by JEFF SKEEN

A versatile LCR Bridge

PART 3

—for laboratory & workshop

In this third and final article on our LCR Bridge we present the calibration procedure and give instructions on how to use the bridge in its various measurement modes.

Assuming that you have constructed our new LCR Bridge there remains the final task of calibration. This is a fairly easy and straightforward procedure although care should be exercised since ultimately the accuracy of the bridge depends upon it.

Superficially, a design such as this should have little need for calibration. After all, close tolerance standard components are specified. However, all those switches and wiring inevitably add resistance to the circuit as well as stray capacitance. We have already talked (last month) about the measures used to minimise stray capacitance. Resistance is another matter and is taken into account by the calibration procedure.

The first step then is to adjust the lowest value range resistors, via VR2 and VR3. The procedure requires an adjustable power supply and two multimeters which should preferably be digital types since they have the best resolution and accuracy.

To isolate the range resistors, switch S1 should be set to either the capacitance or inductance position and the wire leading to the 16Ω terminal on the transformer temporarily disconnected. Rotate the wiper screws of both VR1 and VR2 clockwise until "clicks" are heard. This adjusts the trimpots so that maximum resistance is placed in parallel with the range resistors.

Now switch S2 to the "1Ω" range and connect the circuit shown in Fig. 1 to tests points TP1 and TP2. These test points are shown on the circuit diagram on page 46 of last month's issue and on the accompanying wiring diagram on page 47.

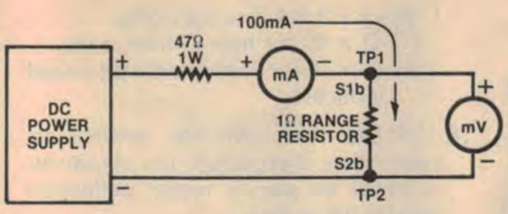

Fig. 1

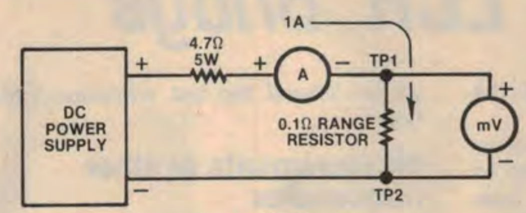

Fig. 2

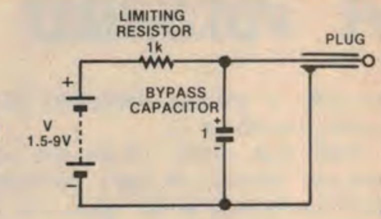

Fig. 3

Switch on the power supply and adjust the output voltage until 100mA flows through the 1Ω range resistor. This will be indicated by the meter which, if it is a DVM, should be set to the 200mA range. Then rotate the wiper screw of VR3 until the voltmeter (DVM set to 200mV) indicates 100mV. It may be necessary to adjust the power supply voltage slightly to maintain the current at 100mA during the adjustment of VR3.

That is all that is required to calibrate the "1Ω" range. The procedure for the "0.1Ω" range is very similar. This time though we use the circuit of Fig. 2 which shows a 4.7Ω/5W resistor instead of a 47Ω/1W resistor.

Set S2 to the "0.1Ω" range and adjust the power supply output voltage to provide a current of one amp through the circuit. If the ammeter is a DVM it should be set to the 2A range. VR2 is then adjusted until the voltmeter again reads 100mV.

This completes calibration of the 0.1Ω range. Remove the circuit used for calibration of the range resistors and solder the lead back on the transformer 16Ω tag.

The next step is to adjust the 1kHz oscillator. Disconnect one of the null meter leads (this spares the meter from possible long periods of overload) and connect a multimeter between ground and the output of IC1c. Set the multimeter to an AC volts range greater than 10V and switch the LCR bridge on (either battery or AC power).

Depending on the initial setting of VR1, the multimeter may or may not indicate a reading. In either case, VR1 should be adjusted so that the multimeter reads zero (ie no oscillation) and then VR1 should be slowly turned until the multimeter reads beween four and five volts. Turn VR1 a shade further to ensure reliable start-up of the oscillator, and adjustment is complete.

If the oscillator refuses to start the most probable reason is lack of range in VR1. Replace VR1 with a 500Ω potentiometer and repeat the oscillator adjustment procedure. If the oscillator still refuses to start, the most likelv cause is incorrect or out of tolerance components in the oscillator circuit. These should be located and replaced.

If you have access to a frequency counter you may wish to trim the oscillator frequency to exactly 1kHz. Adjustments are made by changing the .0018μF capacitor to a higher or lower value. Increasing the .0018μF capacitor to .0022μF will lower the oscillator frequency by about 10Hz while decreasing the capacitor to .0015μF will increase the oscillator frequency by about 10Hz.

The final calibration step involves adjusting out the DC offsets of IC3 and IC4.

Temporarily unsolder the wires leading from S1 to the inputs of IC3 and IC4 and in their place run a wire from each op amp input to a grounded PC pin. Connect a multimeter set to the 200mV range between the grounded PC pin and the output of IC3. Set S1 to the Rdc position, turn the LCR bridge on and rotate the sensitivity control to half maximum. Adjust VR4 so that the multimeter reads zero then increase the sensitivity control to maximum and again adjust VR4 so the multimeter reads zero.

The last adjustment may be a little touchy since with the sensitivity control set to maximum the op amp is amplifying changes in the offset voltage by 150 times. Some small random variations in the output voltage will be noticed at maximum sensitivity. These are due mainly to amplified noise and can be neglected since they will average out to zero.

The multimeter lead should now be swapped over from the output of IC3 to the output of IC4 and the sensitivity control set back to half. The adjustment procedure detailed for IC3 is now repeated for IC4. Following this, the multimeter should be connected between the outputs of IC3 and IC4. With the sensitivity control set to maximum the voltage should be almost zero ie, less than ±3mV (except for small noise variations). Both IC3 and IC4 are now adjusted for minimum offset voltage.

This completes the calibration procedure. The null meter should be reconnected and the grounding wires at the IC3 and IC4 inputs removed and the original wires from S1 reconnected. The final step is to place a small dot of white paint on the digital readout between the first and second digits to act as a decimal point. When turned to the zero position the display should read 0.00. The LCR bridge is now ready to use.

Using the bridge

A bridge such as this may seem a little daunting to use at first when compared to measuring components with digital capacitance meters and the like. Instead of just bunging the component across the terminals you also have to twiddle the dials.

So how do you go about measuring components with the bridge? To make things simple it is a good idea to first rotate the DQ control to its minimum setting. A low setting, almost fully anti-clockwise, should also be used for the sensitivity control. If you use a high setting initially the meter will inevitably be hard off scale.

Incidentally, the meter deflection will always be to the right of zero for AC measurements (AC resistance, capacitance and inductance) but for DC resistance measurements it will swing through zero as the null or balance point is passed. When the meter needle is to the left of zero the resistor value is lower than the bridge setting; when the meter needle is to the right of zero the resistor value is higher than the bridge setting.

So for DC resistance measurements the null condition will be in the centre of the meter scale and the meter pointer will swing either side of zero as the null condition is approached.

For AC measurements the null condition is as close to zero on the meter scale as you can get it and if you are not at the null condition, the meter pointer will be deflected to the right.

Now connect the unknown component to the terminals on the front of the bridge. Make sure that you are making a good connection to both leads of the component. With some types of binding post terminals we have found that the only way to make sure of a good connection is to pass the component leads through the holes in the terminal posts and then screw them up tightly.

Switch the bridge on and rotate the mode selector to C, L or R (AC or DC) depending on the type of component being measured. Set the digital vernier control to about half scale; eg, around 5.00. Now set the sensitivity control to

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provide a modest deflection of the meter, say about 25.

With that done, rotate the range selector through its eight positions to find the setting which gives the least pointer deflection (ie, the closest to zero). Now rotate the vernier control to the setting which gives the minimum pointer deflection. You will find that as you approach this null, you will have to rotate the sensitivity control clockwise to give more meter deflection.

This process is continued until you have the best null condition, ie, the pointer as close to zero as you can get it with the sensitivity control at maximum clockwise setting. Then, and only then, do you try manipulating the DQ control if you are measuring a capacitor or inductor. For the majority of capacitors, with the exception of electrolytics, the dissipation value will be almost negligible.

Once you have achieved the best null possible, you have to read the component value off the bridge. This is done by multiplying the setting of the digital vernier control by the setting of the range multiplier. For example, if the range multiplier is set to "0.1μF" (for capacitance) and the vernier reading is 4.73, the capacitor value is 0.473μF.

If you have used the range extension switch which adds "1.00" to the reading, the previous value would become 5.73 × 0.1μF which equals 0.573μF.

The procedure for measuring resistors and inductors is similar and is outlined in step-by-step form at the end of this article.

Residual capacitance

When measuring capacitors on the 100pF range, the residual capacitance of the bridge must be removed from the reading otherwise an unacceptable error may result. To do this, the bridge is first balanced with the terminals open circuited to obtain the bridge residual capacitance, then the unknown capacitor is measured. The residual capacitance is then subtracted from the bridge reading to obtain the true component value.

The bridge has the option of being powered either by batteries or 12VAC (or both). When AC is connected to the bridge the best null may not be as low as when batteries alone are used. This is due to stray capacitance between the test component, the mains and ground inducing a spurious 50Hz signal across the component. The effects of this signal may be minimised by running a wire between the case of the LCR bridge and mains earth or by placing an earthed screen around the test component (or both).

Measurements at other frequencies

Measurements of capacitance, inductance and AC resistance may be carried out at frequencies other than 1kHz by connecting an audio oscillator with a maximum output of 2V RMS to the EXT AC EXCITATION socket. Be careful not to exceed the maximum signal voltage as this can lead to an incorrect null being obtained. When using frequencies other than 1kHz, multiply the D and Q scales by a factor of f/1000, where f is the signal frequency in Hz.

External bias

A polarising DC voltage may be applied to the capacitor under test via the "Ext DC Bias" socket. Application of a DC bias generally does not cause a large change in capacitance (a 1% change would be typical) unless the bias is left on for a long period. The bias supply needs to have a limiting resistor to prevent possible damage to the range resistors if the capacitor under test becomes short circuit, and a bypass capacitor to allow a low impedance path for the bridge energising signal.

A suitable schematic diagram for the bias supply is shown in Fig. 3. Using the voltage shown, the limiting resistor should be about 1kΩ while the bypass capacitor should be at least the full scale value of the range in use, or 1μF, whichever is larger, and of a suitable voltage rating.

The bias supply is connected so that the tip of the jackplug is connected to positive and the body is connected to negative. When the plug is inserted in the Ext bias socket, the Det +ve terminal of the bridge will be positive with respect to the Det −ve terminal and so the capacitor under test should have its positive lead connected to the Det +ve terminal. To prevent any possiblility of damage to the bridge, the bias supply should be disconnected before changing the bridge configuration or switching the bridge off.

Inductance measurement

1. Connect the unknown inductor between the Det +ve and the Det −ve terminals.
2. Set the component selection switch to inductance.
3. Turn the LCR bridge on.
4. Use the range multiplier switch to select the range in which the inductor value is expected to lie.
5. Set the DQ switch initially to:
   (i) Q × 1 for air cored coils,
   (ii) Q × 10 for high Q filter coils,
   (iii) D × 1 for laminated iron cored inductors.
6. Set the Loss Balance control to minimum, then adjust the sensitivity control to give a meter deflection under full scale.
7. Alternately rotate the digital readout knob and the loss balance control so that the meter deflection decreases. When necessary, increase the sensitivity control to provide a better null indication.
8. When there is no more range left in the sensitivity control, or it becomes impossible to obtain a lower meter deflection, the bridge is nulled. The component value is obtained by mutiplying the dial reading and the selected inductance range together as described previously.

Low Q inductors

For inductors with a Q less than 0.5, the bottom of the null flattens out and it may become impossible to find the minimum null point. This problem occurs mainly with low value RF inductors which have a fairly large series resistance in comparison to their inductance. The problem may often be circumvented by measuring the inductance at a higher frequency, say 10kHz. This raises the Q value by a factor of f/1000 (at 10kHz this equals 10) and so provides a better null.

High Q inductors

If an inductor has a Q higher than 31 at 1kHz it must be measured either at a lower frequency (to lower the Q) or on the D × 1 setting of the DQ switch. In this case, the D value of the inductor is read off the loss balance dial and the corresponding value of Q is found from Q = 1/D. In practice, the value of the loss balance dial will be too small to allow an accurate determination of D and so any calculated Q will be a "ball-park" figure only.

Inductor bias

Due to the non-linear characteristics of iron and ferrite core inductors it is sometimes necessary to know the incremental inductance of a coil at a particular operating point. This is done by using a DC bias current to bring the characteristic to a particular point on the B-H curve while measuring the inductance with a small AC signal.

The circuit shown in Fig. 3 is suitable for providing DC bias currents, the only changes being that an ammeter should be placed between the voltage supply and the limiting resistor to monitor the current and either the limiting resistor or the voltage supply should be made variable so that the bias current can be varied.

AC resistance

1. Connect the unknown resistor between the Det +ve and the Det −ve terminals.
2. Set the component selection switch to AC resistance.
3. Turn the LCR bridge on.
4. Use the range multiplier switch to select the range in which the resistor value is expected to lie.
5. Set the sensitivity control to give a meter deflection of around three quarters full scale.

   There is no need to worry about the settings of the DQ switch and the loss balance control when measuring AC resistance since these controls are switched out of circuit. When measuring high value and wire wound resistors, series inductance and shunt capacitance components will cause the AC resistance (or impedance) to be different to the DC resistance (or marked value). For this reason it is usually better to measure these types of resistors using the DC resistance mode.
6. Rotate the digital readout dial so that the meter deflection decreases. When necessary, increase the sensitivity control to provide a better null indication.
7. When there is no more range left in the sensitivity control, or it becomes impossible to obtain a lower meter deflection, the bridge is nulled. The component value is obtained by multiplying the dial reading and the selected resistance range together as described previously.

DC resistance

1. Connect the unknown resistor between the Det +ve and the Det −ve terminals.
2. Set the component selection switch to DC resistance.
3. Turn the LCR bridge on.
4. Use the range multiplier switch to select the range in which the resistor value is expected to lie.
5. Set the sensitivity control to give a meter deflection of around three-quarters full scale.
6. Rotate the digital readout dial so that the meter deflection decreases. When necessary, increase the sensitivity control to provide a better null indication.
7. When there is no more range left in the sensitivity control or it becomes impossible to obtain a lower meter deflection the bridge is nulled. The component value is obtained by multiplying the dial reading and the selected resistance range together as described previously.

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