Build this 50 + 50W Mosfet Stereo Amplifier

Here are the full circuit details on the

Playmaster Mosfet Stereo Amplifier

In this article on the new Playmaster Mosfet Stereo Amplifier we continue the circuit description, give details of the performance and begin description of the assembly procedures.

by LEO SIMPSON

Having detailed the features of the new amplifier last month together with a broad description of the Mosfet power amplifier circuit, we now move to the input stages and describe the features in this section of the amplifier. Refer to the complete circuit diagram.

The phono preamplifier is similar to that featured in the previous Twin Twenty Five and Forty Forty stereo amplifiers with the addition of a few worthwhile refinements. Q1 and Q2 form a differential amplifier with balanced output to drive a TL071 Fet-input operational amplifier. The TL071 is pin-for-pin compatible with the 741 op amp but has the advantage of higher slew rate capability which can result in lower distortion under high input signal conditions. The purpose of using transistors to drive the op amp is to improve the resultant signal-to-noise ratio of the circuit, as well as increasing the loop again. The latter feature allows more negative feedback to be applied which also reduces distortion.

Collector current of the two input transistors is set at about 87μA by the common 82kΩ emitter load resistor. This value of current is not as low as used in some preamplifier designs but is about optimum for best noise performance with the complex source impedance presented by a typical magnetic cartridge. As another measure to minimise input noise, the collectors of Q1 and Q2 operate at low voltage.

As an option, we have specified an alternative to the two BC549 low-noise transistors in the form of the LM394 supermatch pair. This six-lead device contains two junction isolated ultra-well-matched transistors. The major advantage of this device is very low offset voltage and very low drift. However, we are using it for its low noise and high gain.

A 56kΩ resistor sets the input resistance for the preamplifier at close to 50kΩ while the series 1kΩ input resistor and 47pF shunt capacitor act as an RF suppression network. This helps prevent RF breakthrough from CB radios and mains-radiated interference.

No input capacitor is provided for the preamplifier. We reasoned that since the input bias current to Q1 is typically less than 500 nanoamps, far less than normal signal currents, the capacitor could be dispensed with.

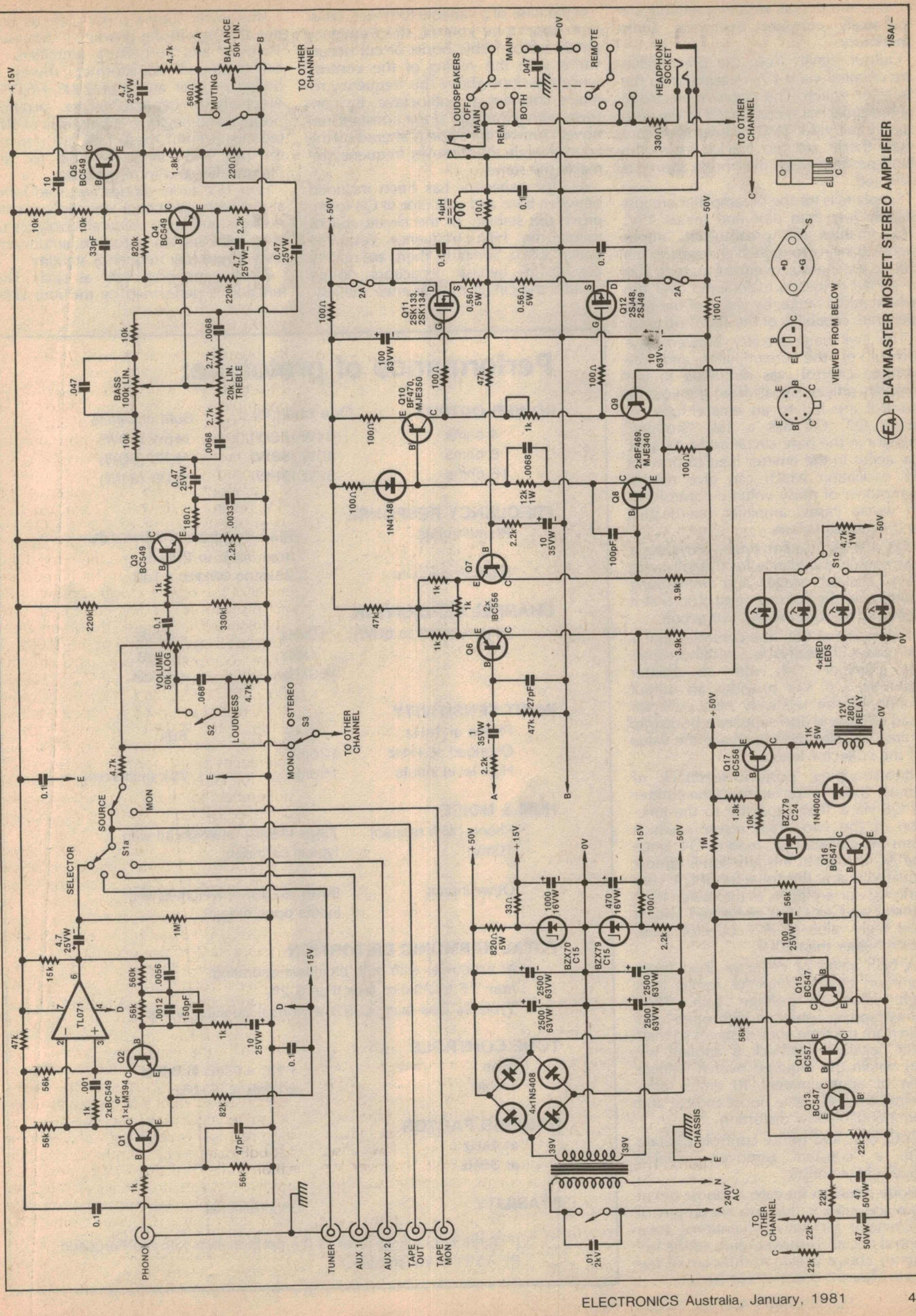
The series network consisting of the 1kΩ resistor and .001μF capacitor between the collectors of Q1 and Q2 ensures stability of the preamplifier at high frequencies. At the same time, the 15kΩ resistor connected from the output terminal of the op amp to the positive 15V rail provides a standing current of 1mA to minimise cross-over distortion from the class-B output stage of the TL071.

Five components are used in the equalisation network (56kΩ, 560kΩ, .0056μF, .0012μF and 150pF) to give an RIAA response which is typically within ±1dB of the RIAA curve from 30Hz to 20kHz, with normal component tolerances of 10% for the capacitors and 5% for the resistors. Much closer adherence to the RIAA curve can be achieved by using the same component values but with tolerances of 1 or 2%.

In addition, we have provided for bass rolloff below 30Hz, as determined by the ratio of the reactance of the 10μF capacitor to the 1kΩ resistor terminating the feedback network at the base of Q2. While this does not provide the 7950μs time-constant recommended by the IEC (and yet to be adopted by the RIAA), the additional rolloffs in later stages of the amplifier combine to give a bass rolloff which is very close to the IEC recommendation.

As such, the Playmaster amplifier has more than adequate rumble filtering without the need for special filter stages.

It may be thought that the combination of exceedingly high open-loop gain in the preamplifier together with the internal 6dB/octave high frequency compensation (rolloff) of the TL071 operational amplifier makes the circuit a "sitter" for the occurence of transient intermodulation distortion. However, the RIAA equalisation means that the negative feedback around the circuit also decreases at the rate of 6dB/octave (albeit with an inflection at about 1kHz),


PLAYMASTER MOSFET STEREO AMPLIFIER
VIEWED FROM BELOW
PHONO
TUNER
AUX 1
AUX 2
TAPE OUT
TAPE MON
SELECTOR
SOURCE
MON
S1a
VOLUME 50k LOG
LOUDNESS
S2
MONO
STEREO
S3
TO OTHER CHANNEL
BASS 100k LIN.
20k LIN. TREBLE
BALANCE 50k LIN.
MUTING
LOUDSPEAKERS
OFF
MAIN
REM
BOTH
REMOTE
HEADPHONE SOCKET
TL071
Q1
Q2
2xBC549 or 1xLM394
Q3 BC549
Q4 BC549
Q5 BC549
Q6
Q7
2x BC556
Q8
Q9
2xBF469, MJE340
Q10 BF470, MJE350
Q11 2SK133, 2SK134
Q12 2SJ48, 2SJ49
Q13 BC547
Q14 BC557
Q15 BC547
Q16 BC547
Q17 BC556
1N4148
1N4002
BZX79 C24
BZX70 C15
BZX79 C15
4x1N5408
4xRED LEDS
S1c
12V 280Ω RELAY
240V AC
CHASSIS
+15V
-15V
+50V
-50V
0V

so that the overall negative feedback is essentially constant over the audio spectrum.

Output signals from the preamplifier are coupled via a 4.7μF capacitor to the Selector switch. The negative electrode of the capacitor is connected to the zero supply rail via a 1MΩ resistor to ensure that there are no clicks from the loudspeakers when the phono source is selected.

Supply rails for the preamplifier are just slightly less than plus and minus 15V. This enables the preamplifier output signal to swing to quite high levels which allows a generous overload margin. This overload margin is maintained over the whole audio range, by virtue of the high slew rate capability of the TL071 op amp.

The switching circuitry between the output of the preamplifier and the volume control was discussed in last month's article. Signals from the volume control are fed to an emitter-follower stage Q3. Q3 has a 1kΩ "stopper" resistor in the base circuit and a .0033μF capacitor in the emitter load to prevent RF oscillation which can give rise to symptoms of noisy volume controls or, in worse cases, amplifier overheating and eventual failure.

Q3 acts as a buffer stage, providing a low source impedance for the following tone control stage and minimising loading on the volume control so that it provides smooth progressive action.

Operation of the tone control circuit is as follows. Basically it is a common emitter amplifier, Q4, with an emitter follower, Q5. Q5 provides an output buffer for the relatively high collector load of Q4 and also supplies a bootstrap voltage to effectively increase the value of the collector load.

Bootstrapping, positive feedback of almost 100%, is applied from the emitter of Q5 via a 10μF capacitor to the junction of the two 10kΩ resistors which form the collector DC load of Q4. Since the AC voltage at this junction is almost equal to that at the collector of Q4, very little AC current flows in the lower 10kΩ resistor and so Q4 is presented with a very high value of AC collector load, much higher than 20kΩ.

A high value of collector load for a common emitter amplifier results in a high value of voltage gain. Thus bootstrapping results in high open-loop gain from the tone control stages so that, after negative feedback is applied we can obtain the required overall voltage gain of approximately 10 times, adequate bass and treble boost and cut and commendably low distortion.

Both bass and treble controls operate with a "constant turnover, variable slope" characteristic.

Slope refers to the rate of boost or cut from the circuit; this is a maximum of 6dB/octave for any conventional tone control circuit. Turnover refers to the frequency above which, in the case of the treble control, boost or cut occurs.

In the case of a variable turnover, constant slope tone control, the frequency above which treble boost or cut occurs varies with the setting of the control, while the slope above this frequency remains constant at 6dB/octave. By contrast, with a variable slope constant turnover control, the slope is altered by the control while the turnover frequency remains the same.

A 33pF capacitor has been included between base and collector of Q4 to improve the stability of the circuit and to rolloff the high frequency response above 30kHz. Similarly, there are quite a few 0.1μF bypass capacitors dotted around the circuit to guarantee stability.

The power supply is not quite as simple as it was in the previous Playmaster Twin 25 and Forty-Forty amplifiers. A centre-tapped transformer drives a bridge rectifier and four 2500μF/63VW electrolytic capacitors to provide positive and negative supply rails of 50V (nominal). From these rails are derived the plus and minus 15V rails for the preamplifier and tone controls.

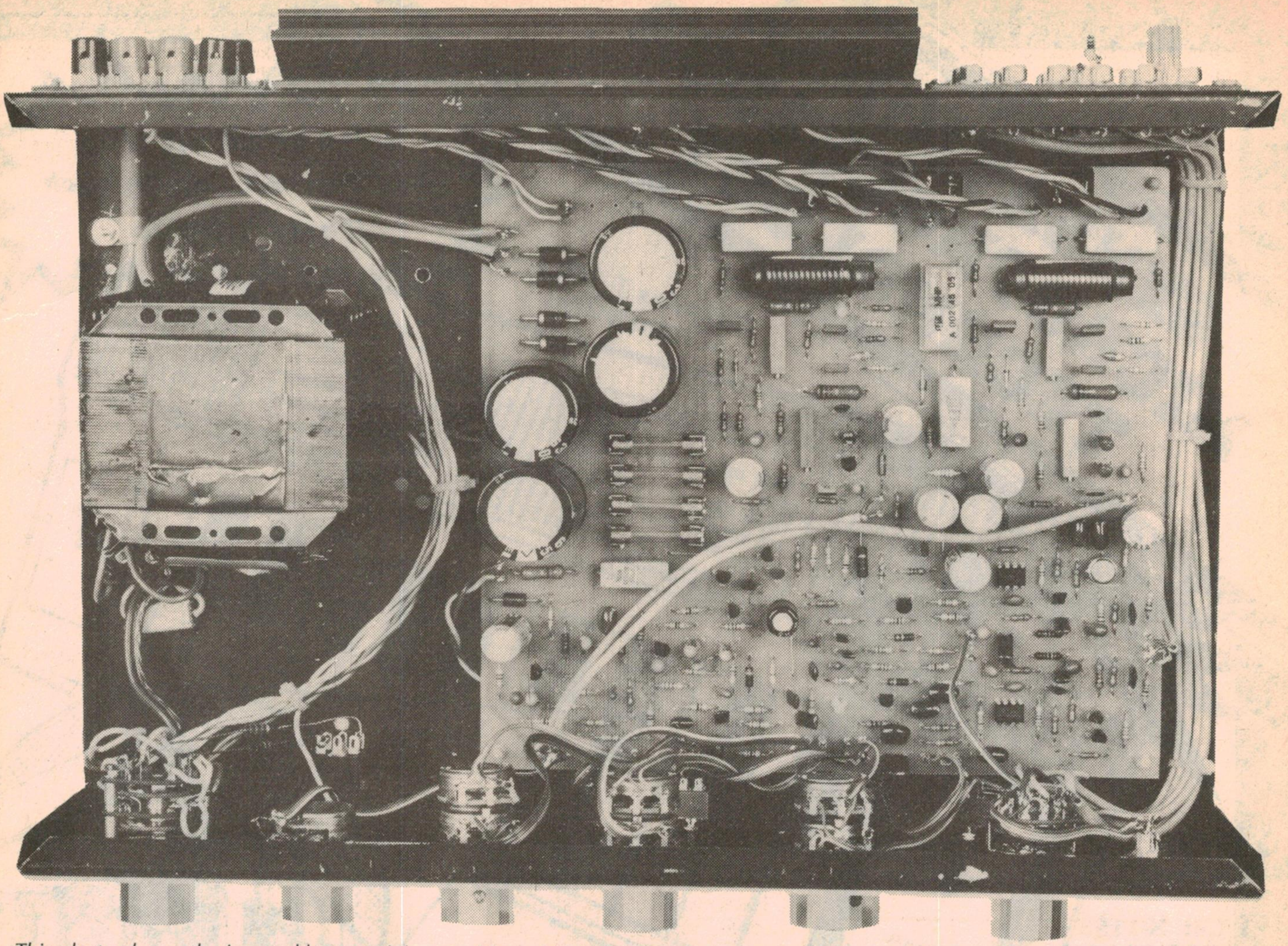
Two 15V zener diodes are used here, along with additional decoupling with resistors and large value electrolytics to keep hum and noise to a minimum and also ensure low frequency stability.

There is no pilot light as such. This function is performed by the four LEDs

Performance of prototype:

POWER OUTPUT	One channel	Both channels
4 ohms	64W (72W)	45W (60W)
8 ohms	50W (56W)	42W (50W)
16 ohms	37W (38W)	31W (31W)
FREQUENCY RESPONSE		
Phono inputs	RIAA equalisation within 1dB from 30Hz to 20kHz	
High level inputs	25Hz to 20kHz ±1dB	
CHANNEL SEPARATION		
(with respect to 50W)	10kHz	−40dB
	1kHz	−47dB
	100kHz	—50dB
INPUT SENSITIVITY		
Phono at 1kHz	2mV	56k
Overload at 1kHz	120mV	
High level inputs	190mV	36k (minimum)
HUM & NOISE		
Phono (with respect 10mV)	73dB (75dB) unweighted with typical cartridge	
Other inputs	80dB (82dB) unweighted with inputs open circuit	
TOTAL HARMONIC DISTORTION		
At full power with both channels operating from 25 to 20kHz: less than 0.2%		
Typically less than 0.05% at normal listening levels		
TONE CONTROLS		
Bass	+12, −13dB at 50Hz	
Treble	±10dB at 10kHz	
DAMPING FACTOR		
at 1kHz	>50	
at 30Hz	>50	
STABILITY	Unconditional	

(Figures in brackets refer to the performance with the Ferguson PF 4361/1 transformer.)



This photo shows the internal layout of the amplifier with the optional Ferguson transformer which is fitted with a copper strap to reduce hum radiation to a minimum.

connected to the selector switch to indicate the signal source in use. These LEDs are fed via a common 4.7kΩ 1W resistor from the negative 50V rail.

This completes the circuit description apart from the loudspeaker protection which may be regarded as optional. However, we strongly recommend that it be included since it adds little to the overall cost. As such, it is a small price to pay to prevent the possible destruction of expensive loudspeakers if an amplifier fault does occur.

Four general purpose transistors, two diodes and one high voltage transistor are employed in the loudspeaker protection circuit. Q17, a BC556 which has a collector voltage rating of 80 volts, drives the relay via a 1kΩ 5W resistor. A diode across the relay/resistor combination protects Q17 against inductive kickback from the relay when it is de-energised.

Q16 controls Q17 via a 10kΩ resistor and 24V zener diode which we can regard as a short circuit for the moment. When Q16 conducts, so does Q17.

Base bias for Q16 is supplied by a network consisting of two 56kΩ resistors, a 1MΩ resistor and a 100μF capacitor. At initial switch-on of the amplifier the 100μF capacitor has zero charge, so no forward bias is applied to Q16 and the relay is off. After about three seconds, the capacitor is charged sufficiently to allow Q16 and Q17 to conduct and energise the relay. So the loudspeakers are connected to the power amplifiers, after three seconds delay.

Q13, 14 and 15 monitor the outputs of the power amplifiers for DC fault conditions. They operate in the following way:

Both channels of the amplifier are monitored via a low-pass filter network consisting of four 22kΩ resistors and two 47μF non-polarised electrolytic capacitors.

Typically, the DC offset voltage at the amplifier outputs can be adjusted to be between ±5 millivolts or better with the aid of the trimpots connected between the emitters of Q6 and Q7 in each channel. However, even if the offset voltage was several hundred millivolts, it would not affect the monitoring network. It is only if one of the amplifier outputs goes negative or positive by two volts or more, that the monitoring circuit reacts.

If one of the amplifier outputs goes negative by two volts or more, Q13 is forward-biased, turning on Q14 which removes the bias from Q16. Thus Q17 and the relay are turned off, disconnecting both loudspeakers. Similarly, if one of the amplifier outputs goes positive by two volts or more, Q15 is forward-biased, which again turns Q6, Q17 and the relay off.

The zener diode between Q16 and Q17 makes the protection circuitry disconnect the loudspeakers, very shortly after power is removed from the amplifier. If the zener diode was not included, the relay would not de-energise until the main amplifier supply rails had dropped to only a few volts. By that time, which may be 30 seconds or more, the power amplifier input stages, Q6 and Q7 are about to lose control of the output stage.

While this does not mean dire consequences for the loudspeakers, due to the low voltages involved, it does mean that the DC offset voltage at the output of each power amplifier may momentarily increase to ±50 millivolts or more. If the relay disconnects the loudspeakers when this relatively large DC offset voltage is present, the loudspeakers will produce an audible click. Since that is not "refined" we added the zener diode between Q16 and Q17 to make sure that the relay drops out when the amplifier supply rails drop below about 30 volts. At this voltage, the amplifier input stage has full control of the output and there is no click from the loudspeakers when they are disconnected.

Incidentally, while some readers may regard the loudspeaker protection circuitry as optional and elect not to incorporate it, the foregoing discussion about offset adjustment does not lead to the same conclusion about the offset adjustment trimpots. These should be left in even if the loudspeaker protection is omitted.

And now for a brief discussion on the performance of the new amplifier. Two sets of figures are provided for power output and signal-to-noise ratios. The slightly lower figures refer to the performance with the Jones JT 320 C-core power transformer while the higher figures refer to the Ferguson PF 4361/1 which is a conventional transformer with a copper strap to minimise flux leakage.

While the differences in power output are relatively small, reflecting the improved regulation of the bigger conventional transformer, the improved signal-to-noise ratios are very worthwhile and constitute a readily audible benefit. In subjective terms, the Ferguson transformer with copper strap renders the hum output of the amplifier virtually inaudible while, in very quiet rooms and with the gain well advanced, the other transformer does cause audible hum from the loudspeakers.

We estimate that the current cost of parts for this project is about

$160

including sales tax

Another advantage of the Ferguson transformer is that it has a pair of 15V windings which may be used in either of two ways. For situations where the mains voltage is consistently above 250VAC, these two windings may be connected together in series and then in series with the main primary winding to reduce the secondary voltage. As well as reducing heat dissipation within the amplifier this will probably also improve long-term reliability.

Alternatively, the start of one 15V winding can be connected to the finish of the other 15V winding and the centre-tap so formed connected to the chassis earth. In this mode the two windings function as an electrostatic screen which can minimise any common-mode noise superimposed on the mains.

Note that the alternatives listed above are just that – alternatives. You must not try to do both. That is, both windings must be connected together. You can-

PARTS LIST

CHASSIS & HARDWARE

1 plated steel chassis 370 x 111 x 245mm (W x H x D) with cover
1 front panel to suit
1 Ferguson PF 4361/1 transformer or JT 320 C-core
1 printed circuit board 221 x 203mm (80sa10)
1 3-pole, 4-position rotary switch
1 4-pole, 4-position rotary switch
1 100kΩ (lin) potentiometer (dual gang)
1 50kΩ (lin) potentiometer
1 20kΩ (lin) potentiometer (dual gang)
6 1kΩ trimpots
1 50kΩ (log) potentiometer (dual gang) with 40% loudness tap
6 knobs to suit front panel controls
4 DPDT miniature toggle switches
1 SPDT miniature toggle switch
1 6.5mm stereo headphone socket without switch (plus insulating washers)
2 6-way RCA socket panels, Ralmar M241 or similar
2 4-way spring loaded terminal panels, Ralmar ST3 or similar
1 single-sided heatsink, Ritronics, or similar, 190mm long
6 Richco CBS-6N plastic PC board supports
4 sets mounting hardware for TO-3 transistors
1 binding post for chassis earth
1 3-way insulated terminal block
8 solder lugs
10 plastic cable ties
1 rubber grommet
1.5 metres 3-core mains cable (7.5 amp)
1 3-pin mains plug
1 mains cable clamp
4 adhesive rubber feet
0.5 metres tinned copper wire
1.5 metres 10-way ribbon cable
2.0 metres figure-8 shielded cable
1 12V DPDT relay (FEME A002 45 05) or similar
8 PC board mounting fuse clips
4 2-amp 3AG fuses
2 x 14μH chokes (see text)
60 printed circuit board pins

SEMICONDUCTORS

4 x 1N5408 power diodes
1 x 1N4002 power diode
2 x 1N914, 1N4148 signal diodes
1 x BZX79/C24 zener diode
1 x BZX70/C15 zener diode
1 x BZX79/C15 zener diode
4 x 3mm red light-emitting diodes
6 x BC549 NPN transistors
3 x BC547 NPN transistors
5 x BC556 PNP transistors
1 x BC557 PNP transistor
4 x BF469, MJE340 NPN transistors
2 x BF470, MJE350 PNP transistors
2 x LM394 NPN super-matched pairs or 4 x BC549 (see text)
2 x 2SK-133 or 2SK-134 Mosfet power transistors
2 x 2SJ-48 or 2SJ-49 Mosfet power transistors
2 x TL071 BiFet op amps

CAPACITORS

4 x 2500μF/63VW electrolytics
1 x 1000μF/16VW electrolytic
1 x 470μF/16VW electrolytic
4 x 100μF/100VW electrolytics
1 x 100μF/25VW electrolytic
3 x 47μF non-polarised electrolytics
2 x 33μF/50VW electrolytics
6 x 10μF/25VW tantalum or low leakage electrolytics
6 x 4.7μF/25VW tantalum or low leakage electrolytics
2 x 1μF/35VW tantalum or low leakage electrolytics
4 x 0.47μF/35VW tantalum or low leakage electrolytics
14 x 0.1μF greencap (metallised polyester)
2 x .068μF greencap
4 x .047μF greencap
6 x .0068μF greencap
2 x .0056μF greencap
2 x .0033μF greencap
2 x .0012μF greencap
2 x .001μF greencap
1 x .01μF/240VAC metallised paper
2 x 150pF ceramic
2 x 100pF polystyrene
2 x 47pF ceramic
2 x 33pF ceramic
2 x 27pF ceramic

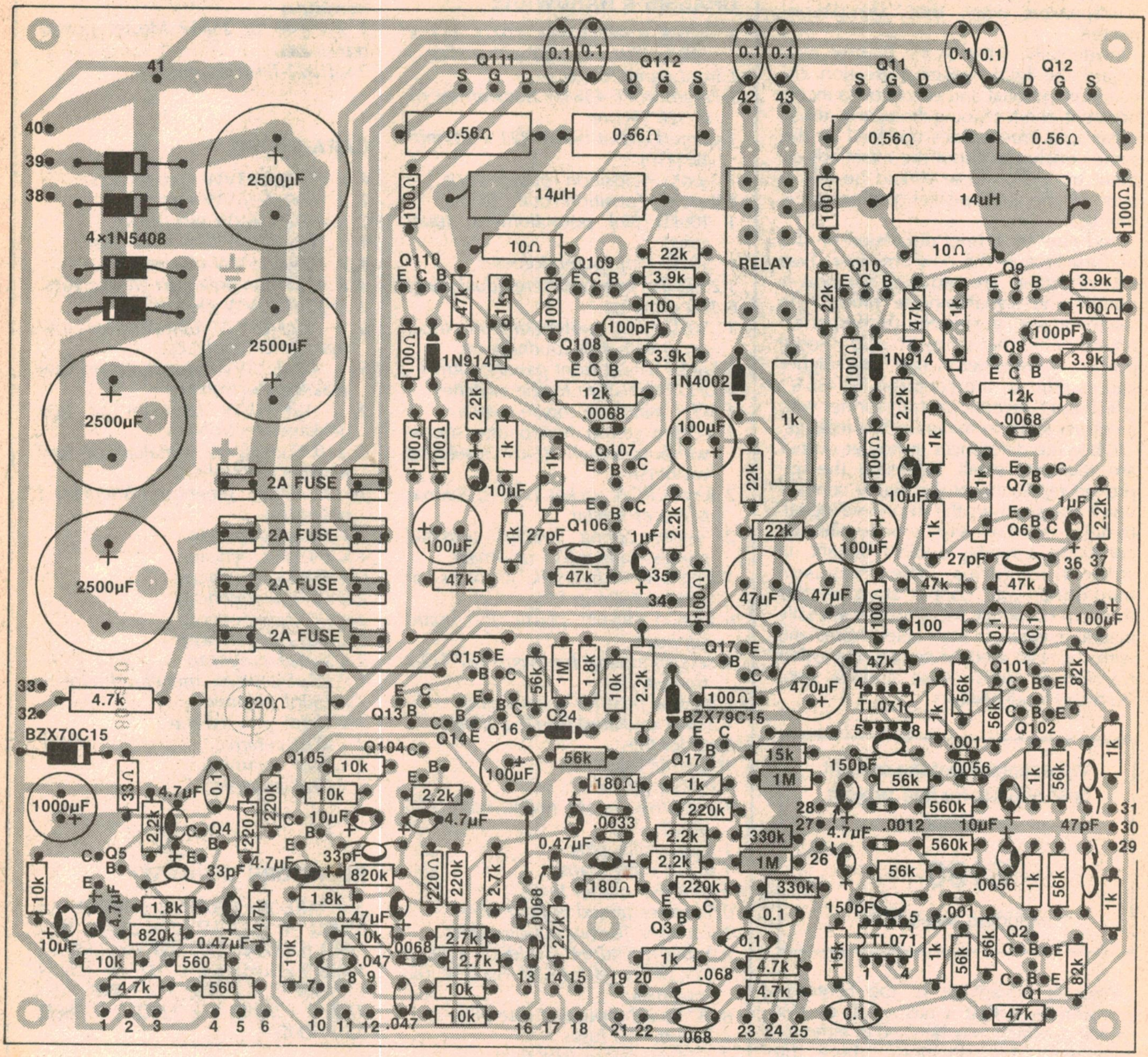
RESISTORS *(all ¼W/5%)*

3 x 1MΩ, 2 x 820kΩ, 2 x 560kΩ, 2 x 330kΩ, 4 x 220kΩ, 2 x 82kΩ, 10 x 56kΩ, 8 x 47kΩ, 1 x 33kΩ, 4 x 22kΩ, 1 x 15kΩ, 9 x 10kΩ, 6 x 4.7kΩ, 4 x 3.9k, 4 x 2.7kΩ, 8 x 2.2kΩ, 3 x 1.8kΩ, 12 x 1kΩ, 2 x 560Ω, 2 x 220Ω, 2 x 180Ω, 15 x 100Ω.

OTHER RESISTORS
2 x 12kΩ (1W), 1 x 4.7kΩ (1W), 1 x 2.2kΩ (½W), 1 x 1kΩ (5W), 1 x 820Ω (5W), 2 x 330Ω (½W), 4 x 100Ω (5W), 2 x 10Ω (1W), 4 x 0.47Ω (5W).

NOTE: Resistor wattage ratings and capacitor voltage ratings are those used for our prototype. Other voltage ratings may be used if available, provided the ratings are not exceeded. Where voltage ratings are not quoted, as for greencaps, they should be 50V or more. "Low leakage" electrolytics specified as an alternative to tantalum are the recently released Elna RBLL series or equivalent ultra low leakage types.

HERE IS THE PC BOARD LAYOUT



not use one as an electrostatic screen while the other is connected in series with the primary.

Naturally the Ferguson transformer is a few dollars dearer, representing the higher cost of more materials and labour. Nevertheless, we think that the extra cost is worthwhile, and it is the one we would recommend.

The power figures we quote are for continuous sine wave output at 1kHz, at just before the onset of clipping with a mains voltage of 240VAC. Altering any of these parameters slightly, ie, load impedance, mains voltage or degree of clipping (say to 1% THD) can alter the figures quite markedly.

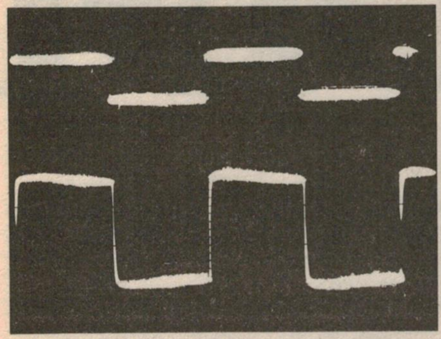
All specifications refer to the whole amplifier from input to output, not just the power amplifiers. The distortion figures apply to all inputs, including the phono input. The distortion curves were taken with the Jones C-core transformer installed.

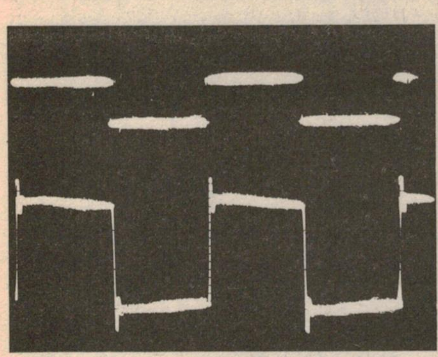
During normal operation, the amplifier heatsink will be just warm to the touch. However, extended operation at high powers can make it very hot. But even under conditions of maximum power dissipation the transistors will still be within ratings. All transistors on the PCB operate cool to the touch at all times but the 820Ω and 1kΩ 5W resistors will be hot at all times.

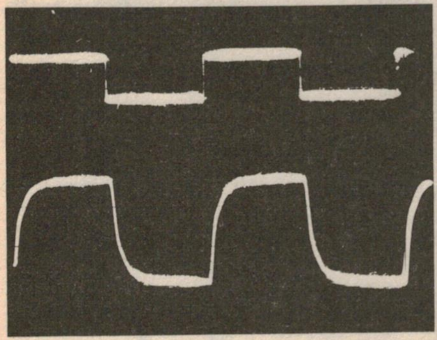
Assembly of the amplifier can begin with the PC board. This is coded 80sa10 and measures 221 x 203mm. The PC board has six mounting points one in each corner, one near Q3 and one near Q109.

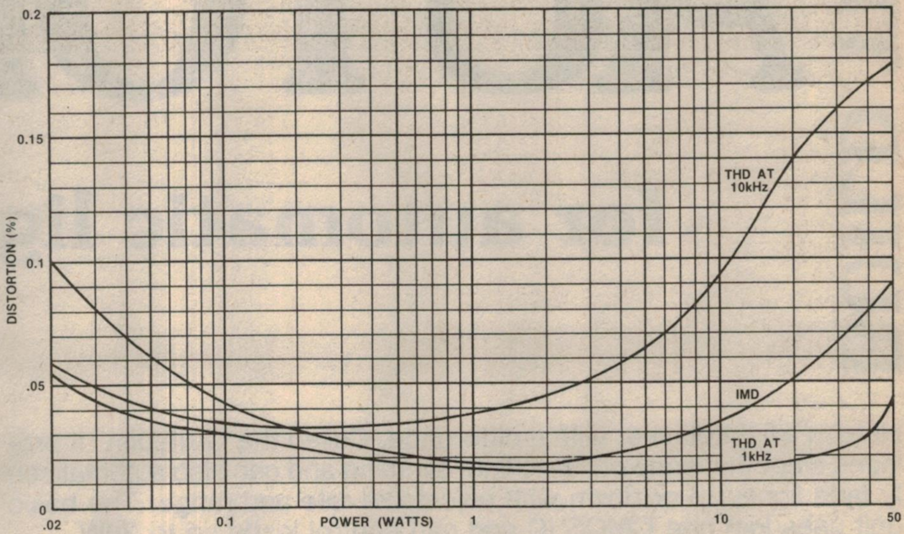
First of all check the PC board for any faults in the etching or drilling. Make sure there are no breaks or bridges in the copper pattern and repair these, if discovered before installing components. Faults of this nature are much harder to discover once the board is covered with lots of components.

While no particular order of assembly is mandatory, some hints may be useful. We recommend the use of PC pins for all connections to the PC board except those from the transformer. (The heavy gauge secondary wires from the

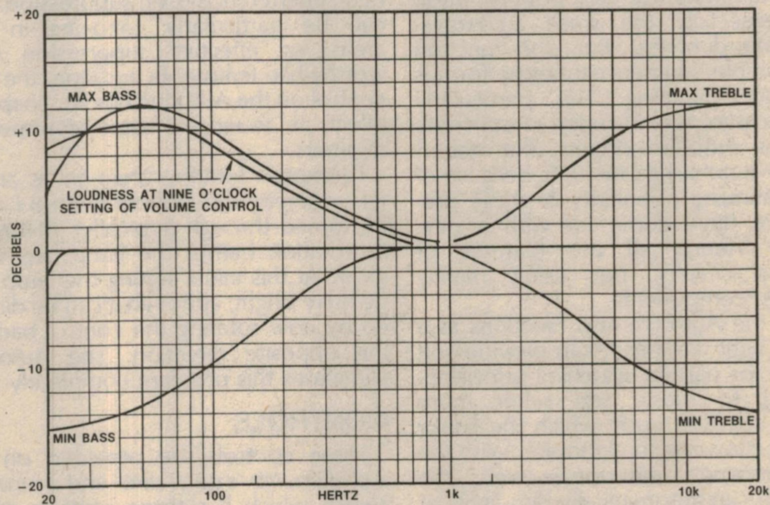




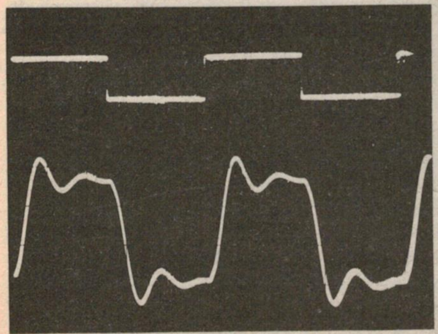




Above is a set of curves showing the distortion performance of the amplifier while below are the tone control and loudness characteristics.



From the top, these square wave oscillograms show the transient performance of the complete amplifier at 50V P-P: 1kHz into 8 ohms; 1kHz into 8 ohms shunted by 1uF; 10kHz into 8 ohms and below, 10kHz into 8 ohms shunted by 1uF. In each case, the top waveform in each photo is the input signal.



transformer should be terminated directly to the PC board, with the appropriate holes enlarged if necessary. Check this point before beginning assembly.)

You will need about 60 PC pins or stakes, allowing for a few spares, in case some roll into cracks in the floor. Use pins or stakes which are a tight fit into the PC holes. Those stakes with square shanks are preferable. For ease of assembly, insert all PC pins first, before other components, because it is often necessary to use some force in this job. For the same reason, insert the fuseholder clips before installing adjacent components.

Low noise cracked carbon or metal film resistors of ¼W or ½W rating may be used throughout except where we have noted otherwise on the circuit diagram. Insert all the resistors so that their colour code bands run in the same direction. This makes components checking easier.

Ensure that tantalum and aluminium electrolytic capacitors are correctly inserted, otherwise they will be reverse polarised and rendered ineffective. Tantalum capacitors are coded with a dot (as shown on the PC layout diagram) or plus sign to indicate polarity.

Take great care in inserting the transistors correctly, according to the PC layout diagram. Note also that the orientation of the two TL071 op amps is not identical – they point in different directions.

The 14μH chokes are wound with 15 turns of 18B&S enamelled copper wire on a special grade of ferrite rod 30mm long and 10mm diameter. Ordinary ferrite rod used for AM radio antennas is not suitable.

Next month we shall complete the details of construction and give a trouble-shooting procedure.