At this point, read the self-resonant frequency of the coil from the GDO dial.

If a coil normally is operated inside a metal shield can, it must be tested in the shield. For this purpose, either link coupling [Fig. 3-5(B)] or direct capacitive coupling [Fig. 3-2(C)] must be employed.

3.11 CHECKING FREQUENCY OF LINEAR TANK

The resonant circuits described previously in this chapter contained lumped inductance and capacitance. However, many uhf and vhf receivers, transmitters, and test instruments employ linear circuits instead. A familiar arrangement is the parallel-line tank, shown in Fig. 3-6, consisting of two wires, rods, or tubes shorted at one end. The resonant frequency is a function of the length, diameter, and spacing of the

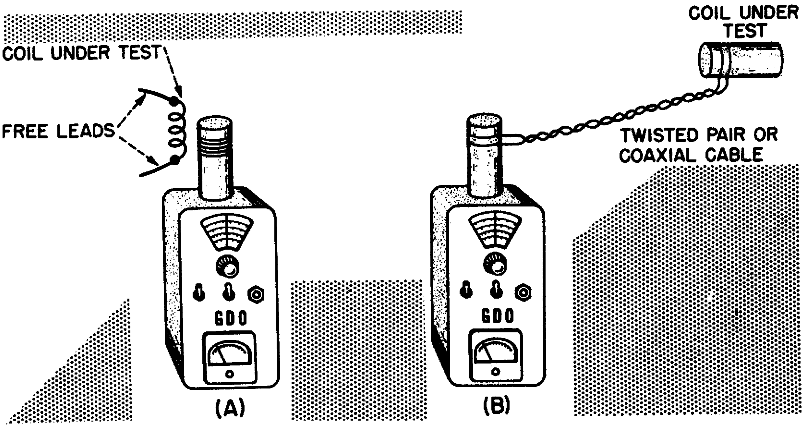


Fig. 3-5. Checking coil for self-resonance.

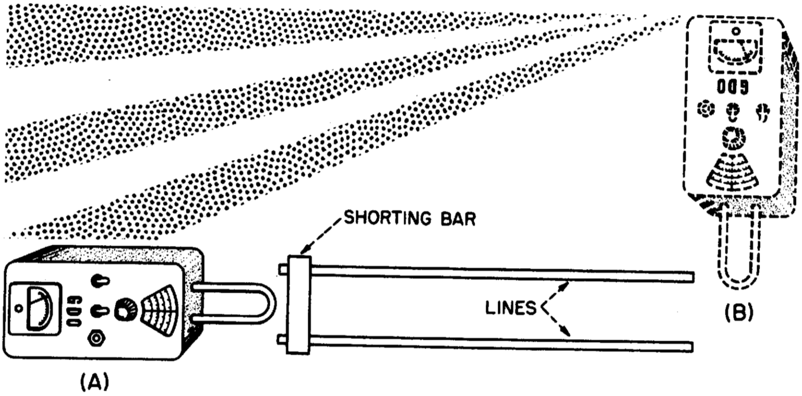


Fig. 3-6. Test setup for linear tank.

lines. Sometimes, a small trimmer capacitor is connected between the lines and made movable along their length.

To check this type of resonant circuit, the GDO may be inductively coupled to the shorting bar at the closed end of the lines, as shown at *A* in Fig. 3-6, or capacitively coupled to the open end, as shown at *B*. In the equipment in which the linear tank is employed, a vacuum tube generally is connected to the open end of the lines and should be so connected when making a frequency measurement, but with power to the tube switched off.

As the GDO is tuned through its range, dip will occur at a number of frequencies. The lowest of these points is the primary resonant frequency and is that frequency at which the line is 1/4 wavelength long. The other dips occur at frequencies which correspond to multiples of 1/4 wavelength.

3.12 CHECKING FREQUENCY OF COAXIAL TANK

Another type of distributed-constant resonant circuit employed in uhf and vhf equipment is the coaxial section. This tank consists basically of a section of coaxial line, although physically it may resemble a tube or can. Because the inner conductor is completely surrounded and shielded by the outer conductor, a small 1-turn coil must be provided, as in Fig. 3-7(A), for inductive coupling to a GDO. This is recommended when the other end of the coaxial section normally is open. When the far end of the coaxial section normally is closed, capacitive coupling must be employed, as shown in Fig. 3-7(B), since the open end of the section is a high-impedance, high-Q point. The hairpin GDO coil is held close to the top of the center conductor of the section, with the plane of the hairpin in line with, and parallel to, the axis of the conductor.

Determine the resonant frequency of the open coaxial tank in the following manner: (1) Use the test setup shown in Fig. 3-7(A). (2) Tune the GDO throughout its appropriate frequency bands. (3) Note that dips occur at several frequencies. The lowest of these points is the primary resonant frequency and is that frequency at which the

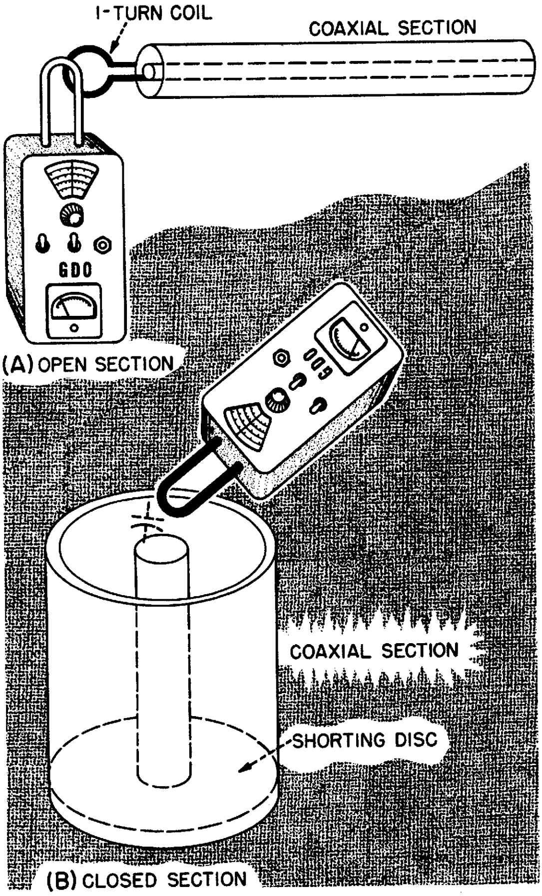


Fig. 3-7. Test setup for coaxial tank.

section is 1/4 wavelength long. The other dips occur at frequencies corresponding to multiples of 1/4 wavelength.

Determine the resonant frequency of the closed coaxial tank in the following manner: (1) Use the test setup shown in Fig. 3-7(B). (2) Tune the GDO through its appropriate frequency bands. (3) Note that dips occur at several frequencies. The lowest of these points is the primary resonant frequency and is that frequency at which the section is 1/8 wavelength long. The other dips occur at frequencies corresponding to multiples of 1/8 wavelength.

3.13 CHECKING ENERGIZED RESONANT CIRCUIT

When necessary, the operating frequency of an *energized* resonant circuit (such as the tank of an operating transmitter, oscillator, or industrial r-f generator) may be checked in three ways with a GDO. The three methods are described below.

When checking a resonant circuit operated at high voltage, avoid touching the circuit with any part of the GDO. Failure to take this precaution may result in electrocution.

GDO used as tuned monitor with aural indicator. This method is usable only when the device under test is amplitude modulated. The GDO is employed as a tuned diode detector with headphones as the resonance indicator.

With the device in operation: (1) Set the OSCILLATOR-DIODE switch of the GDO to its DIODE position. (2) Plug high-impedance magnetic headphones into the HEADPHONE jack of the GDO. Magnetic headphones are necessary to complete the diode circuit. If only crystal headphones are available, a 1000-ohm resistor must be connected in parallel with them. Inserting the headphone plug into the jack automatically disconnects the microammeter from the GDO circuit. (3) Inductively couple the GDO to the live resonant circuit. (4) Starting at the low-frequency limit of the lowest-frequency plug-in coil, tune the GDO through its frequency range, changing coils as required. Tune for maximum headphone signal. (5) The signal is apt to be tuned in at several frequencies. The lowest of these points is the fundamental frequency of the device under test. (6) For sharp tuning, use the loosest practicable coupling between GDO and test circuit. When the coupling is properly loosened, the fundamental frequency will be the only one detected with the GDO.

GDO used as wavemeter with meter indicator. This method is usable with either modulated or unmodulated signals. It is similar to the preceding method except that resonance is indicated by the GDO microammeter instead of headphones.

With the device in operation: (1) Set the OSCILLATOR-DIODE switch of the GDO to its DIODE position. Do not insert a plug into the HEADPHONE jack. (2) Inductively couple the GDO to the live resonant circuit. (3) Starting at the low-frequency limit of the lowest-frequency plug-in coil, tune the GDO through its frequency range, changing coils as required. Tune for peak deflection of the meter. (4) Since relatively high signal intensity is required for good deflection, extraneous responses are not usually encountered with this method, deflection being obtained only at the fundamental frequency when loose coupling is employed. At the point of maximum upswing of the pointer, read the frequency from the GDO dial.

GDO used as oscillating detector. This method gives the highest accuracy and sensitivity and is recommended only with an unmodulated signal. The GDO is employed as an oscillating (heterodyne) detector or frequency meter, with headphones.

With the device in operation: (1) Set the OSCILLATOR-DIODE switch of the GDO to its OSCILLATOR position. (2) Plug high-impedance magnetic headphones into the HEADPHONE jack of the GDO. Magnetic headphones are necessary to complete the grid circuit of the GDO. If only crystal headphones are available, a 1000-ohm resistor must be connected in parallel with them. Inserting the headphone plug into the jack automatically disconnects the microammeter from the GDO circuit. (3) Inductively couple the GDO to the live resonant circuit, using very loose coupling. (With transmitters and power oscillators, the GDO may be situated several feet from an unshielded resonant circuit.) (4) Starting at the low-frequency limit of the lowest-frequency plug-in coil, tune the GDO through its frequency range, changing coils as required. Tune for zero beat with the signal. Unless the coupling is extremely loose, the signal will be tuned in at several frequencies. The *strongest* of these points is the fundamental frequency of the device under test. Unlike the two preceding methods, the tightly coupled oscillating detector will deliver signals at frequencies both above and below the fundamental frequency, but the fundamental should be the strongest. A good way to identify the fundamental when the signals are of nearly equal strength is to note the frequency separation between any two successive beat-note points (f_1 and f_2). The difference between these two (that is, f_2-f_1) equals the fundamental frequency.

3.14 RELATIVE Q OF RESONANT CIRCUIT

When testing cold resonant circuits with a GDO, the dip indication will be sharp for a high-Q circuit and sluggish or broad for a low-Q circuit. The dip with a very-high-Q tank, such as a low-loss coil and air-capacitor combination, is so sharp that it can be missed completely if the instrument is tuned too fast.

This difference in response gives a convenient indication of the relative Q of a circuit under test, but it is strictly a qualitative indication which is suitable only for rough, comparative appraisals. More precise, quantitative methods for checking Q with a GDO will be found in Chapter 9.

Chapter 4

CAPACITANCE MEASUREMENTS

Capacitance checking is one of the principal auxiliary functions of the grid-dip oscillator. The GDO offers a convenient means of checking nonelectrolytic capacitors and of measuring capacitance effects at radio frequencies. In fact, a capacitor may be checked at the actual frequency at which it later will be operated in equipment. A particular advantage of the GDO is its ability to check a capacitor either in or out of electronic equipment.

Various practical methods of checking capacitance with a GDO are explained in this chapter. These are the basic methods of measuring capacitance by resonant-circuit techniques, and have been proved by long experience. However, variations of the procedures, to suit specific conditions, may suggest themselves to the alert reader.

4.1 CAPACITANCE-MEASUREMENT PRINCIPLE

Capacitance is measured *indirectly* with the GDO: The unknown capacitance is connected temporarily in parallel with an accurately known inductance to form a resonant circuit, and the resonant frequency of this combination next is checked with the GDO. Finally, the unknown capacitance is calculated from the known inductance and measured frequency. Figure 4-1 shows the simple test setup. This method may be used with nonelectrolytic capacitors, such as air, paper (oil and wax), mica, ceramic, and plastic types. Electrolytic capacitors, because of their normally low leakage resistance, do not operate satisfactorily in the r-f tuned circuits.

4.2 PRACTICAL CAPACITANCE MEASUREMENT

A precision coil will be required for capacitance measurements. This can be any good coil, with high Q, whose inductance is known accurately. The inductance may be determined beforehand with an accurate bridge or other inductance-measuring instrument or may be measured with a GDO according to the instructions given in Chapter 5. Inexpensive commercial variable inductors are available which have screwdriver-adjusted slugs for setting the inductance closely to some convenient value such as 100, 200, or 500 microhenries (μh).

For occasional capacitance measurements, the leads of the test coil may be connected to the capacitor under test simply by soldering or twisting together. But stability, accuracy, and utility will be enhanced by a permanent capacitor-test fixture, especially when large numbers of capacitors are tested. Figure 4-2 shows an example of a small test fixture. In this device, the coil form is cemented or bolted to a narrow polystyrene strip. A banana plug is mounted on each end of the strip and connected to the coil. Slip-on alligator clips may be snapped onto the plugs to receive the capacitor pigtails. In some tests, the banana plugs will be used without the alligator clips. Some builders may prefer to fasten the clips directly to the strip and dispense with the plugs.

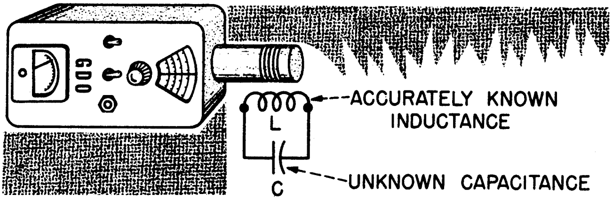


Fig. 4-1. Basic capacitance-measuring setup.

To check capacitance with the GDO: (1) Connect the capacitor (of unknown capacitance C) to the precision test coil (L), using the shortest practicable leads. (2) Inductively couple the GDO to the test coil and tune for dip. (3) At dip, read the resonant frequency (f) of the resonant circuit. (4) Calculate the capacitance from the known inductance and measured frequency:

$$C = \frac{25{,}400}{f^2 L}, \tag{4-1}$$

where C is in $\mu\mu$f, f in mc, and L in μh.

Example: A certain capacitor is connected to a 20-μh test coil. A GDO test shows the resonant frequency of the combination to be 2 mc. Calculate the capacitance.

From equation (4-1)

$$C = \frac{25{,}400}{2^2\,(20)} = \frac{25{,}400}{4\,(20)} = \frac{25{,}400}{80} = 317.5\ \mu\mu\text{f.}$$

For accuracy, it is best to make the actual longhand calculation or to use a conventional slide rule. However, when time must be saved, an approximate answer may be found quickly with the aid of a regular frequency-reactance chart or reactance slide rule. A chart of this type is not printed here, since the small page size would seriously limit the accuracy of results obtained.

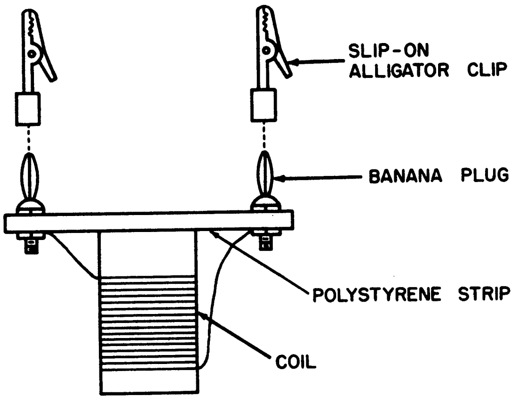


Fig. 4-2. Capacitor-test fixture.

One commercial GDO has tuning scales large enough to permit capacitance graduations in addition to those for frequency. Direct readings are provided between 200 μμf and 3.5 μf, and no calculations are necessary. (See Section 10.1 and Fig. 10-1.)

4.3 CHECKING DISTRIBUTED CAPACITANCE OF COIL

The distributed capacitance of the test coil employed in capacitance measurements is effectively in parallel with the coil and capacitor under measurement. (See Fig. 4-3.) This unavoidably places a certain amount of capacitance in parallel with the unknown and causes the value calculated by means of equation (4-1) to be higher than the true value of the capacitance under test. Thus, $C_m = C_x + C_d$, where C_m is the calculated capacitance from GDO measurement, C_x the true value of the unknown capacitance, and C_d the distributed capacitance of the coil. Because of distributed capacitance, the checking of values lower than about 50 μμf is not recommended with most GDO's.

In many practical cases, the distributed capacitance is so much smaller than the unknown capacitance that it may be ignored. When the unknown capacitance is very small, however, the distributed capacitance becomes significant and must be subtracted from the calculated value. The C_d value for the test coil accordingly must be known. It may be determined by GDO measurement in the following manner: When the inductance (L) of the coil is accurately known, determine the distributed capacitance roughly by checking the self-resonant frequency (f) of the coil, using the method explained in Section 3.10, and calculating C_d from the known inductance and measured frequency:

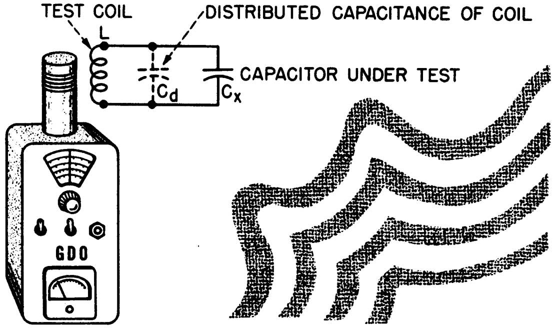


Fig. 4-3. Measuring the effect of distributed capacitance.

$$C_d = \frac{25{,}400}{f^2 L}, \tag{4-2}$$

where C_d is in μμf, f in mc, and L in μh.

Example: A 1.2-μh coil is found to self-resonate at 190 mc. Calculate the approximate value of the distributed capacitance.

From equation (4-2):

$$C_d = \frac{25{,}400}{190^2\,(1.2)} = \frac{25{,}400}{36{,}100\,(1.2)} = \frac{25{,}400}{43{,}320} = 0.59 \text{ μμf}$$

Other (laboratory) methods provide more accurate measurement of distributed capacitance.

4.4 CHECKING SMALL CAPACITANCES

A small capacitance (C_a) may be checked with good success by connecting it in parallel with a larger, accurately known capacitance (C_b), measuring the total capacitance (C_c) with the GDO, and then subtracting C_b. In this way, the distributed capacitance effect is minimized. The test setup is shown in Fig. 4-4.

Capacitance C_b is chosen higher than the recommended low-capacitance limit of the GDO. For example, when the limit is 100 μμf, select $C_b = 200$ μμf. The shortest practicable leads must be used between the capacitors and coil.

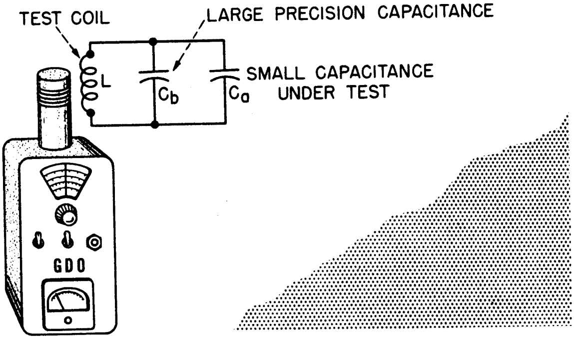


Fig. 4-4. Setup for checking small capacitance.

Example: An unknown capacitance (C_a) is connected in parallel with a 200-μμf capacitor (C_b) and test coil. After checking resonance with a GDO, the total capacitance (C_c), calculated with equation (4-1) is 215 μμf. What is the value of the small capacitance?

$$C_a = C_c - C_b = 215 - 200 = 15 \text{ μμf}$$

4.5 SUBSTITUTION METHOD OF CHECKING CAPACITANCE

The most accurate scheme for checking small capacitances is the *substitution method.* With this method, the stray circuit capacitance and the distributed capacitance of the coil may be ignored.

Figure 4-5 shows the test setup. Here, C_s is a variable air capacitor equipped with a dial reading direct in micromicrofarads. This capacitor is connected in parallel with a test coil (L) and a pair of terminals (X-X) to which a capacitor may be connected for test. All wiring between L, C, and X-X is stationary and rigid. The test procedure consists of resonating the LC_s circuit to the GDO frequency (by tuning C_s) first with terminals X-X open and next with the unknown capacitor connected to these terminals. The unknown capacitance is equal to the difference between the two settings of capacitor C_s.

The following is a step-by-step procedure for substitution-type capacitance measurement: (1) With terminals X-X open, as shown in Fig. 4-5, set the variable capacitor (C_s) to its high-capacitance limit, and record this value as C_1. This is the *initial adjustment.* (2) Couple the GDO to coil L in the test circuit and tune it for dip. Do not subsequently disturb this setting of the GDO. (3) Connect the unknown capacitor to terminals X-X. The addition of this capacitance will detune the circuit, destroying the GDO dip. (4) Retune the test circuit, by setting C_s to a lower capacitance, until dip is restored. This is the *final adjustment.* (5) At this second dip, record the new setting of the variable capacitor as C_2. (6) Calculate the unknown capacitance (C_x) as the difference between the initial and final settings of the variable capacitor:

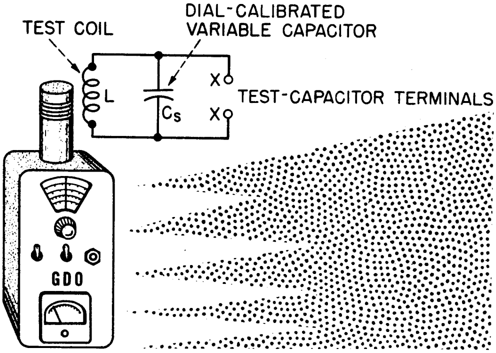


Fig. 4-5. Setup for substitution-type measurements.

$$C_x = C_1 - C_2. \tag{4-3}$$

Example: A substitution-type test circuit is resonated initially when the variable capacitor is set to its top capacitance of 500 μμf. With the unknown capacitor connected, the circuit is re-resonated when the variable capacitor is reset to 488 μμf. What is the value of the unknown capacitance?

Here, $C_1 = 500$ μμf, and $C_2 = 488$ μμf.

$$C_x = 500 - 488 = 12 \text{ μμf}.$$

In the interest of short leads, the capacitor under test should be connected to terminals X-X by its own pigtails. When test leads *must* be used, the initial adjustment should be made with them connected to terminals *X-X*, but disconnected from the external capacitor (or capacitance-exhibiting device), and formed into the position and shape they will occupy when connected to the capacitor. This will automatically compensate for the lead capacitance.

4.6 EFFECT OF EXTERNAL CIRCUIT ON CAPACITOR UNDER TEST

With the GDO, a capacitor may be tested for *condition* (that is, to determine simply whether it is good or bad) without removing it from its circuit. This is an advantage in troubleshooting. For accurate *capacitance* measurements, however, at least one lead of the capacitor must be disconnected from the circuit.

The GDO test is so little affected by the external circuit because the impedance of the test coil used in GDO capacitance measurements usually is very much smaller than any circuit impedance which shunts the capacitor, or can be made so. An interesting experiment is to connect a loop of wire between the terminals of a good capacitor and to check the capacitor with a GDO. At dc and low frequencies, this loop would constitute a short circuit and would make a test impossible. The only indication obtained would be that of a shorted capacitor. But in the GDO r-f test, this capacitor shows up as good. The indicated capacitance, however, will be lower than the true value because of the low inductance of the shorting wire. If, on the contrary, the capacitor is *internally* shorted, it will not resonate the GDO test circuit. An open capacitor likewise will not resonate the test circuit except at a suspiciously high frequency determined by stray capacitances and the distributed capacitance of the test coil.

Where a qualitative (condition) test is sufficient, the GDO thus provides a rapid method of checking capacitors in electronic circuits where they may be shunted by resistors or other components.

4.7 RELATIVE Q OF CAPACITOR

When a high-Q coil (*L* in Figs. 4-1, 4-3, 4-4, and 4-5) is employed in the capacitance test circuit, the character of the GDO dip may be taken as an indication of the Q of the capacitor under test. Thus, a sharp, rapid dip indicates high Q; a broad, sluggish dip, low Q.

This is strictly a qualitative indication useful only for comparative purposes and rough appraisals. More precise methods of measuring Q are explained in Chapter 9.

4.8 SCOPE OF CAPACITANCE MEASUREMENT WITH GDO

The foregoing sections of this chapter have described the checking of actual capacitors with the GDO. But capacitance measurement is not limited to this one component. The same techniques may be employed for checking the capacitance of cables (such as coaxial lines, microphone cords, and twisted pair), 2-wire lines, connectors (such as jacks, receptacles, and cable connectors), semiconductor devices (such as diodes and transistors), and the capacitance between the electrodes of a vacuum tube, between a component and its metal shield, between a component and chassis, or between the windings of a transformer. Simply substitute the capacitance-exhibiting device for the capacitor in the GDO test circuit. These applications are only typical. Many more will suggest themselves to the reader.

The average GDO may be employed in the conventional manner to check capacitances between 50 μμf and 4 μf. Larger capacitors sometimes have appreciable internal inductance which causes them to self-resonate and give false indications. If the distributed capacitance of the test coil is taken into account, as explained in Section 4.3, or the parallel-capacitor method (Section 4.4) is used, the capacitance-measuring range may be extended downward to about 10 μμf. And if the substitution process (Section 4.5) is employed with a precision variable capacitor in the test circuit, capacitances down to less than 1 μμf may be measured.

Chapter 5

INDUCTANCE MEASUREMENTS

Similar to capacitance checking, inductance measurement is a principal auxiliary function of the grid-dip oscillator. The GDO offers a convenient means of checking r-f and i-f coils at radio frequencies. When desired, a coil may be checked at the actual frequency at which it is to be operated in a piece of equipment. In addition to the self-inductance of a single coil, the mutual inductance between two coils also may be determined with the aid of the GDO.

Several practical methods of checking inductance with a GDO are explained in this chapter. These basic methods of measuring inductance by resonant-circuit techniques have been proved by experience.

Other tests concerned with coils appear in Sections 3.9, 3.10, and 4.3.

5.1 INDUCTANCE-MEASUREMENT PRINCIPLE

Like capacitance, inductance is measured *indirectly* with the grid-dip oscillator. The unknown inductance is connected temporarily in parallel with an accurately known capacitance to form a resonant circuit, and the resonant frequency of this combination next is checked with the GDO. Finally, the unknown inductance is calculated from the known capacitance and measured frequency.

Figure 5-1 shows the simple test setup. This method may be used with r-f and i-f coils, either of the airwound and coreless types or those having special cores such as powdered iron, dust, or ferrite. It cannot be used to check iron-core coils of the type employed at audio and power frequencies, since these latter coils have high losses and consequently will not operate satisfactorily in the r-f tuned circuit.

5.2 PRACTICAL INDUCTANCE MEASUREMENT

A precision, high-Q fixed capacitor will be required for inductance measurements. A good-grade mica capacitor with a capacitance tolerance of 1% or better is recommended. The capacitance value may be determined beforehand with an accurate bridge or other capacitance-measuring instrument, or may be measured with a GDO according to the instructions given in Chapter 4. A large capacitance is preferable, since it will mask the distributed capacitance of a coil under test and thus provide better accuracy of inductance measurement. Any capacitance between 0.001 μf and 0.01 μf will be satisfactory, but inductance calculations will be simplified if the capacitance is either 0.001 μf or 0.01 μf *exactly.*

For occasional inductance measurements, the leads of the coil under test may be connected to the precision capacitor simply by twisting together or soldering. But stability and accuracy will be enhanced by a permanent coil-test fixture or jig, especially when large numbers of coils are tested. A fixture similar to the one shown in Fig. 4-2 may be used by substituting the precision capacitor for the coil shown in that illustration. One commercial GDO is equipped with a special 0.001-μf mica capacitor with binding post terminals for inductance measurements. (See Section 10.1.)

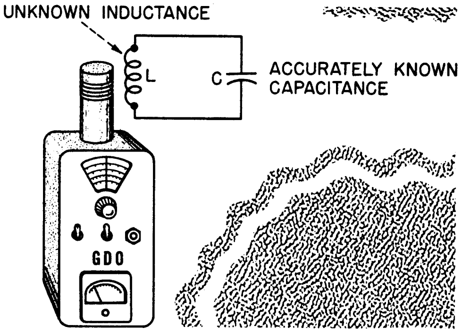


Fig. 5-1. Basic inductance-measuring setup.

To check inductance with the GDO: (1) Connect the coil (of unknown inductance L) to the precision test capacitor (C), using the shortest practicable leads. (2) Inductively couple the GDO to the coil, and tune for dip. (3) At dip, read the resonant frequency (f) of the resonant circuit. (4) Calculate the inductance from the known capacitance and measured frequency:

$$L = \frac{25{,}400}{f^2C}, \qquad (5\text{-}1)$$

where L is in μh, f in mc, and C in μμf.

Example: A small airwound coil is connected to a 0.005-μf (5000 μμf) test capacitor. A GDO test shows the resonant frequency of the combination to be 4 mc. Calculate the inductance.

From equation (5-1):

$$L = \frac{25{,}400}{4^2\,(5000)} = \frac{25{,}400}{16\,(5000)} = \frac{25{,}400}{80{,}000} = 0.318 \text{ μh}$$

For accuracy, it is best to make the actual longhand calculation or to use a conventional slide rule. However, when time must be saved, an approximate solution may be obtained quickly with the aid of a regular frequency-reactance chart or reactance slide rule. A chart of this type is not printed here, since the small page size would seriously limit the accuracy of results obtained.

5.3 COUPLING TO THE TEST COIL

Coils and chokes within the measurement range of conventional GDO's come in many sizes, shapes, and types. When the test coil is much larger or smaller than the GDO coil, ordinary inductive coupling between the two may be hard to obtain. This difficulty is encountered also when the test coil is enclosed. Under such circumstances, special coupling methods must be used.

For an explanation of special coupling methods, the reader should consult Section 3.3. When the Q of the test coil is high, capacitive coupling [shown in Fig. 3-2(B)] often is possible if the GDO coil is turned so that its turns are perpendicular to those of the test coil. When this is not practicable, link coupling [Fig. 3-2(A)] may be used. This type of coupling is very convenient when the test coil is inside an open-end shield or can. When the test coil cannot be reached for either link coupling or simple capacitive coupling but has one terminal exposed, the direct-coupling scheme in Fig. 3-2(C) may be used. However, this latter method introduces an error due to stray capacitance across the GDO coil, and this causes the indicated frequency to be somewhat lower than the true resonant frequency of the LC test circuit.

The special inductive coupling method shown in Fig. 5-2 is very effective for coils which are inaccessible for conventional inductive coupling but which have inductance values of 100 μh or higher. It is often used with coils of large physical size but is equally effective with small-sized units. In this scheme, a 1-turn coupling coil (or ring) L_2 is formed with the same diameter as that of the GDO coil and is connected in series with the coil under test (L_1) and precision capacitor (C). All leads must be kept as short as possible and the plane of L_2 must be at right angles to the turns of L_1 to minimize magnetic linking. Since L_1 and L_2 are in series, their inductances add. For this reason, the inductance of L_1 must be considerably higher than that of the coupling coil L_2 in order to minimize measurement error. (Coil L_2 ordinarily will have an inductance of less than 1 μh, so if the inductance of L_1 is 100 μh or higher, the error due to this source alone will be less than 1%.

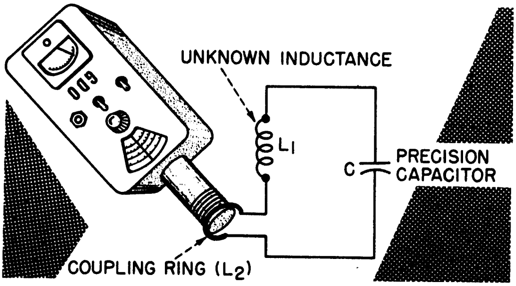


Fig. 5-2. Series inductive coupling for large-size coils.

Coupling methods are illustrated also by Figs. 3-4 and 3-5. When checking the inductance of a rectangular loop or of a single-turn flat coil, the loop is treated as an ordinary coil, but, since its sides are straight, coupling must be made to a wire. Figure 3-3 shows four methods of coupling to a single wire.

5.4 SETTING AN ADJUSTABLE INDUCTOR

Common adjustable inductors include broadcast and shortwave superhet coils, miniature rod-type antennas, TV sync stabilizer (ringing) coils, TV horizontal linearity and width control coils, and TV video peaking coils. These are only a few examples; general-purpose, slug-tuned coils are employed in many electronic systems. Each of these coils must be adjusted to a specified inductance before it is installed in the equipment.

To use the GDO for presetting a coil to a desired inductance value (L): (1) Connect the coil in parallel with a precision capacitor (C)

and inductively couple it to the GDO, as in Fig. 5-1. If simple inductive coupling cannot be secured, use one of the coupling methods explained in Section 5.3. (2) By means of equation (5-2), determine the frequency which (with the precision capacitance C) corresponds to the desired inductance:

$$f = \sqrt{\frac{25{,}400}{LC}}, \qquad (5\text{-}2)$$

where f is in mc, L in μh, and C in μμf.

Example: A coil is to be preset to 0.1 mh (100 μh). The precision test capacitor has a capacitance of 0.001 μf (1000 μμf). What GDO dip frequency will indicate the 0.1-mh setting of the coil trimmer?

From equation (5-2):

$$f = \sqrt{\frac{25{,}400}{100\ (1000)}} = \sqrt{\frac{25{,}400}{100{,}000}} = \sqrt{0.254} = 0.504 \text{ mc} = 504 \text{ kc}$$

For accuracy, it is best to make the actual longhand calculation or to use a conventional slide rule. When an approximate solution will serve, however, the frequency may be found quickly by use of a frequency-reactance chart or reactance slide rule. (3) Set the GDO to the frequency determined by means of equation (5-2). (4) Adjust the inductive trimmer of the coil for dip. At this point, the coil is preset to the desired inductance L.

5.5 CHECKING INDUCTANCE OF R-F CHOKE

The inductance of an r-f choke may be checked in the conventional manner, as explained in Section 5.2. The special shapes of some r-f chokes make it difficult or impossible to secure simple inductive coupling. Under such circumstances, one of the special coupling methods described in Section 5.3 may be used.

Recommended methods of coupling to r-f chokes of two familiar designs are illustrated also by Figs. 3-4(A) and 3-4(B).

5.6 CORRECTION FOR DISTRIBUTED CAPACITANCE

It has been explained in Section 5.2 that a large test capacitance is recommended for checking inductance with a GDO, since this high C masks the distributed capacitance of the coil and reduces error. In some instances, especially when the inductance of the test coil is high and the GDO cannot reach the corresponding low test frequencies, a low test capacitance is unavoidable. In this instance, the distributed capacitance (C_d) can cause appreciable error in the inductance determination when the test capacitance (C) is not several orders of magnitude higher than C_d.

To reduce this error, first measure the distributed capacitance of the coil, as explained below, and then add this value to that of the test capacitance before making the inductance calculation, equation (5-1).

To measure the distributed capacitance of a coil of unknown inductance, use the test setup shown in Fig. 5-3. (1) Connect the coil to a precision variable capacitor which is equipped with a dial reading direct in micromicrofarads. (2) Set the variable capacitor to 50 μμf. Record this capacitance as C_1. (3) Inductively couple the GDO to the coil and tune for dip. Note the resonant frequency. (4) Set the GDO to one-half of this frequency. (5) Restore dip by tuning the variable capacitor. At dip, read the new capacitance setting, and record this value as C_2. (6) Calculate the distributed capacitance (C_d):

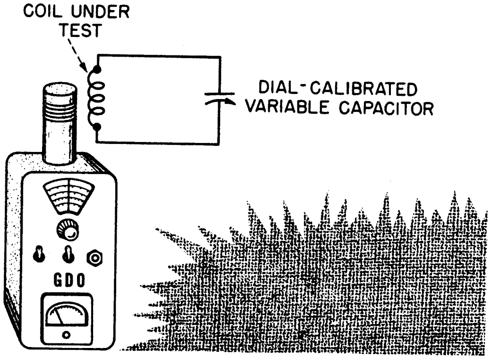


Fig. 5-3. Setup for checking distributed capacitance of coil of unknown inductance.

$$C_d = \frac{C_2 - 4C_1}{3}, \qquad (5\text{-}3)$$

where C_1, C_2, and C_d are in μμf.

Example: When the variable capacitor is set initially to 50 μμf, dip with a particular coil occurs at 4 mc. The GDO next is set to 2 mc (one-half the original frequency) and the variable capacitor is set to 230 μμf to restore dip. Calculate the distributed capacitance.

From equation (5-3):

$$C_d = \frac{230 - 4(50)}{3} = \frac{230 - 200}{3} = \frac{30}{3} = 10\ \mu\mu f$$

When this method is used, it is not necessary to know the inductance of the coil. In the simpler method of checking C_d (Section 4.3), the inductance must be known.

5.7 CHECKING MUTUAL INDUCTANCE

In addition to checking self-inductance (L), the GDO may be employed to check the effective mutual inductance (M) between two coils coupled together. This is a 2-step test employing the setup shown in Fig. 5-4. Use the same precision capacitor (C) employed in other inductance measurements.

To use the GDO to check mutual inductance: (1) First, connect the two coupled coils together and to the precision capacitor, as shown in Fig. 5-4(A). (2) Tune the GDO for dip. (3) Using equation (5-1), calculate the inductance from the known value of C and the measured resonant frequency. Record this inductance value as L_1. (4) Reconnect the coils and precision capacitor, as shown in Fig. 5-4(B). (5) Tune the GDO for dip. (6) Calculate the inductance for this connection and record this value as L_2. (7) Calculate the mutual inductance:

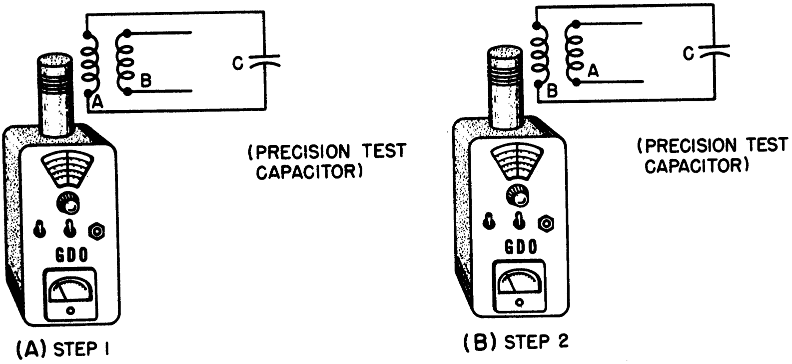


Fig. 5-4. Setup for checking mutual inductance.

$$M = \frac{L_1 - L_2}{4} \qquad (5\text{-}4)$$

5.8 DETERMINING COEFFICIENT OF COUPLING

The coefficient of coupling (k) between two coupled coils may be checked with the GDO, using the test setup shown in Fig. 5-5. Like the mutual inductance check, this is a 2-step test. Use the same precision capacitor (C) employed in other inductance measurements.

To perform the test: (1) First, check the mutual inductance, as explained in Section 5.7. Record this value as M. (2) Connect the precision capacitor to coil A, as shown in Fig. 5-5(A), and leave coil B open. (3) Inductively couple the GDO to coil A. (4) Tune the GDO for dip. (5) Using equation (5-1), calculate the inductance from the known value of C and the measured resonant frequency. Record this inductance value as L_1. (6) Connect the precision capacitor to coil B, as shown in Fig. 5-5(B), and leave coil A open. (7) Inductively couple the GDO to coil B. (8) Tune the GDO for dip. (9) Using equation (5-1), calculate the inductance from the known value of C and the measured resonant frequency. Record this inductance value as L_2. (10) Calculate the coefficient of coupling:

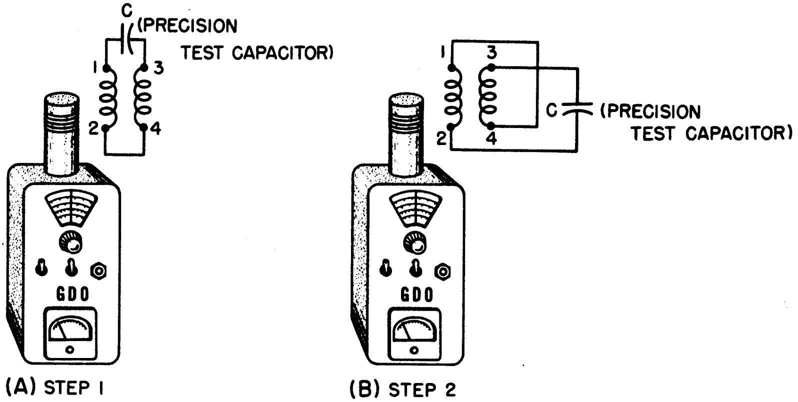


Fig. 5-5. Setup for checking coefficient of coupling.

$$k = \frac{M}{\sqrt{L_1 L_2}} \tag{5-5}$$

5.9 RELATIVE Q OF INDUCTOR

When a high-Q capacitor is employed in the inductance-test circuit, the character of the GDO dip gives a rough indication of the Q of the coil under test. Thus, a sharp, rapid dip indicates high Q; a broad, sluggish dip, low Q. This is strictly a qualitative indication useful only for comparative purposes and rough appraisals of coil quality. More precise, quantitative methods of measuring Q are explained in Chapter 9.

5.10 SCOPE OF INDUCTANCE MEASUREMENT WITH GDO

The inductance range which may be covered with a particular grid-dip oscillator depends upon the capacitance of the test capacitor and the frequency range of the GDO. In order to minimize distributed capacitance errors in the simplest way, a high test capacitance (usually between 0.001 μf and 0.01 μf) is employed.

With a 0.001-μf capacitor, the inductance range will extend from 0.25 μh at 10 mc to 2.5 mh at 100 kc. With a 0.01-μf capacitor, the inductance range will extend from 0.02 μh at 10 mc to 0.25 mh at 100 kc.

Inexpensive, high-Q mica capacitors are not readily available in capacitances higher than 0.01 μf. Two or more 0.01-μf capacitors conceivably might be paralleled to reach lower test frequencies and higher inductances, however, the inherent inductance of such connections can introduce troublesome errors in resonance-type measurements.

Chapter 6

RECEIVER APPLICATIONS

The grid-dip oscillator is convenient for spot-checking and adjusting radio and television receivers. For various applications in this category, the GDO is used either as a tunable r-f oscillator, tuned oscillating detector, or tuned nonoscillating detector. This instrument will not perform *all* of the operations necessary for complete adjustment of a receiver, but it will perform some of them as adequately as another more complicated instrument; and in other instances, it will provide a quick check for localizing circuit trouble.

When the GDO is employed within its capabilities, its simplicity, small size, and directness of operation give it an important place in the receiver laboratory, production line, and service shop. The technician who works exclusively with receivers is urged to familiarize himself thoroughly with the behavior of the GDO by experimenting with it in conjunction with a receiver known to be in excellent operating condition.

Principal applications to receiver checking are described in this chapter. There are additional such uses of the instrument, but many of these have only marginal utility or exhibit poor reliability and accordingly have been omitted.

CAUTION: *To prevent electric shock, be careful when checking any live receiver circuit with a GDO. Read the Safety Notice in the front of this book and the precautions given in Section 3.13. Use an isolating transformer between the power line and any radio or TV receiver having a transformerless power supply.*

6.1 COLD (QUIET) ALIGNMENT OF RADIO RECEIVER

The grid-dip oscillator affords a novel means of aligning a radio receiver quietly (that is, with the receiver power switched off). This method of cold alignment consists of presetting the various tuned circuits in the r-f, oscillator, and i-f stages to their prescribed frequencies, using the GDO dip as the alignment indicator.

The technique is the same as that described for presetting a tuned circuit (Section 3.5): The GDO is set to the desired "peaking" frequency and coupled to the tuned circuit under adjustment (such as r-f, detector, or oscillator coil, or i-f transformer winding). The tuned circuit then is peaked by setting its trimmer for GDO dip.

A typical superhet receiver would be adjusted in the following manner:

I-f amplifier. (1) Set the GDO to the intermediate frequency, for example, 455 kc. (2) Inductively couple the GDO to the secondary of the last i-f transformer (2nd detector input transformer). (3) Adjust the secondary trimmer of the i-f transformer for dip. (4) Repeat with the GDO coupled to the primary of the last i-f transformer, adjusting the primary trimmer for dip. (5) Repeat for each of the i-f transformers, working back to the first i-f stage.

First detector, or detector section of mixer. (1) Tune the receiver to the top (high-frequency end) of its range. (2) Inductively couple the GDO to the 1st detector coil. (3) Set the GDO to the top frequency of the receiver tuning dial. (4) Adjust the trimmer in the detector stage for GDO dip. (5) Check the tuning range by setting the receiver dial to various frequencies and retuning the GDO for dip, reading the frequency each time from the GDO dial.

R-f amplifier stages. (1) Inductively couple the GDO successively to each of the r-f amplifier-stage grid coils. (2) In each of these positions, tune the receiver to the high-frequency end of its range, set the GDO to the top frequency of the receiver tuning dial, and adjust the trimmer in the amplifier stage for GDO dip.

Oscillator stage. (1) Inductively couple the GDO to the oscillator coil. (2) Tune the receiver to its top dial frequency (*f*). (3) Set the GDO to a frequency equal to *f* minus *if*, where *if* is the intermediate frequency of the receiver. Thus, if the receiver dial is set to 1500 kc, and the intermediate frequency is 455 kc, the GDO must be set to 1500 − 455, or 1045 kc. (4) Adjust the trimmer in the oscillator stage for GDO dip.

Because of the extensive shielding in many modern receivers, inductive coupling to the stages may be hard to obtain. This is particularly true of the i-f transformers which usually are completely canned. In such instances, coupling may be obtained by means of one of the schemes given in Fig. 3-2. Whenever the coils are exposed, however, simple inductive coupling between the receiver and GDO should be employed.

Some receivers which are aligned "cold" will require readjustment of the various trimmers when the power is switched on. This is due chiefly to the difference between the hot and cold impedances of the tubes.

6.2 USE OF GDO AS CONVENTIONAL SIGNAL GENERATOR

In an emergency, the grid-dip oscillator may be employed as a signal generator in the conventional manner for the "hot" alignment of a receiver. The r-f output of the average GDO is essentially unmodulated, although there might be enough power-supply ripple in some models to give a small 60-cycle amplitude modulation to the signal. One commercial GDO (Section 10.5 has provision for amplitude modulation from an external audio-frequency source.

When the GDO has no provision for external modulation and the ripple is insufficient to modulate the r-f output, the loudspeaker cannot be used as an alignment indicator. In this case, a d-c vacuum-tube voltmeter may be connected across the 2nd detector load resistor, and the peak upswing of the meter indicates that a trimmer has been set to peak. Figure 6-1 shows the connections.

The separation between the GDO coil and pickup coil must be the maximum permissible, in order to avoid overloading the receiver. Also, the separation must be kept steady to prevent undesired fluctuations of the meter deflection.

When aligning the i-f and 2nd detector stages of the receiver, lead *1* of the pickup coil is removed from the antenna terminal and connected to the grid (or diode) terminal of the stage under test. When this is done, a 0.01-μf capacitor must be connected in series with lead *1* for d-c isolation.

Care must be exercised when using a GDO to align a transistorized receiver. The r-f output of this instrument is reasonably high and can damage certain high-frequency transistors, such as the surface barrier type, if the coupling between GDO and pickup coils is too tight.

6.3 CHECKING OPERATION OF SUPERHET OSCILLATOR

The GDO may be employed to check operation of the oscillator stage in a superhet receiver. In this application, the GDO functions as an oscillating monitor (detector). Use the following test procedure: (1) Plug in the GDO coil corresponding to the frequency range of the oscillator under test. (2) Plug headphones into the PHONE jack of the GDO. This automatically disconnects the GDO meter. (3) Couple the GDO to the oscillator coil and switch on power to both receiver and GDO. (4) Tune the GDO for a beat-note signal. If a signal is not heard, the receiver oscillator is dead. (5) At zero beat, read the oscillator frequency from the GDO dial. (6) If the superhet oscillator is operating, its tuning range may be determined with the aid of the GDO: Tune the oscillator from one end to the other and identify the frequencies by zero-beating with the GDO.

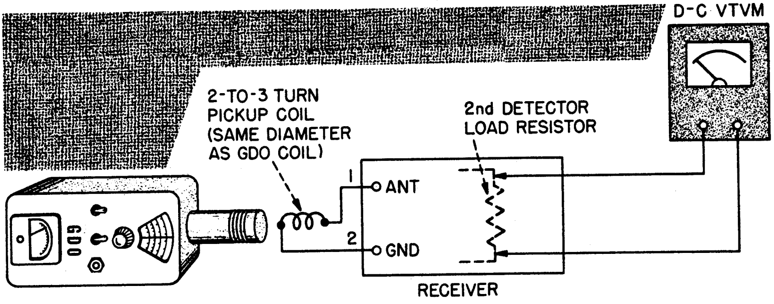


Fig. 6-1. Use of GDO as signal generator.

6.4 GDO AS SUBSTITUTE FOR SUPERHET OSCILLATOR

When the high-frequency oscillator of a superhet receiver is disabled, it may be replaced with the GDO temporarily for test purposes. Figure 6-2 shows the arrangement. The GDO is loosely coupled to a 2- or 3-turn pickup coil which, in turn, is connected to the injection terminals of the 1st detector or converter (mixer) stage in the disabled receiver. This allows the GDO to pinch-hit for the crippled oscillator, provided no serious short circuits or grounds are present in the circuit. Capacitance *C* may require some alteration in individual receivers. Ordinarily, its value will not be less than 25 μμf or more than the indicated 0.01 μf.

6.5 GDO AS SUBSTITUTE FOR C-W OSCILLATOR

A disabled continuous-wave (c-w) oscillator in a communications receiver may be replaced for test purposes, or even for temporary code-signal reception, with the GDO. Use the same connections shown in Fig. 6-2. In this instance, lead *A* is connected to the injection point of the c-w oscillator (usually at the 2nd detector). The GDO, serving as a temporary c-w oscillator, must be tuned around the intermediate frequency of the receiver. This arrangement allows the GDO to pinch-hit for the c-w oscillator, provided no short circuits or grounds are present in the disabled circuit.

The coupling between the GDO and pickup coil must be as loose as practicable to prevent blocking of the receiver. The pitch of the c-w signal is adjustable by tuning the GDO.

6.6 CHECKING AVC OPERATION

To check avc operation in a radio receiver, use the test setup shown in Fig. 6-3. The receiver must be switched on. (1) Connect a 1- or 2-turn coupling coil to the antenna and ground terminals of the receiver. The diameter of this coil should be the same as that of the GDO coil.

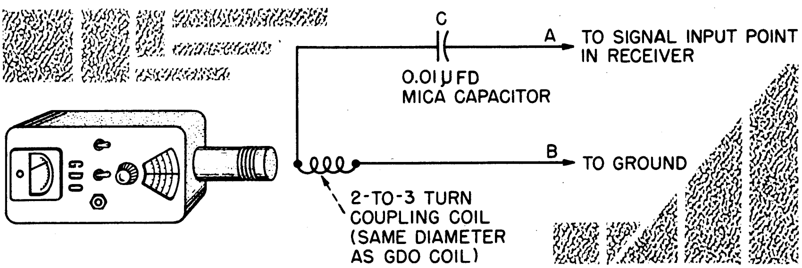


Fig. 6-2. GDO as substitute for superhet oscillator.

If the receiver has a built-in loop antenna, the GDO may be inductively coupled directly to the loop, no pickup coil being needed. (2) Connect a d-c vacuum-tube voltmeter to the output of the avc filter ($R_1-R_2-C_1-C_2$) in the receiver. Set the vacuum-tube voltmeter (vtvm) to its 0–10-volt range. (3) Inductively couple the GDO *tightly* to the pickup coil or loop antenna, as shown in Fig. 6-3. (4) Set the receiver to any convenient operating frequency. (5) Tune the GDO to this same

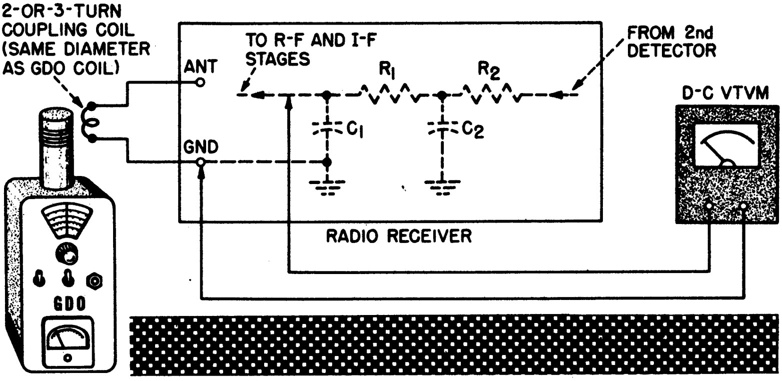


Fig. 6-3. Setup for checking avc action.

frequency, noting peak deflection of the meter. (6) Loosen the coupling by moving the GDO away from the pickup coil. The vtvm deflection should drop proportionately.

A modulated signal is required for checking the effectiveness of the avc. If the GDO can be amplitude modulated, connect an audio voltmeter across the loudspeaker terminals of the receiver, vary the coupling between the GDO and coupling (pickup) coil, and note that the loudspeaker voltage remains substantially constant as the signal strength (coupling) is varied.

6.7 ALIGNMENT OF RADIO OR TV FM DETECTOR

The GDO may be used as an unmodulated signal generator for hot alignment of the fm discriminator or ratio detector in a radio or television receiver: (1) Provide a pickup coil and isolating capacitor for the GDO, as shown in Fig. 6-2. Connect lead *A* to the primary winding of the fm detector transformer. (2) Set the GDO to the specified intermediate frequency of the receiver. (3) Set the pointer of a d-c vtvm to center scale on its 0–1.5 or 0–3-volt range by means of its zero adjustment, and connect this meter across the d-c load resistor in the fm detector. (4) The deflection of the vtvm depends upon the frequency of the GDO signal. This is indicated by Fig. 6-4. (5) With the GDO set exactly to the intermediate frequency, adjust the trimmers of the detector transformer for zero deflection. The detector now is set to the intermediate frequency. (6) To check operation of the detector, tune the GDO a small amount above the intermediate frequency. The vtvm deflection should increase in the positive direction (that is, upscale), as shown by the upper half of the curve in Fig. 6-4. Next, tune the GDO below the intermediate frequency by the same small amount. Now, the deflection should increase in the negative direction (that is, downscale), as shown by the lower half of the curve.

Throughout this test, the separation between the coupling coil and the GDO coil must be maintained constant. Also, in order to keep the GDO r-f output amplitude as constant as possible, the SENSITIVITY control in the GDO should be reset each time the frequency is changed, to restore the deflection of the GDO meter to the same value.

6.8 USE OF GDO AS SIGNAL INJECTOR

An amplitude-modulated signal injector often is used in troubleshooting to inject a test signal into the r-f, detector, and i-f stages of a receiver. The procedure is to work back through the stages successively from the 2nd detector to the antenna terminal, listening for presence or absence of the loudspeaker signal. This technique permits quick isolation of a dead stage.

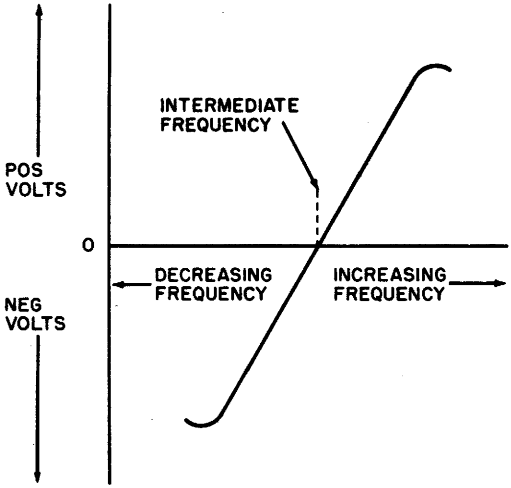


Fig. 6-4. F-m detector alignment curve.

In order to perform the injection test in this conventional manner so as to include the audio stages of the receiver, a GDO used as the signal generator must be amplitude modulated. Only one commercial instrument (Section 10.5) has provision for modulation from an external audio-frequency source. All others are essentially unmodulated, although some GDO power supplies have enough ripple in their output voltage to provide a small amount of modulation. When the GDO is completely unmodulated, as in most instances, the loudspeaker signal will not be present for use as an injection indicator. Instead, a d-c vtvm may be connected across the 2nd detector load resistor, and the deflection of this instrument will indicate presence of the test signal. However, this technique will not include the audio stages in the injection test.

For coupling the GDO to the various stages, use the arrangement given in Fig. 6-2. Because the r-f output voltage of a GDO is high, compared to that of a standard signal generator, the coupling between the GDO and pickup coil must be loosened considerably to prevent overloading the receiver stages.

6.9 COLD ALIGNMENT OF TV RECEIVER

Cold (quiet) alignment of a television receiver follows the same general scheme as the cold alignment of a radio receiver. (See Section 6.1.) Both are superheterodynes. However, because of the higher frequencies involved, the requirements are much more exacting in television. Only a prealignment can be made in most instances, final adjustment being performed with the set in operation. Furthermore, there are two i-f channels (video and sound) and two 2nd detectors in a TV receiver.

Because good picture quality dictates that TV circuit bandwidths be set accurately and since most good GDO's are not designed for the required degree of frequency accuracy, the cold alignment of TV front ends is not encouraged. Nevertheless, if a TV receiver is considerably out of alignment (as might be the case after tampering) and other instruments are not available, the GDO will be handy for cold, "ball-park" prealignment, to be followed by final alignment against either a signal generator, transmitted program, or test pattern. However useful it may be in this emergency application, the GDO cannot be expected to equal the sweep signal generator in either accuracy or speed.

6.10 USE OF GDO AS TV MARKER GENERATOR

A suitable sweep signal generator is employed in the visual alignment of the front end and video i-f amplifier stages of a TV receiver. An unmodulated r-f marker generator is needed for identification of the pass-band frequencies along the response curve set up by the sweep generator on the oscilloscope screen. Through beat-note action, the marker generator sets up a pip at the point on the curve corresponding to the frequency to which this generator is set. Frequency points which must be so identified may be obtained from the receiver service literature.

When the GDO is used as a marker generator, its r-f output may be taken through a coupling coil and isolating capacitor. (See Fig. 6-2.) Some TV sweep generators have input terminals for the marker generator, and leads *A* and *B* of the GDO coupling circuit would be connected to these terminals. When no such terminals are provided, the GDO signal may be injected into the sweep generator output at any point in the receiver circuit that is specified in the receiver service notes. When no point is specified, the GDO (without the coupling arrangement of Fig. 6-2) may be inductively coupled to the wiring of the channel under test simply by positioning the GDO coil close to the wiring.

The strength of the marker signal must be low, otherwise the pip will distort the response pattern and accuracy will be impaired. In order to keep the pip small, the loosest practicable coupling must be employed. This means separating the GDO and pickup coil (or receiver wiring) as much as practicable. The pip on the oscilloscope pattern should be the barest discernible dot or squiggle.

6.11 CHECKING TV OSCILLATOR STAGE

The oscillator stage in the front end of a TV receiver may be checked with a GDO in the same manner explained in Section 6.3, except that the frequencies involved are much higher in TV, and the oscillator has a different *fixed* frequency in each channel.

If the oscillator is disabled, the GDO may be used as a substitute in the manner described in Section 6.4. This often will restore operation of the receiver sufficiently to make further troubleshooting tests.

6.12 TV SOUND CHANNEL ALIGNMENT

To prealign the 4.5-mc sound channel of a TV receiver: (1) Tune the GDO to 4.5 mc and couple it to the sound i-f input through the coil-capacitor arrangement shown in Fig. 6-2. To prevent overloading the channel, loosen the coupling by separating the GDO and coupling coils as much as practicable. (2) Connect a d-c vtvm (with its pointer set to center scale) across the fm sound detector load resistor, as explained in Section 6.7. (3) With the receiver in operation, adjust the i-f and detector trimmers for zero deflection of the meter. (4) Check the detector response by tuning the GDO above and below 4.5 mc. The response should be similar to that shown by the curve in Fig. 6-4 and discussed in Section 6.7.

Sound channel alignment requires an accurate 4.5-mc signal source. Prealignment with the GDO should be followed up with a final adjustment with a crystal-controlled oscillator. Only one commercial GDO has provision for crystal control. (See Section 10.1.) In other instances, a separate crystal-controlled oscillator will be required in the final alignment.

6.13 ADJUSTING TV WAVE TRAPS

The GDO may be used to set the wave traps in a TV receiver to their prescribed frequencies. The adjustment may be made with the receiver switched off, but final trimming of the adjustment should be done with the set in operation. Follow the general procedure for checking and adjusting a wave trap given in Section 3.6.

If the crowded environment of the wave trap under the receiver chassis prevents simple inductive coupling, use link coupling or capacitive coupling. [See Figs. 3-2(A) and 3-2(C) respectively.]

Chapter 7

TRANSMITTER APPLICATIONS

A number of tests and adjustments may be made on transmitters with the aid of a grid-dip oscillator. Because of its wide tuning range, the GDO is serviceable in all types of stations. A particular advantage of this instrument is the "cold" tune-up adjustment it permits.

Amateur station operators and model-control hobbyists will find the GDO especially attractive in situations where a limited budget dictates that a single instrument be used for several purposes. In the practical design and development of transmitters, the GDO will circumvent many hours of calculations through its ability to indicate resonant frequencies directly.

CAUTION: The high voltages employed in transmitters are dangerous to life. To prevent electric shock, use extraordinary care when checking a live transmitter with a GDO. Study the Safety Notice in the front of this book and the precautions given in Section 3.13.

7.1 COLD PRETUNING OF TRANSMITTER TANKS

Using the GDO, a transmitter tank may be preset to a desired frequency without switching on the transmitter voltages. This cold adjustment has two advantages: (1) On-the-air interference, due to tuning up without a dummy antenna, is prevented; and (2) heavy, tube-damaging, off-tune currents are averted.

To pretune a tank: (1) Set the GDO to the desired tank frequency. (2) Inductively couple the GDO to the tank coil. Transmitter tank coils often are much larger than the GDO coil, making simple inductive coupling difficult or impossible. In such instance, use link coupling [Fig. 3-2(A)] or capacitive coupling [Fig. 3-2(B)]. (3) Adjust the tank tuning capacitor for GDO dip.

Each of the tank circuits in a transmitter (oscillator, buffer, doubler, tripler, quadrupler, and final amplifier) may be pretuned in this manner, with the GDO set to the proper frequency in each case. This is a rough tuning of the transmitter. Slight readjustments later may be made with the transmitter power switched on, and using the grid and plate milliammeters instead of the GDO.

7.2 CHECKING RESONANT FREQUENCY OF TANK

Frequently, the resonant frequency of a tank circuit must be known before the transmitter power is switched on. This is particularly true in the case of frequency multipliers (doublers, triplers, and quadruplers) where the tank might inadvertently be set to the wrong harmonic.

To make a cold check of the resonant frequency: (1) Inductively couple the GDO to the tank coil. (2) Tune the GDO for dip. (3) At dip, read the tank frequency from the GDO dial. (4) If this is not the desired frequency; set the GDO to that frequency, couple it to the tank coil, and tune the tank capacitor for GDO dip.

7.3 CHECKING RESONANT FREQUENCY OF UNUSED COIL

In a bandswitching transmitter, the unused tank coils often are close enough to the one used to be coupled to the latter and to absorb energy from it. This results in a loss of r-f power and also in heating of the unused coils. In some transmitters, these coils are shunted with trimmers, which compounds the mischief.

When impaired efficiency has been observed in a transmitter, especially in a bandswitched final amplifier stage, the trouble often may be traced to an unused coil which is resonating either at the fundamental or at a harmonic of the frequency to which the used coil is tuned. Once the offending coil is located, the remedy is to move it to another switch position out of range, turn it around so as to be perpendicular to the used coil, or rewind it to change its distributed capacitance.

The resonant frequency of each unused coil may be checked without switching on the transmitter power: (1) Inductively couple the GDO to the unused coil. If the coil is too large for simple inductive coupling, use link coupling [Fig. 3-2(A)]. (2) Tune the GDO for dip. (3) At dip, read the resonant frequency from the GDO dial. Notice whether this frequency is in harmonic relation to the transmitter operating frequency or is equal to the fundamental of the latter.

Because of their geometry, some coils will exhibit more than one self-resonant point. Therefore, the GDO should be tuned throughout its range, from the fundamental frequency of the transmitter upward. Each self-resonant point will be indicated by a dip.

7.4 GDO AS TUNED MONITOR (NON-OSCILLATING DETECTOR)

When the DIODE-OSCILLATOR switch in the GDO is thrown to its DIODE position, the d-c plate voltage of the tube is interrupted, but the filament continues to burn. Oscillation therefore ceases, but the tube now functions as a diode, the grid acting as the anode. The diode receives its r-f voltage from the tuned circuit of the GDO and delivers d-c output proportional to the strength of an r-f signal to which the instrument is tuned. When the r-f signal is amplitude modulated, it can be heard with headphones plugged into the HEADPHONE jack. In this way the GDO serves as a tuned monitor.

As a monitor, the GDO may be used for aural checking of hum or noise on a carrier and of the quality of a phone signal (that is, for presence of distortion). It may be used also as a keying monitor for modulated c-w signals.

In this application, the GDO is a simple diode detector with microammeter tuning indicator and thus has low sensitivity. However, with most medium- and high-powered transmitters, it will operate satisfactorily with the GDO a foot or more from the exposed tank coil of the modulated stage in a transmitter. The GDO may be link coupled to a low-powered transmitter, as shown in Fig. 7-1.

To use the GDO as a tuned monitor: (1) Throw the DIODE-OSCILLATOR switch to its DIODE position. (2) Plug high-impedance magnetic headphones into the PHONE jack. (3) Place the GDO near the tank of the modulated stage of the live transmitter. (4) Tune in the signal by setting the GDO tuning dial for loudest headphone signal. (5) If sufficient signal cannot be picked up, link couple the GDO to the transmitter, as shown in Fig. 7-1. The pickup coils L_1 and L_2 each are two turns of insulated wire. L_1 is of the same diameter as the tank coil, L_2 the diameter of the GDO coil. If desired, L_2 may be wound around the free end of the GDO coil. L_1 must be coupled to the cold (ground) end of the tank coil and must not be placed any closer to the tank coil than is necessary for a comfortable signal in the headphones. (Close coupling to a high-powered transmitter can transfer enough r-f energy to damage the GDO.)

7.5 GDO AS ABSORPTION WAVEMETER

The GDO makes a good, wide-range absorption wavemeter with microammeter resonance indicator. In this function, it can be used to check the frequency of a live transmitter, industrial oscillator, diathermy, or similar equipment.

To use the GDO as a wavemeter: (1) Throw the OSCILLATOR-DIODE switch to its DIODE position. This converts the GDO into a tuned diode detector, as explained in Section 7.4. (2) In this application, do not insert a plug of any kind into the HEADPHONE jack. The microammeter automatically is connected to the diode ouput, and its deflection will be proportional to the strength of the r-f signal to which the GDO is tuned. (3) Hold the GDO coil near the energized tank coil of the equipment under test. (See Fig. 7-2.) (4) Tune the GDO for peak deflection of its microammeter, and read the frequency from the GDO dial. For accuracy, employ the loosest coupling which will give a readable deflection of the microammeter.

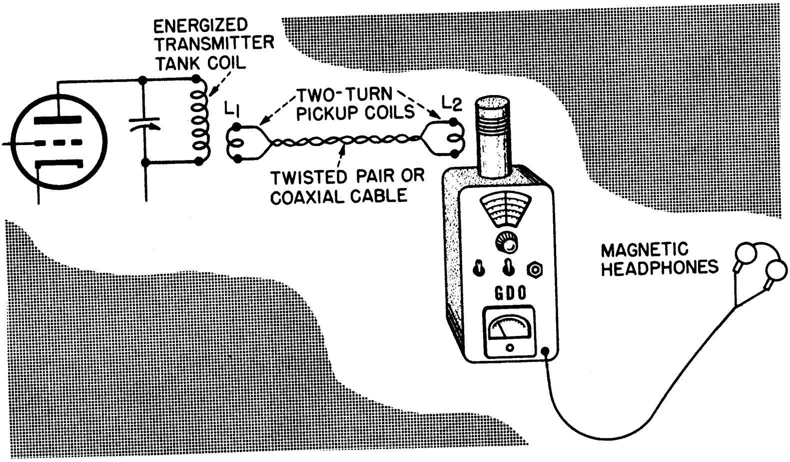


Fig. 7-1. Link coupling GDO monitor to transmitter.

7.6 GDO AS TUNED OSCILLATING DETECTOR (C-W MONITOR)

The simple diode monitor described in Section 7.4 cannot be used with unmodulated (c-w) signals, since it is non-oscillating and cannot make such signals audible. However, the GDO operating normally (that is, with its DIODE-OSCILLATOR switch thrown to its OSCILLATOR position) will serve as a tuned, oscillating detector when headphones are plugged into its HEADPHONE jack.

In this application, the GDO is tuned either to the low or high side of the zero beat to render audible a picked-up signal. The pitch of the resulting whistle may be adjusted by means of the GDO tuning. The GDO is very sensitive when used as an oscillating detector, hence it need not be placed close to the transmitter or oscillator under test. Figure 7-3 shows the setup. When the transmitter is remote from the GDO and/or is very low powered, a small pickup antenna may be required for the GDO. This may consist of a rod, whip, or short length of wire connected to a single turn of insulated wire wound tightly around the end of the GDO coil. The small amount of capacitance between this single turn and the GDO coil will couple enough r-f energy from the antenna to the GDO.

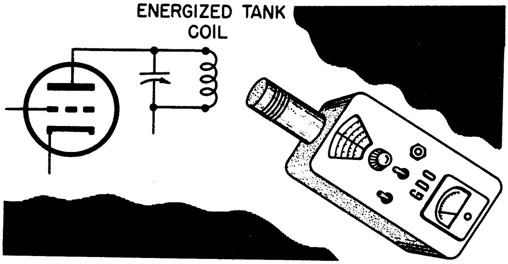


Fig. 7-2. Use of GDO as absorption wavemeter.

The oscillating detector has many applications, including use as a c-w keying monitor, signal-quality monitor, carrier presence indicator, etc.

7.7 GDO AS HETERODYNE FREQUENCY METER

When the GDO is operated as an oscillating detector, as explained in Section 7.6, it may be used as a heterodyne frequency meter: (1) Set the DIODE-OSCILLATOR switch to its OSCILLATOR position. (2) Plug high-impedance magnetic headphones into the HEADPHONE jack. (3)

Employing the loosest practicable coupling, tune in the unknown r-f signal. If the signal source is distant and/or low powered, employ a small pickup antenna, as shown in Fig. 7-3. (4) At zero beat, read the unknown frequency from the GDO dial.

Since the GDO, as an oscillating detector, will respond to harmonics as well as to the fundamental frequency, tune upward from the lowest GDO frequency, changing coils as required. Several beat notes will be found and must be identified: The fundamental frequency usually will produce the loudest beat note. However, beat notes will be present also when the GDO is set to a subharmonic of the unknown signal.

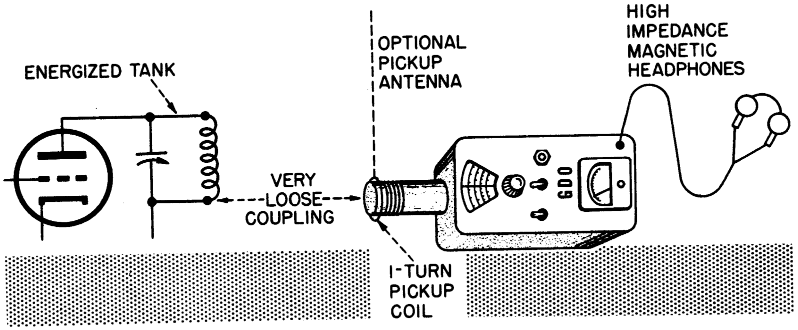


Fig. 7-3. Use of GDO as oscillating detector.

As a double check, therefore, the frequency separation between several zero-beat points should be determined. For harmonics, this separation is equal to the fundamental frequency. Thus, a 7-mc signal will produce beat notes at several points including 7, 14, 21, and 28 mc. Note that the separation in each case is 7 mc, and this pattern continues out to some high frequency at which the beats become too weak to hear. Below the 7–mc fundamental (*f*), however, beats are produced at 0.875, 1.75, and 3.5 mc. But these "subharmonic" frequencies are not separated by 7 mc but are equal to 1/2 *f*, 1/4 *f*, and 1/8 *f*.

Because of its sensitivity, the GDO as an oscillating detector can pick up other signals than the one intended. Thus, if the intermediate stages of a transmitter are unshielded, signals may be picked up from the oscillator, buffer, and multipliers, as well as from the final amplifier. The source of the signal may be identified by switching off the stages successively, starting with the final amplifier under test.

7.8 NEUTRALIZING AMPLIFIER WITH POWER OFF

Figure 7-4 shows a typical neutralized triode r-f amplifier or buffer stage with link-coupled input and output. To neutralize this stage: (1) Switch off all plate and filament power. (2) Set the neutralizing capacitor C_n to minimum capacitance. (3) Set the grid tank (L_1C_1) and plate tank (L_2C_3) to the desired operating frequency, according to the instructions given in Section 7.1. (4) Loosely couple the GDO to the grid coil L_1 as shown in Fig. 7-4. If the transmitter is capacitance coupled instead of link coupled, couple the GDO instead to the preceding *driver* plate tank (which has been preset to the operating frequency). (5) Tune the GDO for dip. (6) Slowly rotate the plate tuning capacitor C_3, noting that the GDO dip "flicks" as C_3 is tuned through resonance. (7) Adjust the neutralizing capacitor C_n while C_3 is being rotated, noting that the disturbance of the GDO dip becomes less pronounced. At one point in the adjustment of C_n, the rotation of C_3 through resonance will have no effect on the dip. At that point, the stage is neutralized.

7.9 NEUTRALIZING AMPLIFIER WITH EXCITER POWER ON

In some transmitters, somewhat cleaner neutralization may be obtained by the "hot" method. That is, the exciter delivers full r-f to the amplifier under adjustment, but the plate voltage of the amplifier

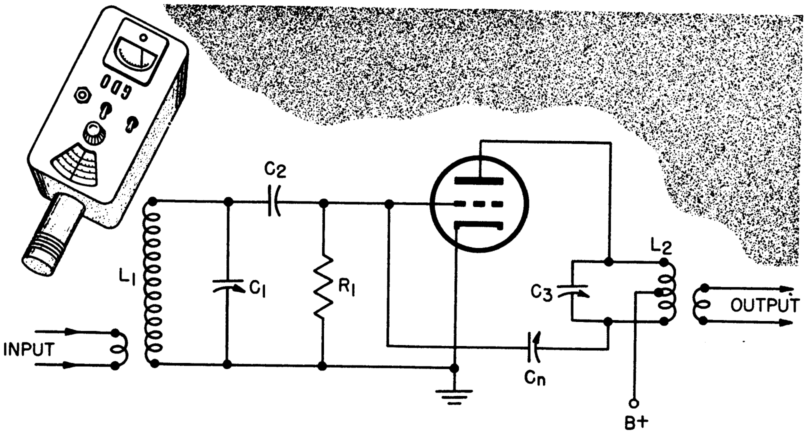


Fig. 7-4. Neutralization without power.

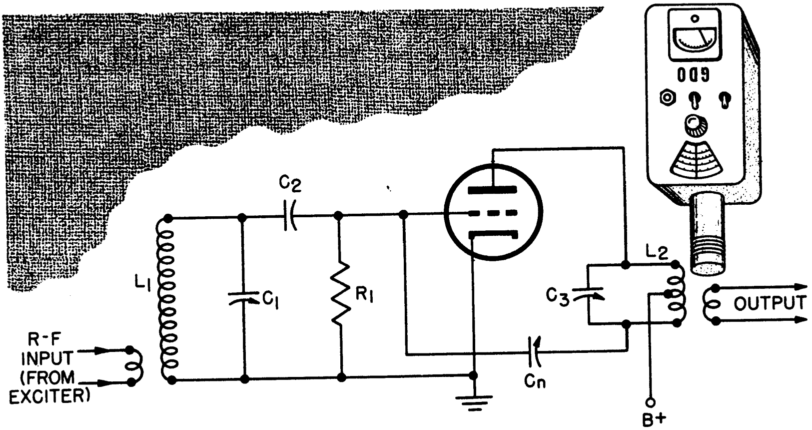


Fig. 7-5. "Hot" neutralization of amplifier.

is switched off. Figure 7-5 shows a typical link-coupled, neutralized triode amplifier or buffer.

To neutralize by the hot method: (1) With *all* transmitter power off, set neutralizing capacitor C_n to minimum capacitance and set the grid tank (L_1C_1) and plate tank (L_2C_3) to the desired operating frequency, according to instructions given in Section 7.1. (2) Set the DIODE-OSCILLATOR switch in the GDO to its DIODE position. (3) Inductively couple the GDO to the plate tank, as shown in Fig. 7-5. (4) Switch on the exciter. (5) Tune the GDO for peak deflection of its microammeter. Retune C_1 and C_3, as required, to increase the peak. (6) Adjust the neutralizing capacitor C_n for GDO dip. At exact dip, the stage is neutralized.

Since there is some interaction between the adjustment of C_n and C_3, the latter should be retuned slightly after each trial setting of C_n.

7.10 CHECKING PARASITICS WITH POWER OFF

Parasitics in r-f oscillator and amplifier stages usually are caused by spurious, high-frequency oscillator circuits set up by the inductance and capacitance of wiring and components. These troublesome circuits often can be located with a GDO without switching on the equipment under test.

The parasitic circuit is checked in the same way as any other tuned *LC* circuit: (1) Place the GDO coil close to a suspected portion of the wiring of the stage under test and tune the GDO carefully for dip. Since most parasitic circuits are low Q, the dip usually is broad. (2) At dip, read the parasite frequency from the GDO dial. After the frequency has been determined in this manner, the offending components or wiring may be isolated and corrective steps taken.

During this test, the GDO coil should be rotated in every possible direction to insure adequate coupling between the instrument and circuit.

7.11 CHECKING PARASITICS WITH POWER ON

Close wiring and crowded components often render impractical the cold test for parasitics described in the preceding Section 7.10. In such a case, the transmitter should be operated at full power into a dummy antenna, and the GDO employed as a tuned oscillating detector to locate parasitics.

To make this "hot" test for parasitics: (1) Operate the GDO as a tuned oscillating detector, as explained in Section 7.6. (2) Couple the GDO to various parts of the circuit and tune for beat-note signals, changing coils to cover the entire range of the instrument. (3) The transmitter carrier will produce a clean, clear whistle in the headphones, whereas the parasitic oscillations invariably are rough and tend to shift or jump in frequency. It is easy to identify parasitics because, in addition to the rough sound, their frequencies are not usually in harmonic relation to the carrier. (4) Parasitics may be found at one or several frequencies. The frequency of each may be read directly from the GDO dial.

Parasitics are not confined to the r-f stages of a transmitter. Resonant loops in audio amplifiers and modulators also give rise to these r-f

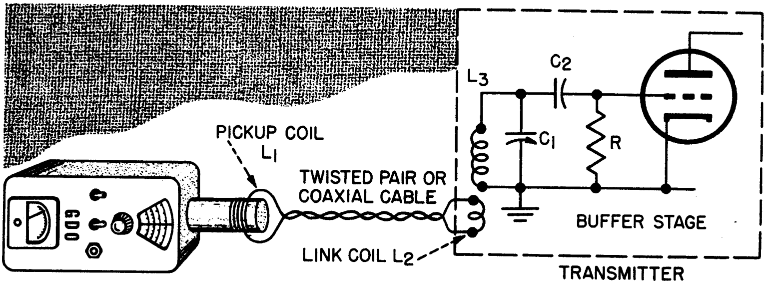


Fig. 7-6. GDO as emergency master oscillator.

self-oscillations, and this impairs audio quality. These spurious oscillations may be searched out in the same way as explained in the preceding paragraphs.

7.12 GDO AS MASTER OSCILLATOR

Although the GDO is not specifically designed for the purpose, it may be employed as an emergency master oscillator in a transmitter. Figure 7-6 shows the setup.

Link coupling between the GDO and transmitter is recommended. For this purpose, a 2-turn pickup coil (L_1 in Fig. 7-6) of insulated wire is wound tightly around the free end of the GDO coil and connected to a length of twisted pair or coaxial cable. The other end of the cable is connected to a 2-turn coupling (link) coil (L_2) wound around, or supported near, the cold (grounded) end of the grid tank coil (L_3) in the buffer or frequency multiplier stage in the transmitter. The GDO is set to the desired carrier frequency, and the other stages of the transmitter are then tuned, in the conventional manner, to that frequency.

If the GDO has provision for crystal control of its frequency (as in the commercial instrument described in Section 10.1), it will serve as a completely stable, crystal-controlled master oscillator for semipermanent, as well as emergency, use.

Chapter 8

ANTENNA AND TRANSMISSION-LINE TESTS

The grid-dip oscillator is perhaps the simplest instrument for checking characteristics of antennas and transmission lines. Its accuracy is satisfactory for practical purposes and can be increased by making a close, individual frequency calibration of the instrument. Because of its simplicity and economy, the GDO will be particularly useful to the transmitting radio amateur.

This chapter describes typical tests which are within the capabilities of the GDO. Experienced technicians undoubtedly will find other antenna and transmission-line applications in which the instrument functions basically as a signal source, resonance indicator, or detector.

8.1 CHECKING RESONANT FREQUENCY OF ANTENNA

The resonant frequency of a simple, grounded antenna may be checked with the setup shown in Fig. 8-1. Here, the GDO is inductively coupled to the antenna through a 1-turn coil connected *directly* in the lead-in (or single-wire feeder) between the antenna and ground. This coil should have the same diameter as the GDO coil.

To make the test: (1) Tune the GDO from its highest frequency downward, changing coils as required, and watching carefully for dip. (2) Usually, a dip will be obtained at the resonant frequency and also at one or more harmonics. The fundamental resonant frequency will be the lowest one at which dip occurs, hence the importance of tuning downward throughout the instrument range.

When the antenna is ungrounded, its resonant frequency may be checked, using the same technique described in the preceding paragraph, but the GDO must be coupled directly to the antenna as shown in Fig. 8-2. This is fairly easy with vertical antennas where the operator can work at the base, but may prove impracticable for horizontal antennas supported high above terrain or buildings. Inductive coupling, with the turns of the GDO coil parallel to the antenna wire [Fig. 8-2(A)] is best at a low-impedance point; while capacitive coupling, with the turns of the GDO coil perpendicular to the antenna wire [Fig. 8-2(B)] is best at a high-impedance point.

Resonance measurements are invaluable when cutting an antenna to proper length for a desired operating frequency. The measurement should be made with the feeders disconnected, unless they are known to be perfectly matched. When the antenna is of the center-fed type, close the center opening, during the measurement, with a short, straight piece of wire of the same diameter as the antenna wire.

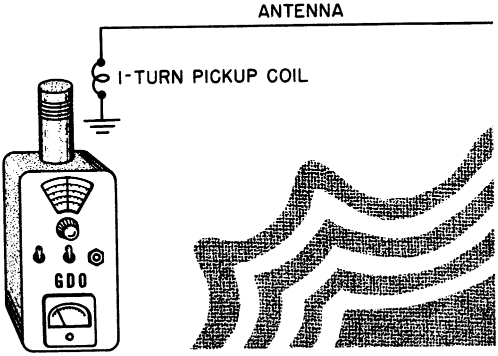


Fig. 8-1. Setup for checking grounded antenna.

8.2 CHECKING ELECTRICAL LENGTH OF TRANSMISSION LINE

Figure 8-3 shows test setups for checking the electrical length of three common types of transmission line: open-wire [Fig. 8-3(A)], flat ribbon [Fig. 8-3(B)], and coaxial [Fig. 8-3(C)]. In each instance, the GDO is inductively coupled to one end of the line; the opposite end is open-circuited during the test.

For coupling, a 1-turn coil *L* of the same diameter as the GDO coil, is connected to the input end of the open-wire line, as shown in Fig. 8-3(A). A small coupling loop is made at the input end of the flat-ribbon line by temporarily soldering together the two emerging wires of the line, as shown in Fig. 8-3(B). At the input end of the coaxial cable, a similar coupling loop is made by pulling a short length of the inner conductor around and soldering it to the outer conductor, as shown in Fig. 8-3(C).

To check the line: (1) Inductively couple the GDO to the line, as shown in Fig. 8-3. (2) Tune the GDO for dip, starting at the highest frequency and tuning downward. (3) Dips will be obtained at several frequencies (the fundamental and odd harmonics). The lowest of these is the primary resonant frequency of the line. This is the frequency at which the line is 1/4 wavelength long.

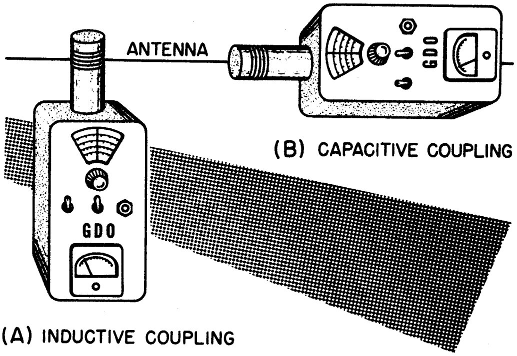


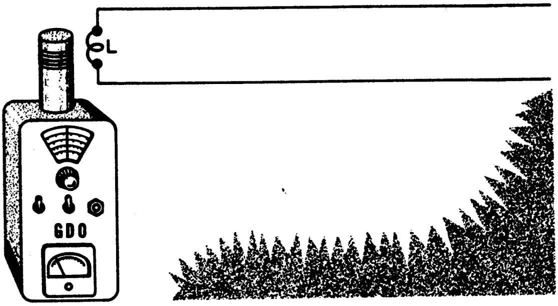
Fig. 8-2. Setup for checking ungrounded antenna.

8.3 CHECKING IMPEDANCE OF TRANSMISSION LINE

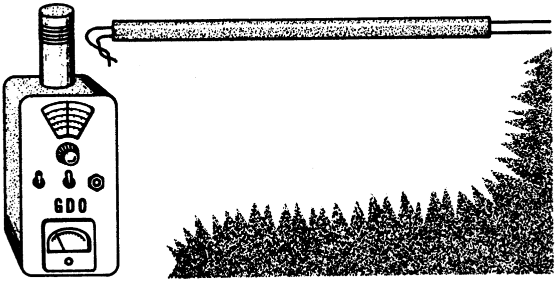
There are two ways of checking the characteristic impedance of a transmission line open-circuited at the far end. In the following explanation, the simpler method is described first.

Method 1. (1) Inductively couple the GDO to the input end of the line, as shown in Fig. 8-3. (2) Check the resonant frequencies indicated by dips as the GDO is tuned, as explained in Section 8.2. (3) Connect a variable *noninductive* resistor to the output end of the line (by the shortest possible leads) and repeat the GDO tuning at various settings of the resistor. (4) When the resistance setting is equal to the characteristic impedance of the line, the dip point will disappear. At this point, the resistance setting indicates directly the impedance of the line.

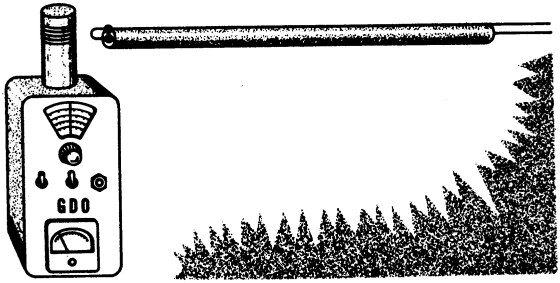
Method 2. This method requires a precision variable capacitor having a dial graduated directly in micromicrofarads. Like Method 1, it also requires a variable *noninductive* resistor. The advantage of this



(A) OPEN-WIRE LINE



(B) FLAT (RIBBON) LINE



(C) COAXIAL CABLE

Fig. 8-3. Checking electrical length of transmission line.

method is the possibility it provides of making all measurements at the input end of the line. This is very convenient when the output end of the line cannot easily be reached for connection of the resistor.

Test procedure: (1) Connect the variable capacitor *C* to a coil *L* having inductance such that the resulting *LC* circuit [Fig. 8-4(A)] will resonate at the operating frequency of the transmission line when

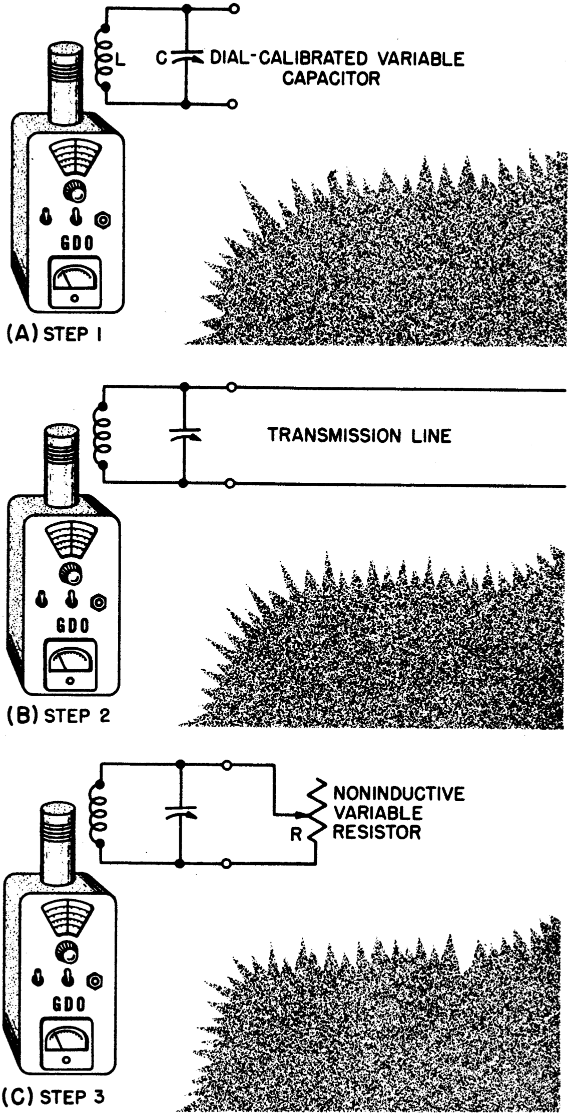


Fig. 8-4. Checking impedance of transmission line (Method 2).

the capacitor is set to the middle of its range. (2) Inductively couple the GDO to coil *L*. (3) Set the GDO to the frequency at which the transmission line is to be operated. (4) Adjust the variable capacitor

C for GDO dip. (5) Note the capacitance setting. (6) Without disturbing the setting of the GDO or the separation between the instrument and coil *L*, connect the transmission line to the circuit, as shown in Fig. 8-4(B). The dip will disappear. (7) Retune the variable capacitor to restore the dip. (8) Note the new capacitance setting. (9) The equivalent input capacitance (C_i) of the line is equal to the difference between the two settings of the variable capacitor. (10) Note the reading of the GDO microammeter. (11) Without disturbing the setting of the GDO or the separation between the instrument and coil *L*, remove the transmission line and connect the noninductive variable resistor *R* to the circuit, as shown in Fig. 8-4(C). (12) Adjust resistor *R* to give the same deflection of the GDO microammeter as that noted in step (10). (13) The equivalent input resistance (R_i) of the line is equal to the setting of resistor *R*. (14) Calculate the impedance (*Z*) of the line in terms of the equivalent capacitance C_i [Step (9)] and equivalent resistance R_i [Step (13)], by means of the following equation:

$$Z = \sqrt{R_i^2 + \left(\frac{1}{6.28\,f\,C_i}\right)^2}\,, \tag{8-1}$$

where *R* and *Z* are in ohms, *f* is in mc, and *C* is in μf.

In order to obtain resonance when the line is approximately 1/4 wavelength long at the test frequency, it may be necessary to connect the variable capacitor in series with coil *L* and the line, instead of in parallel as shown in Fig. 8-4.

8.4 GDO AS FIELD-STRENGTH METER

A field-strength meter is indispensable in the checking of directional antennas, antenna matching, and radiation patterns. An expensive, superhet-type field-strength meter is not necessary for applications in which direct readings of field intensity in microvolts are not required. A simple diode-type field-strength meter will suffice in these cases.

Figure 8-5 shows how the GDO may be employed as a diode-type field-strength meter. A short pickup antenna (usually vertical) is required. It may be a conventional whip antenna or a rod or stiff wire from 2 to 4 feet long. This antenna is inductively coupled to the GDO coil. If one of the regular GDO coils is used, a coupling coil consisting of 2 turns of insulated wire must be wound tightly around the GDO coil, as shown in Fig. 8-5 (A). One end of this coupling coil is connected to the bottom of the antenna, and the other end to the GDO case. If the high-frequency, hairpin-type GDO coil is used, the coupling coil must be a single turn of insulated wire supported in the loop of the hairpin, as shown in Fig. 8-5(B). The coupling coil may be Scotch-taped to the hairpin. For rigid mounting, the antenna may be fastened to a block of insulating material strapped or taped temporarily to the GDO case.

To use the GDO as a field-strength meter: (1) Connect the antenna, as shown in Fig. 8-5. (2) Throw the OSCILLATOR-DIODE switch in the GDO to its DIODE position. (3) With the transmitter in operation, tune the GDO to the transmitter signal. (4) Resonance is indicated by peak deflection of the GDO microammeter. The deflection also is proportional to the field (signal) strength.

Capacitance due to the pickup coil may shift the GDO dial calibration somewhat, particularly at the higher frequencies. But this will cause very little difficulty in most instances.

8.5 CHECKING ANTENNA MATCHING

To check the matching of an antenna to a transmitter: (1) Set up the GDO as a field-strength meter, as explained in Section 8.4. (2) Place the GDO as far as practicable from the antenna. (A second oper-

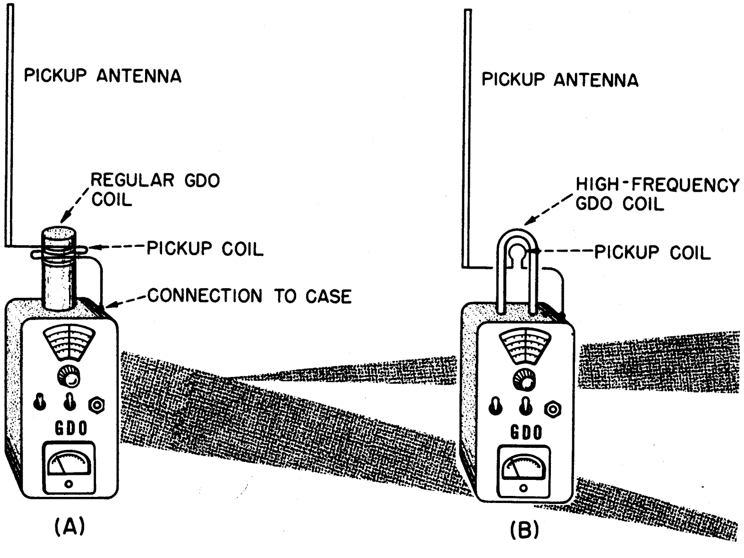


Fig. 8-5. Use of GDO as field-strength meter.

ator may be required when the distance is great.) (3) Switch on the transmitter. (4) Tune the antenna matching network. (5) Tune in the signal with the GDO, and note the reading of the GDO microammeter. (6) Make any adjustments necessary to the antenna tuner or matching network, noting the effect they have on the GDO deflection. (7) The deflection will be maximum when the antenna is correctly matched to the transmitter.

8.6 GDO AS STANDING-WAVE INDICATOR

Unshielded transmission lines (such as open-wire and flat-ribbon types) carrying r-f energy may be inspected for standing waves by coupling a GDO, as a diode detector, to the line and moving it along the latter in search of variations in signal strength. Because of its shielding, the coaxial line cannot be checked in this manner. (See Section 8.7 for a method which will work with coaxial cable.)

Test procedure: (1) Throw the OSCILLATOR-DIODE switch in the GDO to its DIODE position. (2) Switch on the transmitter. (3) Tune the GDO to the transmitter frequency by inductively coupling it loosely to the transmitter and tuning for peak deflection of the GDO microammeter. (4) Inductively couple the GDO to the transmission line, as shown in Fig. 8-6 [(A) or (B) whichever applies]. (5) Move the GDO slowly along the line for a distance of at least 1/4 wavelength. If there are standing waves, the deflection will rise at each current loop (voltage node). If there are no standing waves, the deflection will remain steady all along the line.

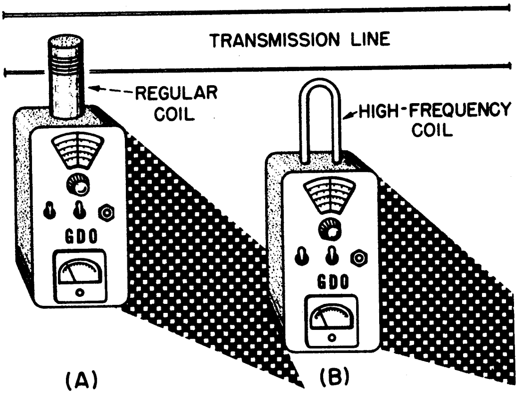


Fig. 8-6. GDO as standing-wave indicator.

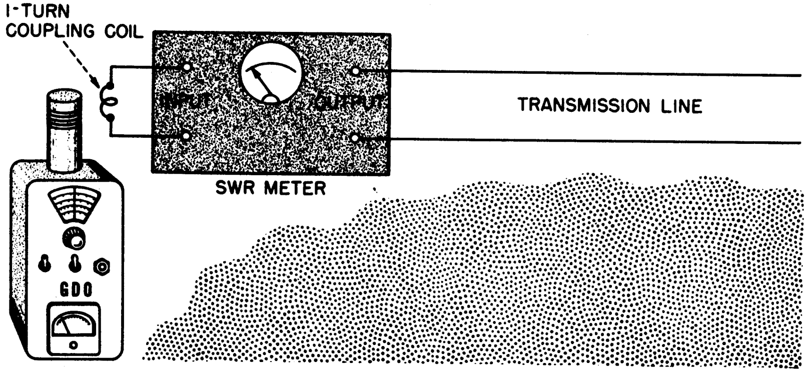


Fig. 8-7. Use of GDO with SWR meter.

For inductive coupling, as shown in Fig. 8-6, the turns of the GDO coil are parallel to the transmission line. If the GDO is rotated so that the turns of its coil are perpendicular to the line, the coupling will be capacitive, and the response will be the opposite of that described in the preceding paragraph. That is, the microammeter deflection will peak at each voltage loop (current node).

Throughout this test, the coupling between transmitter and line, and between line and antenna, must be maintained constant, as must also the spacing between the transmission line and GDO coil.

8.7 GDO AS SIGNAL SOURCE FOR SWR METER

A number of simple *standing-wave-ratio* (SWR) meters are commercially available, either factory-built or in kit form. These instruments permit direct measurement of the standing-wave ratio of transmission lines and components.

If the indicating meter in the SWR meter has a full-scale deflection of not more than 200 μa, the GDO may be used as the r-f source to drive the instrument. This is particularly advantageous when checking a transmission line connected to an antenna, since the lower power of a GDO is less apt to cause radio interference than when a transmitter is used as the signal source.

Figure 8-7 shows the connections. A 1-turn coupling coil is connected by the shortest possible leads to the input terminals of the SWR meter. (Some SWR meters already have this coil, rigidly mounted.) The transmission line or component under test is connected to the output terminals. The GDO is inductively coupled *loosely* to the 1-turn coil and tuned to the desired frequency. In this application, the GDO functions simply as an r-f signal source. All adjustments and readings are made at the SWR meter and will differ with different instruments.

8.8 GDO AS SIGNAL SOURCE FOR R-F IMPEDANCE METER

The GDO may be used as an r-f signal source for most of the simple r-f impedance meters now available commercially in factory-built and kit-type models.

The connections are similar to those described in Section 8.7 and illustrated by Fig. 8-7. As in the preceding application, all adjustments and readings are made at the impedance meter and will differ with different instruments.

Chapter 9

MISCELLANEOUS APPLICATIONS

Presented in this chapter are several tests and applications which do not have a natural place in the other parts of the book. Some of them, such as Q measurements, have been referenced in earlier chapters.

There has been no attempt to include all of the known GDO applications not covered by the other chapters, since many of the possible applications do not fully meet the criterion of practical utility.

9.1 Q MEASUREMENTS

At several points in preceding chapters, we explained how the Q of a tuned circuit might be estimated roughly from the liveliness of the deflection of the GDO microammeter. This section describes quantitative measurements of Q.

Two methods are included. At the outset, it should be stated that neither method is completely satisfactory for the measurement of high capacitor Q. The reason for this is the unavoidable Q reduction caused by the vtvm.Thus, the difference between an excellent capacitor and a good one is barely discernible. For the same reason, all Q values obtained by the methods described here will be somewhat lower than true Q.

In each instance, the coupling between the GDO and test coil must be maintained constant throughout the measurement. Also, the test circuit must be as nearly in the clear as possible; that is, all extraneous objects and materials must be removed from the field of the coil and from contact with any part of the circuit. This includes insulators as well as conductors, since both affect the Q. When a dielectric material *must* be used (for example, to support the coil or capacitor of the test circuit), it must be a dry, high-quality material such as polystyrene.

In addition to the GDO, an r-f vtvm will be required for all Q measurements.

Method 1. Use the test setup shown in Fig. 9-1. The circuit under test is comprised by coil L and capacitor C. The r-f probe of the vtvm must be attached directly to the test circuit without an intervening lead. The negative lead from the vtvm should be as short as possible. In some instances, accuracy will be improved by grounding the negative terminal (bottom of L and C).

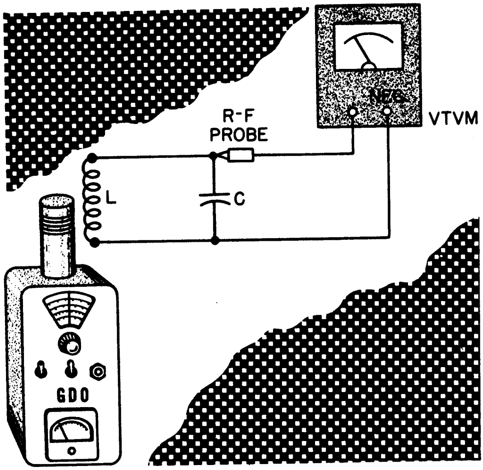


Fig. 9-1. Q-measurement setup for resonant circuit.

Test procedure: (1) Inductively couple the GDO loosely to coil L, as shown in Fig. 9-1. (2) Set the vtvm to its lowest voltage range. (3) Tune the GDO for peak deflection of the vtvm. Record this voltage as E. (4) Note the GDO dial reading and record this frequency as f_r. This is the resonant frequency of the LC test circuit. (5) Without disturbing the coupling, detune the GDO to a higher-frequency point at which the vtvm deflection drops to a value equal to 0.707 E. (6) Record this frequency as f_2. (7) Without disturbing the coupling, detune the GDO back through f_r and to a lower frequency point at which the vtvm deflection again drops to 0.707 E. (8) Record this frequency as f_1. (9) Calculate the Q of the test circuit by means of the following equation:

$$Q = \frac{f_r}{f_2 - f_1}, \tag{9-1}$$

where f_1, f_2 and f_r each is in the *same* units (that is, either kc or mc).

> **Example:** At resonance, f_r for a tuned circuit is found to be 2 mc. The corresponding vtvm deflection is 1 volt. When the GDO is detuned to 2.05 mc, the deflection drops to 0.707 volt. Also, when the GDO is tuned to 1.95 mc, the deflection again drops to 0.707 volt. Calculate the Q.
>
> From equation (9-1):
>
> $$Q = \frac{2}{2.05 - 1.95} = \frac{2}{0.1} = 20$$

The higher the Q of the circuit, the closer together will be the frequency points f_1, f_2 and f_r. For very-high-Q circuits, these points may be so close together that they cannot be read accurately from the GDO dial.

The foregoing procedure gives the circuit Q of the entire test circuit. If it is desired to find the Q of a coil only, choose for C a high-quality silvered mica or air capacitor (50 to 500 μμf). Since the Q of such capacitors is many times higher than that of a coil having the same reactance, the assumption may be made safely that the measured Q is that of the coil. However, Method 2 provides a more accurate measurement.

Method 2. This method requires a precision variable capacitor having a dial graduated directly in μμf in addition to the GDO and r-f vtvm. Figure 9-2 shows the test setup.

Test procedure: (1) Connect the coil (L) under test by the shortest possible leads to the precision variable capacitor (C), as shown in Fig. 9-2. (2) Set the vtvm to its lowest voltage range. (3) Set the variable capacitor to some convenient high capacitance. (4) Record this capacitance as C_r. (5) Inductively couple the GDO *loosely* to coil L. (6) Tune the GDO for peak deflection of the vtvm. Record this voltage as E. (7) Without disturbing the frequency setting of the GDO or changing the coupling, set the variable capacitor to a capacitance higher than C_r, at which the vtvm deflection drops to 0.707 E. (8) Record this capacitance as C_2. (9) Without disturbing the frequency setting of the GDO or changing the coupling, set the variable capacitor to a capacitance lower than C_r, at which the vtvm deflection again drops to 0.707 E. (10) Record this capacitance as

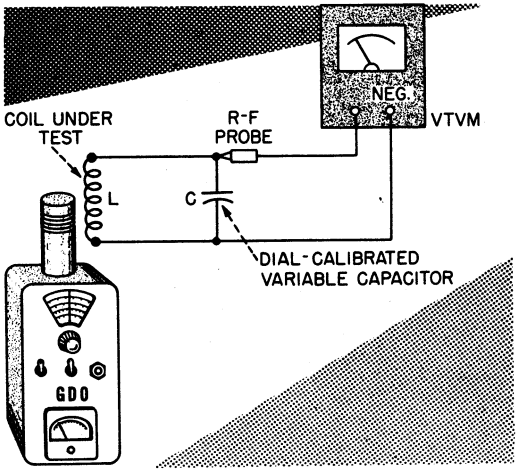


Fig. 9-2. Q-measurement setup for coil.

C_1. (11) Calculate the Q of the coil by means of the following equation:

$$Q = \frac{C_r}{C_2 - C_1}, \qquad (9\text{-}2)$$

where C_1, C_2 and C_r each is in μμf.

Example: At resonance, C_r for a coil under test is 425 μμf. The corresponding vtvm deflection is 1 volt. When the capacitor is set to 427 μμf, the deflection drops to 0.707 volt. Also, when the capacitor is set to 423 μμf, the deflection again drops to 0.707 volt. Calculate the Q.

From equation (9-2):

$$Q = \frac{425}{427 - 423} = \frac{425}{4} = 106.2$$

9.2 CALIBRATING A GDO

An unmodulated r-f signal generator or frequency standard may be employed to calibrate the tuning dial of a GDO, as shown in Fig. 9-3. The zero-beat method is used, the GDO functioning in its normal manner as an oscillator but with headphones plugged into its PHONE jack.

When the signal generator is used, many GDO dial points may be checked over a continuous tuning range. The frequency standard provides higher accuracy but gives only spot frequencies (for example, every 100 or 1000 kc).

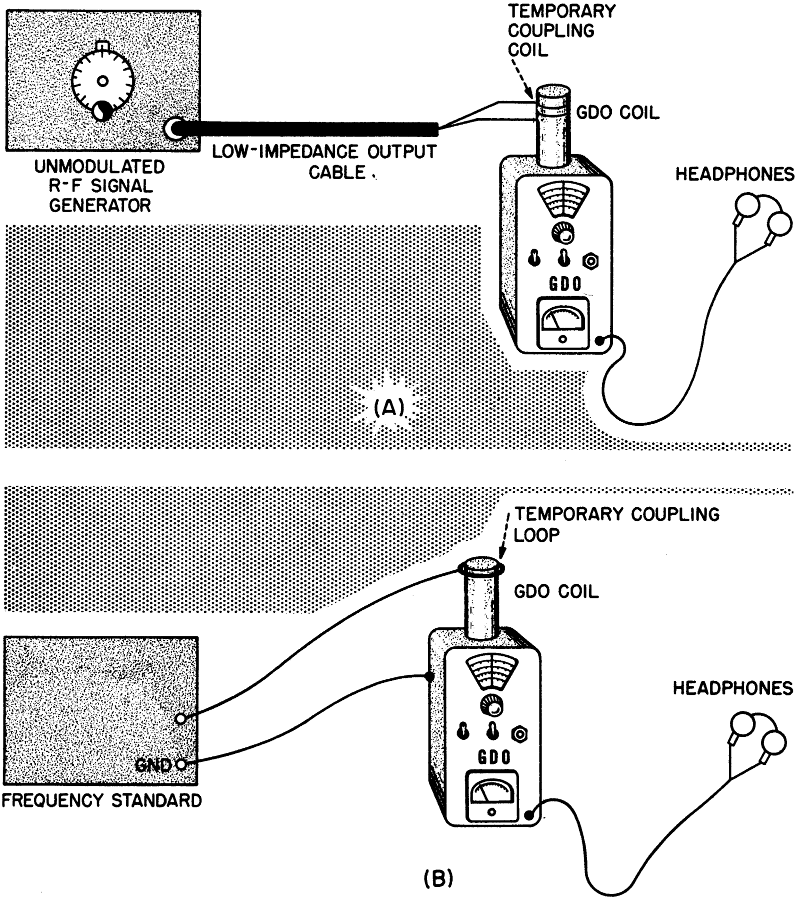


Fig. 9-3. GDO calibration setups.

Calibration procedure: (1) When using the signal generator, wind a coupling coil of 1 or 2 turns of insulated wire temporarily around the end of the GDO coil in use, as shown in Fig. 9-3(A), and connect this coil to the output cable of the signal generator. This coil provides inductive coupling to the GDO. (2) When using the frequency standard, make a tight, single-turn loop of insulated wire around the end of the GDO coil in use, as shown in Fig. 9-3(B), and connect this loop to the "hot" output terminal of the standard. The loop provides capacitive coupling between the GDO and the high-impedance output circuit of the frequency standard. Connect the grounded output termi-

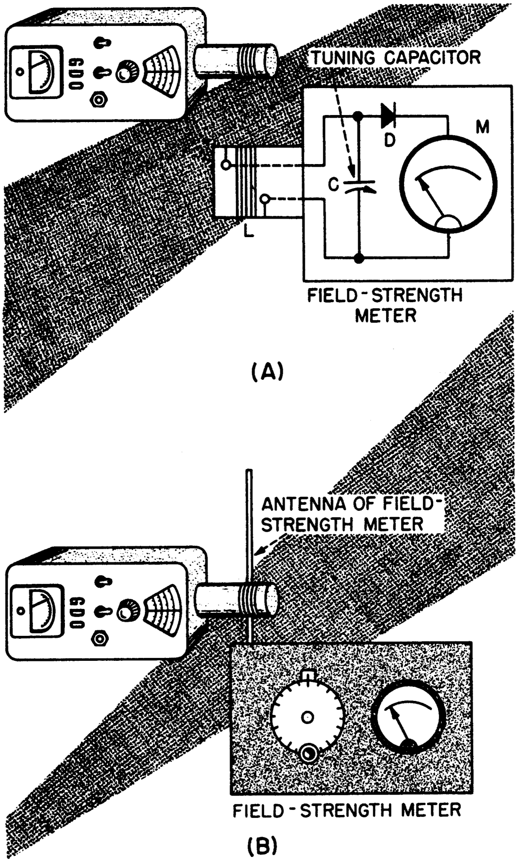


Fig. 9-4. Setup for calibrating field-strength meter.

nal of the standard to the GDO case. (3) Plug high-impedance magnetic headphones into the GDO PHONE jack. (4) Throw the OSCILLATOR-DIODE switch in the GDO to its OSCILLATOR position. (5) Allow a 15-minute warmup period for both generator and GDO. (6) With the signal generator set successively to each desired check frequency, tune the GDO for zero beat and read the GDO dial setting. (7) If the frequency standard is used, tune the GDO throughout its range, noting its dial reading at zero beat for each of the spot-frequency points set up by the standard. (8) The usual precautions should be taken to ensure that fundamental frequencies of the generator, rather than harmonics, are being tuned in with the GDO; or that the proper harmonic of the frequency standard is tuned in.

9.3 CALIBRATING FIELD-STRENGTH METER WITH GDO

Although the GDO is not a precision signal generator, it may be used in an emergency to calibrate a simple, diode-type field-strength meter (FSM) with sufficient accuracy for most practical purposes. The FSM circuit is shown in Fig. 9-4(A). Coil *L* usually is of the plug-in type for band changing and is tuned by the variable capacitor *C*. The crystal diode *D* delivers d-c output (proportional to the r-f input to coil *L*) to drive the d-c microammeter or milliammeter *M*.

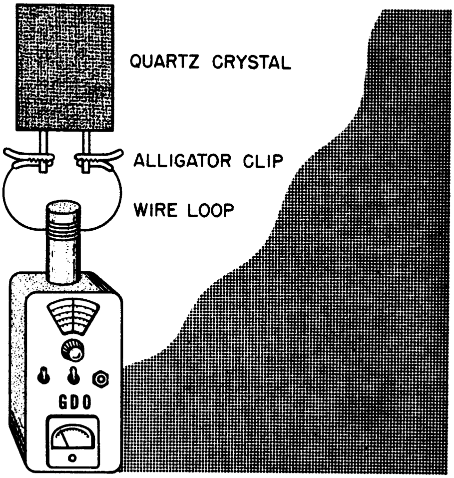


Fig. 9-5. Crystal-checking setup.

The GDO is operated in its conventional manner as an oscillator. It may be coupled directly to the field-strength meter coil, as shown in Fig. 9-4(A) or to the pickup antenna of the FSM, as shown in Fig. 9-4(B).

Test procedure: (1) Loosely couple the GDO to the FSM, as shown in Fig. 9-4. (2) Set the FSM tuning dial (on capacitor *C*) to its high-frequency end. (3) Tune the GDO for peak deflection of the FSM meter *M*. (4) Read the frequency from the GDO dial and inscribe this frequency on the FSM tuning dial. (5) Advance the FSM dial a small amount and check the frequency at this point by retuning the GDO for peak deflection of meter *M*. (6) Repeat at as many points as practicable until the low-frequency limit of tuning capacitor *C* is reached. (7) An alternative method is to set the GDO successively to desired dial frequencies and then to tune the FSM successively to these frequencies.

9.4 QUARTZ CRYSTAL CHECKING

The fundamental frequency of an unmarked quartz crystal may be checked easily with a GDO. Figure 9-5 shows the test setup.

To check the crystal: (1) Fasten a small alligator clip to each end of a short piece of insulated wire. (2) Clip this lead to the pins of the crystal holder so as to form a single-turn loop, as shown in Fig. 9-5. (3) Inductively couple the GDO to this loop, orienting the GDO coil so that its turns are parallel to the loop. (4) Tune the GDO carefully for dip. (5) At dip, read the fundamental frequency of the crystal from the GDO dial.

One commercial GDO (Section 10.1) provides a front-panel crystal socket into which an unknown crystal may be plugged for frequency check. Crystals which do not fit this socket may be connected, by means of supplied clip leads, to the GDO circuit.

Quartz crystals are high-Q components. Dip accordingly is very lively and the tuning is sharp, so that the resonant point can be passed over completely if the GDO is not tuned carefully.

Chapter 10

COMMERCIAL GRID-DIP OSCILLATORS

Circuit diagrams, photographs, and technical specifications of commercial GDO's are presented in this chapter. This information is offered with the kind permission of the manufacturers of the instruments.

The units described in Sections 10.3 and 10.4 are kit-type instruments for assembly by the user. (The one featured in Section 10.3 is available either as a kit or ready-made.) All others are factory-built.

This material will permit the reader to examine commercial designs and to survey the specifications of different instruments prior to purchasing a GDO to suit his particular needs.

No attempt is made here to present a particular group or equipment in a particular price range; rather, it is felt that the following represents a cross section of available GDO's.

10.1 AEROVOX MODEL 97 LC CHECKER

This instrument is shown in Figs. 10-1 and 10-2. All coils are self-contained and are switched individually by means of a 6-band rotary RANGE switch. The tuning dial reads directly in frequency (kc and mc) and capacitance (μf). Dip is indicated by a magic-eye tube.

Tubes employed are (1) 6C4, (1) 6E5, and (1) OA2. D-c plate power is supplied by a transformerless voltage doubler employing a selenium rectifier; filament power by a 6.3-volt transformer. Power consumption is 30 watts at 115 volts ac. Dimensions: 13 × 8½ × 6 inches. Weight: 6½ pounds.

FREQUENCY RANGES	CAPACITANCE RANGES
Band A. 72–225 kc	Band A. Not used
Band B. 200–600 kc	Band B. 0.8–3.5 μf
Band C. 550–1650 kc	Band C. 0.1–0.8 μf
Band D. 1.5–5 mc	Band D. 0.014–0.1 μf
Band E. 4.5–14.5 mc	Band E. 0.0015–0.011 μf
Band F. 13–44 mc	Band F. 0.00015–0.0016 μf

Special features. R-f output for conventional GDO tests is provided through a probe consisting of a 1½-inch diameter, 1-turn coupling coil (L_3 in Fig. 10-2) permanently mounted on the end of a flexible, concentric cable. When the instrument is in use, this coil, or ring, is held close to the circuit under test.

A separate fixture is provided for testing capacitors. This unit consists of a rigid half-turn of flat strip (L_4 in Fig. 10-2) attached securely to a plastic disc. Clips are provided at the ends of the half-turn for gripping the pigtails of the capacitor under test. The stable inductance of the half-turn thus is added to the capacitance of the capacitor to form the resonant test circuit. The coupling coil L_3 snaps into a groove in the disc to provide inductive coupling between this resonant circuit and the GDO. In Fig. 10-1, the loop is shown snapped in place on the disc of the capacitor-test fixture.

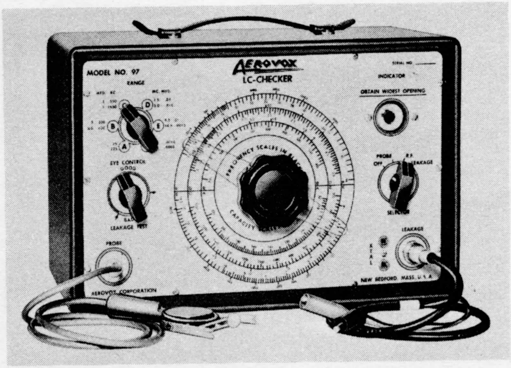


Fig. 10-1. Aerovox Model 97 LC Checker. *Courtesy* Aerovox Corp.

A 2-pin socket is provided on the front panel of the LC Checker for insertion of a quartz crystal. When tuned to the crystal frequency, the instrument becomes a crystal-controlled oscillator for the generation of precise radio frequencies.

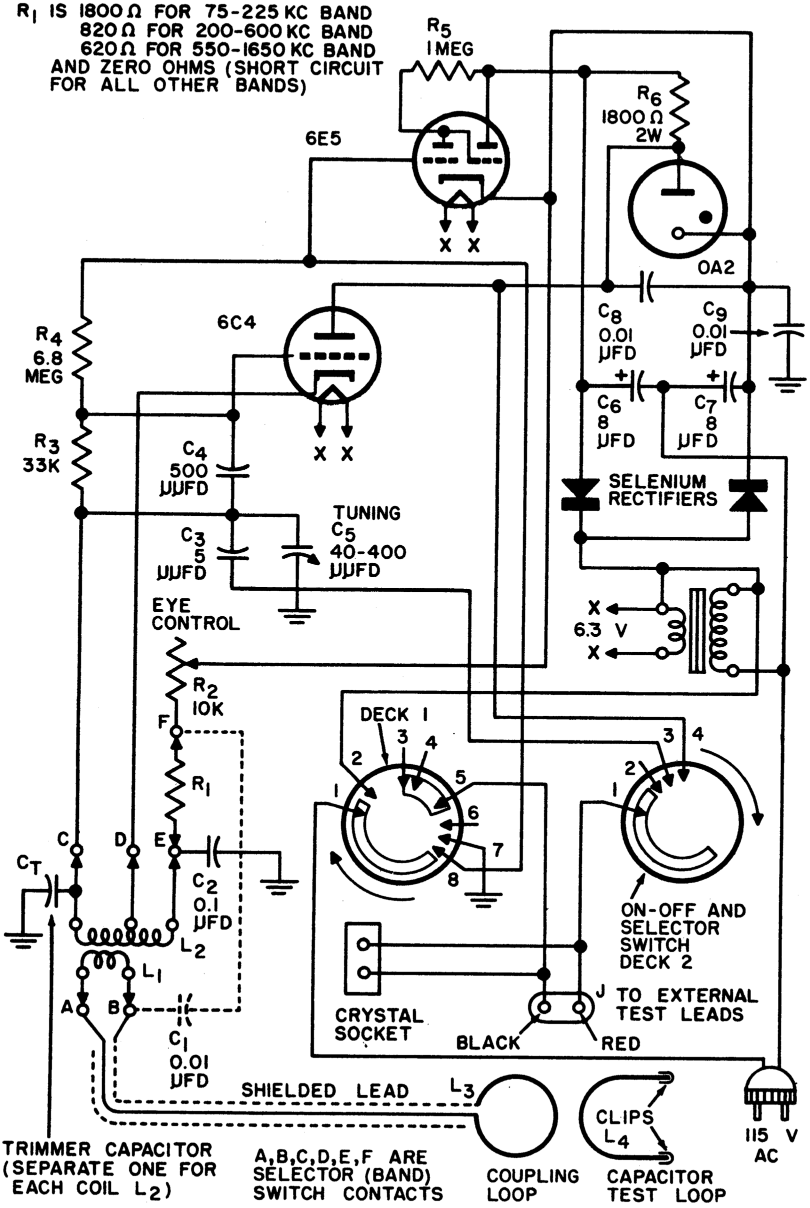


Fig. 10-2. Aerovox Model 97 LC Checker circuit.

Shielded test leads with clips are supplied for connection to jack *J*. In one position of the selector switch, the r-f output of the oscillator is available at these leads, and the instrument is usable as an r-f signal generator and for checking the frequency of quartz crystals. In another position of the switch, a capacitor may be connected to the leads for a d-c leakage test in conjunction with the eye tube and the eye-control potentiometer.

Fig. 10-3. Barker & Williamson Model 600 Dip Meter. ***Courtesy Barker & Williamson, Inc.***

A precision 0.001-μf mica capacitor with binding post terminals is available for making inductance measurements in the manner described in Chapter 5 of this book.

10.2 BARKER & WILLIAMSON MODEL 600 DIP METER

This instrument is shown in Figs. 10-3 and 10-4. It employs five plug-in coils to cover the frequency range 1.75 to 260 mc.

A single 955 acorn tube and one selenium rectifier are employed. Dimensions: 3 × 3 × 7 inches. Weight: 2 pounds. The indicator is a 0–500 d-c microammeter.

FREQUENCY RANGES

Coil 1.	1.75–5.2 mc
Coil 2.	5–14 mc
Coil 3.	14–36 mc
Coil 4.	36–95 mc
Coil 5.	95–260 mc

Special features. When the diode switch (S_1 in Fig. 10-4) is closed, the circuit oscillates and the instrument is usable as a conventional GDO. When S_1 is opened, B-plus is removed from the tube and the latter then acts as a diode detector in conjunction with magnetic headphones plugged into jack *J* (when the instrument is used as a monitor) or in conjunction with meter *M* (when the instrument is used as a wavemeter or field-strength meter).

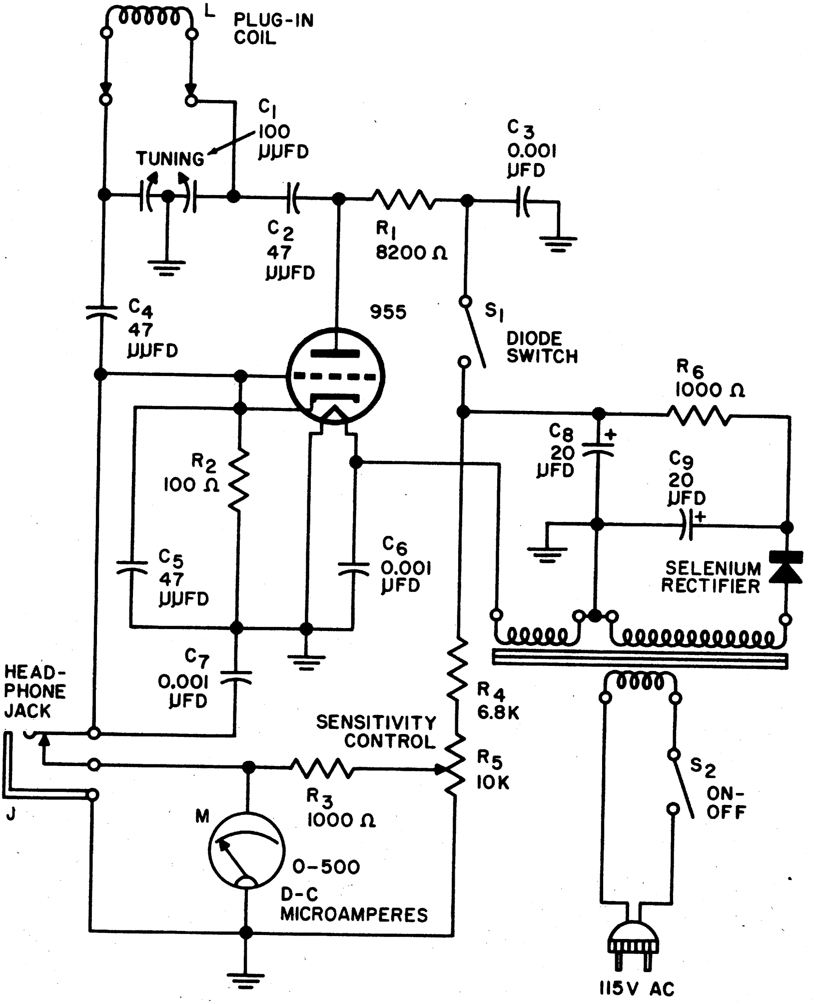


Fig. 10-4. Barker & Williamson Model 600 Dip Meter circuit.

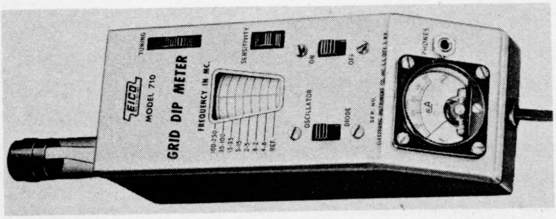


Fig. 10-5. EICO Model 710 Grid-Dip Meter. Courtesy *Electronic Instrument Co., Inc.*

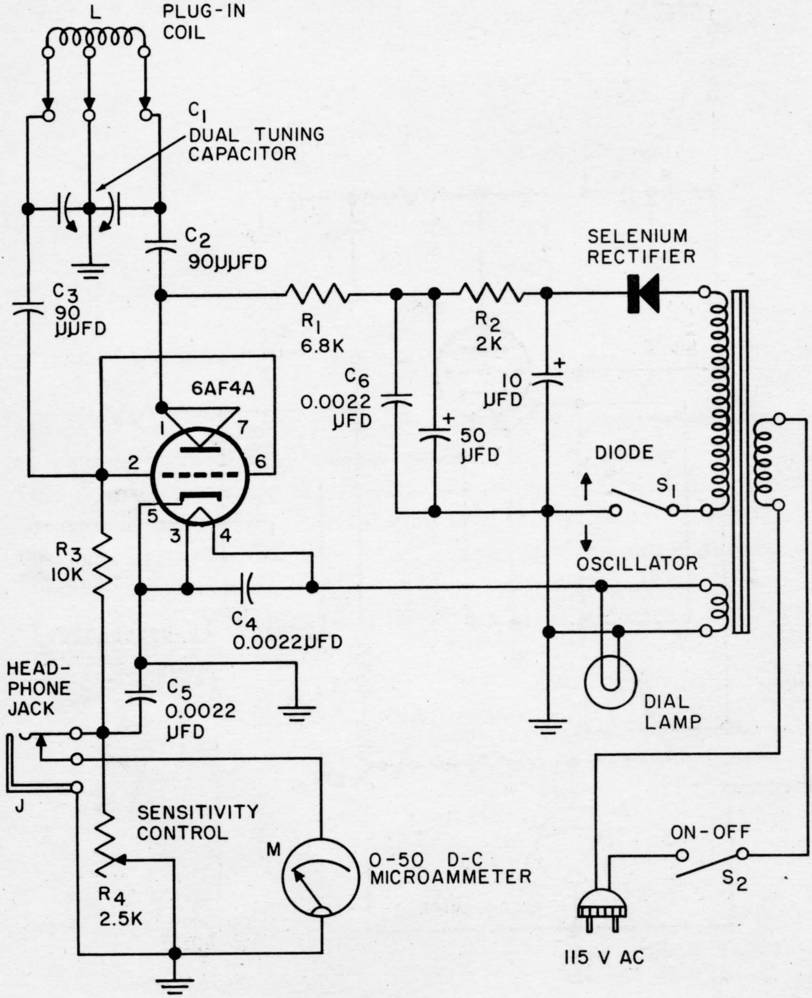


Fig. 10-6. EICO Model 710 Grid-Dip Meter circuit.

10.3 EICO MODEL 710 GRID-DIP METER

This instrument is shown in Figs. 10-5 and 10-6. It employs eight plug-in coils to cover the frequency range 400 kc to 250 mc. This instrument is supplied either factory-built or in kit form for private assembly. In each instance, the coils are ready-wound.

A single 6AF4A tube and one selenium rectifier are employed. Dimensions: 2-1/4 × 2-9/16 × 6-7/8 inches. Weight: 3 pounds. Power: 10 watts at 117 volts ac. The indicator is a 0–50 d-c microammeter.

FREQUENCY RANGES

Coil A.	400–700 kc
Coil B.	700–1380 kc
Coil C.	1380–2900 kc
Coil D.	2.9–7.5 mc
Coil E.	7.5–18 mc
Coil F.	18–42 mc
Coil G.	42–100 mc
Coil H.	100–250 mc

Special features. When the OSCILLATOR-DIODE switch (S_1 in Fig. 10-6) is closed, the circuit oscillates and the instrument is usable as a conventional GDO. When S_1 is opened, the B-minus line is interrupted, and the tube then acts as a diode detector in conjunction with magnetic headphones plugged into jack *J* (when the instrument is used as a monitor) or in conjunction with meter *M* (when the instrument is used as a wavemeter or as a field-strength meter).

Fig. 10-7. Heathkit Model GD-1B Grid-Dip Meter. Courtesy Heath Company.

10.4 HEATHKIT MODEL GD-1B GRID-DIP METER

This instrument is shown in Figs. 10-7 and 10-8. It employs five plug-in coils to cover the frequency range 2 to 250 mc. Additional coils are available to extend the range downward to 250 kc. This instrument is available only in kit form for private assembly, but the coils are ready-wound. Each coil covers a frequency range of about 1 to 3.

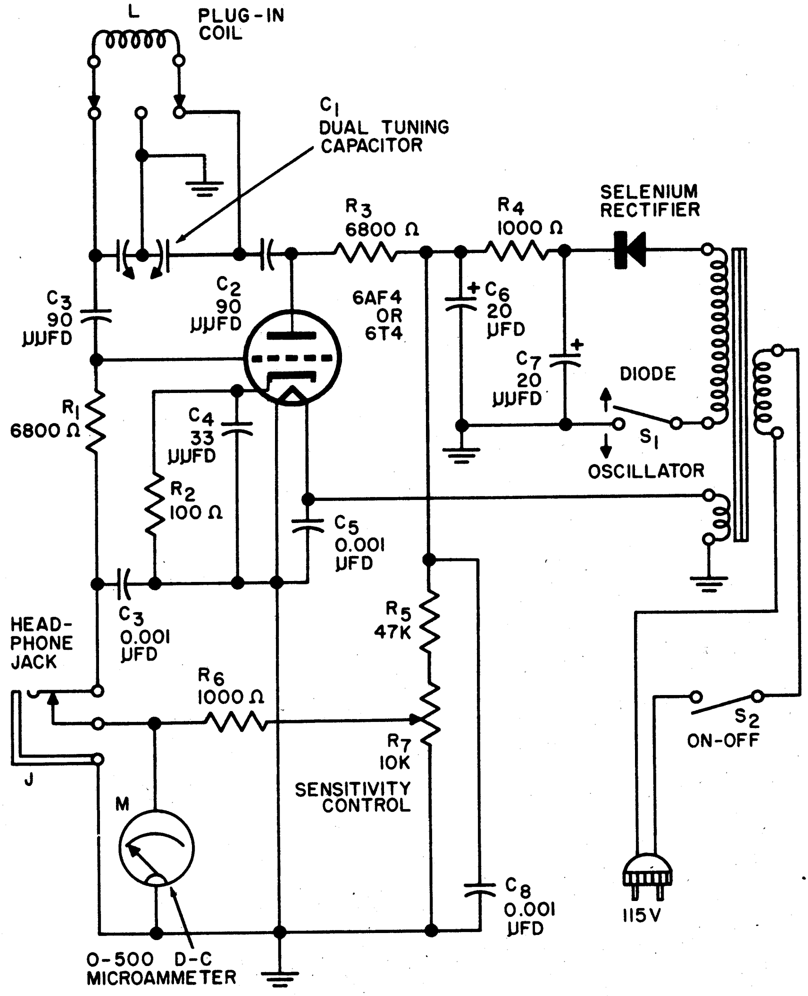


Fig. 10-8. Heathkit Model GD-1B Grid-Dip Meter circuit.

A single 6AF4 tube and one selenium rectifier are employed. Dimensions: 7 × 2½ × 3¼ inches. Net weight: 2 pounds. Power: 5 watts at 117 volts ac. The indicator is a 0–500 d-c microammeter.

FREQUENCY RANGES

Coil A.	2–5 mc
Coil B.	5–14 mc
Coil C.	14–37 mc
Coil D.	37–100 mc
Coil E.	100–250 mc

Special features. Two additional *3-prong* coils are available to extend the tuning range down to 250 kc. Individual calibration charts are supplied with these coils.

When the DIODE-OSCILLATOR switch (S_1 in Fig. 10-8) is closed, the circuit oscillates and the instrument is usable as a conventional GDO.

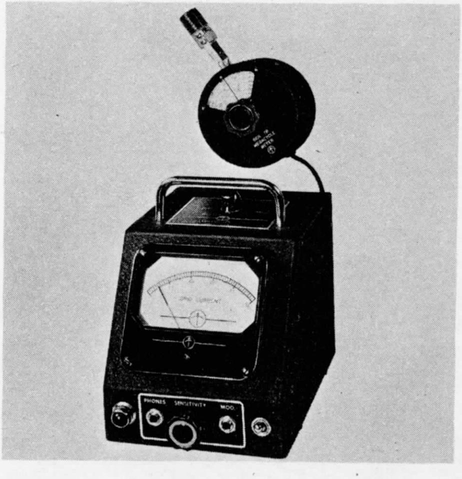


Fig. 10-9. Measurements Model 59 Megacycle Meter. *Courtesy Measurements Div., McGraw-Edison Company.*

When S_1 is opened, the B-minus line is interrupted, and the tube then acts as a diode detector in conjunction with magnetic headphones plugged into jack *J* (when the instrument is used as a monitor) or in conjunction with meter *M* (when the instrument is used as a wavemeter or field-strength meter).

The dual tuning capacitor C_1 provides the necessary capacitance to resonate with the plug-in coils.

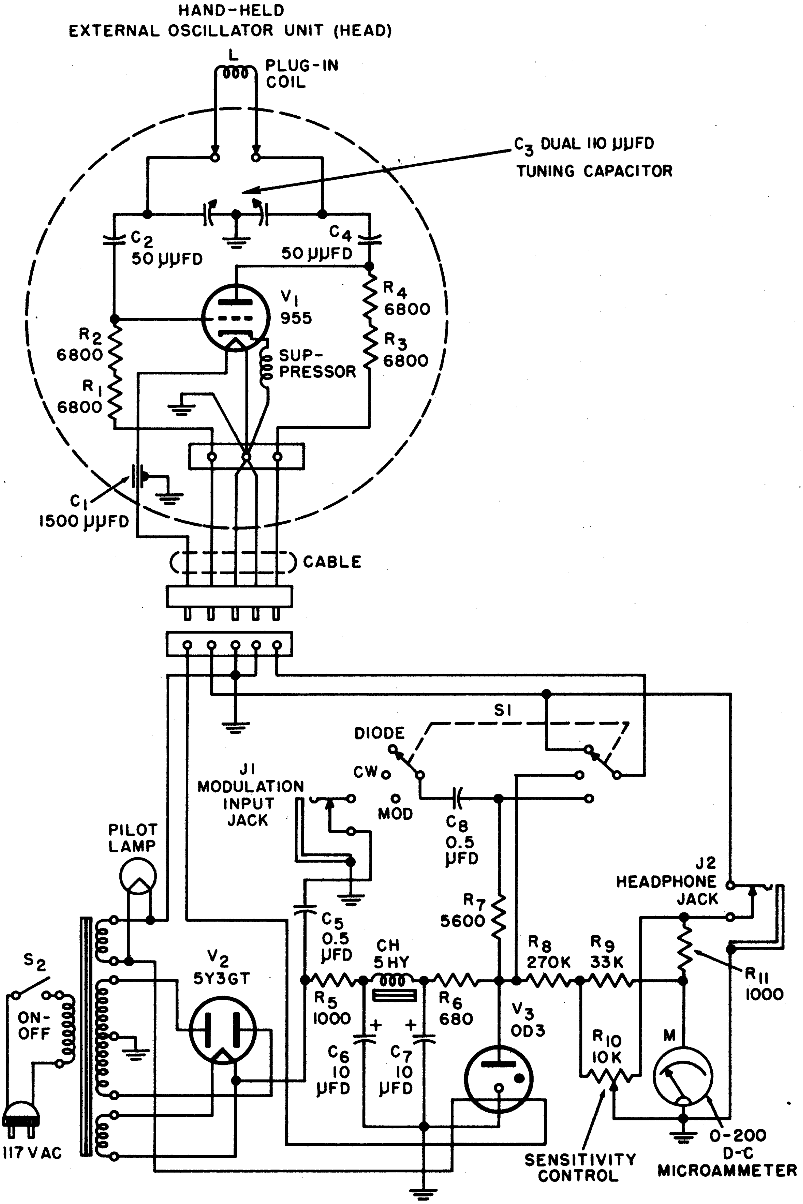


Fig. 10-10. Measurements Model 59 Megacycle Meter circuit.

10.5 MEASUREMENTS MODEL 59 MEGACYCLE METER

This instrument is shown in Figs. 10-9 and 10-10. Additional accessories for extending the frequency range are shown in Figs. 10-11 and 10-12.

The Megacycle Meter consists of two sections: a voltage-regulated power supply (housed in the cabinet bearing the grid current meter, Fig. 10-9) and an external hand-held oscillator head (shown above the cabinet in Fig. 10-9), which receives the plug-in coil and is connected to the power supply through a flexible cable. The power-supply circuit is shown in the lower half of Fig. 10-10, and the basic model 59 oscillator circuit in the upper half.

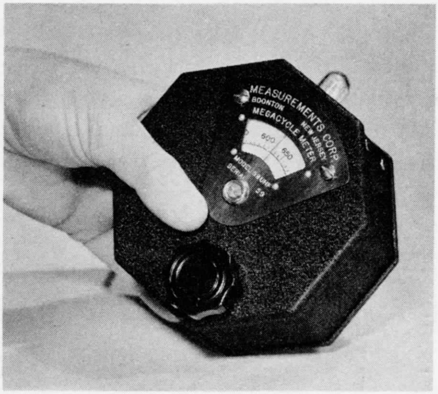


Fig. 10-11. Ultra-high-frequency oscillator head for the Megacycle Meter. *Courtesy Measurements Div., McGraw-Edison Company.*

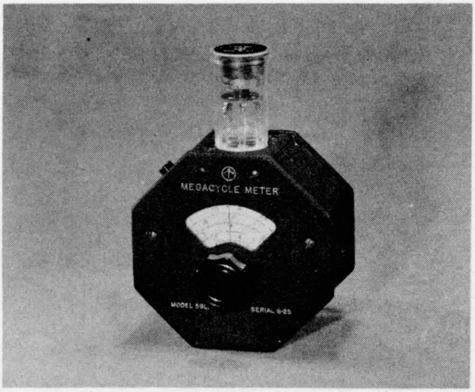


Fig. 10-12. Low-frequency oscillator head for the Megacycle Meter. *Courtesy Measurements Div., McGraw-Edison Company.*

The power supply employs one 5Y3GT and one OD3 tube. The basic model 59 oscillator head employs one 955 acorn tube. Dimensions: power supply 5-1/8 inches wide, 6-1/8 inches high, 7-1/2 inches deep; oscillator head 3-3/4 inches diameter, 2 inches deep. Weight: power supply 6-1/2 pounds; oscillator head 1 pound. Power: 20 watts at 117 volts ac. The indicator is a 0–200 d-c microammeter. The basic model 59 uses 7 plug-in coils to cover the frequency range 2.2 to 420 mc.

Separate oscillator heads, shown in Figs. 10-11 and 10-12, may be connected to the power supply to extend the frequency range. The model 59UHF head (Fig. 10-11) has a tuning range of 420 to 940 mc with a single built-in coil. The model 59LF head (Fig. 10-12) employs four plug-in coils to cover the range 100 kc to 4.5 mc. The model 59UHF head uses a single 6AF4A tube, the model 59LF head a single 6C4 tube. The complete set of three oscillator heads give the Megacycle Meter a total frequency range of 100 kc to 940 mc.

FREQUENCY RANGES

With model 59LF head	Coil 1.	100–250 kc
	Coil 2.	250–550 kc
	Coil 3.	550–1500 kc
	Coil 4.	1500–4500 kc
With model 59 head	Coil 1.	2.2–5 mc
	Coil 2.	5–10 mc
	Coil 3.	10–22 mc
	Coil 4.	22–45 mc
	Coil 5.	45–100 mc
	Coil 6.	100–250 mc
	Coil 7.	200–400 mc
With model 59UHF head	Single Coil.	420–940 mc

Special features. When switch S_1 (Fig. 10-10) is set to its DIODE position, plate voltage is removed from the oscillator tube. The latter then acts as a diode detector in conjunction with magnetic headphones plugged into jack J_2 (when the instrument is used as a monitor) or in conjunction with meter M (when the instrument is used as a wavemeter or field-strength meter). When S_1 is set to its CW position, the circuit oscillates, and the instrument is usable as a conventional GDO or unmodulated signal generator. When S_1 is set to its MOD position,

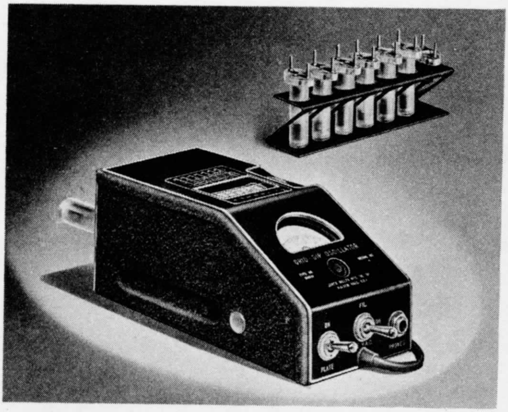


Fig. 10-13. Millen No. 90651 Grid-Dip Meter. *Courtesy James Millen Manufacturing Co., Inc.*

the circuit again oscillates, but an audio-frequency modulating signal may be introduced at jack J_1 to amplitude modulate the r-f output of the oscillator.

10.6 MILLEN NO. 90651 GRID-DIP METER

This instrument is shown in Figs. 10-13 and 10-14. It employs seven plug-in coils to cover the frequency range 1.7 to 300 mc. Four additional coils are available to extend the frequency range downward to 220 kc.

A single 9002 tube and one selenium rectifier are employed. Dimensions: 7 × 3-3/16 × 3-3/8 inches. Weight: 3½ pounds. Power: 110–120 volts ac or external batteries. The indicator is a d-c microammeter.

FREQUENCY RANGES

With regular coils	Coil A.	1.7–2.9 mc
	Coil B.	2.9–7.5 mc
	Coil C.	6.4–16 mc
	Coil D.	13–32 mc
	Coil E.	25–60 mc
	Coil F.	60–150 mc
	Coil G.	140–300 mc
With extra coils	No. 46705.	220–350 kc
	No. 46704.	325–600 kc
	No. 46703.	500–1050 kc
	No. 46702.	925–2000 kc

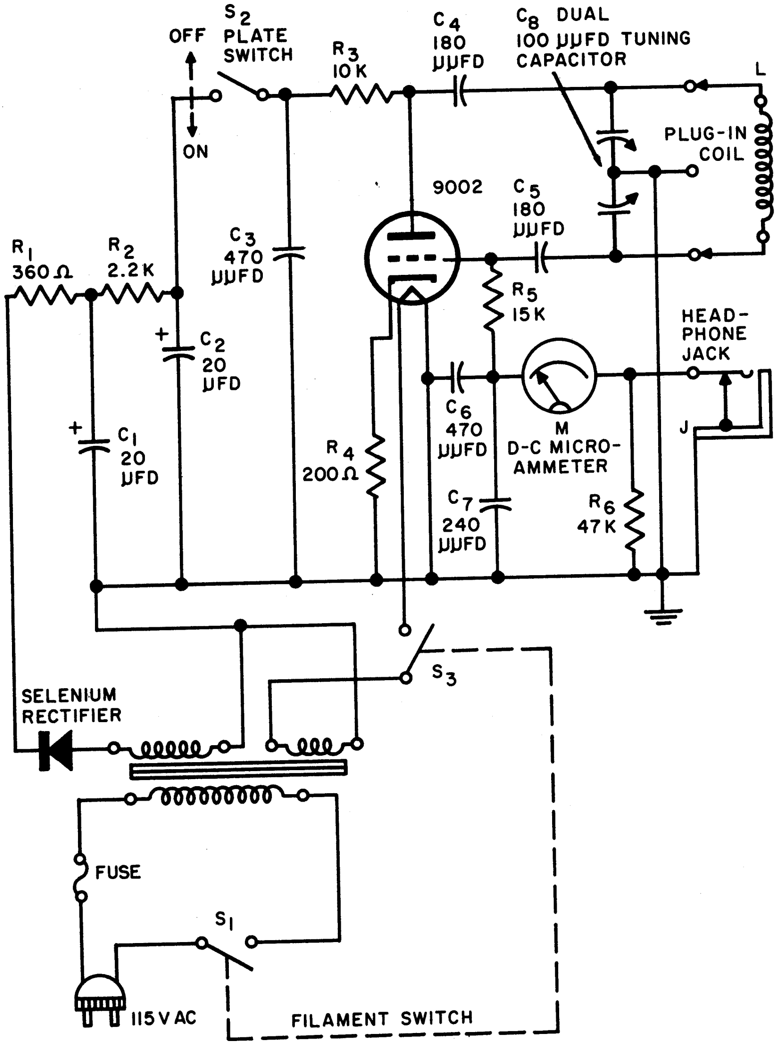


Fig. 10-14. Millen No. 90651 Grid-Dip Meter circuit.

Special features. Terminals are provided for connection of external A and B batteries when portable operation or isolation from the a-c power line is desired.

When the PLATE switch (S_2 in Fig. 10-14) is set to its ON position, the circuit oscillates, and the instrument is usable as a conventional

GDO. When S_2 is set to its OFF position, the B-plus line is interrupted and the tube then acts as a diode detector in conjunction with magnetic headphones plugged into jack *J* (when the instrument is used as a monitor) or in conjunction with meter *M* (when the instrument is used as a wavemeter or field-strength meter).

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