Assembly Manual for the

R-L-C BRIDGE

K-3468

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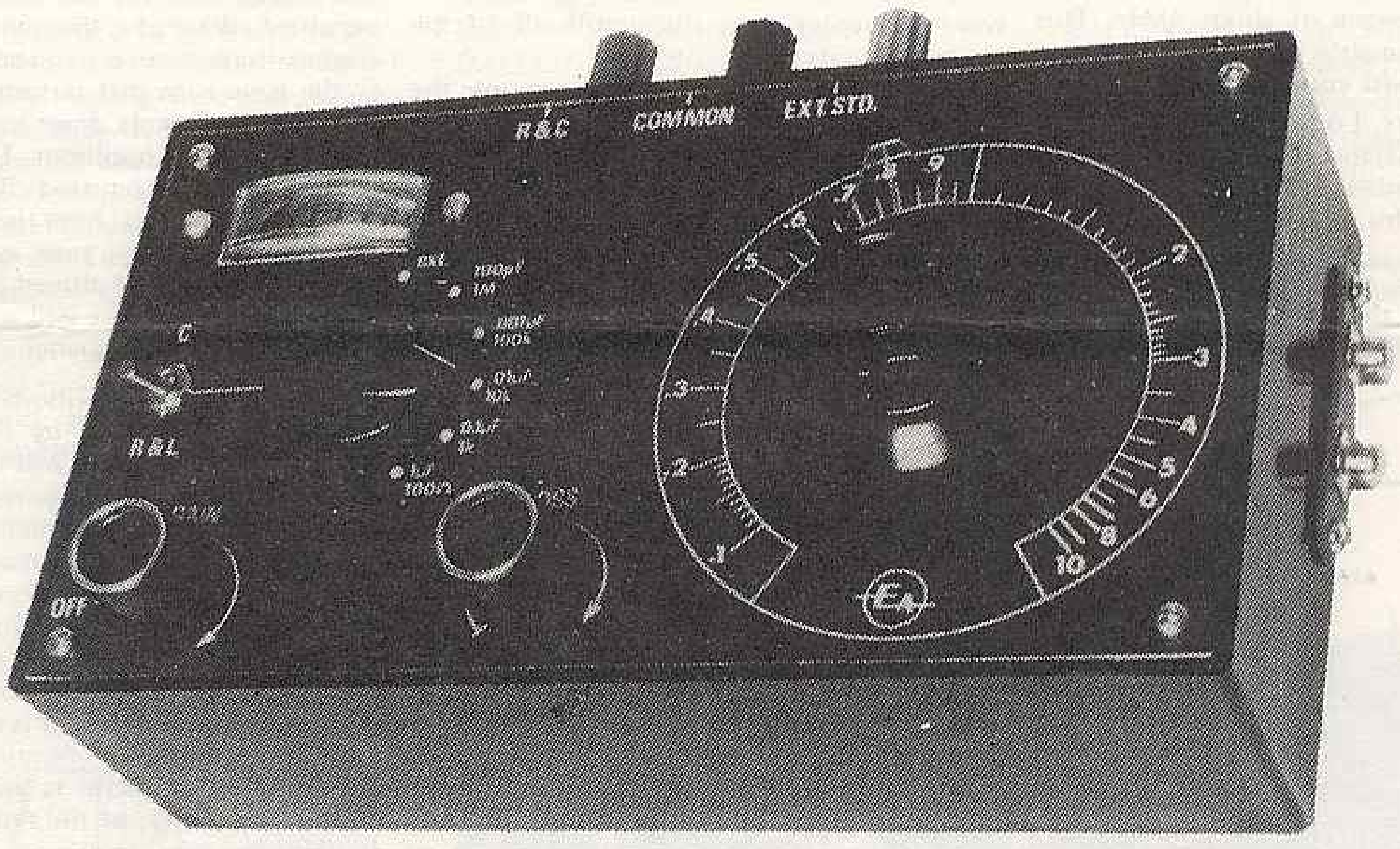


Even in these days of digital instruments, the tried and proven RLC bridge is a handy and easy to use piece of test equipment. It can be used to check the values of new and used components and also to determine the actual value of wide-tolerance capacitors such as electrolytics and ceramics. There are ten ranges on this instrument, enabling measurements from 10 ohms to 10 megohms and from 10 picofarads to 10 microfarads.

Useful measurements can be made on inductors with values down to about a few hundred micro-henries. When making these measurements it may be necessary to connect a 1k potentiometer (connected as a variable resistor) in series with the external standard inductor to balance the series resistance of the unknown inductor.

The principle of operation is simple and is based on the Wheatstone Bridge. This is named after Sir Charles Wheatstone (1802-75) who, while doubtless having independently invented it himself, acknowledged that he was beaten to it by a Mr S. H. Christie, some ten years previously.

Fig. 1 shows the basic Wheatstone Bridge. No doubt many hapless students have come across it in archaic form in ill-equipped science laboratories. It really consists of two voltage dividers strung across a common power supply. The first voltage divider consists of R1 and R2 where the value of R1 is known and R2 is unknown. The second voltage divider is R3 and R4 which in reality are both part of a potentiometer.

In use, the operator adjusts the potentiometer so that no current flows through the null indicator, ie, so that the bridge is in "null". In the old days the null indicator was usually a sensitive mirror galvanometer, but these days it is more likely to be an amplifier driving a milliammeter.

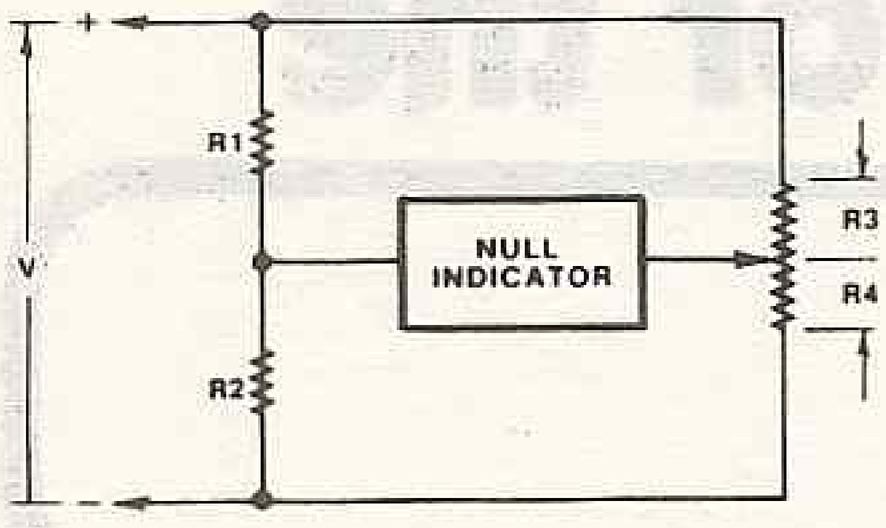
Since no current flows through the indicator when the bridge is in null, this means that the voltages at both sides of the indicator are the same. This means that the ratios of the two voltage dividers are the same. Therefore:

$$\frac{R1}{R2} = \frac{R3}{R4}$$

If we invert both sides of the formula, cross-multiply and divide, we get:

$$R2 = \frac{R1.R4}{R3}$$

Text and illustrations courtesy of Electronics Australia



$\frac{R1}{R2} = \frac{R3}{R4}$, R2 (UNKNOWN) $= \frac{R1.R4}{R3}$

FIG. 1

So that if R1 is the known value (the standard) we can multiply it by the ratio of the potentiometer to find the value of the unknown, R2. In practice, the potentiometer has a calibrated scale and the standard component is a multiple of ten, so that measurements are straightforward and do not require any calculation.

Note that the accuracy of the bridge is not affected by changes in the voltage source or sensitivity of the null indicator, although the "sharpness" of the null will be a function of these two variables.

If capacitors and inductors are to be measured the voltage source must be AC, preferably a sinewave of about 1kHz. This results in a reasonable range of impedance values for the most commonly used capacitors and inductors. Lower frequencies result in very high impedance values for small capacitors, while higher frequencies give very high impedances for inductors of 1 millihenry or less.

For resistance measurements, it is immaterial whether the voltage source is AC or DC, although the null indicator must be designed to suit.

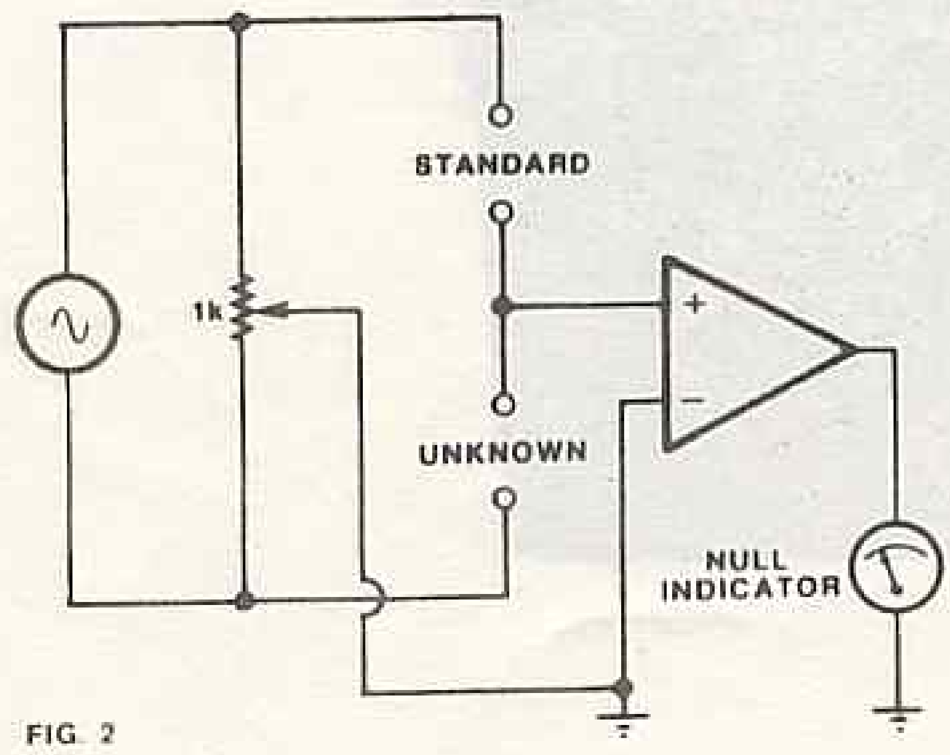


FIG. 2

Fig. 2 shows the Wheatstone bridge concept adapted for measuring capacitors and inductors, as well as resistors. We still have two voltage dividers connected across a voltage source, while the null indicator is schematically shown as an amplifier driving a meter. Not shown is some sort of rectifier which is required between the output of the amplifier and the meter.

There is one more wrinkle. The impedance of capacitors is inversely proportional to capacitance so if the same scale is to be used on the ratio potentiometer, the standard and unknown need to be swapped around for capacitance measurements.

Now if you understand the foregoing discussion we can progress to discuss the complete circuit. If not, I suggest you go back and re-read the foregoing. Fig. 3 on the back page is the complete circuit diagram.

Some of the requirements for the sine wave source for the bridge are that it should have a low output impedance, be completely floating with respect to the null indicator circuitry and require no adjustment. Our circuit, based on 555 and 741 integrated circuits plus a miniature transformer, meets these requirements.

The 555 timer IC is connected to provide a 1300Hz rectangular wave with a duty cycle very close to 50%, ie, it is close to being a perfect square wave. The output of the 555 is fed to a third-order Butterworth filter employing a 741 operational amplifier. It is based on the low-pass filter in the "Active filter unit" featured in the February 1978 issue of "Electronics Australia".

The low-pass filter has a slope of 18dB per octave above the 3dB point at 1kHz. Hence it effectively removes all the harmonics of the square wave. Harmonic distortion of the resulting 1300Hz sine wave is 1.5%, and is predominantly 3rd harmonic. The higher harmonics are masked by residual noise of the circuit.

Readers may wonder why the frequency of the 555 timer is not set at 1kHz to match the nominal 3dB point of the following filter. If this was the case, the filter would be driven into overload because the amplitude of the fundamental frequency in a square wave is greater than the amplitude of the square wave itself.

A small transformer is used to couple the low impedance output of the filter to the bridge circuit. This is necessary because the null indicator amplifier has one side of its input circuit connected to the negative supply rail, and so requires that the bridge have a "floating" voltage source.

The bridge itself is quite straightforward. The ratio potiometer is 1k and has small presets in series to provide for scale calibration. A 2-pole rotary switch S1 selects the standard resistors or capacitors, while switch S2 swaps the standard and unknown arms from one side of the bridge to the other for capacitance measurement. Provision is made for connection of external standards, for things like measurement of inductance.

A potentiometer connected in series with the switching for the capacitance standards allows the loss factor of electrolytic and low voltage ceramic capacitors to be balanced out. Most other capacitors have such a low power factor that it will not be necessary to touch the Loss knob. Just leave it at minimum setting.

When high value resistors or low value capacitors are being measured, one side of the bridge becomes a very high impedance voltage divider. This means that the input of the null detector amplifier must also have a very high input impedance. Accordingly, the two-stage direct-coupled null detector amplifier has a "boot-strapped" input.

Bootstrapping is a form of positive feedback, used in this case to effectively negate the shunting effect of the voltage-divider bias network for the first transistor. It works as follows.

One end of the 270k bias input resistor is connected to the emitter of the BC549, as far as AC signals are concerned, by a .01uF capacitor. By virtue of emitter follower action, almost 100% of the AC input signal appearing at the base of the BC549 transistor also appears at its emitter. This means that very little of the input signal current flows in the 279k resistor, and thus its value is effectively multiplied many times.

A 10k potentiometer in the feedback loop of the amplifier varies the gain. Reducing the gain of the null detector "broadens" the null of the bridge and makes it easy to find a rough null. Then the gain can be increased, to obtain a very sharp and deep null to provide an accurate measurement.

The output of the null detector amplifier is fed to a half-wave voltage doubler rectifier (also known as a "Diode pump"), consisting of two capacitors and two germanium diodes. The lower forward voltage drop of germanium diodes, compared to silicon, gives a worthwhile effective increase in gain. The 3.3k resistor in series with the meter movement offers a degree of protection against overloads.

The complete bridge circuit is powered from a nominal 9V supply, provided either by an Eveready 2362 battery or an external plug-pack mains supply.

A suitable supply of this type would be the Dick Smith M-9525 battery eliminator.

Assembly of the PCB is straightforward.

The preset 100 ohm potentiomenters are miniature types with the pins at 0.1 in spacing. Any germanium signal diodes available may be used.

Use the PC board pins supplied in the kit to simplify connections to the PCB. There are a few holes on the PCB which are unoccupied. We make this remark just in case readers think there is a mistake.

We have provided outputs, via a pair of RCA phono sockets, from the sinewave filter and square wave oscillator. These are optional and can be omitted if not required.

Extra pot nuts have been supplied in the kit so that the pots can be mounted with a minimum of thread protruding from the front panel. This will enable the knobs to be set close to the panel.

The 1k ratio potentiometer is a 3 watt wirewound type made by IRH. Do not use other types as they will not match the calibrated scale. The edge-reading meter has a sensitivity of 400 microamps FSD, and fits a panel cutout of approximately 35 x 15mm.

Binding posts-cum-jack-sockets were used for the three bridge terminals although spring-loaded terminals may be just as suitable. The battery clamp is made from a scrap of aluminium and is secured with the nut for the "ext. std." terminal.

A special connector is used for the external power supply, of the type used on many battery-operated appliances. The outer connector of the matching plug is positive. They are available with 2.1mm or 2.5mm centre-pin. The A&R plugpack is compatible with both, but whatever type of external power supply connector you obtain, ensure that you are also supplied with matching metric screws.

Connections from the PCB to other components may be made with rainbow cable split and cut into suitable lengths. It is important that the connecting wires to the three terminals, and those to the 2-position changeover switch be run separately, otherwise capacitance between wires will prejudice accuracy

The front panel should be connected to the negative supply rail to minimise the effects of hand capacitance. The connection can be done by soldering a wire to the locknut for the gain potentiometer and then connecting it to the pot wiper.

Make the cursor knob for the ratio potentiometer from the piece of perspex supplied in the kit. The cursor line can be scribed on the plastic with a compass point. The knob supplied may differ slightly from the one shown in the illustration.

With the wiring complete and the instrument working, the job of calibration remains.

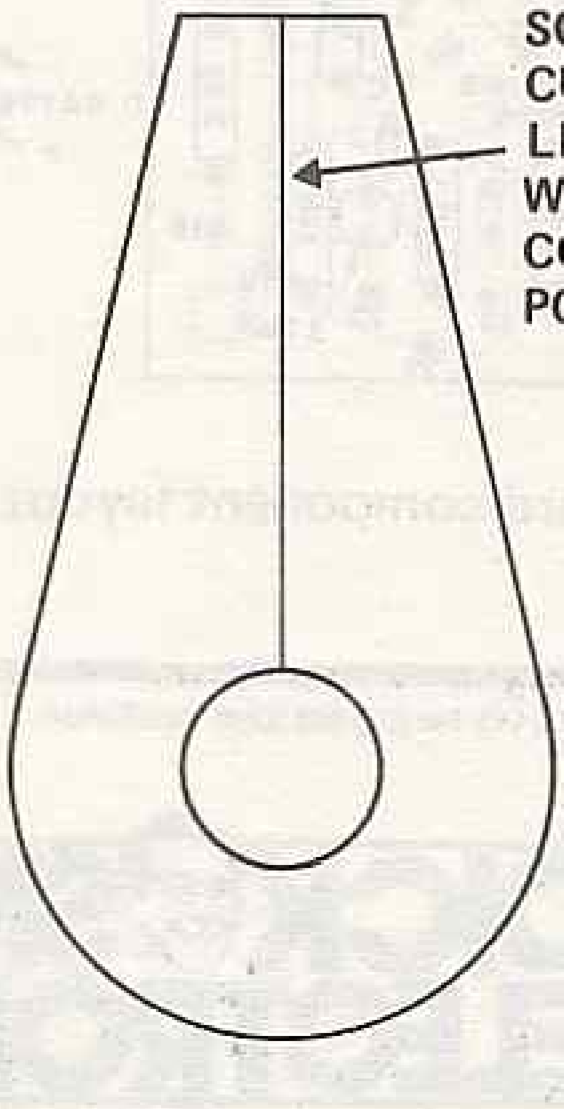
The five resistors supplied in the kit for the standards are 2% tolerance types, while the five standards capacitors have been specially hand picked. They should provide sufficiently accurate calibraiton for most purposes. If a higher order of accuracy is required, close-tolerance components should be obtained separately and used for the standards.

As a first step in calibration, make sure that the ratio potentiometer shaft and the calibrated scale are concentric. If this is not the case, you will tear your hair out trying to calibrate it! If all is well, set the knob with its cursor so that it swings to the extremities of the scale. If there is slight under or overtravel, make it symmetrical.

Set the two 100 ohm presets to their midpositions. Then connect the 100 ohm resistor and select the 1k range. The null should coincide precisely with the "0.1" setting. If not, tweak the present slightly the one nearest the 741. Now connect the 10k resistor and null the bridge again. It should coincide with the "10" setting. If not, tweak the other preset.

This will throw out the first adjustment, and it will be necessary to go over the settings a couple of times to bring both ends of the scale into line. Having done that, check the centre of the scale by connecting a 1k resistor. This should line up on "1" automatically. If sufficient error is noted, the cursor knob should be shifted slightly on the potentiometer shaft. This will make it necessary to go over the calibration procedure again.

Once calibration has been performed on the 1k resistance range, all the other ranges should be correct, consistent with the tolerance of the standard components.



Use this full size drawing as a template for cutting the cursor from the perspex provided. Glue the cursor to the back of the knob with 5-minute epoxy.

PARTS LIST

1 plastic case with aluminium lid, 197 x 60 x 112mm
1 printed front panel
1 PCB, 78b2
3 binding posts
4 knobs
1 2-pole 6-position rotary switch
1 3-pole 2-position toggle switch
1 edge-reading meter, 200-400uA FSD
2 Eveready 2362 battery connectors
1 miniature iron-core coupling transformer, 3k:3k, DSL M-0222
1 2.1mm DC input jack socket plus suitable metric screws
1 pair of RCA phono terminals

SEMICONDUCTORS
1 555 timer integrated circuit
1 741 op amp integrated circuit
1 BC549 NPN low noise transistor
1 BC558 PNP transistor
2 OA91 or similar germanium diodes

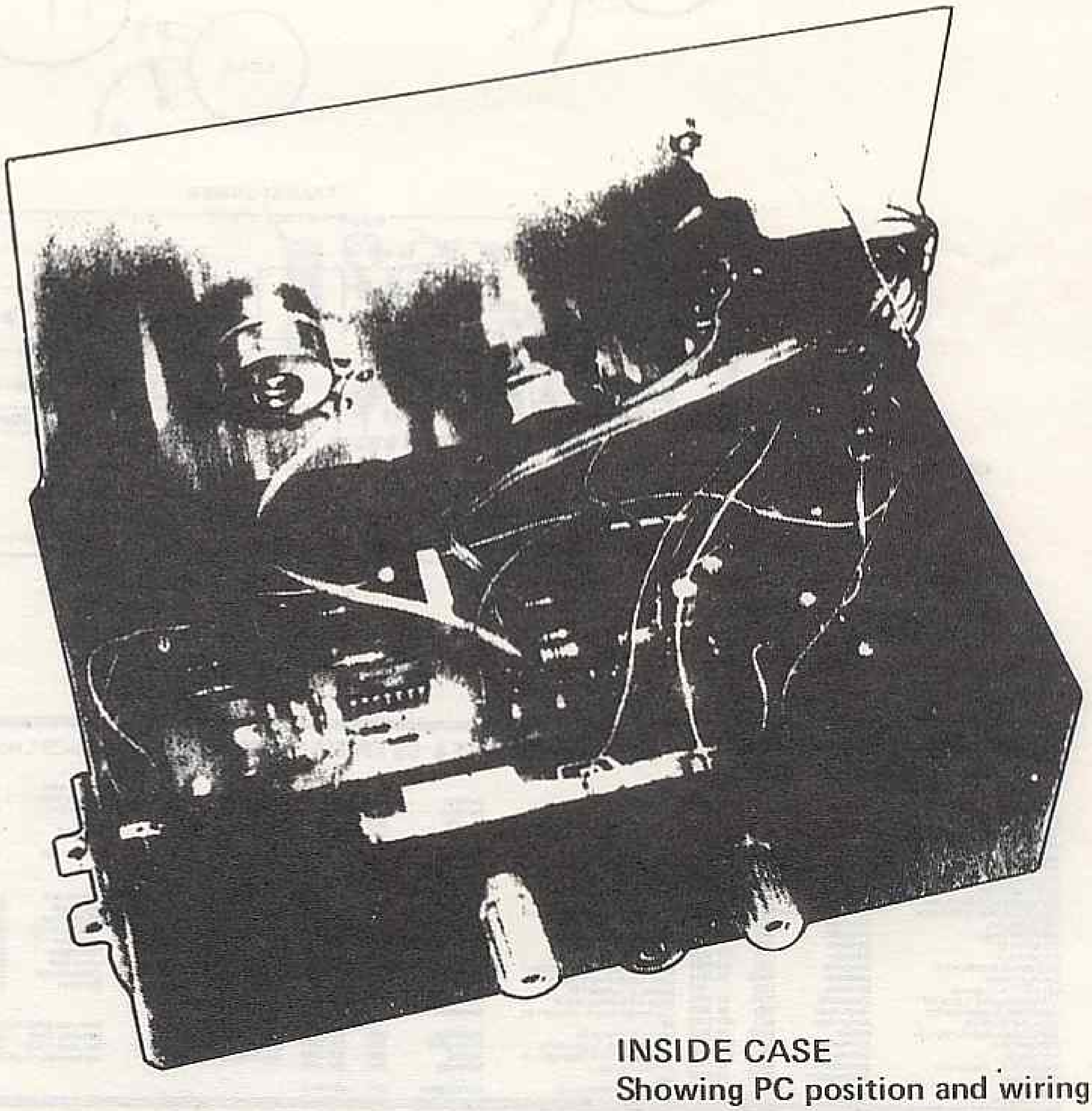
CAPACITORS
3 10uF electrolytic
4 2.2uF electolytic
1 0.039uF metallised polyester
1 0.033uF metallised polyester
3 0.01uF metallised polyester
1 0.0027uF metallised polyester or polystyrene

RESISTORS
(¼ or ½W, 5% tolerance)
1 680k; 2 270k; 1 120k; 1 68k; 2 56k; 3 22k; 4 10k; 1 3.3k; 1 2.2k; 2 1k; 1 470 ohm
1 10k (log) switchpot
1 1k 3W wire wound potentiometer (IRH)
1 500 ohm potentiometer
2 100 ohm preset potentiometers with 0.1in pin spacing

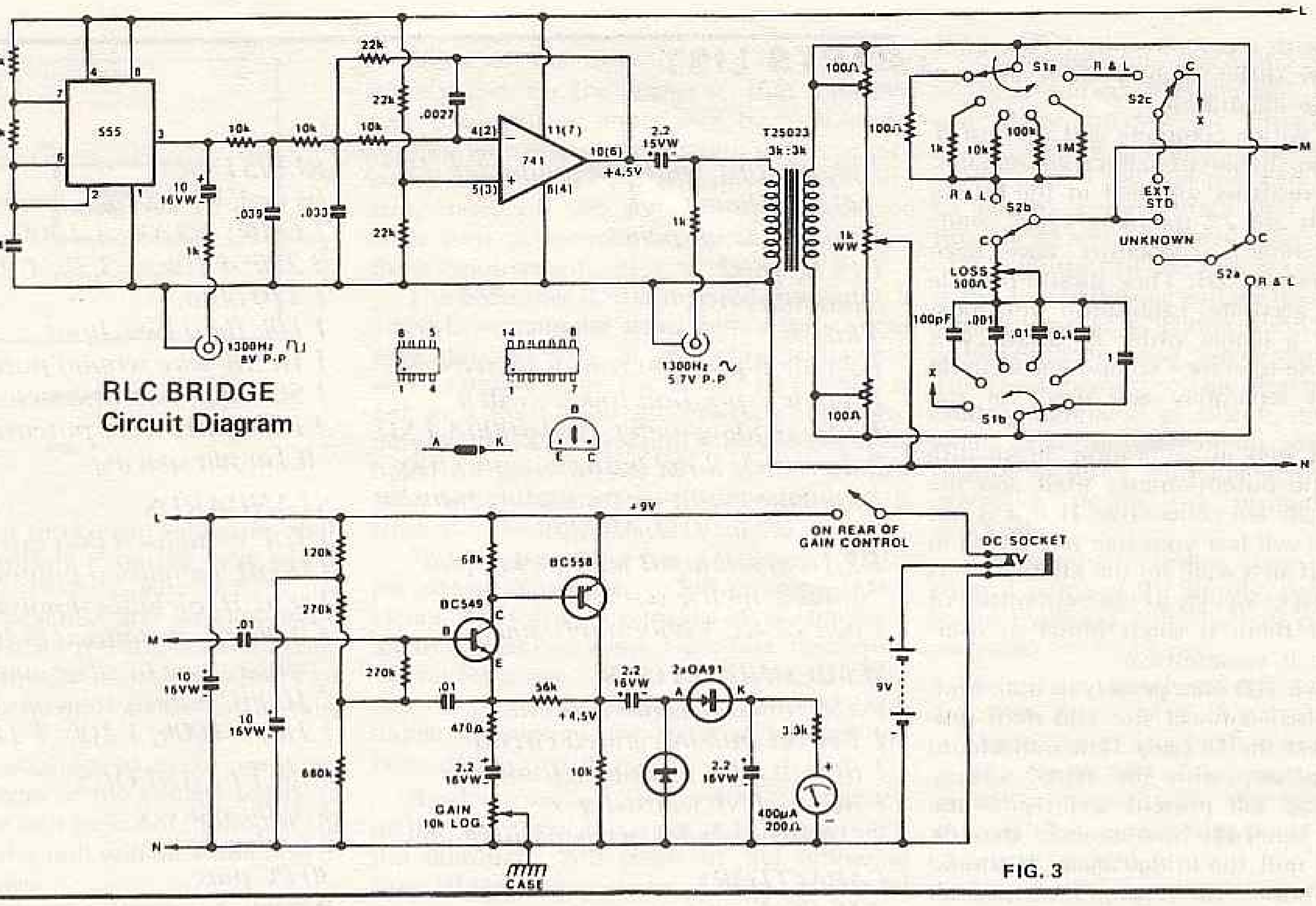
STANDARDS
1 1uF metallised polyester
1 0.1uF metallised polyester
1 0.01uF metallised polyester
1 0.001uF metallised polyester or polystyrene or silver mica
1 100pF polystyrene or silver mica
1 1M; 1 100k; 1 10k; 1 1k; 1 100 ohm

MISCELLANEOUS
4 3/8in spacers
4 rubber feet
30 PC pins
Perspex for pointer knob, hookup wire, screws, nuts, washers, solder etc.

NOTE: Components with lower ratings may be used provided their ratings are not exceeded. Components with higher ratings may also be used if physically compatible.

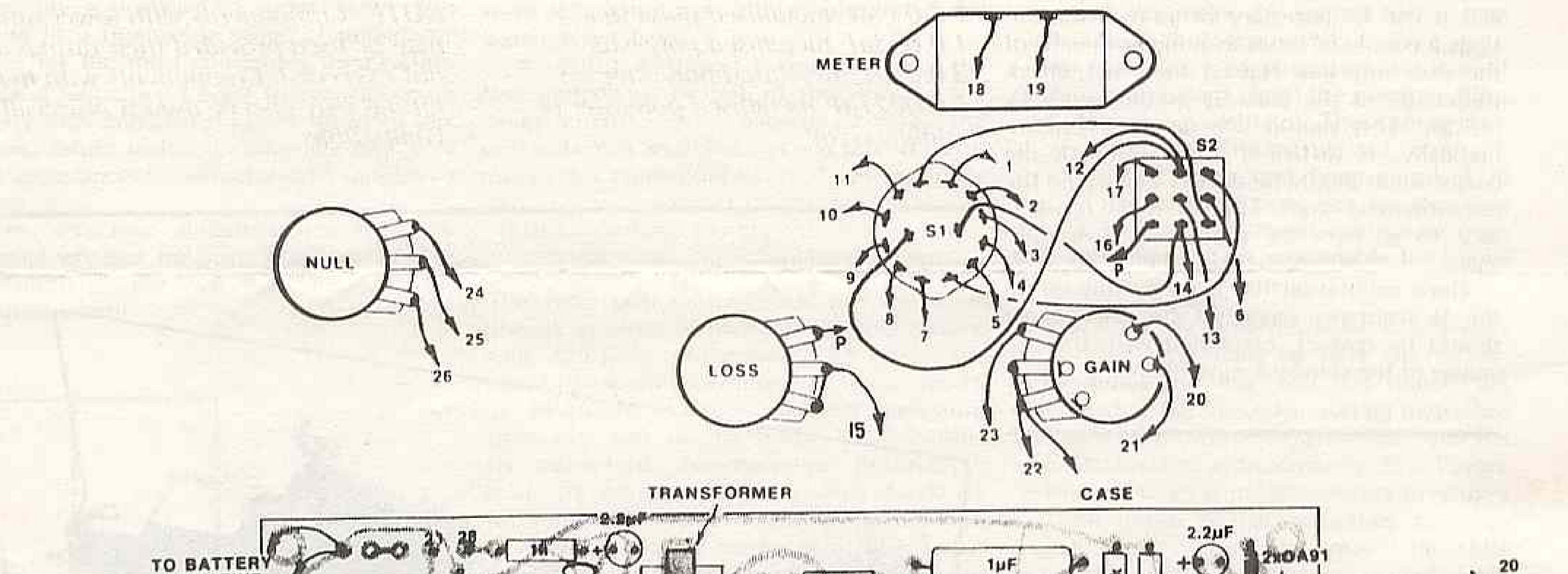


INSIDE CASE
Showing PC position and wiring



RLC BRIDGE
Circuit Diagram

FIG. 3



PC Board component layout and wiring

Text and illustrations courtesy of Electronics Australia

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