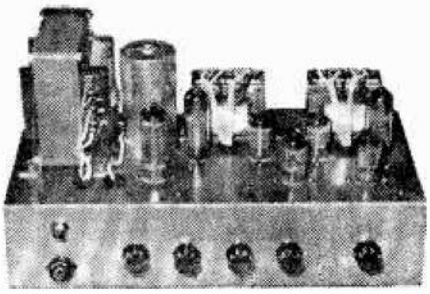
The "7-20" stereo amplifier



by M. L. Michaelis

A NEW DESIGN USING THE ECLL800 AUDIO VALVE

THE most modern trend in high power stereophonic amplifiers is presented in this design. For clubs, schools, dances, parties and similar functions, for open-air use and even for the musical specialist at home some 8 to 10W power output on *each* channel is required.

Push pull operation is virtually essential for any high-power amplifier, as it affords the only really economical method of obtaining sufficient reduction of distortion and tolerable power efficiency. The principle objection to high-power push-pull output stages was formerly the relatively large number of valves required. In place of the single output valve of a single-ended amplifier, a pair of power valves was required, and, furthermore, a phase-splitter valve.

A basically new valve has now appeared on the market which is likely to revolutionise valve-operated audio power amplifiers.

Unidrive Push-Pull Output Valve ECLL800

The ECLL800 is, as its type designation implies, a combination of a phase-splitter triode and *two* power pentodes within a single envelope. It thus contains all the requirements for a push-pull output stage in the form of a single valve which is of *the same physical size* as a conventional EL84 pentode, and uses the same noval base. Furthermore, a set of Class B operating conditions is possible, under which the ECLL800 takes exactly the same h.t. drain as an EL84. The ECLL800 thus offers many very interesting opportunities for amateur experiments.

The present stereophonic amplifier design shows this valve under normal optimum operating conditions as recommended by the makers (Class AB).

The designation "Unidrive" for the ECLL800 means that the input drive signal required is that from a conventional single-ended voltage amplifier, e.g. from the anode circuit of one section of an ECC83, or from the anode circuit of an EF86. The ECLL800 contains its own phase-splitter, and this is in fact itself a completely new design and not a mere inclusion of a conventional voltage amplifier triode within the same glass bulb.

The tubular cathode of one pentode section is extended upwards beyond the end of the pentode anode. The protruding section is positioned symmetrically inside a re-entrant half-cylindrical anode. Midway between the extended cathode and this anode, on both sides, are situated flat metal plates with a large rectangular cut-out to allow the electron clouds to pass through. These "rectangular iris windows" are joined together and to the control grid of one pentode system, and connected externally to pin 2 of the noval base. This combination electrode, conventionally termed "triode grid plus pentode No. 1 control grid", is the input electrode of the ECLL800, requiring a single-ended drive signal of 8V r.m.s. for 8·5W push-pull output at 5 per cent distortion.

With the adoption of the usual negative feedback arrangements, as employed in our present design too, the total distortion of the *entire amplifier* is less than 1 per cent at 8W output *per channel*.

The rectangular iris grid of the phase-splitter triode is designed such that the triode has a gain of exactly unity when an anode load of 150kΩ is employed (R64, R65 in our design). The signal at the triode anode (pin 1) is then of the same amplitude but opposite phase, as the input signal, and can be coupled externally to pin 6, the control grid of the other pentode section.

All three cathodes and both suppressor grids are commoned together to pin 7 of the base, and the screens of the two pentodes are commoned to pin 9. Pins 3 and 8 are the two pentode anode connections going to the two ends of the centre-tapped primary of a push-pull output transformer, the common h.t. supply being fed in, as usual, at the centre tap.

All electrodes of the three valve sections are thus accommodated on seven pins, the remaining two being used for the heater, in the normal position, pins 4 and 5. The total heater consumption of an ECLL800 is only 0·6A at 6·3V, which is astonishingly low for a complete push-pull output stage.

Curvature Compensation

The control characteristic of the rectangular irises on the triode has been made such that its residual curvature (non-linearity) is compensatory to that of the pentodes, so that the overall linearity of the ECLL800 is better than for any of its

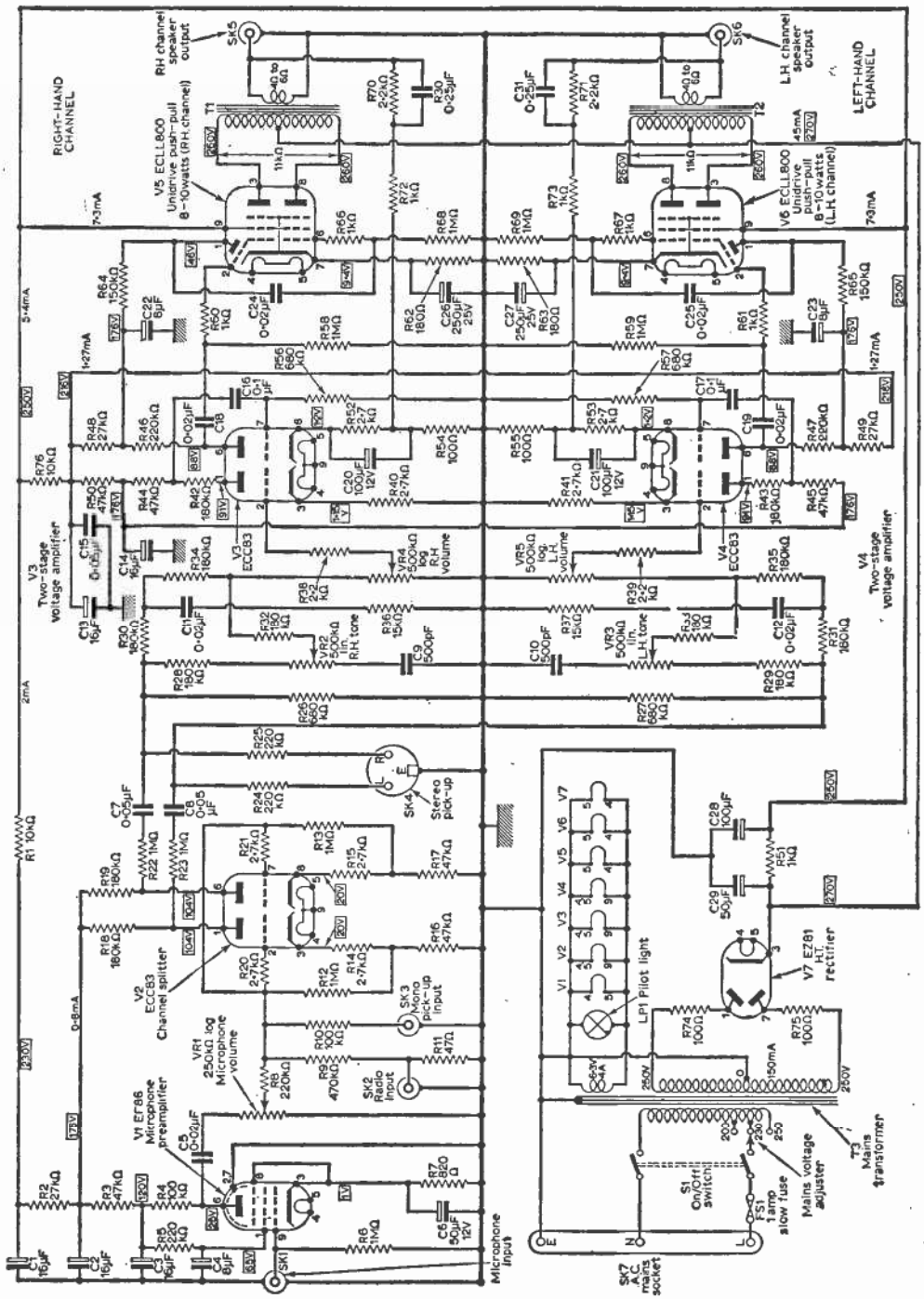


Fig. 1: The circuit. Numbers in circles indicate positive voltages w.r.t. chassis, as measured for prototype, using 20kΩ/V meter and with all volume controls at zero setting (no signal). Values shown against arrows on h.t. feeds are as calculated from above mentioned voltage readings.

sections alone. This is the first deliberate exploitation of this method of compensating distortion known to the author in commercial production practice. Certainly it is in general simpler and more economical to use negative feedback for improving linearity, in the familiar manner, yet the adoption of "compensatory control characteristics" for two or more stages in an amplifier chain offers, in principle, the possibility of driving the amplifier well beyond the linear part of the characteristics of individual stages, without undue overall distortion.

In *combination* with conventional negative feedback, this leads to greatly improved conversion efficiency of h.t. input power to audio output power. The ECLL800 probably represents nowhere near the ultimate of what may be achievable with such techniques, and valve manufacturers will doubtless bring out new types along these lines in the future.

Functions of the "7-20" Stereo Amplifier

This amplifier is designed for universal stereo and monaural (conventional) applications. V2 is here a channel-splitter, for feeding ordinary monaural inputs evenly onto both channels, the amplifier then functioning as 20W power output system for such signals.

The fact that half of this power is fed to each of two speakers or speaker systems, which can be placed some distance apart (ideally in opposite corners of the room, or opposite wings of a stage, for stereo use), enables an impressive projection of the sound into the room to be achieved, even for monaural inputs from ordinary pickups, tape decks or radio tuners. The use of such an amplifier system, employing two channels, is thus definitely worth while even for such signals. The sound appears to stand in the room, and *not* "come out of a hole", as otherwise with single speaker systems. Moreover, the intensity of sound is greater for the same power, and subjective quality and brilliance are improved.

It is, of course, essential to use speakers able to handle 10W peak power. It is not safe to use smaller speakers, even if one keeps the general volume turned low, because transients could still drive the amplifier momentarily to full power and rupture the cone and voice-coil system of a small speaker. Examples of suitable speakers are the WB Stentorian units HF 1016, in any of the makers cabinets or well designed amateur-built cabinets. For outdoor use, suitable horn speakers may be employed.

The Pre-amplifier

The pre-amplifier system included in the "7-20" stereo amplifier is quite comprehensive since the public address and entertainment applications require the frequent use of an announcer's or soloist's microphone.

High gain reserves are incorporated, which can be brought into use by internal variation of certain component values (as discussed below), to any extent such as to trim the complete amplifier to simultaneous optimum performance at all inputs for a particular microphone, tape deck, stereo pickup, etc.

The channel-splitter, V2, allows *simultaneous* monaural and stereophonic operation without mutual interference. Such requirements arise, for example, if a public stereophonic concert (or an educational stereophonic concert in a school) is being given in a hall, with the two speakers in the wings of the stage, and a commentator wishes to inject explanations or announcements into the amplifier via a microphone. He may do so without any switching whatsoever, and whilst a stereo recording is actually playing, his voice will come equally over both channels, and will thus appear to originate from mid-stage, where he will, in fact, probably be situated.

Controls

The arrangement of controls has been designed with such applications in mind. Thus each main channel has been given two controls, a volume control and a treble tone control. Balance controls and other ganged arrangements have been discarded, as they bring added complexity and confusion. It was decided to dispense with a manual bass control too, in order to keep the number of controls down to a very minimum. A treble control is much more important than a bass control, and it is generally satisfactory to run the amplifier with some 15dB fixed bass boost for musical purposes and associated commentaries, as has here been done. Details of varying the degree of fixed bass boost are given below, as well as for the introduction of manual bass controls if required—there is still ample room for such on the chassis.

These considerations led to the use of just four simple controls for the main amplifier, with the addition of a fifth, VR1, the microphone volume control. The commentator can "mix himself in" on to a playing stereo or monaural recording at any desired relative intensity from zero to full power.

Monaural Inputs

The microphone input at SK1 may, of course, be used for any other weak signal input requiring greater amplification than a pick-up, e.g. a conventional monaural tape deck. V3 and V4 anode circuits (pin 1) can be adjusted (see below) such that inputs of 1mV or less at SK1 suffice to fully load the amplifier. VR1 is operative only for inputs at SK1. Inputs at SK2 and SK3, as well as stereo inputs at SK4, are controlled only by the four main amplifier controls, which, of course, also control SK1 inputs once again.

The radio input at SK2 is intended to be fed from the extension speaker sockets of a radio (low impedance). R11 is inserted to make this input insensitive to hum pick-up, so that long unscreened twin flex leads can be employed. If the insertion of the appropriate plug in the extension speaker sockets of the radio disconnects the internal speaker, the value of R11 must be reduced to the speaker impedance of the radio receiver, and must be of sufficient power rating to absorb the entire output power of the radio set. This demand can be satisfied by leaving R11 as shown, and wiring the necessary additional parallel resistor in or near the plug fitting SK2, if desired.

The input at SK3 must be screened. The resistors R8, R9 and R10 effect mutual decoupling of the three monaural inputs, so that all three may be left connected even when not operative. Many

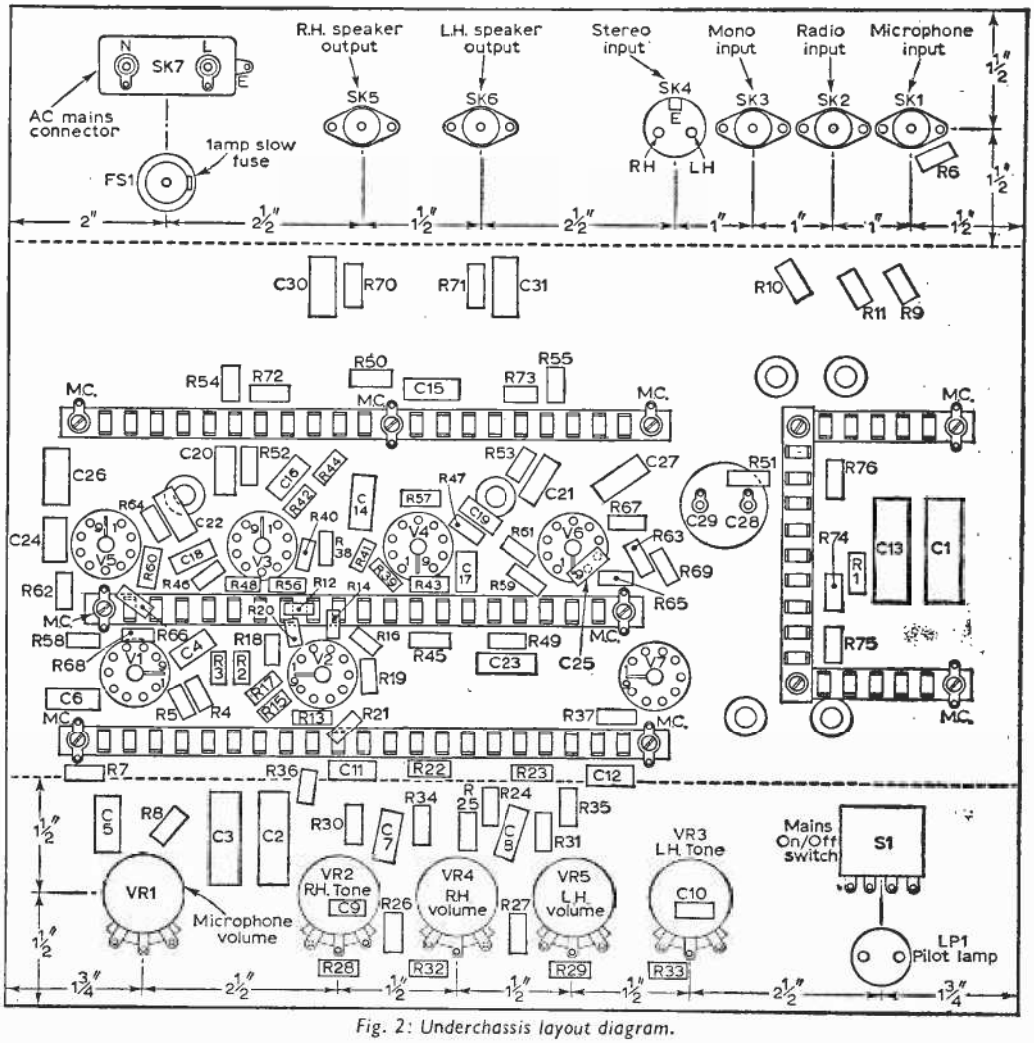


Fig. 2: Underchassis layout diagram.

pick-up units have extra contacts shorting the output when the motor is not running: R10 (and R24, R25 in the case of the stereo input SK4) thereby prevent shorting of other signals in the amplifier. At the same time, these decoupling resistors permit a wide range of fixed adjustments to the relative gains for the various inputs to be made, for optimum performance with a particular set of equipment.

Hum Removal

The principal gain *reserves* of the "7-20" stereo amplifier lie in the anode circuits of V3, V4 at pin 1. Gain can be increased by increasing the values of R44 and R45 and decreasing the values of R42, R43 by the same amount—and vice versa. In the extremes, the gain of the entire amplifier can be raised by a factor of five times, or reduced to zero, by these measures.

When making adjustments, it should first of all be checked whether the arrangement shown, with split anode loads, gives least hum output, or whether it is better to replace R42-R45 by a pair of 220kΩ ½W resistors, taking C16 and C17 still to the tops of R56 and R57, but splitting these resistors appropriately for the grid pin 7 feeds. The precise conditions will here depend somewhat on the exact positions of heater wiring, etc.

In general, heater wires should be run low in the chassis, hard up against the metal bottom, and other circuit wiring held well clear. If necessary, heater wires should be in the form of tightly twisted leads, one of which is earthed to chassis in passing each valveholder. It may also prove of advantage to experiment with small aluminium shields (earthed to chassis) between the rectifier (V7) valveholder and the control panel VR1 to VR4.

Gain Adjustments

Having minimised residual hum, the split anode or grid loads (whichever are finally adopted) in V3 and V4 should be adjusted until the desired *normal* volume of output (not necessarily full power) is obtained from the chosen microphone connected at P1 and whilst speaking at the average intended distance and loudness, VR1 being at mid-track and all other controls at maximum.

Having completed this adjustment, VR1 should be turned down to zero, and all other controls to half-track. The desired radio receiver should then be adjusted to normal intensity on its internal speaker, and then switched over to SK2 of the amplifier, making adjustments to R11 if necessary, as already discussed. R9 should then be adjusted until the amplifier is on the verge of overloading, on both channels.

The radio receiver should then be disconnected from SK2 and the desired monaural pick-up connected at SK3. If the makers specify a particular pick-up circuit, the additional resistors and capacitors must be included below the pick-up arm mount on the record player.

The four main amplifier controls should be advanced to maximum, and a medium intensity record played. R10 should be adjusted such that the amplifier definitely overloads, to allow a margin of safety for weaker recordings. The same procedure should then be repeated for the stereo input socket, SK4, adjusting the values of R24 and R25 (but always maintaining them equal).

It should be added here that, in general, the use of both monaural and stereo pick-ups, at SK3 and SK4, is not necessary, as all stereo record players will also play normal monaural records (but *not* vice versa; stereo records are immediately destroyed if played on a normal record player). However, the use of two turntables, only one of which need be stereophonic, gives greater scope for the producer and his helpers during dances and other functions.

Choice of Components and Alternatives

Specified values of electrolytics should not be reduced, though slightly larger values, if able to be accommodated are permissible.

The main smoothing resistor, R51, may be replaced by a choke of about 10 to 20 henries inductance and about 30mA (not less) current rating. C28 and C29 must be high surge-rating electrolytic cans; whether two separate cans or a single double-value can is used is immaterial. The voltage rating must be 500V. for low leakage current at the operating voltage. All other electrolytics are small tubular items of lower voltage rating, as specified in the parts list.

The mains transformers h.t. windings must be 250-0-250V. Other voltages, lower or higher, are *not* permissible. The no-signal d.c. current drain from the rectifier cathode is 110mA and rises to 150mA at full drive. The transformer and rectifier must thus be rated for 150mA.

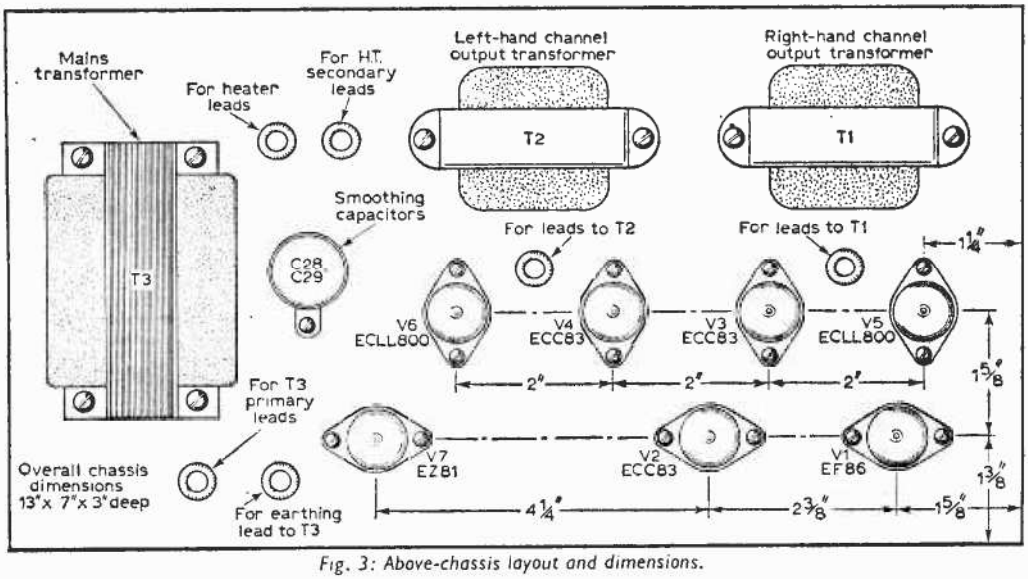


Fig. 3: Above-chassis layout and dimensions.

Regarding output transformers, types standardised for a pair of 6V6 or EL84 valves in push-pull are usable, and should present no difficulty in obtaining. If winding these items oneself, according to general tables and experience, one should aim at an impedance of 11kΩ anode-to-anode, this being the optimum value, but by no means over critical.

An EZ81 rectifier, as specified, is essential. Type EZ80 is *not* suitable as a substitute, as it has insufficient maximum current rating.

Tone Controls

In the following discussion, component numbers from the right hand channel will be referred to. Similar remarks apply to corresponding components in the left hand channel.

Beyond C7 the feed to V3 is split into a bass branch (via R30) and into a treble branch (via R28). The treble branch is variable, giving maximum (level) treble response with VR2 slider at the top: movement of the slider towards C9 reduces treble response. The action can be made more powerful, if desired, by increasing the value of C9, and vice versa. If rising treble response is desired, a capacitor of between 100pF and 250pF should be inserted between the top end of VR2 and R28.

The bass branch gives about 10dB fixed boost. This can be reduced by increasing the value of R34. Increase of bass boost is achieved in the negative feedback circuit if required (see below).

If a variable bass control is to be added, this should be in the form of a 500kΩ linear potentiometer whose track is connected across C11, R34 then goes to its slider.

A further (approximately) 5dB of bass boost are obtained by means of R70 and C30, which reduce negative feedback over the main amplifier loop at low frequencies and thus increase gain. The amount of bass boost contributed here can be increased by increasing the value of R70, and vice versa. The turnover frequency for the bass boost can be *raised* by *decreasing* the value of C30, and vice versa.

Whatever alterations are made to one channel during all these adjustments *must* be made to the

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COMPONENTS LIST

Resistors:

R1	10kΩ 1W	R39	2·2kΩ
R2	27kΩ 1W	R40	2·7kΩ
R3	47kΩ 1W	R41	2·7kΩ
R4	100kΩ 1W	R42	180kΩ
R5	220kΩ	R43	180kΩ
R6	1MΩ	R44	47kΩ
R7	820Ω	R45	47kΩ
R8	220kΩ	R46	220kΩ
R9	470kΩ	R47	220kΩ
R10	100kΩ	R48	27kΩ
R11	47Ω 1W	R49	27kΩ
R12	1MΩ	R50	47kΩ 1W
R13	1MΩ	R51	1kΩ 2W
R14	2·7kΩ	R52	2·7kΩ
R15	2·7kΩ	R53	2·7kΩ
R16	47kΩ	R54	100Ω
R17	47kΩ	R55	100Ω
R18	180kΩ	R56	680kΩ
R19	180kΩ	R57	680kΩ
R20	2·7kΩ	R58	1MΩ
R21	2·7kΩ	R59	1MΩ
R22	1MΩ	R60	1kΩ
R23	1MΩ	R61	1kΩ
R24	220kΩ	R62	180Ω 2W
R25	220kΩ	R63	180Ω 2W
R26	680kΩ	R64	150kΩ
R27	680kΩ	R65	150kΩ
R28	180kΩ	R66	1kΩ
R29	180kΩ	R67	1kΩ
R30	180kΩ	R68	1MΩ
R31	180kΩ	R69	1MΩ
R32	180kΩ	R70	2·2kΩ
R33	180kΩ	R71	2·2kΩ
R34	180kΩ	R72	1kΩ
R35	180kΩ	R73	1kΩ
R36	15kΩ	R74	100Ω 2W
R37	15kΩ	R75	100Ω 2W
R38	2·2kΩ	R76	10kΩ 1W

All Carbon, ½W, ±10%, unless otherwise stated.

Capacitors:

C1	16μF electrolytic 350V
C2	16μF electrolytic 350V
C3	16μF electrolytic 350V
C4	8μF electrolytic 350V
C5	0·02μF paper 500V
C6	50μF electrolytic 12V
C7	0·05μF paper 500V
C8	0·05μF paper 500V
C9	500pF ceramic 500V
C10	500pF ceramic 500V
C11	0·02μF paper 500V
C12	0·02μF paper 500V
C13	16μF electrolytic 350V
C14	16μF electrolytic 350V
C15	0·05μF paper 500V
C16	0·1μF paper 500V
C17	0·1μF paper 500V
C18	0·02μF paper 500V
C19	0·02μF paper 500V
C20	100μF electrolytic 12V
C21	100μF electrolytic 12V
C22	8μF electrolytic 350V
D23	8μF electrolytic 350V
C24	0·02μF paper 500V
C25	0·02μF paper 500V
C26	250μF electrolytic 25V
C27	250μF electrolytic 25V
C28	100μF } double can electrolytic 500V
C29	50μF }
C30	0·25μF paper 500V
C31	0·25μF paper 500V

Potentiometers:

VR1	250kΩ log	VR4	500kΩ log
VR2	500kΩ lin	VR5	500kΩ log
VR3	500kΩ lin		

Valves:

V1	EF86	V5	ECLL800
V2	ECC83	V6	ECLL800
V3	ECC83	V7	EZ81
V4	ECC83		

Sockets:

SK1	Coaxial panel type
SK2	Coaxial panel type
SK3	Coaxial panel type
SK4	Stereo pick-up
SK5	Stereo speaker
SK6	Stereo speaker
SK7	Mains connector, 3 pole

Transformers:

T1, T2	Push-pull output transformer. Primary 11kΩ, secondary to suit speaker. (Allen OP1348). Any conventional transformer for 6V6 or EL84 valves is suitable.
T3	Mains transformer. Secondaries: 250-0-250V 150mA; 6·3V 4A.

Miscellaneous:

FS1	Panel fuse
LP1	Panel pilot lamp 6·3V
S1	D.P.S.T./Q.M.B. on/off toggle switch

Chassis 7in. x 13in. x 3in. approx. Perforated cover. Wire, sleeving, tagstrips, bolts, grommets. Control knobs. Seven noval (B9A) valve holders.

shadow. Once balanced the control should be left in gang (apart from a periodic check) and any further balance compensation for particular commercial recordings carried out by decreasing volume to the appropriate speaker on the "monitor" control.

It was found initially that a "whistle" was recorded and this was traced to a beat note between the two erase oscillators. To cure this, switch to record on both channels and adjust the tuning slug on either one of the erase oscillator coils until the whistle disappears. The oscillators are remarkably stable as I have only had to carry out this operation once and no reappearance of "beat" has manifested in 18 months.

Mono Operation

For mono operation one amplifier at a time can be used—the other amplifiers being muted by the appropriate "monitor" control (or separate mains switches can be inserted). Ample volume is available for ordinary domestic purposes with only one channel used. Full track mono use is available by this method and "head" switching is avoided.

On home recordings it was found that a disappointing amount of bass was evident. Compensation is made in the circuit to level out the characteristic of the amplifier in the record position; this was altered by removing C16 (in the Martin circuit) from the record/play switch and placing a short across this connection: C16 was then placed in series with the sliding contact of this switch and the cathode of V2A (thus reducing bass feedback). An immediate improvement was evident and I reported this to Martins assuring them I was not a "boom" addict: they replied that technically I had "messed" up the response and they could not explain the apparent improvement. Constructors may like to try this modification if they are similarly disappointed.

Stereo Operation

The subject of stereo recording is an enormous one and outside the scope of a constructional article. For some really demonstrative instruction I would recommend the purchase of a four-track stereo tape called "Stereo Confidential" issued by Music on Tape and available in either a 3¾ or 7½in./sec. version.

To feed an external stereo amplifier the outputs from the pre-amplifier in the tape recorder can be taken from the "radio" sockets. Stereo discs can be directly recorded by providing two jack plugs from a stereo pickup (red to Channel A) using the Radio sockets (remember, however, the re-recording of commercial discs is prohibited by the usual copyright regulations).

Quality is extremely good and adjudged superior to quite expensive console stereograms. With the internal output stages it would not be good enough for the hi-fi purist but this recorder is, by comparison, portable and very much cheaper. Cost of the deck and units was about £36 but "careful" buying could possibly reduce this price. ■

The "7-20" Stereo Amplifier

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other one too, in exactly the same position and to the same extent. It is of paramount importance to maintain absolute symmetry between the two channels.

Adjustments of frequency response in the main amplifier should be carried out such that subjectively correct reproduction, with ample bass and treble, results from stereo records over SK4, with VR2 and VR3 set at mid-track. If this does not lead to sufficient speech clarity from a microphone over SK1 (too much bass), reduce the value of C5 until satisfactory performance is obtained. Much will depend upon the type of microphone used. A certain amount of treble boost in the microphone preamplifier, V1, alone is also obtainable by replacing C6 with a paper capacitor of about 0·1μF capacity.

Wherever grid stoppers are specified (resistors directly in series with control grid connections) these must be wired hard up against the respective valveholder pins.

Loudspeakers

As already mentioned, speakers, or speaker groups, of adequate power rating are essential. The circuit as shown in Fig. 1 is for 4 to 6Ω speakers or groups.

If 15Ω units are to be used, the output transformers must be obtained with the appropriate secondaries and the components in the main amplifier negative feedback loops must be changed. The correct values for R70, R71 are then 3·9kΩ, for R72, R73 1·8kΩ and for C30, C31 0·15μF. If original values were altered during frequency response adjustments, the above values for 15Ω speakers require alteration in the same *proportion*.

There is no objection to the use of series-parallel combinations of smaller speakers at different locations, provided that the total power rating remains adequate and the normal rules of matching are observed. Furthermore, with such multiple speaker positions, care should be exercised that stereophonic reproduction (if used) is not thereby confused.

Final Checks

Upon completion of the amplifier, even if it appears to be working satisfactorily, voltages at all points shown on Fig. 1 should be compared with the prototype figures entered in Fig. 1. A meter of at least 20kΩ per volt sensitivity must be used, or a valve voltmeter.

If a meter of lower sensitivity is used, readings may in some cases be falsified (indicate low). Slight departures from prototype figures are possible, and may be ignored. But large differences—especially if different for corresponding points of the two channels, indicate faulty components or wiring errors, and should be traced and removed. It is advisable to check all wiring very carefully before first switching the completed amplifier on. ■