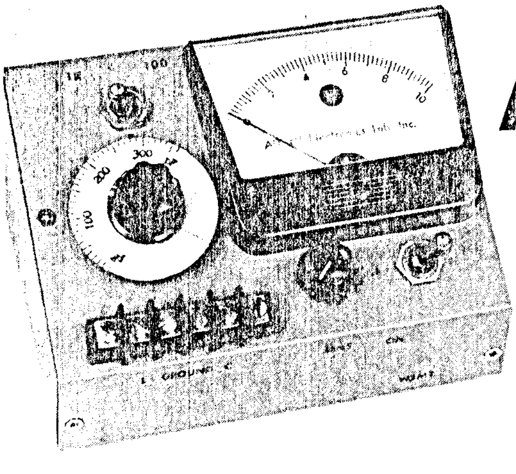

A Simple L-C Meter

Build this circuit and unlock the secrets of unmarked components

By Frank Noble,* W3MT

The instrument described in this article minimizes pitfalls that tend to discourage the prospective builder: It is relatively cheap to build, the set-up is fast, the L/C calculations are easy and the accuracy is good. A miniature crystal-controlled oscillator, in conjunction with the unknown coil, forms the "heart" of the device. Voltage across the coil is indicated on a meter; it will be maximum when the coil is resonant. The coil is resonated with a calibrated variable capacitor. Operating frequencies for the crystal oscillator are chosen so that the unknown inductance is an integer power of 10 times the reciprocal of the resonant-tank capacitance. This simplifies the math involved. It is easily shown that the frequencies required will have the number sequence either $1/2\pi$ or $\sqrt{10}/2\pi$.[1] I used 5033- and 15,915-kHz crystals with a 365-pF broadcast variable capacitor in the tank circuit. This results in an inductance range of 0.286 to 28.6 μH and a capacitance range of 10 to 330 pF — values commonly used in the range of 2 to 30 MHz.

The Circuit

Fig. 1 is the schematic diagram of the meter. The positive battery terminal and one end of the coil are directly grounded, which simplifies the metering circuit. A Pierce crystal oscillator is used because it does not require a tuned circuit. Other oscillators require tuned tank circuits that must be switched, increasing complexity and cost. The oscillator FET source resistor value was found experimentally. This value produces the cleanest waveform; it is free from harmonics that can produce false meter indications. A capacitive voltage divider is used as an interstage coupling network, employing a small input capacitor to minimize oscillator loading and a large output capacitor to reduce amplifier drive. With the amplifier operating in the linear mode, the chance for spurious meter indications is further reduced. An unbypassed source resistor in the amplifier stage reduces distortion and increases the effective drain resistance, reducing the load on the output circuit. This increases the tuning sharpness. A 1N34A germanium diode rectifies the rf energy, which is then displayed on a sensitive μA meter.

Measuring Inductance

To measure inductance, the unknown coil is connected, the instrument is energized, and the variable capacitor is tuned until the coil resonates; this is indicated by a peak in the meter reading. If it does not peak, the crystal is switched and the unit is tuned again. At resonance, the inductance in microhenrys is $1000/C_{pF}$ when using the 5033-kHz crystal; and $100/C_{pF}$ for the 15,915-kHz crystal.

Instrument accuracy is limited by crystal tolerance and the variable capacitor calibration. Crystal frequency accuracy far exceeds the dial calibration accuracy, so low-tolerance crystals make economic sense.[2] The specified capacitor has semi-circular plates and a capacitance range from 10- to 365-pF, which is close to 2 pF-per-degree of shaft rotation. Accuracy adequate for amateur purposes may be obtained by dividing the dial in increments of 10 pF, or 5 mechanical degrees, by means of a protractor. Accent the 50-pF points and label the 100-pF points to make the dial easily readable.

A correction for amplifier output capacitance, including the rectifier diode and strays, may be made by resonating a standard 5-μH coil, using the 1000 switch position and setting the variable capacitor to read 200 pF.[3] Since the capacitance variation is linear with shaft rotation, calibration will be correct throughout its range.

Measuring Capacitance

To measure capacitance over the range of 10 to 333 pF, set the crystal switch to 1000 and resonate a 3-μH coil with the variable capacitor; note the dial reading.[4] The unknown capacitor is then connected across the coil, and resonance is established by tuning the variable capacitor. The difference between the two capacitor-dial readings is equal to the unknown capacitance, within the dial calibration accuracy. Frequency has no effect as long as it is constant; with crystal control this is no problem.

Construction

The mechanical layout of the circuit is not critical. As with all rf gear, use short, direct leads, with the output circuits separated from the input to prevent spurious oscillations. I used Vectorbord®, supported by the capacitor frame, to mount the rf circuits. The crystals were "epoxied" to the board with the pins protruding through, and wires were soldered directly to the pins. Amplifier output capacitance should be minimized by keeping leads short and away from grounded objects. I installed the circuit, including a surplus 3-1/2-inch meter and battery, in a steel sloping-front cabinet, as shown in Fig. 2.

Conclusions

There are a number of practical uses for

[1]Notes appear on page 27.
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LCM2

a fast and simple inductance meter. Rather than fiddle with inductance formulas or calculators, it is much easier to wind too many turns on a form and measure the inductance, then remove turns until the desired value is reached. This is especially true for slug-tuned and toroidal coils when the permeability is not known.

Capacitors are usually labeled with their value, which negates the need for a capacitance meter. With time, however, labels deteriorate and capacitors open, leak or short. If the builder uses old or surplus stock, measurement may be the only way to go.

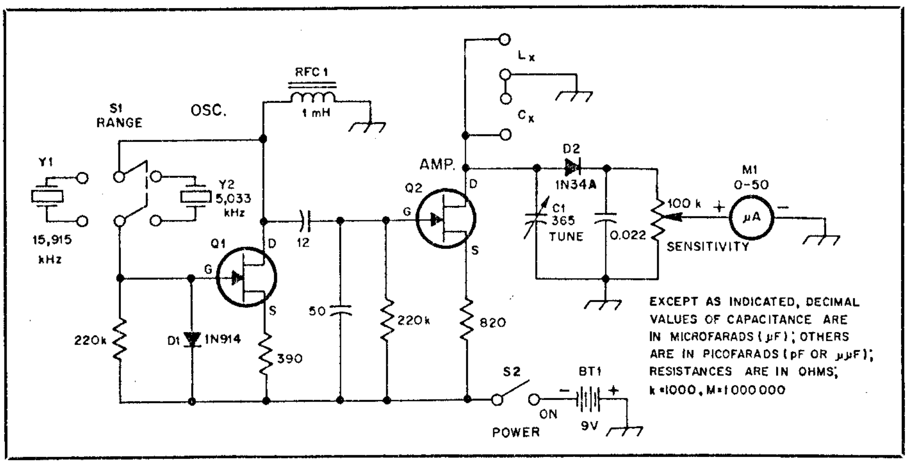


Fig. 1 — Schematic diagram of the L-C Meter. Resistors are carbon composition, 1/4- or 1/2-W; capacitors are disc ceramic, 100-V units.

C1 — 10- to 365-pF variable capacitor. See text for details.
D1 — 1N914 silicon switching diode.
D2 — 1N34A germanium point-contact diode.
M1 — Small dc meter, 50 μA.
Q1, Q2 — Silicon JFET, Radio Shack 276-2035 or equiv.
Y1* — 15,915-kHz quartz crystal, 32-pF loading, HC6/U holder, ICM type 434115 or equiv.
Y2* — 5033-kHz quartz crystal, 32-pF loading, HC6/U holder, ICM type 433115 or equiv.
*The exact crystal frequencies may be found by using the following equations:

$$Y1 = \frac{10^5}{2\pi} \text{ kHz}$$

$$Y2 = \frac{10^4\sqrt{10}}{2\pi}$$

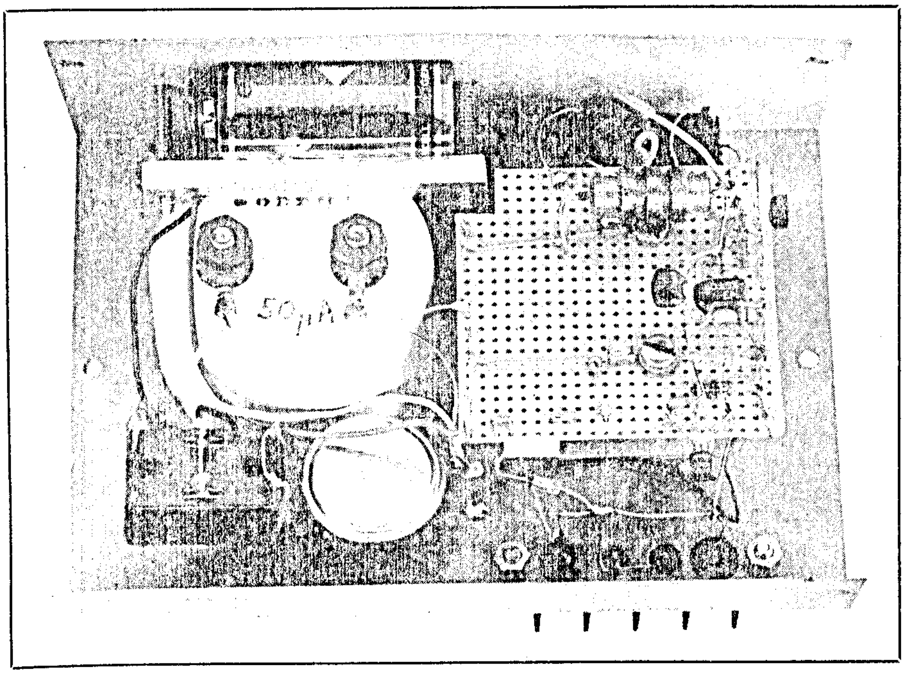


Fig. 2 — Interior view of the L-C meter.

Notes

[1]From the resonance formula

$$L = \frac{1}{\omega^2 C} \quad \text{(Eq. 1)}$$

we require that

$$L = \frac{10^{-N}}{C} \quad \text{(Eq. 2)}$$

where N is any integer.

From the above

$$\omega^2 = 10^N \quad \text{(Eq. 3)}$$

so that

$$\omega = 10^{N/2} \quad \text{(Eq. 4)}$$

If N is an even number, N/2 is an integer, which we will call M. Then

$$f = \frac{10^M}{2\pi} \quad \text{(Eq. 5)}$$

f will have the number sequence of $1/2\pi$; the decimal position will be determined by M.
If N is an odd number, N − 1 is an even number that we will call P. Then

$$\omega^2 = 10^P \times 10^1 \quad \text{(Eq. 6)}$$

$$\text{and } \omega = 10^{P/2} \times 10^{1/2} \quad \text{(Eq. 7)}$$

But P/2 is an integer, which we will call K. Then

$$\omega = 10^K \sqrt{10} \quad \text{(Eq. 8)}$$

and

$$f = \frac{10^K \sqrt{10}}{2\pi} \quad \text{(Eq. 9)}$$

f will have the number sequence of $\sqrt{10}/2\pi$; the decimal position will be determined by K.
[2]The crystals are general-purpose (GP) types available from International Crystal Mfg., 10 North Lee, Oklahoma City, OK 73102.
[3]For details describing the 5-μH coil, see recent editions of the *ARRL Handbook* under Dip Meter, Measuring inductance and capacitance.
[4]I used a home made, 3-μH coil, consisting of 11 turns of number 20 tinned wire, with a total length of 5/8-inch. The exact value of this inductor is not critical, but the tank should resonate within a dial reading of 300 to 350 pF.

Strays

I would like to get in touch with . . .

☐ anyone having an instruction manual and circuit diagram for an OS-8C/U Navy Department oscilloscope, manufactured by Jetronic Industries, Inc., Philadelphia. Leo H. Hansen, WB0TDU, Star Rte., Box 2032, Virginia, MN 55792.

☐ other amateurs who are involved in the emergency services field, particularly EMTs and paramedics. Jeff Howell, WB9PFZ, P.O. Box 463, Madison, IN 47250.

☐ University of Texas alumni who are hams, to join the UTARC as associate members. Lee Murrah, WD5CID, 5303 Scenic View Dr., Austin, TX 78746.

☐ any hams who were cadets at the Florida Military Academy in St. Petersburg. H. Vandergrift, WA4WME, 2308 Zinnia Ct., Killeen, TX 76541.

***QST* congratulates . . .**

☐ Frank Thornburgh, WA6GYR, of Pleasant Hill, California, on being appointed as a communications specialist at the Federal Emergency Management Agency (FEMA) Region IX Headquarters.

Measure or Match Capacitance with a 555 IC

There are occasions when it is desirable to know the value of a capacitor to better than its tolerance value. In addition, the calibration of homemade capacitance meters requires several capacitors of known value. It is possible to determine the values of capacitors using a 555 IC, a few resistors and a scope or frequency counter. See the references at the end of this article.

The 555 IC is connected as an astable multivibrator. See Fig A. The frequency and period of the multivibrator may be calculated from the equation:

$$f = 1/T = \frac{1.443}{(R_1 + 2R_2)C} \quad \text{(Eq 1)}$$

where
f is the frequency in hertz
T is the period in seconds
R_1 and R_2 are in ohms
C is in farads

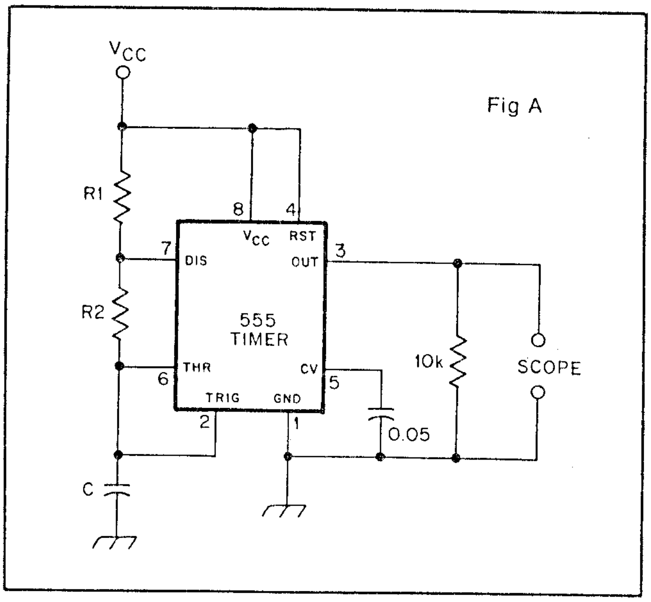
If R_1 and R_2 are known, and the period T measured with a scope, the capacitance is calculated:

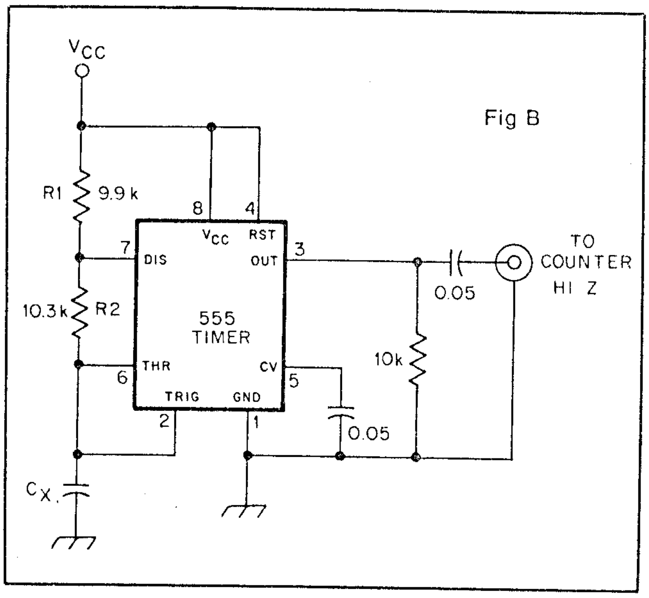
$$C = \frac{1.433T}{(R_1 + 2R_2)} \quad \text{(Eq 2)}$$

If the frequency of the multivibrator is measured with a digital counter, the capacitance may be calculated from

$$C = \frac{1.443}{(R_1 + 2R_2)f} \quad \text{(Eq 3)}$$

Note that the value of the supply voltage does not enter into the calculation. Changing the supply voltage from 5 to 9 or 12 V had no observable effect on the value of T.





I tested several capacitors to determine if using this method would be better than using a commercial capacitance meter. Table 1 lists the results of those tests.

A solderless breadboard was used to assemble the circuit. Using a perfboard would probably result in less stray capacitance. When the 0.0001- and 0.0004-μF capacitors were measured with R_1 = 9900 ohms and R_2 = 10,030 ohms, the calculated values were considerably off. Changing the resistor values to those shown in Table 1 resulted in satisfactory measurements. An early version of the 555 IC, limited to about 100 kHz, was used. Later CMOS 555s have an upper limit of 2 MHz and will provide a greater measurement range.

The circuit in Fig B was used to evaluate the possibility of using a frequency counter instead of a scope. This configuration showed promise for matching capacitors. The frequency readout provides a quick means of selecting capacitors for best matching within the tolerance range. The percentage of difference between the frequencies observed is equal to the percentage of difference between the capacitors.

While the value of capacitance measured with the 555 IC is not as accurate as a commercial capacitance meter, it is more accurate than the marked value. Capacitance values obtained by this method should be accurate enough for calibrating homemade capacitance meters. The method also offers a quick and easy method for selecting matched capacitors when used with a frequency counter.—*Harold C. Anderson, NØBX, 737 Forest Dale Rd, New Brighton, MN 55112*

Table 1
Capacitance Measurement Comparison

Marked Value on Capacitor (μF)	*Measured with a Commercial Meter (μF)*	*Calculated from the Measured Value of T (μF)*
25.0	25.2	25.67
1.0	1.338	1.4738
0.1	0.1010	0.10114
0.1	0.1042	0.1122
0.04	0.0425	0.04335
0.03	0.0282	0.0288
0.01	0.01079	0.0173
0.002	0.00182	0.00193
0.0004	0.000396	0.0004218
0.0001	0.000094	0.0000917

The 25-μF capacitor was measured with R_1 = 468 Ω and R_2 = 468 Ω. The scope was not a storage type, so the sweep rate was speeded up to read T. Capacitors between 1.0 and 0.002 μF were measured with R_1 = 9900 Ω and R_2 = 10,030 Ω. The 0.0001- and 0.0004-μF capacitors were measured with R_1 = 1.022 MΩ and R_2 = 1.017 MΩ. Resistances were measured with a digital ohmmeter. A stray capacitance of 0.000005 μF was measured by leaving the unknown capacitor out of the circuit when T was measured. T was again measured with the unknown capacitor and the stray in parallel, and the stray capacitance was subtracted to determine the value in column 3.

References
Berlin, H. M., *The 555 Timer Applications Source Book,* Indianapolis: Howard W. Sams & Co, Inc.
Gilder, J. H., *110 IC Timer Projects,* Rochelle Park, NJ: Hayden Book Co.
Neben, H. M., "A Simple Capacitance Meter You Can Build," *QST,* Jan 1983, p 34.