TECHNICAL INSTRUCTION
S.8

Loudspeakers and Loudspeaker Units

BRITISH BROADCASTING CORPORATION

ENGINEERING DIVISION

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LOUDSPEAKERS AND LOUDSPEAKER UNITS

SECTION 1

LOUDSPEAKER UNIT LSU/10

Introduction

The LSU/10 is an entirely redesigned cabinet-type loudspeaker unit for quality checking. The RK loudspeaker, which has been used for this purpose for a number of years, has been replaced by a Parmeko dual loudspeaker, LS/1, comprising a 15-inch cone, with a separate high-frequency horn, the two units having a common axis.

A commercial amplifier, coded LSM/8, is used to drive the two units, the output of the amplifier being connected to the loudspeaker speech coils through a filter, F/28, which has a cross-over frequency of 1,200 c/s.

The loudspeaker, amplifier and filter are housed in a redesigned acoustic cabinet, LB/8.

Loudspeaker LS/1

The Parmeko loudspeaker has two concentric units, the larger consisting of a straight-sided cone diaphragm (Fig. 1.1) 15 inches in diameter carrying a speech coil 3 inches in diameter situated in the annular gap of a large permanent magnet. This unit has a fundamental resonance of 30 c/s and is used to radiate frequencies below 1,200 c/s. The smaller unit has a light aluminium diaphragm of domed construction and $1\frac{3}{4}$inches in diameter; it is attached to a speech coil of the same diameter placed in the gap of a second magnet smaller than the first and situated at the rear of it. A tapered hole is formed in the centre pole of the front magnet to form the throat of a high-frequency

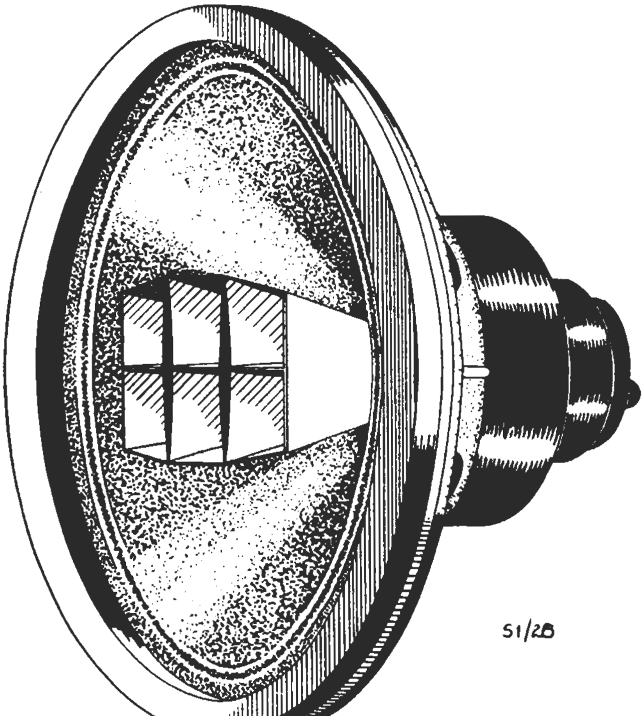


FIG. 1.1 PARMEKO DUAL LOUDSPEAKER: SHOWING CO-AXIAL MOUNTING OF CONE AND HORN

horn into which the high-frequency unit radiates. The throat leads to an external multi-cellular horn bolted to the face of the centre pole. To give wide-angle radiation this external horn is divided into six sections arranged 3 cells wide by 2 cells deep. The cells are of metal and the space between them is filled with sound-deadening material to prevent the walls ringing.

Because of the horn-loading and the higher flux density in the gap, the smaller unit is more efficient than the other ; it is therefore given a higher impedance to ensure approximately correct distribution of power between the two units when they are connected in parallel. The parallel connection is made via a cross-over filter designed to feed frequencies above 1,200 c/s to the horn and frequencies below 1,200 c/s to the cone.

Reduction of H.F. Pick-up

To reduce h.f. pick-up, which might otherwise give trouble at certain locations, the loudspeaker framework and F/28 filter chassis have been earthed to the programme earth of the unit. For the same reason R21 and R22 have been added to the LSM/8.

LOUDSPEAKER AMPLIFIER LSM/8

General Description

The LSM/8 amplifier is a commercial product, manufactured by H. J. Leak & Co., Ltd., and known as type TL/12, but the programme input circuit has been modified to make the amplifier suitable for use in the loudspeaker unit LSU/10. The performance of this amplifier is similar to that of the MPA/1, but it is more sensitive and has a lower output impedance.

The output stage consists of two triodes in push-pull and these are preceded by a cathode-coupled phase-splitting stage. The phase splitter is preceded by a voltage-amplifying stage consisting of an RC-coupled pentode, to which is applied a negative feedback voltage obtained from the output stage.

An input level of —20 db is required to give the maximum output of 10 watts. The amplifier incorporates its own mains unit and is constructed on a conventional chassis for base-board mounting.

Electrical Design Considerations (Fig. 1)

The output stage consists of two KT66 beam tetrodes connected as triodes and operating in push-pull. The valves are used under Class-A conditions and the anode current remains steady during operation, permitting the use of a mains unit in which no special precautions need be taken to ensure good regulation. The valves are connected as triodes to keep the anode a.c. resistance low, and this is further reduced to give a low output impedance by the use of voltage feedback.

A double-triode valve is used for phase-splitting, the circuit being similar to that used in the LSM/4 and other BBC amplifiers. One of these triodes (*a*) operates as an RC-coupled amplifier, feeding one of the output valves, but has a high-value (11kΩ) cathode resistor. The signal p.d. developed across this resistor is applied to the second half (*b*) of the double-triode valve, the anode of which is coupled to the second output valve. To obtain a push-pull output from the double valve, the two cathodes must be bonded, and the grid of the second valve must be earthed. Thus the common cathode resistor carries both anode currents and the alternating components cannot be precisely equal. Equality in output voltages is obtained, however, by making the anode load of triode (*b*) larger than that of (*a*).

The first stage is an RC-coupled pentode giving high voltage gain. A negative feedback voltage from the secondary winding of the output transformer is injected into the cathode circuit, the component values in the feedback loop being chosen to give the desired overall gain. The amplifier has a signal-input socket connected directly in the grid circuit of the first stage, but for BBC use this socket is replaced by an input transformer with a gain control connected across the secondary winding.

The mains rectifying and smoothing circuit is conventional but an unusual feature is that all smoothing and decoupling capacitors are of paper dielectric, no high-voltage electrolytic capacitors being used anywhere in the amplifier.

Mechanical Design Considerations

The amplifier is constructed on a chassis measuring 12½ inches by 10 inches by 3 inches and is fitted with a base plate which is slightly longer than the chassis and overlaps it for a short distance at either side. The flanges thus formed have bolt holes which are used for securing the amplifier in the LSU/10 compartment.

The five valves are mounted above the chassis in a row at the front of the amplifier. Behind them are the input, output and mains transformers ; the choke and the smoothing-capacitor block and their tag connections project through the hole in the chassis so that there is no wiring above the chassis. The remaining small components are located underneath the chassis on a single tag panel which occupies almost the whole length of the amplifier.

When the amplifier is used in the LSU/10 a baffle plate is secured to the chassis between the valves and the large components to assist ventilation by deflecting hot air out of the amplifier compartment.

On the right-hand side of the amplifier are mounted the loudspeaker output socket, mains input socket, mains fuse, mains-transformer primary-tapping selector, and a terminal block at which an external mains switch may be terminated.

The front panel carries the gain control which has a pointer moving over a scale arbitrarily calibrated from 0 to 10. In the LSU/10 this control projects through a hole at the right-hand side of the cabinet.

On the left-hand side of the amplifier is a 4-pin plug for connection of programme input.

Circuit Description (Fig. 1)

The programme input is connected via the input plug and socket to the primary winding of a screened transformer Type AGG/1SA. This has a turns ratio of 1 : 2 and is loaded on the secondary side by a 50-kΩ gain control R1, giving the amplifier a balanced input impedance of 12,500 ohms.

The slider of the gain control is connected to the grid of the voltage amplifier stage V1, an EF37 pentode with an anode resistor (R4) of high value (470kΩ). The screen V1 is fed from a potential divider (R6, R7) and is decoupled to cathode by the 0·25-μF capacitor C2. The anode and screen supplies are smoothed and decoupled by the 220-kΩ resistor R5 and the 4-μF capacitor C10. The cathode circuit of V1 includes a 2·2-kΩ resistor R3 which provides most of the grid bias, and a 100-Ω resistor R2 which is part of the feedback circuit. To avoid current feedback which would reduce the gain of V1, R3 is decoupled by the 50-μF capacitor C1. R2, of course, must not be decoupled, but its value is so small that it causes negligible current feedback.

The output of V1 is coupled to grid (*a*) of the 6SN7 double-triode valve V2 by the 0·25-μF capacitor C3 and 1·5-MΩ grid leak R8. This grid leak, and the grid leak R11 of the valve (*b*) are both returned to the junction of the 1-kΩ resistor R9 and the 10-kΩ resistor R10, in the common cathode circuit. Thus R9 provides grid bias for both halves of the phase-splitter, whilst the two cathode resistors in series provide coupling between the two halves. Grid (*b*) of the 6SN7 is earthed via the 0·25-μF capacitor C4. The anode resistors of the two halves of the phase-splitter are slightly different in value, R13 being 57kΩ and R12 68kΩ, to make up for inequality in the a.c. components of the anode currents. The time constants of the grid-circuit components are longer than usual to minimise phase-shift at low frequencies and prevent instability due to negative feedback.

Valve (*a*) of the phase-splitter stage is coupled to V4 by the 0·25-μF capacitor C6 and the 470-kΩ grid leak R15, the time constant again being long for the reason given above. Valve (*b*) is coupled to the grid of V3 by C5 and R14 which have the same values as C6 and R15 respectively. The KT66 output valves are used as triodes, the anodes being strapped to the screen grids by 100-Ω resistors R19 and R20 which are included as a precaution against parasitic oscillation. The valves are biased by 600-Ω cathode resistors R16 and R17, this giving a cathode current of 65 mA per valve with an h.t. supply of 470 volts. These cathode resistors are decoupled by 25-μF capacitors C7 and C8 respectively. To enable the amplifier to deliver its full output at high audio frequencies, 0·001-μF capacitors C14 and C15 are connected across each half of the output-transformer primary winding. The secondary winding is in four sections which may be connected in series, parallel or a combination of both to suit output loads of between 1 and 16 ohms. When the amplifier is used in conjunction with an LS/1 loudspeaker the secondary winding is connected for a 4-ohm load as shown in Fig. 1.

Negative voltage feedback is obtained by coupling the output-transformer secondary winding to the cathode of V1 by R18 and R2, and to avoid instability at high frequencies R18 is shunted by capacitor C9. The gain of the amplifier from input to anode of V3 or V4 is largely determined by the output transformer ratio and the values of

R18 and R2, which together fix the gain of the feedback loop. As the transformer ratio must be altered to suit different values of output load, the value R18 (and hence C9) must be altered also to keep the feedback and amplifier gain constant. The table in Fig. 2 gives values of R18 and C9 for various output loads.

Input Loss-pad

To bring the normal setting of the volume-control potentiometer to a higher part of the range, where fine control of level may more easily be carried out in studios, it has been found necessary to insert a fixed loss-pad prior to the input plug and socket of the LSM/8. This loss-pad is carried by a resistance holder mounted in the amplifier compartment of cabinet LB/8, and comprises a 4·7-kilohm resistor in each leg of the programme circuit followed by a 1·2-kilohm resistor in shunt. Where the resultant attenuation is not required the series resistors are replaced by straps and the shunt resistor is also omitted. Neither the loss-pad nor the resistance holder is normally fitted to loudspeaker units in recording and reproducing rooms.

The mains rectifying equipment includes the transformer T3, a U52 full-wave rectifying valve V5 and a π-type smoothing circuit.

No feed-measuring facilities are included in the amplifier and the anode currents should be measured by the p.d's. developed across the cathode-bias resistors, using the meter on the range specified in the Valve Data table.

General Data

Impedances

Normal Source, 300 ohms.

Input, 12,500 ohms ±10% (balanced).

Output, 0·5 ohms max. at 1,000 c/s (connected for 4-ohm load).

Load, 4 or 16 ohms (unbalanced).

Maximum Gain

38 db into 4-ohm load.

Sensitivity

—20db input gives +18 db across 4-ohm load corresponding to 9·5 watts output. (Avo. reading 6·2 V a.c.)

Frequency Characteristic

Within ±0·3 db from 60 c/s to 8,000 c/s

Within ±1·5 db from 30 c/s to 15,000 c/s

Input —20 db. Gain control set for output of +2 db.

Total Percentage Harmonic Content

Level across 4-ohm load	Power output	60 c/s	1,000 c/s
+18 db	9·5 watts	0·5%	0·2%
+10 db	1·6 watts	0·25%	0·1%

Noise

—70 db compared with normal output volume.

Valve Data

Stage	*Type*	*Bias Resistor*	*P.D. Across Bias Resistor*	*Filament Voltage*	*Filament Current*
V1	EF37	R3	* 1V ± 15%	6·3V	0·2A
V2	6SN7	R9	* 4·5V ± 10%	6·3V	0·6A
V3	KT66	R16	†37·5V ± 10%	6·3V	1·27A
V4	KT66	R17	†37·5V ± 10%	6·3V	1·27A
V5	U52	—	—	5·0V	3·0A

* *Avometer Model* 40 *Range* 12V. † *Avometer Model* 40 *Range* 120V.

H.T. Voltage 470 volts measured across C12. *Avometer Model* 40 *Range* 1,200V.

Filter Unit F/28 (Fig. 1.2)

The high-frequency unit of the loudspeaker LS/1 must not receive low-frequency inputs because the large amplitudes which can be developed at these frequencies might cause damage. It is also undesirable for the cone unit to radiate high frequencies because these would cause interference with the output from the h.f. unit. A filter unit, F/28, is therefore included between amplifier and loudspeaker to ensure that only high-frequency signals are fed to the h.f. unit and only low frequencies to the l.f. unit. The frequency at which the cross-over occurs is determined by the design of the loudspeaker and is 1,200 c/s for the LS/1.

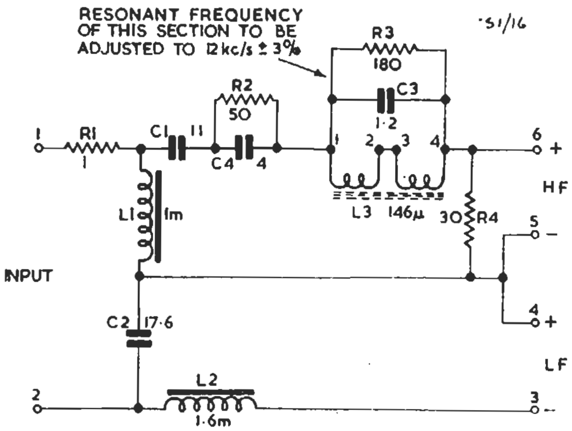


FIG. 1.2 FILTER F/28: CIRCUIT

The filter is basically a simple series type the main components being L1C1 and L2C2. L1 and C2 are connected across the input terminals and resonate at 1,200 c/s. At this frequency equal voltages are developed across L1 and C2 but as frequency is reduced the reactance of C2 increases, causing a greater voltage to be fed to the l.f. unit of the loudspeaker, and the reactance of L1 falls, causing a smaller voltage to be delivered to the h.f. unit. The performance of the filter is improved by the inclusion of L2 which, in conjunction with the l.f. speech-coil impedance, forms a potential divider which further reduces the signal fed to the l.f. unit at frequencies above 1,200 c/s and by the inclusion of C1 which similarly attenuates the signal fed to the h.f. unit at frequencies below 1,200 c/s.

The h.f. unit is more efficient than the l.f. unit and, with a filter consisting simply of L1C1 and L2C2, the output from the loudspeaker shows a sharp increase or " step " as frequency is increased through 1,200 c/s. To eliminate this, the components R2 and R4 are introduced ; these reduce the output from the h.f. unit to approximately the same value as that from the l.f. unit at frequencies near the cross-over value. The attenuation so introduced is too great at high frequencies and a fixed capacitor C4 is shunted across R2 to reduce the loss at these frequencies.

To eliminate a peak in the loudspeaker output at about 12,000 c/s a parallel-tuned circuit L3C3 is inserted in series with the h.f. unit and the Q of the circuit is reduced to the desired value by the fixed resistor R3.

The input impedance of the filter unit with the loudspeaker in circuit has a minimum value of approximately 4 ohms and the secondary windings of the LSM/8 output transformer are connected to match this load. When the LS/1 is used in conjunction with an MPA/1 amplifier the two secondary windings on the output transformer should be connected in parallel as for a 4-ohm load.

The output impedance of the LSM/8 is less than that of the MPA/1 and when an LSM/8 is used with the filter unit and loudspeaker a 1-ohm resistor R1 is inserted in one leg of the filter input circuit. This resistor is short-circuited when an MPA/1 is used to ensure that the filter unit is always effectively fed from the same source impedance.

Loudspeaker Amplifier LSM/10

Certain LSU/10 units are now fitted with a commercial amplifier type LSM/10 in place of the LSM/8. The circuit of the LSM/10 is basically similar to that of the LSM/8 and is given in Fig. 2 (Serial Nos. 101-470) and Fig. 2A (Serial Nos. 471 onwards).

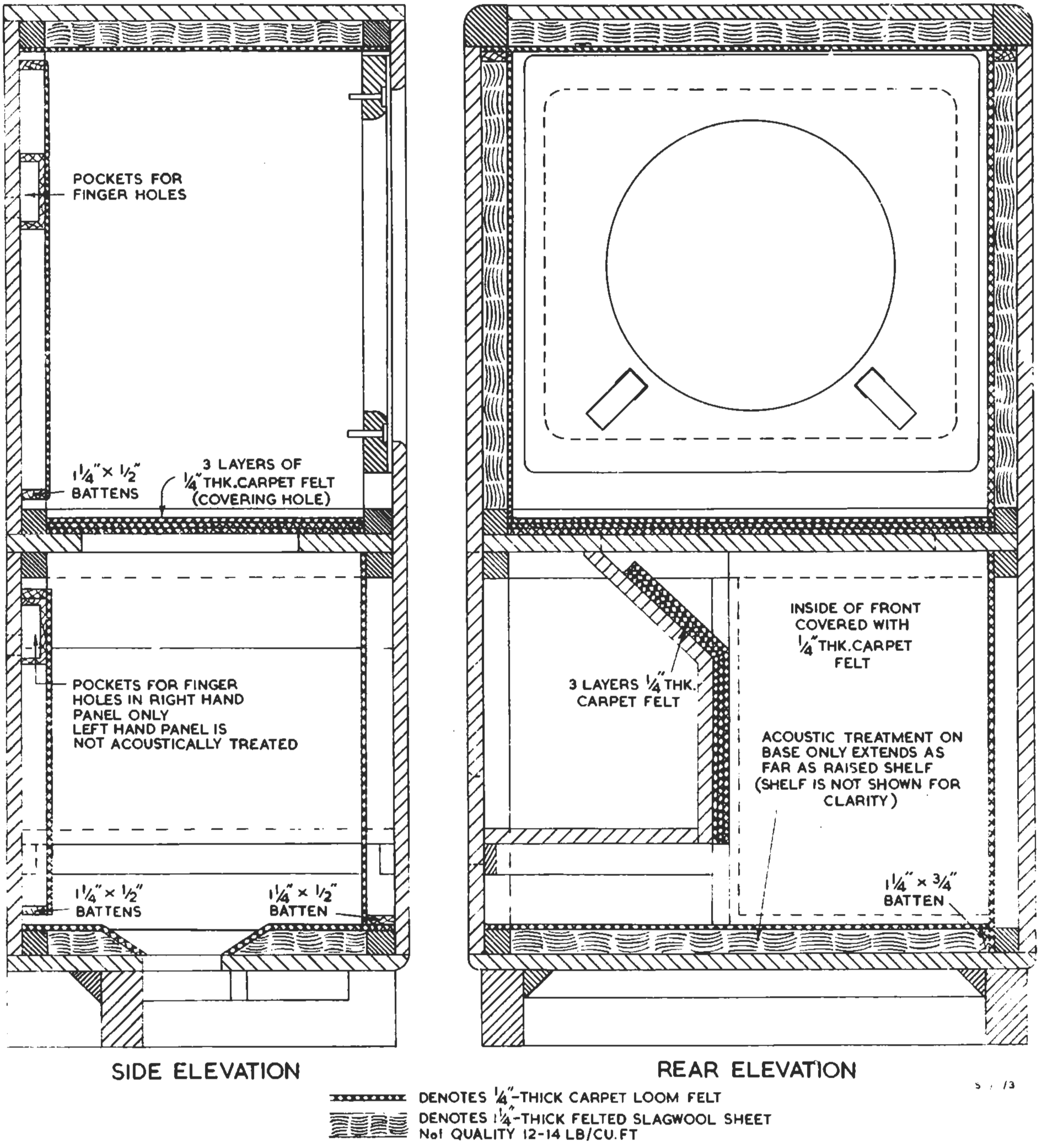


FIG. 1.3 LOUDSPEAKER CABINET LB/8: CONSTRUCTION

Cabinet LB/8 (Fig. 1.3)

The cabinet is constructed in the form of a vented enclosure which gives a smoother and wider-range bass response than the box baffles used hitherto. The rear of the cabinet is completely boxed in and an opening or vent in the form of a rectangular hole is provided in the base. This vent opens into a cavity between the base and the floor and is bounded by the plinth which supports the cabinet. The plinth is arranged as three sides of a square and directs sound waves transmitted through the vent outwards from the front of the cabinet. The vent and associated cavity have the nature of an acoustic inductance whilst the air enclosed inside the cabinet behaves as a capacitance and the dimensions are chosen to give resonance at the lowest frequency it is desired to reproduce. Low-frequency sound waves generated at the rear of the loudspeaker diaphragm are transmitted through the vent and, over a limited frequency range, are in phase with the radiation from the front of the loudspeaker. The design is such that the useful range of the loudspeaker is extended downwards by about half an octave.

To prevent high-frequency sound waves being transmitted through the vent the upper half of the cabinet is lined with about 1¼-inch thick slag wool. This is obtained in pre-formed slabs which are stuck to the sides of the cabinet and are then covered with a layer of carpet loom felt. Such treatment is effective in suppressing high-frequency sound waves but does not sufficiently eliminate low-frequency vertical air-column resonance which occurs at about 120 c/s. This is suppressed by three ¼-inch layers of carpet loom felt stretched horizontally across the centre of the cabinet where the standing waves have maximum particle velocity. Very little high-frequency radiation reaches the lower half of the cabinet and the only acoustic treatment necessary is provided by a single layer of carpet loom felt. If a thin layer of absorbing material were attached directly to the walls the absorption would be low because particle velocity is a minimum close to a reflecting surface. For this reason the felt in the lower half of the cabinet is attached to battens to space it about 1¼-inch from the walls.

The loudspeaker amplifier LSM/8 is situated on a shelf within a small compartment in the lower half of the loudspeaker cabinet and at the right-hand side (viewed from the front) and the gain control is accessible through a hole in the lower right-hand panel. This panel and the rear panel adjacent to the amplifier have windows of expanded metal to provide ventilation and a baffle is fitted to the amplifier chassis to direct hot air out of the amplifier compartment. Before the amplifier can be removed the side and rear panels of the amplifier compartment must be detached. These are each held in place by a number of screws and the amplifier itself is secured to the shelf by four bolts. There is, of course, no need for acoustic treatment of the interior of the amplifier compartment but the outside is lagged with three layers of carpet felt.

SECTION 2

GENERAL PURPOSE LOUDSPEAKER LS1/1

General Description

Loudspeaker LS1/1 is a general purpose loudspeaker used in offices and talks studio cubicles and similar positions where the cost of a high-quality monitoring loudspeaker is not justified. It is designed for a programme input level of 0 to —10 dB.

It consists of a Cabinet CT4/2, 20 in. high by 15 in. wide by 10¼ in. deep, in which is mounted an 8-in. Goodmans Loudspeaker Unit Type R77/837/3 a mains-operated 3-watt Loudspeaker Amplifier AM8/2 and an Equaliser LS1A/1 for improving the frequency response of the loudspeaker. (Goodmans Axiette 8-in. Loudspeaker Unit was fitted in early models and Type R77/837/3 is interchangeable with it both mechanically and electrically.)

A combined volume control and mains switch is fitted on the right-hand side of the cabinet together with a warning light to indicate when the amplifier is switched on.

A mains lead 11 ft long, fitted with a 3-pin plug, and an input lead consisting of a 6-ft P.O. cord fitted with a P.O. plug No. 316 are permanently connected to the equipment.

Loudspeaker Amplifier AM8/2 is described in Instruction S.3.

Loudspeaker Cabinet CT4/2

The loudspeaker cabinet is constructed of ⅝-in. thick light oak faced plywood. The greater part of the volume is used to form an enclosure for the loudspeaker unit, a small recess at the front being provided for the amplifier. The loudspeaker compartment has a solid front in which is cut a 7⅛-in. diameter hole for the loudspeaker unit and has two small acoustic vents opening into the amplifier compartment below; the latter compartment has an open front which, except for a ventilation slot, is filled by a wooden panel fixed to an expanded aluminium grille which covers the front of the cabinet. This grille is constructed on a wooden framework the top edge of which is fitted with two brass pins which fit into holes in the top of the cabinet and which, together with two screws through the bottom of the cabinet hold the grille in position.

Access to the amplifier and the front of the loudspeaker and its fixing screws is obtained on removal of the grille by levering it outwards from the bottom corners after removing the two grille fixing screws. Removal of the back panel of the cabinet gives access to the back of the loudspeaker and to the equaliser.

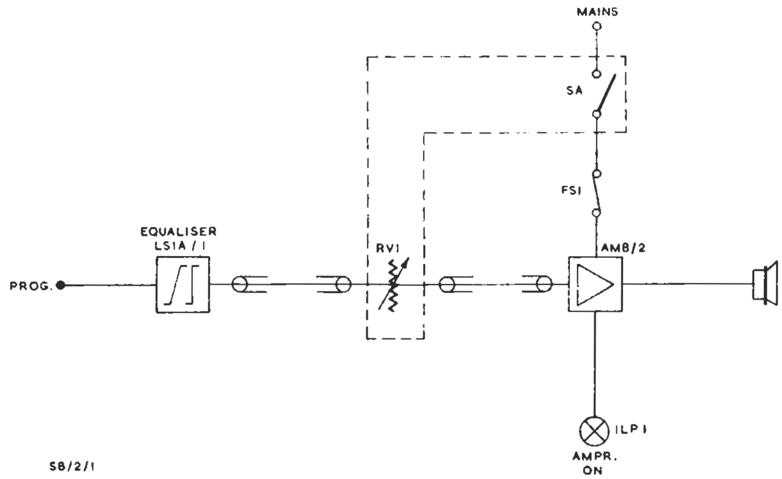


FIG. 2.1 LOUDSPEAKER LS1/1: SCHEMATIC DIAGRAM
DRAWING NO. EA 10133

A rectangular hole covered with expanded aluminium is cut in the bottom of the cabinet to ventilate the amplifier compartment.

The top and sides of the loudspeaker compartment and the inside surface of the rear panel of the cabinet are lined with 2-in. thick blankets of glass fibre.

connected to the loudspeaker which has a nominal impedance of 3 ohms.

The mains supply for the amplifier arrives via an external plug and lead which terminates on a 3-way tag block mounted in the amplifier compartment. It then passes through a double-pole switch which is fitted to the loudspeaker volume control

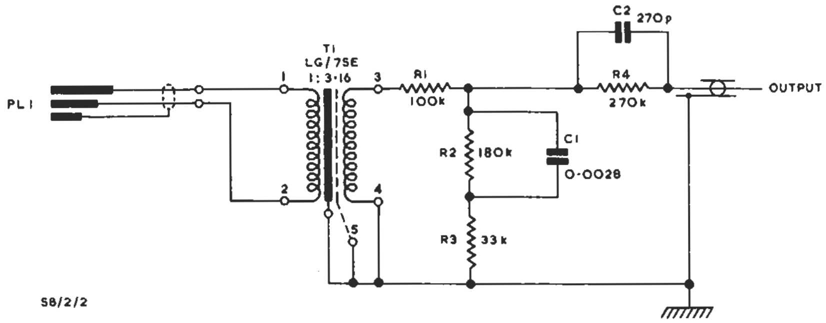


FIG. 2.2 LOUDSPEAKER EQUALISER LS1A/1: CIRCUIT DIAGRAM
DRAWING NO. EA 10130

Circuit Description

The circuit schematic is shown in Fig. 2.1 The incoming programme arrives via a P.O. plug and cord at the input terminals of the equaliser; the output of the equaliser is connected by a low-capacitance coaxial cable to the loudspeaker volume control which is mounted near the bottom of the right-hand side of the cabinet with its knob projecting through a hole in the side. Another low-capacitance coaxial cable connects the volume control to the input of the loudspeaker amplifier. Low-capacitance coaxial cable is used because of the high impedance of the circuit, the resistance of the volume control potentiometer being 50 kilohms and the input capacitance of the amplifier being less than 150 pF. The output of the amplifier is and operated by the same knob, and through a pair of 1-amp fuses to the AM8/2.

An 8-volt, 0·2-amp indicating lamp to show when the amplifier is switched on is fitted below the volume control behind a lens in the side of the cabinet and is fed from the heater supply on the amplifier.

Equaliser LS1A/1

The circuit of the equaliser is shown in Fig. 2.2. It has a frequency response which rises about 3 dB at 100 c/s and about 4 dB at 10 kc/s compared with the response at 1 kc/s. The loudspeaker unit by itself has a cone resonance which lies within the frequency range of 55 to 70 c/s, and a frequency characteristic which begins to fall at about 10 kc/s.

SECTION 3

O.B. LOUDSPEAKER LS3/1

General Description

Loudspeaker LS3/1 has been designed for use at O.B. points where a monitoring loudspeaker is required which has a greater output and better quality than are provided by loudspeakers such as the General Purpose Loudspeaker LS1/1, but which is more easily transported than the high-quality loudspeakers used in studio listening rooms, e.g., the LSU/10.

It consists of two separate units as follows:

(a) Cabinet CT4/1, approximately 2 ft 6 in. high by 18 in. wide by 12 in. deep, in which is mounted a Plessey L.F. Loudspeaker Type CP73025/12/5, two G.E.C. H.F. Loudspeakers (G.E.C. Pressure Unit Type BCS 1852/T247) and a cross-over Filter FL6/1. The total weight is 47 lb.

(b) Mains-operated 15-watt Loudspeaker Amplifier AM8/1 which is described in Instruction S.3 Section 10.

The response at the low-frequency end of the range is about half an octave less than that of the LSU/10 and the acoustic power output is also less.

The considerations leading to the design of this and other high-quality monitoring loudspeakers are described in a Paper by D. F. L. Shorter published in *Proc. I.E.E.* Vol. 105, Part B, No. 24, November 1958.

Loudspeaker Cabinet CT4/1

Cabinet CT4/1 is constructed of $\frac{3}{8}$-in. thick plywood with a layer of $\frac{3}{8}$-in. soft building board firmly glued to the internal surfaces. This construction reduces sound transmission through the walls to a sufficiently low level while keeping the weight to a minimum. The top, sides and back are lined with sound-absorbing material consisting of glass-fibre blankets 2 in. thick, and the bottom of the cabinet is filled with similar material in a cotton bag to a depth of approximately 5 in.

For ease of transport and because space at O.B. points is often limited the size has been restricted to the dimensions mentioned and a carrying handle is fitted to each side. As the internal volume of the enclosure is only $2\frac{3}{4}$ cubic feet no vent is provided since the performance of the loudspeaker at low frequencies is better without one.

Also because of the limited space at O.B. points the listener may be very close to the loudspeaker; it is therefore essential that the low-frequency and high-frequency units should be as nearly coaxial as possible. The two h.f. units are therefore mounted within the cone of the l.f. unit behind a rectangular opening 10 in. high by $7\frac{1}{2}$ in. wide in the front of the cabinet.

A partially perforated aluminium plate is fitted in the opening, an area of $7\frac{3}{4}$ in. by $5\frac{1}{2}$ in. in the middle being left unperforated to form a baffle and support for the two h.f. units which are mounted on it behind two holes $2\frac{7}{32}$ inches in diameter. The plate offers little obstruction to sound from the l.f. unit.

The front of the opening in the cabinet is covered with woven material, and a metal cover plate is provided which can be clipped into position for protection when the loudspeaker is not in use. A parking position for this cover plate is provided on the back of the cabinet.

Care has been taken in the design of the cabinet and in the mounting of equipment in it to prevent the occurrence of unwanted vibrations and rattles as far as possible, but it is essential that all fixing screws and similar items should be kept quite tight if this object is to be achieved.

L.F. and H.F. Loudspeaker Units

The low-frequency moving-coil unit has a 15-inch cone and without the crossover network has an axial frequency range extending to about 4 kc/s. When used with a full-sized circular opening in the front of the cabinet the response is appreciably directional above 500 c/s but by making the opening rectangular in shape and restricting it to $7\frac{1}{2}$ inches in width and 10 inches in height the axial response at the upper end of the range is slightly lowered and the response at oblique angles in the horizontal plane is raised, thus making the system less directional in the horizontal plane.

The two high-frequency units are of the moving-coil type commonly used in conjunction with horns but are designed for use as direct radiators without horns. The diaphragm is of plastic-impregnated fabric and moves as a whole up to at least 10 kc/s. A thin metal plate is fitted in front of the diaphragm, and the centre portions of both are slightly conical in shape. Slots are cut in the front plate at a tangent to the cone-shaped centre portion to provide an outlet for the sound. The overall diameter is only 2½ in. and the unit is therefore less directional at high frequencies than a conventional cone or single horn radiator.

Two h.f. units are used to increase the power-handling capacity of the system and they are mounted one above the other on a small baffle to improve the response at the lower end of their frequency range. As used in the LS3/1 the axial frequency range extends from about 1·5 kc/s to 12 kc/s.

Cross-over Filter FL6/1

The cross-over Filter FL6/1 is mounted inside the loudspeaker cabinet below the loudspeaker units and is wired to them; it therefore forms a permanent part of the loudspeaker system. Its input is wired to a plug near the bottom of the removable back of the cabinet, sufficient length of wire being left to allow the back to be removed and placed against the side of the cabinet when access is required to the filter or loudspeaker units. A connector lead is provided for connecting the output of the loudspeaker amplifier AM8/1 to the input of the filter.

The cross-over filter consists of a low-pass filter to feed the l.f. loudspeaker unit, and a high-pass filter to feed the two h.f. units. These two filters are connected in parallel across the

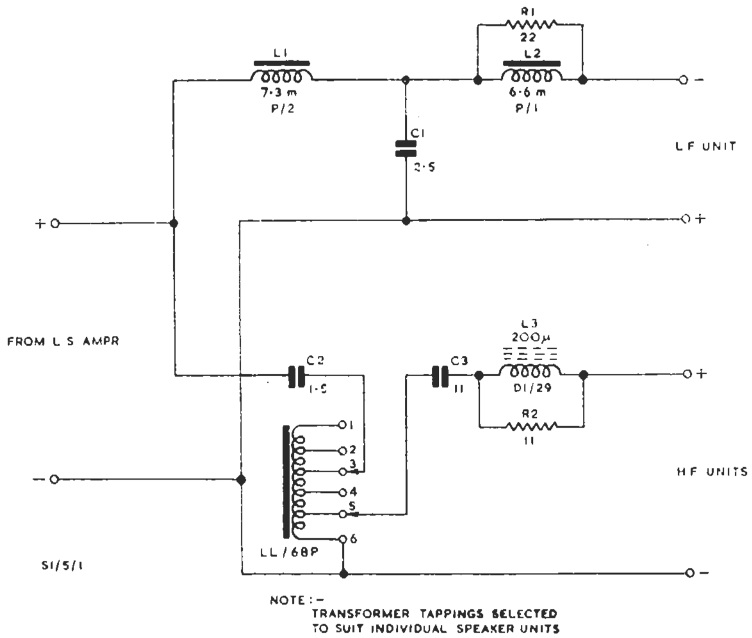


FIG. 3.1. CROSS-OVER FILTER FL6/1: CIRCUIT DIAGRAM
DRAWING NO. EA 9712

input terminals as shown in Fig. 3.1. As the output impedance of the loudspeaker amplifier is low interaction between the filters is negligible and a constant-resistance cross-over network is unnecessary.

The inductor L2 shunted by the resistor R1 in the low-pass filter equalises the frequency characteristic of the l.f. unit; the inductor L3 shunted by the resistor R2 performs a similar function for the h.f. units.

The input transformer for the high-pass filter is

L.F. Unit

Flux density: 12,000 gauss
D.C. resistance: 11—13·4 ohms
Fundamental resonance of unit unmounted: 25 ±5 c/s

H.F. Units

D.C. resistance: 11—12·5 ohms each
Fundamental resonance: 1·6 kc/s
Impedance at resonance: 45 ohms each approx.

used as a combined choke and auto-transformer, and is tapped to provide initial adjustment of the signal level to the h.f. units according to the relative sensitivity of the particular h.f. and l.f. units with which it is used.

Any change in input tapping alters the shunt inductance in the cross-over network; the value of C2 has therefore to be adjusted accordingly to maintain the correct frequency characteristic. The output in all cases is taken from Tap 5.

The sensitivities of the l.f. and h.f. units are measured relative to standard units in each case. For the normal condition, i.e., using Tap 3 and with the value of C2 equal to 1·5 μF, the cross-over frequency occurs at 1·75 kc/s when the low-pass filter is loaded with 12 ohms to represent the input impedance of the l.f. unit, and the high-pass filter is loaded with 6 ohms to represent the input impedance of the two h.f. units in parallel. Under these conditions the voltage loss introduced by each filter at the cross-over frequency is about 17 dB relative to the output from the loudspeaker amplifier, and the low-pass filter gives a loss of about 30 dB at 4 kc/s and the high-pass filter gives a loss of about 30dB at 1 kc/s.

It is important that the loudspeaker units are correctly phased by connecting the leads between them and the filter to the appropriate terminals, red wires being connected to positive terminals and black wires to negative terminals. The polarity markings on the l.f. and h.f. units follow opposite conventions but this disparity is taken into account in the crossover network.

SECTION 4

STUDIO LOUDSPEAKER LS5/1

General Description

Studio Loudspeaker LS5/1 is a high-grade loudspeaker designed for quality checking and it supersedes the LSU/10. The low-frequency and high-frequency units employed are of the same type as in the O.B. Loudspeaker LS3/1 described in Section 3, but the design differs in several respects. The limitations imposed on the LS3/1 by the need for easy transportability and for listening in restricted spaces do not apply to the LS5/1, and it has been possible to employ a cabinet with better acoustic properties, to separate the l.f. and h.f. units and to accommodate the loudspeaker amplifier in the same cabinet.

The LS5/1 loudspeaker consists of a Cabinet CT4/4 in which are mounted the following:

(a) Plessey L.F. Loudspeaker, Type CP73025/12/5 and two G.E.C. H.F. Loudspeakers (G.E.C. Presence Unit Type BCS1852/T534).
(b) Cross-over Filter FL6/2.
(c) Mains-operated 15-watt Loudspeaker Amplifier AM8/4 which is described in Instruction S.3 Section 10.

The response at the low-frequency end of the range is similar to that of the LSU/10 but the axial frequency response is maintained substantially flat up to 13 kc/s, while the variation in response with angle is very much less.

The main considerations leading to the design of the loudspeaker are discussed in a Paper by D. E. L. Shorter (Research Department) published in *Proc. I.E.E.*, Vol. 105, Part B, No. 24, November 1958.

Loudspeaker Cabinet CT4/4

As the restrictions imposed on the design of the cabinet CT4/1 which is used in the O.B. Loudspeaker LS3/1 do not apply to the CT4/4 it has been possible to increase the dimensions of the latter to extend the low-frequency range and also to accommodate the loudspeaker amplifier; the increase in size naturally involves the use of thicker material to give the necessary rigidity. The cabinet is constructed in two portions, an upper one which is the loudspeaker cabinet proper in which the loudspeaker units and the cross-over filter are mounted, and a lower one in the form of a pedestal which houses the loudspeaker amplifier and supports the upper one to which it is firmly fixed.

The upper portion is 2 ft 9 in. high by 17 in. wide by 19 in. deep and is constructed from $\frac{3}{4}$-in. thick chipboard on a framework of 1-in. by 1-in. hardwood battens, and has a removable back. A small vent, $3\frac{1}{2}$ in. by $2\frac{1}{2}$ in., is cut near the right-hand bottom corner of the front panel to resonate with the enclosed volume of air at about 30 c/s and give a slight increase in low-frequency output. The internal surfaces are lined to a depth of 4 in. to 6 in. with sound-absorbing material in the form of glass-fibre blankets folded into pads and contained in polythene bags for the top, sides and back and in a cotton bag for the bottom. These are secured in position with twine through screw eyes for easy removal to facilitate fitting and removal of the loudspeaker units and the cross-over filter. The use of polythene bags, besides making for easier handling, slightly increases the sound absorption at low frequencies, the action being similar to that of the membrane absorbers used in studio treatment. For the bottom bag, however, which is in the immediate vicinity of the vent, the use of polythene is undesirable since at high sound levels this material is liable to buzz.

An aluminium-alloy tie rod is fitted between the front and back of the upper portion to restrict the vibration of the removable rear panel.

The l.f. loudspeaker unit is mounted behind a rectangular opening 10 in. high by $7\frac{1}{2}$ in. wide as in the LS3/1, but as the LS5/1 is not intended for listening at close ranges it is permissible to mount the h.f. units above the l.f. unit, an arrangement which gives a more uniform frequency response. Under normal listening conditions the separation between sound sources is not noticeable to listeners at distances over 4 ft.

The whole of the front of the loudspeaker compartment is covered with an expanded metal grille on a wooden frame which is fixed in position by screws inserted from inside the cabinet.

The pedestal on which the loudspeaker compartment is mounted and which houses the loudspeaker amplifier consists of a rectangular compartment with overall dimensions of 10½ in. wide by 13 in. deep by 9½ in. high supported by four outward sloping legs, giving a total height of 16 in. Large cut-outs in the back and two sides and the base give access to the amplifier and provide ventilation. The pedestal, which has an open top, is screwed to the bottom of the loudspeaker compartment to which a sheet of asbestos, 11 in. by 8 in. by $\frac{1}{16}$ in. thick, is glued, to give protection from the heat dissipated by the amplifier. Two steel mounting bars supported on rubber grommets are fitted along the bottom of the pedestal compartment for mounting the amplifier.

In the design of the cabinet and in the mounting of equipment care has been taken to prevent the occurrence of unwanted vibrations and rattles as far as possible, but it is essential that all fixing screws, etc., should be kept quite tight if this object is to be achieved.

the centre portions of both diaphragm and plate are slightly conical in shape. Slots in the front plate at a tangent to the cone-shaped centre portions provide an outlet for the sound. Because of the low overall diameter of 2½ in. the unit is less directional at high frequencies than a conventional cone or single horn radiator.

Two h.f. units, selected as a matched pair and tested against a standard unit, are used to increase the power-handling capacity of the system, but as the spectral distribution of energy in normal programme material falls off towards the upper end of the frequency range, it has been found unnecessary to employ both units at the highest frequencies. Accordingly, one of the units is made inoperative at the upper end of the frequency range, the input to the other being correspondingly increased by a top-lift circuit in the loudspeaker amplifier to preserve uniform response; this

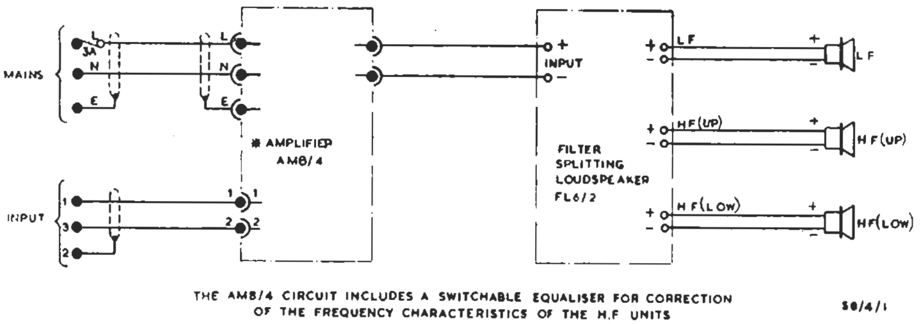


FIG. 4.1. STUDIO LOUDSPEAKER LS5/1: CIRCUIT
DRAWING No. EA 10845

L.F. and H.F. Loudspeaker Units

These units are of the same type as those used in the LS3/1. The l.f. unit, which has a 15-in. cone and an axial frequency range extending to about 4 kc/s without the cross-over filter, is mounted behind a rectangular opening 10 in. high by 7½ in. wide as in the LS3/1. This gives a less directional system in the horizontal plane than with a circular opening by reducing slightly the axial response at the upper end of the range and raising the response at oblique angles in the horizontal plane.

The two h.f. units are used as direct radiators without horns, and are of the moving-coil type with a plastic-impregnated fabric diaphragm which moves as a whole up to at least 10 kc/s. A thin metal plate is fitted in front of the diaphragm and

arrangement avoids unwanted directional effects in the vertical plane at high frequencies which result when both units are used. As used in the LS5/1 the axial frequency range extends from about 1·5 kc/s to 13 kc/s.

L.F. Unit

Flux density: 12,000 gauss
D.C. resistance: 11-13·4 ohms
Fundamental resonance of unit unmounted: 25 ±5 c/s

H.F. Units

D.C. resistance: 11-12·5 ohms each
Fundamental resonance: 1·6 kc/s
Impedance at resonance: 45 ohms each approx.

Cross-over Filter FL6/2

The cross-over filter FL6/2 is mounted on one side of the loudspeaker compartment near the h.f. units. It has three separate outputs which are wired to the three loudspeaker units as shown in Figs. 4.1 and 4.2, the upper and lower h.f. units being marked *Up* and *Low* respectively. Separate outputs are provided for the two h.f. units to enable the inductor L4 to be introduced in the output to the upper unit to attenuate the output at the upper end of the frequency range; as already indicated, this improves the directional characteristics in the vertical plane.

adjusted accordingly to maintain the correct frequency characteristic. The output in all cases is taken from Tap 8.

In the low-pass filter for the l.f. loudspeaker unit the resistor R1 shunted by the inductor L2 corrects, at the cost of some mid-band loss, for the rising frequency characteristic of the l.f. unit between 100 c/s and 1 kc/s, and the rejector circuit L5 C6 reduces the output of this unit in the 2·2-kc/s region to avoid interference effects in the cross-over region. L3 and C5 in series with R2, which is adjusted on test, correct the shape of the frequency characteristic between 300 c/s and 500 c/s.

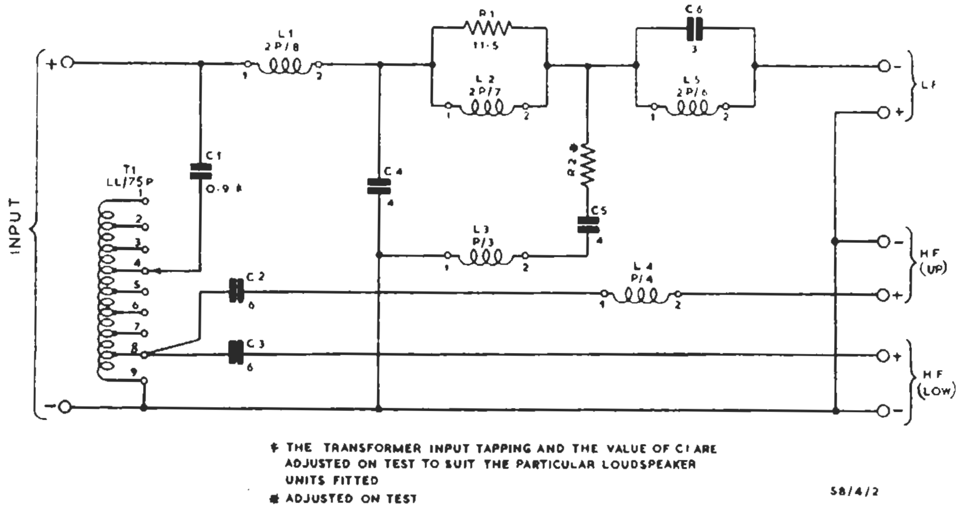


FIG. 4.2. CROSS-OVER FILTER FL6/2: CIRCUIT
DRAWING NO. EA 10835

A flexible lead is wired to the input tags of the filter and run to the amplifier compartment where it terminates on a 2-pin socket for connection to the output of the amplifier.

As the output impedance of the loudspeaker amplifier is low a constant-resistance cross-over network is unnecessary and the high-pass and low-pass filters are connected in parallel across the input and work independently of each other with negligible interaction.

The input transformer for the high-pass filter is used as a combined choke and auto-transformer, and is tapped to provide initial adjustment of the signal level to the h.f. units according to the relative sensitivity of the particular h.f. and l.f. units with which it is used. Any change in input tapping alters the shunt inductance in the cross-over network; the value of C1 has therefore to be

Provision is made for adjusting the shape of the frequency characteristic above 3 kc/s by an electrical network included in the loudspeaker amplifier which gives a peak of about 4 dB at 10 kc/s in the frequency characteristic of the amplifier. (See Instruction S.3, Section 10.)

When the input to the high-pass filter is connected to Tap 4 of the transformer via C1 the value of C1 is normally 0·9 μF. The voltages appearing at the terminals marked *L.F.*, *H.F.* (*Up*) and *H.F.* (*Low*) are then equal at about 1·75 kc/s when the low-pass filter is loaded with 15 ohms to represent the input impedance of the l.f. unit and each of the h.f. outputs is loaded with 12 ohms. Under these conditions the voltage loss introduced by the filter at the cross-over frequency is about 18 dB relative to the input voltage to the filter, and the low-pass filter gives a loss of about 30 dB at 2 kc/s and the high-pass filter a loss of about 30 dB at 1·2 kc/s. The acoustic cross-over frequency, i.e., the frequency at which equal sound pressures are produced on the loudspeaker axis by the l.f. and h.f. units respectively, is about 1·7 kc/s.

It is important that the loudspeaker units are correctly phased by connecting the leads between them and the filter to the appropriate terminals, red wires being connected to positive terminals and black wires to negative terminals. The polarity markings on the l.f. and h.f. units follow opposite conventions but this disparity is taken into account in the cross-over network.

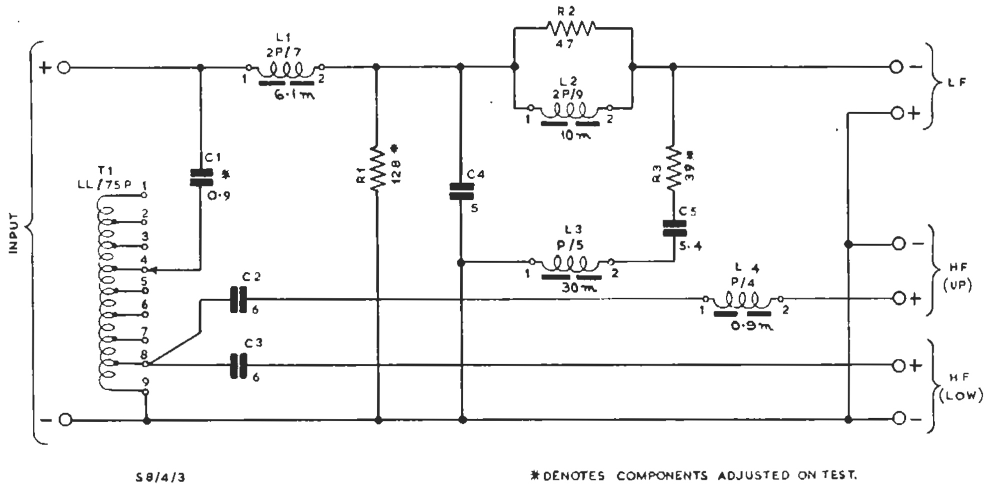


FIG. 4.3. CROSS-OVER FILTER FL6/4: CIRCUIT
DRAWING No. [illegible]

Loudspeaker Amplifier AM8/4

The amplifier used in the LS5/1 is described in Instruction S.3, Section 10. It should be noted that the amplifier incorporates a correction circuit to compensate for the changeover from two h.f. units to one at the high frequencies. (Provision is made for switching out this equaliser when the amplifier is used for other purposes.) The amplifier chassis is bolted to the two mounting bars which are supported on rubber grommets on the bottom of the pedestal compartment.

The cut-out in the right-hand side of the pedestal compartment gives access to the gain control and fuses, that in the left-hand side gives access to the input socket and the one in the back gives access to the mains switch and mains input socket and to the output plug to which the filter input lead is connected. Access to the valves is obtained through the cut-out on the right-hand side by removing the valve shield, which is done by removing the rear fixing screw only and slackening the front screw, the front fixing hole being slotted. An input jack is fitted to the front of the amplifier and connected in parallel with the input socket, but is not accessible when the amplifier is fitted in the pedestal compartment.

A 20-ft mains connecting lead and a 20-ft input lead are provided as part of the LS5/1.

Maintenance

Should it become necessary to change either the l.f. loudspeaker unit or an h.f. unit the whole loudspeaker should be returned to Equipment Department as the overall performance is closely adjusted on initial test.

Loudspeaker LS5/1A

In later models of the LS5/1 the Plessey l.f. loudspeaker has been replaced by a Goodmans loudspeaker Type C129B/15PR/15 ohm, and such models are coded LS5/1A.

The characteristics of the Goodmans loudspeaker are slightly different from those of the Plessey unit, and in order to give the same overall performance the combined equaliser and cross-over filter FL6/2 has been replaced by the FL6/4 which has the modified circuit shown in Fig. 4.3.

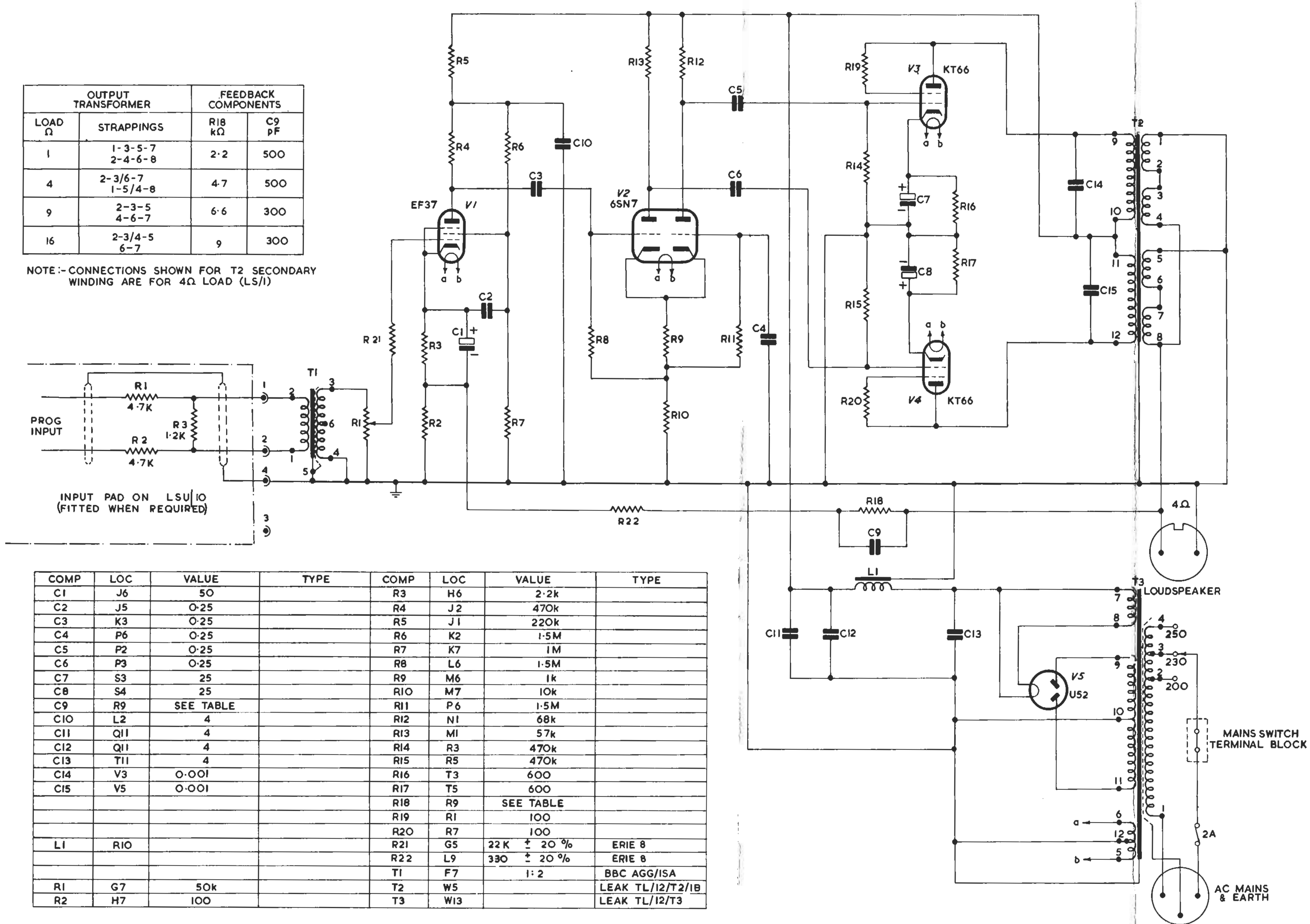
W.G. 9/63

EB7407

FIG I S8

OUTPUT TRANSFORMER		FEEDBACK COMPONENTS	
LOAD Ω	STRAPPINGS	R18 kΩ	C9 pF
1	1-3-5-7 2-4-6-8	2·2	500
4	2-3/6-7 1-5/4-8	4·7	500
9	2-3-5 4-6-7	6·6	300
16	2-3/4-5 6-7	9	300

NOTE :- CONNECTIONS SHOWN FOR T2 SECONDARY WINDING ARE FOR 4Ω LOAD (LS/1)



COMP	LOC	VALUE	TYPE	COMP	LOC	VALUE	TYPE
C1	J6	50		R3	H6	2·2k	
C2	J5	0·25		R4	J2	470k	
C3	K3	0·25		R5	J1	220k	
C4	P6	0·25		R6	K2	1·5M	
C5	P2	0·25		R7	K7	1M	
C6	P3	0·25		R8	L6	1·5M	
C7	S3	25		R9	M6	1k	
C8	S4	25		R10	M7	10k	
C9	R9	SEE TABLE		R11	P6	1·5M	
C10	L2	4		R12	N1	68k	
C11	Q11	4		R13	M1	57k	
C12	Q11	4		R14	R3	470k	
C13	T11	4		R15	R5	470k	
C14	V3	0·001		R16	T3	600	
C15	V5	0·001		R17	T5	600	
				R18	R9	SEE TABLE	
				R19	R1	100	
				R20	R7	100	
L1	R10			R21	G5	22K ± 20 %	ERIE 8
				R22	L9	330 ± 20 %	ERIE 8
				T1	F7	1:2	BBC AGG/ISA
R1	G7	50k		T2	W5		LEAK TL/12/T2/1B
R2	H7	100		T3	W13		LEAK TL/12/T3

AMPLIFIER LSM/8

57/JWG/001/DJE
EA 8874

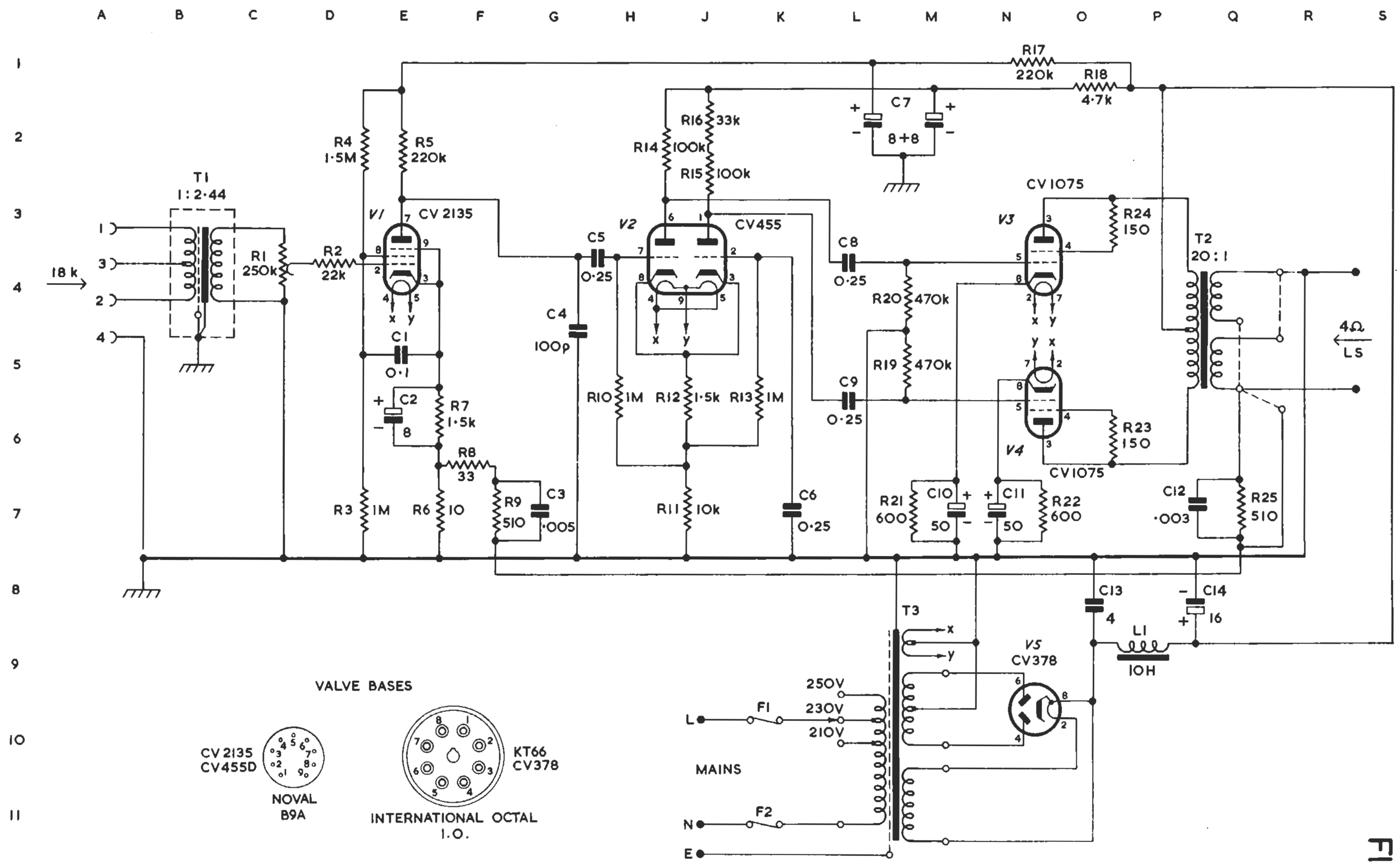
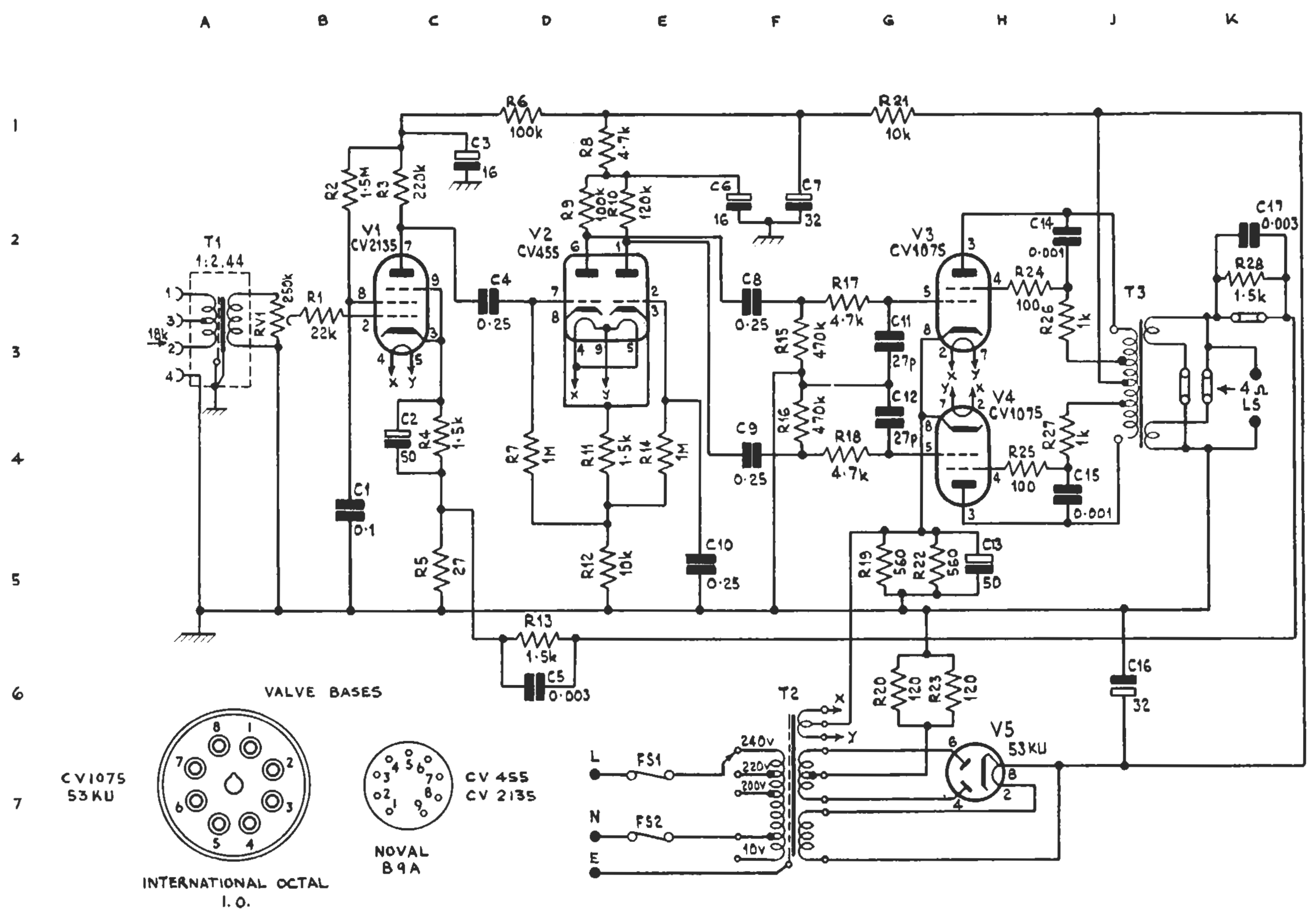


FIG 2

LOUDSPEAKER AMPLIFIER LSM/10 CIRCUIT

SERIAL Nos 101 TO 470

61/GH/101
EA10873



LOUDSPEAKER AMPLIFIER LSM/10: CIRCUIT DIAGRAM

SERIAL Nos 471 ONWARDS

FIG 2A
ISSUE 2

S8