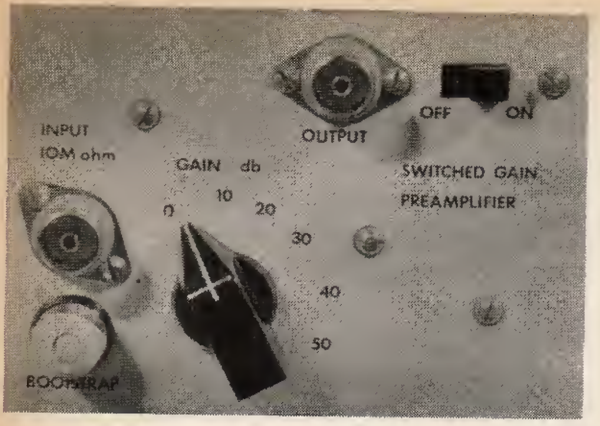


Switched Gain Preamplifier

By D. Crocker

THE amplifier to be described was designed to serve as a general purpose unit for a wide range of applications. It may be used, for example, between a signal source and a power amplifier to increase sensitivity, as an a.c. coupled oscilloscope preamplifier, a monitor amplifier to feed a crystal earpiece directly, or as an impedance matching device for coupling a crystal or ceramic pickup or a crystal microphone to an amplifier having a low input impedance.

In order to make the amplifier as versatile as possible, it was decided that a variable gain of up to 50dB was required together with a wide band width and high input and low output impedances. It should also have a low power consumption so that it may be run from batteries, making it self contained.

CIRCUIT DESCRIPTION

The complete circuit is shown in Fig. 1. In order to obtain a high input resistance, use of a field effect transistor is made in the first stage. Unlike a bipolar (conventional) transistor, that is a voltage operated device drawing very little current from the input signal. The current flowing between the source and drain terminals is varied by the voltage between the gate (the third terminal) and the source.

This varying current is fed to the base of a *p-n-p* transistor, TR2, comprising the second stage.

Since it is desirable to apply negative feedback to the source of TR1 in order to accurately determine the gain and widen the frequency response, the open loop gain (i.e. the gain before feedback is applied) should be above 3,000 for a closed loop gain of 50dB. Although the phase shift between TR1 source and TR2 collector is the required 180 degrees (TR2 having provided this), the gain provided would be much less than 1,000 if TR2 was given a simple resistor as a collector load. Another common emitter stage cannot be used as it would provide an extra 180 degree phase shift, making the feedback positive; an emitter follower, TR3, has therefore been used.

As this can provide no voltage gain by itself, R9, the collector load of TR2, has been bootstrapped by C4. This makes R9 appear to be in parallel with TR3 emitter-base junction, and since the effective resistance of this is lower than R9, most of TR2 collector signal current flows through TR3, giving rise to an amplified collector/emitter current in TR3 which flows through R12, developing an output voltage across it.

SPECIFICATION

Gain
Switched gains of 0, 10, 20, 30, 40, and 50dB

Bandwidth
Low frequency: —3dB at 10Hz
High frequency: —3dB at:
200kHz (50dB gain)
500kHz (40dB gain)
800kHz (30dB gain)
>800kHz (0, 10 or 20dB gain)

Maximum output
12V p-p (no load)
7V p-p (10kΩ load)
1·5V p-p (1kΩ load)

Slewing rate
Approximately 10V/μS minimum

Noise
Referred to input: approx. 150μV p-p (input open)
approx. 25μV p-p (input shorted)

Supply current
Approximately 1·2mA

Input resistance
12MΩ with S3 out.

The overall effect of the emitter follower TR3 and bootstrapped resistor R9 is to make the collector load resistance of TR2 very high, so that TR2 gives a high voltage gain.

FEEDBACK

Negative feedback is applied from the output to TR1 source through R11. As well as enabling the gain to be varied, this stabilises d.c. conditions throughout the amplifier and reduces its output impedance. When S1 is set for unity gain (0dB), full negative feedback is applied; for higher gains resistors R4 to R8 are switched in to reduce the amount of feedback.

For an amplifier of this sort, the gain is given by the formula

$$G = \frac{A(Rs + Rf)}{Rf + Rs.A} \qquad \text{if } A \gg 1$$

or

$$G = 1 + \frac{Rf}{Rs} \qquad \text{if } A \gg G$$

In this circuit A, the open loop gain, is between 3,000 and 7,000 depending on the load. Rf is R11 of Fig. 1 and Rs is the resistor switched in by S1. This resistor is connected in series with C3 in order not to disturb the d.c. conditions.

The current consumption of the amplifier has been reduced to about 1·2mA by giving R12 the rather high value of 10kΩ. This limits the maximum output available when a low impedance is used to the figures given in the specification. Whilst this has proved to be satisfactory, any constructor requiring a higher output current capability can decrease the value of R12 (but not below about 2kΩ) at the expense of reduced battery life.

an open loop gain of over 6,000, so that over 67dB of feedback is applied when the amplifier is set for unity gain, this form of instability has not occurred in the prototype.

CONSTRUCTION

In order to avoid hum pick-up at the high impedance input, the amplifier is constructed in an aluminium box which provides screening. Most of the circuitry is constructed on a piece of 0·1in matrix Veroboard measuring 25·4mm × 50·8mm.

Before mounting the components, breaks are made in the copper strips as shown in Fig. 2 and terminal pins are inserted from the copper side of the board. These should then be soldered in place and tinned.

The pins in row 7 support the screens; these are made from 2 pieces cut from tin measuring about 9mm × 33mm and 17mm × 33mm. They are flattened, cleaned, and one side of each is coated with solder. After placing small pieces of p.v.c. insulating tape between the 5 terminal pins over rows B, D and F, the screens are soldered in place on the terminal pins in the position shown in Fig. 2. The smaller piece of tin is fitted on the copper side of the board. The components may then be wired in the positions shown in Fig. 3. Component wires should be sleeved where appropriate. An aluminium box measuring 4in × 2¾in × 1½in with lid is required. The lid is drilled to accommodate the switches and sockets and these fitted.

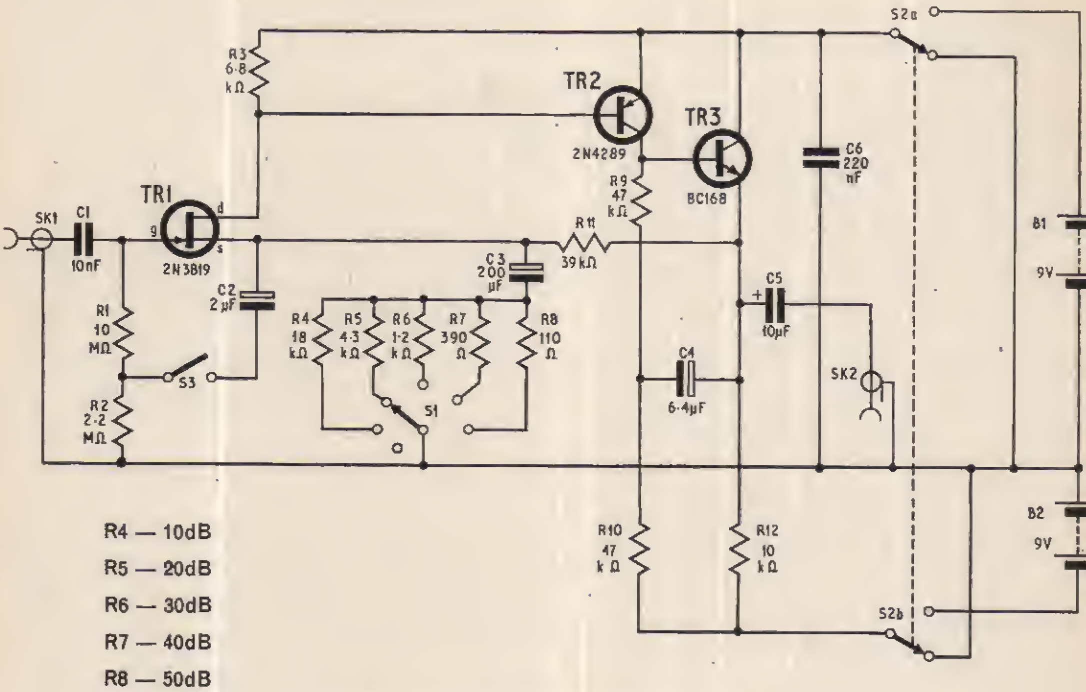


Fig. 1. Circuit diagram of preamplifier.

Since the output offset voltage may be positive or negative, the output capacitor C5 is a tantalum type; these can withstand small reverse voltages.

STABILITY

There are two ways in which an amplifier of this sort might be unstable. First, since the amplifier has a high, non-inverting gain and a high input impedance, feedback from the output to the input can easily occur causing oscillation. This is prevented by placing an earthed metal screen on the circuit board and using co-axial input and output connectors.

Secondly, due to extra phase shift in the amplifier, the feedback through R11 could become positive at high frequencies. In spite of the fact that the amplifier has

MOUNTING THE BOARD

In order to mount the circuit board, one face of a ⅜in 6 B.A. tapped hexagonal pillar is tinned and soldered to the screen on the copper side of the board, placing it approximately below hole F8 (see Fig. 2), without allowing the screen to part from the pins. The pillar

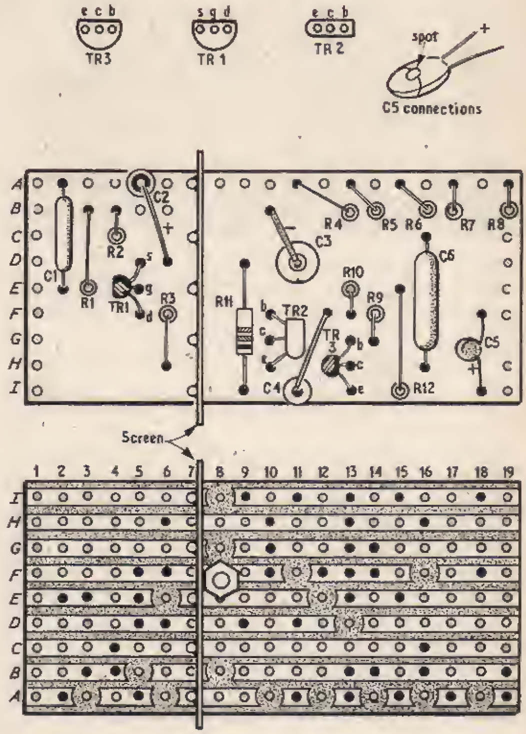


Fig. 2. Component assembly and wiring details.

COMPONENTS . . .

Resistors
R1 10MΩ
R2 2·2MΩ
R3 6·8kΩ
R4 18kΩ
R5 4·3kΩ
R6 1·2kΩ
R7 390Ω
R8 110Ω
R9 47kΩ
R10 47kΩ
R11 39kΩ
R12 10kΩ
All ⅛W 5% carbon

Capacitors
C1 0·01μF miniature polyester
C2 2μF 16V miniature electrolytic
C3 200μF 6·4V miniature electrolytic
C4 6·4μF 25V miniature electrolytic
C5 10μF 25V tantalum bead electrolytic
C6 0·22μF miniature polyester

Transistors
TR1 2N3819
TR2 2N4289
TR3 BC168B or BC169

Switches
S1 2 pole 6 way miniature wavechange switch (only 1 pole used)
S2 d.p.d.t. slider switch
S3 s.p.s.t. push on/push off switch (see text)

Miscellaneous
SK1, SK2 Surface mounting co-axial sockets (2 off). B1, B2 9V PP3 batteries (2 off). Aluminium box 4in × 2¾in × 1½in with lid
0·1in matrix Veroboard 2in × 1in. Veropins for 0·1in matrix Veroboard (12). 6BA bolts (¼in), nuts and washers ⅜in or ½in. Terry clips (2). PP3 battery connectors (2)

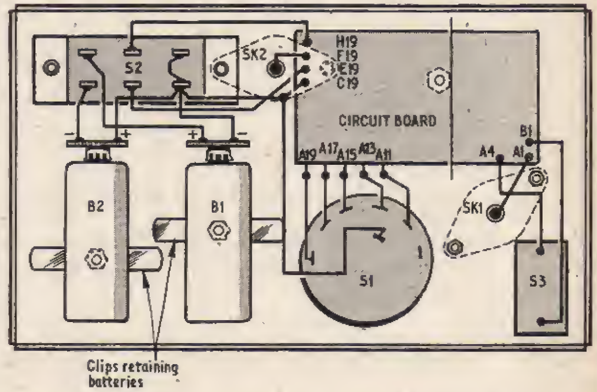
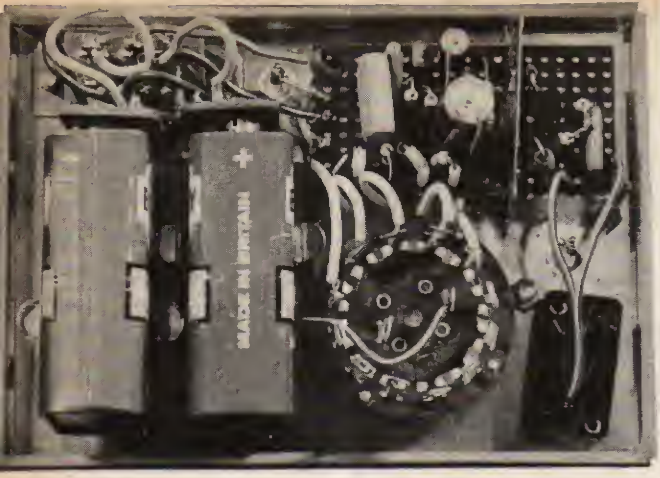


Fig. 3. Total component assembly within the aluminium box.



Rear view of the preamplifier front panel showing layout of components and position of circuit board

should not touch the board itself. It is then necessary to see if the board can be screwed into place by a 6 B.A. bolt passing through the appropriate hole in the lid into the pillar; check that the box will still fit inside the lid, and if necessary desolder and re-position the pillar. This pillar also earths the case.

Once the circuit board has been mounted the components may be wired up as in Fig. 3.

TESTING

When the wiring has been completed and checked the batteries may be inserted. If a milliammeter is available, it may be connected in series with B1. When the circuit is switched on it should read about 1mA (ensure that S3 is out when measuring this). The amplifier can be tested using a signal generator or other signal source and an oscilloscope, power amplifier or crystal earpiece.

USING THE AMPLIFIER

This preamplifier has many uses in the workshop. As an audio preamplifier when a power amplifier has insufficient sensitivity or an input impedance too low for the signal source, as an audio signal tracer (using a crystal earpiece or a small power amplifier), as an i.f. signal tracer (using a detector diode at the output) or as a general purpose oscilloscope pre-amplifier.

In normal use a screened input lead should be used to prevent feedback or hum pick-up, this is not always necessary when the amplifier is fed from a low impedance source.

It should be noted that a very low frequency damped oscillation occurs for several seconds after S3 is closed. Closing S3 gives the amplifier a very high input resistance due to the bootstrapping effect on R1; this may be several hundred megohms when a low gain is being used. However, since the 12 megohm input impedance obtained when S3 is out is usually quite sufficient, some constructors may prefer to omit this facility.

Due to the low current drain the batteries should give several months of operation. The use of silicon planar transistors should make this unit very reliable. ★