Guitar Amplifier for practice sessions

27W output plus tone controls & tremolo

Compact in size, with 27 watts RMS continuous output capability, this new guitar amplifier is designed for practice work and for use in small halls. The unit is fully solid-state and features tone controls, a tremolo facility, and high and low level inputs.

by JOHN CLARKE

While expensive guitar amplifiers with ratings of several hundred watts are necessary for professional musicians, there are many guitarists who do not need this kind of power output. Instead, the main requirement appears to be for a relatively compact amplifier suitable for use in the home and for practice work.

Ideally, though, a guitar amplifier should have a sufficient reserve of power to cope with parties and small halls. To this end, we don't need an amplifier with several hundred watts output. Twenty to thirty watts is more than adequate for most situations.

Our new guitar amplifier has been specifically designed to meet this need. It is easy to build, uses readily available components, and should cost you approximately $80. In spite of the slightly modest claim on the front panel, the prototype actually boasts a power output of 27 watts RMS into an 8 ohm load and 35 watts into a 4 ohm load.

These factors, coupled with the tone control and tremolo facilities we have provided, should make the new amplifier an attractive proposition for many readers. You don't have to spend a lot of money paying for features and a power output that you don't really need. And, of course, there's the satisfaction of having built it yourself.

Many of the parts used, including the power transformer and the chassis, are common to those used in the Playmaster Twin Twenty-Five stereo amplifier. This has been partly responsible for keeping the cost down. But the completed unit still looks impressive. As with all our recent amplifiers, we have provided a professional-looking front panel with an anodised scratch-grain finish.

Let's take a closer look at some of the circuit facilities.

As can be seen from the accompanying photograph, two jack sockets are provided on the front panel to accept the guitar input. Input sensitivity is 20mV or 100mV for full power, depending upon which input is selected. The less sensitive (HIGH) input should be used for bass guitars or guitars which have a higher than usual signal output. This prevents overloading of the preamplifier stage. Input impedance is approximately 100kΩ for the LOW input and 47kΩ for the HIGH input.

Tone controls for a guitar amplifier usually provide more bass and treble boost and cut than is normal with "high fidelity" amplifiers. This is to allow the guitarist more flexibility in setting the tone of his instrument. Accordingly, the tone controls on this unit provide ±18dB at 50Hz and ±20dB at 10kHz.

Electronic short circuit protection has not been provided. The amplifier will withstand short-circuits of a brief duration without damage – the fuses will blow. However prolonged overloads, such as using the amplifier with a loudspeaker of too low an impedance could possibly cause permanent damage. Do not use loudspeakers of less than 4 ohms impedance.

Comprehensive specifications for the amplifier are given in an accompanying panel. The main point to note is that the signal to noise ratio given is unweighted, which means that it refers to wideband noise. A weighted figure would result in a much higher signal to noise ratio. Certainly, all specification figures are in line with current performance standards.

THE CIRCUIT

Refer now to the circuit diagram. It can be divided into four basic sections: a power supply, an input preamplifier and tone control stage, the tremolo circuit, and a power amplifier.

NPN transistors Q1 and Q2 make up the direct coupled preamplifier circuit which has a voltage gain of approximately 22 times. This is set by the ratio of the 33kΩ resistor to the 1.5kΩ resistor. Bias for the input transistor is derived from the junction of the 330Ω and 270Ω resistors. Notice that there are two DC feedback networks in the circuit: the bias network and via the 33kΩ resistor to the emitter of the input transistor.

A 100pF capacitor shunting the 33kΩ resistor increases the negative feedback at high frequencies and thus rolls off the response above the audible range to assure low RF sensitivity. Similarly, a 100pF capacitor between the base and collector of Q3 lowers the cutoff frequency of this transistor.

In addition to rolling off the response at high frequencies, there is an RF attenuation network in the input circuit consisting of a series of 10kΩ resistor and shunt 100pF capacitor.

Following the preamplifier stage is an active tone control stage using NPN transistor Q3. This stage has a gain of unity with the tone controls set for a flat response.

The output from the tone control stage is fed to the volume control and thence to the tremolo control stage consisting of transistors Q4 and Q5. Q4 is a com-

mon emitter amplifier stage with gain control provided by varying the emitter degeneration via the N-channel FET Q6.

Under normal operation, the gate of the FET is held at ground potential with the normal tremolo switch. This provides a low drain-source resistance which shunts the 1.2kΩ emitter resistor. With the lower emitter degeneration, the gain of this stage is at maximum.

When the normal-tremolo switch is open, the gate of the FET is driven by sine wave oscillator Q5. The varying voltage at the gate gives a corresponding variation in the drain-source resistance of Q6 and so varies the gain of Q4. Consequently the amplified guitar signal is modulated by the varying gain of this stage.

The actual amount of modulation or "tremolo" is adjustable by means of the intensity control.

The tremolo oscillator is essentially a voltage amplifier with a phase shifting network connected between the output and the input. At one particular frequency, the phase shift produced by this network will be exactly 180°, which allows continuous oscillation to occur provided the gain is adequate. By making one of the resistors in the phase shift network adjustable in value, the oscillation frequency may be varied. This allows adjustment of the vibrato speed.

ohms. This ensures that the voltage excursions at the collectors of Q7 and Q8 are always similar.

Signal output from the differential input stage is taken from the collector of Q7 and amplified by common emitter stage Q11. Local negative feedback in this stage is in the form of emitter degeneration provided by the 39Ω resistor. The no-signal current through Q11 is set by constant current source Q10 which also uses D1 and D2 as its voltage reference.

Q16, a Vbe multiplier, sets the quiescent current in the output transistors. This configuration is very stable and will keep this quiescent current within a close tolerance.

The output stages operate essentially as Darlington emitter followers with slightly less than unity voltage gain but considerble current gain.

Q12 and Q14 combine to form a conventional Darlington emitter follower while Q13 and Q15 form a compound transistor also operating as an emitter follower. Diode D3 provides the same overall Vbe drop as the Q12/Q14 Darlington and thus helps to make the output stage more symmetrical. The .022uF capacitor across D3 compensates for the load capacitance in the collector circuit of Q13 due to the Miller capacitance of the base-collector junction of Q15. The

PERFORMANCE

POWER OUTPUT
4 ohms: 35W at .13% distortion
8 ohms: 27W at .13% distortion

FREQUENCY RESPONSE
20Hz to 20kHz: ±1.5dB

INPUT SENSITIVITY
LOW at 1kHz: 20mV
HIGH at 1kHz: 100mV
Overload at 1kHz: 130mV and 600mV

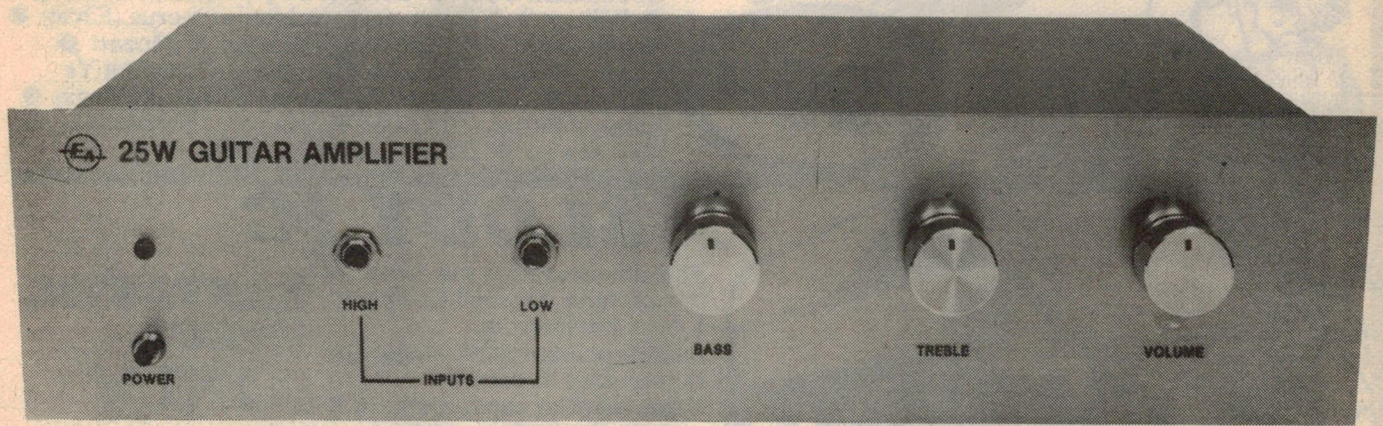
SIGNAL-TO-NOISE RATIO
59dB with respect to 10W

HARMONIC DISTORTION
Typically less than 0.07% at normal listening levels (see graph)

TONE CONTROLS
Bass
see graph
Treble

DAMPING FACTOR
at 1kHz: 75
at 30Hz: 50

STABILITY
unconditional



The prototype was housed in a Playmaster Twin-25 chassis, with the tremolo switch on the rear panel.

The power amplifier is the same as that used for the Playmaster Twin Twenty-Five stereo amplifier published in April, 1976. This uses rugged, yet inexpensive, 2N3055 power transistors connected in a quasi-complementary output stage. Direct coupling is used throughout the amplifier and only one electrolytic capacitor is employed.

Q7 and Q8 form a differential pair which enables the amplifier quiescent output voltage to be set close to 0V and thus eliminate output capacitors. Current through the differential pair is set by the constant current source Q9 which uses D1 and D2 as its voltage reference. To ensure that the differential input stage remains balanced, Q8 has a collector resistor of the same value as Q7; ie 680

capacitor thus gives another small improvement in output stage symmetry.

Voltage gain in the amplifier is set by the ratio of the 22kΩ and 1kΩ resistors in the base of Q8. Low frequency response is set by the 22μF feedback capacitor.

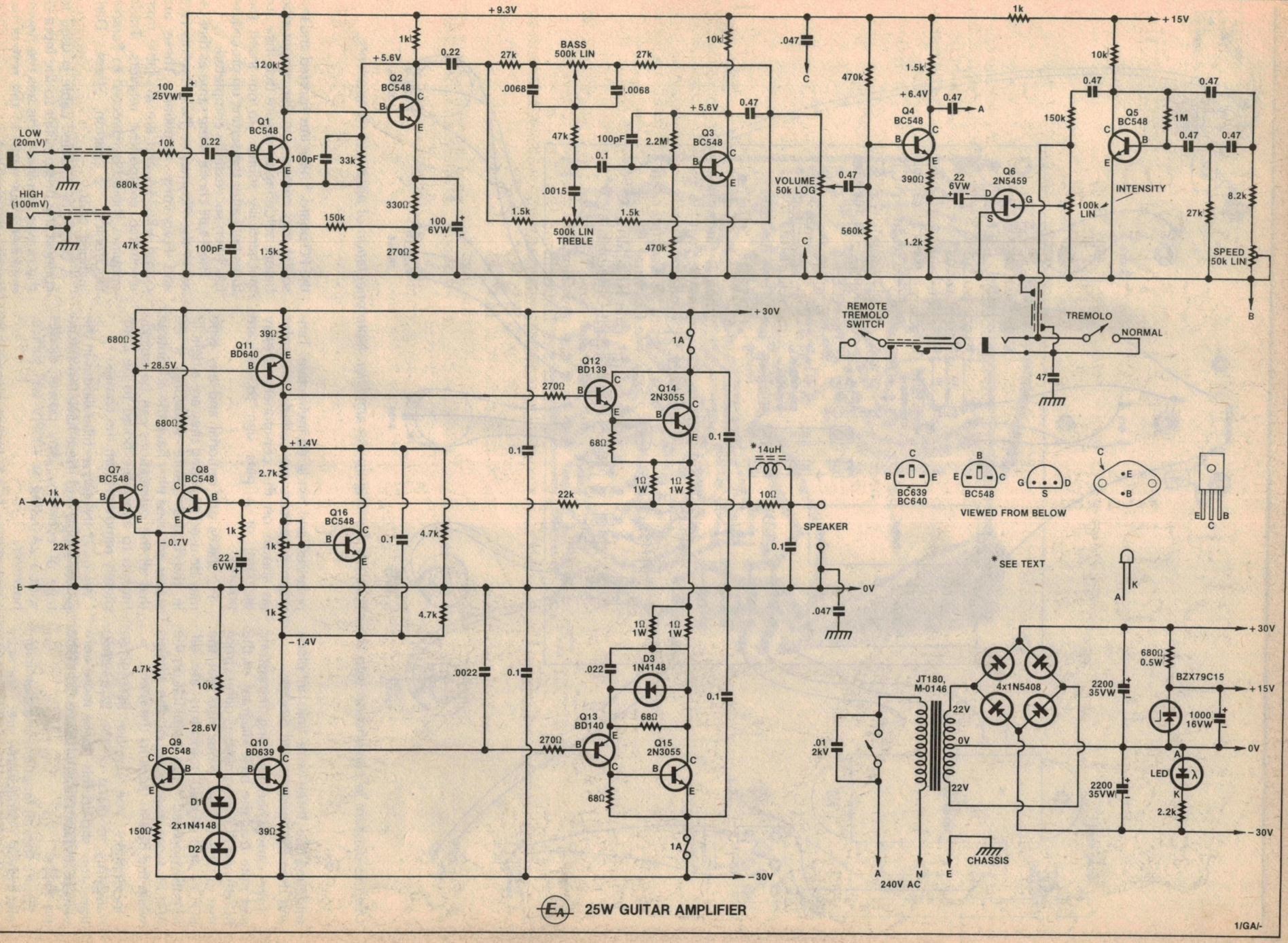
An RLC network connects the load to the amplifier, to ensure amplifier stability with highly reactive loads. The network is highly effective and renders the amplifier unconditionally stable. As a bonus, the network prevents radio interference picked up by long loudspeaker leads from being fed back to the amplifier input via the feedback network.

CONSTRUCTION

We built our guitar amplifier into a Playmaster Twin Twenty-Five case, measuring 370 x 77 x 245mm (W x H x D). This case is readily available from Dick Smith Electronics stores, but is by no means the only case suitable for the amplifier. The Horwood cases are a viable alternative, and feature carrying handles on the front panel.

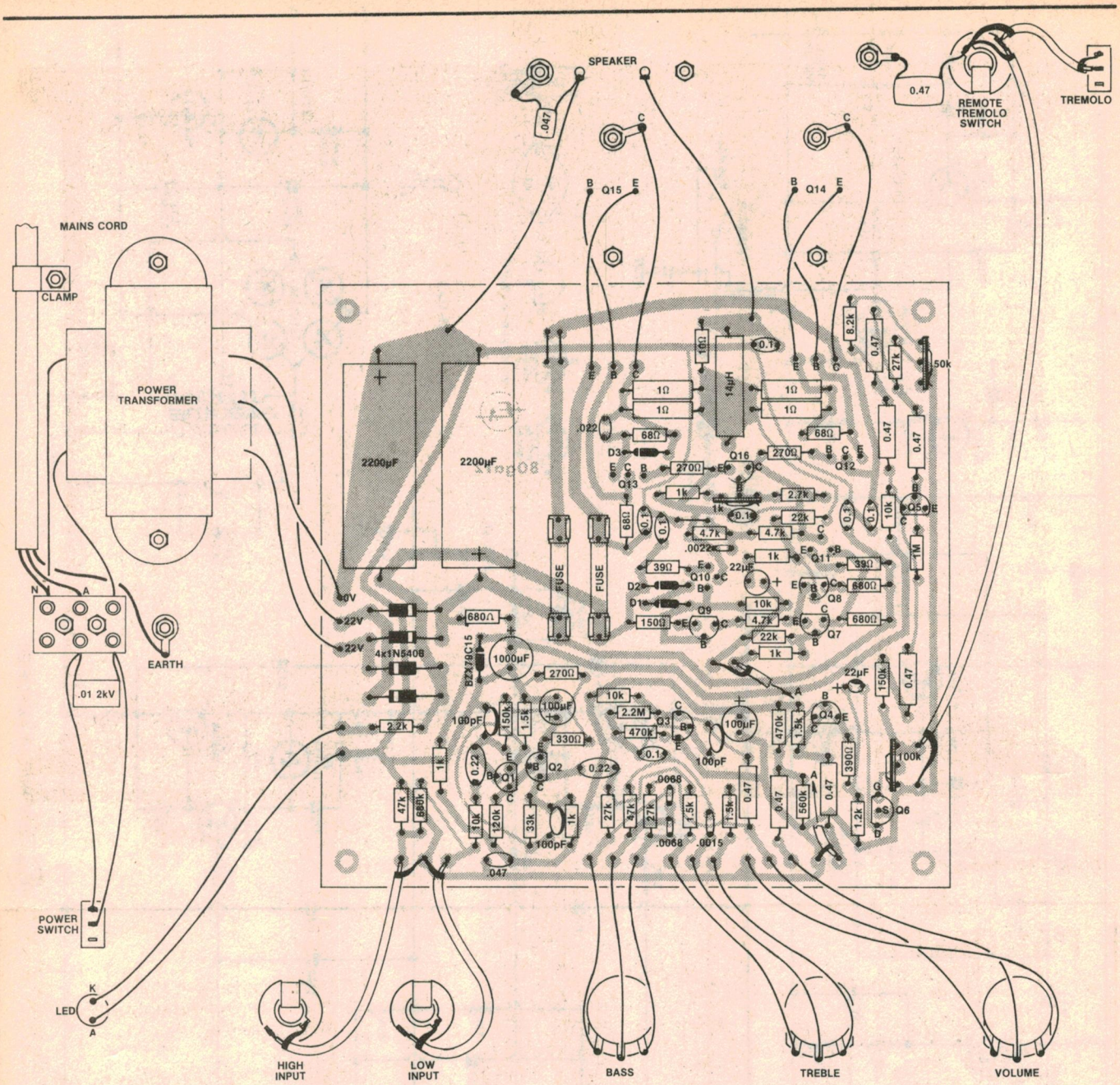
Note, however, that the front panel artwork would have to be altered for cases other than the Playmaster Twin Twenty-Five chassis.

The majority of components are mounted on a printed circuit board (PCB) coded 80ga12 and measuring 160 x 154mm. Assembly can begin with the PCB. Follow the overlay diagram carefully when mounting components as mistakes can lead to disaster. Start by



25W GUITAR AMPLIFIER

1/GA/-



Use this diagram in conjunction with the circuit when wiring up the amplifier. Note orientation of polarised components.

soldering the three wire links in place and then the resistors and diodes.

Take care when inserting transistors, and note that the base diagram of the BC639 and BC640 transistors differs from that of the BC548. Note also that the BD139 and BD140 transistors are differently oriented – the metal flat on the BD139 faces the front of the chassis while the BD140 faces to the rear.

Incidentally, you can use BD139/140 transistors in place of the BC639/640 transistors should this prove more convenient. In fact, this is what we did in the prototype.

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

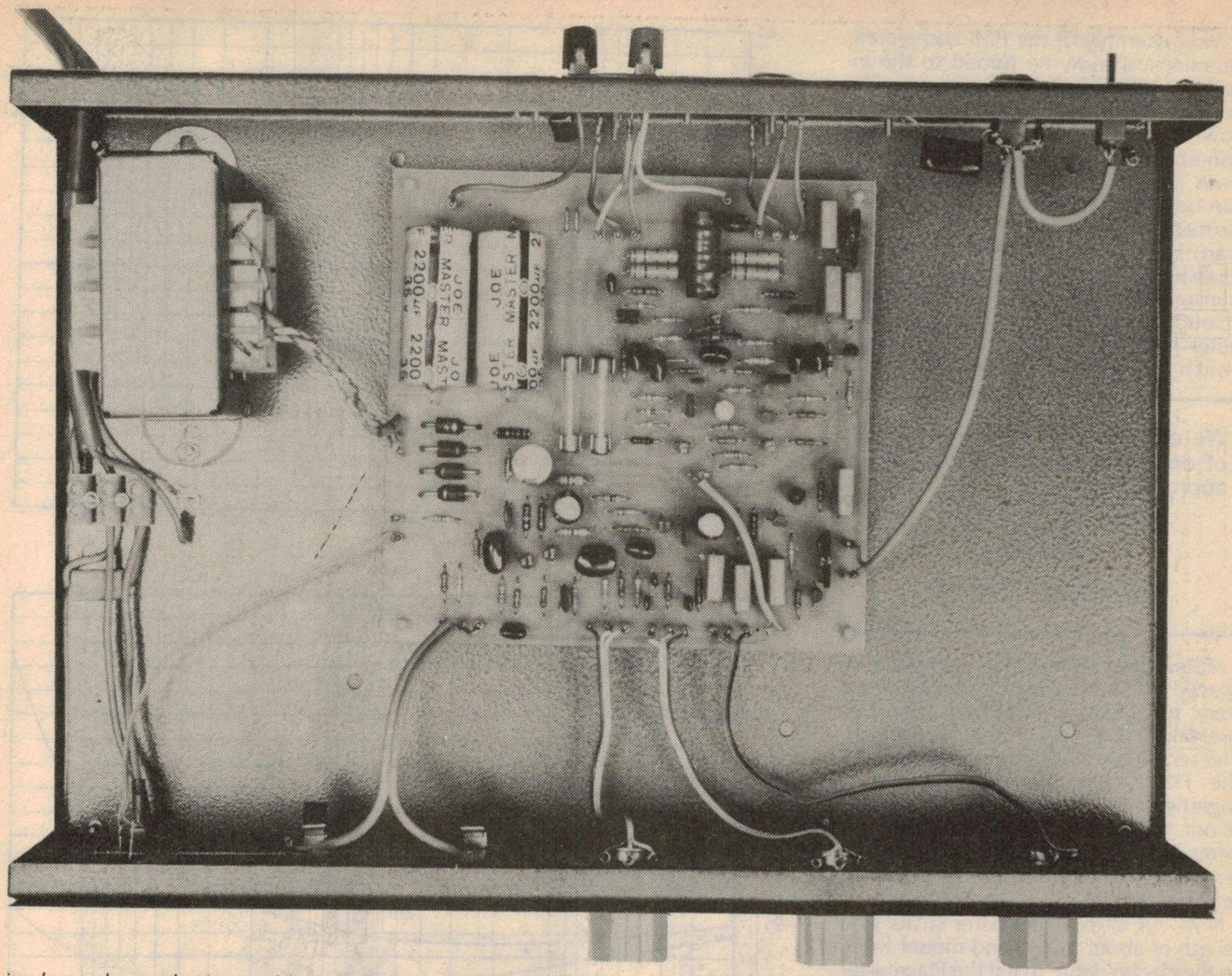
PC stakes are optional and any type may be used provided they are a tight fit in the board before soldering. If PC stakes are used they have the advantage that all the connections can be quickly broken to allow the board to be completely removed from the chassis.

We used 1N5408 rectifier diodes in the power supply and these have the advantage of economy. Any power diodes with a 2A rating at 100PIV will suffice, however.

Four Swann FC1 fuseclips are used on the PC board. These are inserted and the solder tags crimped on the copper side before soldering to ensure that they are mechanically sound. Do not insert the fuses until after the setting up procedure has been successfully completed.

The 14μH choke is the same as that used in the Playmaster Twin Twenty-Five and Forty-Forty amplifiers. These are coded VPC14A and are available from electronic component retailers. Trade enquiries should be directed to Paradio Electronics, 7a Burton Street, Darlinghurst, NSW.

A length of shielded cable is used to connect the preamplifier to the input of the power amplifier. This ties the power amplifier input earth to the rest of the board earth network.



This photo shows the internal layout of the amplifier. Keep all mains wiring neat and tidy.

PARTS LIST

1 PC board code 80ga12, 160 x 154mm
1 metal case, 370 x 77 x 245mm, Playmaster Twin-25 case or equivalent
1 transformer, 44V CT 1.25 amps, M-0146 or Jones JT.180
1 front panel to suit case
1 14μH choke, type VPC14A
2 SPDT miniature toggle switches
3 6.5mm panel sockets
1 two-way speaker terminal
3 knobs to suit panel
1 3-way mains terminal block
1 mains cord and plug
1 grommet and cord clamp to suit mains cord
4 rubber feet
4 Richo CBS-6N PC board supports
2 1A 3AG fuses
4 fuse clips, Swann FC1
5 solder lugs
2 sets of mounting hardware for TO-3 power transistors; ie mica washers, insulating bushes plus screws and nuts
1 red LED

SEMICONDUCTORS
2 2N3055 NPN power transistors
1 BD139 NPN transistor
1 BD140 PNP transistor
9 BC548 NPN transistors
1 BC639 NPNtransistor
1 BC640 PNP transistor
1 2N5459 N-channel FET
3 1N4148 signal diodes
4 1N5408 3A rectifier diodes
1 BZX79C15 15V/400mW zener diode

CAPACITORS
2 2200μF/35VW pigtail electrolytic
1 1000μF/16VW PC electrolytic
1 100μF/25VW PC electrolytic
1 100μF/6VW PC electrolytic
2 22μF/6VW PC electrolytic
8 0.47μF metallised polyester (greencap)
2 0.22μF metallised polyester
7 0.1μF metallised polyester
2 .047μF metallised polyester
1 .022μF metallised polyester
1 0.01μF/2kV ceramic or 250VAC polycarbonate
2 .0068μF metallised polyester
1 .0022μF metallised polyester
1 .0015μF metallised polyester
3 100pF ceramic

RESISTORS (¼W, 5% unless noted)
1 x 2.2MΩ, 1 x 1MΩ, 1 x 680kΩ, 1 x 560kΩ, 2 x 470kΩ, 2 x 150kΩ, 1 x 120kΩ, 2 x 47kΩ, 1 x 33kΩ, 3 x 27kΩ, 2 x 22kΩ, 4 x 10kΩ, 1 x 8.2kΩ, 3 x 4.7kΩ, 1 x 2.7kΩ, 1 x 2.2kΩ, 4 x 1.5kΩ, 1 x 1.2kΩ, 5 x 1kΩ, 2 x 680Ω, 1 x 680Ω ½W, 1 x 390Ω, 1 x 330Ω, 3 x 270Ω, 1 x 150Ω, 3 x 68Ω, 2 x 39Ω, 1 x 10Ω, 4 x 1Ω 1W, 1 x 100kΩ trimpot, 1 x 50kΩ trimpot, 1 x 1kΩ trimpot, 2 x 500kΩ lin potentiometers, 1 x 50kΩ log potentiometer.

MISCELLANEOUS
Screws, nuts, shielded cable, hookup wire, mains rated wire, PC stakes, solder.
NOTE: Ratings are those used on the prototype. Components with higher ratings may generally be used provided they are physically compatible.

With assembly of the PCB completed, attention can now be turned to the installation of hardware in the chassis. The accompanying wiring diagrams shows how the various components are positioned. If you are using a Playmaster Twin Twenty-Five chassis, existing holes can be used to mount virtually all components, including the power transformer, front panel controls, loudspeaker connector and output transistors.

You will have to drill new mounting holes for the PCB and for the tremolo switch and socket, however.

We estimate that the current cost of components for this project is approximately

$79

This includes sales tax.

Mount the transformer so that it is spaced off the chassis by at least 3mm using brass nuts or washers. This is to prevent hum induction into the chassis. The secondary leads should be closest to the PCB. Twist the secondary leads together and cut them to a length of about 10cm. Similarly, twist the primary wires together and cut to a suitable length for termination at the insulated terminal block.

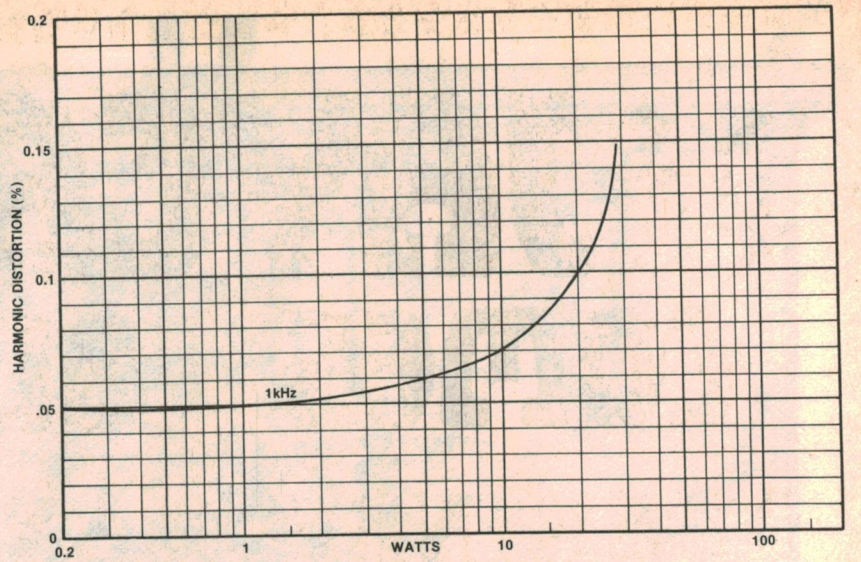
Now cut all potentiometer shafts to a length of about 12mm and mount these to the chassis. Note that if the Playmaster Twin Twenty-Five case is used, the hole for the treble control will need to be filed so that the control can be lined up with the bass and volume controls. Install the switches and sockets but leave the escutcheon plate off at this stage to avoid scratching.

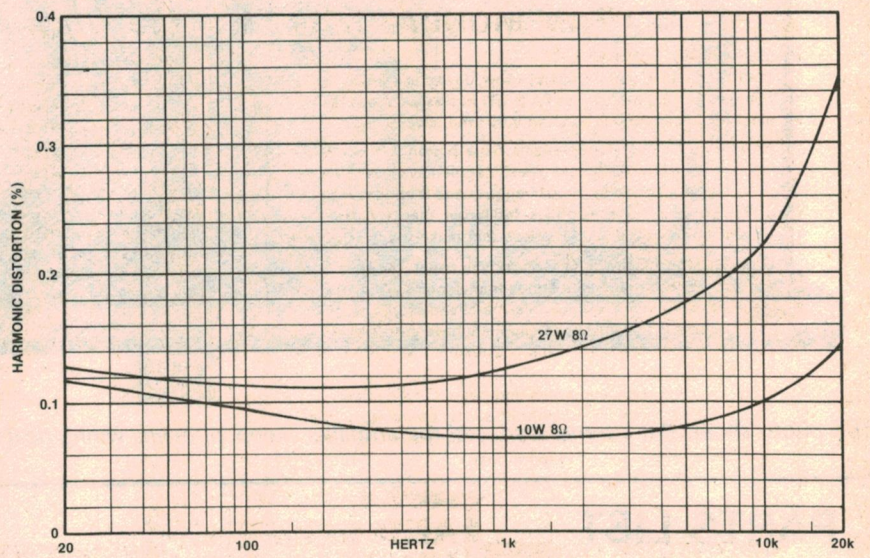
The remote tremolo switch socket mounted at the rear of the chassis needs to be insulated from the case to prevent earth loops. We insulated it with a rubber grommet, but insulating tape wrapped around the shaft would serve equally as well.

The loudspeaker terminals we used are spring-loaded and are more convenient than the cheaper screw terminals.

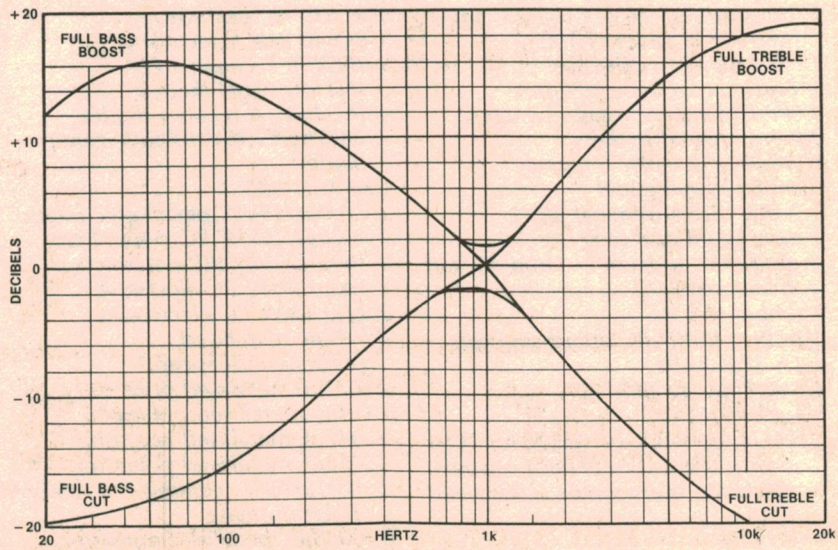
Before mounting the output transistors, ensure that the contact area is completely smooth and free of burrs and swarf. If the case is painted, scrape away the paint at the transistor contact area. Smear this contact area, both sides of the mica washers and the base of the transistors with heatsink compound. The mica washers are necessary, along with insulating bushes, to isolate each transistor from chassis. Attach a solder lug to one of the retaining screws of each transistor.

After mounting the transistors, check the electrical insulation between the chassis and the transistor cases with an ohmmeter. Any short to chassis must be

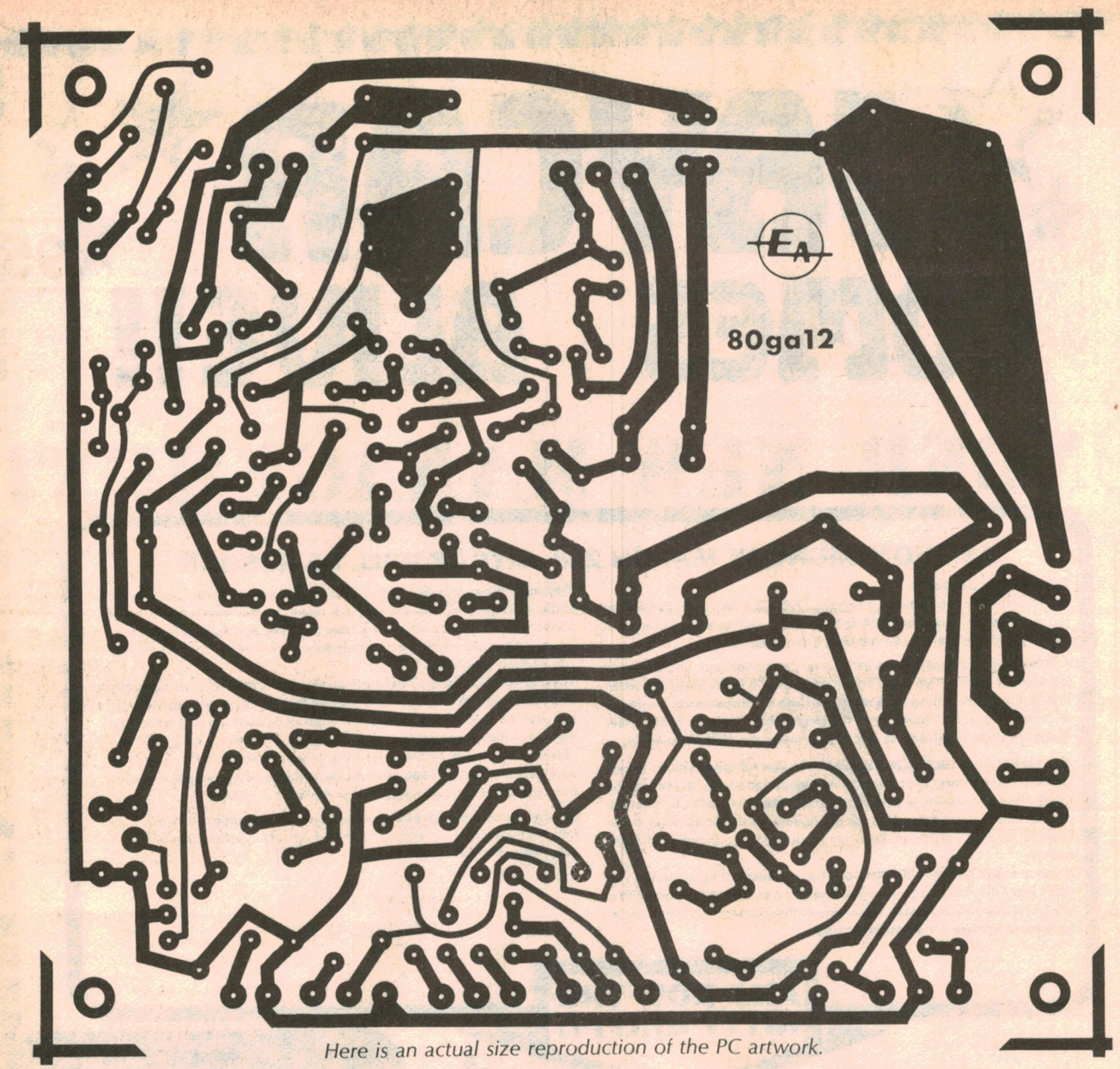




Above are two graphs showing the distortion performance of the amplifier. Harmonic distortion is typically less than .07% at normal listening levels.



This graph plots the tone control characteristics.



Here is an actual size reproduction of the PC artwork.

repaired at this stage. Either the mica washer has punched through or the transistor has been mounted incorrectly.

The mains cord should be passed through a grommetted hole in the rear of the chassis and anchored with a cord clamp. Terminate the mains active and neutral to the terminal block and solder the earth wire to a solder lug near the transformer. Run two mains rated wires from the terminal block to the switch.

The mains switch has a 0.1μF/2kV ceramic or 250VAC polycarbonate capacitor wired across it at the insulated terminal block. Use insulating sleeving on the capacitor leads. As well, before soldering the wires to the mains switch, slip some insulating sleeving over the wires and after soldering, push the sleeving over the terminals of the switch. The spare terminal, if a double throw switch is used, should also be insulated.

The PC board can now be dropped into place in the chassis and mounted using Richco plastic supports. Make all connections from the PC board to the chassis components exactly as indicated in the chassis wiring diagram. We used ribbon cable for the volume, tone controls and LED indicator, but shielded cable must be used for the input wiring and the wiring to the normal-remote switch and remote tremolo switch socket.

Double check all wiring against the circuit, PC layout and chassis wiring diagrams. You are now ready for the setting up procedure.

Solder 100Ω1W resistors across each fuse holder. Now, looking from the front of the chassis, rotate the 1kΩ trimpot fully clockwise. The volume control should be set to minimum. Do not connect any loads to the amplifier at this stage.

Apply power and check voltages in the power amplifier. There should be less than 1 volt DC across each 100Ω test resistor and less than plus or minus 100mV DC at the amplifier output. If these checks prove okay, the quiescent current can be set. Rotate the 1kΩ trimpot to obtain 2 volts DC across one of the 100Ω resistors. This corresponds to a quiescent current of 20mA.

As a final test, check all the voltages shown on the circuit diagram. If these are all within 10 per cent of specification then the 100Ω resistors can be removed and the fuses installed. Connect a loudspeaker to the amplifier, apply power and the project is ready for use.

One final comment. If a remote tremolo switch is used, make sure that the switch lead to the amplifier is run in shielded cable. The switch can be a heavy duty momentary push-on type mounted in a box suitable for foot operation.

For those who expect to use the tremolo feature regularly, potentiometers can be used instead of trimpots for the speed and intensity controls. These can be mounted on the rear of the chassis and wired with ribbon cable. The speed control potentiometer can be logarithmic type for improved control, while a linear type should be retained for the intensity control.