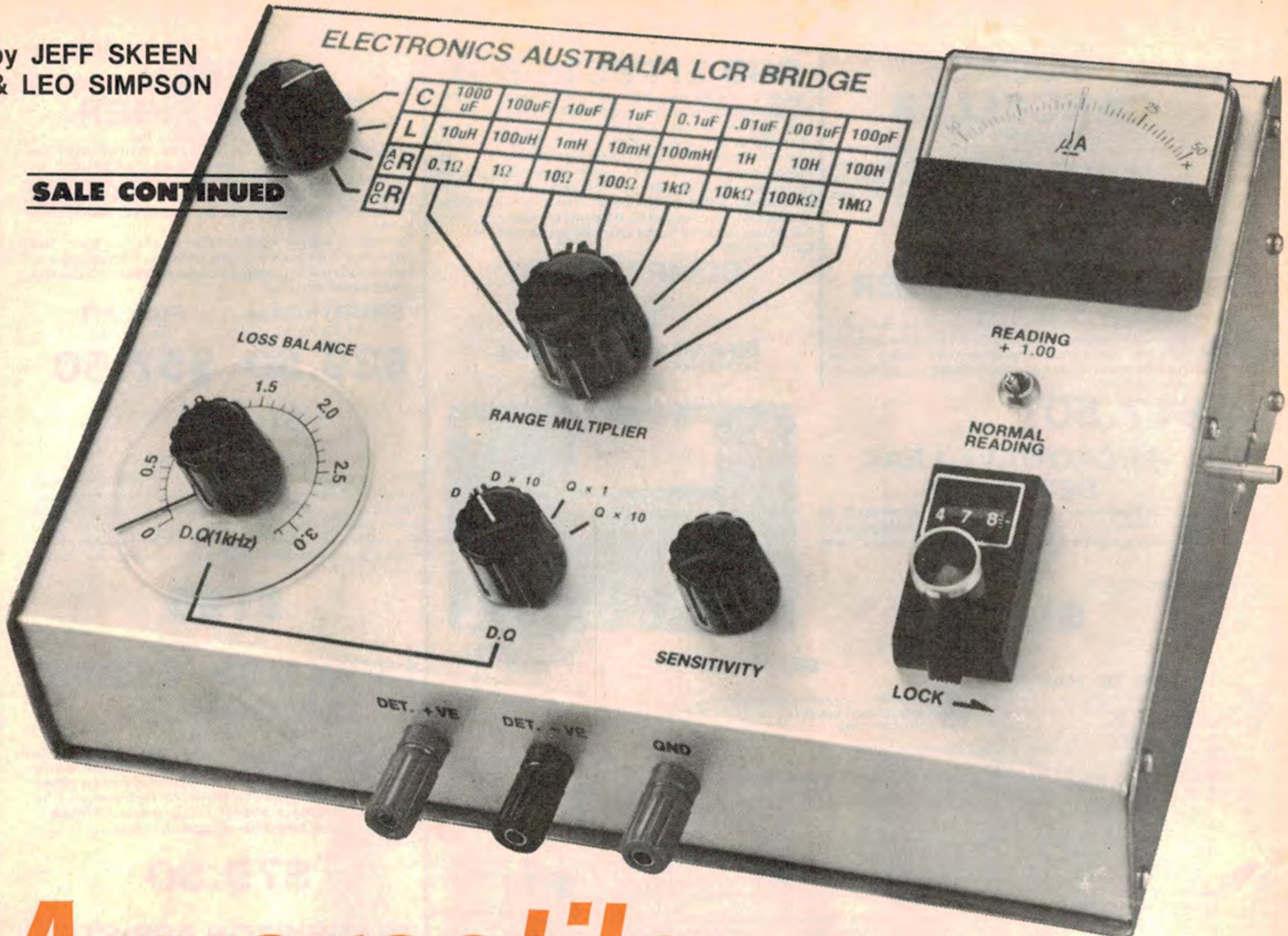
by JEFF SKEEN
& LEO SIMPSON

SALE CONTINUED



A versatile LCR Bridge

PART 2 — for laboratory & workshop

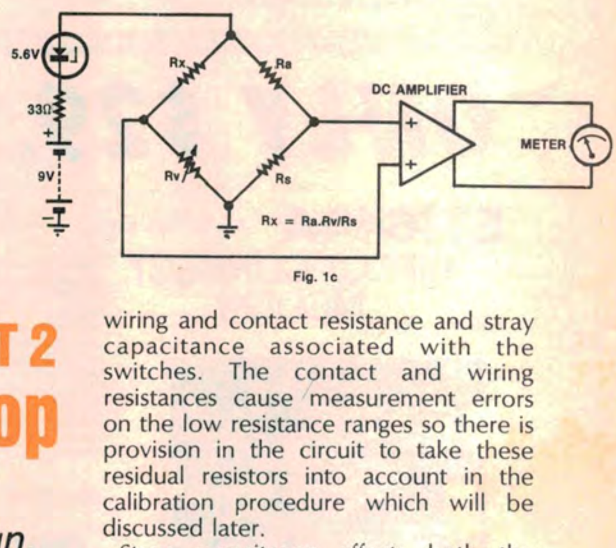


Fig. 1c

Last month we presented the basic circuit concepts behind our all new LCR Bridge design. This month we present the full circuit and the construction details.

Five variations of the basic Wheatstone Bridge configuration are used in our new LCR Bridge, as discussed last month. While each of these variations in themselves represent a simple circuit, when you tie them all together it starts to become a trifle complicated. Add in the range switch wiring and you have the potential for a real bird's nest.

This raises two problems. First, there is the tedious job of wiring up the switch banks and second, there is additional wiring and contact resistance and stray capacitance associated with the switches. The contact and wiring resistances cause measurement errors on the low resistance ranges so there is provision in the circuit to take these residual resistors into account in the calibration procedure which will be discussed later.

Stray capacitance affects both the capacitance and inductance ranges so it must be kept to an absolute minimum. Fortunately, the stray capacitance in the circuit is due more to the interwinding capacitance of the transformer than to the wiring. This means that we have to specify a transformer with a low value of interwinding capacitance.

At the same time, the wiring layout has been arranged to keep stray capacitance

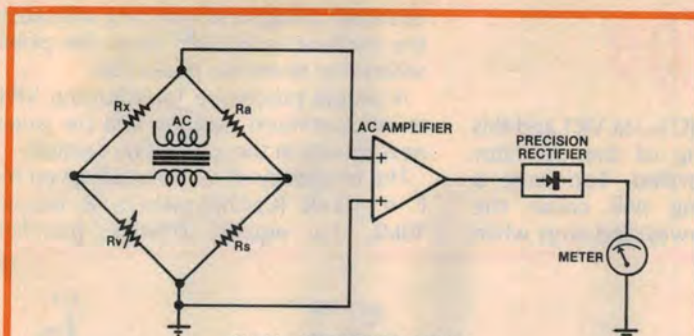


Fig. 1d AC RESISTANCE BRIDGE

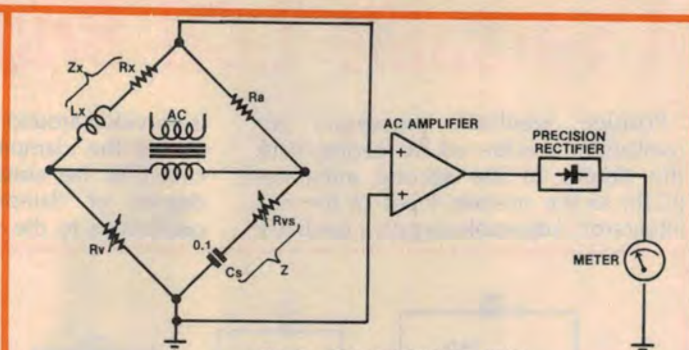


Fig. 1e HIGH Q INDUCTANCE BRIDGE

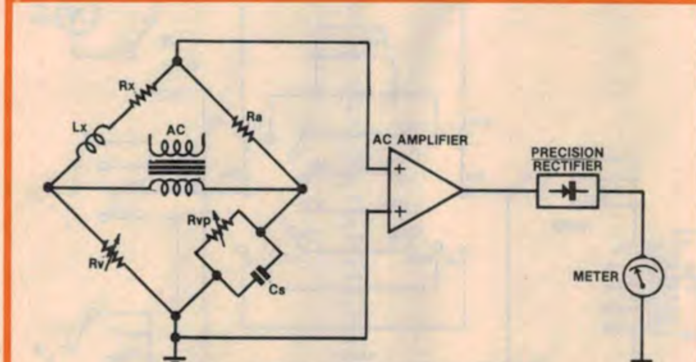


Fig. 1f LOW Q INDUCTANCE BRIDGE

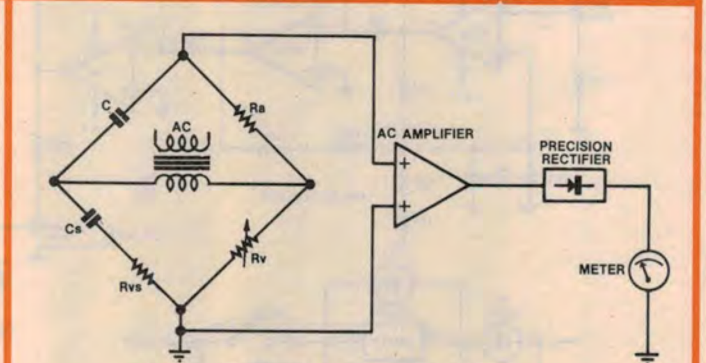


Fig. 1g CAPACITANCE BRIDGE CONFIGURATION

to a reasonable minimum. In fact, while our initial remarks may give the opposite impression there is not a great deal of wiring in this project but the complete circuit does look a bit of monster.

Incidentally, if you haven't already perused last month's article on this project you would be wise to do so. If you don't you probably won't make a great deal of sense out of the circuit description.

Circuit Description

Having put you on notice that you should read last month's article, let's recap on the five basic configurations used and then see how they are brought together in the main circuit diagram.

We have reproduced the five configurations again this month for handy reference and used the same diagram numbering as for last month.

Fig. 1c is the configuration used for DC resistance measurements. It uses DC energisation for the bridge itself and a DC amplifier to measure the null condition. Rx is the unknown resistor, Rv is the 10-turn pot with three-digit readout, Rs is the standard resistor and Ra is the range multiplier.

All five of the bridge configurations utilise the same components for Rv (ie, there is only one 10-turn pot) and Ra, the range multiplier. Similarly, the configurations used for measuring inductance and capacitance all use the one standard, a close-tolerance 0.1μF capacitor.

Of the five configurations, Fig. 1c is the odd one since it uses DC energisation. The other four configurations use AC energisation via a transformer and an AC null indicator.

Fig.1e and 1f are essentially the same with the only difference being the provision of Rvs or Rvp. Fig.1g, for capacitance measurement, has the bottom legs of the bridge swapped over, to take care of the fact that the impedance of a capacitor is in inverse proportion to its actual value.

Now let's take a look at the complete circuit diagram and how it relates to the five basic bridge configurations. First of all note S2, the range multiplier switch. S2a and S2b, the two poles of S2, switch in the multiplier values for Ra. As might be expected, these values increase from one range to the next by a factor of 10.

S1 is the selector switch. Various parts of S1 seem to be all over the circuit. It has a messy job to do and so has a lot of poles. In fact it has 12 poles, labelled S1a to S1l, all accommodated on three double-sided wafers. S1 has four positions, Rdc for DC resistance measurements, Rac (yep, you guessed it, for AC resistance measurements), L and C. Each one of the switch pole positions is labelled with one of these four legends, to make the function clear.

Have a look at S1a and S1c for example. They switch the meter between the DC and AC modes. At the same time, S1i and S1k change the configuration of the metering circuit from a differential amplifier to a single-ended input amplifer followed by a precision rectifier.

Note that one of the poles, S1j, is not used and so is not shown on the circuit.

S3 is the D.Q switch. It switches either of two legs of a dual gang pot into the circuit to provide Rvp or Rvs, depending on the particular measurement being performed. The 5kΩ track of the pot covers the D and Q ranges while the 50kΩ track covers the D × 10 and Q × 10 ranges.

Finally, there is S4 which is the "+1" switch. It connects a close tolerance 1kΩ resistor in series with the vernier drive pot. Rv, to increase the scope of any range from 10.00 to 11.00. This allows the ranges to overlap which is essential when measuring values at the top of a range.

So when you account for all the connections provided by the four switches there is really not all that much circuitry in the LCR bridge. Even so, there are some unusual circuit features. The first of these is the oscillator.

Two-phase oscillator

This is an interesting configuration which is not often used but which has the desirable features of low distortion, high output and very good amplitude stability. It's surprising that it is not used more often. It uses two op amps, Ic1a and Ic1b.

The configuration is basically a two-phase oscillator. IC1a is connected as a bootstrap integrator (non-inverting) while IC1b is connected as an inverting integrator.

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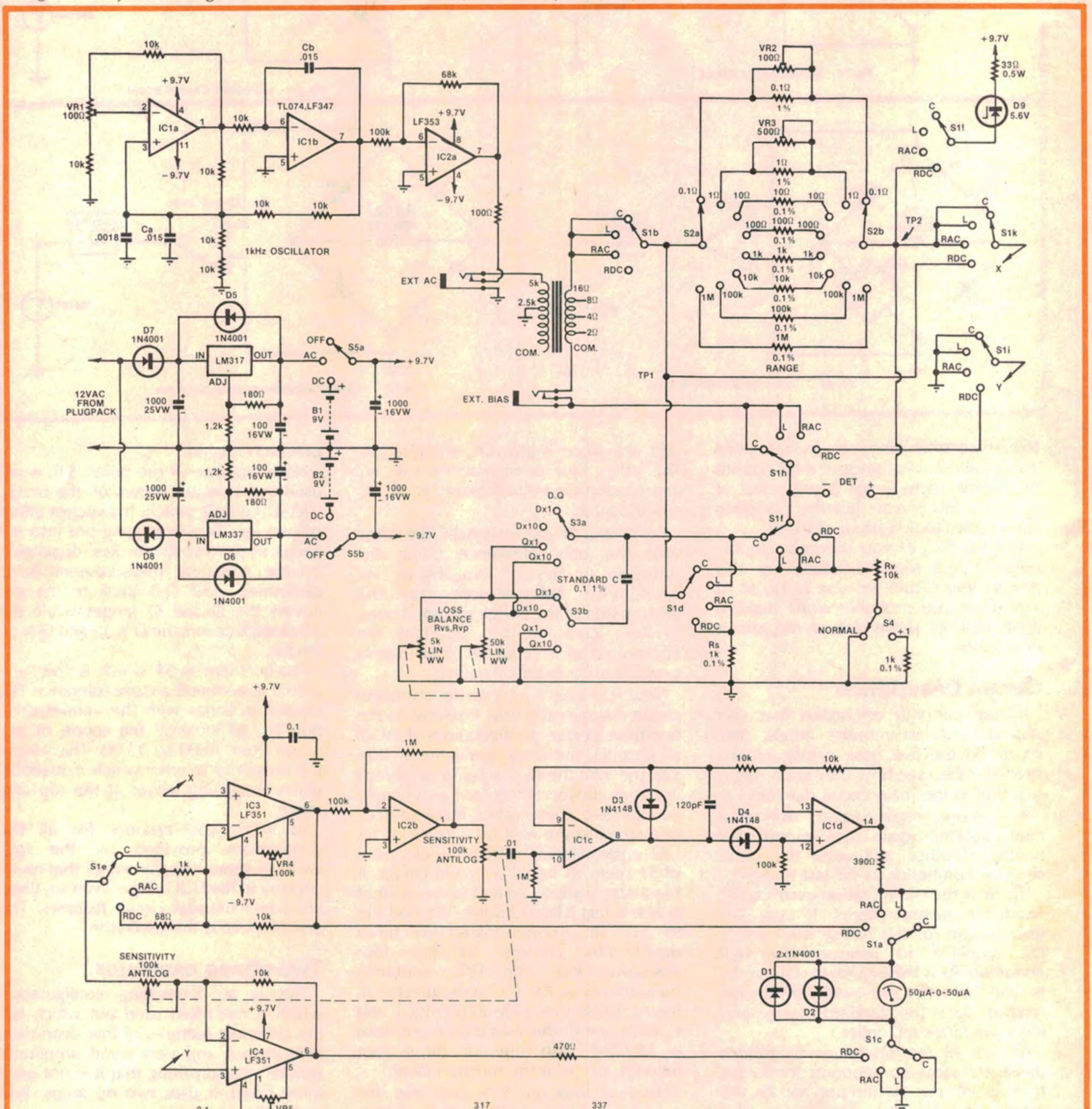
Positive feedback (necessary for oscillation) is achieved by feeding back the output of the second integrator (IC1b) to the positive input of the first integrator. Adjustable negative feedback is provided around IC1a via VR1 and this allows the damping of the oscillator circuit to be controlled. Too large a degree of damping will cause the oscillations to die away and stop while too small a degree of damping will cause the oscillations to build up to the point where the sinewave peaks clip.

A simple procedure for adjusting VR1 to the optimum position will be given next month in the calibration section.

The frequency of oscillation is given by $F = 1/2\pi R\,(C_aC_b)^{1/2}$, where R equals 10kΩ, Ca equals .0168μF (parallel



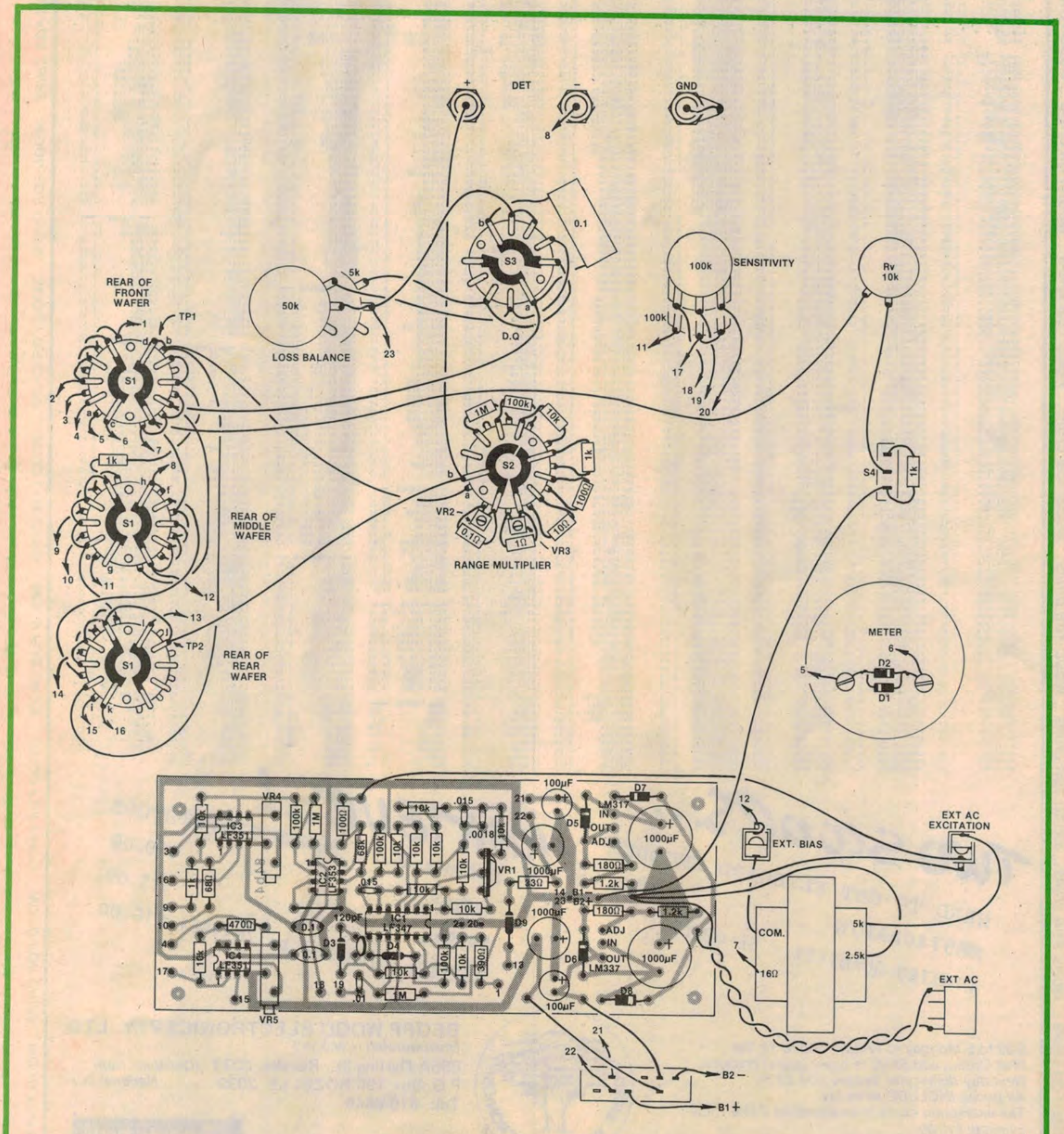
combination of the .015μF and the .0018μF capacitors) and Cb equals .015μF.

The output of IC1b is buffered by IC1c which has a gain of less than unity so that the output amplitude is reduced. This is done because the transformer load driven by IC1c is a low impedance and if maximum drive was applied the output would be clipped due to current limiting.

Only part of the transformer primary winding is used which means that the effective turns ratio is increased and a higher voltage is developed across the secondary. The jack socket in series with the transformer primary allows an external oscillator to drive the bridge.

The insulated socket labelled "external bias" is a further refinement on the basic bridge circuit and allows the connection of either polarising voltages when measuring electrolytic and tantalum capacitors or DC bias currents when measuring iron cored inductors.

This allows components to be measured under conditions approximating normal circuit operation.



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We estimate the cost of parts for this project to be approximately

$149

This includes sales tax.

Nulling amplifier

As noted before, the nulling amplifier configuration is changed depending on whether DC or AC measurements are being performed.

In the DC mode, only IC3 and IC4 are involved. They function together as a true differential amplifier and drive the meter via S1a and S1c. IC2b is also connected to the output of IC3 but this is of no consequence in the DC measurement mode.

Now comes the fiddle. In the AC measurement modes, the input of IC4 is grounded by S1i which effectively disables it, as far as AC signals are concerned. So for AC signals, the signal chain is via IC3, IC2b, IC1c and IC1d.

Going back to the DC measurement mode again, IC3 and IC4 can be regarded as non-inverting amplifiers which share a common 100kΩ gain control. The gain is given by the expression $G = 1 + Rf/R$ where Rf is the 10kΩ feedback resistor and R is the series combination of the 100kΩ potentiometer and 68Ω resistor (selected by S1e).

This gives a minimum gain of 1.1 and a maximum gain of about 148.

In the AC mode, IC3 has a variable gain set by the combination of the 100kΩ potentiometer and the 1kΩ resistor (again selected by S1e). The range of gain is from 1.1 to about 11 times.

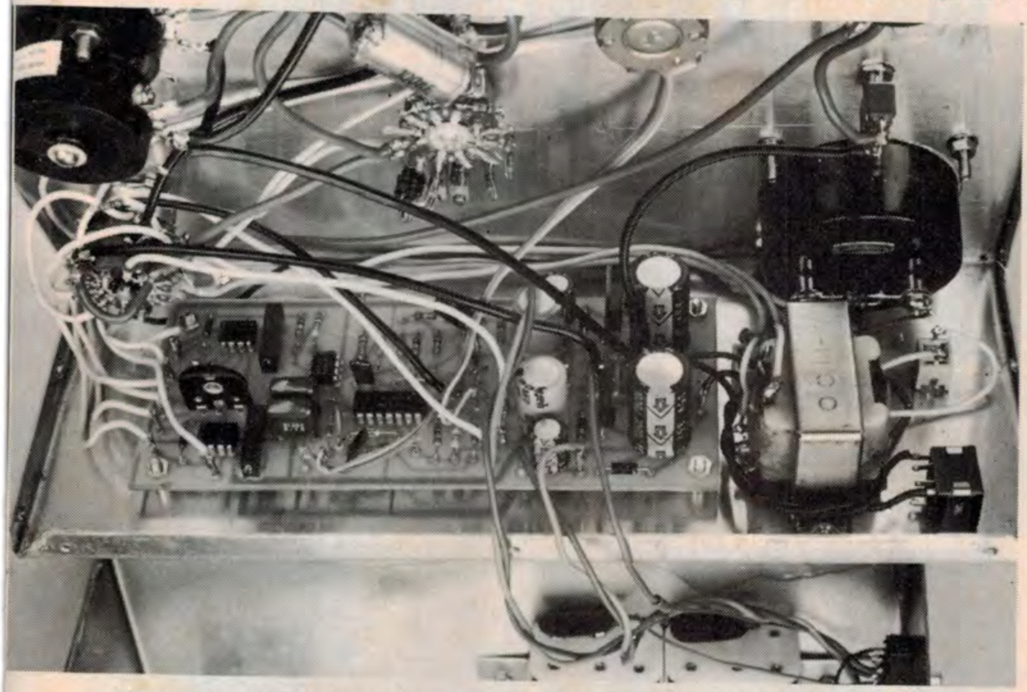
IC2b is an inverting amplifier with a gain of 10. It feeds a 100kΩ potentiometer which is ganged with the 100kΩ pot in the feedback circuit of IC3 and IC4. Output from the wiper of the pot is then coupled via a .01μF capacitor to IC1c and IC1d which together form a precision full-wave rectifier. The way in which the two op amps work is interesting.

Consider a positive going signal (eg, the postive excursion of a sine wave) applied to the input of IC1c. This is connected in non-inverting configuration and so the output signal from IC1c is also positive going which forward-biases D4 and reverse-biases D3. So the signal is also applied to IC1d which works as a non-inverting voltage-follower.

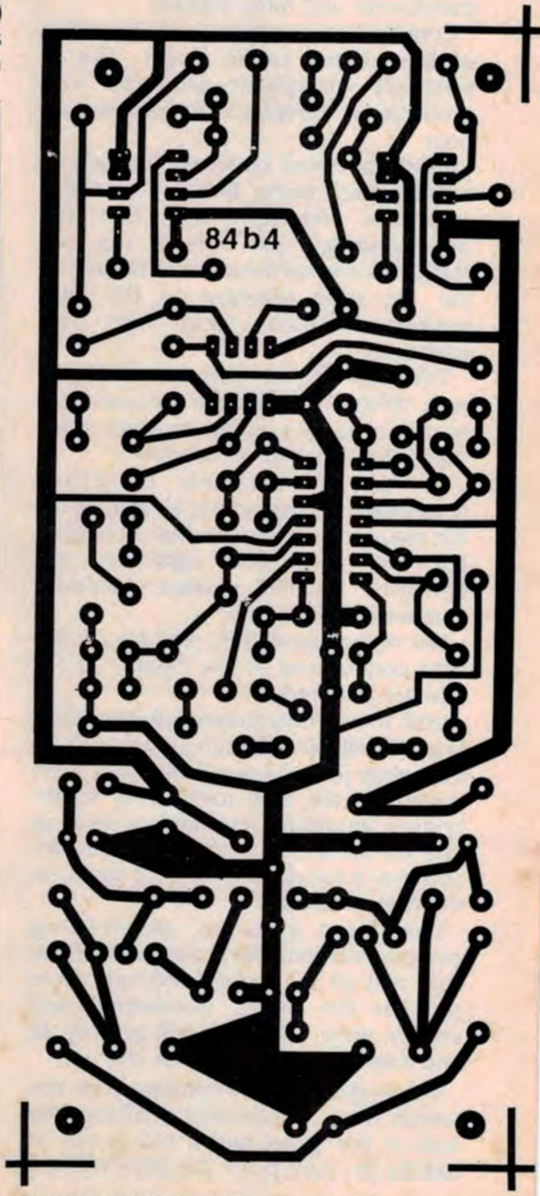
Since D3 is reverse-biased, the feedback network for IC1d also applies feedback to IC1c with the result that for positive-going signals the circuit has a gain of unity.

For negative-going signals, the mechanism is different. Here, because D3 is forward-biased and D4 is reverse-biased, IC1c acts as a unity gain follower while IC1d acts as a unity gain inverter.

Hence, the two op amps form a full-wave rectifier. The 120pF capacitor across D3 is added to ensure RF stability.



Above: view inside the prototype. Note that a few minor changes were made to the PCB after this photograph was taken. Below is a view of the rear panel. The external bias socket must be isolated from chassis.



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The output of IC1d drives the meter via a 390Ω resistor and S1a (and S1c).

Power supply

If other parts of the circuit are unusual, the power supply is strictly conventional. It uses an external AC plugpack to provide 12VAC. This is applied to two half-wave rectifiers to provide positive and negative DC rails. These are filtered and then regulated to ±9.7V by adjustable 3-terminal regulators.

Construction

A sloping front metal case houses the new LCR bridge. Measuring 260 × 173 × 103mm, it is designed for easy viewing of the controls and good access to the internal wiring. The printed circuit board, measuring 151 × 64mm (code 84b4), is mounted vertically inside the back panel of the case, together with the audio transformer and three sockets.

Construction can begin with assembly of the printed circuit board. This is relatively straightforward and can probably be completed in less than an hour.

Install the small components such as resistors and diodes first and then the regulators and ICs. Note that the orientation and pin outs of the two regulators are not the same so be sure to put the right regulator in the right position and don't swap them over inadvertently.

The two multi-turn pots. face the same way. While this may look awkward it is necessary to give access to them once the PCB is installed in the case.

Correct orientation of other components is important, as well as for the regulators. Make sure that all diodes, ICs and electrolytic capacitors are correctly installed before soldered connections are made.

We recommend PCB pins for all the wire connections to the board. 22 PC pins are required.

With the PC board complete check the layout carefully and have a close look at the solder joints to see if any have been missed or are cold joints. Any solder bridges should be removed as soon as you see them. If you leave them till later you may have difficulty finding them on the next occasion.

The first step in assembling components into the chassis is to make sure that all the major hardware items such as the meter, transformer and vernier drive assembly will actually fit and that the mounting holes line up.

This is particularly important with the vernier drive. It requires a small locating hole in the panel and if this is not in exactly the right place the drive will not run freely. On the other hand, if the hole is too large, the vernier drive will tend to wobble from side to side. Having said this, it would be a good idea to do a "dry run" with all the front panel hardware before the front panel is affixed.

If the front panel is a Scotchcal it should be sprayed with a clear lacquer and allowed to dry before affixing. Note that the external bias socket on the rear panel must be isolated from chassis.

Special components

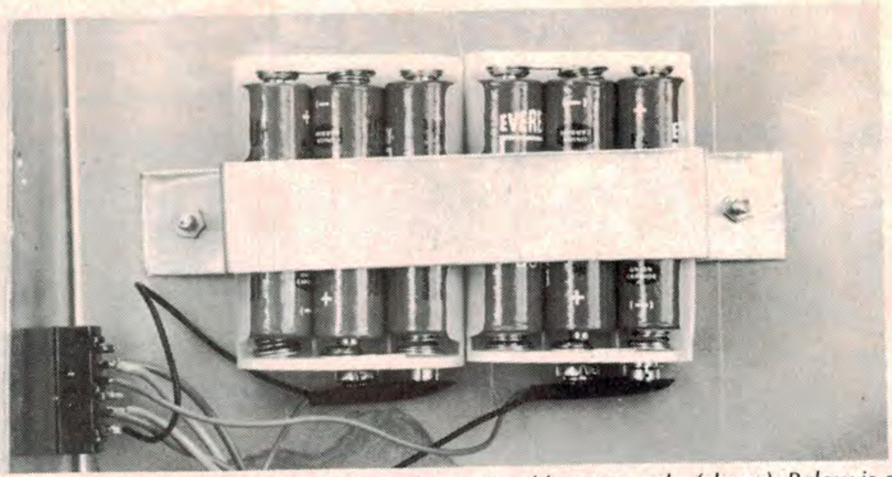
The transformer has been specially selected for its low interwinding capacitance and good frequency response. It can be purchased from Jaycar as part number MM-2001 or from Altronics as M-1105 (although the one used in our prototype had M-1100 stamped on it). At the time of writing we know of no suitable substitutes for this transformer.

Another special component is the D.Q potentiometer which is a 5kΩ + 50kΩ ganged type made by A. G. Naunton & Co Pty Ltd, Melbourne. We obtained our prototype sample from Watkin Wynne Pty Ltd, 68 Alexander St, Crows Nest, NSW 2065. The D.Q dial is intended for use with this pot so substitutes may not be suitable.

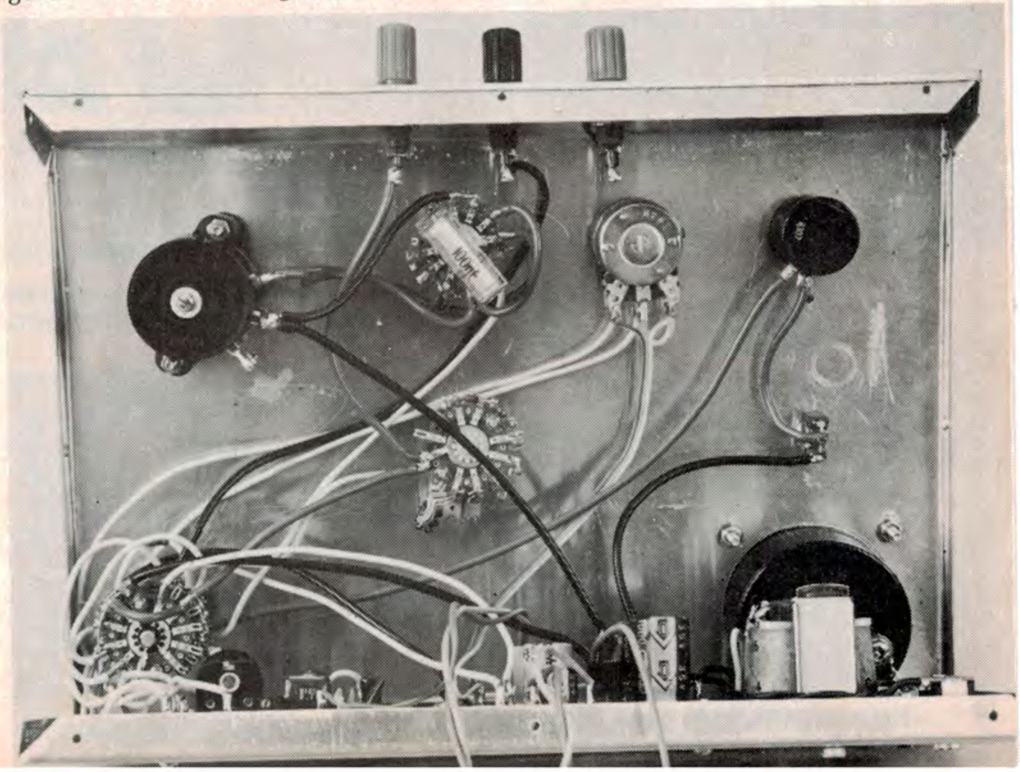
The 10-turn vernier dial is made by Copal and is distributed by Mayer Kreig & Co, 49/51 Brodie St, Rydalmere, NSW 2116.

The 10-turn pot that goes with it is a standard item with 0.25% linearity. It is made by a number of manufacturers such as Bourns.

The 0.1μF 1% standard capacitor is installed across the D.Q switch S3. The capacitor is a polystyrene. It is labelled 100nF/100V and is made by Rifa Pty Ltd. The code number on the capacitor is



An aluminium clamp is used to secure the optional battery packs (above). Below is a general view of the wiring to the front panel controls.



PFE216F. Other 0.1μF polystyrene capacitors of 1% or closer tolerance may be substituted for this unit.

The three multi-position switches, S1, S2 and S3, are made by Lorlin and distributed by C&K Electronics (Aust) Pty Ltd, 15 Cowper St, Parramatta, NSW 2150. We purchased switches for our prototype from Radio Despatch Service, 869 George St, Sydney.

Most of the wiring between the internal hardware components is centred around the multi-wafer switch S1. No matter which way you approach this job it will be tedious. Some of the wiring will have to be done with the switch out of the chassis.

Perhaps the best way to approach it would be to do all the wiring between the switch terminals first as this can be done with the switch out of the chassis. We suggest you start with the wafer closest to the front panel, S1a, and work back from there.

Ordinary hookup wire should be used for the wiring between the terminals of S1. Do not use shielded cable. All other wiring, with the exception of that to the gain control, should be run in heavy duty hook-up wire such as 24 × 0.2mm. This is to keep the resistance of the wiring between the switches as low as possible.

Note that all the multiplier resistors associated with the range multiplier switch S2 are wired on the switch itself. The 0.1Ω multiplier posed a problem. Where do you get it? We used ten 1Ω 2% resistors wired in parallel. Two multi-turn pots are wired to S2 as well.

Follow the wiring diagram and check your work against the wiring diagram and circuit, to make sure you know what you are doing.

Next month we shall complete this series on the LCR bridge by giving the calibration procedure and instructions on how to use the bridge to best advantage.

(To be continued).

PARTS LIST

1 sloping front metal case, 260 x 173 x 103mm.
1 printed circuit board, code 84b4, 151 x 64mm.
1 Scotchcal front panel to suit.
1 50μA centre zero meter, Standard ST-670 or equivalent.
1 12-pole, 4-position rotary switch, Lorlin RA style.
1 2-pole, 8-position rotary switch, Lorlin RA style.
1 2-pole, 4-position rotary switch, Lorlin RA style.
1 4W speaker transformer, Jaycar cat. No. MM-2001, Altronics cat. No. M-1105 or equivalent.
1 10-turn drive mechanism with digital readout, Copal model CD-10 (see text).
3 21mm wing knobs.
1 28mm wing knob.
1 21mm plain knob and matching 63mm clear plastic dial.
2 battery holders (six AA size batteries, optional).
2 battery clips to suit holders.
1 small strip of scrap aluminium for battery bracket, 186 x 20 x 1mm.
1 12VAC plugpack transformer, Ferguson PPB/500 (optional).
1 3.5mm stereo jackplug.
1 SPST toggle switch.
1 2-pole, 3-position slide switch.
2 3.5mm mono jackplug sockets.
1 3.5mm stereo jackplug socket.
3 binding post terminals, one red, one black, one green.
1 3m length heavy duty hook-up wire, 24 x 0.2mm.
22 PC board stakes.
4 6mm PC board spacers.
4 stick-on rubber feet.
8 sets 12mm x 1/8 inch nuts and bolts.

SEMICONDUCTORS
1 LF347 quad operational amplifier.
1 LF353 dual operational amplifier.
2 LF351 operational amplifiers.
1 LM317T positive voltage regulator.
1 LM337T negative voltage regulator.
6 1N4001 diodes.
2 1N4148 diodes.
1 5.6V 1W zener diode.

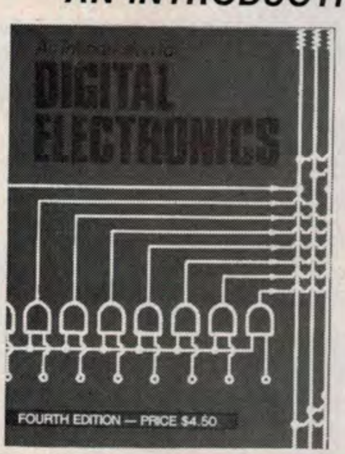
CAPACITORS
2 1000μF 25VW PC mount electrolytics.
2 1000μF 16VW PC mount electrolytics.
2 100μF 16VW PC mount electrolytics.
2 0.1μF greencaps.
1 0.1μF polystyrene, 1% or better, Rifa type PFE216F (see text).
2 .015μF greencaps.
1 .01μF greencap.
1 .0018μF greencap.
1 120pF ceramic.

RESISTORS (¼W, 5% unless stated)
2 x 1MΩ, 3 x 100kΩ, 1 x 68kΩ, 12 x 10kΩ, 2 x 1.2kΩ, 1 x 1kΩ, 1 x 470Ω, 1 x 390Ω, 2 x 180Ω, 1 x 100Ω, 1 x 68Ω, 1 x 33Ω½W, 1 x 1Ω 1% ½W, 1 x 0.1Ω 1% ½W.

RESISTORS (½W, 0.1%)
1 x 1MΩ, 1 x 100kΩ, 1 x 10kΩ, 3 x 1kΩ, 1 x 100Ω, 1 x 10Ω.

POTENTIOMETERS
2 100kΩ 10-turn trimpots.
1 100kΩ dual gang antilog taper.
1 50kΩ/5kΩ dual gang wirewound linear taper. [Manufactured by A. G. Naunton & Co., Melbourne (see text)].
1 10kΩ 10-turn, 0.25% linearity wirewound.
1 500Ω 10-turn trimpot.
1 100Ω 10-turn trimpot.
1 100Ω large vertical mount trimpot.

AN INTRODUCTION TO DIGITAL ELECTRONICS



Electronic equipment now plays an important role in almost every field of human endeavour. And every day, more and more electronic equipment is "going digital". Even professional engineers and technicians find it hard to keep pace. In order to understand new developments, you need a good grounding in basic digital concepts, and An Introduction to Digital Electronics can give you that grounding. Tens of thousands of people — engineers, technicians, students and hobbyists — have used the previous editions of this book to find out what the digital revolution is all about. The fourth edition has been updated and expanded, to make it of even greater value.

Available from "Electronics Australia", 57 Regent St, Chippendale, Sydney, 2008. **PRICE $4.50** OR by mail order: Send Money Order or Cheque to "Electronics Australia", PO Box 163, Chippendale 2008. **PRICE $5.40.**