RF INDUCTANCE METER

J. Bareford

It is a downright shame not to be able to use many of your inductors simply because their value is not known. First in a new series of budget test equipment for the home constructor, the RF inductance meter leaves coloured bands and unfamiliar codes on high-frequency inductors for what they are, and gives a reliable indication of inductance as well as relative *Q* (quality) factor on an analogue scale. The usable range extends from about 50 nH to 4 mH.

The present inductance meter is intended for high-frequency inductors, and for this reason it is based on a measuring method rather different from that of the digital inductance meter described in Ref. 1.

The principle adopted here is applying a known frequency to an *L-C* tuned circuit of which the inductance, *L*, is unknown, and the capacitance, *C*, is variable but calibrated. At a certain value of *C*, the tuned circuit resonates, which is detected by means of a signal rectifier. The value of *C* required to achieve resonance at the known test frequency provides a measure of the inductance, which can be read off as the relative setting of the variable capacitor. The resultant voltage across the *L-C* combination provides a measure of the relative loaded *Q* (quality) factor of the inductor under test: the higher the *Q* factor, the higher the resonance voltage.

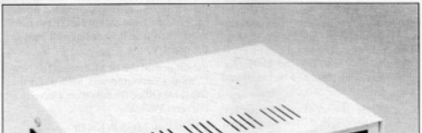
Circuit description

The circuit diagram of Fig. 1 may conveniently be divided into five functional parts.

To begin with, there are two clock oscillators. One, a 7.5 MHz oscillator is set up around quartz crystal X_2 and low-power Schottky inverter N_5. The other, set up around N_1 and X_1, oscillates at 24 MHz, or about $\sqrt{10}$ times 7.5 MHz. The ratio of $\sqrt{10}$ ensures the correct scale factors for the ranges of the instrument.

The second functional part of the circuit is formed by dividers IC_2 and IC_3. Circuit IC_2, a Type 74HCT390 dual decade counter, is driven by the 24 MHz clock signal, and supplies 2.4 MHz (divide-by-10) at output QA1, and 240 kHz (divide-by-100) at output QA2. The second divider, IC_3, is a decade counter Type 74HCT4017. It is driven by the 7.5 MHz clock signal, and supplies 750 kHz (divide-by-10) at the $\overline{\text{CARRY OUT}}$ ($\overline{\text{CO}}$) pin.

Five HCMOS bus drivers and associated double *L-C* band-pass filters form the third functional block. Impedance matching resistors are fitted between the buffers and the filter inputs. Each band-pass filter is accurately tuned to its input signal frequency to prevent the inductor under test resonating at an harmonic of the test frequency, which would cause too low inductance values to be indicated.



The fourth block is formed by range selector S_1 and wideband push-pull amplifier T_1-T_2. The available ranges and associated multipliers are shown inset in the circuit diagram, and on the front panel of the instrument.

The last functional block consists of the inductor under test, L_x, and the signal rectifier, D_4-C_{34}. The high signal levels used for testing inductors allow a fairly simple rectifier to be used in combination with a common 100 µA moving-coil meter, M_1. L_x is made to resonate with the aid of tuning capacitor C_{33} which is shunted by trimmer C_{32} for calibrating the instrument.

The 5 V regulated power supply around IC_5 is entirely conventional. Permissible unregulated input voltages from a mains adapter lie between 9 V and 12 V. Current consumption is about 190 mA, so that a 250 mA mains adapter may be used.

Construction

Anyone with some experience in electronic construction should be able to build the inductance meter without undue problems. This is mainly by virtue of the double-sided printed-circuit board shown in Fig. 2, which helps to obviate awkward problems with stray inductance, shielding and wires.

The PCB has a large copper surface at the component side to ensure proper screening and decoupling (remember that relatively high signal frequencies are involved). Component terminals inserted in a PCB hole without a white overlay spot are soldered direct to the ground surface at the component side.

Start the construction with fitting the resistors, inductors and diodes. Next, fit the capacitors in the filter sections at the centre of the board. Mount the transistors, trimmer C_{32} (two pitches are allowed; be careful not to overheat the device), and regulator IC_5 (bolt this direct on to the board).

Do not use sockets for the integrated circuits. Study the orientation of the chips, insert them, and solder the following pins direct to the ground plane at the component side:

IC_1: pins 3, 7 and 9;

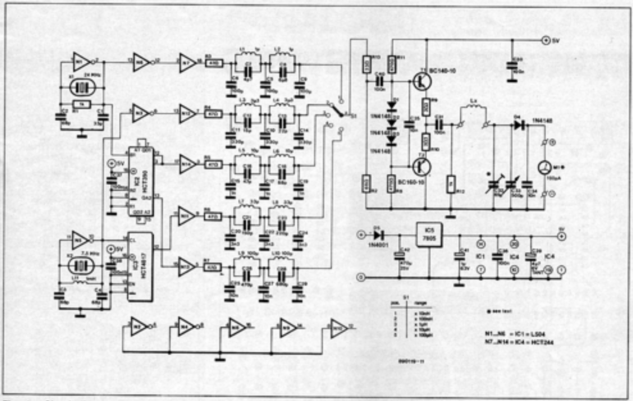


Fig. 1. Circuit diagram of the inductance meter for high-frequency coils.

IC_3: pins 13, 11 and 7;
IC_2: pins 12, 2, and 7;
IC_4: pins 1, 10 and 19.

Then fit the remainder of the components. Do not attempt to solder the enclosures of the quartz crystals to ground, and be sure to use a *PCB-mount* rotary switch — panel-mount types with wires result in too much stray inductance.

The tuning capacitor is a 500 pF mica or PTFE foil type as used in inexpensive MW and SW radios. Mount it at the track side of the board, and use short wires to reach the solder islands (the maximum wire length is about 15 mm). If the tuning capacitor has a separate ground terminal, this must be connected to the grounded solder spot also. The photograph of Fig. 5 shows the completed board.

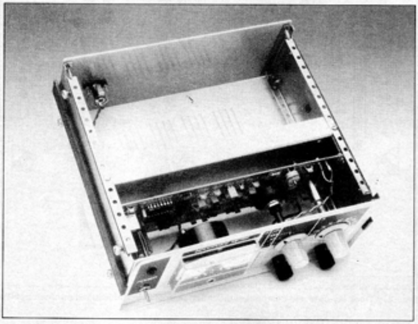
The inductance meter is housed in an ivory white, steel sheet enclosure Type LC850 from Elbomec/Telet. The front and rear panels are made of aluminium. Two side brackets with rows of holes are provided to enable circuit boards mounted in the enclosure to be removed without the need of having to disassemble the box completely.

The front-panel foil for this project is not available ready-made, but its true-size lay-out is given in Fig. 3. Copy the drawing and use it to drill and cut the holes in the front panel of the enclosure. Do not spoil the appearance of the instrument by using the screws provided to secure the aluminium front panel. Instead, use double-sided tape or glue.

Use 20 mm long PCB spacers to mount the completed PCB on to a U-shaped aluminium support bracket (see Fig. 4).

Now fit the moving-coil meter into its front panel clearance, and determine how much space you want to leave between the rear of the meter and the components on the PCB. Insert the support bracket with the PCB on it between the side bars, and shift it forward until the holes in the support bracket align with the holes in the side brackets of the enclosure. Depending on the mounting depth of your panel meter, the fifth or sixth hole from the front of the side brackets should be used. Now mount the front panel and pass the spindles of the range switch and the tuning capacitor through the relevant holes. Determine the length of the spindles required to fit the knobs, and remove the front panel. Use a vice to cut the spindles to the required length.

Mount the POWER LED in a holder. In-



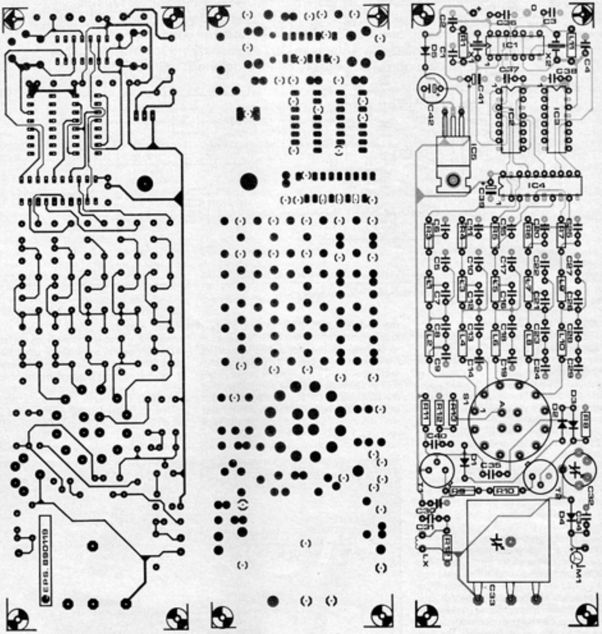


Fig. 2. Track lay-outs and component mounting plan of the double-sided printed-circuit board for the RF inductance meter.

Parts list

Resistors:

R_1;R_{12} = 1k0
R_2 = 68Ω
R_3–R_7 = 47Ω
R_8;R_{11} = 470Ω
R_9;R_{10} = 3Ω3
R_{13} = 33Ω

Capacitors:

All ceramic capacitors are 5-mm pitch
C_1 = 33p ceramic
C_2;C_3;C_4;C_{18} = 68p ceramic
C_5;C_6;C_9 = 100p ceramic
C_7 = 4p7 ceramic
C_8 = 6p8 ceramic
C_{10};C_{11};C_{14} = 330p ceramic
C_{12} = 15p ceramic
C_{13} = 22p ceramic
C_{15};C_{17};C_{19} = 1n0 ceramic
C_{16} = 47p ceramic
C_{20};C_{22};C_{24} = 3n3 ceramic
C_{21} = 150p ceramic
C_{23} = 220p ceramic
C_{25};C_{27};C_{29} = 10n ceramic
C_{26} = 470p ceramic
C_{28} = 680p ceramic
C_{30};C_{31};C_{36};C_{37};C_{38};C_{40} = 100n
C_{32} = 60p trimmer
C_{33} = 500p mica-foil tuning capacitor
C_{34};C_{35} = 10n
C_{39} = 4μ7; 6 V; tantalum
C_{41} = 1μ0; 63 V; radial
C_{42} = 470μ; 25 V; radial

Semiconductors:

D_1–D_4=1N4148
D_5 = 1N4001
T_1 = BC140-10
T_2 = BC160-10
IC_1 = 74LS04 (do not use HC or HCT versions)
IC_2 = 74HCT390
IC3 = 74HCT4017
IC_4 = 74HCT244
IC_5 = 7805

Inductors:

All inductors are axial types
L_1;L_2 = 1μH0
L_3;L_4 = 3μH3
L_5;L_6 = 10 μH
L_7;L_8 = 33 μH
L_9;L_{10} = 100 μH
L_{11} = 1mH0

Miscellaneous:

S_1 = 5-way, single-pole rotary switch for PCB mounting.
X1 = 24 MHz quartz crystal (3rd overtone; 30 pF parallel resonance).
X2 = 7.5 MHz quartz crystal (fundamental frequency; 30 pF parallel resonance).
M_1 = 100 μA moving-coil meter.
Collet knob with pointer (for range switch).
Collet knob with double pointer (for tuning capacitor).
Solid spindle coupling for tuning capacitor.
Mains adaptor chassis socket.

Enclosure: Telet/Elbomec Type LC850.
Telet srl • Via dell'Intagliatore, 4 • 40138 Bologna • Italy. Telephone: +39 51 534908.
Fax: +39 51 538717.
PCB Type 890119

stall the ON/OFF switch and the two black, insulated wander sockets on to the front panel, then wire these components. The wires between the wander sockets and the PCB terminals marked L_x must be relatively thick, and as short as possible. Do not twist them!

The final assembly and the connecting of wires to the terminal posts on the PCB is straightforward. The rear panel is drilled to accept a mains adaptor socket as

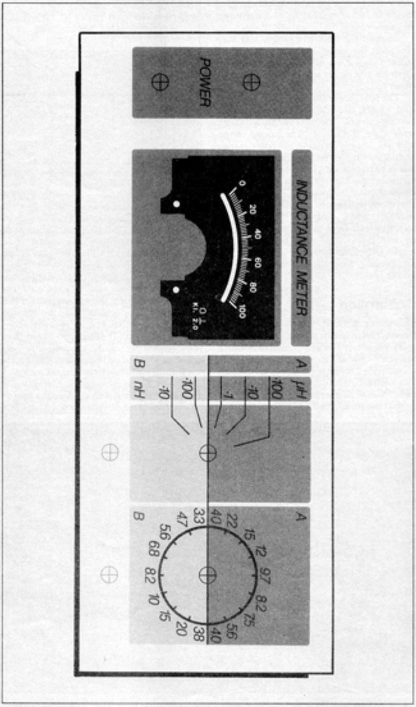


Fig. 3. The front-panel. If possible, the areas marked 'A' should be given a different colour from areas marked 'B' to avoid confusion in the use of the two scales.

used on portable cassette recorders and calculators. Be sure to observe correct polarity!

Practical use

Any inductance measurement must start in the range for the highest inductance values (range switch position 5 in the circuit diagram), i.e., using the lowest test frequency. Do not switch up from the low-value ranges to the high-value ranges — this is likely to cause false readings owing to the inductor resonating at a harmonic frequency.

Start in the ×100 µH range, and turn C_{33} until the meter deflects. Switch to a lower range if the meter does not deflect. Operate C_{33} again until a sharp peak is observed.

The first three ranges, ×100 µH, ×10 µH and ×1 µH, use scale 'A' (4.0–40) of the tuning control. The next range, ×100 nH, uses scale 'B' (3.3–38). The lowest range, ×10 nH, is only suitable for comparative inductance measurements, since the internal capacitance and inductance of the instrument are significant at 24 MHz. The calibration of the lower half of scale 'B' is, therefore, unlikely to be valid for accurate measurements, but still allows comparative tests to be carried out on batches of inductors. Similarly, the maximum meter indication provides a relative, not an absolute, indication of the Q factor in all ranges.

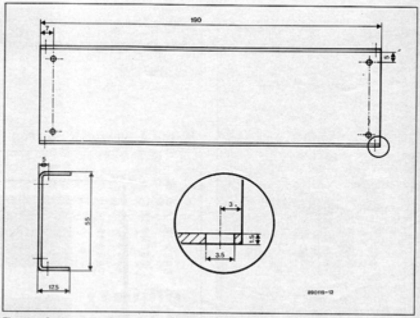


Fig. 4. Construction details of the aluminium bracket that holds the PCB.

Calibration

The meter is fairly simple to calibrate. Connect an inductor whose value is accurately known. If you are unable to obtain a reference inductor, use a ready-made choke with a tolerance of 5% (e.g., Cirkit's FL4 series). A value near the maximum indication within a range must be chosen, so that the tuning capacitor is set to minimum capacitance. This ensures the largest effect of the parallel capacitance formed by trimmer C_{32}. Connect a choke of 220 µH or 390 µH (scale 'A', range ×10 µH), and set the tuning capacitor as accurately as possible to indication '22' or '40' respectively. Carefully adjust trimmer C_{32} for maximum meter deflection. Connect other, but similarly selected, inductors, and repeat the adjustment for the three highest ranges until an acceptable compromise is reached as regards accuracy of the scale. It should be noted that the resolution and repeatability so achieved depend on the accuracy at which the tuning scale has been reproduced.

Finally, some moving-coil meters have such a low internal resistance as to require an external series resistance to be fitted to prevent the needle hitting the right end of the scale when a high-Q inductor is being tested. The value of the series resistor, if required, must be determined experimentally.

Reference:

1. "Self-inductance meter". *Elektor India, October 1988.*

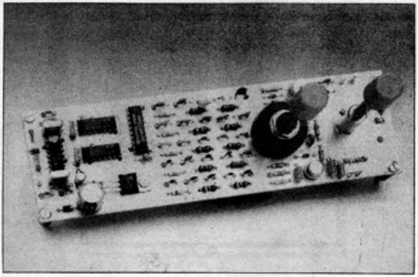


Fig. 5. Completed PCB before installation in the enclosure. Note that a dual-pointer knob is fitted on the spindle of the tuning capacitor.