



Fig. 3.7. UNIT "A" Operational amplifier circuit

COMPONENTS . . .

UNIT "A" OPERATIONAL AMPLIFIER

The following items are for a single amplifier, and are required in triplicate to cover the three amplifiers employed in UNIT "A".

Resistors

- R1 3.9M Ω 5% carbon film
- R2-R4 27k Ω 5% carbon film (3 off)
- R5 2.2k Ω
- R6, R7 15k Ω (2 off)
- R8 470 Ω
- R9 39k Ω
- R10 330 Ω 2W
- R11 100 Ω
- All $\pm 10\%$, $\frac{1}{2}$ W carbon composition, except where otherwise stated

Potentiometer

- VR1 5k Ω vertical skeleton pre-set

Capacitors

- C1 0.022 μ F miniature polyester 250V d.c.
- C2 39pF polystyrene 125V d.c.

Transistors

- TR1-TR3 2N2926 orange (General Electric) or 2N3904 (Motorola) (3 off)
- TR4 2N3906 (Motorola)
- TR5 2N1893 (Bentron), 2N696, or 2N697 (General Electric).

Miscellaneous

- S.r.b.p. panel 2in \times 2 $\frac{1}{2}$ in
- Eight small turret tags
- TO-5 transistor cooler Type BC105B (Bentron)
- 6 B.A. screws, nuts, and spacers
- Stranded core p.v.c. wires; red, green, blue, orange, mauve, grey, yellow, and white
- 12in \times 4in s.r.b.p. amplifier mount
- Note: All transistors and cooler can be obtained from Rastra Electronics Ltd., 275-281 King Street, Hammer-smith, W.6.

earth, and low drift with change in temperature when TR1 and TR2 are closely matched. The long-tailed pair also gives good rejection of drift induced by changes in supply voltage, and has a reasonably large input impedance at low collector current levels.

An input signal will undergo a phase change of 180 degrees between the base and collector of TR1, and the voltage datum level is shifted away from earth towards the positive rail voltage. Ignoring for the moment C1, the signal is passed straight to the base of TR3.

VR1, R5, and R7 form an adjustable potential divider across positive and negative supply rails, and the VR1 setting determines the working points of direct coupled stages TR3, TR4, and TR5. Front panel control VR15 sets the amplifier input at zero volts, while VR1 does the same for the output.

TR3, while contributing some voltage gain, also introduces another 180 degree change of phase, to bring the overall phase difference between the amplifier input and TR3 collector to zero. Obviously, the voltage at the collector of TR3 will be even closer to positive rail voltage than the collector of TR1, but this cumulative voltage shifting can be virtually eliminated by using a *pnp* transistor for TR4. At the same time, TR4 common emitter stage brings more voltage gain and another and final phase change of 180 degrees.

So, the situation at the collector of TR4, when VR15 and VR1 are at correct settings, will be no overall voltage shift, a total phase difference of 180 degrees, and a total voltage gain in the region of 5,000.

Finally, the addition of an emitter follower stage provides the low input impedance required for driving a variety of useful loads, without unwanted circuit complications. TR5 causes negligible further voltage shifting, adds no change of phase, and with a voltage gain very close to unity, will simply reduce the output impedance of the operational amplifier without modifying its other characteristics.