Number 12 on your Feedback card

A Direct-Reading Linear Inductance Meter

Check out your coils with a digital voltmeter.

by Arthur C. Erdman W8VWX

The meter described here allows you to use an inexpensive digital voltmeter (DVM) to directly display inductance in microhenries. The basic principle of operation is that *the width of a pulsed voltage is directly proportional to inductance.* The DVM reads the average (direct, or DC) value. Inductor resistance degrades the linearity (stray capacity has minimal effect), but the circuit constants are such that if measurements are limited to about 250 mV (and 250 µH), the linearity is excellent.

One integrated circuit chip is used for the circuit. One 9-volt transistor radio battery and a 5-volt regulator make up the power supply. A line-powered supply could be used. There are no special construction problems.

The main component is a 14-pin integrated circuit (IC) chip, 74HC132 (the 74HC132 and the RF choke coils are available from Mouser Electronics, 2401 Highway 287 North, Mansfield TX 76063, phone (800) 346-6873). The IC consists of four two-input NAND gates. The IC also has what are called Schmitt inputs. The Schmitt circuits trigger the NAND gates at precise voltage levels.

The complete circuit for the inductance meter is shown in Figure 1. NAND 1 generates the square wave. NAND 2 is an isolation stage. NANDs 3 and 4 produce the desired output pulsed voltage. One input of each NAND is connected to +5 volts. The NANDs operate as inverters. The pulse width is equal to the time it takes the voltage across the unknown inductor to fall from 5 volts to the lower triggering level (about 1.8 volts at room temperature).

Construction

The only construction caution is to try to keep the internal leads to the inductance terminals as short as possible. In my unit, the combined length of the two leads to the terminals is about four inches. I selected 5 µH as a minimum reading. These leads do not cause much unwanted inductance compared with the minimum.

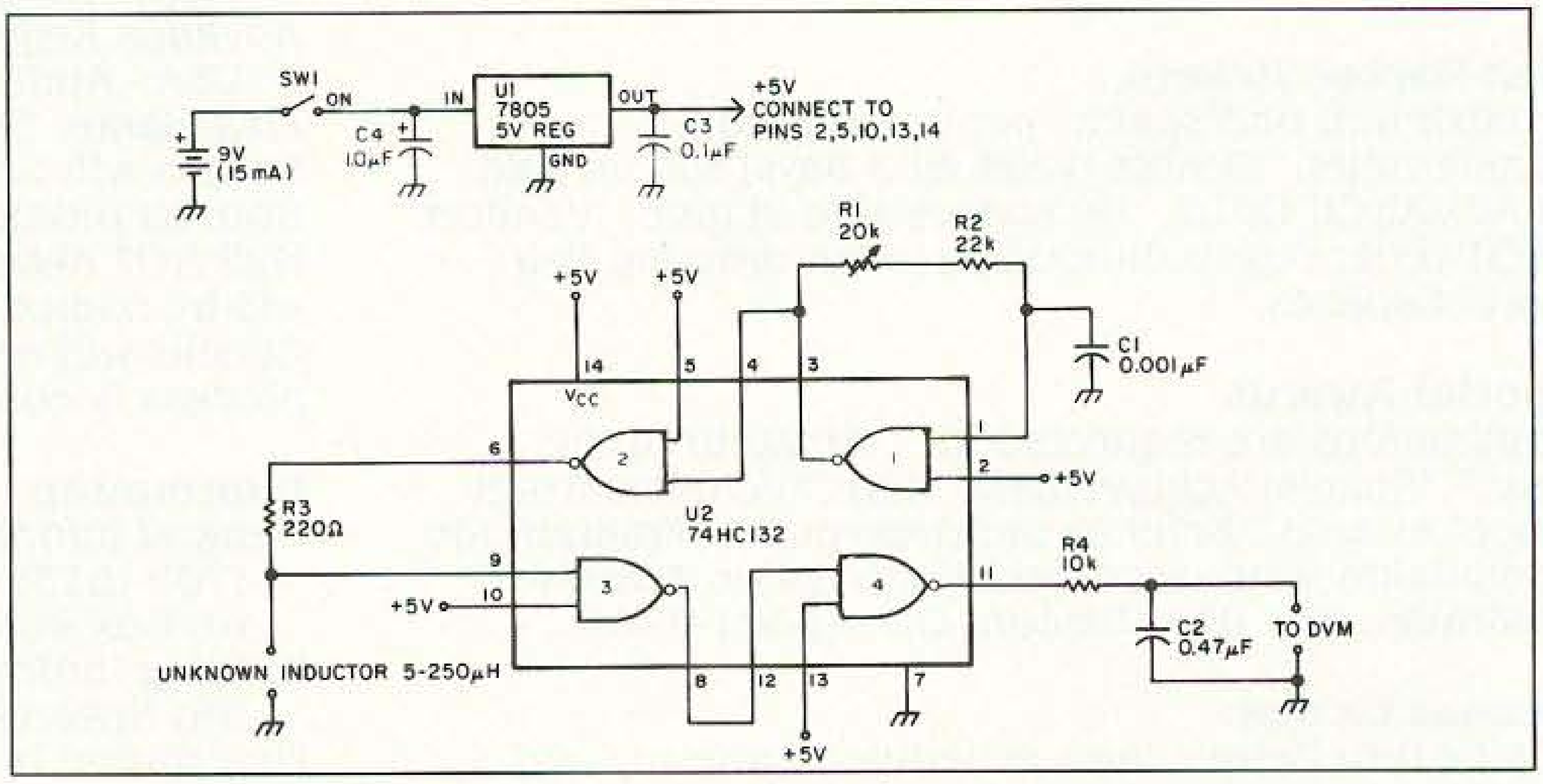

Figure 1. Direct-reading inductance meter.

Calibration

Known-value inductors (5% tolerance) are available from Mouser Electronics for about $1 each.

To calibrate, connect a known-value inductor that has a value close to 250 µH (220 µH inductors are available). If a 220 µH part is used, adjust R1 for an output reading of 220 mV. No other adjustments are needed. If you have other known-value inductors less than full-scale, check the linearity. Don't forget that your inductors have, at best, a 5% tolerance. If you have measured the inductance of an inductor using the inductor in an oscillator circuit, the error in measurement is related to the ratio of fixed external capacitance to the inductor's stray capacitance. The value found by that method is the APPARENT inductance. The value is higher than the true self-inductance. The measuring method used in our unit measures closer to the true self-inductance. (Capacitive effects are minimal.)

This unit will measure inductances from 5 µH to 250 µH. While readings greater than 250 mV are possible, the linearity becomes poor.

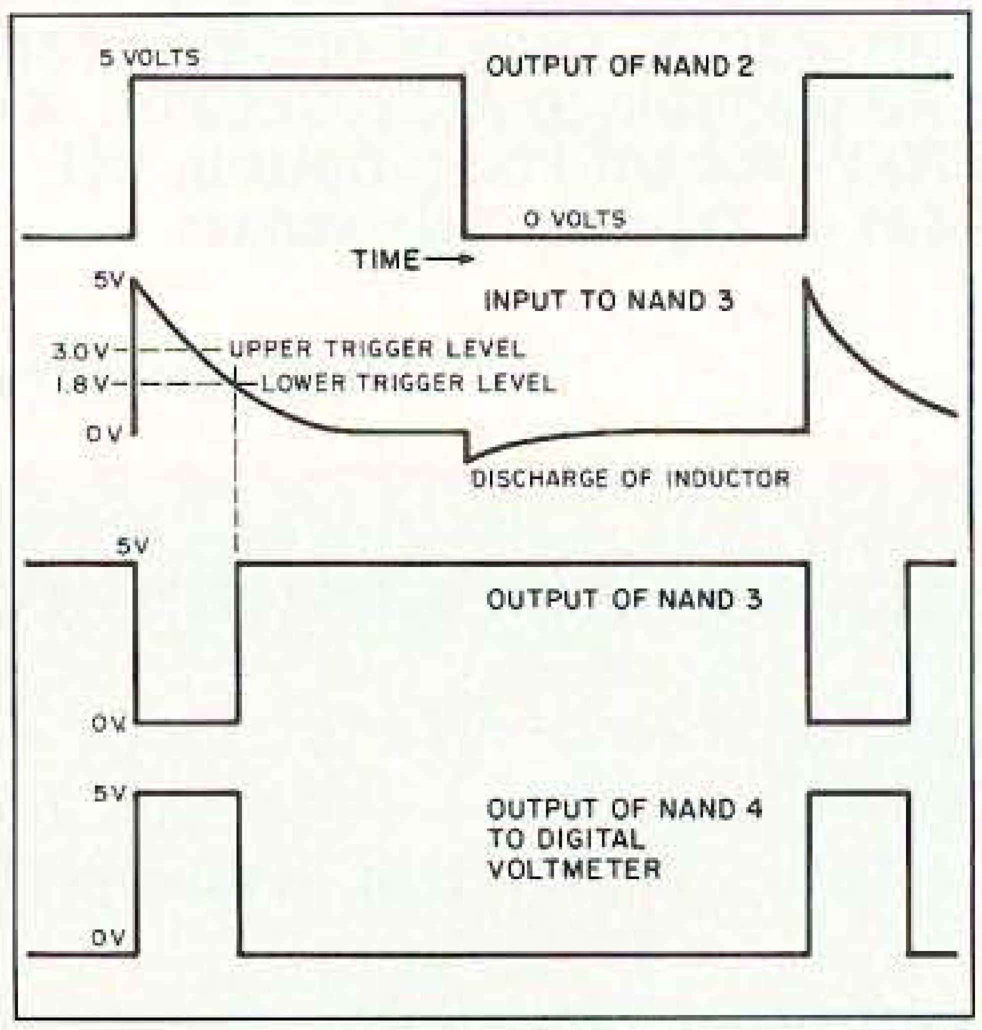

Figure 2. Voltage waveforms for the inductance meter.

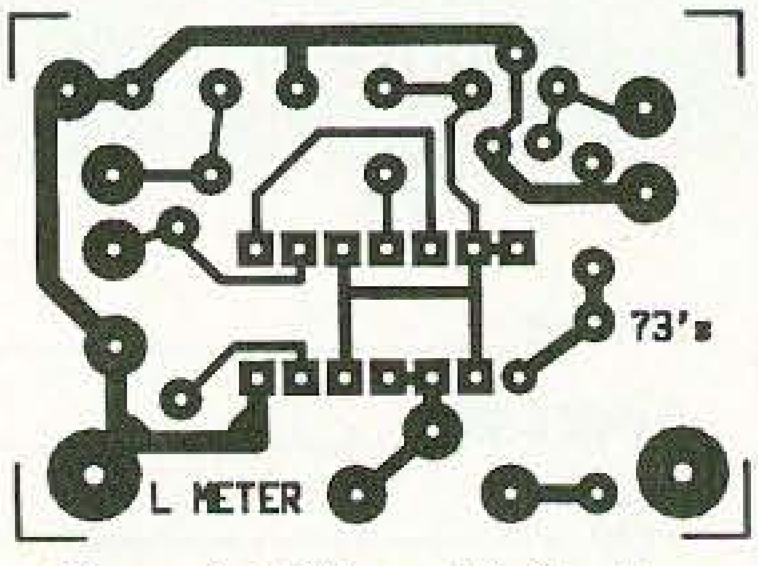

Figure 3. PC board foil pattern.

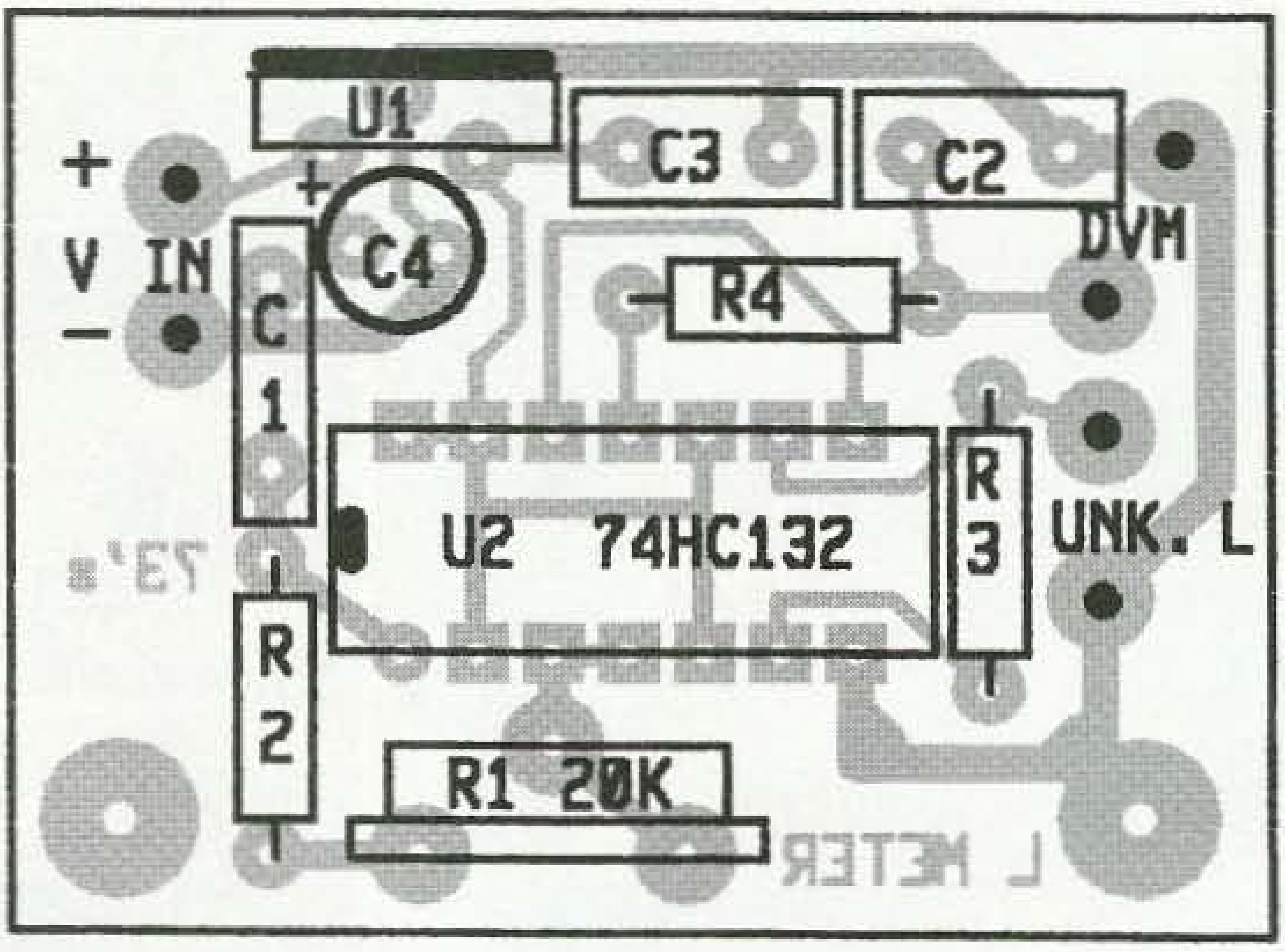

Figure 4. Parts placement.

Theory of Operation

Figure 2 indicates the waveforms of the voltages present. At the instant the input square wave goes positive (5V), so does the voltage across the inductor. The NAND trigger level is about 3 volts, therefore the NAND 3 output goes LOW (inverter action) while NAND 4 output goes HIGH. When the voltage across the inductor decays to the lower triggering level (1.8V), NAND 3 goes HIGH and NAND 4 goes LOW. In other words, an output pulse is formed. We will be show that the pulse width is directly proportional to inductance.

Examine Equation 1 and Equation 2 to see the linearity, in spite of the fact that the inductor voltage dies exponentially.

Assume no coil resistance. R = external resistance

Equation 1: $V_L = 5e^{-(RT_w)/L} = 1.8V$

T_W is the time it takes the inductor to go from 5 to 1.8 volts. Re-arrange Equation 1 and take the natural log.

Equation 2: $T_W = (L/R)\ \mathrm{LN}\ (5/1.8)$

L is in microhenries, R is in ohms, T_W is in microseconds, and LN is the natural log 1.022.

All the terms in Equation 2 are constants. Therefore, the pulse width, T_W, is a linear function of inductance.

The equation for the average (DC) voltage of a rectangular pulse is: (T_P = time of square wave)

Equation 3: $V_{AVG} = (T_W/T_P) \cdot \text{height of pulse } [5V]$

Equation 4: $f(MHz) = 1/T_P$
(T_P in microseconds)

Equation 5: $V_{AVG} = 5 \cdot T_W(f)$
(T_W in microseconds, f in kHz, V_{AVG} in mV)

From Equation 5, if T_W is a linear function of inductance then average voltage is also a linear function. Experimentally (using a scope), we found that the effect of stray capacitance is greatly reduced if the resistor, R3, is about 250 ohms. Values of R3 much higher than 250 ohms prevented the inductor voltage from reaching 5 volts due to stray capacitance. As a result, linearity suffered. I used a 220 ohm for R3. If R3 is much lower than 220 ohms, the battery current is too high and linearity becomes poorer due to the longer time constant (L/R). The time constant must be short enough so that the inductor voltage falls to nearly zero every positive half cycle of the square wave. I added an RC filter on the output so that the frequency response of your particular DVM won't matter. (My DVM is a Micronta 22-188 from Radio Shack.) The DVM should have about 1 megohm input impedance.

Parts List

C1	0.001 µF, 16V or higher
C2	0.47 µF
C3	0.1 µF capacitor
C4	1.0 µF/35V tantalum or electrolytic
R1	20k pot
R2	22k
R3	220 ohm ¼W
R4	10k ohm ¼W
R5	22k ohm ¼W
U2	74HC132 integrated circuit
U1	7805 5-volt regulator

A blank PC board is available for $3 + $1.50 shipping per order from FAR Circuits, 18N640 Field Court, Dundee IL 60118.

There are many possible variations in the value of R3 and the frequency of the square wave. However, due to the wide variation in the stray capacitance and DC resistance of inductors in the mH range, linearity is seriously degraded. Consequently, no attempt was made to include readings above 250 µH.

Readers will probably determine that the same circuit, with only a few minor changes, could be used to measure capacitance. True, and I have already built one, but there are so many capacitance meters out there that I decided to drop that feature and reduce the complexity by not adding more adjustment pots and switches.

Contact Arthur C. Erdman W8VWX at 224 Chaucer Court, Worthington OH 43085. Please enclose an SASE.