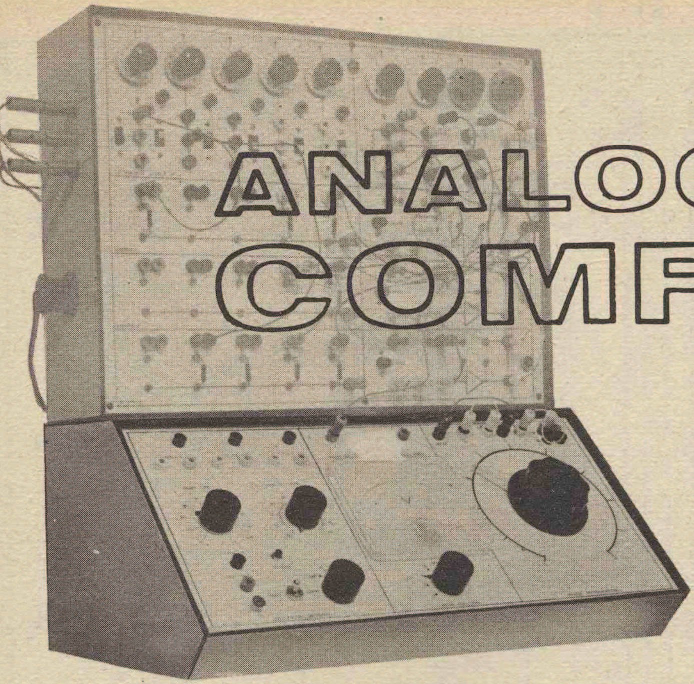


ANALOGUE COMPUTER

PEAC

By D. BOLLEN

THE PEAC basic equipment has now been dealt with and this month we commence a detailed description of the chief ancillary unit. Subsequent articles will cover the remaining two ancillary units.

Perhaps it should be repeated at this stage that the three ancillary units are purely optional add-on items. The additional facilities they each provide, are indicated in the PEAC Specification (January 1968, page 38).

PEAC UNIT "B"

UNIT "B" reinforces the facilities of UNIT "A", but does not introduce new computing circuit elements. A master potentiometer and a suitably scaled readout meter improve the accuracy and ease of handling of UNIT "A", while the integrator mode switching circuit opens up further possibilities in the solution of Calculus problems.

UNIT "B" FRONT PANEL

It may not be necessary to use hardboard for the front panel if a thick grade of plastic laminate is used, since the wooden surround in the box front gives plenty of support.

Prepare a $17\frac{3}{4}$in × $8\frac{3}{4}$in white laminate panel and establish hole centres with a sharp spike, from the drawings Fig. 6.1 and Fig. 6.2. Next, drill only the holes for all sockets, S7, S8, the meter mounting studs, and cut out a hole for the meter body with a fretsaw.

Beginning with the master potentiometer dial, draw a 300 degree arc of radius $2\frac{11}{16}$in with a pencil compass (refer to Fig. 6.2). Divide the arc into 3-degree divisions with protractor and pencil. The accuracy of the master potentiometer will benefit from careful preparation of the dial. Draw in the dial arc and divisions with Indian ink.

Rub-on transfers are suitable for the dials of VR18 and VR19, and will save time, but make sure that the transfer gives main divisions spaced at 30-degree intervals, for a 1–10 calibration.

When dials are complete, drill holes to take the spindles of VR18–VR20, S9 and S10. Draw in all ink lines, add transfer numerals, and varnish.

BOX CONSTRUCTION

Commence building the UNIT "B" box by cutting out two side panels from hardboard; they are shown in Fig 6.3. Fix $\frac{1}{2}$in square softwood lengths *A*, *B*, *C*, and *D* to the inside of the side panels. Join the side panels together by means of horizontal lengths *E*, and *F*, using countersunk woodscrews and glue. Square up with the assembly placed on a flat surface.

Cover the box framework with hardboard top, bottom, and front strip panels, and, when firm, reduce overlapping edges with a rasp and sandpaper. Finish off the box with a layer of white plastic laminate, and paint exposed hardboard edges to match the UNIT "B" box.

MASTER POTENTIOMETER AND NULL METER

A d.c. voltmeter connected to the slider of a computing potentiometer will impose a small load, and when the voltmeter is removed the measured coefficient will increase slightly, to the extent of about $1\frac{1}{2}$ per cent in the case of a 10V 20,000 ohms/volt meter, and a 10 kilohm potentiometer set with its slider near mid-track. One way of avoiding the error is to leave the voltmeter connected to the potentiometer after a coefficient reading has been taken, but this is seldom convenient.

Ideally, the instrument used to measure coefficients or computer voltages should impose no load at all, and this condition can be satisfied fairly easily by employing an accurately calibrated master potentiometer.

In Fig 6.4, a permanent load is placed on the coefficient potentiometer CP by the computing resistor R_{in}, thus causing a significant dial setting error. To find the true coefficient of CP, both potentiometers are supplied with a reference voltage of + 10V, so that potentiometer coefficients of 0–1 will be multiplied by 10 to conform to a 0–10 dial calibration. When

COMPONENTS . . .

UNIT "B" FRONT PANEL

NOTE: All front panel controls are numbered consecutively, following on from UNIT "A", but internal sub-assemblies have individual component numbering.

Potentiometers
VR18 100kΩ carbon linear
VR19 100kΩ carbon linear
VR20 25kΩ wirewound, 3in, 25W instrument potentiometer. (G. W. Smith & Co. (Radio) Ltd., 3 Lisle Street, London, W.C.2)

Switches
S7 Miniature push button, push to make, one pole
S8 Toggle, single pole changeover
S9 4 pole, 3 way rotary
S10 2 pole, 6 way rotary

Sockets
5 red, 3 black, 5 blue, 4 yellow, 4 white, and 2 green

Knobs
One Bulgin K403, 2⅜in knob with 3in skirt. Three Radiospares type PK 1⅛in knobs with pointers

Meter
M1 "Sew" MR85P, 100–0–100μA, internal resistance 1,000Ω

Miscellaneous
Plastic laminate (thick) for front panel, 1 off, 17¾in × 8¾in. Rub-on dial transfers and letters, black (Radiospares)

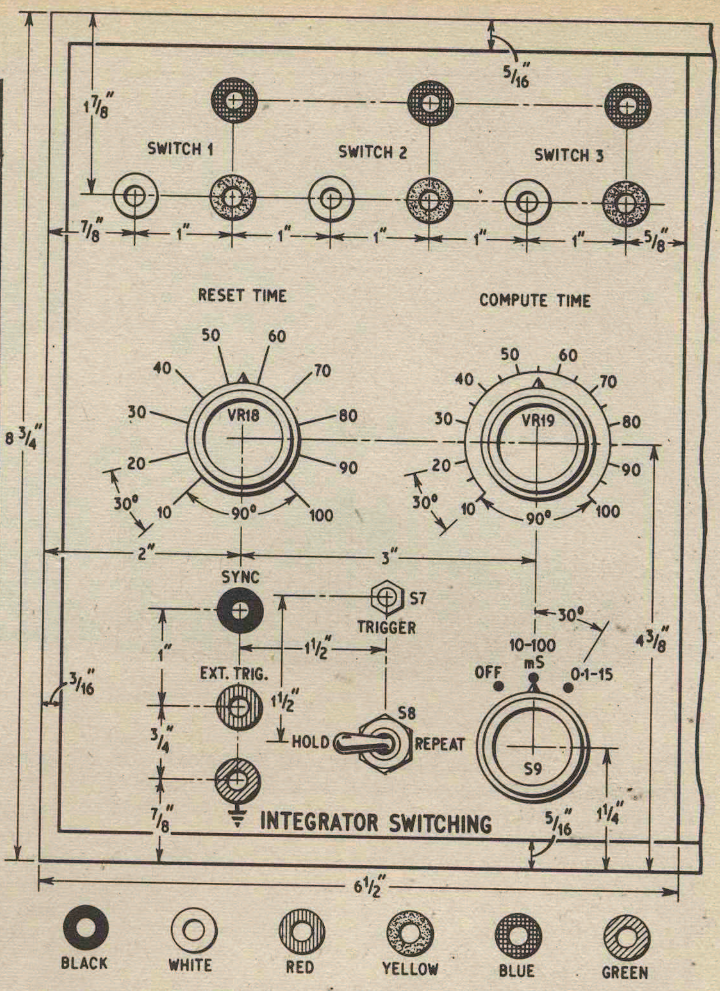


Fig. 6.1. UNIT "B" front panel, integrator switching section

UNIT "B" MASTER POTENTIOMETER

Resistors

R1 200Ω	R3 47Ω	R5 820Ω
R2 820Ω	R4 47Ω	R6 200Ω

All 5%, ½W carbon film or metal oxide

Pre-set potentiometers
VR1—VR4 100Ω wirewound (4 off) panel mounting type

Miscellaneous
16 s.w.g. aluminium sheet 6in × 4in. Tag strip with three tags.

UNIT "B" READOUT METER

Resistors

R1 82kΩ 10%	R3 7·5kΩ 5%	All ¼W, carbon composition
R2 22kΩ 10%	R4 1·2kΩ 10%	

Pre-set potentiometers
VR1 22kΩ
VR2 10kΩ
VR3 2·2kΩ
VR4 1kΩ
All miniature horizontal mounting skeleton construction

Meter protection diodes
D1, D2 OC71 or similar "inverted" germanium transistor (2 off)

Miscellaneous
S.R.B.P. panel 2⅛in × 2in.

UNIT "B" INTEGRATOR MODE SWITCH

Resistors

R1 10kΩ	R4 4·7kΩ	R7 27kΩ
R2 10kΩ	R5 27kΩ	R8 4·7kΩ
R3 1kΩ	R6 1kΩ	R9 10kΩ
R10 10kΩ	R12 3·3kΩ	R14 1kΩ
R11 1kΩ	R13 10kΩ	R15 560kΩ

All 10%, ½W carbon composition

Pre-set Potentiometers
VR1 10kΩ
VR2 5kΩ Both vertical mounting

Capacitors
C1 1,000μF elec. 15V
C2 1μF polyester 250V d.c. C6 1μF polyester 250V d.c.
C3 1·4μF polyester 250V d.c. C7 1·4μF polyester 250V d.c.
C4 14μF elec. 25V C8 14μF elec. 25V working.
C5 0·1μF polyester 250V d.c. C9 0·068μF polyester 250V d.c.
(The values of C3, C4, C7, and C8 are approximate—see text)

Transistors
TR1–TR6 ACY28 *or* AC126.

Diodes
D1, D2 OA95 (2 off)
D3–D14 1B30 (Radiospares) (12 off)

Reed Coils
RLA, RLB Miniature triple 12V Osmor type MT12V (2 off)

Reed Switches
RLA1—RLA3, RLB1—RLB3 Hamlin MRG2, 20-40AT (R.T.S. Ltd., P.O. Box 11, Gloucester St. Cambridge) (6 off.)

Miscellaneous
S.R.B.P. panels: 1 off 6¼in × 2½in; 1 off 3in × 2in.
Small turret tags.

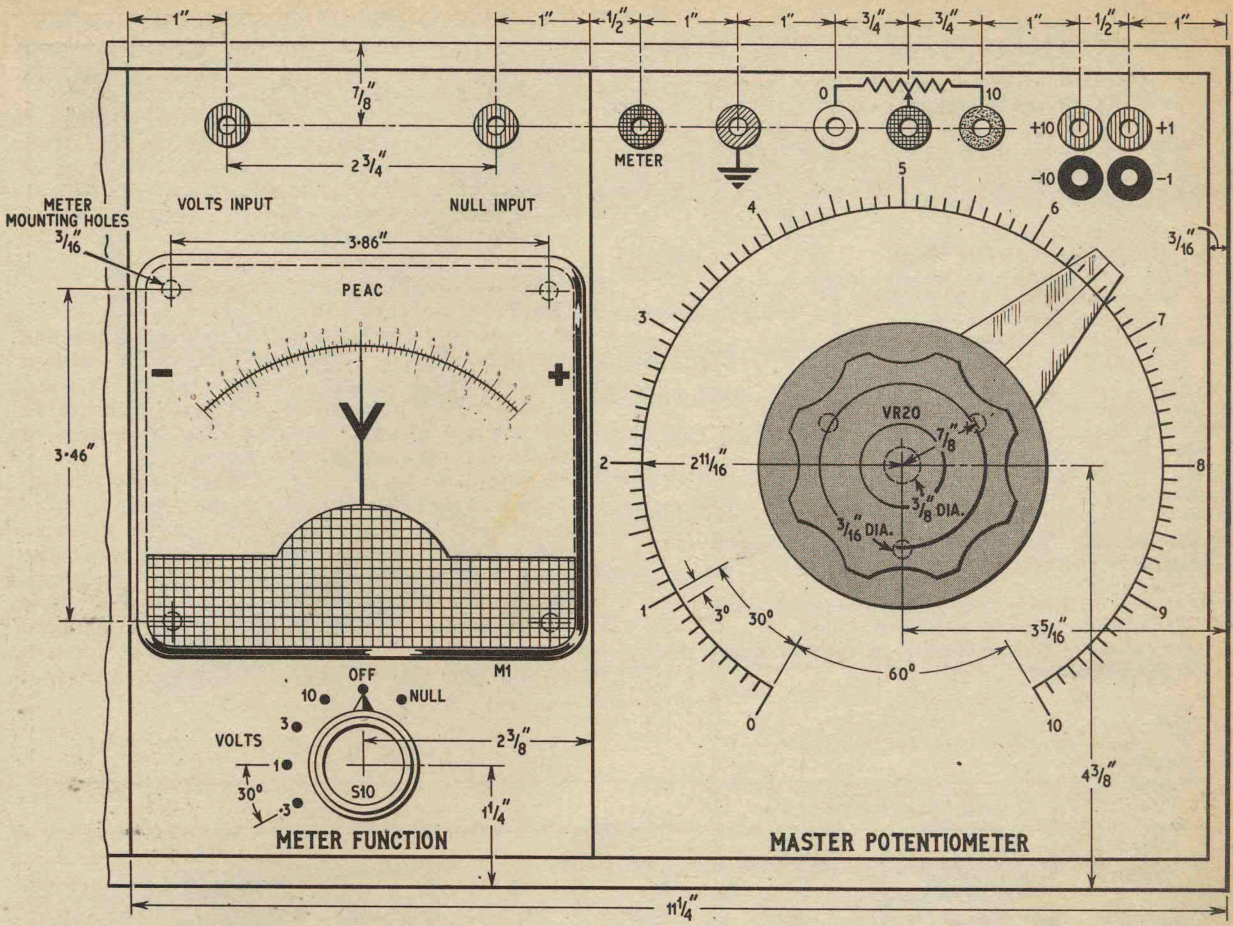


Fig. 6.2. UNIT "B" front panel, readout meter and master potentiometer

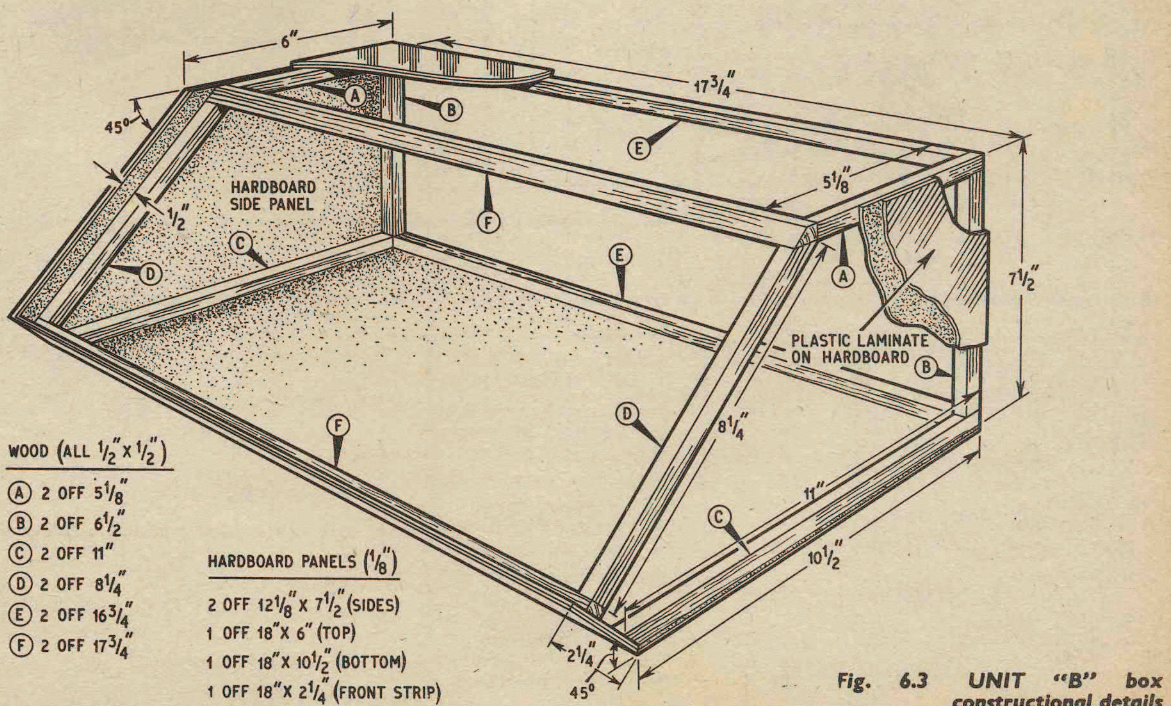


Fig. 6.3 UNIT "B" box constructional details

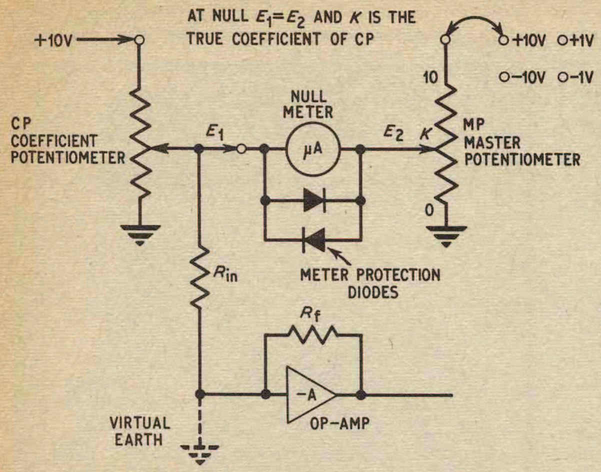


Fig. 6.4. Master potentiometer circuit for measuring coefficients

the voltage at the slider of CP is identical to the slider voltage of MP, no current flows through the null meter, and the true coefficient of CP can be read straight off the dial of MP.

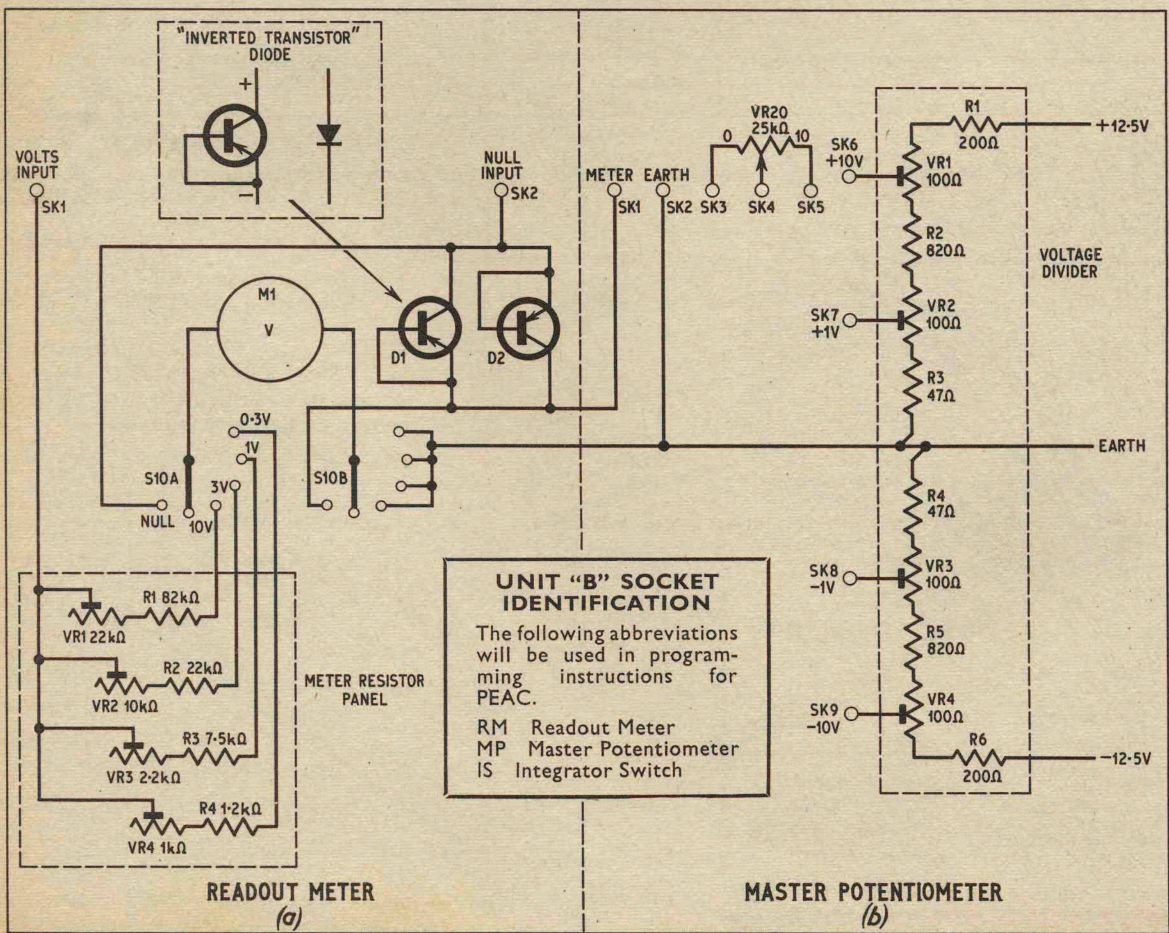
Since no current flows at null point, no load is imposed, and the input resistance of the measuring circuit is virtually infinite. Meter protection diodes are included to preserve good meter sensitivity without allowing damaging currents to flow through the meter when the circuit is off balance.

READOUT METER AND MASTER POTENTIOMETER CIRCUITS

One meter movement serves for null indication and voltage measurement. Considering first the readout meter circuit Fig 6.5a, miniature pre-set resistors VR1–VR4 will permit calibration of each meter range to an external voltage standard, and also help to eliminate discrepancies between ranges.

The way in which meter protection diodes D1 and D2 are wired may be unfamiliar to the reader, so some explanation is called for. If a transistor is operated "inverted", that is with collector-emitter polarities reversed, it will exhibit a very low "on" resistance when the base is near emitter potential. With base connected straight to emitter, the transistor therefore becomes a diode with lower than normal forward resistance, and yet will still offer a high resistance

Fig. 6.5 (below). Circuit diagram of readout meter and master potentiometer



reverse characteristic. The arrangement eliminates the need for a meter series resistor while still giving adequate protection.

In Fig. 6.5b, VR20 is a 3in instrument potentiometer of good linearity. The voltage divider network, composed of R1–R6 and VR1–VR4, taps off four standard voltages from the computer power supply, so that the master potentiometer will measure inputs of 0 to + 1V, 0 to − 1V, 0 to + 10V, and 0 to − 10V on its 0–10 scale. The accuracy of the master potentiometer, bearing in mind the 14in scale length, approaches that of a laboratory voltmeter.

FRONT PANEL AND MASTER POTENTIOMETER ASSEMBLY

Mount all sockets, potentiometers VR18–VR20, switches S7–S10, and meter, on the UNIT "B" front panel. Make up an aluminium bracket from the measurements given in Fig. 6.6, and glue it to the front panel, along with the small tag strip, in the position shown in Fig. 6.7. A hot soldering iron applied to the aluminium bracket will solidify the epoxy resin glue in a matter of minutes, sufficient to hold the bracket in place until the joint sets hard.

Rest the front panel inside-out on the UNIT "B" box front, to protect panel markings during assembly. Mount pre-set voltage divider potentiometers VR1–VR4 to the aluminium bracket, and then proceed with the

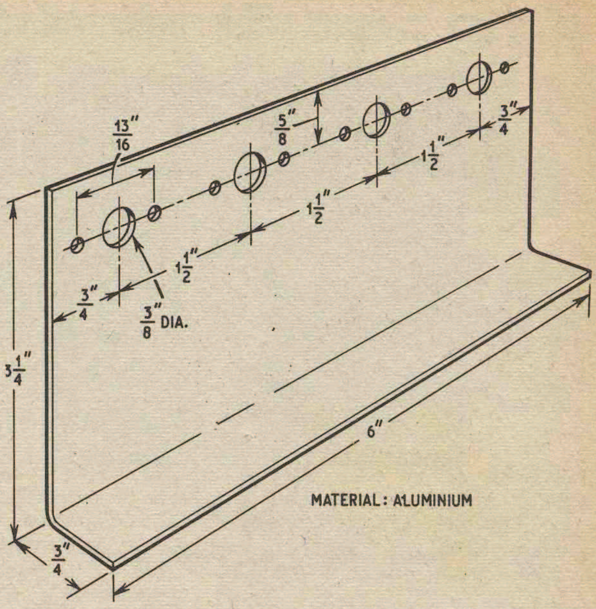


Fig. 6·6. Mounting bracket for pre-set potentiometers

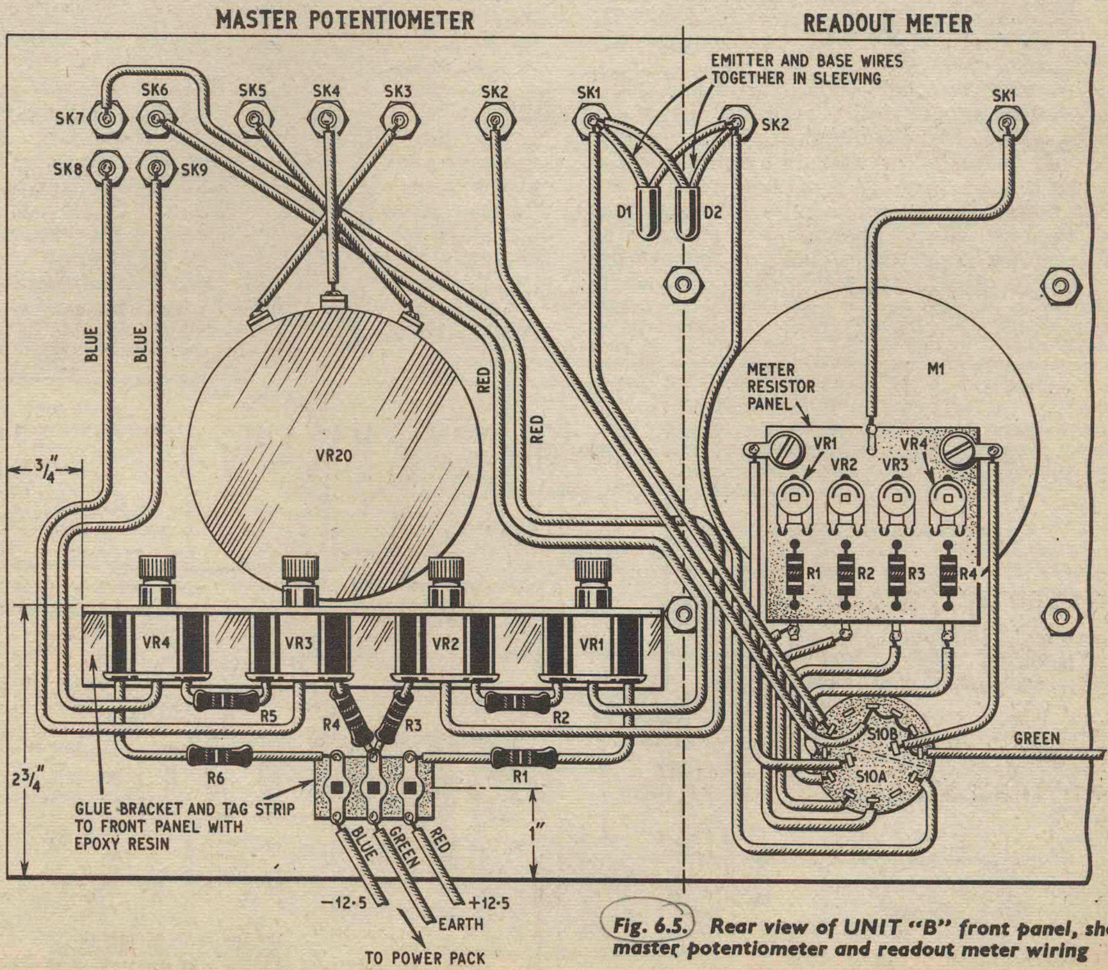


Fig. 6.5. Rear view of UNIT "B" front panel, showing master potentiometer and readout meter wiring

Fig 6.7

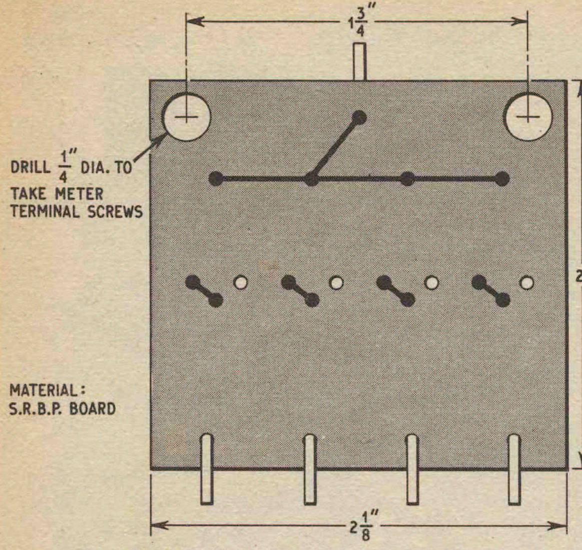


Fig. 6.8. Meter resistor panel, underside view

wiring of master potentiometer components, using 20 s.w.g. tinned copper wire and sleeving.

READOUT METER ASSEMBLY

Make up the meter resistor panel shown in Figs 6.7 and 6.8, and attach to the meter terminals. Solder D1 and D2 to MP/SK1 and RM/SK2, then complete S10 and resistor panel wiring.

As centre-zero voltmeters with 10–0–10 and 3–0–3 scale calibrations are not readily available, a scale will have to be made. Perhaps the most satisfactory way of fabricating a new and really accurate meter scale is to draw it two to four times full size, photograph it, and then have the resulting negative enlarged back to the original size on glossy photographic paper. The enlarging can be done commercially if the oversize drawing carries a thick black line to represent a length of 1in on the finished scale, just outside the scale perimeter.

When taking the photograph, ensure that the camera lens is in line with the centre of the scale card, and that the film plane is parallel to the surface of the oversize drawing, to prevent optical distortion.

Another tip, use white Formica for the drawing, as then mistakes in ink can be erased without leaving unsightly grey areas.

To remove the existing scale from the meter, prise off the transparent meter front, and carefully remove the scale card by undoing the two holding screws. Measurements can then be taken for preparing the oversize drawing.

To fit the new scale, cut out the photographic reproduction and paste it over the old scale, with edges and mounting holes of both scales properly registered.

SETTING UP MASTER POTENTIOMETER AND READOUT METER

With red, green, and blue p.v.c. covered wires, connect the master potentiometer tag strip (Fig 6.7) to the solder tags on the power pack output terminals. Also, temporarily link the rear of MP/SK2 to the green earth wire. Rotate VR20 spindle fully clockwise and patch MP/SK2 to SK3, MP/SK5 to SK6, MP/SK1 to SK4, and link RM/SK2 to VS1/SK1. Switch on the computer and S6, and adjust VS1 for an exact +10V. Now obtain a null on the readout meter by setting VR1 on the voltage divider bracket, from the back of UNIT "B" box.

Repeat for VR2 with an input of +1V by transferring the patching lead plug from MP/SK6 to SK7, and again for VR3, SK8, with an input of –1V, and VR4, SK9, with an input of —10V.

After that, while still nulling with a —10V input, rotate VR20 spindle slightly clockwise, until the meter pointer just begins to move away from zero. Place the large knob on VR20 spindle, with the transparent plastic cursor aligned with the "10" division, and tighten the grub screw. Set VR20 cursor to the "5" division and check for null with an input of —5V. It may be necessary to slightly re-position VR20 knob on the spindle, and trim VR1–VR4 again to minimise errors.

Calibration of the readout meter is straightforward. Apply a selection of known voltages to RM/SK1 and

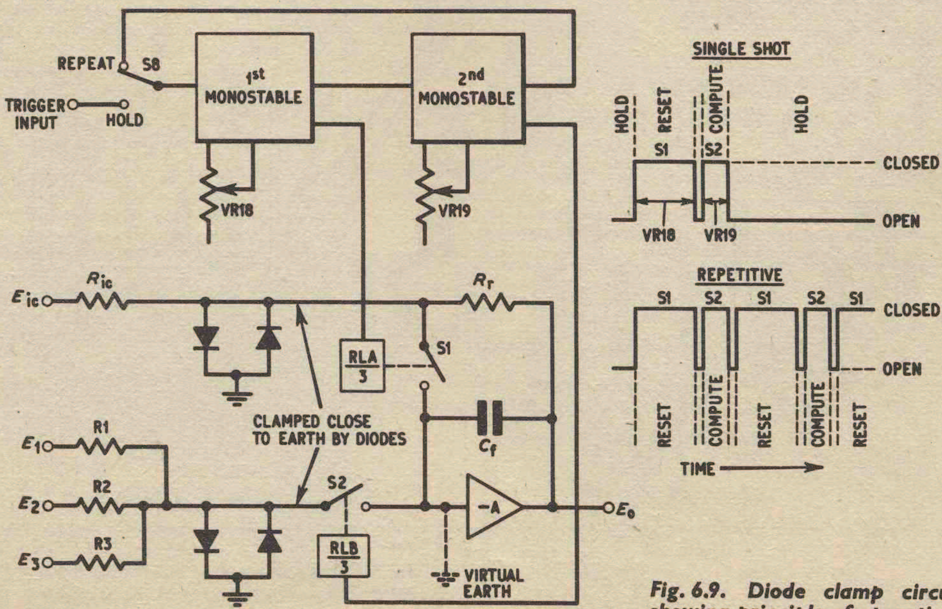


Fig. 6.9. Diode clamp circuit, showing principle of operation

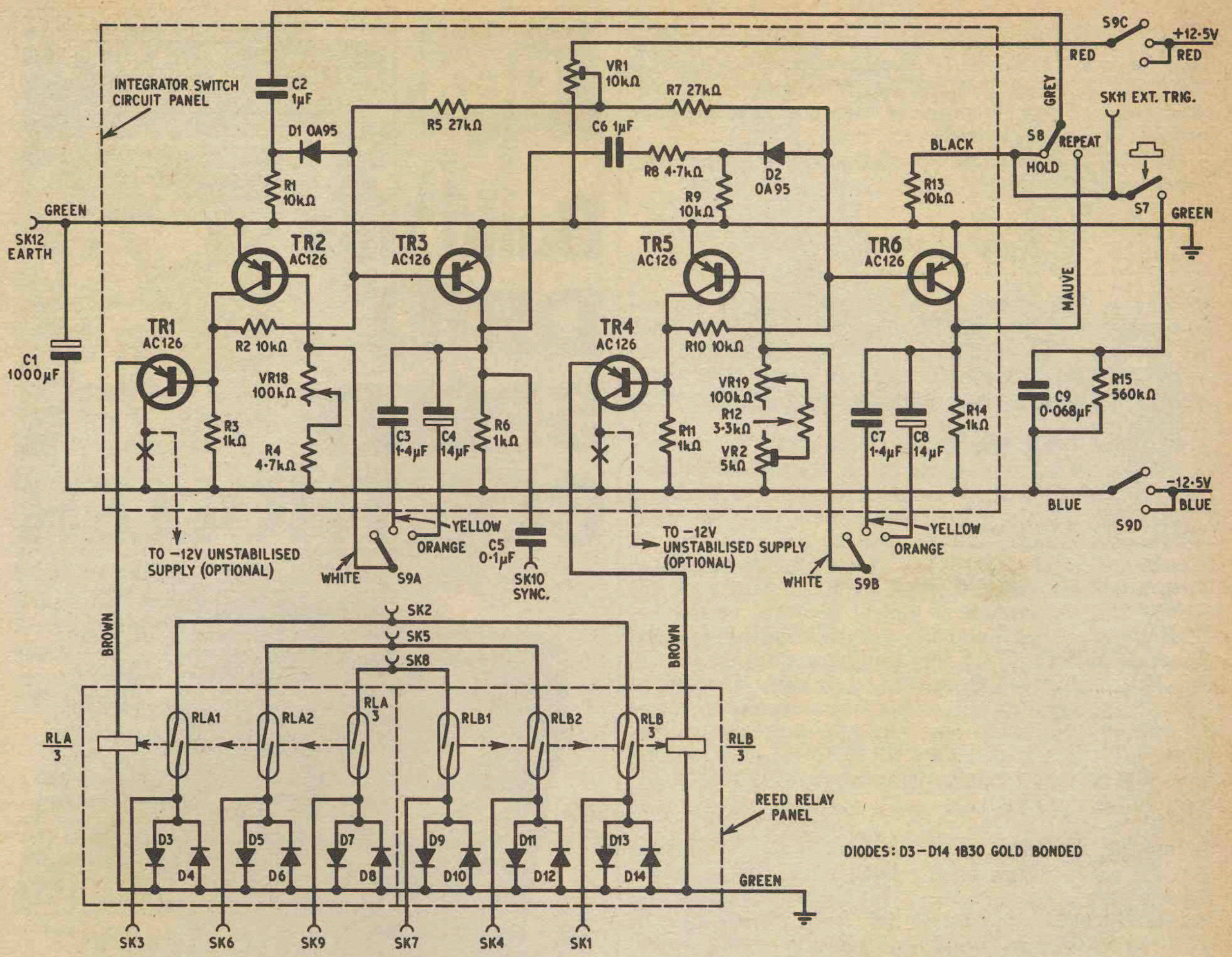


Fig. 6.10. The complete circuit diagram of the integrator switch

adjust VR1–VR4 on the resistor panel for optimum accuracy on each range.

INTEGRATOR MODE SWITCHING

The simplest type of integrator switch employs a mechanical relay with several sets of contacts, driven by an astable multivibrator, and this system is used for small demonstration and educational analogue computers. The relay is arranged to "gate" the inputs of several amplifiers simultaneously.

The PEAC integrator switch goes a stage further, with reed relays for a "clean" switching action at high speeds, full initial condition facilities, and a circuit based on two independently timed monostable multivibrators.

Referring back to the basic integrator switch shown in Fig 1.2c, two changeover switches S1 and S2 are opened and closed in a pre-determined sequence, governed by an external timing circuit. It is important to ensure that integrating amplifier input resistors are not left floating when they are disconnected from the virtual earth summing junction, as this could seriously disturb input and other computer voltages, hence the presence of S1 and S2 earthed contacts.

DIODE CLAMPS

To eliminate the need for expensive reed switches with changeover contacts, diode clamps can be used instead of an earthed contact, see the alternative amplifier circuit of Fig 6.9. The diodes do not interfere with the normal working of the integrator, but will nevertheless hold resistor junctions close enough to earth to prevent load variations when S1 and S2 are open, and this modification more than halves the cost of switching components.

In the block diagram of Fig 6.9, the 1st monostable—controlled by VR18—determines the period of closure of S1. When S1 opens after a timed interval, a pulse is delivered to the input of the 2nd monostable, thus closing S2. S2 will remain closed for an interval controlled solely by VR19.

For "single shot" operation, a trigger pulse applied to the 1st monostable input, when S8 is switched to "hold", will initiate the closure of S1 (reset) and bring the integrating amplifier to its initial condition.

As soon as S1 opens, S2 closes (compute) and connects input resistors to the summing junction. At the end of the compute period, S1 and S2 are both open (hold), the monostables are quiescent, and the amplifier output voltage is held steady by the action of capacitor C_f. The next computer run is started by another trigger pulse applied to the 1st monostable input.

Repetitive operation is achieved by passing the output pulse from the 2nd monostable back to the input of the 1st monostable, when S8 is switched to "repeat". S1 and S2 are then made to open and close alternately, and the "hold" facility is deleted.

The method of inserting an inital condition voltage is as follows. When S1 is closed the reset resistor R_r is connected between the amplifier output and summing junction, and can therefore be regarded as a feedback resistor in parallel with C_f.

As long as S1 remains closed, R_{ic} will be acting as an input resistor, so that

$$E_o = -E_{ic}\frac{R_r}{R_{ic}}$$

and $E_o = -E_{ic}$ when $R_r = R_{ic}$. R_{ic} and R_r are disconnected from the amplifier summing junction when S1 opens, but C_f will "remember" the initial condition voltage and hold the amplifier output steady prior to the application of compute voltages when S2 closes.

INTEGRATOR SWITCH CIRCUIT

The complete circuit of the integrator switch is shown in Fig 6.10. The 1st monostable consists of TR2 and TR3, with RLA actuated by emitter follower TR1. VR18 continuously covers two ranges given by C3 (10–100ms), and C4 (0·1–1s). Components associated with the 1st monostable input are C2, R1, and D1.

The 2nd monostable is almost identical to the 1st. TR4 drives RLB, C7 and C8 offer the same timing range coverage as C3 and C4, and input components are C6, R8, R9, and D2. However, more care is taken to establish the correct values for 2nd monostable timing capacitors C7 and C8, and VR2 allows precise calibration of the "fast end" of the VR19 timing scale, so that compute intervals can be determined by a reasonably accurate dial setting.

VR1 establishes the working point of both monostables, to achieve reliable operation at all dial settings. S7 is a push button on the front panel for starting a "single shot" computer run. Full control of an oscilloscope trace, from UNIT "B" front panel, can be realised by suitable connection to the integrator switch circuit. With S8 switched to "hold", the mode sequence can be triggered repetitively, with a variable hold interval, by the oscilloscope timebase output or by a separate oscillator. Consistant syncronisation of the trace, with continuous or single-sweep timebases, is made possible by linking IS/SK10 to an appropriate oscilloscope input

A SEPARATE SUPPLY

The load capacity of the existing stabilised power supply can be improved by wiring the collectors of TR1 and TR4 (shown dotted in Fig. 6.10) to a separate −12V unregulated supply, which can be housed inside the UNIT "B" box, and in this event C1 could be omitted from the Fig. 6.10 circuit, as it merely serves to prevent current pulses from flowing in the negative stabilised supply line during relay switching.

RLA and RLB consist of two triple-switch coils, catering for the needs of three integrating amplifiers. A duplicate relay panel could be added later, by wiring relay coils in parallel, to increase the switching capacity to six amplifiers.

CORRECTION

In Fig. 5.7, the captions for the first and second oscillographs (top row, left and centre) should be transposed.

Next month: Assembly and setting up of the Integrator Switch; practical examples in the use of this section. Introduction of UNIT "C" Function Generator.