Stereosonic Magnetic Recording Amplifier

ARTHUR W. WAYNE

Describing a specific amplifier designed for a Ferrograph Tape Deck, but one which could be adapted fairly easily to accommodate any other type of stereo deck with heads of similar impedances and drive requirements.

THE BASIC REQUIREMENTS of any magnetic recording system are few and simple. They are:

(1) A tape transport deck
(2) (a) A loudspeaker and (b) a box or baffle for it.
(3) An amplifier
(4) A reasonable amount of intelligence in the use of (1) (2) and (3).

Requirement (4) is easily disposed of, as it is obvious that every reader of AUDIO will more than satisfy it; and of the remaining three items, the only ones in reach of the ordinary amateur constructor are (2) (b) and (3). So far as (2) (b) is concerned, suggestions will be made in Appendix 2 for the construction of a resonant enclosure suitable for use with *one particular make of speaker only:* and, as there are few amateurs with the necessary facilities for acoustic determinations, where other loudspeakers are preferred, the maker's recommendations should be sought.

This leaves us with (3); and a strictly practical description of a commercial amplifier, intended for stereosonic or single-channel use at will, and eminently suited for amateur construction, follows.

With a genuine high-fidelity output of 15 watts per channel, rising to 25 watts peak, and a comprehensive tone-control system, it provides a quite useful amount of noise for the smaller P.A. operator as well as for the home.

The basic amplifier, the Shirley Laboratories Ltd. FS101, shown in *Fig.* 1 was deliberately developed with "listenability" in mind, a subtle facet of hi-fi, not always completely covered by contemporary design. Most modern amplifiers have approximately equal characteristics, but there is no doubt that, to paraphrase "Animal Farm," some amplifiers are more equal than others. Now, we engineers are a parochial lot, much given to blinding ourselves by science, and with a touching faith in figures: moreover, we labour under the extraordinary delusion, perhaps in company with the biologists, that these figures tell the whole story. Even here we don't play fair, for we talk glibly about square waves and sine waves, and all the other sorts of waves, without explaining that these are functions, part of a general system of analysis of which our familiar audio problems are a very small part indeed. (Even the concept of a square—cubic?—wave in three dimensions seems a little difficult, and we do hear in three.)

The FS103 is designed to work with the "Ferrograph" type C88 stacked-head deck, now becoming available in the U.S.A.; and it has been demonstrated in conjunction with this deck at various Audio Shows in New York and elsewhere, where it appeared to arouse interest. For the amateur who wishes to experiment, Appendix 1 gives details of some possible modifications, one or two of which are in use on versions of the amplifier manufactured for specialized purposes. It is not proposed to discuss the theory of magnetic recording, as this has been fully covered in this journal and elsewhere.

Over-all Circuitry

In the over-all schematic *Fig.* 2, the figures and letters in the circles refer to the tag strips on the underside of the C88 deck. All function switching on Ferrograph equipment is provided on the decks themselves, which makes the task of the constructor considerably simpler than it would be if the switch units were incorporated in the amplifier. At the same time, it renders possible the provision of heavier and hence more reliable switch banks, those on the C88 being very substantial. The terminal strip locations are shown in *Fig.* 3, and the spare positions on the switches may be used for a variety of functions, as dictated by the will of the constructor. Where a letter and a digit appear in a circle, e.g. 3L, OU, this is to be taken that the letter indicates "L" for the left-strip and "U" for the upper strip, the digit referring, of course, to the number opposite the tag. The circuit description of the amplifier proper will be of one channel only, the left one in the diagram, the second channel being a mirror image of the first. The transpositions are obvious.

On replay, the input from the head is taken, through a standard co-ax socket, to T_3, the head-lift transformer, and via J_2 to the grid of voltage amplifier V_5, a low-noise pentode. The output from the anode of this valve is by the way of C_{16}, C_{17}, R_{18}, and J_1 to the top of P_2, the gain control. C_{17} and R_{18} supply a small amount of treble lift, the significance of which will be considered later, and R_{21} and C_8 are an RC bass lift network, providing most of the necessary compensation for the tape losses. Further amplification is by V_4, another low-noise pentode, the output from which is through C_{11} and the tone-control network P_1-P_2-R_{13}-R_{24}-R_{24A}-C_{12}-C_{14}-C_{15}-C_3-C_{13}. When the controls are at their mid positions, there is a boost of approximately 2.5 db at 50 cps. In theory, such a network should be fed from a low impedance source to avoid high frequency losses, but in fact, the difficulty does not occur, capacitor C_{13} compensating up to about 45 kcps. However, it is very easy to reduce the source impedance by the

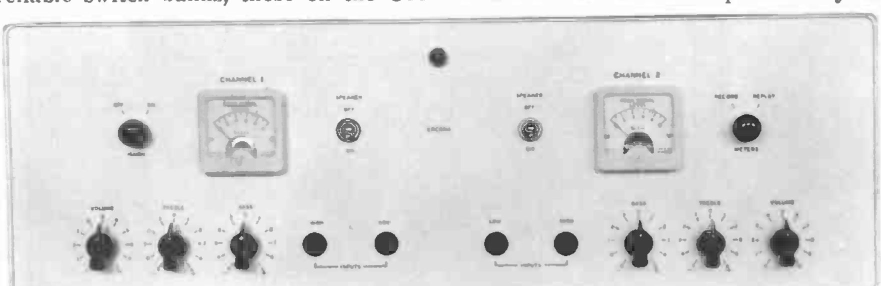


Fig. 1. Front panel arrangement of the completed stereo recording and playback amplifier.

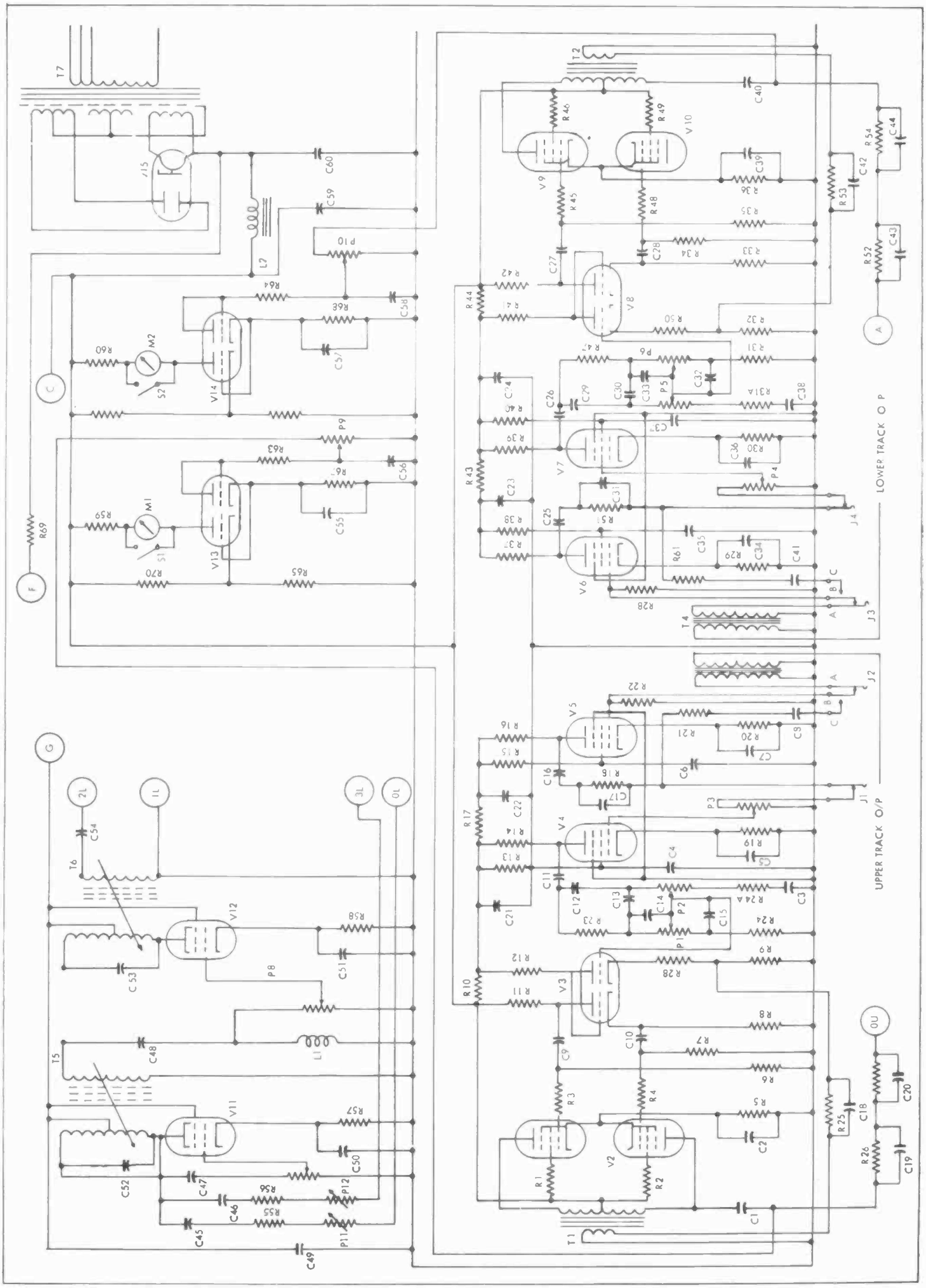


Fig. 2. Over-all schematic of the amplifier described.

simple expedient of connecting a 10-megohm resistor between the grid of V_4 and the junction of C_{11} and C_{12}. A 47,-000-ohm resistor from the grid of V_4 to the arm of P_3 will tend to prevent any interaction with V_5. The maximum bass lifts and cuts are 18 db at 20 cps relative to 800 cps, the treble lift and cut at 20,000 cps being 14 db and 18 db respectively.

V_{3A} is another voltage amplifier, with feedback via potentiometer R_{25}, R_9 in the cathode circuit, phase correction being provided by C_{18}. Actually, C_{18} is more in the nature of an insurance against r.f. when the output tubes are viciously overdriven, it being quite superfluous under normal conditions. Additional feedback is obtained by the omission of a bypass capacitor for R_{28}. It is difficult to apply feedback over the whole of the amplifier because of (a) the provision of the two inputs at different levels and (b) the equalizing and tone-control networks; but the circuits of V_4 and V_5 are so calculated as to introduce negligible distortion in these stages. V_{3A} is d.c.-coupled to V_{3B}, the phase splitter, which operates with equal loads, R_8 and R_{11} in the anode and cathode circuits, thus providing the out-of-phase driving voltages for V_1 and V_2, feeds being via C_9 and C_{10} and the grid stoppers R_3 and R_4. For hair-splitting in addition to phase splitting, R_8 should be about 12 per cent lower in value than R_{11}, but in practice, very little difference in output voltage from the two sides will be observable. V_1 and V_2 are operated in class AB1 with common cathode resistor R_5, bypassed by C_2. Should it be desired to use the output valves in pure class A the anode-to-anode load must be altered to 11,000 ohms, R_5 dropped to 75 ohms, and C_2 omitted, when the valves will become self-balancing under most conditions, owing to feedback in R_5. R_1 and R_2 are screen-grid stoppers, to remove a possible source of unwanted r.f. oscillation on full drive, the stoppers being considerably more effective in this position than in the anode leads. Feedback to ensure valve balance may be attained by the inclusion of an undecoupled resistor of 150 ohms in the common H.T. feed between the junction of R_{10} and R_{11} and R_1 and R_2; but it is, however, unnecessary, unless the emissions of V_1 and V_2 are markedly different, in which case the valves should be changed, anyway.

T_1, the output transformer, must be chosen with care, as it is a very critical component, and only the best will do here. It should not be overlooked that it has to deliver up to 15 watts on continuous sine-wave drive, rising to 25 watts on peaks, and yet not lose its inductance under low-signal conditions; its coupling must be tight, its self-capacitance low, and its resonance points right outside both the audio and low r.f. ranges, this latter because of the inevitable stray bias appearing at the anode of the V_2, when recording: so it will be seen that no second-rate component from the surplus market will be satisfactory.

Power Supply

The power pack is perfectly normal, except for the provision of a 100-µf capacitor for smoothing. This is to prevent interaction between the channels at low frequencies, a point not to be forgotten if the constructor contemplates using existing stocks of different values off the shelf. The reservoir capacitor, too, must be chosen with care, that used in the commercial equipment being capable of handling a ripple current of 600 ma. As the total current drawn by the amplifier on RECORD is approximately 230 ma., it will be seen that the 600 ma. ripple requirement is not excessively high. The formulas for calculating both the impedance of the smoother and the ripple current in the reservoir are given in Appendix 1, as well as an alternative power supply section, to cater to the more impecunious reader.

R_{69} must be explained at this point. On the Ferrograph decks, a quick-release device is fitted in the form of a solenoid, the armature of which normally holds the switches and linkages "in" when operating. Depression of a small button on the deck control panel short-circuits the solenoid coil, so releasing the armature and stopping operations. R_{69} is the limiting resistor for the solenoid current, the minimum requirement of which is 30 ma., the coil resistance being 300 ohms.

On RECORD, movement of the deck control knob to that function automatically disconnects the heads from the input sockets, and joins the B+ lines to the oscillators, of which more anon. It also connects the anodes of the recording output valves to their respective heads, together with the bias inputs. On the amplifier, recording is done, in the case of low-level inputs, via J_2, which is a double circuit jack socket. Insertion of the jack changes over both the ground and live contacts, breaking the first, so disconnecting the bass equalizing chain

PARTS LIST

C_1, C_{40}	0.25 µf, 500 v. paper
C_2, C_5, C_7, C_{33}, C_{36}, C_{39}	25 µf, 25 v. electrolytic
C_3, C_{38}	3200 µµf, mica or ceramic
C_4, C_6, C_9, C_{10}, C_{11}, C_{16}, C_{25}, C_{26}, C_{27}, C_{28}, C_{35}, C_{37}, C_{48}, C_{50}, C_{51}, C_{54}	.05 µf, 500 v. paper
C_8, C_{41}	.012 µf, 500 v. paper
C_{12}, C_{29}	500 µµf, mica or ceramic
C_{13}, C_{30}	30 µµf, mica or ceramic
C_{14}, C_{33}, C_{56}, C_{57}	1000 µµf, mica or ceramic
C_{15}, C_{32}, C_{45}, C_{46}	.01 µf, 500 v. paper
C_{17}, C_{18}, C_{20}, C_{31}, C_{42}, C_{43}	200 µµf, mica or ceramic
C_{19}, C_{44}	1500 µµf, mica or ceramic
C_{21}, C_{22}, C_{23}, C_{24}, C_{34}	16 µf, 350 v. electrolytic
C_{47}	2200 µµf, mica or ceramic
C_{52}, C_{53}	3000 µµf, Silver Mica
C_{59}	100 µf, 450 v. electrolytic
C_{60}	60 µf, 450 v. electrolytic
L_1	2.5 mh.
L_2	10 Hy. 250 ma, 200 ohms
P_1, P_2, P_3, P_4, P_5, P_6	2 megohms, audio taper
P_7, P_8, P_9, P_{10}	50,000 ohms, linear, preset
P_{11}, P_{12}	10,000 ohms, linear, preset
R_1, R_2, R_{46}, R_{49}	47 ohms, ½ watt, 10%
R_3, R_4, R_{44A}, R_{31A}, R_{45}, R_{48}	4700 ohms, ½ watt, 10%
R_5, R_{36}	130 ohms, 4 watts
R_6, R_7, R_{34}, R_{35}	0.47 megohms, ½ watt, 10%
R_8, R_{11}, R_{12}, R_{14}, R_{16}, R_{33}, R_{37}, R_{39}, R_{41}, R_{42}	0.27 megohms, high stability, 5%
R_9, R_{32}	47 ohms, ½ watt, matched to within 5%
R_{10}, R_{17}, R_{26}, R_{27}, R_{43}, R_{44}, R_{53}, R_{54}	47,000 ohms, ½ watt, 10%
R_{13}, R_{15}, R_{38}, R_{40}	1.5 megohms, high stability, 5%
R_{18}, R_{51}, R_{59}, R_{60}, R_{63}, R_{64}	0.1 megohms, ½ watt, 10%
R_{19}, R_{30}, R_{50}	2200 ohms, ½ watt, 10%
R_{20}, R_{29}	2200 ohms, high stability, 5%
R_{21}, R_{55}, R_{56}, R_{61}	15,000 ohms, ½ watt, 10%
R_{22}, R_{28}	1.0 megohm, ½ watt, 10%
R_{23}, R_{47}	0.22 megohms, ½ watt, 10%
R_{24}, R_{31}	22,000 ohms, ½ watt, 10%
R_{25}, R_{52}	1000 ohms, high stability, 5%
R_{57}, R_{58}	470 ohms, 1 watt, 10%
R_{62}, R_{70}	0.33 megohms, ½ watt, 10%
R_{65}, R_{66}	10,000 ohms, ½ watt, 10%
R_{67}, R_{68}	10.0 megohms, ½ watt, 10%
R_{69}	10,000 ohms, 15 watts, wirewound
T_1, T_2	push-pull output transformer, 10,000 p-to-p/15.
T_3, T_4	Wright & Weaire type 969
T_5, T_6	Wright & Weaire type 579
T_7	Power transformer. Primary as required; secondaries: 300-0-300 v. at 250 ma; 5 v. at 3 amps; 6.3 v. at 8 amps, CT.
V_1, V_2, V_9, V_{10}	EL84
V_3, V_8	ECC83 (12AX7)
V_4, V_5, V_6, V_7	EF86 (Z-729)
V_{11}, V_{12}	6V6
V_{13}, V_{14}	ECC35
V_{15}	GZ34

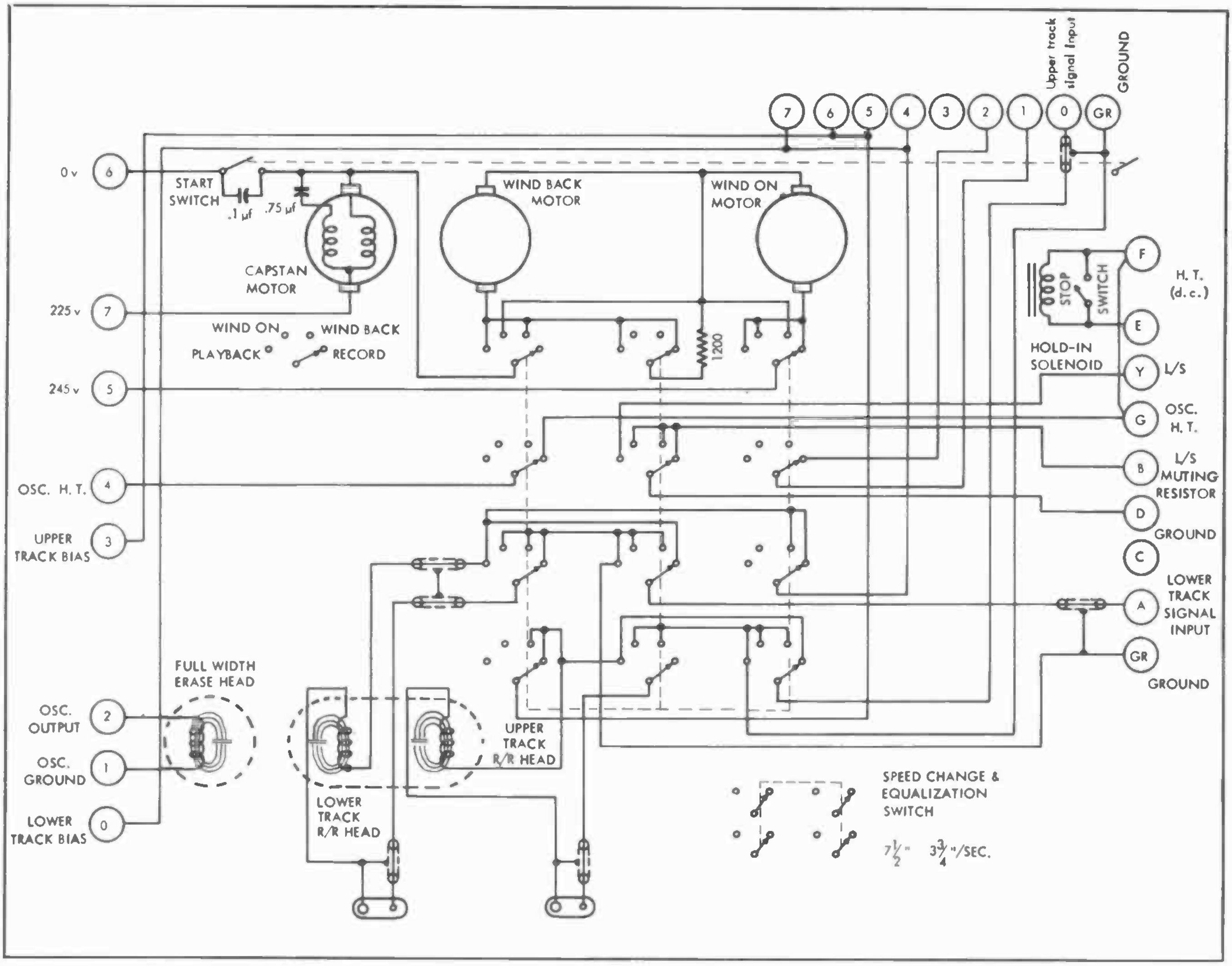


Fig. 3. Semi-pictorial diagram of the underside of a Ferrograph tape deck showing the locations and designations of the terminal or tag strips.

R_2 and C_9, and transferring the grid input of V_5 from the secondary of T_3 to the tip of the jack. It will be noticed that the small treble lift capacitor, C_{17}, remains in circuit, when by rights it should be in use only on replay; but it was found to be of assistance when recording from certain sources deficient in top, so the original provision for disconnection has been discarded. Its effect may be countered quite easily by use of the treble tone control. High-level inputs, such as those available from tuners and crystal pickups, are fed into J_2, which is an ordinary single-circuit socket. When this is in use, the whole of V_5 and its associated circuit is completely isolated from the rest of the amplifier, so avoiding the possibilities of noise from this stage breaking through. The tone-controls are effective on RECORD as well as on REPLAY, and the value of this feature, unconventional though it may be, has been demonstrated again and again, the author's experience being that, once an operator has made use of this facility, he will not willingly revert to the standard arrangement of no control on RECORD. The ability to suit the recording to both the acoustic surroundings and the material being transcribed, enables satisfactory tapes to be produced under conditions which would preclude the use of an amplifier with less flexible characteristics. The more conventional user has only to leave the controls on the "zero" positions to satisfy his fastidiousness.

Feed to the head is from V_2 through C_1 and R_{26} and R_{27} to present constant current conditions. A capacitor across the feed resistor as a treble equalizer is quite conventional English practice, but the division of both capacitor and resistor into two is rather unusual. It has been dictated by the necessity of ensuring corrections suitable for all tape speeds, without adding more complication than is essential. Its effectiveness is not to be doubted. At 3¾ i.p.s., C_{19} gives the required lift, C_{20} hardly having any effect at all, while at 7½ and 15 i.p.s., the combined effects of C_{19} and C_{20} together with the head losses at each speed permit a response up to the theoretical maximum. In accordance with accepted standards as dictated by the physics of magnetic recording, nearly all the treble equalization is on RECORD and most of the bass correction on REPLAY: the characteristics of the tone controls give the recommended NARTB bass boost on RECORD, while C_{17} does the same for treble on REPLAY.

Modulation control is by M_1 and its associated circuitry, where, if at all possible, the meter specified should be used, as its ballistics are ideal. The arrangement is conventional for a sustained-peak-reading voltmeter, the delay on peaks being determined by the time constant of C_{55} and R_{67}. The values chosen appear to satisfy most conditions, but there is no reason why the constructor should not make alterations to suit himself. R_{61} and R_{65} bias the meter down to its zero position, and may be replaced by a potentiometer of 500K ohms, while P_9 is for setting the overload point on the scale. Directions for doing this will be given later. The meters are in circuit on both RECORD and REPLAY, and in the latter position are used only to ensure balance between the two channels. Switches S_1 and S_2 short-circuit them when this operation is completed.

Bias Supply

The bias section comprises V_{11} and V_{12}, V_{12} being a slave oscillator controlled by V_{11}. A two-valve oscillator is the simplest way of providing the r.f. requirements, as the demands of the Ferrograph "C" decks in this direction are quite heavy; but other arrangements are quite feasible and two alternative circuits are shown in Appendix 1.

Recording bias to the heads is from the anode of V_{11} via C_{45}, R_{55}, P_{11}, etc., the rheostats being an essential part of the circuit, as each individual head has a bias requirement peculiar to itself. The values will be found on a label under the fly-wheel housing under the deck. Erase voltage is supplied by the separate oscillator V_{12}, and as it is not possible to ensure absolute matching of frequency between the two oscillators, it is controlled by a grid drive from V_{11}, via the secondary of T_5 and P_8, bias loading being provided by the 2.5 mh coil L_1. The oscillators and power pack are built on a chassis separate from the main amplifier.

This completes the description of the FS103, the construction of which should provide a few week-ends of amusement for the competent amateur. It is, in essence, a resonably simple piece of apparatus to make, needing patience, a certain amount of skill, and a fairly well-equipped workshop; but a hint or two as to assembly and what may be expected from the completed amplifier may not be out of place.

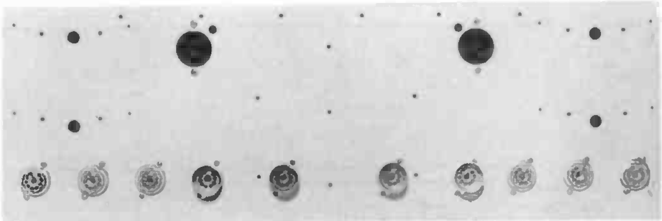


Fig. 5 Top view of the chassis with tube sockets mounted.

Construction

As seen in the parts list, certain resistors are 5 per cent high-stability units. In the commercial equipment, all these, with the exception of R_9 and R_{25}, are 1 per cent, but this is perhaps painting the lily. C_1 must, repeat must, be of very high insulation, as any leakage here will result in noisy recording; and R_{26}, R_{27}, C_{19}, and C_{20} should be chosen to within 5 per cent. C_{49} is to prevent a too rapid decay of oscillation when the RECORD switches are broken, and if switch clicks are objectionable, a 100-ohm resistor may be inserted in series with the B+ line. L_1 may sometimes be replaced by a 1000-ohm resistor. P_3, in view of the high gain—85 db or so[1]—must be absolutely above suspicion, and the author's unvarying choice is either the Morganite type "A" pot, or the Clarostat type "H," both of which are outstanding in the matter of silence. The group board in *Fig.* 4 was made up with Morganite type "S" resistors, and their neat appearance will be noted. They have excellent characteristics, particularly in their long term resistance to change, an important matter in matched amplifiers. *Figures* 5, 6, and 7 show the top and bottom views of the chassis in various stages of construction.

There must be one ground point, and one point only, for the whole amplifier; and this point is where the co-ax inlets from the heads are located. The simplest method is to solder a bus-bar consisting of a piece of #16 s.w.g. wire along the tube sockets, taking all ground returns to it. The sections are screened from each other by a partition that divides the underneath of the chassis completely, while screens isolate each input side—that is T_3, V_5, C_{16}, R_{18}, C_{17}, R_{15}, R_{16}, C_6, R_{20}, R_{21}, C_7, C_8, R_2, and J_2 and the equivalents of Channel 2 from their respective amplifiers. The two co-ax shells are joined by a short length of #16 s.w.g. wire, so making them one from the ground point of view.

Substitutes for the values in the amplifying chains should not be used, as the basic amplifier was actually designed around those specified; and this injunction applies particularly to V_4 V_5 V_6 V_7, the Mullard low-noise pentode type EF86, for which the author has found no really adequate alternative. The oscillators are located on the power pack, which is a separate unit, and no special precautions need be taken here, except to see that the coils are under the chassis, to prevent undue radiation.

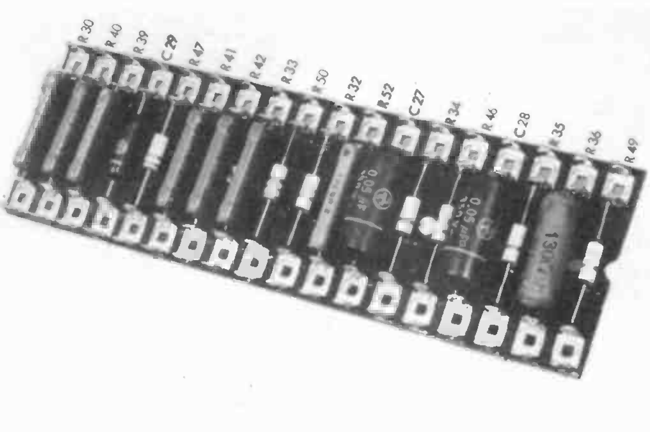
[1] From the grid of V_4 to output.

Performance

It is difficult to give a figure for permissible residual hum and noise, as it depends on what the individual defines as "permissible"; but some idea of the possibilities will be suggested by the fact that, on the commercial amplifier, given reasonably smooth mains, with the grid of V_4 short-circuited and with the ear held close to the speaker, it is literally impossible to detect a trace of hum even with the bass control at full boost; while with the heads connected and P_3 at full gain, the noise level is still much below the tape differential. At half gain, which is generally the maximum on REPLAY with a properly recorded tape, the background is nearly at vanishing point. There is no doubt that this desirable state of affairs is due in large part to the excellence of the EF86 as a low-noise amplifier.

The setting-up procedure is not difficult, neither need the test gear be particularly involved, at least for the amateur. An audio oscillator capable of a range of 50 cps to 50 kcps, a VTVM, and an

Fig. 4. Arrangement of components on terminal board which makes for simple and direct wiring.



oscilloscope are the essentials. After making the usual tests and adjustments on the amplifiers in detail, the speakers can be phased by feeding a 100 cps signal into both channels simultaneously, and changing round the output leads to one of the speakers to the position that makes most noise: but the signal must be kept to a reasonable level, as the ripping of speaker cones off the spiders is not unknown. Next, the grids of V_6 and V_7 are short-circuited, the bass controls tuned to maximum and the volume controls to full gain, with the treble controls at about 12 o'clock. The interaction between the channels should be at least 100 db down, and if it is very much

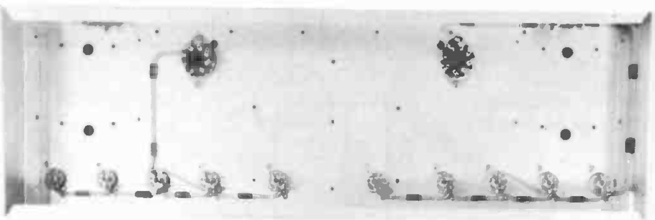


Fig. 6 Under side view of chassis with filament wiring in place.

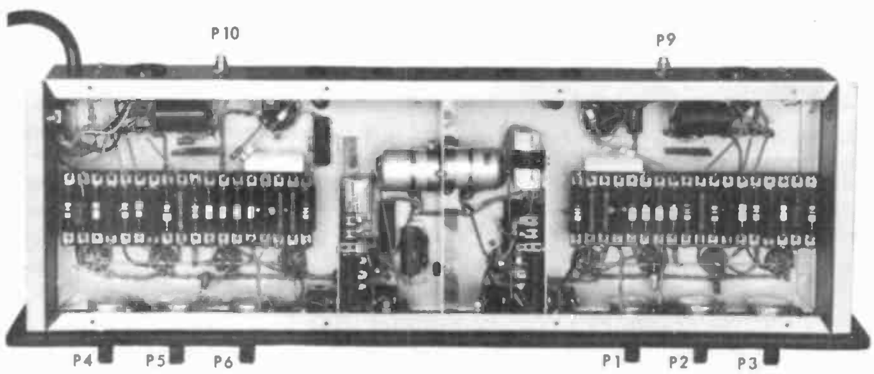


Fig. 7. Bottom view of completed amplifier chassis.

different, the cause should be sought and cured before proceeding further. A possible source of trouble is a high power-factor or low capacitance C_{59}. If the first, a paper capacitor of 1 or 2 µf will sometimes overcome the trouble, while the cure for the second is obvious.

The connections to the deck may now be wired, and the hold-in solenoid tested, after the following alterations to the under-deck connections have been made. The link between *F* and *G* is removed, *C* on the right tag-strip is joined to 4 on the left tag-strip, 5 and 7 on this strip are joined, and the motor mains connected to 6 and 7. If all is in order here, a known good full-width tape should be played, using each channel separately by manipulation of the volume controls. If the results are satisfactory, the meters may be balanced. A 1000 cycle signal is injected into each channel in turn, with the tone controls all at 12 o'clock and P_9 and P_{10} adjusted so that, with 40 volts across the recording networks, the meters stand at the 7½ mark, which represents peak signal level. Note that this is *not* a reasonable sine-wave recording signal, but the maximum permissible instantaneous peak. Amplifier balance is checked by feeding signals at various frequencies into each channel in turn, and noting the relationships between the positions of the respective controls, for equal indications on the meters. The differences, if any, should be small, and large discrepancies tracked and cured.

The deck should now be switched to RECORD, and the oscillators checked for performance. With the oscilloscope connected between the top of P_7 and ground, the slider of this control is advanced to the maximum consistent with good wave-form, and T_5 is tuned, by means of its adjustable core, to 50 kcps. The classical means of calibration is to feed a signal of known frequency direct to the X plates, while the output from the oscillator is taken to the Y plates, the timebase meanwhile being rendered inoperative, and observing the resultant ellipse or Lissajous figure; but with the simpler oscilloscopes, it may prove difficult to attain sufficient stability, and it is far easier to use the oscilloscope in the normal way, filling the screen with, say, four waves from the known source, then disconnecting this and substituting the output from the top of P_7, adjusting T_5 until the same configuration appears. It takes about a minute to do. P_{11} and P_{12} are then set to provide the correct biases to the heads, after which, further adjustment of P_7 may be needed. The oscilloscope input lead is transferred to C_{54}, the slider of P_8 advanced about half-way, and the core of T_6 adjusted until V_{12} locks in. The slider of P_8 is now set as far as it will go without distorting the waveform, and a quick check made at the various positions already covered, as some slight further readjustment may be called for. This completes the preliminary setting up.

The chassis may be of brass, steel or aluminum, depending on the pocket and/or the metal-working skill of the constructor. The one shown in *Figs.* 5 and 6 is of 20-gauge steel, and measures 21 × 10 × 2 in. It is fitted with a bottom cover, thus making a completely enclosed box. Octal sockets are used for the deck connections, and screening of the recording feed wires is unnecessary. Replay leads must be of good quality nonmicrophonic coaxial, and it is suggested that those supplied with the deck be replaced, as they are a little on the short side for custom installation. The ground connection from the deck chassis should be entirely separate from the head cable returns, and is to be taken to some point on the amplifier chassis remote from the co-ax inputs.

(Part II of this article begins on following page)

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Concluding the description of a specific amplifier designed for a Ferrograph Tape Deck, but adaptable to accommodate any other type of stereo deck with heads of similar impedances and drive requirements.

In Two Parts – Part II

THE FIRST INSTALLMENT of this article described the amplifier without showing the derivations of some of the statements made. Here in the Appendix the author indicates the direction to take in case further delving into performance and operation is indicated or desired, suggests suitable loudspeakers for use with the equipment, and offers some helpful hints about operation.

APPENDIX 1

(1) Although the FS103 amplifier gives professional results, there is no reason why the experienced amateur should not do a little experimenting. After all, what is politely known as development work is really nothing more than the application of brute-force-and-ignorance methods to designs that look well on paper and satisfy the most esoteric manipulations of the slide-rule, but sound horrible when built, or just won't work at all.

One of the more interesting fields for experiment is in the matter of equalization, where many methods are in use, the applications of some being rewarding from the points of view of both interest and results. The twin-T feedback network is one of these, and the basic circuit is given in *Fig.* 8. The whole of the tone control network R_{23}, R_{24}, R_{24A}, P_1, P_2, C_{12}, C_{13}, C_{14}, C_{18}, and C_3 is omitted, and in its place, on RECORD, a feedback network is applied between anode and grid of V_4.

The formula for "resonance," when the impedance of the network is at its maximum, is

$$f = \frac{159 \times 10^6}{R \times C}$$

where R is in thousands of ohms and C is in thousandths of microfarads (picafarads) and the amount of feedback may be varied by tapping off the anode load R_{14}. With $R = 220$K and $C = 68$ pf (.068 μf), the lift at around 10,000 cps is about 18 db: but in the author's opinion, it is too peaked, and more satisfactory aural results may be achieved with a bridged-T network. The reactance of CA gives the small bass boost, with RA responsible for the levelling-off.

Bass boost on replay is obtained by the substitution of a series feedback network consisting of 680K and 180 pf between anode and grid of V_4. However, the lift of about 25 db at 50 cps compared to 2,500 cps is perhaps too much for American replay standards, and 1.8 meg. will bring this down to approximately 18 db.

(2) The calculation of the coupling between the two channels, as represented by the impedance of the smoothing capacitor, is given by the formula

$$ZC = \frac{10^6}{2\pi \times f \times C(\mu f)}$$

In the FS103, the smoothing capacitor = 100 μf. Common impedance =

$$\frac{10^6}{6.28 \times 50 \times 100} \text{ at 50 cps} = 32 \text{ ohms approximately.}$$

Ripple current is approximately 1.4 times the load current. On RECORD, current = 230 ma; ripple current = 230 × 1.4 ma = 322 ma, which figure must be borne in mind when choosing the reservoir capacitor.

An alternative power circuit, which avoids the difficulties associated with high ripple currents, as well as being cheaper and lighter than that of the FS103 is given in *Fig.* 9. The capacitors should have a working voltage of 450 although 350 wv is permissible.

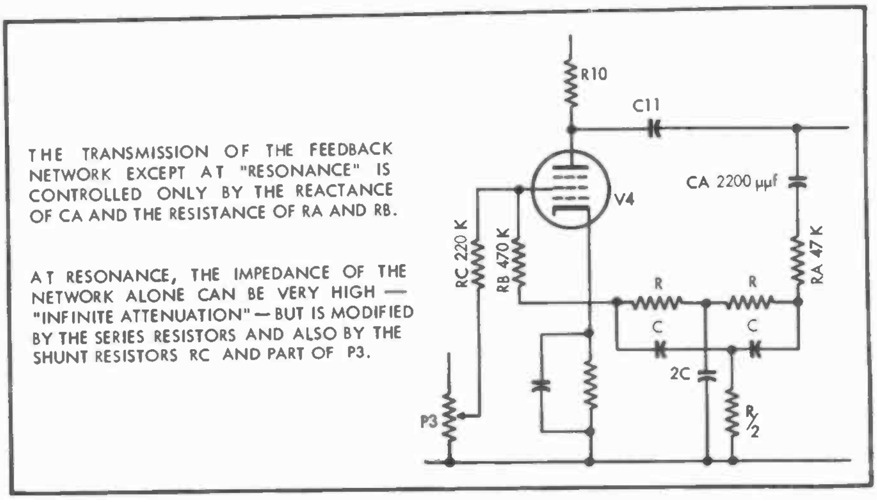


Fig. 8. The transmission of the feedback network except at "resonance" is controlled only by the reactance of CA and the resistance of RA and RB. At resonance, the impedance of the network alone can be very high—"infinite attenuation"—but is modified by the series resistors and also by the shunt resistors RC and part of P_3.

(3) Two out of the many possible oscillator circuits will be found in *Fig.* 10. In the oscillator of (A), V_{11} is omitted altogether, and V_{11} is a Mullard EL34. P_7 is returned to ground through the Varite thermistor type V1011, adjustments being made as before. The EL34 is a power valve capable of a really remarkable r.f. output, and the thermistor stabilizes the drive to the grid, chiefly in the direction of bypassing it when the current increases beyond a predetermined level. In (B) of *Fig.* 10, V_{12} is again dispensed with, and a Mullard ECL82 is substituted for V_{11}. This is a combined triode-output pentode, the master oscillator being the triode section. Control is by grid-leak bias, and the circuit is largely self-regulating. As the amplitude of the oscillations increases, the grid capacitor charges and raises the negative bias, until a state of balance is reached in which the oscillations are the maximum

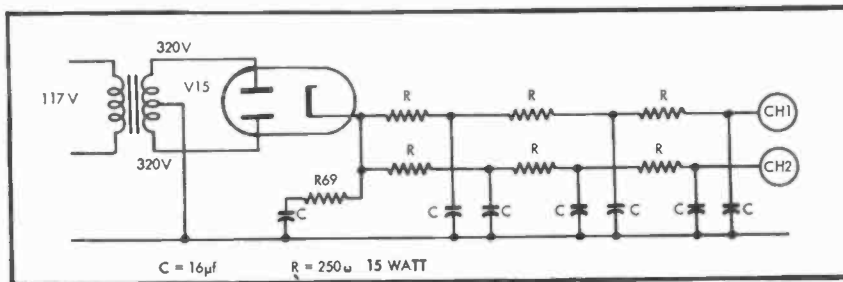


Fig. 9. Schematic of simple power-supply circuit which has a low ripple-current content.

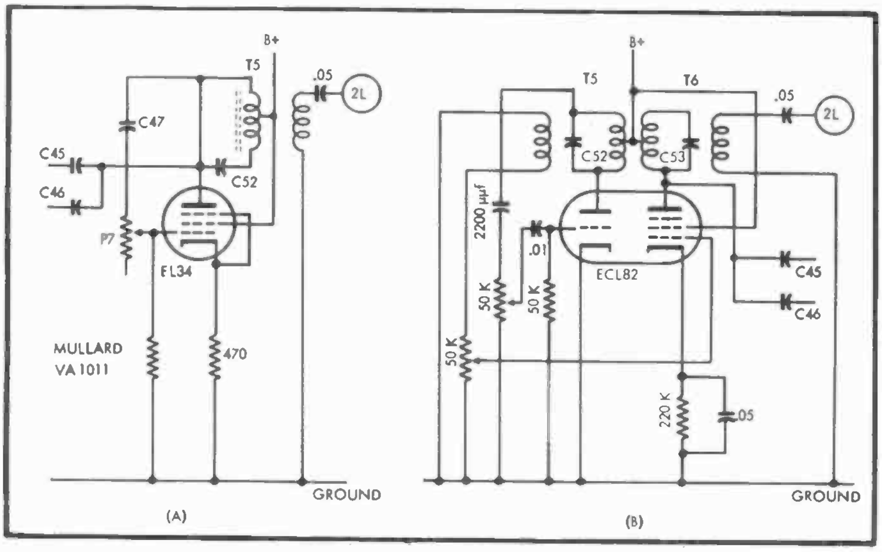


Fig. 10. Two possible circuits suitable for the bias/erase oscillator.

possible, taking into consideration the setting of P_7. The pentode section of the ECL82 is arranged as the slave oscillator, but with both bias and erase taken from it, leaving the master oscillator free from external influences.

(4) Some constructors may consider fitting bias traps in the head feed circuits, to keep r.f. off the output plates. It seems a rather unnecessary refinement, as bias and signal do go together, but two circuits for the purpose are given in *Fig.* 11.

APPENDIX *2*.

The suggested choice for loudspeakers for use with the amplifier is the Goodmans Axiom 22 or Axiom 150 Mk. 2. There are, no doubt, equally good speakers on the market, but the author has yet to hear them. Their response is wide enough to dispense with crossover systems and tweeters—which can introduce serious problems in phase shift—and it is characterized by quite silky smoothness. These speakers have only one fault—if the amplifier is not of the best, they proclaim it to the world unhesitatingly and unequivocally. A resonant enclosure of the dimensions shown in *Fig.* 12 gives good results, the separation and definition being excellent. Note that, when making power measurements, a resistor as load will not give a picture of the true output. The amplifiers are designed expressly to work into a loudspeaker load, and the dummy should consist of a

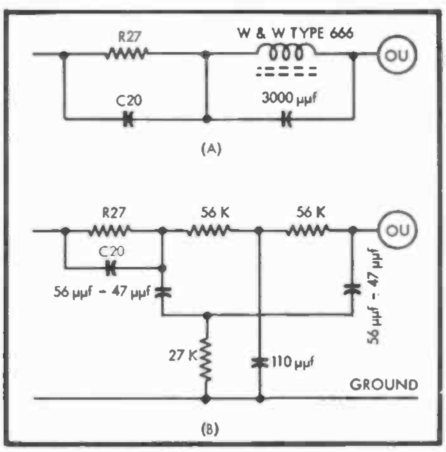


Fig. 11. Two types of bias-trap circuits which may be employed if considered desirable, although they are not absolutely necessary.

reactance of 15 ohms total impedance at 400 cps. An inductor of 3½ mh in series with 10 ohms is about right.

APPENDIX *3*

On the operation of stereosonic reproducers.

An operator, using this type of equipment for the first time, will almost certainly try to achieve perfect balance between channels. Indeed, he is exhorted to do so, more than one writer on the subject stating it is mandatory that the gain and tone controls be ganged for the very purpose. This, in common with many other pontifical pronouncements by the engineering and hi-fi fraternity, is nonsense. To forestall righteous anger and condemnation, the author proposes to make a slight digression.

As was suggested earlier in this article, engineers are, on occasion, apt to make definitive statements about subjective matters, without always considering all the available evidence. If this be not so, how can one account for the changing fashions in the Hi-Fi world? Each new circuit is equated with the "real thing," and each subsequent one is so much better than the last; but it is also the "real thing," a sort of ultra-real realness. At one time, 10 watts was ample for the average living-room; now, according to one concatenate authority admittedly not overmuch given to understatement, 100 watts is the figure. And, as mentioned before, we aren't really honest about it. We use co-ordinate geometry as proof of our statements, and raise Fourier analysis to the dignity of a gospel; but a Fourier series merely happens to be a convenient tool in the manipulation of partial differentials, while, for statements about problems in which subjective perception is an important factor, tensors appear to be the appropriate discipline. Whichever way the matter is viewed, the figures are merely a manipulative convenience, and not statements of fact.

Now, the author is a very ordinary engineer, busily engaged in scratching a modest living in a competitive business; but he is, also, a professional musician of vast, literally vast experience. This is not to say that he is anything but a mediocrity, even in that profession, but his first public appearance was at the age of 7, and he is not going to say how long ago that was: (off the record, he would be a grandfather now if his children weren't so lazy!) And on the strength of long acquaintance with hi-fi in the raw, his advice to the amateur using stereo for the first time is to give up listening with the slide-rule but use, instead, certain rather old-fashioned instruments, a couple of which can be found in most well-appointed homes. They are known as ears, and their discrimination is remarkable—in fact, they are the standard by which all the other instruments are, or should be, judged. If stereo sounds better with one channel slightly louder than the other, play it so. If the performer seems to be in the room, with treble up on track 1 and bass up on track 2, that's where the controls should be. If it sounds right, it *is* right, and don't let any long-haired back-room boys—including the author—tell you it's not. Your ears aren't perfectly matched, neither are the two halves of your room, nor your tastes with the next man's, and all the controls are for use, not ornament.

In conclusion, acknowledgments are due to Charles H. Frank Jr. of the Ercona Corporation, without whose encouragement—not to say vigorous prodding—the original FS103 would probably never been built.

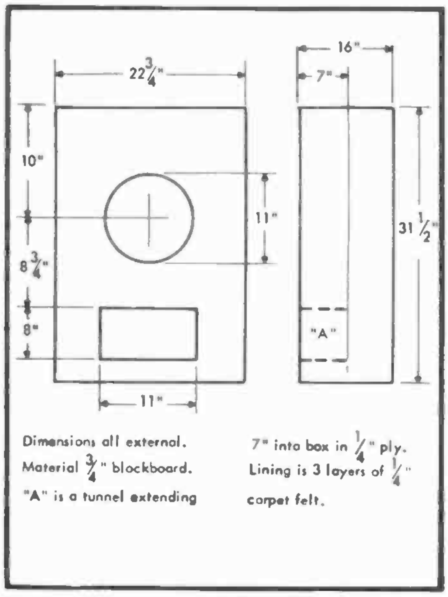
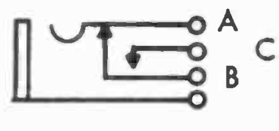


Fig. 12. Dimensions of a "resonant type" enclosure suitable for use with Goodmans Axiom 22 loudspeaker unit.

Errata to Part I

A few minor (?) errors crept into the drawing for *Fig.* 2 in Part I of this article, and at the end of Part II seems the most ideal place to bring them to the attention of readers who may have been particularly interested in this unit.

The jacks J_2 and J_3 were incorrectly drawn, and should have been shown as indicated here. The correct jack is typified by



Switchcraft MT-332C, although Mallory 4A, 704A, 5, and 705 may be wired to produce the same results. The lettering refers to the original diagram.

The resistor in parallel with C_{10} in the lower left corner of the drawing is R_{57}; the voltage divider for the cathode of V_{11} consists of R_{62} at the top and R_{66} at the bottom; and the plate of V_{10} should be connected to the line leading from the primary of T_4 to capacitor C_{10}.

It is suggested that you make these corrections on the original drawing. Æ