SECTION 8

GENERAL PURPOSE AMPLIFIER, GPA/1

General Description

The General Purpose Amplifier, GPA/1, has been designed to function as a high-grade amplifier having a maximum gain of 80, 65, 50 or 35 dB and operating between 600-ohm terminations.

For 35-dB maximum gain, the amplifier employs a single stage ; in all other conditions two stages resistance-capacitance coupled are used. Selection of maximum gain is effected by two range switches, one of which switches the first stage out of circuit when the 35-dB range is required ; the other varies the amount of feedback applied to the first stage.

A fine gain-control, calibrated from 0 to − 18 dB in 2-dB steps, is provided in the grid circuit of the second stage, thus permitting variable gain over an extensive range. The minimum gain obtainable from the amplifier is approximately 17 dB. The amplifier is rack-mounted and takes its supplies from a standard mains unit, such as the MU/16.

from austerity restrictions obtaining at the time of its design.

This applies in particular to noise level and valve " ponging," both of which have been materially reduced in the GPA/1, particularly in the lower ranges of maximum gain.

Mechanical Design

The mechanical design of the GPA/1 has taken into consideration possible modifications in the design of future apparatus bays, the layout being such that the unit can be accommodated, without redesign, on a 19-inch bay and, in order to economise in bay space, two units may be mounted back to back, with the cable form running down the bay channel.

The components are mounted on both sides of the panel, so arranged that most of the wiring is accommodated at the back and is therefore

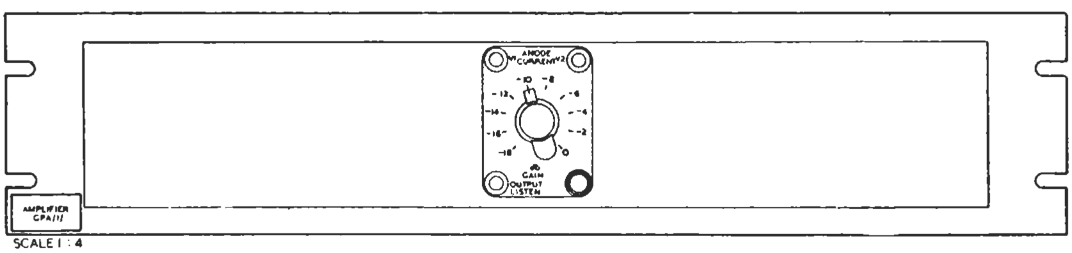

Fig. 8.1. Face Panel GPA/1

Design Considerations

In the pre-war period, audio-frequency amplifiers were designed on a single-purpose basis, which resulted in a large number of different types of amplifiers being included in the programme chain. War conditions made it necessary to reduce very considerably the number of different types of amplifier, and the D/11 was designed to meet this need. Experience has shown that this principle of a general purpose amplifier has many advantages over the pre-war system and the GPA/1 has been designed to retain these advantages and at the same time to remove the deficiencies inherent in the amplifier D/11, which resulted

screened by the panel itself. The first valve, together with the input transformer and associated components, is mounted on a sub-panel which is attached to the main panel through a very flexible mounting. This arrangment, which has been used on previous high-grade amplifiers, minimises microphonic noises.

The front of the amplifier unit is shown in Fig. 8.1. It will be seen that the only control accessible with the dust cover in position is the fine gain-control. The range switches, which determine the maximum operating gain, are deliberately concealed, since in all normal circumstances they are pre-set on installation. In order to economise in meters and switches, anode feeds are measured by means of a portable meter, via appropriate feed-jacks. An output listen jack and a pilot lamp are the only other items appearing on the front of the unit with the dust cover in position.

Electrical Design

The GPA/1 is designed to provide voltage gain which may be varied, according to requirement, between the limits of 17 and 80 dB and thus, in general, can be used at any point in the programme chain where the required minimum gain is not less than about 20 dB. Arrangements are included which, by varying the amount of feedback, permit the pre-setting of maximum gain at 80, 65 or 50 dB, and cut out the first stage for maximum gain of 35 dB. A fine gain-control calibrated in 2-dB steps, caters for intermediate values.

It should be noted here that some overlap between the maximum ranges is obtainable by suitable adjustment of the fine gain-control. For instance, in the 50-dB maximum-gain position, the amplifier will operate at a gain of 32 dB if the fine gain-control is set to − 18.

Frequency Response

The frequency response of the amplifier is almost level between 50 c/s and 10,000 c/s for all conditions of working, the tolerance being ± 0·5 dB. There is a slight fall in the response below 50 c/s and above 10,000 c/s due to the input transformer, but the losses do not exceed 1 dB at 30 c/s and 15,000 c/s. It is anticipated that the low-frequency response will improve when better materials become available.

Distortion Factor

The amount of harmonic distortion naturally varies with the maximum gain working conditions, but since feedback is applied under all conditions the total percentage distortion is very low and, except under 80-dB maximum-gain conditions, does not exceed 0·5 per cent at peak volume of + 8 dB, which is the normal working condition. Under the same output conditions, but with the range switch set for 80-dB maximum gain, the total distortion does not exceed 1 per cent, provided that the variable gain-control is not set to − 18 dB.

If in the 80-dB position the switch is set at − 18 dB, the feedback at the first stage is insufficient to prevent distortion exceeding 1 per cent. For this reason, this position of the switch is engraved in red.

Noise Level

Under high-gain conditions, the greater part of the background noise is associated with the first stage. Since the fine gain-control is interposed between the two stages, it follows that the noise applied to the grid of the second stage is reduced as the gain-control is brought down. In this way, the signal-to-noise ratio is maintained at its optimum value at all times. Further, the reduction of maximum gain from 80 dB to 65 dB and from 65 dB to 59 dB is achieved by varying the amount of feedback on the first stage. This again reduces the noise level approximately, but not exactly, in the same ratio as the reduction in gain.

Two other points are worth mentioning with regard to noise level. Firstly, the input transformer is designed with the highest possible voltage step-up, ensuring maximum signal-to-noise ratio at the grid of the input valve. Secondly, the heater circuits have been designed to keep the hum down to a lower value than that obtaining in earlier amplifiers. In previous amplifiers, hum voltage has been injected into the cathode circuit by virtue of imperfect insulation between cathode and heater and, where the cathode is maintained at a high impedance with respect to earth, the hum may be considerable.

This condition is avoided in the GPA/1 by maintaining the cathode virtually at earth potential.

Circuit Description (Fig. 24)

The input transformer T1 has an impedance ratio of 1 : 416 and therefore to maintain an input impedance of 600 ohms across its primary terminals, it must be loaded by 0·25 megohms across the secondary winding.

Under 80-dB maximum-gain conditions, the load is obtained artificially. The 2-megohm resistor R4 (Fig. 8.2), instead of being connected between the grid of V1 and earth, is connected between grid and a point on a potentiometer across the anode circuit, comprising the variable gain control. in series with R20, R21. This point on the potentiometer is at a potential of 7 volts negative when the instantaneous potential on the grid is 1 volt positive. Thus, for example, if the grid of V1 is given a potential of + 1 volt with respect to earth, R4 will have a potential of 8 volts across it. A little consideration will show that the value of the current through R4 will be the same as that which would obtain if a resistor equal to $\frac{R4}{8}$ were connected between grid and earth and a potential of 1 volt applied across it. Since this current must be supplied by the transformer, the apparent load on the transformer is 0·25 megohms. It should be noted that, because R4 is connected to the junction of the resistors R20, R21, which are included in the anode circuit, a certain amount of feedback (5 dB) is applied to the first stage even in this condition of maximum gain.

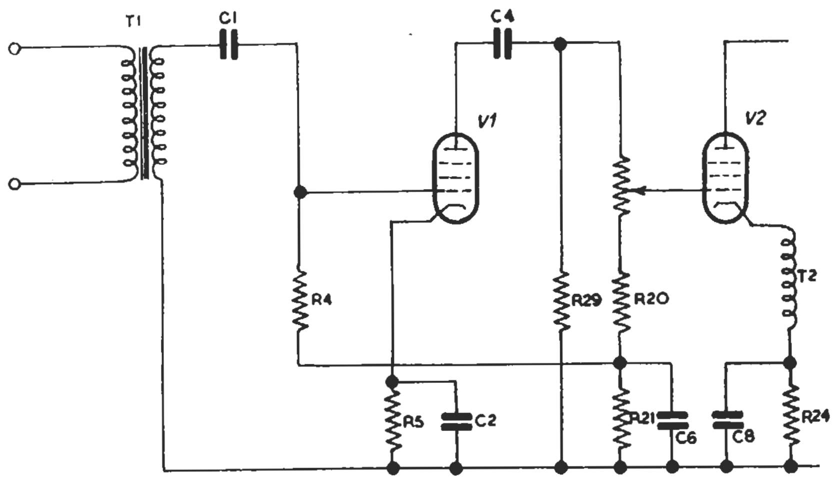

Fig. 8.2. Circuit for 80-dBgain

This is in itself an improvement on previous amplifiers such as the D/11, where, at the highest maximum gain, feedback is eliminated in the first stage. The capacitor C6 shunted across R21 slightly reduces the feedback at high frequencies to compensate for slight losses in other parts of the circuit.

Under 65-dB maximum-gain conditions (Fig. 8.3) the feedback applied to the first stage is increased to 19 dB by connecting the lower end of R4 to a point on the potentiometer which is at a higher potential than that used in the case of 80-dB maximum gain. This has the effect of making the apparent load on the transformer much less than 0·25 megohms for reasons previously discussed and, in order to compensate for the reduced load, R2 is switched in series with R4 and the secondary of T1.

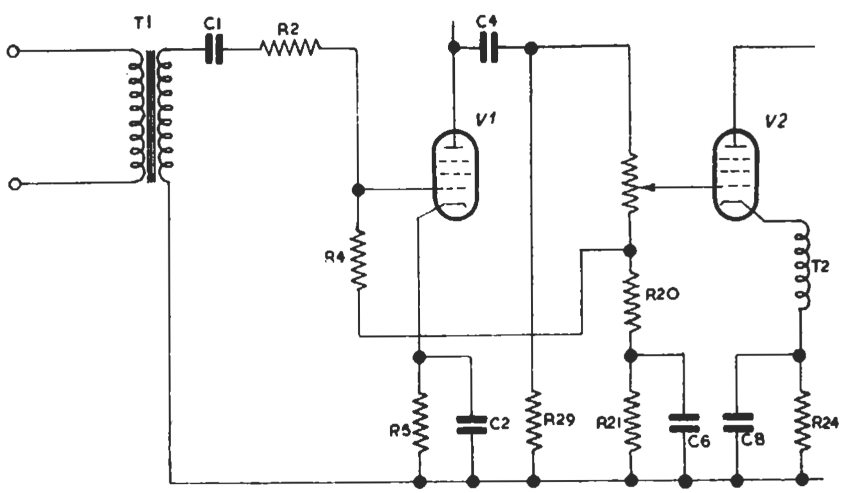

Fig. 8.3. Circuit for 65-dBgain

Under 50-db maximum-gain conditions (Fig. 8.4), the feedback is increased to 33 dB by switching the lower end of R4 to the high-potential side of the anode circuit potentiometer, so that virtually

R4 is connected between anode and grid of V1. This reduces the impedance of R4 still further, to compensate for which R1 is connected in series with R2, etc., thus still maintaining the correct load on the transformer T1.

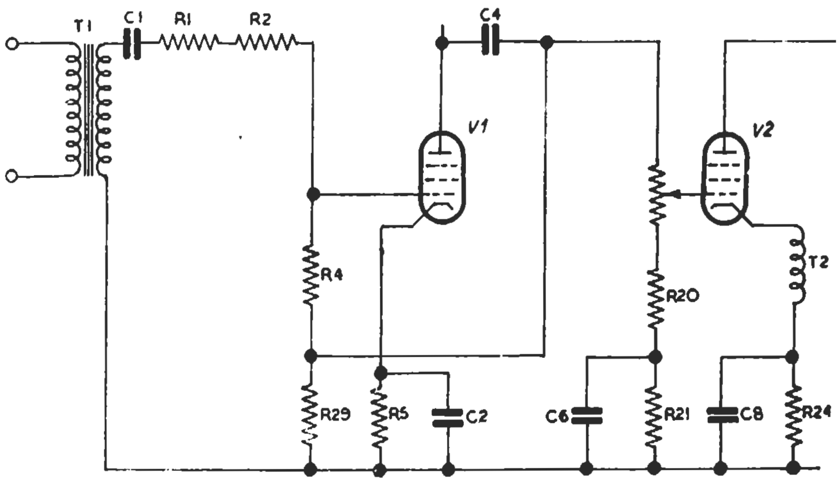

Fig. 8.4. Circuit for 50-dB gain

Under 35-dB maximum-gain conditions (Fig. 8.5), the secondary of T1 is disconnected from the grid of V1 and connected to the top end of the gain-control, thus cutting V1 out of circuit. The load

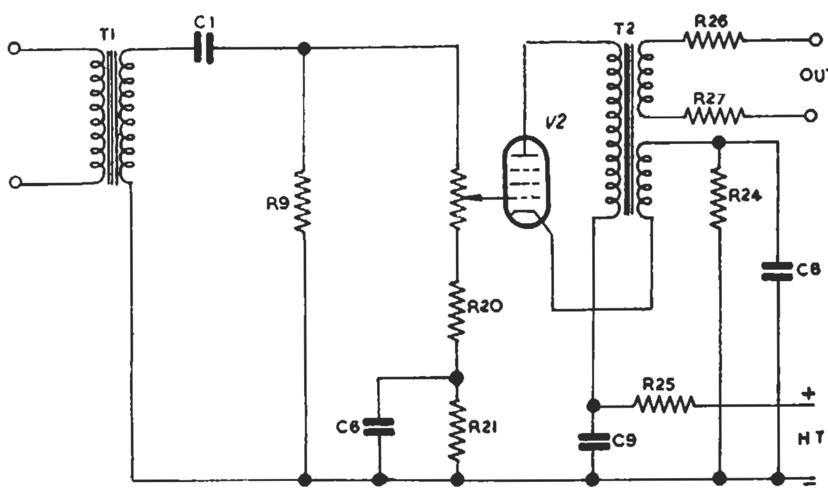

Fig. 8.5. Circuit for 35-dB gain

on T1 is maintained at 0·25 megohms by shunting R9 across the gain-control and R20, R21.

In order to prevent the grid of V1 being left open-circuited under these conditions, the lower end of R4 is connected to earth via the high resistance R29 (Fig. 24).

The output circuit is of a type developed by the BBC before the war, and which has since become standard. It employs a form of voltage feedback usually referred to as cathode-injected feedback, in which a third winding of the output transformer is used to inject the feedback voltage into the cathode circuit of the valve. This method of feedback has the merit of allowing the grid circuit of the valve to operate under normal conditions, its input impedance remaining at a high value.

Dealing with the circuit in detail (Fig. 8.5), when the normal 600-ohm load is connected to the output terminals, the two resistors R26 and R27 (the function of which is described later) increase the load impedance to 960 ohms. The impedance ratio of T2 is 65 : 1, and, by taking into account the resistance of the primary winding, the total anode load applied to the valve is 71,000 ohms.

Now, where the anode load of a pentode is low compared with its internal impedance, the gain operating between the grid and anode is approximately equal to the product of the anode load in thousands of ohms and the mutual conductance in mA/V.

In this case, the mutual conductance is 5·2, hence the gain of the valve is 370 times, i.e. 51 **dB.**

The third winding of T2 is connected in series with the cathode circuit, the feedback voltage thus introduced reducing the gain to 32 **dB**. The transformer introduces a further loss making the overall gain of the stage approximately 8 **dB.**

It is explained in E.T.S.3, that the application of voltage feedback has the effect of reducing the output impedance of the amplifier and in this case the value of the output impedance at the terminals of the transformer secondary winding is 240 ohms. An output impedance of 600 ohms is obtained by padding out the secondary winding with the two 180-ohm resistors R26 and R27.

Valve Data

Valve	*Anode Volts*	*Anode Current mA*	*Screen Current mA*	*Fil. Volts*	*Fil. Amps.*
Stage 1, AC/SP3A RH	80	1·7	0·6	4	1·0
Stage 2, AC/SP3B RH	260	5·0	1·75	4	1·0

Total Feed, 9·5 mA.
H.T. Supply, 300 V.
L.T. Supply, 4 V a.c.

General Data

	No. of Studs	*Loss per Stud*	*Loss on lowest Stud*
Gain-control	10	2 dB	18 dB.

*Range-switch S*1 *S*2 Yaxley, 2-bank, 4-position, Type A, N.S.
*Range-switch S*3 British N.S.F. single-pole, 2-position, Oak, Type 23.
Gain-control switch, Yaxley, 1-bank, 10-position, Type A., C.C.
*Potentiometer R*28, Painton, 25 Ω, Type CV2/25P.
Pilot Lamp, P.O. No. 2, 4 V.

Impedances
Input Z = 600 Ω.
Output Z = 600 ,,
Normal Load Z = 600 ,, (balanced).

Normal Working Levels
Input – 15 to – 80 dB.
Output Zero. (Max. + 4 dB.)

Test Data

Maximum Working Voltage and 600-ohm Test Gain
Test Conditions :
Fine gain-control at zero attenuation.
Tone Source Sending Level, – 80dB, – 65 dB, – 50 dB, – 35 dB.
Maximum gain at 1,000 c/s :
80 dB, ± 2 dB.
65, 50 or 35 dB, ± 1 dB.
Frequency Characteristics, 50-10,000 c/s ± 0·5 dB, 30-15,000 c/s ± 1·0 dB.

Total Percentage Harmonic Content (Max.)

	Normal level	*8 dB above normal level*	*12 dB above normal level*
100 c/s	0·5 %	1·0 %	1·5 %
1,000 c/s	0·2 %	0·5 %	0·8 %

Noise Level
– 45 dB at 80-dB gain.
– 55 dB at 65-dB gain.

AMPLIFIER GPA/1A

See Notes 5 and 6 on Fig. 24.