8/57

'3-3' QUALITY AMPLIFIER CIRCUIT

Mullard

This circuit has been developed from the 3-valve 3-watt amplifier which was designed for those constructors wishing to make a simple amplifier having a reasonably high quality. A few changes to the original design have resulted in improved low frequency stability and in less distortion at maximum output. The '3-3' circuit gives an output of 3 watts at a total harmonic distortion of 1%.*

CIRCUIT DESCRIPTION

The amplifier, which is operated from a.c. mains, uses three Mullard valves: an EF86 as the voltage amplifier, an EL84 in the output stage and an EZ80 as the rectifier. The circuit (Fig. 1) includes three controls: volume (RV1), treble (RV2) and bass (RV14).

The comparatively high sensitivity of the amplifier (100mV for 3W output) permits the use of all types of crystal pick-up, and allows, if required, the use of equaliser networks between the pick-up and amplifier. The 3·75Ω and 15Ω output terminations are suitable for almost all kinds of loudspeaker, and, although the circuit is designed to make the most effective use of the single output valve, the best possible results will only be achieved if a suitably housed, high quality speaker is used.

The EF86 is used under 'starvation' conditions; the valve currents and voltages are very much smaller than they would be under normal working conditions because of the high resistance (R4 = 1·0MΩ) in the anode circuit. Direct coupling from the anode of the EF86 to the control grid of the EL84 is also used. These two factors together produce a very high stage gain, and, although feedback of approximately 20dB is used around the whole circuit, an input of only 100mV is required to give an output of 3W.

The working points of the valves are stabilised by the d.c. negative feedback provided when the screen grid feed of the EF86 is taken from the cathode circuit of the output stage.

*Mullard 3-valve 3-watt amplifier circuit (TP283, August 1955) and "Radio Constructor," April 1956.

PERFORMANCE

With the treble and bass controls in their minimum effective positions, the frequency response is essentially flat from 35c/s to 30kc/s (Fig. 2). With maximum application of the respective controls, a treble cut of 20dB is available at 10kc/s, and a bass boost of 15dB is available at 70c/s. The bass boost is obtained by reducing the main feedback at low frequencies by means of RV14 and C6 (Fig. 1).

SUMMARY OF PERFORMANCE

Output Power (at 400c/s)
3W at 1·0% total harmonic distortion.

Power Response
Flat from 100c/s to 10kc/s.

Frequency Response
Flat within ±1dB (relative to the response level at 1kc/s) from 35c/s to 30kc/s.

Tone Control
Maximum Treble Cut: Approx. 20dB at 10kc/s.
Maximum Bass Boost: Approx. 15dB at 70c/s.

Sensitivity
100mV for 3W output.

Hum and Noise Levels
At least 70dB below 3W.

The relationship between the total harmonic distortion and the output power is shown in Fig. 3. It will be seen that, for a typical amplifier, for outputs above about 3·5W, the distortion increases rapidly. This indicates the point beyond which overloading of the amplifier occurs.

CONSTRUCTIONAL DETAILS

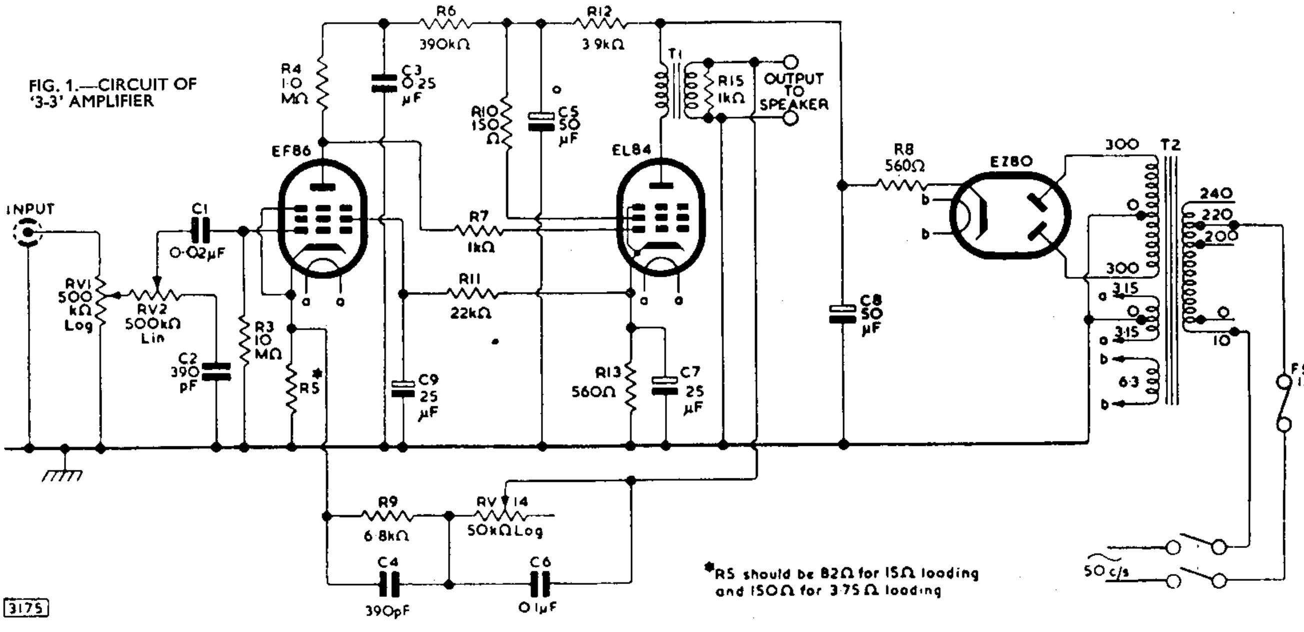
The photograph is of the prototype amplifier, and it gives a suitable layout for the main components. The dimensions of the chassis are 8in. × 6in. × 2in. The can of the electrolytic capacitors should be isolated from the chassis if the can is used as the negative side. The earth connection to the chassis is made at the input socket only. A bottom cover plate to the amplifier is not necessary.

The mains transformer should have an h.t. rating of 300 – 0 – 300V, 60mA, and it is preferable, though not essential, that a separate l.t. winding (6·3V) be used for the EZ80 rectifier. This is indicated in the circuit diagram, and also in the list of components. A transformer recommended for the low loading operation of the 5-valve 10-watt amplifier is suitable for this equipment.

D.C. CONDITIONS

Line Voltage	
C8 at 48mA:	310V
C5:	295V
EL84	
Anode Voltage:	290V
Cathode Voltage:	27V
Cathode Current:	48mA
Screen Grid Voltage:	295V
EF86	
Anode Voltage:	30V
Anode Current:	190μA
Screen Grid Voltage:	27V
C3:	220V

FIG. 1.—CIRCUIT OF '3-3' AMPLIFIER



*RS should be 82Ω for 15Ω loading and 150Ω for 3·75Ω loading

3175

LIST OF COMPONENTS

Valves: Mullard EF86, EL84, EZ80.

RFJ
8/57

Resistors

RV1	500kΩ[1]		
RV2	500kΩ[2]		
R3	10MΩ	±20%	¼W
R4	1·0MΩ	±10%	H.S.
R5	82Ω ±10% for 15Ω load		¼W
	or 150Ω ±10% for 3·75Ω load		¼W
R6	390kΩ	±10%	¼W
R7	1kΩ	±20%	¼W
R8	560Ω[3]	±20%	2W
R9	6·8kΩ	±10%	¼W
R10	150Ω	±20%	¼W
R11	22kΩ	±10%	¼W
R12	3·9kΩ	±10%	½W
R13	560Ω[3]	± 5%	3W
RV14	50kΩ[1]		
R15	1kΩ	±20%	¼W

[1]Logarithmic; carbon. [2]Linear; carbon.
[3]Wire-wound.

Output Transformer T1

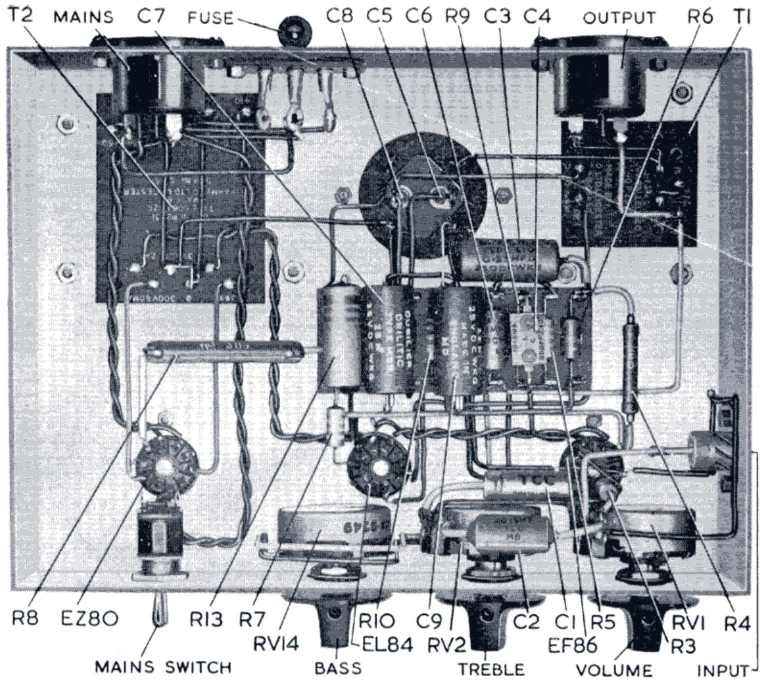
Primary: 5000Ω.
Secondary: 3·75Ω or 15Ω.
The following commercial types have been tested in the circuit and found to be satisfactory:

Manufacturer	*Type No.*
Colne	35206
Gilson	WO767
Parmeko	P2641
Partridge	SVO/1
Wynall	W.1452

Mains Transformer T2

Primary: 10 – 0 – 200 – 220 – 240V.
Secondaries: H.T. 300 – 0 – 300V, 60mA.
L.T. 3·15 – 0 – 3·15V, 1A (for EF86, EL84).
0 – 6·3V, 1A (for EZ80).

If only one 6·3V secondary winding is available, it should have a 2A rating to supply all three valves.



Sockets
Mains input: Bulgin, 3-way, P340.
Output: Bulgin, 2-way, P350.
Coaxial: Aerialite, 149.

Pilot Lamp (optional)
Bulb: 6·3V, 0·04A.
Holder: Bulgin, D180/red.

Valveholders: Noval (EF86 skirted, nylon loaded).

Mains switch: 230V, 2A, Toggle, double-pole, NSF, 8280/K15.

Fuse: 1A, Belling Lee, Minifuse, L575.

Group Board: Bulgin, C125, 10-way.

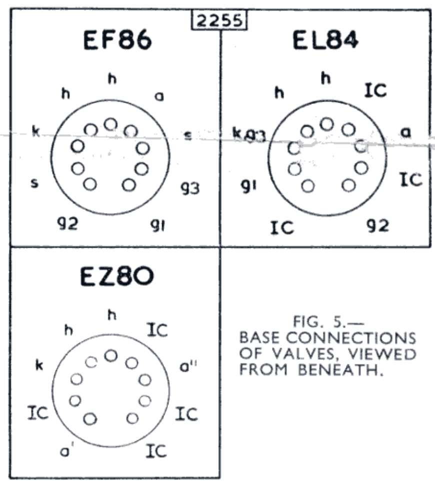


FIG. 5.—BASE CONNECTIONS OF VALVES, VIEWED FROM BENEATH.

Capacitors

C1	0·02µF	Paper	150V min.
C2	390pF±10%	Silvered Mica or Ceramic	
C3	0·25µF	Paper	350V wkg.
C4	390pF±10%	Silvered Mica or Ceramic	
C5, C8	50–50µF	Double Electrolytic	350V wkg.
C6	0·1µF	Paper	150V min.
C7	25µF	Electrolytic	50V wkg.
C9	25µF	Electrolytic	50V wkg.

FIG. 2.—FREQUENCY RESPONSE OF AMPLIFIER, SHOWING RELATIVE GAIN WITH MINIMUM TONE CONTROLS, AND ALSO WITH MAXIMUM TREBLE CUT AND MAXIMUM BASS BOOST.

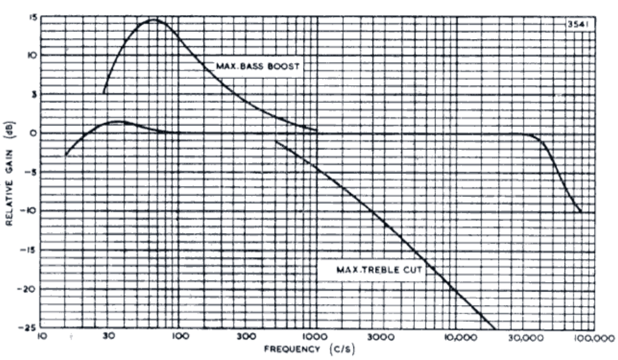
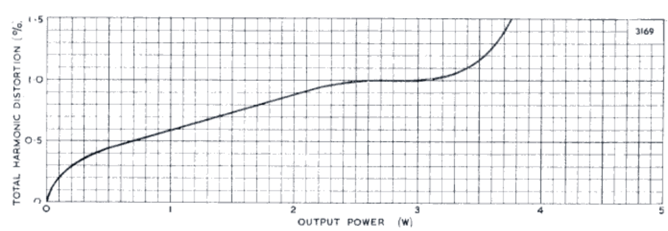


FIG. 3.—TOTAL HARMONIC DISTORTION PLOTTED AGAINST OUTPUT POWER.



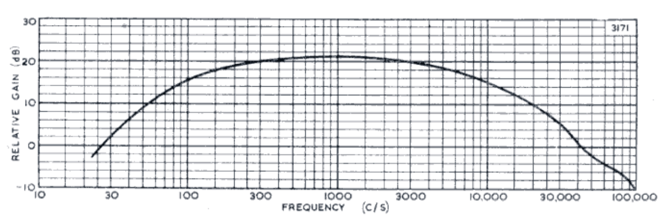


FIG. 4.—LOOP GAIN CHARACTERISTICS

PUBLISHED BY TECHNICAL SERVICE DEPARTMENT, MULLARD LIMITED, MULLARD HOUSE, TORRINGTON PLACE, LONDON, W.C.1 REPRINT FEBRUARY 1957 TP303

RTJ 8/57

FOUR-CHANNEL INPUT MIXING AMPLIFIER

It may often be desirable to use several signal sources with an amplifying unit which has provision for only one input signal. The circuit described in this leaflet is capable of handling four input signals and of supplying a mixed output voltage suitable for driving a single-input amplifier. Two of the input channels of the mixer are suitable for microphone signals, a third for a radio or equalised tape input, and a fourth for pick-up signals.

The circuit as it stands provides an output voltage of 40mV and was intended to be used with the Mullard Five Valve Ten Watt High Quality Amplifier in which the tone-control network is disconnected. With a simple modification to the output stage, the mixer will provide an output voltage of up to 800mV.

The equipment has not been designed to professional standards. The number of components has been limited to the minimum compatible with a performance which will be satisfactory in conjunction with a high quality audio amplifier of the Mullard 'Five-Ten' type. It is felt that this input mixing amplifier will therefore be of interest principally to the home constructor.

CIRCUIT DESCRIPTION

Both microphone input stages of the input mixing circuit are identical. Each is equipped with the Mullard low noise pentode, type EF86, operating with grid current bias obtained by means of the high-valued grid resistor R1.

The internal impedance of a crystal microphone is predominantly capacitive, and the capacitance is of the order of 2000pF. Therefore, to avoid loss in terminal voltage at low audio frequencies, the microphone should be connected to a high impedance input stage. If a low value of resistance of 1·5MΩ is chosen for R1, for example, the combination of the series capacitive elements of the microphone, the grid circuit capacitance C1 and the grid resistance R1 will result in a loss of about one-third of the output voltage from the microphone at a frequency of 100c/s. Consequently, a value of 10MΩ has been selected for R1 to provide the high impedance input for the crystal microphone and to prevent the loss in bass output voltage.

If it is required to use a low-impedance microphone such as a moving-coil or ribbon type, the mixer can be made suitable by using a step-up transformer in the grid circuit of either EF86. The arrangement for the low-impedance microphone is shown in Fig. 2. The connections marked A and B in Fig. 2 should replace those similarly marked in Fig. 1. The leads of the microphone transformer should be made as short as possible to avoid hum pick-up and loss of treble response.

The output from each microphone input stage is R-C coupled to the grid of one half of the Mullard high-μ double triode, type ECC83. The radio and pick-up input stages are also connected to this grid by way of the resistors R11 and R12, RV13. This half of the ECC83 is arranged as a voltage amplifying stage.

The potentiometers RV4, RV9 and RV13 serve for the adjustment of signal level and the mixing of the microphone and pick-up input channels. Adjustment for the fourth channel will be achieved by means of the gain control incorporated in the radio unit used at the radio input terminals. (If it is required, control of the radio input can be achieved by connecting a potentiometer to the radio input socket in the way that RV13 is joined to the pick-up socket.)

The values of the resistors R5, R10, R11 and R12 have been chosen so that, in combination with the potentiometers RV4, RV9 and RV13, they prevent any interaction between the channels. Of course, these fixed resistors also ensure that the grid of the ECC83 will not be short-circuited when any one of the potentiometers is set at a minimum.

The output stage of the mixer unit is suitable as it is shown in Fig. 1 for use with

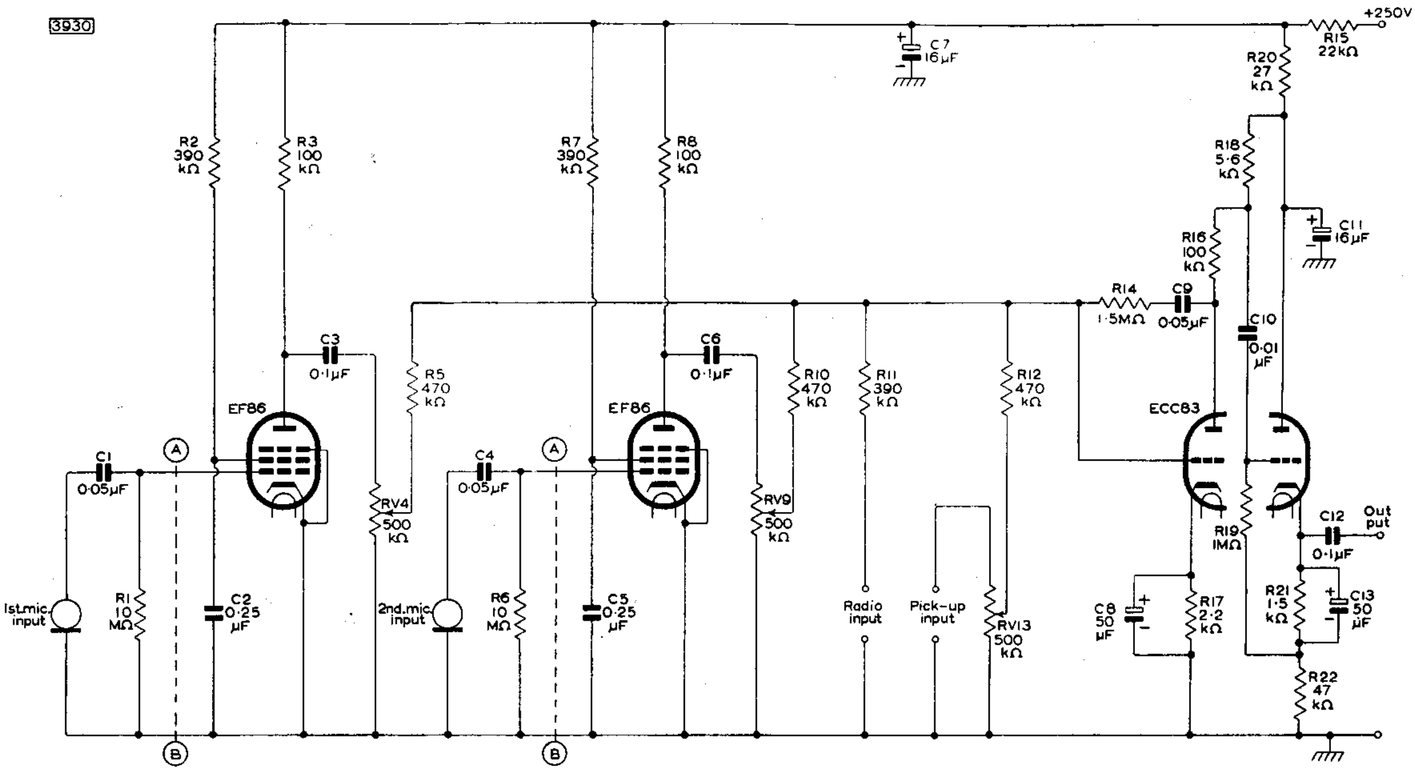
SUMMARY OF PERFORMANCE

Output Voltage
Low-gain connection: 40mV
High-gain connection: 800mV

Sensitivity
(For full output in either low- or high-gain connection)
Microphone input: 3mV
Radio input: 230mV
Pick-up input: 250mV

Frequency Response
Microphone channels:
Flat to within ±3dB (relative to level at 1kc/s) from 20c/s to 20kc/s
Radio or Pick-up channels:
Flat to within ±2dB (relative to level at 1kc/s) from 15c/s to 20kc/s

Hum and Noise Level
50dB below full output



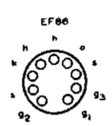
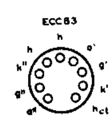


FIG 1—CIRCUIT OF FOUR-CHANNEL INPUT MIXING AMPLIFIER



a Mullard 'Five-Ten' amplifier in which the tone-control network is non-operative. The circuit has been arranged so that the sensitivity at the microphone inputs is 3mV for an output voltage of 40mV, and this is sufficient for crystal microphones. The sensitivities of the other input stages, for the same output voltage, are 230mV and 250mV for the radio and pick-up terminals respectively.

Feedback is taken from the anode to the grid of the first half of the ECC83 by way of the components R14 and C9. The purpose of this is to provide a low impedance at the grid and hence minimise the loss in response at treble frequencies caused by the Miller effect between the anode and the grid of the triode.

The output voltage is obtained from the second half of the ECC83 which has been connected as a cathode follower. This type of connection provides a low output impedance which, in Fig. 1, has the approximate value of 600Ω. Because of this low impedance, no attenuation of high notes will occur in consequence of cable capacitance if a long cable is required between the mixer unit and the main amplifier. But the input impedance of the main amplifier must be greater than 100kΩ to ensure that the bass frequencies will not be attenuated by the coupling capacitor C12.

PERFORMANCE

Output and Sensitivity

The maximum output voltage of the mixer unit as it is drawn in Fig. 1 is 40mV. This output is obtained with an input signal voltage of 3mV at either microphone socket, 230mV at the radio terminals or 250mV at the pick-up terminals.

If greater outputs from the unit are required to drive, for example, an amplifier incorporating a tone-control network, these can be achieved simply by adjusting the coupling between the anode of the first triode of the ECC83 and the grid of the second. If the capacitor C10 is joined directly to the anode of the first triode, an output of 800mV will be available. Intermediate values of output voltage can be achieved by altering the values of R16 and R18. If, for example, R16 and R18 were each 47kΩ, the output voltage of the unit would be about 400mV.

If the required output voltage from Fig. 1 had been obtained by attenuating the output voltage from the cathode load in the final stage, the low output impedance resulting from the cathode follower action would have been lost.

Frequency Response

The response curve of the mixer unit, measured between microphone input and output terminals is shown in Fig. 3. The curve is flat to within ±3dB, relative to the response level at 1kc/s, from 20c/s to 20kc/s. The response curve measured between either the radio or the pick-up socket and the output terminals is also shown in Fig. 3. Because the EF86 stages are not included for this second position of measurement, the bass response is slightly extended and the curve is flat to within ±2dB, compared with the 1kc/s level, from 15c/s to 20kc/s.

Hum and Noise

Measurements of hum and noise were made with 100kΩ resistors connected across the microphone and pick-up terminals and with the potentiometers fully advanced. These arrangements simulate a reasonable practical condition. The mixer was connected to a Mullard 'Five-Ten' amplifier and measurements were made across a 15Ω load resistor. The voltage measured in this way was 38mV.

The full output of the amplifier is 10W which corresponds to a voltage of 12·3V across the 15Ω load resistor. Consequently the hum and noise level is 50dB below 10W. The background level of the 'Five-Ten' amplifier alone is better than 70dB below 10W, so the figure of 50dB must be attributed to hum and noise in the mixer unit.

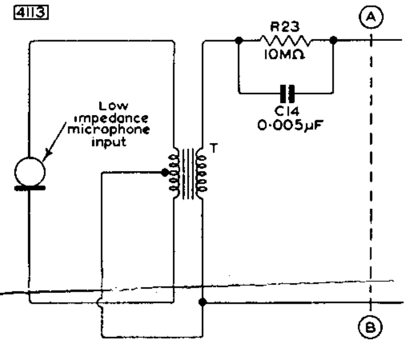
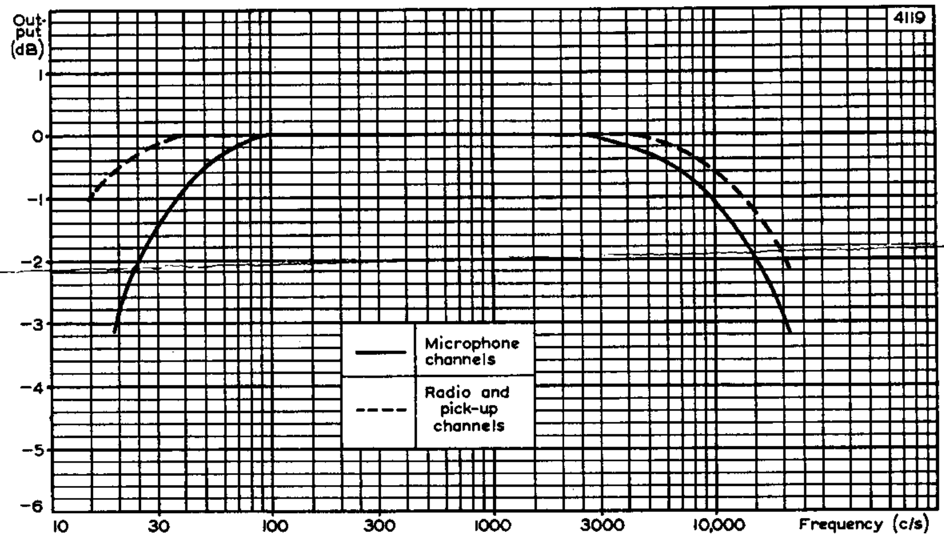


FIG. 2 (above)—ALTERNATIVE ARRANGEMENT OF MICROPHONE INPUTS FOR LOW-IMPEDANCE MICROPHONES

FIG. 3 (right)—FREQUENCY RESPONSE CURVES FOR MICROPHONE AND RADIO OR PICK-UP SIGNALS



LIST OF COMPONENTS

Resistors

R1, R6	10 MΩ			H.S.
R2, R7	390 kΩ			H.S.
R3, R8	100 kΩ			H.S.
RV4	500 kΩ log. carbon pot.			
R5, R10	470 kΩ	±10%		½W
RV9	500 kΩ log. carbon pot.			
R11	390 kΩ	±10%		½W
R12	470 kΩ	±10%		½W
RV13	500 kΩ log. carbon pot.			
R14	1·5MΩ	±10%		½W
R15	22 kΩ	±10%		½W
*R16	100 kΩ	±10%		½W
R17	2·2 kΩ	±10%		½W
*R18	5·6 kΩ	±10%		½W
R19	1 MΩ	±10%		½W
R20	27 kΩ	±10%		½W
R21	1·5 kΩ	±10%		½W
R22	47 kΩ	±10%		½W
R23 (Fig. 2)	10 MΩ			H.S.

*Values may be altered for higher output voltages

Values

Mullard EF86 (two), ECC83

Sockets

Supply input: Elcom P04
Coaxial (five): Aerialite, 149; Belling Lee, L/734/S

Valveholders

B9A (noval) nylon-loaded, with screening skirt and flexible mounting (two for EF86s). McMurdo, XM9/U61

B9A (noval) nylon-loaded, with screening skirt. McMurdo, XM9/UD1, skirt 811

Capacitors

C1, C4	0·05 μF	paper	250V working
C2, C5	0·25 μF	paper	250V working
C3, C6	0·1 μF	paper	250V working
C7+C11	16+16μF	double electrolytic (wire-ended)	350V working
C8	50 μF	electrolytic	12V working
C9	0·05 μF	paper	250V working
C10	0·01 μF	paper	250V working
C12	0·1 μF	paper	250V working
C13	50 μF	electrolytic	12V working
C14 (Fig. 2)	0·005 μF	paper	150V working

The voltage ratings quoted for the paper capacitors should be regarded as minimum values. Capacitors with higher ratings may be used if so desired.

PUBLISHED BY TECHNICAL SERVICE DEPARTMENT, MULLARD LIMITED, MULLARD HOUSE, TORRINGTON PLACE, LONDON, W.C.1 AUGUST 1957 TP319