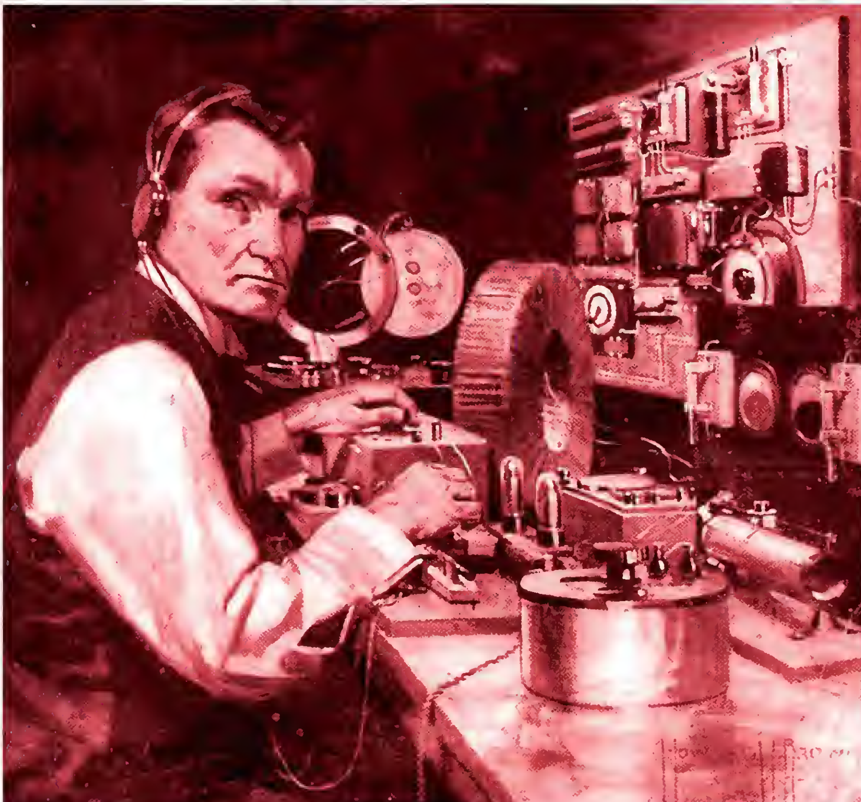
The Impoverished Radio EXPERIMENTER

Tricks, tips, and secrets to help the builder of simple radios and electrical gear achieve high performance at minimal cost!



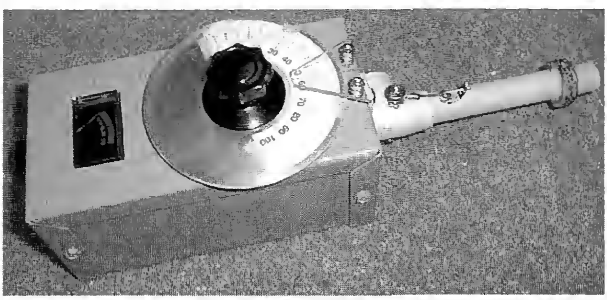
2

Build A Grid Dip Oscillator, a Shortwave Converter, a Slow-Motion Dial Drive, Space-Wound Coils & more!

EXPERIMENTER

Building a Grid Dip Oscillator, Shortwave Converter & more...

I wouldn't attempt to build a radio without a volt-ohm meter, and a grid-dip oscillator, or GDO. A meter will measure AC and DC voltages, current, and resistance. But with a GDO you can determine the resonant frequency of a tank circuit, or resonant circuit, or whatever term you prefer to describe an L-C circuit. You can use a GDO to determine the value of an unknown capacitor or coil, use it as a signal source, and even use it as a simple frequency meter.



This simple, inexpensive grid dip oscillator is an excellent project that you can use to expand your radio building skills while creating a measurement instrument that greatly simplifies radio building.

You can find used GDO's at flea markets, and probably on internet auctions sites as well. A number of commercial models were marketed by Knight-Kit, Heathkit, Millen, B&W, and others. Asking prices at hamfests or on the internet auction sites have run from $20 to $70.

You can always buy one which is a quick and dirty way of solving the problem, but you won't learn much. Our goal as builders is to learn, and building a GDO will teach valuable lessons and probably save money.

The GDO appeared as such after World War II as a commercial entity, but it really goes back to the earliest days of radio. The earliest version I've seen so far appeared in the August 1926 edition of QST. It was a battery-powered 201A oscillator. The numerous commercial versions appearing after WWII were tube models as well, but before long solid-state versions appeared.

Our GDO will be solid state. It fires up instantly, has no power cord, is low cost, and is mechanically easier to build than a tube machine. Again, tubes are for fun. We use transistors

[A pre-publication proof of this booklet was sent to C. F. Rockey, amateur radio operator since 1934, veteran radio builder, and author of "Secrets of Homebuilt Regenerative Receivers". His comments will be found as footnotes throughout these pages.]

The Improverished Radio Experimenter Volume 2

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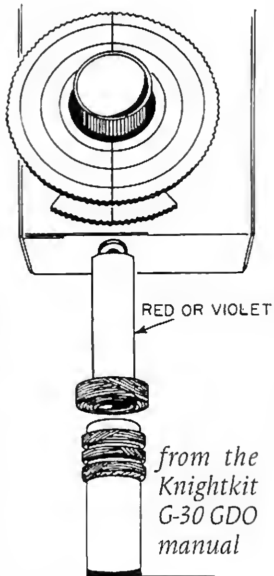
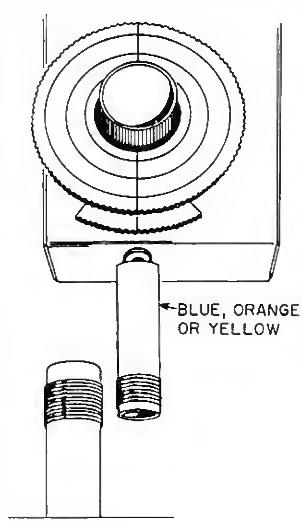
for performance.[1]

A GDO is simply an oscillator whose frequency can be varied over a wide range. Somewhere in the circuit is a meter that measures the amount of energy "vibrating" in the tank circuit.



from the Knightkit G-30 GDO manual

If we assume that our GDO is oscillating at 4.8 mHz and the energy meter is reading 8 on a scale of ten, and if we bring another tank circuit whose resonant frequency is very close to 4.8 mHz, we'll see the meter drop to perhaps 5. Pull the second tank circuit away, and the meter jumps back up to 8. What is happening is that the two tank circuits are "hearing" one another because of the electromagnetic fields that link the two. The second tank circuit starts ringing, and the energy it needs to do so is "sucked" out of the GDO tank circuit. The meter registers the energy being sucked out as a drop in the meter reading.



But let's explain it again another way. Suppose we have a bell and we are tapping it with a hammer. Our bell rings at a particular pitch related to its size. And suppose we have a meter that shows how loud our bell is ringing.

Suppose we bring a second bell of smaller size close to the bell we're hammering. Because the bell is smaller, it will have a higher pitch. We see on our meter that the loudness is unchanged.

Now suppose we remove the second bell and move in a third bell of exactly the same size and pitch as the first bell. The third bell starts vibrating because it is on exactly the same pitch as the first. It's sucking energy out of the hammered bell using the sound waves traveling through the air between them. And because power is being extracted, we see that our loudness meter now reads much lower than before.

In a GDO, a coil and variable capacitor form a tank circuit that is "hammered" by the plate of a tube, the collector of a transistor, or the drain of a field effect transistor. The tank circuit rings at a particular radio frequency which depends on the size of the coil and the capacitor. And we have a meter measuring the "loudness" of the electrical energy in the tank circuit.

If we bring near another coil and capacitor that rings at the same frequency as our GDO, we'll find that the meter needle drops. The second tank circuit is obviously removing energy. And this makes sense, because quite literally our GDO is a small transmitter and the second tank circuit is a receiver.

We can calibrate the dial on the GDO

[1] Rockey: I might put this the other way myself...

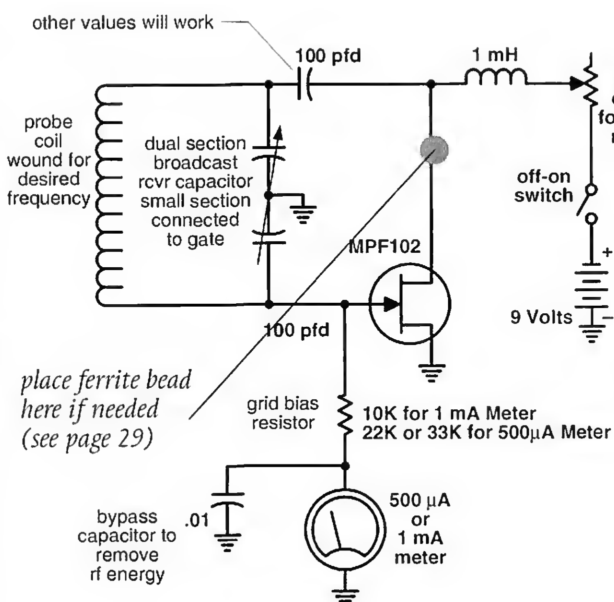
capacitor in units of frequency, kilocycles per second in the old days, now in megaHertz (mHz). We can slowly turn the GDO variable capacitor until we see the needle drop. When this happens, we know that the GDO is on the same frequency as the receiving tank circuit. And we can read the frequency off the calibrated dial. This is an extremely useful way of measuring and adjusting the frequency of tank circuits needed for radio construction.

Just to be sure there is no confusion, let's explain it one more time. In use, the GDO sensitivity control is adjusted to put the meter needle almost to its maximum. The exact setting is not important. The GDO is brought close to an unknown tank circuit. Next, the GDO variable capacitor is slowly varied until the meter begins to drop quite suddenly. It will drop, more and more, until it suddenly jumps back up to its original reading. At this point you can read the frequency off the GDO dial. This is the resonant frequency of the unknown circuit.

To put a radio on a band of frequencies that interests you requires that you be able to create resonant circuits of a particular frequency. Being able to measure the natural frequency of such resonant circuits greatly simplifies construction. If the frequency is lower than needed, you can remove coil turns. Or if the frequency is too high, you can add turns.

But a GDO is useful in other ways. If you know the value of either the coil or capacitor with some accuracy, you can use a simple formula and a pocket calculator to quickly calculate the value of the other component.

Circuits of the various GDO's illustrated on these pages shows that the circuit is just an oscillator with a grid-leak bias. Some of the energy in the resonant circuit gets rectified to supply a negative bias voltage to the grid, or in the case of our field-effect transistor, the gate. If we put a very sensitive meter in the grid/gate circuit, we can indirectly measure the energy in the GDO resonant circuit. It's exceptionally simple circuit that performs beautifully.



I. General

The Millen 90651 Grid-Dip Meter may be used in any of the following manners:

1. Grid-dip oscillator for use as an oscillating frequency meter to determine the resonant frequency of de-energized r.f. circuits.

Plate potential is applied to the Grid-Dip Meter and it becomes an r.f. oscillator. A d.c. meter in the grid return indicates relative power. When a circuit, resonant at the oscillator frequency, is coupled to the "probe" inductance, power is absorbed from the oscillator by the resonant circuit and is so indicated by a dip (decrease) in the grid meter reading. The "Grid Dipper", employed in this manner, may then be used to check the resonant frequency of a circuit without the application of power to the circuit in question. This results in a considerable saving of time, and a definite assurance of correct frequency adjustment of a circuit is obtained. Circuits may be checked or pretuned before completion of the unit in which they are to be used. Only minor trimming is generally required under actual operation. Guesswork or "cut and try" methods are eliminated. Possible damage to components during initial tune up and adjustment is eliminated.

2. Oscillating detector for determining the fundamental or harmonic frequencies of energized r.f. circuits.

Plate potential is applied and the instrument is used as an r.f. oscillator. Instead of observing the grid-meter reading, a pair of phones is inserted in the phone jack and an audible beat may be heard when the instrument is tuned to the fundamental or harmonic frequency of a source of r.f. The frequency may be read directly from the calibrated dial.

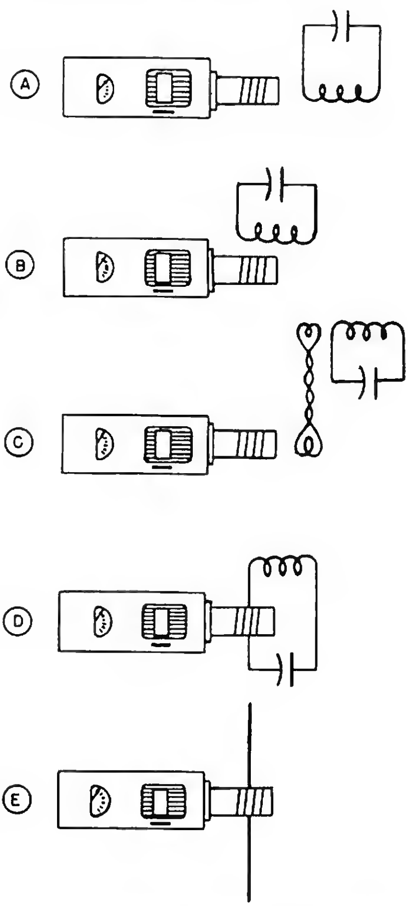
3. Signal generator. The instrument may be employed for this purpose generally in place of a standard signal generator, except where special shielding or a known r.f. output voltage is required.

4. Tuned r.f. diode or non-oscillating detector for use as an absorption-type frequency meter. No plate potential is applied and the internal tube is used as a diode. The grid meter is then in the diode load circuit and will read up-scale (current increase) when the instrument is tuned and closely coupled to a source of r.f. energy.

II. METHODS OF COUPLING

Correct methods of coupling the grid-dip meter to circuits under tests are shown in Fig. 1. When used as a grid-dip oscillator harmonics of lumped-constant resonant circuits will not be indicated; however, other resonant frequencies are sometimes indicated. These will be due to other resonant circuits formed by circuit wiring, stray capacitances, etc. In most cases these will occur at a higher frequency. On the other hand, harmonics of antennas, transmission lines, etc. will be indicated as will be explained later in the text under the heading "antennas."

When looking for the grid dip, it will be noted that the grid current reading slowly varies as the dial is rotated; however, correct resonance is indicated when the meter takes a sharp or pronounced dip.



It is suggested that the user of the "Grid Dipper" at first set up test L/C combinations, short test antennas, etc., and check them with the instrument in order to become familiar with the coupling methods and with the general behavior and operation of the unit.

III. APPLICATIONS

Receiver tuned circuits. Use the instrument as a grid-dip oscillator. Remove power from the receiver and resonate each tuned circuit to the desired frequency as indicated by the meter dip. Gang tuned circuits should be aligned for tracking by checking at each end of the ganged range. A check at one or two points in between will also be helpful. Methods of electrically obtaining the desired bandspread or tracking will not be explained here. Reference may be made to any good radio text book.

Following the above procedure, power may be applied to the receiver and the grid-dip meter employed as a signal generator for checking final alignment. A very short antenna should be connected to the receiver input terminals and the "Grid Dipper" should be placed on the bench removed from nearby conductors, and where body movements are least apt to affect the r.f. signal from the instrument. Some sort of indicating device such as an "S" meter or v.t.v.m. at the receiver detector must be used. If the r.f. signal is too strong, the receiver antenna may be shortened, or the instrument may be removed to a more remote or partially shielded location.

Where a superheterodyne type of receiver in involved and, if the receiver fails to function, it is quite possible that the receiver local oscillator is not working. This may be checked by employing the "Grid Dipper" as an r.f. diode detector or absorption type wave meter. Couple it to the oscillator coil and, if the meter does not go up-scale when the instrument is tuned to the resonant frequency of the oscillator tank, the oscillator is not functioning. An alternative method having greater sensitivity and capable of more accurate frequency measurement is to use the instrument as an oscillating detector and listen for the local oscillator beat in the headphones.

Transmitter tuned circuits. Use the instrument as a grid-dip oscillator with plate power removed from transmitter and proceed to adjust tanks to desired frequency as with receiver circuits. Tubes should be in place, and where capacitive coupling is used between stages, the grid circuit associated with following tube should be completed.

After the above procedure, plate power may be applied and final alignment made according to grid and plate meter indications. R.f. power at correct frequency in each tank may be checked by employing the "Grid Dipper" as a diode absorption frequency meter or it may be utilized as an oscillating detector. Due to its greater sensitivity in the latter state, care must be taken not to mistake audible beats from some other energized r.f. circuit. This may be checked by moving the instrument closer to the circuit under test and noting whether or not the beat increases in volume. If it does, the beat heard is from the desired circuit. Harmonics also may be heard, so it is wise to check for the beat heard at the lowest frequency.

Neutralization. Employ the instrument as a grid-dip oscillator. Remove all plate power from the transmitter. Couple the "Grid Dipper" to grid tank of stage to be neutralized, or in the case of capacitive coupling to the preceding plate tank (it is assumed that the tank has already been tuned to correct frequency) . Couple fairly close and leave instrument set in position with its meter deflected at bottom of the resonant dip.

Neutralization is then indicated when rotation of amplifier plate tank capacitor has no[1] reaction on the deflected meter reading. Another method is to use the instrument as a diode absorption-type meter and proceed to neutralize in the manner normally employed when using absorption-type wavemeter, or as with similar indicating device, i.e.:

Remove plate power from amplifier stage to be neutralized, and apply power to stage driving the grid. Couple the "Grid Dipper" to the amplifier tank, tune the instrument to the driving frequency and check for the presence of r.f. in the tank as indicated by a rise in the "Grid Dipper" meter current. Adjust neutralizing capacitor until no reading is seen on the meter.

Parasitic oscillations. Apply power to transmitter and use instrument as an oscillating detector while listening on headphones for beat of parasitic oscillation. As an alternative, the parasitic frequency may be determined by using the instrument as a tuned r.f. diode or absorption type frequency meter. Then parasitic frequency has thus been determined, as read from the "Grid Dipper," scale, remove power from transmitter and use instrument as a grid-dip oscillator to locate circuits or components, such as r.f. chokes, circuit wiring, etc., resonant at parasitic frequency.[2]

Parallel resonant traps. Use as a grid-dip oscillator. Trap may be tuned or checked either before or after connecting it in desired circuit. If tuned

[1] Rockey: It would be better to say "minimum" rather than "no"

[2] Rockey: Oh! I wish these d*** things were <u>that easy</u> to find and to fix!

before installation, adjustment will remain correct upon installation if its inductance is physically removed from other conductive components which may alter the inductance value. This is not usually the case, so further minor adjustment will probably be required after installation. When in the circuit, it is possible that its resonant frequency may be quite a bit off as indicated by the "Grid Dipper". Actually the trap itself will still be tuned to approximately correct frequency but the grid-dip oscillator reading may be found at some other frequency (usually lower) due to circuit "strays" across the trap.

Final precise adjustment may be made by applying power to circuit and by' tuning trap under actual. operation for desired effect. In many cases this will not be necessary as pretuning is quite accurate.

Series resonant traps.[1] Follow same general procedure as with parallel resonant trap. To check or tune prior to installation, trap may be first connected as a parallel trap. At high frequencies or where the trap inductance is low, the lead completing the parallel circuit should be of large wire or wide copper ribbon to keep its inductance low, and care should be taken not to permit this lead to be positioned so as to add stray capacitance. Leads to be used upon final installation must also be included when external measurements are being made.

R.F. chokes. To determine self resonance of r.f. chokes, use "Grid Dipper" as a grid dip oscillator.

Measure circuit Q.[2] Use the "Grid Dipper" as signal generator. Connect a v.t.v.m. across the circuit to be measured. Couple instrument to circuit (Fig. 1A) and resonate for maximum, or peak reading, on v.t.v.m. Note frequency at which this occurs. Then shift the instrument each side of resonance to the frequency where the voltmeter reading drops to approximately 70.7% of that at resonance. Note the frequency of these two point and calculate the circuit Q from equation "A", Appendix 1, where fr is the resonant frequency and delta f is the difference between the "off resonance" frequencies just found. The original coupling should be adjusted for a convenient maximum reading of the v.t.v.m. and then should be left fixed at this position for the remainder of the procedure.

When the circuit Q is quite high, it may be necessary to check the frequencies with a calibrated receiver, because the "off resonance" points will occur too closely together for accurate reading on the instrument scale.

Relative circuit Q at a given frequency. Use as a grid-dip oscillator and observe character of the dip whether broad or sharp. The sharper the dip, the higher the Q.

Measurement of capacitance. Several methods may be employed. All involve the use of the "Grid Dipper" as an oscillator.

A small jig (Fig. 2) must be made, into which may be plugged any one

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[1] Rockey: Series traps in most applications are rare.

[2] Rockey: This is really only an estimate. Not an true measurement in most cases.

of the "Grid Dipper" coils.

To check an unknown capacitor, it is then only necessary to clip the jig, with a coil inserted, across the unknown capacitance. Find the resonant frequency and refer to the calibration chart for value of capacitor with the coil employed. For over-all accuracy, it is best to employ one of the coils from the medium frequency range.

Due to the distributed capacitance of the coils, a slight error will be encountered at very low capacitance measurements. Likewise, due to self inductance of large capacitors, a small error will be found when measuring these. Errors will be negligible for most practical purposes.

Measurements below 50 mmf are generally not obtainable because resonance at these values usually falls out of range of the coils left available for frequency checking. For measurements below 50 mmf an additional calibrated coil is required.

For these measurements, in a great number of cases, the capacitor need not be removed from the circuit in which it is wired unless the capacitor is heavily loaded.

Another method, similar to that above, is to employ a known inductance and find the resonant frequency with the unknown connected across it....

A third method, for capacitors up to about 1000 mmf, requires an inductance which is shunted by a calibrated variable capacitor. The capacitor is set at maximum and the resonant frequency of the circuit is found. The unknown capacitor is then connected across the variable and the capacitance of the latter decreased to a point where the circuit resonates at the original frequency. The difference between the first and last settings of the calibrated variable capacitor is the value of the unknown.

Measurement of inductance of r.f. coils. Connect a capacitor of known value across the coil and as the "Grid Dipper" as a grid-dip oscillator to find the resonant frequency of the resulting L/C combination. The inductance of the coil may be calculated...

In measuring small values of inductance, be sure to employ a low inductance standard condenser, connected to the unknown coil by wide ribbon, in order to obtain most accurate results. Due to the distributed capacitance, especially in large coils, some slight error will result; however, if the value of the low inductance known capacitor is fairly high, the error will be negligible.

Relative Q of capacitors or inductances at a given frequency may be noted by observing the character of the dip, as previously described...

Articles of possible interest from later issues of QST

June 1972 p46 "High Accuracy FET Dipper" - a design comparable to the one described in this book by a British amateur radio operator

Jan 1974 p16 "The Art of Dipping" - Brief info the beginner and novice

Jun 1974 p33 "A Hybrid Gate-Dip Oscillator" A four transistor GDO that uses a single-section capacitor and an untapped coil.

Building a GDO is a great project for a radio builder...

In our home made GDO we use a common, inexpensive MPF102 field effect transistor as the active element. This is a n-channel junction device, and just about any such transistor will work. If you have a p-channel, use it. Just reverse the battery polarity.

Battery power is supplied to the drain through a 1 mH choke whose purpose is to keep the radio-frequency energy in the oscillator circuit and out of the power supply where it would be shorted to ground. Other choke values will work, a common 2.5 mH for instance, but use larger values rather than smaller values.

Pulses of energy coming off the drain flow through a 100 pfd capacitor and hit the resonant circuit, much like a hammer hits a bell, causing it to ring. A 100 pfd silver mica is called for in many circuits, but a common ol' .01 mfd disc ceramic will work quite well. The smaller value is preferred to improve oscillator stability.

Our GDO is a Colpitts oscillator which uses two capacitors in series with the common connection grounded. Across the pair is a coil wound to resonate at the frequencies we wish to measure. A common two-section, broadcast-receiver variable capacitor serves very well here. These were very common years ago, and still are at hamfests. A number of dealers in electronics parts can supply you with brand new and surplus varieties. But scavenge before you buy. Millions of them were manufactured back when AM tube radios were being built.

These broadcast capacitors usually had a 365 pfd section and a smaller 260 pfd section. In our GDO the two sections are used in series with the frame grounded. The smaller section is connected to the gate of the transistor.

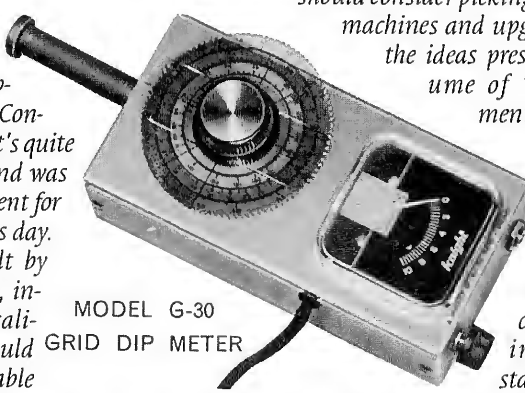
Off the gate is a 10K resistor. This and the 100 pfd capacitor form a classic grid-leak pair common in early radio detector and tube oscillator circuits. The 10K value must be adjusted to accommodate the sensitivity of the meter. The higher the value of resistor used, the less current that will be allowed to flow. So if you use a 1 mA meter, a 10K is about as large a value as you dare use if you are to get 1 mA of current to flow through the meter. If you use a 1/2 mA meter, that is 500 µA, then a 22K or 33K will do. If you use a 100 µA meter, a 100K or more may be needed.

To keep any RF energy that gets through the 10K resistor from getting into the meter and messing up the performance, we must bypass the meter with a .01 capacitor. A common disc ceramic of this value or greater will do. The radio frequency flows through the capacitor to ground, but the direct current is forced to flow through the meter to ground providing a reading.

We adjust the meter to full scale by increasing the power that flows in the tank circuit. This is done with the 1000 ohm pot between the battery and the 1 mH choke. The pot, in effect, changes the voltage across the oscillator, and as a result, the DC power flowing into the circuit. One thousand ohms works well if you use a 1 mA meter. If you use a more sensitive meter, a larger value will be needed. In my demonstration unit, I used a 500µA meter in series with a 33K resistor, and a 5000 ohm pot to adjust the meter to full scale. In other words, a more sensitive meter can measure smaller amount of energy in the oscillator, and therefore a larger pot is needed to reduce the amount battery power flowing into the oscillator.

The oscillator you use does NOT have to be a Colpitts. Just about any LC oscillator circuit should work. You can use a Hartley oscillator, in which case, you need only a single section capacitor, but you must tap the inductor. And the big problem with using a tapped inductor is mechanical. Every coil you wind for a Hartley GDO has three connections to the circuit, rather than just two for the Colpitts circuit here. (My "overkill" GDO, described briefly later on, is a Hartley using commercial plug-in coil forms.)

The Knight G-30 Grid Dip Oscillator

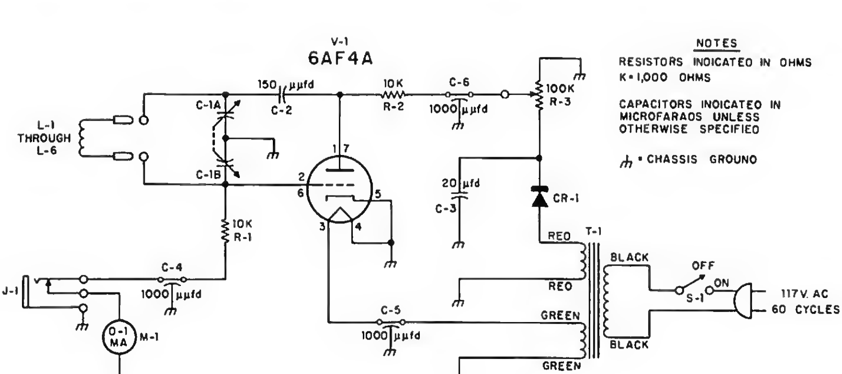


MODEL G-30
GRID DIP METER

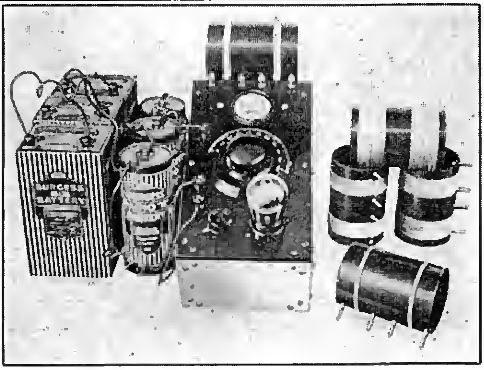
These illustrations are taken from the instruction booklet that came with the Knight-Kit Grid-Dip Oscillator Kit G-30 that first appeared in 1959. Construction-wise it's quite a nice device, and was a lot of instrument for the money in its day. Its biggest fault by far is the cheap, ineffective dial calibration. You could get a very readable dip with the coils provided, but you had to guess at the frequency. The dial was anything but accurate.

One of the projects I've been intending to get to "next week" is to modify the dial to a reliably calibrated system, and convert the unit to solid state. Instead of building a GDO totally from scratch you should consider picking up one of these machines and upgrading it using the ideas present in this volume of "Radio Experimenter." The majority of the mechanical problems will have been solved for you, and in the process of converting it to solid-state, you'll learn a great deal.

Solid state construction makes the GDO beautifully portable with no cords and no warm up time. That along with an accurate dial gives you a machine that provides quick, accurate measurements.



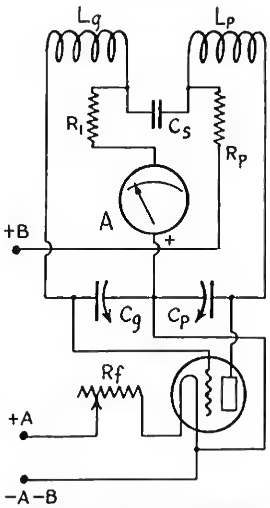
The "First" Grid-Dip Oscillator



12 TO 800 METER OSCILLATOR-DRIVER AND ALL COILS

The first mention of a GDO that I could find appeared in the August 1926 issue of QST in an article by W. A. Hoffman entitled "A Grid-Meter Driver". An examination of the schematic shows that it is the same Colpitts oscillator circuit used in GDO's forty years later. About the only difference between then and now was the common practice of feeding high voltage to the tube plate through the coil – series feed. All modern GDO's I've seen feed voltage to the plate through an RF choke (or resistor and capacitor if it's a cheap design) in a configuration called parallel feed.

This device had no calibrated dial. The frequency was determined by bringing a calibrated wavemeter near the GDO coil and adjusting the wavemeter dial until it's meter jumped up. The frequency could be read off the wavemeter dial. It was the 20's equivalent of a frequency counter.



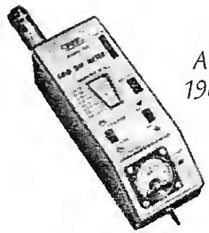
THE SCHEMATIC CIRCUIT OF THE GRID-METER DRIVER (COLPITTS)

List of Parts:

Tube—UV-199, UX-201-A, UX-210, depending on output power desired. Larger tubes are necessary for measuring antenna constants. Those suggested are excellent for making measurements of natural wavelength, and determining capacitance and inductance values by comparison with known capacity and wavelength standards.
Socket—Any standard base for the type of tube used.
Panel—6" x 10" x 3/16" bakelite.
Metal box or metal-lined box 6" x 4½" x 10".
Dial—National Velvet-vernier.
Rf—Filament rheostat to fit tube used.
Rp—Plate supply resistance—100 to 500 ohms.
Ri—5,000 ohm grid leak.
Cs—6,000 µµf. fixed Sangamo or Micadon condenser.
Cg-Cp—Cardwell double unit condenser, 350 µµf. each part.
A—0-5 milliampere range ammeter.
Lg and Lp—Coils wound on 3" diameter, 4½" long, micarta tubes as below:

Winding of each section	Wavelength range
2 turns of No. 16 D.C.C.	12 to 32 meters
5 turns of No. 16 D.C.C.	25 to 67 meters
13 turns of No. 16 D.C.C.	54 to 150 meters
33 turns of No. 22 D.C.C.	135 to 370 meters
74 turns of No. 22 D.C.C.	310 to 800 meters

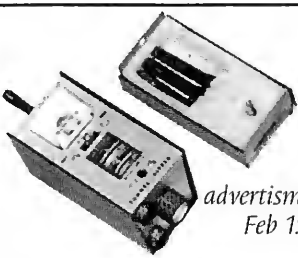
(Early issues of QST are available on the used book market. A complete set is available on computer CD-ROMs from the American Radio Relay League. Issues prior to World War II are especially valuable to tube radio builders.)



EICO GDO
Allied Radio
1964 Catalog

GRID-DIP METER KIT

MODEL 710-K. Operates as oscillating detector or wavemeter—covers 400 kc to 250 mc in 8 ranges. Finds frequencies of oscillators or tuned circuits; pre-tunes and neutralizes transmitters; etc. Has sensitivity control; 500 μa meter; 1:7 drive ratio; phone jack; plug-in coils. 2¼x2⁹⁄₁₆x6⅞". For 110-120 v., 60 cycle AC. 3 lbs.
69 F 260. *$5 Monthly*. **29.95**
69 F 261. Model 710. Above, wired. . . 49.95



advertisment
Feb 1964

Heathkit "Tunnel-Dipper"
Extremely useful in amateur work! Functions as a signal generator or sensitive RF detector. Covers 3 to 250 mc. 6 color-matched coils & dial scales. Uses tunnel-diode oscillator—no tubes. Portable!
Kit HM-10A . . . 3 lbs. . . . $34.95

advertisement
Summer 1975

New solid state Heathkit Dip Meter...59.95

A better dip meter at lower cost. The Colpitts oscillator covers 1.6 to 250 MHz in fundamentals with MOS-FET paraphase amplifier and hot-carrier diodes for more sensitivity and better dip. Q-multiplier for greater detector sensitivity and responsive 150 μA meter movement for positive resonance indications. Phone jack for modulation monitoring. Solid-state design and 9-volt battery operation. Custom molded gray carrying case protects the meter and the 7 color-coded, pre-adjusted, plug-in coils in transit, and makes a handy storage place. Build it in one evening. Nearly everything mounts on two circuit boards. And when you finish, you'll have the best dip meter around — for a lot less money.

Kit HD-1250, less battery, 4 lbs.. mailable. . **59.95***

no ham shack is complete without this . . .

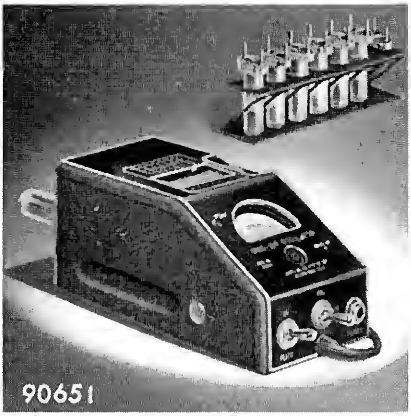
Grid Dip Meter Kit (GD-1B)

The Heathkit GD-1B can be used either as an oscillator or absorption wave meter. *Align* IF stages, *adjust* traps, filters, and tuned circuits, use it in coil winding applications, *tune up* transmitters, etc. A phone jack is provided for listening to modulation. 500 ua meter and variable sensitivity control. Prewound plug-in coils provide continuous frequency coverage from 2 mc to 250 mc.

Model GD-1B . . . 4 lbs. **$21.95**

ADDITIONAL PLUG-IN COILS: (2) Extend frequency coverage down to 350 kc. 1 lb. No. 341-A **$3.00**

Heath Catalog
Fall & Winter
1960-61



90651

GRID DIP METER

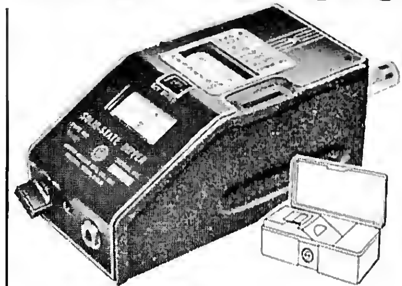
The No. 90651 MILLEN GRID DIP METER is compact and completely self contained. The AC power supply is of the "transformer" type. The drum dial has seven calibrated uniform length scales from 1.7 MC to 300 MC with generous over laps plus an arbitrary scale for use with special application inductors. Internal terminal strip permits battery operation for antenna measurement.

No. 90651, with tube.................

Additional Inductors for Lower Frequencies

No. 46702—925 to 2000 KC..........
No. 46703—500 to 1050 KC..........
No. 46704—325 to 600 KC..........
No. 46705—220 to 350 KC..........

vacuum tube Millen – 1949



Harrison has MILLEN GRID DIPPERS

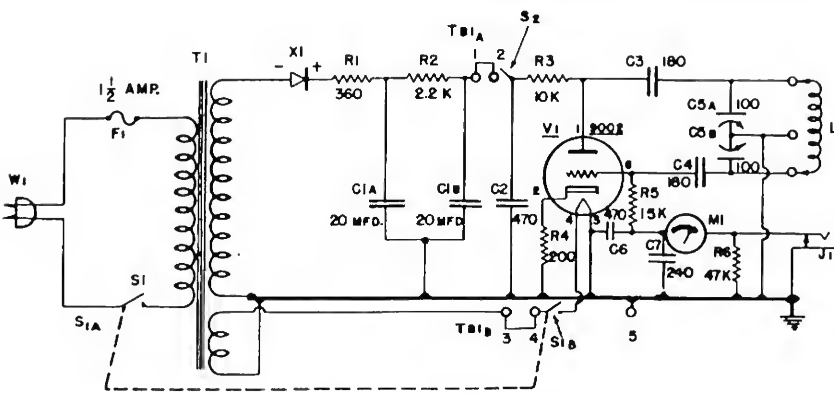
- Smooth meter reading over tuning range of 1.6 to 300 MHz with 7 coils.
- Q Multiplier for very sensitive absorption type wavemeter.
- Sensitive metering system using zero suppressing circuit.
- Performance equal to or superior to best type tube dippers.
- No power cord - runs on internal batteries.
- Unbreakable carrying case included.

All Solid State, Model 90652

$138

TUBE TYPE 90651-A - with transistorized DC Amplifier Runs on 110 AC or optional battery. Limited supply, at $114.

solid-state Millen - Summer 1975



The schematic diagram of the Millen 90651 grid dip oscillator. The early-1940's 9002 triode was descendant of the 955 high frequency acorn tube that appeared in the mid-1930's. Before you start whining that parts are impossible to find, you must know that I just bought an almost complete WWII VHF receiver with several 9001 and 9002 tubes at a flea market for $2. An immaculate signal generator with a 955 tube an incredible slow-motion dial drive was had for only $5. No one wants these components. You can find similar bargains. Go look!

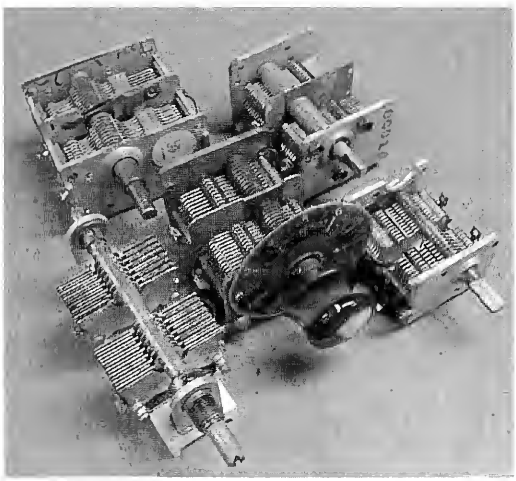
Choosing the Components...

The most difficult part in building a grid dip oscillator is dealing with the mechanical requirements. The electrical circuit here is very simple, but mounting components in a small, portable box with easily changed coils is another matter. Why should we reinvent the wheel? Why not merely copy the layout of manufactured models changing the design in small ways to accommodate the components you happen to have or can scrounge up?

You might want to buy an old gdo, and not build at all. Or you might buy an old Knight-Kit, for instance, and convert it to solid-state. But my attitude is that if you cannot build a decent GDO, then you're not going to be able to build any decent radio, because they, too, are more about the mechanical than the electrical.

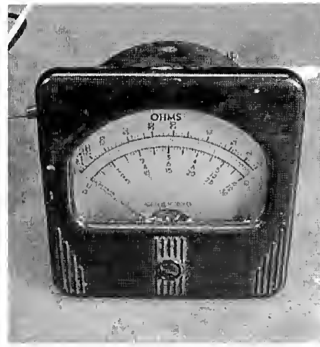
Use the project of building a GDO as an exercise in improving your radio building expertise. Plan on building it more than once. You will probably not be happy with the first attempt, and that's okay. You'll learn so much from the first attempt that you'll want to strip it down and build it again using the new knowledge acquired from your mistakes. And that's EXACTLY what you want to happen. You learn more from mistakes than successes. So be prepared to fail and to learn from the experience.

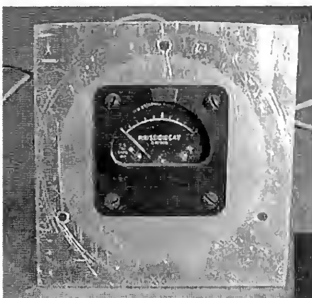
(right) Find a suitable twin-section variable capacitor. They were commonly used in AM radios for decades. Here are some in my junk box. The cap in the lower left is NOT from a receiver but is a Hammarlund dual 100 pfd model picked up at a hamfest. It is really too small for a GDO. The tuning range would be awfully limited with just 100 pfd. A dual cap in the neighborhood of 365 pfd works quite well.



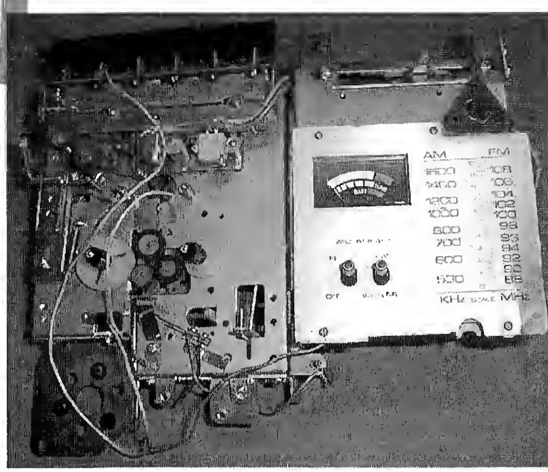
(left) This filthy old capacitor was chosen for the job because it was of reasonable size and because it had threaded mounting holes in the base. The first step was to remove all the wires, the plate, and knob, and unmesh the plates. The entire cap was soaked for about 30 minutes in hot water laced with detergent and TSP. After careful rinsing and drying, graphited oil for use in locks was applied to the bearings.

The next major component for the GDO is the meter. You need to find one that is large enough to be easy to read, but small enough to fit in a small cabinet so that your GDO is portable. (right) An old, inexpensive VOM was picked up at a hamfest a couple of years ago for a dollar, not because it was a wonderful meter, but because it had a beautiful wooden box. The meter was rated at 1000Ω per volt. Ohm's law tells me that one volt divided by 1000 ohms yields 1 mA. So this is a 1 mA basic movement which is the least sensitive we want to use. One half mA, or 500 µA, or even 100 µA (one-tenth mA) would be better.





(left) Years ago I bought a filthy, dirty (most of my purchases are that way now that I think about it...) homebrew amateur transmitter that had been converted from a tube television chassis. It was a mess, and I bought the whole thing for parts. This was the meter it used. It's a 1 mA movement, but is quite tiny. It would be useful on a GDO where space is limited.

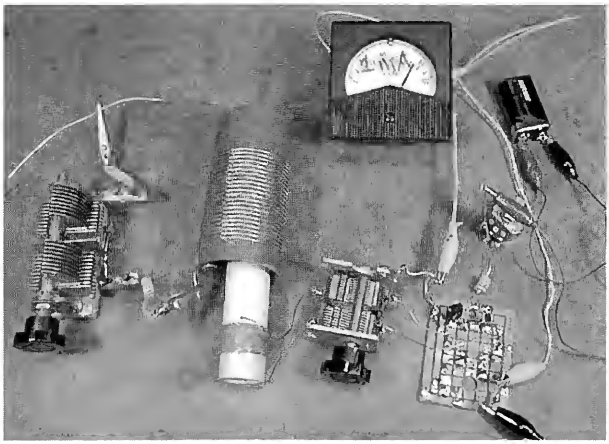


(right) But I remembered an old imported boom-box chassis with a meter. Putting the meter in series with a flashlight battery and very high variable resistor, I found that it would register full scale with about one-half mA flowing. That was the meter I wanted. Cost? The whole pile of junk probably didn't cost more than a dollar.

The remaining components, choke, pot, switch, nine volt battery are standard items that can be purchase new or salvaged from existing gear. Since they are relatively small and easily mounted, they are of lesser importance when planning the mechanical layout of the GDO.

The next step is to breadboard the circuit and get it working. I do this by using small 2x3 printed circuit boards on which pads are etched. To these pads I solder components long enough to test a circuit. When made from surplus pc board, these breadboards can be very inexpensive. You could just as easily mount components on phenolic tie strips screwed to a wooden board.

(right) A GDO has been "breadboarded" to test the basic circuit. The capacitor and meter are components from the junkbox chosen for their proven performance. The GDO circuit is lashed together to the right with a liberal use of alligator patch cords, with the transistor, itself, mounted on the small printed circuit board at the lower right.



The white coil form holds the GDO oscillator coil. It is slipped inside of a larger coil wound on a phenolic tube that I happened to have from another project. A variable capacitor, far left, is connected in parallel to create a resonant circuit. By varying either variable capacitor it was possible to observe the dip on the 1 mA meter at the top. The circuit worked on the first attempt. I figured if the 1 mA would give a usable dip, then the half mA (500µA) meter I intended to use should provide an even better dip since it was more sensitive.

Once the circuit is working, the actual components to be used can be put into the circuit one by one, to be sure that they, too, will work. This brute-force-and-ignorance type of design, the ol' "cut and try", will work quite nicely.

I've done that, too. It works. And it, too, is cheap. Dirt cheap.

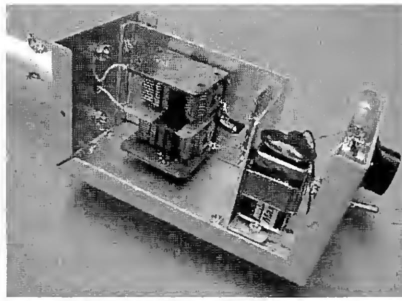
Breadboarding is an opportunity to test your components together to be sure they operate as expected. To simply push ahead and build the final machine without breadboarding is foolhardy, I think.

When building any electronics project, I find that the mechanical problems are far more difficult to solve than the electrical. So if you plan to build with any regularity, you would be smart to invest in tools that will allow you to take low cost materials and form them into the components you need.

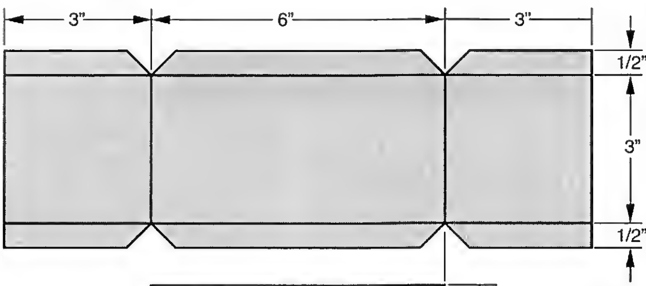
My example GDO is

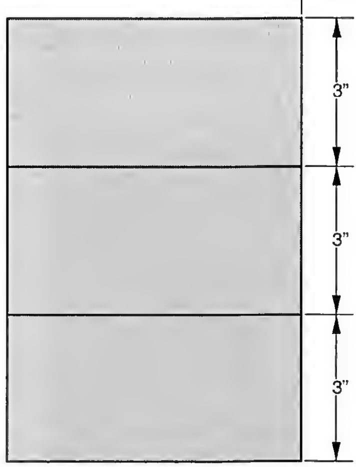
housed in a custom-made mini-box. You can buy such boxes in standard sizes, but I made one to fit my components. To make it, I used tin snips, a simple sheet metal brake, and an inexpensive bench top drill press. The .050 aluminum was purchased at a sheet metal shop for about $3.50 a pound, meaning that this box cost me not much more than a dollar.

An L-bracket with a couple of tabs is attached inside the mini-box to provide a surface to which the variable capacitor can be attached.



(left) the pattern used for the mini-box. You will, no doubt, have to change the dimensions to accommodate the parts you've managed to accumulate for this project. Below is the pattern for the L-bracket capacitor mount.

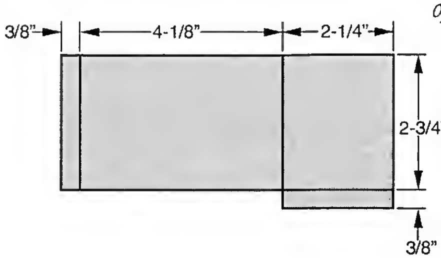


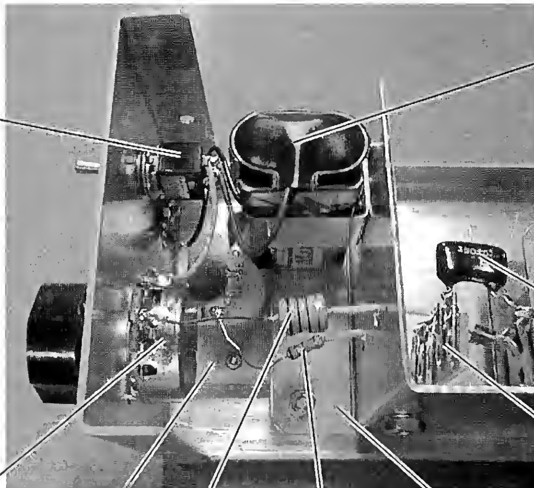


If you're new to working sheet metal, it would probably be wise to cut the pattern out of cardboard, and fold it to see if your pattern produces the box you need.

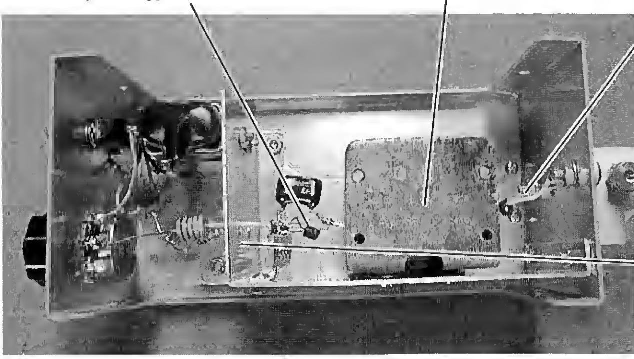
And when bending the final sheet metal, you must think ahead and allow for the thickness of the metal when bending. Practicing with cardboard will teach you where the problems lie, and how to overcome them.

Making simple sheet metal boxes is a skill that greatly simplifies and accelerates the process of the building electronic equipment. Instead of buying a few expensive ready-made boxes, put your money into tools, and fabricate many custom boxes from inexpensive materials. You'll recover your investment in surprisingly little time.





(above) Close up of the DC section of the GDO. To the left of the L-bracket is the direct current section: where power into the oscillator is controlled and where the power out of the oscillator is registered on the meter. To the right of the bracket is the oscillator where radio frequency currents are generated.



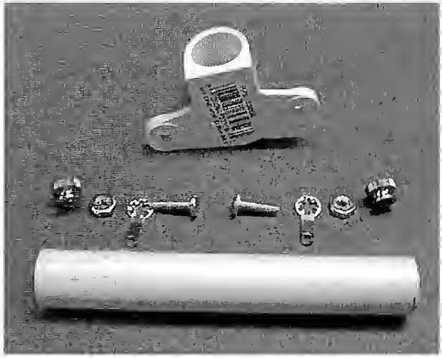
Your GDO will probably be laid out somewhat differently. You'll have to fabricate a bracket to match the particular capacitor you have chosen to use. And you'll have to figure out how the small components will connect with the larger components. You'll probably have to provide some type of terminal strip for mounting the transistor.

If you have never built something like this, it may appear complicated. Everything you try is complicated until you've done it. Solving the problems you encounter while building this simple instrument will teach you lessons that will make radio building much easier and make your results look far more professional. You will learn by doing.

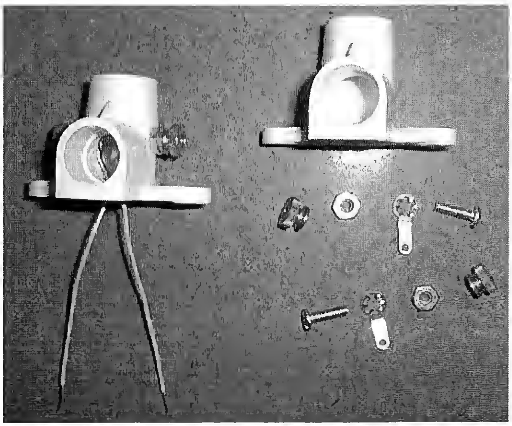
Coil Forms

Finding coil forms on which to wind the oscillator coils is difficult. If you have old four or prong coil forms, you may want to use them. Perhaps you can use bases from old four-prong tubes, and plug them into a socket mounted on standoffs to put distance between the coil and the mini-box.

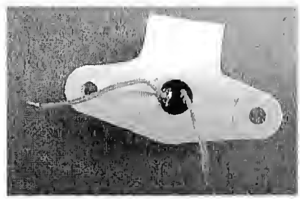
For the sake of demonstration, I assumed that commercial bases were not available. A search of the plumbing section at the hardware store turned up a 1/2" CPVC Wing Elbow and several feet of 1/2" CPVC tubing. Short pieces of tubing on which coils can be wound will slip into the elbow "socket" mounted on the box.



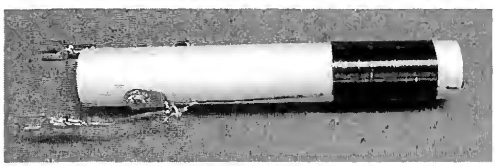
(above) The 1/2" CPVC Wing Elbow and its hardware, and a length of 1/2" CPVC on which the coil will be wound.



(above) Another view of the elbow "socket" and how the components fit together.



(above) A hole in the bottom of the elbow allows leads to be brought inside the mini-box.



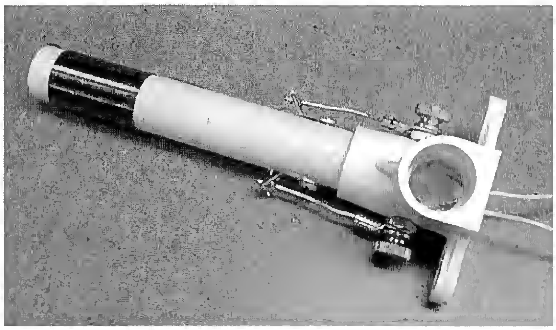
A typical coil. Leads are brought down the sides of the tubing and soldered to the lugs. Leads from the lugs are cut so that the spade tips lie under the knurled thumb nuts on the elbow. The coil should "painted" with clear nail polish, Duco™ cement, corona dope, or some other varnish so that the coil and its leads are rigid and immovable.

Two 6-32 machine screws were brought through holes in the side of the elbow. Wires from the heads of the screws inside the elbow where brought through a hole was drilled into the base and mini-box. Knurled thumb nuts (hardware store variety) were screwed onto the threaded ends of the screw that protruded through the elbow. This provided a crude, but effective socket.

To build a coil, a four inch length of tubing was cut and trimmed and the coil wound. The two leads where brought down the sides of the tubing to solder lugs held to the tube with 4-40 machine screws. To each lug a stiff piece of tinned copper bus wire (#16 or #18) was soldered. At the lower end of the wire a common spade tip was soldered.

The tubing on which the coil was wound was slipped into the elbow with a tight friction fit, and the spades fit nicely under the thumb nuts on the elbow. After a simple twist of each thumb nut, coil is connected to the oscillator, and the GDO is ready to use.

Although this type of coil mount is not as convenient as plug-in coil forms produced decades ago, it works surprisingly well and is satisfyingly inexpensive. (That means it appeals to cheapskates like us!)



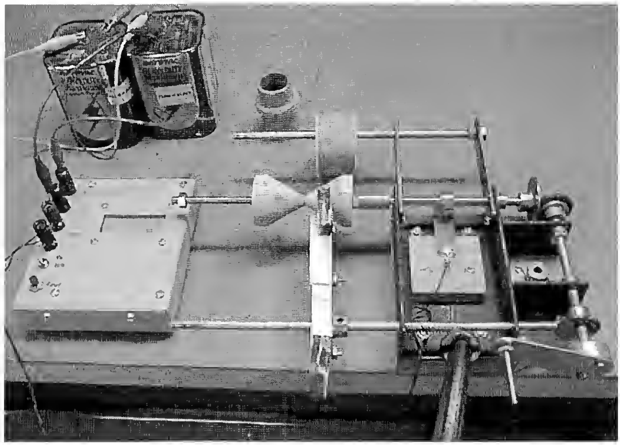
(right) The coil "plugged" into the elbow socket ready for use. Larger diameter plumbing stock may be useful for winding larger coils for simple radio receivers and test equipment.

(left) The lowest frequency coil is a universal wound coil. The spider-web-like appearance minimizes the capacitance that builds up between windings and which decreases the tuning range. Huge coils like these were used in the very-low-frequency receivers common in the earliest days of radio.

Coil Specifications

The exact number of turns you'll need for your coils will depend on the size of the capacitor you use. I wound three coils, (left) 1.1-3.0 mHz, (above) 2.6-7.6 mHz, and 7.1-20 mHz (not shown). The highest frequency coil required only 16 turns of #26 wire, and the middle coil 65 turns of #26.

I think the way to approach coil winding is to wind your lowest frequency coil first. For my GDO I used a modified "Gingery" coil winder which is a homebrew version of the old Morris coil winder. With it I was able to *(right) A Gingery coil winder which uses a digital counter, to the left, powered by lantern batteries. This machine together with Litz wire and lots of beeswax will enable you to wind large coils of high inductance that exhibit remarkably low self capacitance – perfect for low frequency work.*



wind a large coil with minimal self-capacitance thereby allowing a greater frequency range. I found that the high frequency with the variable capacitor at minimum capacitance was about 3 mHz. The next step was to wind a coil whose frequency when the variable capacitor was at maximum capacitance was somewhat below 3 mHz.

The second coil tuned from about 2.6 to 7.6 providing a good overlap with the first coil. The third coil had to have a low frequency of something less than 7.6 to provide the overlap in frequencies.

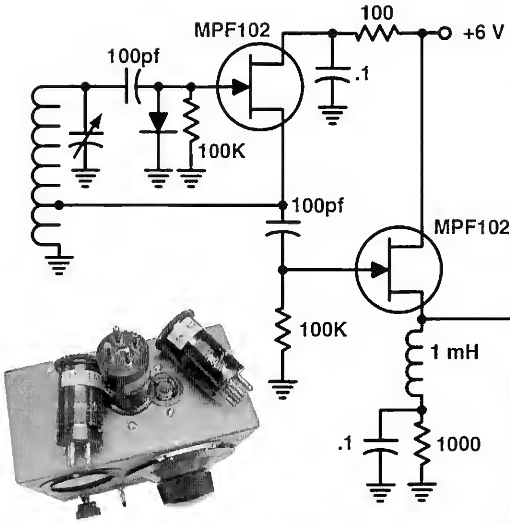
Trial and error coil winding works pretty well here. First, you wind the lowest frequency coil. Let's suppose that the high frequency of this coil is 3.4 mHz. Next, wind the next higher coil with many more turns than you think you'll need. When you test it, you may find its lowest frequency is 2.9 which provides the overlap you need. But now, you carefully remove a few turns and test again. You'll find that the lowest frequency now rises to perhaps 3.1. Removing a few more turns will put the lowest frequency at 3.3. Now you seal the coil, and see what the highest frequency is. Finally, wind a third coil with more turns than needed so that it's lowest frequency below the high frequency of the second coil. Removing turns will take the frequency up.

If this sounds complicated, just try it. Study basic resonant circuit theory, and try again. This concept might be aggravating in the beginning, but you'll learn quickly by doing. There is no substitute for lessons learned from the school of hard knocks. And the lessons learned here, no matter how frustrating, will allow you to quickly and accurately wind coils for other projects.

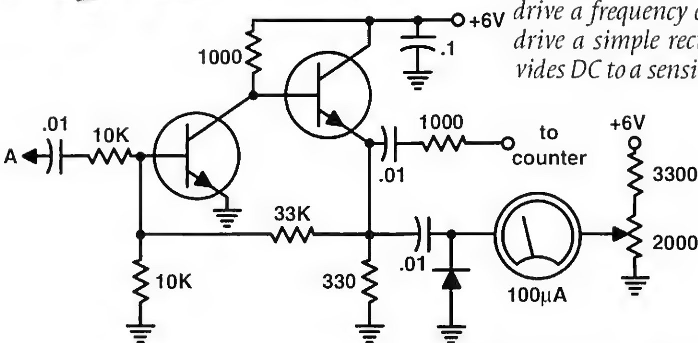
Radios described in books and magazines specify so many turns on a coil form of such a size for use in a particular receiver. You *should not* need those specifications (which often don't deliver the results promised).[1] If you're a real radio builder you can create your own high performance coils without those specifications. The skills you need are right here.

[1] Rockey: But it IS suggested that you get a bit of experience with some coils of known properties first. Wind a coil according to specifications and learn from it.

A "Killer" Grid Dip Oscillator.



Actually, it's an overkill. This was built a number of years ago for a precision measurement experiment, and not so much for radio building. The circuit is a simple Hartley vfo circuit commonly used by radio amateur's for receivers and low-power transmitters. The top fet is the oscillator which feeds another below whose job it is to amplify and buffer the oscillator from the "outside world". The transistors at the bottom amplify the signal to drive a frequency counter and to drive a simple rectifier that provides DC to a sensitive meter that is adjusted with a simple bridge circuit.



An ancient National stainless steel dial drive provides very slow tuning of the tank circuit. Dips that are encountered are very deep because of amplification. The slow tuning rate combined with deep dips allow very precise measurement of the resonant frequency of an unknown resonant circuit.

A Hartley oscillator uses a tap on the coil for feed back. Therefore, coils were wound on old four-prong forms because three pins were needed.

The only draw back to this machine is its slow tuning rate. Finding the dip can take far longer than with a simple GDO.

Coil Winding and Calibration

So you want to wind a coil. Where do you start? Well, you can start by estimating the size of the capacitor, and using the following formula to estimate how much inductance you'll need to hit the frequency you want.

$$f = \frac{159}{\sqrt{LC}} \qquad (1)$$

Rockey: <u>Great Stuff!</u> Important to emphasize – so much confusing info on these is lurking around today!

or rearranged

$$L = \frac{25{,}330}{f^2 C} \qquad C = \frac{25{,}330}{f^2 L} \qquad (2)$$

for L in µH, C in pfd, and f in mHz

For instance, let's suppose our two section capacitor is 365 pfd in one section and 260 in the other, a fairly reasonable guess. Two capacitors in series, A and B, can be calculated with

$$C_{total} = \frac{A \times B}{A + B}$$

$$C_{total} = \frac{365 \times 260}{365+260} = 152 \text{ pfd}$$

The two sections may vary from 12 to 365, and 10 to 260 pfd. To calculate the minimum capacitance of the two variable capacitors in series, we plug the minimum capacitance numbers into the formula –

$$C_{total} = \frac{12 \times 10}{12 + 10} = 5.5 \text{ pfd}$$

If we assume we want a coil whose lowest frequency will be 3 mHz when the capacitance is maximum, or 152 pfd, we can use formula (2) above

$$L = \frac{25{,}330}{f^2 \times C} = \frac{25{,}330}{3^2 \times 152} = 18.5 \ \mu H$$

Now we can take 18.5 µH and plug it back into formula (1) to see what frequency we get when the capacitors are opened up to their minimum capacitance of 5.5 pfd.

$$f = \frac{159}{\sqrt{LC}} = \frac{159}{\sqrt{18.5 \times 5.5}} = \frac{159}{\sqrt{102}} = 15.7 \text{ mHz}$$

So if we wind a coil with 18.5 µH of inductance, it should tune from about 3 to 15 mHz. It won't be exactly that because we don't know the exact capacitance range of our variable capacitor, nor the stray capacitance involved, and we certainly won't end up with exactly 18.5 µh of inductance. But at least we have a ball park figure for the range.

So how many turns will we need on what kind of a coil form? Fortunately, there's a ball park formula to calculate inductance as well. Harold Wheeler revealed in the October 1928 issue of the TRANSACTIONS OF THE INSTITUTE OF RADIO ENGINEERS a formula that his employer ol' Doc Hazeltine had worked out by "empirical methods" which is a fancy was of saying "by trial and error". It has been found to be accurate to within 1% for the kinds of coils we wind. The formula you find in amateur handbooks is very similar to this, and in fact, was derived from Hazeltine's work.

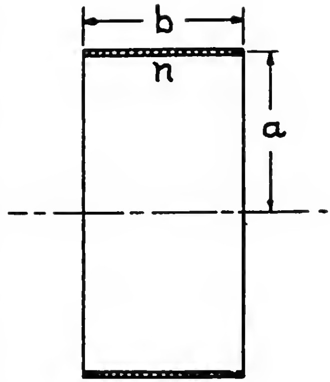


Fig. 2
from
Simple Inductance Formulas for Radio Coils
by Harold A. Wheeler
PROCEEDINGS OF THE INSTITUTE OF RADIO ENGINEERS
Vol 16 No. 10 p 1398
October 1928

$$L = \frac{a^2 \times n^2}{(9 \times a) + (10 \times b)}$$

for L in µH, n=number of turns, and dimensions in inches. (See Fig. 2. from the original article.)

If we use a plastic tube 1" in diameter, then *a*, the radius, is half that or .5". Now we have to guess. Let's assume we'll wind on 30 turns of #22 wire. If #22 is wound to about 40 turns per inch, then the length of the coil *b* will be 30/40 or about .75" inch.

Our formula becomes

$$L = \frac{.5^2 \times 30^2}{(9 \times .5) + (10 \times 30/40)} = 18.75$$

which is not bad for a first guess. To get a slightly lower inductance, we can remove a few turns, or we can spread out the 30 turns.

What if we take a 1/2" diameter coil form and wind it with 50 closewound turns of #26 wire at about 60 turns per inch (tpi)? The formula becomes

$$L = \frac{.25^2 \times 50^2}{(9 \times .25) + (10 \times 50/60)} = \frac{.0625 \times 2500}{10.58} = 14.8$$

Not enough inductance. So how about 60 turns at 60 tpi?

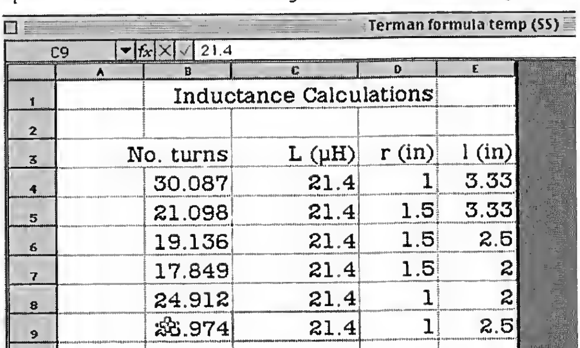
$$L = \frac{.25^2 \times 60^2}{(9 \times .25) + (10 \times 60/60)} = 18.4$$

That's a little low. But, again, this formula just gets us into the ballpark. In practice I would probably wind 64 or 65 turns and coat the windings. I would probably have too much inductance, but it's always a simple matter to carefully peel off a few turns until I get the range I want. Adding turns is next to impossible.

American Wire Gauge	Approximate Turns Per Inch
16	18-19
18	20-23
20	24-29
22	30-37
24	35-46
26	42-60
28	48-72
30	55-90

These calculations may seem complicated, but they're right out of high school algebra, and they're easy to perform with an inexpensive pocket calculator. My favorite way to use them is in a computer spreadsheet. I simply "program" each formula into a single spread sheet line from left to right. It's extremely easy to copy the formula down the page as many times as you want. Then you can go into each line and change the number of turns, or the diameter, or the wire size, and see the effect on inductance immediately. And with all the lines on the screen staring you in the face, you can pick one of the solutions that suits you, or at least see a pattern emerge that suggests what changes you have to make to get the inductance you need.

You don't need a fancy computer to run a spreadsheet. Old 386 and 486 computers are obsolete and can often be had for a few dollars. They'll run a spread sheet that will save you all kinds of design time. The first time you load a formula in can be slow, but after you save it on the hard disk, you can bring it back whenever you want and start plugging in values and getting results immediately.



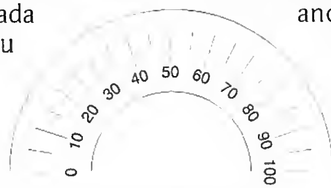
No. turns	L (µH)	r (in)	l (in)
30.087	21.4	1	3.33
21.098	21.4	1.5	3.33
19.136	21.4	1.5	2.5
17.849	21.4	1.5	2
24.912	21.4	1	2
[illegible].974	21.4	1	2.5

Even the simplest computer spreadsheet program run on an ancient personal computer will greatly reduce guess work in radio building by making calculations fast and easy.

So you drill tiny holes in your 1/2" diameter coil form and wind 75 turns or whatever you decide is necessary, coat it with clear nail polish or corona dope, and plug it into your GDO. So how are you going to calibrate your machine?

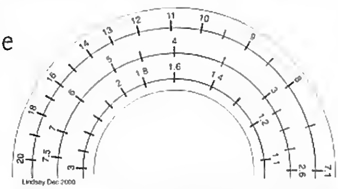
What I do is create a temporary dial card numbered from 0 to 100 with a computer drawing program. It's fast, accurate, and I can print as many copies as I want. You can do it by hand with the pencil, ruler, and compass. It will work just as well. Then you can tape the dial card to the aluminum dial on the GDO. When you locate a frequency, you can jot down the number from 0 to 100, and the frequency to which it corresponds. Once you've made several such locations you can create the final dial card.

If you have a working shortwave receiver, no matter how accurately it is calibrated, you can use it to find known frequencies on your GDO. For instance, you can calibrate by tuning in radio stations on known frequencies such as CHU, Canada on 3.333 mHz. Next, you bring your GDO near by and adjust the tuning dial until a howl is heard. As you adjust the dial, the howl gets lower and lower in pitch until the tone disappears. You now have "zero-beat" meaning that the GDO is almost exactly at the same frequency as the received station, in this case, 3.333 mHz.



temporary dial card

You jot down the reading on the temporary dial card, and tune in CHU on 7.333 and zero beat your GDO to it. You jot down that dial reading also. You'll find WWV at 2.5, 5.0, 10, 15 mHz and higher. These become known calibration points.


final dial card with three scales

Next, you draw a graph using this information. (See the illustration on page 27) From the graph you can find positions on the dial card that correspond to standard frequencies such as 3, 4, 5, 6 mHz and so on. In other words, you use the graph to "translate" the odd-ball frequencies used to calibrate the GDO, into standard frequencies. The graph then lets you draw the final dial calibration card.

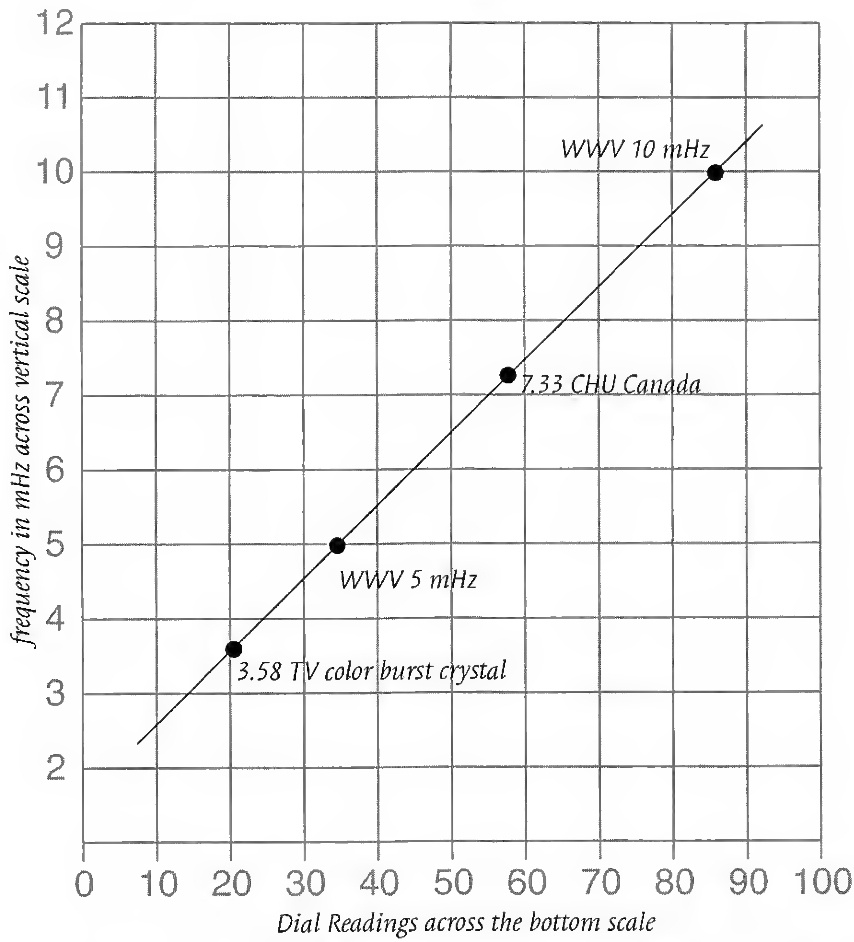
Generally I draw a new dial card with a computer drawing program, print it on heavy paper, carefully cut it out, turn it over and coat it with spray adhesive, and then quickly apply the card to the dial. The dial may have to be adjusted left or right a little to get the markings to line up under the crosshair, but once done, the markings are surprisingly accurate and professional looking.

If you don't already have a shortwave receiver, you can calibrate your GDO by bringing the GDO coil near another coil that is connected to the input of a frequency counter. If you have a counter, you don't even need to calibrate the GDO. Once you find a dip, you can use the frequency counter to tell you the frequency. My "overkill" GDO is equipped with a separate amplifier circuit included to drive a counter.

A counter may sound exotic, it really isn't, not these days. I have a 200 mHz counter I built back when Heathkit was still in business and funds were low. But since then I've acquired a used, somewhat beat up, but totally functional Hewlett-Packard 100 mHz counter for $60. I recently saw one experimenter/ entrepreneur offer digital readout modules for receivers that could be used as frequency counters for $50 in kit form.

Another way to calibrate your GDO is to scavenge, or buy, a range of crystals that can be plugged into an oscillator to provide a calibration signal. For instance, you could use a TV color burst crystal at 3.579 mHz (American standard) to provide a signal. When you tune your GDO to match the frequency of the test signal the GDO meter will jump UP slightly. You'll know what frequency you're tuned to. Surplus computer crystals are available these days for a wide range of frequencies for less than a dollar each. And they're more than accurate enough for our needs.

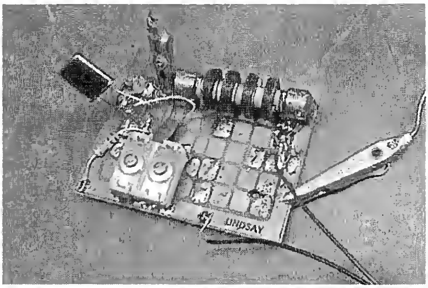
Calibration Chart for the Grid Dip Oscillator or a Home Built Radio Receiver



To create a dial calibration chart, you mark off dial readings across the horizontal axis and frequency along the vertical axis. Next, plot readings from your calibration tests. For example, you found that your GDO when set at 34 on its dial interfered badly with WWV on 5 mHz as heard in your receiver, so you put a dot at that place on the grid. You found that your GDO scale jumped while "listening" to a TV colorburst crystal as the GDO dial crossed 21. Put a dot there.

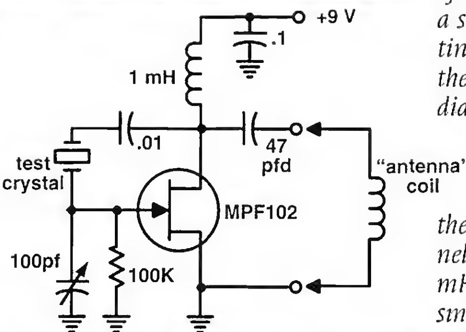
When you have several points plotted you connect them with a straight line, or in some cases a gracefully curving line. Once you have the line, you can translate dial readings into frequency. For instance, above we know that we'll find 6 mHz at approximately 44 on the dial.

Rarely will dots line up in a straight line. You have to draw a line that best fits the scattered dots. A simple mathematical method for ***calculating*** *such a line is called "linear regression". High end spread sheets often have the technique built in and refer to it as a "tool".*

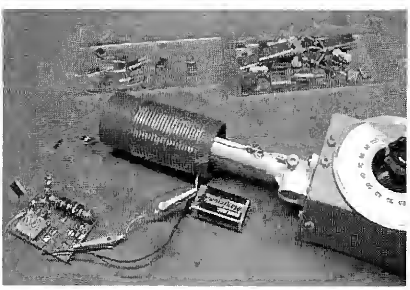


Calibration Oscillator

You can used this simple oscillator with inexpensive computer crystals to provide test frequencies that your GDO can "listen" to. A coil wound for another project was connected to the output of the oscillator to act an "antenna". When the GDO was tuned to the same frequency as that of the crystal, the GDO meter jumped up a small amount. By recording and plotting a number of these frequencies, and their position on the 0 to 100 temporary dial, the GDO can be calibrated to a reasonable degree of accuracy.



You're not obligated to use exactly the values specified. Just about n-channel JFET transistor should work. The 1 mH choke can be larger, but shouldn't be smaller in value. The 100 pfd variable could be replaced with a 100 pfd fixed capacitor. If the oscillator doesn't seem to want to oscillate, you can increase feedback by reducing the value to 47 pfd. Don't use a capacitor too much larger than 47 pfd to attach the antenna coil to the transistor drain.



(left) The gdo being calibrated with surplus computer crystals.

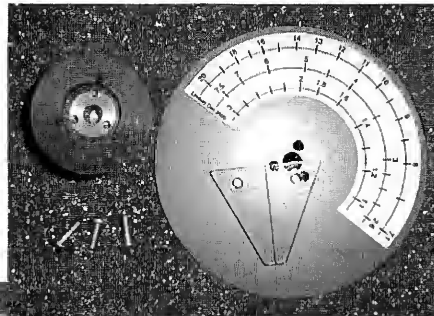
Dial Construction

(right) The dial assembly for this GDO consists of an aluminum plate held to a large knob with 4-40 machine screws. In this view a basic 0-100 scale has been glued to the dial plate for calibration purposes. Above the dial plate is a small piece of 1/8" acrylic plastic into which a line has been scribed and filled with a bit of black ink. It is held in place with long 4-40 machines screws, nuts and washers.

At first cutting a circular dial plate may seem quite difficult, but it is not.

First a small indent from a center punch or nail is placed in the center of a piece of .050 or .063 aluminum. Next a pair of dividers (the type draftsmen once used before computers) is used to lightly scribe a circle. A pair of tin snips is then used to remove most of the metal coming no closer than 1/4" to the scribed line to prevent puckering the edge of the disk. Next a pair of aviation snips removes thin strips from the edge of the disk until the scribed line is reached. Finally, careful work with a file will quickly bring the disk into a perfect circle than almost looks like it had been cut on a lathe. It is important to resist cutting too closely to the scribed line in a single pass, otherwise you'll end up with a bent circle of metal that will be unusable.

Next a 1/16" drill is used to bore a pilot hole in the dimple used as the center for scribing. The small hole is then drilled out to 1/4" diameter. Three 7/64" diameter holes are drilled around the 1/4" shaft hole in locations such that they are located over the "meat" of the dial and not voids. Placing a 1/4" shaft through the hole of the disk and into the hole of the knob ensure alignment and centering of the disk. The holes in the disk are scribed in the backside plastic of the knob. These three holes in the knob are then drilled out carefully and tapped 4-40 using an inexpensive drill and tap set from the hardware store. The shaft is used again to secure alignment, and the disk is screwed into the back of the knob. The result is a knob with a large dial plate that runs true without wobble.



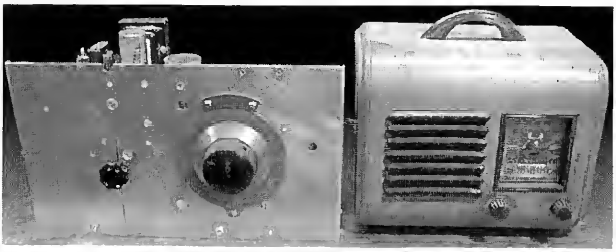
(above) A knob with a large molded-in brass insert was chosen. Holes were drilled and tapped for 4-40 screws. To the right is the final calibrated dial and the hairline plate. (left) the underside of te completed gdo dial

Note: If you're tuning your GDO, and the meter suddenly goes bananas even though there is nothing near the coil, you may have a problem with parasitics. Field-effect transistors are such great amplifiers at high frequencies that they can suddenly start oscillating at a frequency entirely different from the intended one. This can happen with tube oscillators in radios as well. The traditional term for this problem is squegging. It's often the result of too much feedback in the oscillator.

The solution here is to put a ferrite bead on the drain lead of the field-effect transistor. The simple demonstration GDO shown in this booklet needed a ferrite bead. The "killer" GDO described needed no such bead. The bead eats up excess energy, and, in effect, makes the field-effect transistor operate more like a sluggish ol' vacuum tube.

Single Tube Shortwave Converter

Back in the early days of radio, the only tubes available were triodes. Then in the late 1920's a fourth element was added to create a tetrode, or as it was called, the screen-grid tube. Next, in the early thirties, came the pentode which solved some of the tetrode's negative-resistance problems by adding a suppressor grid.

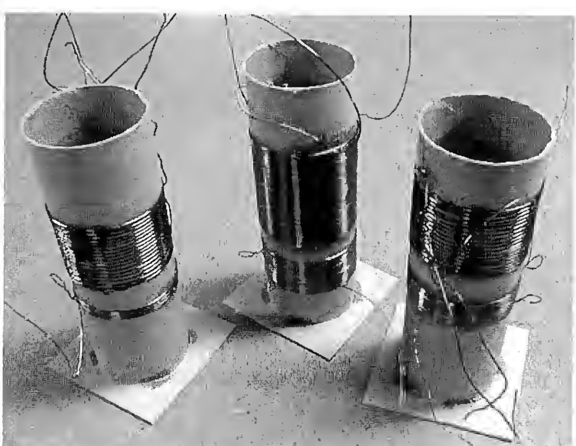


The prototype converter to the left converts a 5 mHz signal to 1.6 mHz and feeds it to the "All-American Five" broadcast receiver to the right. The connection is made simply by bringing a wire from the output tank circuit close to the built-in antenna of the old receiver.

Early superhets used one tube as an oscillator to generate a signal that was mixed in a second tube with a shortwave signal coming in off the antenna. The output of the mixer contained both the original frequencies and two new frequencies: the sum and the difference of the originals. The new lower frequency was fed to an amplifier and then detected. This was Armstrong's superheterodyne. The receiver could be made more selective, lower in noise, higher in fidelity, and more stable in reception.

In the mid-1930's along came the converter tube. This tube combined both the mixer and the oscillator tube combined into a single package to reduce cost. It was the tube that manufacturers needed to reduce the cost of building an AM radio.

These days, you can take a converter tube and build a shortwave converter that can convert the frequency of a shortwave station down to a frequency in the AM band. This new signal can then feed a standard ol' AM radio, or your hot-rod crystal set. Although it cannot pick up code or single-sideband signals, it will allow



(left to right) Input coil, output coil, oscillator coil. If you spend as much time on the toilet as I do, I'm sure you'll have plenty of these toilet-paper tubes on which to wind your coils. The tubes were glued to small cardboard squares that can be attached to the breadboard. Clear nail polish and Duco cememt was used to glue the windings to the tubes.

you to listen in on the sometimes wacky world of shortwave broadcasting.

The circuit of a shortwave converter is simple. A coil and capacitor (tank circuit) tuned to the incoming frequency is connected to the input grid of the converter tube. The oscillator side of the converter tube has a coil and capacitor tuned to a frequency such that when the two frequencies are mixed you get a new signal with a frequency you need.

For instance, if you want to listen to WWV on 5 mHz using a broadcast receiver tuned to 1000 on the dial, you need to create an input tank circuit tuned to 5 mHz and hook it to the input grid. Your oscillator needs to be tuned to either 6 mHz or 4 mHz, so that when the signals mix, that is, add and subtract, one of the output signals will be 1 mHz, or 1000 kHz on the dial. The tank circuit in the plate circuit of the converter tube must be tuned to the output frequency. In this example 1 mHz.

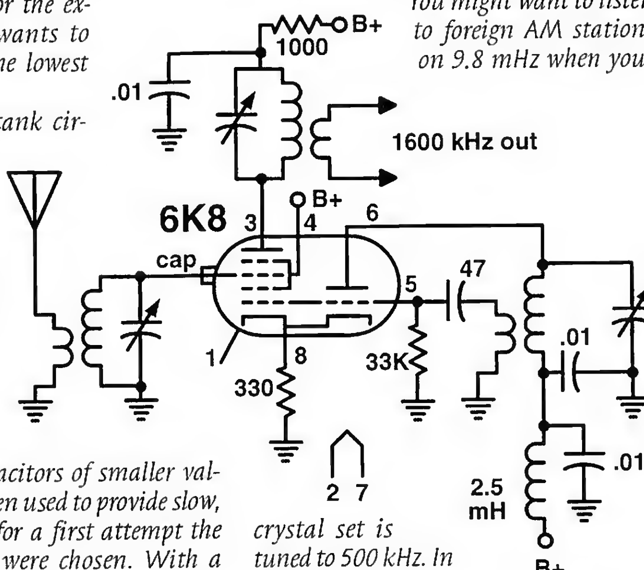
Converter Circuit

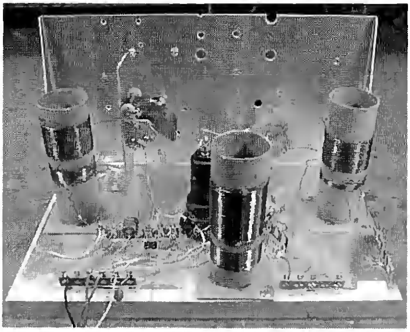
A metal 6K8 converter tube is used in this circuit. These tubes are still readily available, new in the box, for less than a dollar if you look, probably because there is no demand for them. They're not the ultimate converter tube, but they will work quite well for the experimenter who wants to build radios for the lowest possible cost.

The various tank circuits have to be custom made. Here the input tank circuit is tuned to about 5 mHz. The coils were wound and tested with the GDO to resonate with 140 pfd variable capacitors. Variable capacitors of smaller values should have been used to provide slow, fine tuning. But for a first attempt the larger capacitors were chosen. With a large capacitor a large tuning range will be possible, but trying to zero on a desired signal can be very difficult.

The oscillator coil was wound to 3.4 mHz so that when 5 mHz was mixed with it, the difference of the two (5 less 3.4 = 1.6) would give 1600 on the AM dial. The tank circuit in the plate of the tube was wound to resonate at 1.6 mHz providing extra gain from the tube and providing some filtering action.

You can choose other frequencies. You might want to listen to foreign AM stations on 9.8 mHz when your crystal set is tuned to 500 kHz. In this case, the input tanks must resonate at 9.8 mHz, the plate tank at .5 mHz, and the oscillator coil needs to be at 9.8 less .5, or 9.3. Remember to choose a frequency that your GDO can tune to so that you can use it to reso-





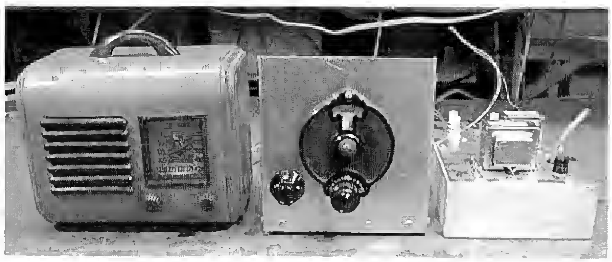
(right) back side of the prototype machine

nate tank circuits and to provide a test signal for testing.

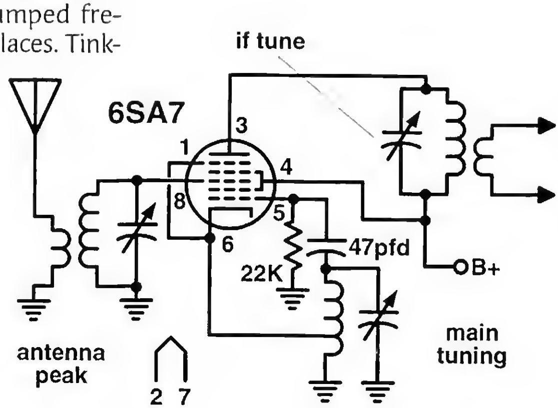
If these concepts are new to you, it would be very smart to read up on basic superheterodyne theory in early radio books and almost any edition of the Radio Amateur's Handbook. You need to understand problems like images, spurious responses or "birdies", conversion gain, and pulling. It sounds all so strange and complicated. But it isn't. What you're doing here, so to speak, is building a superheterodyne crystal set.

Second Generation Shortwave Converter

The 6K8 converter circuit is supposed to be easy to build and get working. But I found that it can be cantankerous when built on a breadboard. The long lead lengths cause the oscillator to be unstable. Adjusting the tickler to achieve the appropriate amount of feedback can be tricky. When built on a metal chassis, the 6K8 will give excellent results. The results I got were mixed. The converter worked, but oscillator jumped frequency at unpredictable places. Tinkering with feedback windings, grid leak capacitance and resistance, and the introduction of shielding would no doubt

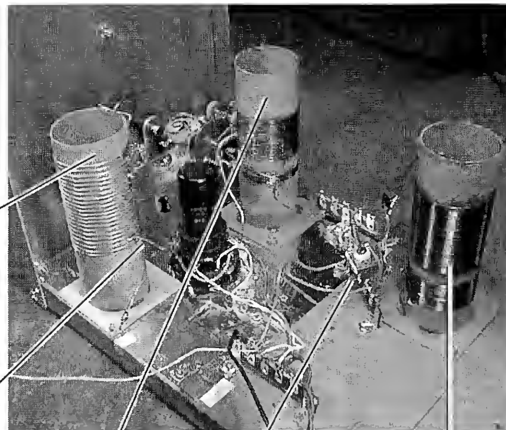


The second generation shortwave converter is built around a 6SA7 pentagrid converter tube powered by the simple power supply we built in Radio Experimenter Vol 1. The output signal drives our All American Five to fill the lab with unusual shortwave signals from around the world.



The 6SA7 circuit uses fewer components than the 6K8 version, and that always appeals to an impoverished experimenter.

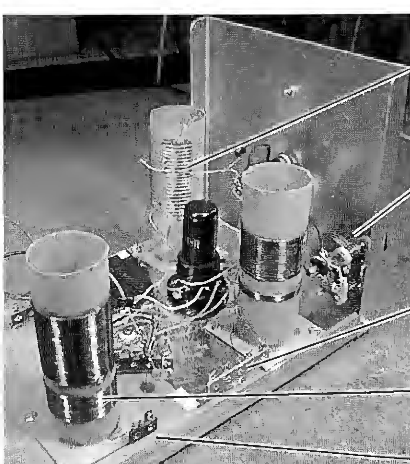
The rebuilt converter has a new oscillator coil, and the pentagrid converter tube is now nestled between the coils to reduce lead lengths which gave trouble in the 6K8 model.

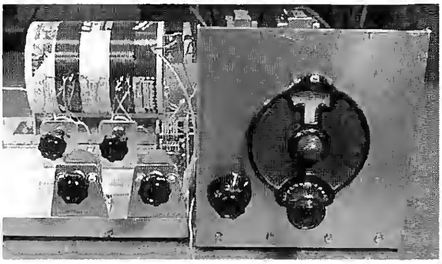


solve these problems.

But I decided to try another common metal octal vacuum tube: the reliable old 6SA7 pentagrid. In this circuit one of the grids acts as the oscillator plate. But instead of tickler feed back like the 6K8, here we use a Hartley oscillator with the cathode tapped very close to the ground end of the oscillator tank circuit.

A new coil was wound with no. 18 tinned bus wire on another toilet paper tube. The original oscillator coil had 18 turns. The new oscillator was wound with about 26 turns and secured with Duco cement as before. Next, a 35 pfd variable capacitor was connected across all the windings and the frequency checked with the GDO. It was much too low. The capacitor was then connected from the bottom end (which is connected to ground in the circuit) to a point about four turns from the top. The GDO showed the frequency still to be too low. So the connection was brought down several





The 6SA7 converter driving the Vol 1 crystal set. Like any crystal set, the volume was not great, but the shortwave broadcaster coming in were easily heard. A carefully built, high quality crystal set would probably give better volume. Still, it's all home built, and it works!

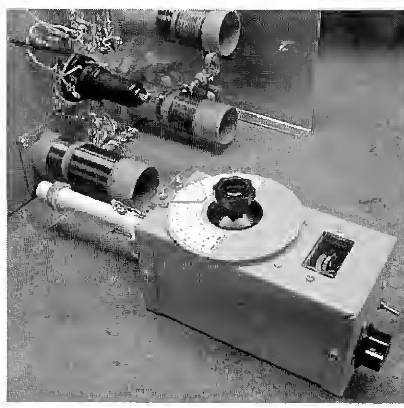
more turns from the high end. This continued until the tank circuit resonated at about 6.3 mHz. An oscillator tunes from 6.1 to 6.8 mHz will mix with signals from 4.5 mHz to 5.2 mHz to create a 1.6 mHz intermediate frequency to be fed to the AM radio. By putting small capacitors both fixed and variable across the 35 pfd variable capacitor, and by adjusting the point at which they connected to the high end of the coil, I could get the oscillator tank to tune a range somewhat larger than I wanted.

In rebuilding the converter, I also used a smaller 50 pfd variable capacitor in the grid tank circuit so that it would be easier to tune, or "peak". Here again, I put various fixed capacitors from 10 to a 100 pfd and checked the resonant frequency with the GDO. It only took a few minutes to get a combination such that in running the capacitor from minimum to maximum capacitance, it tuned from 4.5 to 5.2 mHz and not much else.

If you're not one who is comfortable with math, the trial and error method of building tank circuits might be your only option. I can't imagine how you could do it without an grid dip oscillator. Even if you DO calculate the necessary values, a GDO will still help get you right on frequency.

The tap for the 6SA7 cathode was attached at about 3 turns up from the ground end. Just a guess. But it turned out to work very well, and I didn't change it.

Using the gdo to be sure that the tank circuits tune to the desired frequencies.



Laying the converter on its side, it was possible to use the gdo to adjust the tank circuits (align them) to their necessary frequencies.

The 6SA7 converter circuit is simpler than the 6K8, and I always like that. In using the converter, I found that the oscillator would tune smoothly and predictably and not jump the like the 6K8. And this was on power supplied by the simple power supply described in Radio Experimenter Vol 1.

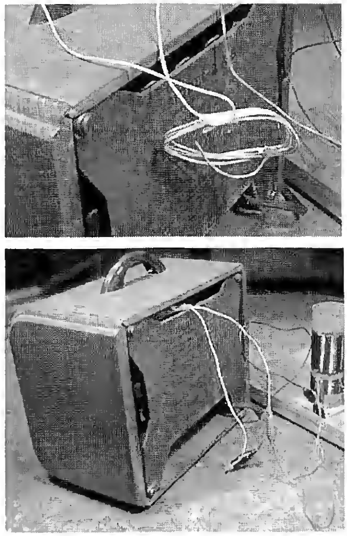
To test the converter, I wanted to

try it on the crystal set built in Vol 1. But geez, there are three different frequencies of importance, and the circuits all have to be adjusted to these frequencies if the radio is going to work.

The first step was to choose an intermediate frequency. This comes out of the converter and into the crystal set. I set the GDO to 1600, and put the coil near the crystal set while it was hooked to an antenna. Many faint signals could be heard in the earphones, but when the controls were tuned to 1600, the signal go quiet. It was the GDO acting as a radio station. But without any modulation on the signal, the only thing to be heard in the earphones was silence. So the crystal set controls and coil taps were adjusted to give "maximum" silence. How's that for a bizarre concept?

Next, without touching the GDO dial, the coil was put very near the output coil of the converter. A screwdriver-like plastic shaft alignment tool was used to adjust the compression trimmers across the coil until the GDO meter dipped. That indicated that the output circuit was very close to 1600 kHz or 1.6 mHz as well.

I decided to use WWV on 5 mHz as a test signal. If you have a signal generator, you can generate your own test signal, but WWV will come booming in quite nicely after the sun sets. Putting the GDO near the grid tank circuit and setting the dial to 5 mHz, I managed to find the setting of the variable capacitor that produced a dip on the GDO. That told me that this is about where I want to set the control while receiving.



A simple multi-turn coil of insulated hookup wire was slipped inside the back of the AM radio near its built-in loop antenna. The coil was connected with alligator clip leads to the output terminals of the converter.

Last, I applied power to the converter and brought the GDO coil near the oscillator coil and adjusted the GDO control to give a low meter reading. As I tuned the GDO dial, the meter suddenly jumped way up, indicating resonance. Here, the GDO was acting as a wavemeter, or primitive frequency meter. By closing the plate of the main tuning capacitor and by adjusting the variable capacitor across the main tuning capacitor I could get the lower frequency down below the desired 6.1 mHz. Then opening the plates, the GDO showed me that the high frequency was close to 7 mHz. Then I set the GDO to 6.6 mHz and adjusted the main tuning capacitor until the GDO popped upward. This told me about where the main tuning dial should be to get WWV.

Now that the "alignment" was complete, the only thing left to do was hook the converter up the crystal set, connect an antenna, and turn on the power supply. Did it work? Not immediately. Very careful tuning of the main tuning capacitor to either side brought in something. Slow tuning of the grid capacitor made the signal louder, that is, "peaked" the signal. Then the crystal set was adjusted to increase signal strength. Finally, the compression trimmers were once again adjusted with the alignment tool. The result? Sure enough. This voice was telling me that it was "coordinated universal time 2 hours 13 minutes". Not bad!

Next, a coil of insulated hookup wire was slipped down inside the back of old AM tube radio I had. And when I powered up the converter and tuned the radio to about 1600, WWV filled the basement lab with more announcements of coordinated universal time. But now there were a few problems. For one thing, there were faint commercial AM stations about where my converter was operating. I shut off the converter and searched the AM band for a "clear channel". Then I fired up the converter and found that WWV was now in a different location on the converter tuning dial (which makes sense because of the frequency mixing going on). The only thing left to do was readjust the compression trimmers on the converter output tank circuit. Now WWV was really coming in.

Well, I have to admit listening to time stations t'aint quite all that exciting. So I rolled the tuning up the dial until I heard some crazy evangelist proclaim that the world was going to hell in a hand basket and that he alone knew the solutions the problem. The problem is, that just up the dial is another dime-store prophet whose solutions are completely different. Fortunately not far away is the world service of the BBC out of London, and the Canadian Broadcasting Company, Radio Belgium, and Deutsche Welle out of Germany, and a dozen other stations with interesting music, stories and news.

And this is exactly what people found so exciting in the 1920's when shortwave broadcasting began – back before television, long distance telephone, and the internet.

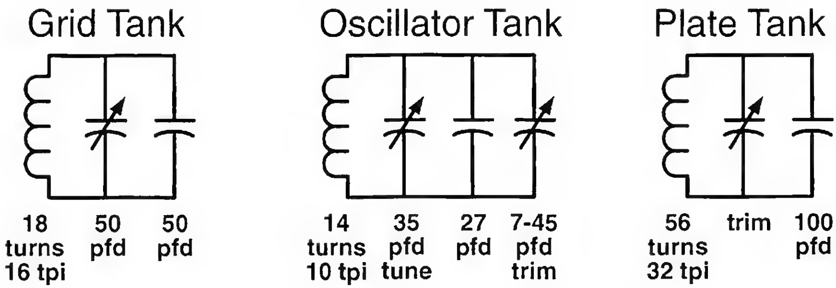
Bandspreading

In the original converter circuit, one twist of the tuning condenser from closed to open took the frequency from 3.8 to about 7.2. That meant that to zero in on a particular station took a very steady hand even if the capacitor was driven by a very smooth dial drive. The tuning capacitor covered just too much territory.

In order make tuning easier on second version of the converter, I decided to use smaller variable capacitors. But how does one go about doing this? Simple. First, tune the converter so that the stations you want can be heard. Take a look at the plates of the variable capacitor. If they're about 50% meshed, and your capacitor has a maximum value of 140 pfd, then you must be at about 50% of 140 or about 70 pfd (true only if the plates are circular and not elliptical).

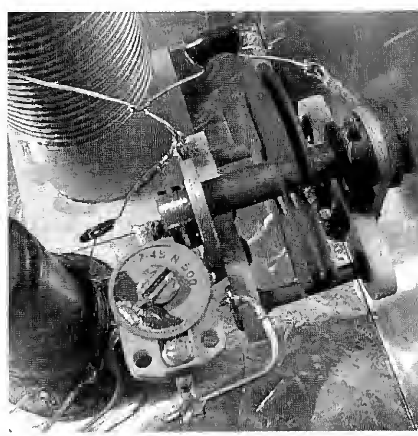
If you tune either side of the desired station, you can get a feel for the width of the band frequencies you want to receive. Lets suppose that frequencies you want to listen to can be heard when the plates are from 40% to 60% meshed. That means the range must be from 40%x140 or 56 pfd to 84 pfd. That's a range of 84 minus 56 or 28 pfd. So you merely remove the 140 pfd variable capacitor, and substitute at 35 pfd capacitor, about the closest standard value to 28.

The minimum capacitance of

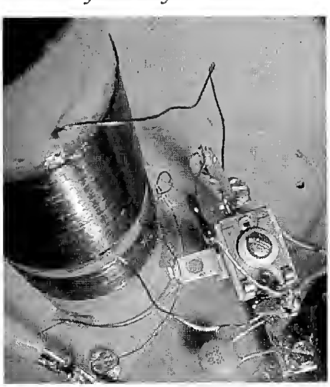


These are the combinations of fixed and variable capacitances and the number turns on 1-5/8" toilet paper tube for each of the tank circuits used in the second shortwave converter. These values will probably NOT work for you without tinkering. A GDO makes adjustment fast and relatively easy.

small variable capacitors will run between 6 and 8 pfd, and in larger capacitors maybe 10 pfd. So when we open up the plates of the capacitor we'll only have about 6 pfd. Yet we observed that we needed at least 40% of 140 pfd or 56 pfd. So we simply solder a 50 pfd fixed capacitor across the 35 pfd variable. Since capacitances in parallel add, we know that when



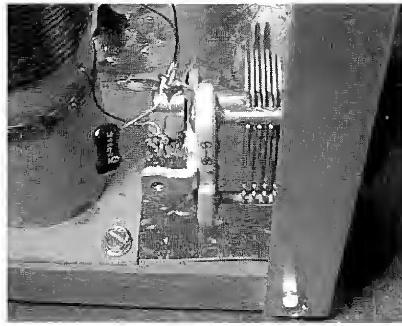
(above) The main 35 pfd tuning capacitors is mounted on the front panel. Across it's terminals is a 27 pfd fixed capacitor, and a 7-45 pfd ceramic trimmer. The trimmer allows you to adjust the range to exactly what you want.



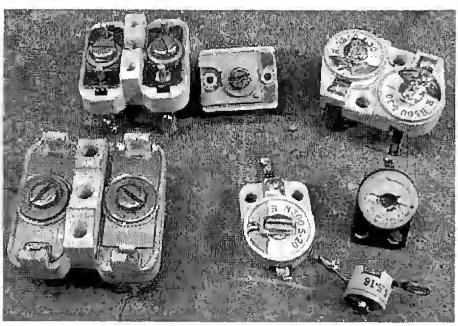
(left) Across the plate tank circuit is a common compression trimmer. Across it is connected a 100 pfd silver mica capacitor soldered to alligator clips. One great tool for experimenters is to have a range of silver mica capacitors, say 22, 47, 100, 200, 470 soldered to small alligator clips. You can quickly clip a capacitor across a coil or another capacitor to see its effect on the circuit you're developing. If you have precision capacitors, say 1% or 2% tolerance, you can use them to measure the inductance of the coils you wind by measuring resonant frequency with your gdo.

the variable is opened up and it's minimum capacitance is 6 pfd, the 50 additional pfd will add with it to give 56 pfd. When we close the plates all the way down and the capacitance is now 35 pfd, the additional 50 pfd will give 85 pfd. In a sense the fixed capacitor changes the range of the variable capacitor from 6-35 pfd to 56-85 pfd, and that's almost exactly what we estimated we needed above.

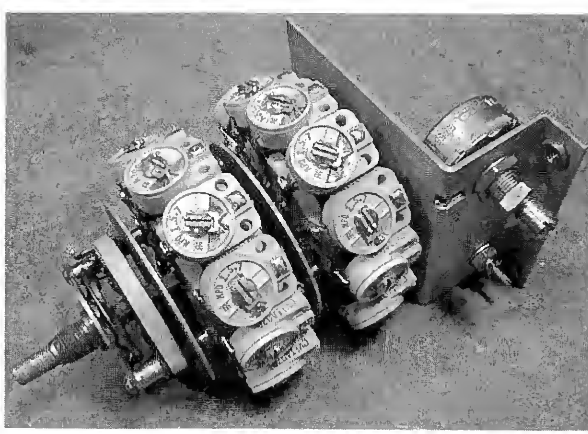
The new combination of smaller variable capacitor in parallel with a fixed capacitor (added to make up for the missing variable capacitance) spreads the stations out across the dial, and makes tuning much easier.



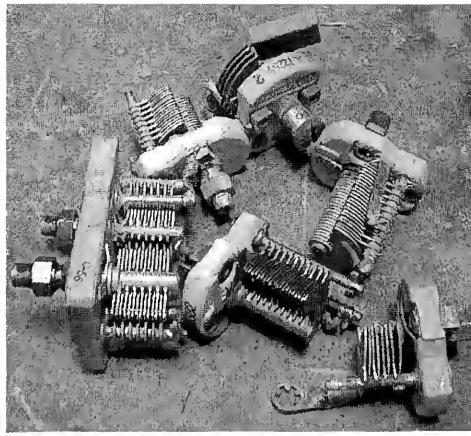
The grid tank circuit. Here is an old Hammarlund variable capacitor of about 50 pfd max capacitance. Across the stator and rotor terminals is a fixed 50 pfd silver mica. Silver mica's are among the most stable capacitors available. If you find new capacitors too expensive, consider disc ceramics, instead.



A variety of salvaged trimmer capacitors can be found. Some are sheets of metal sandwiched between sheets of mica, and are called compression trimmers. Those on the left were probably removed from early IF transformers. The ceramics to the right are far better quality and can often be found in vacuum test equipment from the 1950's and 1960's.



What is this? I dunno. It must be some kind of a selector switch salvaged from an old piece of test equipment. I picked it up at a flea market for $5 just to get the ceramic trimmers. Three different ranges are present, and all are useful in radio building. These kinds of discoveries are available to you, too.



These trimmers are among the best ever made: air trimmers. I suspect these where removed from long distance telephone microwave equipment. They may be filthy, but once soaked in detergent and TSP, they will be as good as new. They may not be as convenient as other trimmers to mount on your breadboard, but they are low loss and their adjustment is about as permanent as you can get. In other words, they are truly industrial strength capacitors.

Calculating Needed Inductance[1] and Capacitance Values

Creating a tank circuit that spans exactly the band of frequencies desired and no more can be an ordeal if you use the trial-and-error method of design. Here is a simplified formula that I derived using good ol' high school algebra. And amazingly enough it really works!

$$C_{pad} = \frac{(f_L^2 \times C_H) - (f_H^2 \times C_L)}{f_H^2 - f_L^2}$$

$$L = \frac{25{,}330}{f_L^2 \times (C_{pad} + C_H)}$$

First, you determine the range of frequencies you want to cover. For instance, let's assume we want to tune our regenerative receiver or oscillator from 4.5 to 5.2 mHz where numerous shortwave broadcast stations can be found. And let's suppose we have a variable capacitor of about 80 pfd maximum value. We'll assume that its minimum value is about 8 pfd.

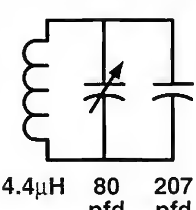
So we plug these values of frequency and capacitance into our first formula and find that we need a fixed capacitor of about 206 across the variable 80. Taking that value and plugging it into the next formula we find that need about 4.4 µH of inductance.

$$C_{pad} = \frac{(4.5^2 \times 80) - (5.2^2 \times 8)}{5.2^2 - 4.5^2}$$

$$= 206.7 \text{ pfd}$$

$$L = \frac{25{,}330}{4.5^2 \times (206.7 + 80)} = 4.4\ \mu\text{H}$$

If you put a 80 pfd variable capacitor in parallel with a 207 pfd fixed capacitor and put it across a 4.4 µh coil, you'll get a tank circuit that tunes from 4.5 to 5.2 mHz.



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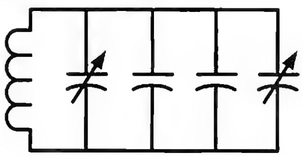
[1] Rockey: Good Stuff! Useful!

This is, of course, the ideal. In reality there is capacitance between the wires in the coil and between the wires connecting the tank circuit to your oscillator. And even a straight wire has some inductance. So all these minor imperfections louse up the calculations.

To overcome these difficulties, the wise approach is to split the 207 pfd up into a number of paralleled capacitors across a trimmer.



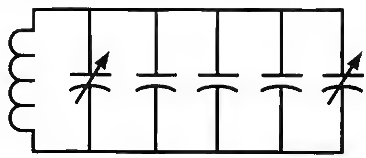
4.4μH 80 pfd 150 pfd 22 pfd 7-45 pfd trim

total trimmer range: 179-217 pfd

For instance, the 207 could be replaced with a 150 and 22 pfd fixed capacitor in parallel with a 7-45 pfd ceramic trimmer. The 150 and 22 add up to 172. Adding 172 to the 7-45 gives a capacitor of 179 to 217 pfd total. The calculation calls for 207. That means the trimmer would be set at 28 pfd to add with the 179 pfd for a total of 207. But suppose the coil has 6 pfd of its own capacitance, and the circuit wiring contributes another 4 pfd. That's a total of ten. The trimmer would be reduced by ten, to 18 pfd to get the calculated bandspread: 150 fixed, 22 fixed, 18 trimmer, 6 coil stray, and 4 circuit stray total up to 207 pfd.

All this may sound complicated, but it really isn't. In practice, you wire the two fixed capacitors and the trimmer across the 80 pfd variable capacitor. Then you set the 80 pfd tuning capacitor with the plates fully meshed which puts you at the low edge of the desired band. Then you adjust the trimmer until the frequency hits 4.5 mHz. If you've wound the coil correctly and know the value of your variable capacitor fairly accurately, you can open the tuning capacitor plates all the way up, and you'll find that you're at 5.2 mHz.

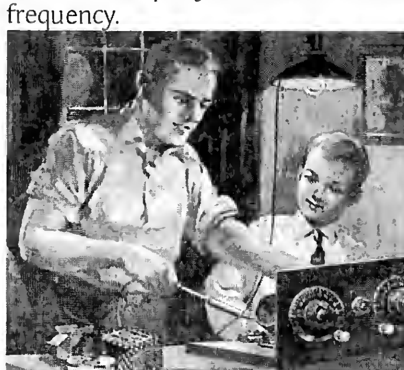
Your calculations will probably come up with some crazy value of capacitance. But that's no problem, because you can mix and match capacitors to get what you need.



4.4μH 80 pfd 100 pfd 47 pfd 22 pfd 7-45 pfd trim

total trimmer range: 176-214 pfd

For our example here, another way to build the tank circuit would be to use a 100, a 47, and a fixed 22 pfd capacitor across the 7-45 trimmer. The resulting range would be 176-214 pfd. If you find that your coil or circuit has much more stray capacitance than you anticipated, and that you cannot make your trimmer go low enough, you can simply remove the 22 pfd fixed capacitor, and you should find that your trimmer will put your tank circuit on frequency.



Early QST is a great resource for tube radio builders...

One exceptionally valuable article for builders on using early converter tubes entitled "Practical Design of Mixer or Converter Circuits" was written by Curtis Hammond and was published in the February 1941 issue of QST. Shown here are six different circuits based on the converter tubes available at that time. Details in the article explain the advantages and disadvantages of each tube. Other circuits using separate oscillator tubes are discussed. These issues are still available on the used book market and on CD-ROM from the League.

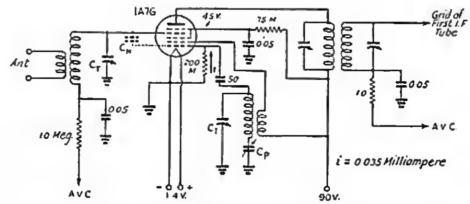


Fig. 2 — Converter circuit for the 1A7G or 1A7GT

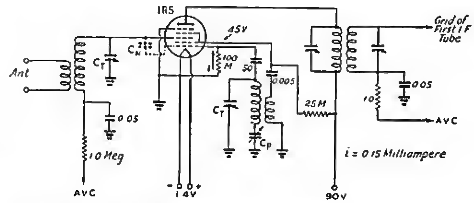


Fig. 3 — The 1R5 converter circuit.

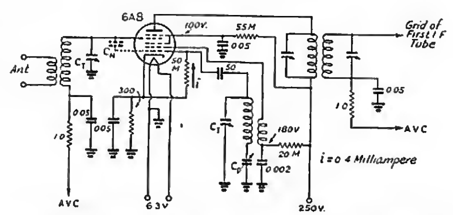


Fig. 4 — Converter circuit for use with the 6A8, 6A8G, or 6A8GT.

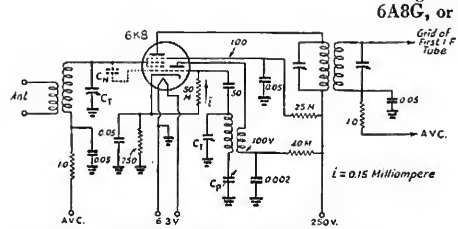


Fig. 5 — The 6K8, 6K8G or 6K8GT converter.

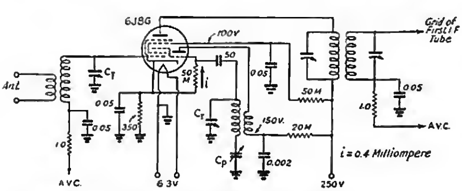


Fig. 6 — Converter circuit for the 6J8G.

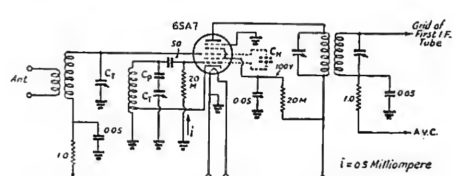


Fig. 7 — The 6SA7 converter circuit.

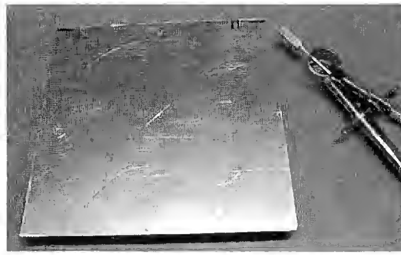
Probably the best converter tube (and probably the last designed) was the 6BE6 9-pin miniature tube. And they're like cockroaches – they seem to be everywhere! Details on using the 6BE6 can be found in the handbooks and in the back of almost any late tube manual. You can use the same schematic shown on page thirty two if you change the pin numbers accordingly. A four page article on building a 6BE6 shortwave converter with plug-in coils appeared in Popular Science magazine in the 1940's and was reprinted in "How to Build 78 Radio and Television Sets".

Fabricating a Slow-Motion Dial Drive

When it comes to carefully tuning a radio signal, some type of reduction drive is helpful. Usually a reduction of at least 5 to 1 is helpful. In other words in order to get your variable capacitor to move from plates fully closed to fully open takes only half a turn. But with a 5 to 1 dial drive, you'll have to turn the tuning knob 2 1/2 turns.

If you build radios for the shortwave band, reduction dial drives are essential. Trouble is, they aren't made anymore. You can sometimes bid on old dial drives auctioned on internet sites, but you'll pay a hefty price for your ignorance. I've picked up half a dozen or so National dial drives at a flea market for about $5 each. You can, too.

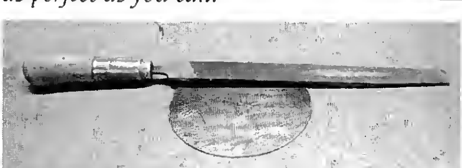
But finding old dial drives is not essential because you can make your own. It's easy. The performance is actually better than a lot of the original old drives. No, you don't need a lathe, milling machine, foundry or any of that. A table top drill press is useful, but not required. All you need are just simple hand tools. Here's how it's done.



1) For this demonstration I started with a small sheet of aluminum, .050" thick. In the center I put a dimple with a center punch. The dimple was then use with a pair of dividers from an old drafting set to lightly scribe a circle on the aluminum.

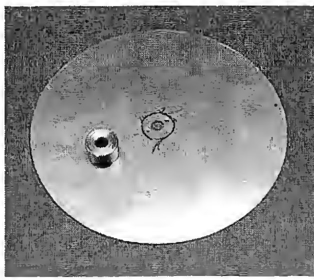
2) Next, using tin snips large pieces of aluminum were quickly removed. It's important not to come too close to the scribed circle, since the metal has a tendency to pucker the cut edge. It is essential that the finished dial be as flat and free from puckers and distortions as possible.

3) (right) Once the bulk of the metal has been cut away, a closer cut is made with a pair of aviation snips. These are like manicure scissors for sheet metal. Very precise and delicate cuts are possible. The first pass should come close to the scribed line but not exactly on it. Let the second pass come closely as possible. Try to make the circle as perfect as you can.



4) (left) The next step is to use a metal file to remove the small amount metal outside the scribed line. Aluminum files quickly and easily. You may have to clean the file with a wire brush if it loads up excessively.

The aluminum disk must be joined to a 1/4" shaft collar so that the disk can turn the capacitor shaft. This is where your creativity can pay big dividends. I used aluminum here because I have plenty on hand. But it's difficult solder without special fluxes. I decided to use a large diameter 1/4" shaft collar and attach it with 4-40 screws.



First, you must drill the disk center out to 1/4". I do this with progressively larger drills starting 1/16" to keep the hole from drifting away from exact center. Next, a piece of 1/4" shaft is used to center the collar on the disk, and a circle is draw with a Sharpie® marker. Inside the circle two 3/32" are center-punched and drilled. Using the 1/4" to again align the collar under the disk, a marker is used to transfer the location of the holds to the edge of collar being careful to avoid the set screw.

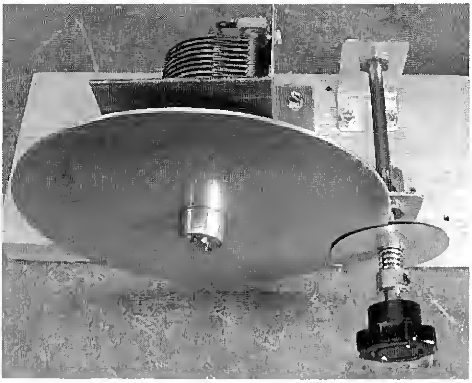
These spots are carefully center punched and drilled out 5/64". Then the holes are enlarged with a no. 43 drill that can be found in an inexpensive tap and drill set from the hardware store. A 4-40 tap is used to cut threads into the collar. Actually 4-40 screws are a bit too big for this project. A pair of 2-56 screws would be better, but I didn't have a 2-56 tap on hand. Once tapped, two 4-40 by 1/4" machine screws will attached the disk firmly to the shaft collar.

A possibility here is use epoxy cement to join the shaft collar. In this case it would be wise to use a 1/4" hardwood dowel to align the collar and disk. Excess glue would probably glue the dowel inside the assembly. It would probably be necessary to drill the dowel out, and wood is easier to remove than metal.

If you choose not to use epoxy or machine screws, you might consider finding a large piece of sheet brass and soldering the disk to the collar as is demonstrated later on. This disk is 5" in diameter and is about as small as you would want to go. Finding brass sheet that wide can be a problem, although smaller sizes are available in hobby shops.

If you have a lathe, you can mount a piece of plywood to the faceplate and attach the sheet metal to it with screws at the corners. After drilling the center hole, a perfect circle can be cut using a 60° threading tool. But despite how complicated it may look here, it's almost faster to cut the disk by hand. And the results are remarkably accurate. It's actually very easy.

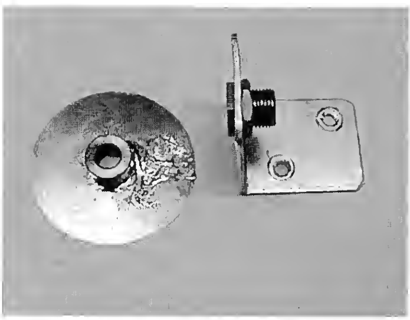
Here is a friction dial drive on an old General Radio impedance bridge. The smaller dial to the lower right drives the larger dial at a reduced rate proportional to the diameter of the dials. In other words if the larger dial is five times larger than the smaller dial, the reduction is about five to one. These disks function like gears without teeth. They mesh using only friction. That makes the drive easy to make and low-cost, and more importantly eliminates backlash.



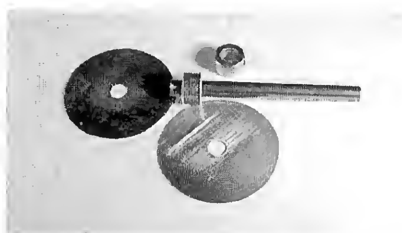
(left) Here we see the completed dial drive. We've just fabricated the large drive disk shown here attached to the shaft the variable capacitor. We need to create the friction drive on the lower right.

We repeat the process. From a strip of 2" wide brass from the hobby shop are cut two circles using the same technique just described. Here, however, the circles don't need to be quite as perfect.

One brass circle is soldered to the steel collar with lead-tin soft solder. A common propane torch will be needed to deliver enough heat to raise the temperature of the collar. A 1/4" steel rod is chucked in a vise and used to center the collar on the brass disk.



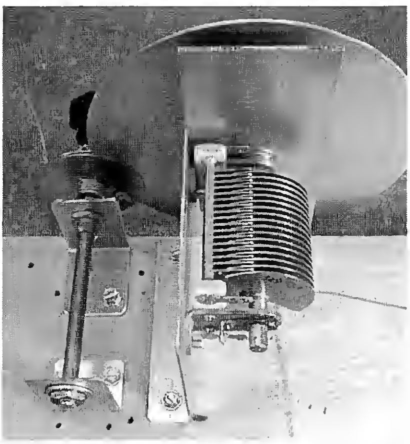
(above) Be sure when soldering to do a nice sloppy job like I did. After all, we don't want anyone to think this is professional! To the right is a simple L bracket fitted with a 1/4" panel bearing.



Two brass disks, two collars and a section of 1/4" shaft ready for soldering.

(left) Assembly and adjustment is easy. You put the 1/4" shaft through the panel bearings at front and rear as shown. Next, slip on the small brass disk soldered to the collar. The large disk is then put on the capacitor. Finally the second brass disk slipped onto the shaft to form a sandwich. Pressure is applied to the sandwich with a spring that I salvaged out of a computer ribbon cartridge, but there are many available at the hardware store. A second shaft collar is positioned to make the spring put significant pressure on the brass disk and produce the necessary pressure.

The only critical adjustment here is getting the small disks the right distance from the large disk. You want the large disk to be sandwiched deeply between the brass disks near their shaft. This ensures adequate friction for a smooth drive, and the point of contact produces a greater "gear" ratio. Here, for instance, the brass disks are about 1-3/4" in diameter, but



(left) Here I used two angle brackets and two panel bearings salvaged from old equipment to hold the 1/4" shaft. You probably don't need them. You could drill holes in thick aluminum, and carefully enlarge them a tiny amount with a T-handle reamer. Bearing wear is certainly not a concern here.

The shaft needs to be fairly firmly affixed to the chassis or breadboard, although a small amount of play is acceptable. The capacitor to the right is mounted on a homemade angle bracket, and a second aluminum strip supports the front capacitor bearing. The capacitor needs to be quite rigid.

This drive works remarkably well. It's smooth, sensitive and has zero backlash. And it was very easy to build. Just be sure that your variable capacitor rotates fairly easily without binding. If the capacitor is too tight, this drive might slip.

the large disk is riding more than halfway in between the sandwich. So the effective diameter is about half the 1 3/4" or about 7/8". If the large disk is 5" in diameter, then the reduction ratio is 5" divided by 7/8", or about 5.7 to one.

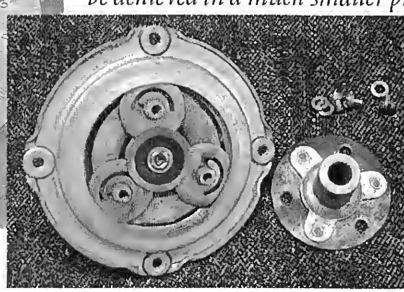
Finishing Touches

Here you have the basic slow motion dial drive mechanism. How you use it is up to you. You can draw up a fancy scale with a protractor and pen or use computer program, and glue the scale to the large disk. A pointer at the top or to the side can indicate what frequency you're tuned to. Or you could position the large dial with its scale behind the front panel of your radio in which a small window has been cut. As you tune the radio, the frequency comes into view.

Another possibility is to extend the capacitor shaft forward through a hole in the radio front panel and attach a large pointer of sheet metal or plastic. Behind the pointer on the front panel is a paper scale, or a scale created with decals, or, if you're really determined, an engraved scale just like the fancy radios from the early 1920's.

Another idea to pursue is the creation of dial drives using dial cord, as was used in inexpensive broadcast receivers produced in the decades preceding the introduction of television. This would entail creating pulleys of wood or metal, and that means having a lathe of some type. But with this technique it is quite possible to create your own slide-rule dials. Think about it.

Here we see the front and back of the classic, patented National Type B dial drive. The back side shows the friction drive at the bottom. An eccentric controlled with a lever seated in notches on the front, moves the small friction wheel closer or farther away from the large disk, thereby offering a variety of "gear" rations. Friction drive was cheap and easy to manufacture.



(left) Another classic National dial is this old unrestored beast. It, too, uses friction drive, but here the drive is provided by a planetary drive very much like the transmission in an old Model-T. This allows a sizeable gear reduction ratio to be achieved in a much smaller physical space and increases friction so that larger capacitors can be controlled without slipping.

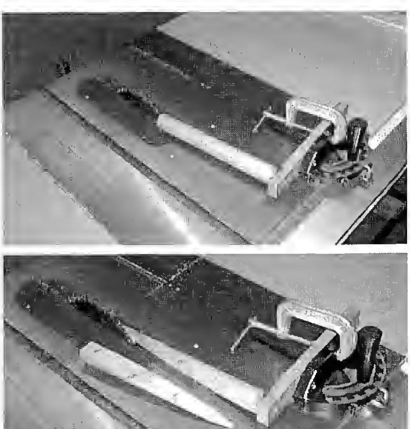
This Marco dial drive patented in 1925 is another example of an inexpensive friction dial drive. A tiny drive wheel gave large reduction ratios.

Creating Space Wound Coils

You can wind high-Q space wound coils using a technique shown in a short article by A. D. Muldoon published in a late-1920's issue of QST. It also appeared in the early issues of the ARRL's "Hints and Kinks".

A mandrel is prepared by sawing at a diagonal a length of hardwood having roughly a square cross section. The two pieces are held together with wood screws, the heads being counter

1) A length of dowel about a foot long is cut with the table saw, and two 1/16" diameter pilot holes are drilled across the diameter about 6" apart. The end of the dowel is glued to a scrap piece of 1x2.

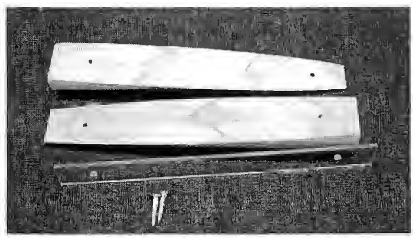


2) The dowel assembly is clamped to the miter gauge of the table saw and adjusted to an angle such that the saw blade will slice the dowel in two diagonally. Set up can be tricky here.

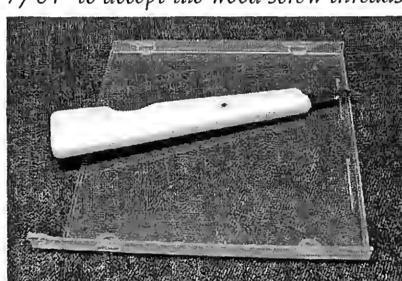
sunk. Next, the piece is chucked up in a lathe and turned to create a cylindrical mandrel on which to wind the coil.

If you have a lathe, especially a metal lathe, it's an easy process, and it produces a superior form. But if you only have a table saw you can still build a fairly good form by using a section of closet pole with a diameter of 1-5/16" or something similar.

This is how it's done.



3) Since the saw blade removes 1/8" thickness from the dowel, a spacer sawn from common 1/8" acrylic plastic sold in hardware stores for replacing broken windows is fabricated. This brings the assembly back to roughly a cylindrical shape. The pilot holes in the thin sections are drilled 9/64" to allow a #6 wood screw to pass through, while the pilot holes in the thick section are enlarged to 7/64" to accept the wood screw threads.



An inexpensive acrylic plastic scoring tool is used to score a crystal case that once housed a Compact Disk. Once the scribed lines are deep enough, narrow strips of styrene can be broken free quite easily. You can get by with cardboard, but this is the best material I've found yet.

Winding the Coil[1]

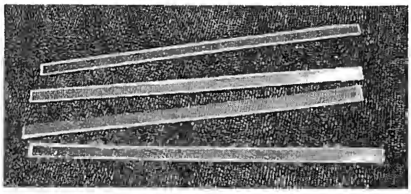
Solder lugs are attached to the mandrel with sheet metal screws to serve as anchors for the ends of the coil. Next, a couple of layers of wax paper are wound around the mandrel, and taped in place. The four plastic strips are spaced around the mandrel and held in place with masking tape.

One end of about 14 feet of No. 16 tinned copper bus wire is held in a vice, and the other end is secured in one of the solder lugs. The wire is carefully wound round the mandrel, using heavy twine to evenly space the wires. After winding, the wire is cut, and the loose end is secured in the other lug.

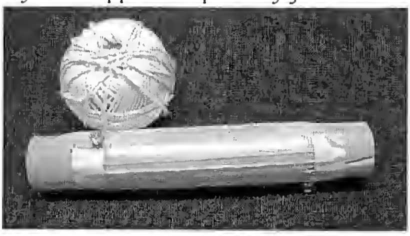
Next, Duco® is used to weld the wire to the styrene strips. These strips are desirable because styrene is a superior insulator and cement actually melts into the plastic forming a bead of plastic around the wires. Acrylic or other plastics could probably be used, but plastic from CD cases is thinner than most other plastics I've come across.

After each strip receives at least two, and preferably three, coats of cement, the beads are allowed to harden overnight. Then all the masking tape is stripped, the wood screws removed, and a slight tap on one end of the mandrel will cause the mandrel halves and acrylic spacer to fall free from the coil.

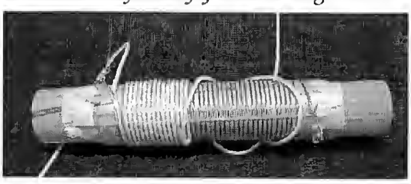
The result is a high quality coil that is easy and inexpensive to make. It took much longer to write this brief explanation than it did than to wind the coil.



Styrene support strips ready for use.



The assembly ready for winding.



The coil immediately after winding.

The first bead of cement has been laid.

The completed coil is seen at center bottom. The larger coils were wound with a turned mandrel. The coil to the right has been cemented to a section of 1/4" thick acrylic plastic to allow mounting on standoffs.

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[1] Rockey: This should be of great interest to us hams who build our own rigs and antenna tuners!

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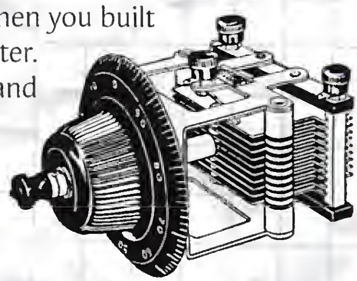

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