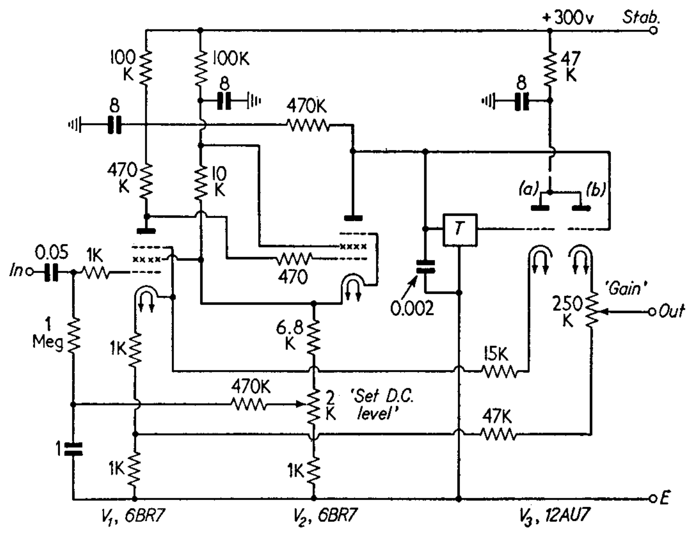
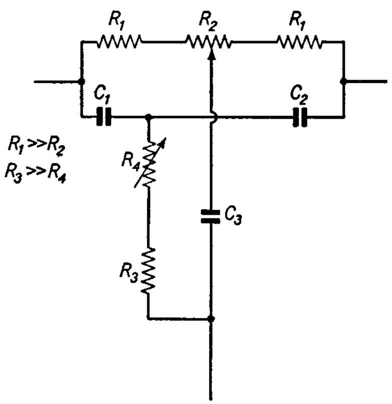
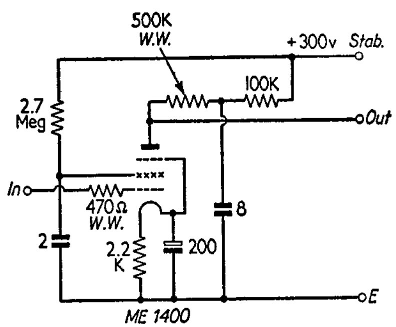


(a)



(b)



(c)

FIG. IV.2a. L.F. main amplifier.

FIG. IV.2b. Twin-T network. At peak frequency ω_0, assuming R_2 is center tapped,

$$1/\omega_0^2 = (2R_1 + R_2)(R_3 + R_4)C_1C_2$$

and

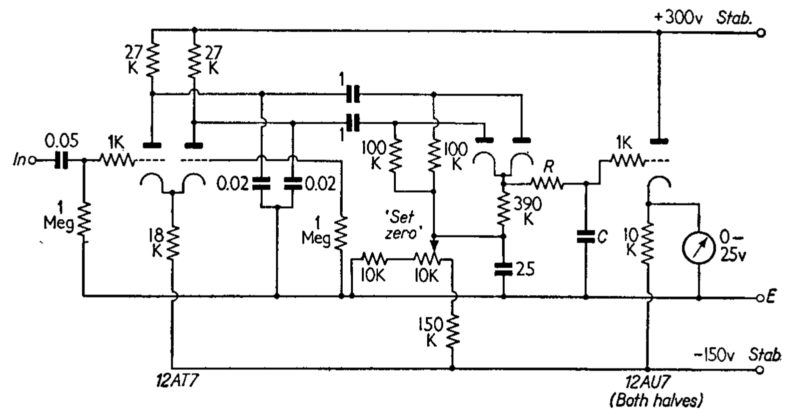
$$\omega_0^2 = \frac{C_1 + C_2}{C_3C_1C_2[R_1 + (R_2/2)]^2}$$

R_2 and R_4 are made variable to compensate for component tolerances and enable the network to be "tuned" over narrow limits.

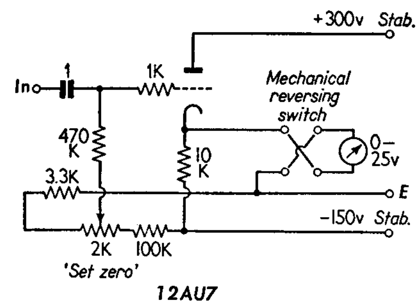
FIG. IV.2c. Head amplifier.

3. A Low Frequency Amplifier

A very successful low frequency amplifier for use with thermopiles or bolometers has been described and used by the authors (21). It is a modification of an earlier circuit by Brown (16) who in turn based the design on the work of Sturtevant (22). One stage of the main amplifier is shown in Fig. IV.2a. This unit of three tubes has a peak voltage gain of about × 200. Feedback is applied in two separate ways. One, via V_{3b} gives over-all stability in the usual way. The other, via the twin-T network, T (see Fig. IV.2b), and V_{3a}, applies selective feedback which gives zero attenuation at



(d)



(e)

FIG. IV.2d. Phase-splitter and double-diode rectifier, with smoothing time constant = RC.

FIG. IV.2e. Mechanical phase-sensitive rectifier.

the characteristic frequency and an attenuation which increases as the signal moves away from the peak. With two such circuits in cascade, Brown obtained a bandwidth of 0.63 cps centered at 5 cps, and corresponding bandwidths of 2 cps at $16\frac{2}{3}$ cps, and 4 cps at $33\frac{1}{3}$ cps. With suitable circuit constants this arrangement can be used at frequencies up to 1 kc.

The head amplifier uses a selected pentode valve operated at very low anode current (see Fig. IV.2c). Wiring and mounting of the head amplifier follows the principles set out above. The electrolytic cathode decoupling condenser shown was found to be satisfactory at $33\frac{1}{3}$ cps but unsuitable at 5 cps. Two forms of output circuit have been used; in one a phase-splitting "long tailed pair" is followed by a double-diode rectifier, Fig. IV.2d, and in the other there is a simple form of phase sensitive rectifier in which a cam-operated reversing switch is mounted on the shaft carrying the radiation chopper (Fig. IV.2e). The position of the cam can be varied with respect to the chopper to alter the phase of the rectifier switch. The whole amplifier is fed from stabilized power supplies, and dc heater voltages are used in the head amplifier and the first amplifying unit.

With either output circuit an over-all voltage gain of about 5×10^6 is achieved, the output being linear up to some 25 volts. Brown describes a suitable input transformer to transform a thermopile impedance to a value of 1 megohm, chosen as sufficiently greater than the equivalent noise input resistance at 5 cps. For an indication of the precautions necessary to avoid trouble from stray pick-up or microphony in the transformer, Brown's arrangement is worth studying. The core and windings are inside a mumetal box; outside this is a copper box for electrostatic screening and then a soft iron magnetic shielding box. All these boxes are mechanically insulated from each other by soft rubber packings. It is then necessary to place the whole on sponge rubber inside a $\frac{1}{4}$-in. thick mild steel box which is itself on a rubber base. With this system Brown observed an increase of output noise with the phase sensitive rectifier when the transformer secondary replaced a short circuit across the amplifier input. Since the resistance across the primary was 3 ohms, the noise from a thermopile of, say, 10 ohms was easily observed and the amplifier does not limit the detector sensitivity.

4. An Amplifier Suitable for a Photoconductive Cell

Brown (23) has also described a tuned amplifier working at 800 cps for use with relatively high resistance photoconductive cells. This amplifier has an over-all gain of 10^7, stable to $\frac{1}{3}\%$ with respect to normal tube tolerances and 15% variations in mains supply voltage. The bandwidth is about 50 cps. The basic unit is again a group of three valves with negative feedback applied to the group to give the required stability. The circuit of one such unit is shown in Fig. IV.3; to a first approximation the gain of the

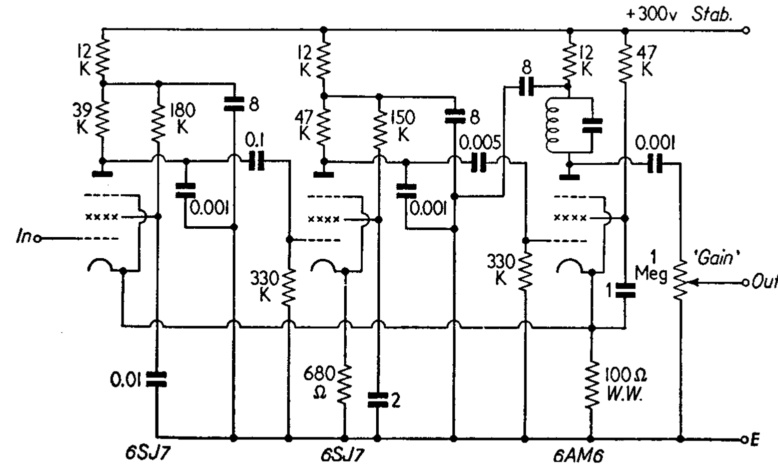


FIG. IV.3. 800 cps amplifier, main stage.

stage is given by the ratio of the dynamic impedance of the tuned circuit in the anode of V_3 to the resistance of the cathode resistor common to V_3 and V_1. The coils used have an inductance of 0.4 henry and a Q value of 20, giving a stage gain of $\times$ 400. Two such stages are "stagger-tuned" to give the bandwidth of 50 cps. In the third, the tuned circuit is replaced by the primary of a transformer whose center-tapped secondary feeds a double-diode rectifier. The amplifier has an equivalent noise input resistance of 40,000 ohms, which is suitable for direct use with most lead salt cells (see Chapter III). If lower resistance cells are to be used, e.g., of InSb, a matching transformer is needed.

5. Phase Sensitive Rectifiers and Wide Band Amplifiers

The photocell amplifier discussed above might well employ a phase sensitive rectifier with the attendant advantages at a low signal-to-noise ratio. Mechanical difficulties, however, restrict a cam-operated switch to low frequencies and an electronic phase-sensitive rectifier is needed. Such a system has two parts: the actual rectifying "switch" which is "on" or "off"