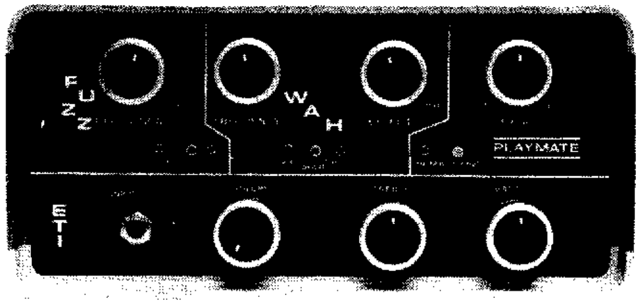
Playmate Guitar Effects/Amp

PROJECT

The sounds of the superstar in your own room – or in the middle of a field! The PLAYMATE will help you on your way. Design and development.

by Phil Walker



THE PLAYMATE is a small practice amplifier giving a few watts output while also providing some of the basic effects used by many musicians. It is ideally suited to those who do not carry all the various effects units around in their guitar cases, but would like to be able to practise at odd moments or in out-of-the-way places.

In addition to the amplifier and standard tone controls, etc, various distortion and wah-wah effects are possible. As a by-product of the circuitry a sustain effect is also possible.

The sound output is provided by a small internal loudspeaker and the whole module is powered from a small power adapter or batteries. An external foot pedal could be used with the wah effect if required. This consists of a variable resistor and a couple of other resistors to provide the necessary control current. The internal control is still active at this time and can be used to set an operating range.

The Circuit

The circuit is generally straightforward. It consists of an input buffer with a gain of about 50, followed by a signal compression stage which reduces the dynamic range greatly in order to feed the effects circuitry at a constant level. The effects consist of a distortion-inducing stage for fuzz and a variable band-pass filter for the wah wah. After the effects stages, the dynamic range of the signal is restored to normal before being fed to the mixer, tone controls and power output stages.

The input buffer consists of a single 3140 CMOS op-amp whose gain is set at 48 by R2, R3. The following dynamic range compressor consists of one part of a LM13600 dual transconductance amplifier. The gain of this device is a function of the amplifier bias current, the input diode current and the load resistor. The output buffer of the device is used here as a peak detecting rectifier which charges a capacitor (C3) to the peak value of the output signal less two base-emitter drops (about 1V4). If this voltage is greater than about 0V7, the resulting current flowing through the input linearising diodes causes the effective stage gain to decrease and keep the output level constant.

Distorting The Facts

Distortion effects in this project are of two types. The first is mainly even-harmonic, generated by half-wave-rectifying the input, inverting it and then mixing it with the original signal, allowing a range of no distortion to complete frequency doubling. In addition to this, overload type distortion is provided by a high gain clipping amplifier using non-linear feedback (IC3a,3b).

Wah wah sound effects are produced by a current-controlled state variable filter. The control current determines the centre frequency of the pass band, while a two-gang variable resistor sets the bandwidth and compensates for inevitable gain changes.

Tone controls are of a standard type and use frequency-selective feedback networks around an op-amp. The following power amplifier has been designed to have a low quiescent current. This is important if batteries are to be used, as many amplifiers of the IC variety take 30 mA or more, or are designed for single rail working.

The LM13600

This device is used for two functions in this project. One of these is the compressor/expander while the other is the wah wah. In both of these, use is made of the fact that the gain of the device is dependent on the amplifier bias current and the linearising diode current (provided that the input current is less than half the diode current). In fact, the output resistor also determines the gain but is not so easily varied.

If the diode current is zero, then the manufacturers' data sheet shows that the transfer function of the device is:—

$$I_{out} = \frac{I_{abc} \times q \times V_{in}}{2KT} = \frac{I_{abc}}{26 \times 10^{-3}} \times V_{in}$$

If the diode current is not zero and the signal current is less than $I_{D/2}$ then the transfer function is:—

$$I_{out} = \frac{2 \times I_{abc} \times I_s}{I_D}$$

where
I_s = signal current
I_{abc} = amp. bias current
I_D = lin. diode current
I_{out} = output current

If we use resistors for input and output, it can be seen that the voltage gain of a stage using this device can be controlled easily by use of the bias and linearising diode currents.

Figure 3 shows the basic circuit for a voltage amplifier and from it we can show that the output voltage V_0 is dependent on the bias and diode currents.

$$V_o = \frac{V_{in} \times 2 \times I_{abc} \times R_L}{R1 \times I_D}$$

$$I_{in} = V_{in}/R_{in} \quad \text{Therefore}$$

and the gain $\frac{V_o}{V_{in}} = 2 \times \frac{I_{abc}}{I_D} \times \frac{R_L}{R1}$

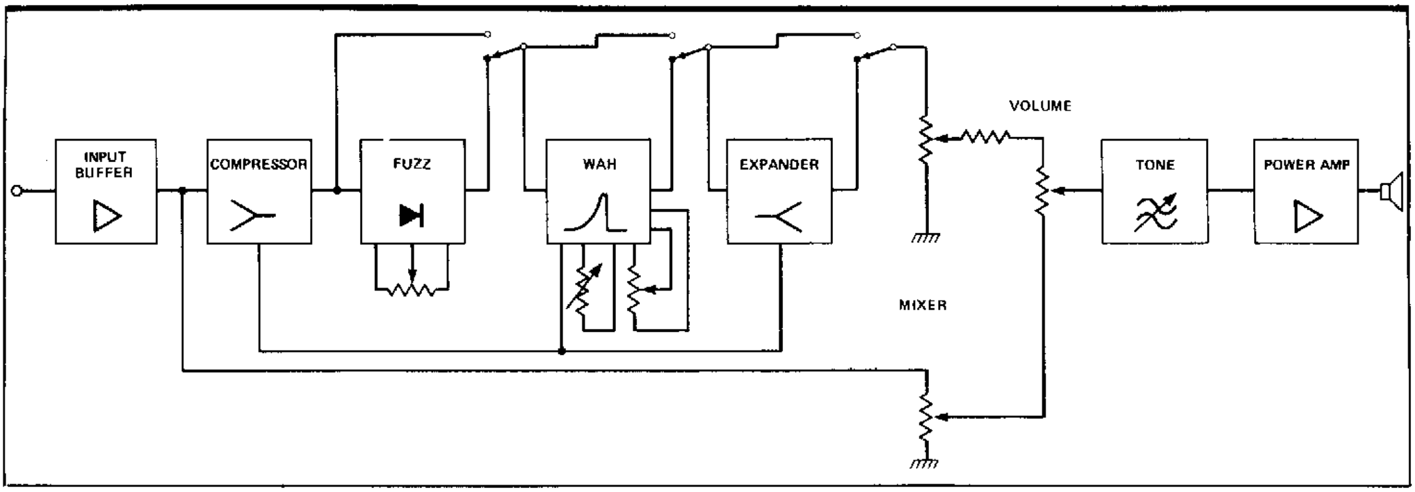


Fig. 1 Block diagram of the Playmate.

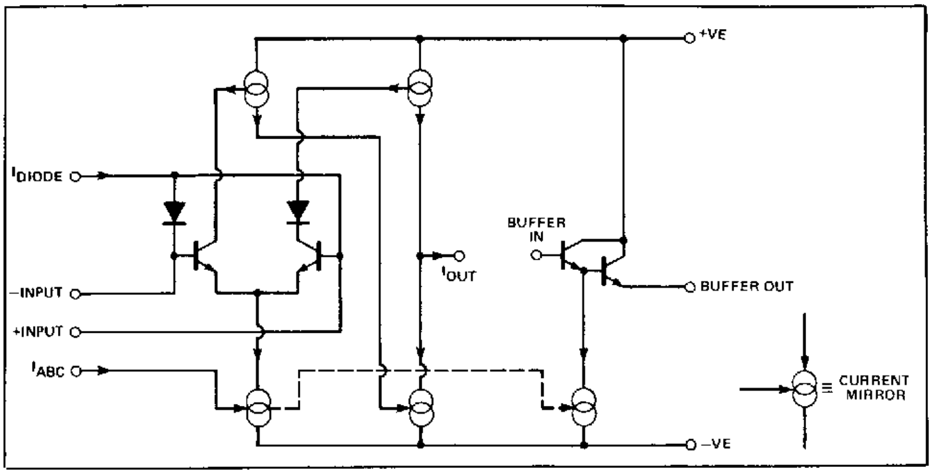
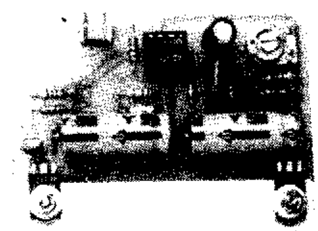
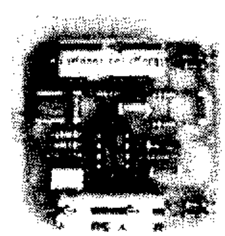


Fig. 2 Internal circuitry of the LM13600 — an operational transconductance amplifier!





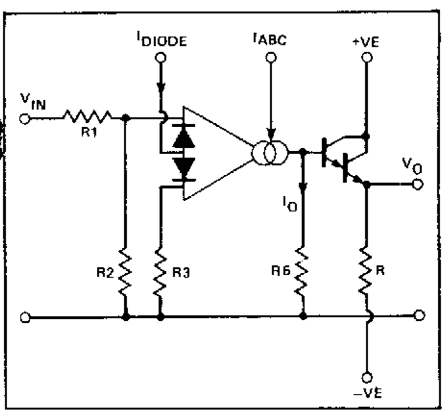


Fig. 3 Basic voltage amplifier circuit.

Compressing With The LM13600

Figure 5 shows the circuit used in this project to compress the dynamic range of the signal input. For very small signals I_D is virtually zero and the amplifier operates with a very high gain. As the signal increases, the output peak voltage will reach a level sufficient to charge the capacitor C to about one diode drop. If the input signal tries to increase further, the resulting current into the input diodes will cause their impedance to fall, thus increasing the attenuation of the input and maintaining a constant output level.

At any time the current flowing into the diodes is:—

$$I_D = 2 \times \frac{(V_o - 3 \times 0.7)}{R2}$$

The 3 x 0.7 represents the voltage drops associated with the base-emitter junctions of the output buffer transistors and the voltage drop of the linearising diodes. This voltage does vary with temperature and current, and since another control current is required for the expander function, this is derived by using a resistor and common base transistor. The configuration gives a current output which tracks the compressor control current very closely, since it has the same number of junctions in series.

The LM13600 As An Expander

If the current produced by the above circuit is fed into the bias current input of a virtually identical stage while the diode current is held a constant, then the voltage gain equation above shows that the gain of the circuit will be increased as the current increases. Moreover the product of the two gains will be constant giving an invariant overall signal transfer function.

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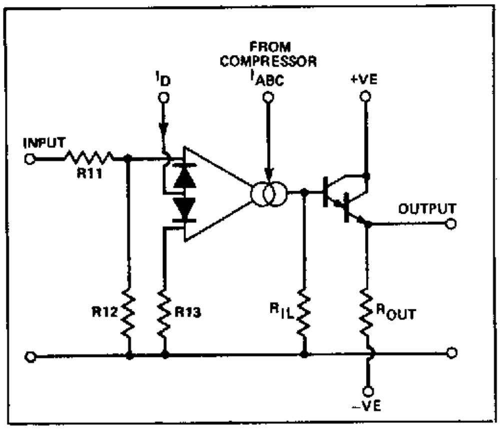


Fig. 4 The LM13600 as an expander.

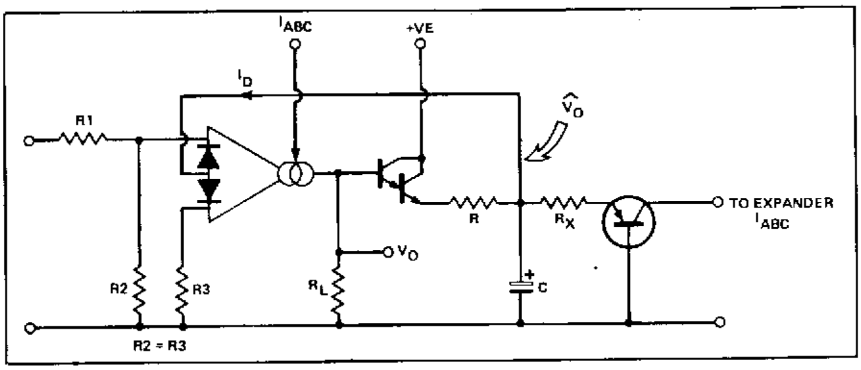


Fig. 5 Here the LM13600 is configured as a compressor.

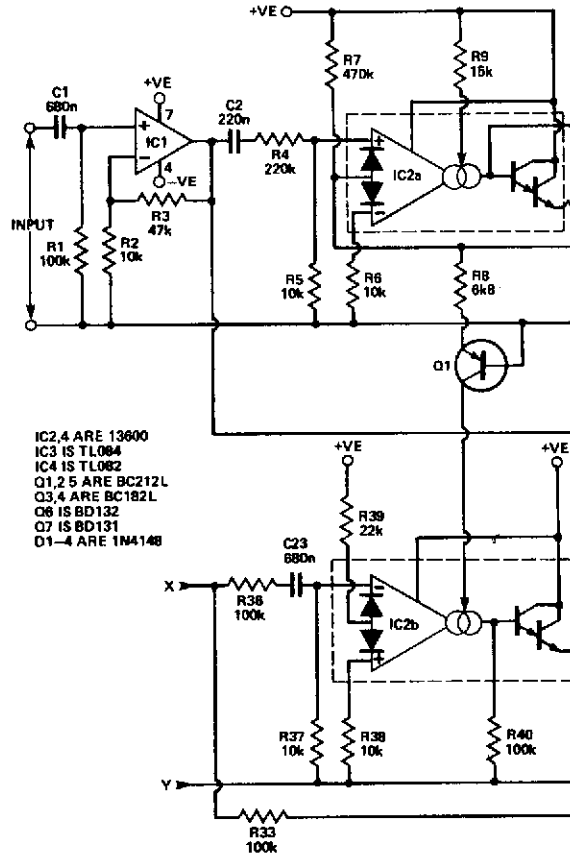
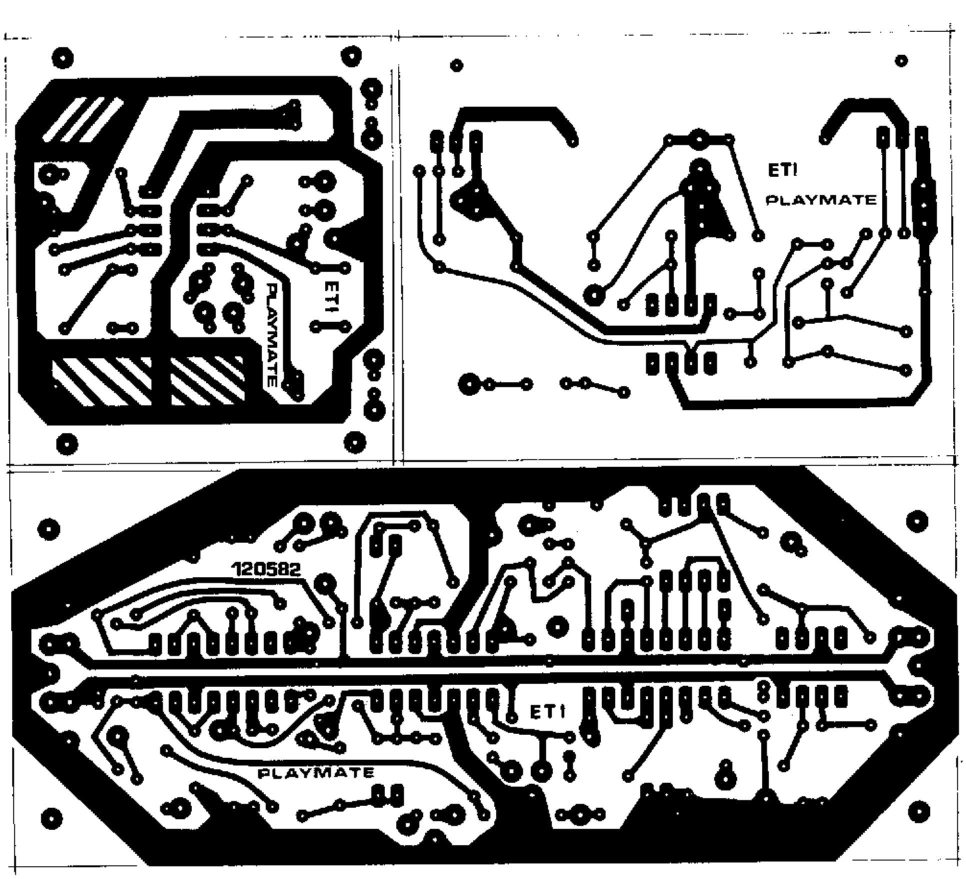


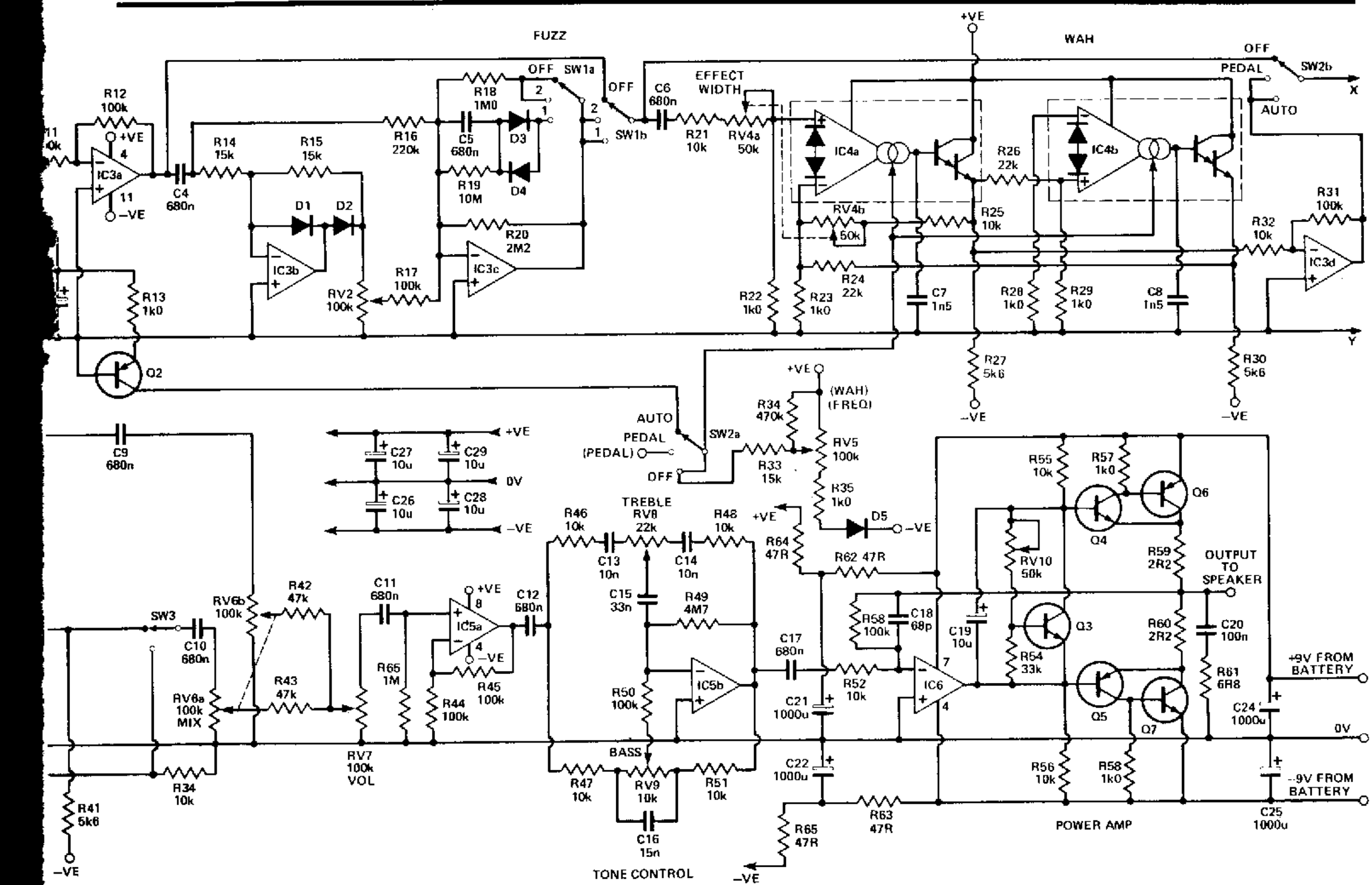
Fig. 6 Circuit diagram for the Playmate.



How it Works

The gain of the input buffer IC1 is set by R2 and R3 at 48. R1 determines the input impedance while C1 provides DC blocking. The output from this device goes to the dynamic range compressor IC2a and its buffer IC3a. This part of the circuit also provides control signals for the expander circuit and, if required, for the wah wah effect. The buffered output from the compressor then goes via C4 to the first part of the fuzz effect circuitry constructed around around IC3b. Here an inverted half-wave-rectified version of the input signal is produced by the action of D1 and D2 in the feedback network of IC3b. This is applied to RV1 from which a portion is selected and mixed with a little of the original signal. As the half-wave-rectified signal at this point of the circuit is twice as great as the straight-through signal, by varying the setting of RV1, amounts of distortion varying from none to virtual frequency doubling can be selected.

The mixture of signals obtained above is now applied to IC3c where they are amplified. The amount of amplification is determined by the setting of SW1. In position 3 minimum gain is provided and in fact the whole fuzz section is bypassed. Position 2 gives the same gain, allowing the first distortion stage to be effective. The final position connects D3 and D4 via C5 and R19 into the feeback circuit of IC3c instea of R18. This has the effect of greatly i



creasing the small signal gain but causing the output to limit sharply, thus clipping and squaring the output. This facility is available on whatever output is coming from IC3b.

The output from the fuzz stages now passes to the wah wah. This effect is produced by the current controlled state variable filter used in a band-pass mode. The filter is realised by using a LM13600 device with a controlled bias current providing the variable centre frequency. The 'Q' factor is controlled by a dual gang potentiometer, half of which is used to control the 'Q' factor while the other half compensates for the effective gain change as this is altered. In this type of circuit the frequency range is determined by the values of C7, C8, R24 and R26, while the actual centre frequency is controlled by the amplifier bias current. If the bias current is allowed to become too small it is sometimes found that a thump is heard at the output; in order to prevent this R34, R35, D5 and R33 are used in the control circuitry to keep the current above this threshold.

SW2 selects between the control options for the wah wah circuit. The 'off' position bypasses the circuit altogether, the 'pedal' position makes access to an external foot pedal if fitted, while the 'auto' position connects to an output from the compressor stage. This control signal is a current which is proportional to the amount of signal compression being applied to the input signal. The magnitude of this current increases as the input signal increases. The result of this is that when the input signal is loud, the wah wah centre frequency is high and as the input decays, the wah wah frequency decreases with it. The effect of this is to make a wah sound automatically whenever a string or chord is played.

The output from this section is buffered and adjusted in level by IC3d. After this the signal passes to the signal expansion stage built around IC2b. C23 provides DC isolation and R36 converts the input voltage to a suitable drive current for the IC. For this application the linearising diode current is held constant while the amplifier bias current is varied. Q1 in the compressor circuit provides the control current for this stage allowing a good match in the attenuation/gain characteristics of the two stages. SW3 selects either the output from the expander or bypasses it as required to give normal or sustain on the effects channel.

A dual gang potentiometer RV4 allows mixing between the original signal and the effect-modified signal. This is followed by a volume control RV5 to set the output sound level.

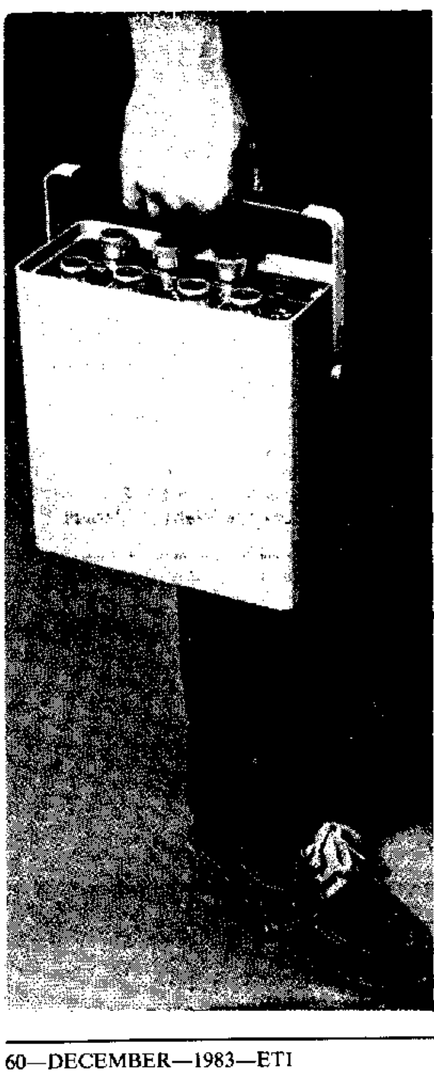
After the volume control, IC5a buffers the signal before applying it to the tone control circuit around IC5b. The configuration used here is a very common type of feedback arrangement. As an approximation, the gain of an op-amp with feedback is taken as —(feedback resistor value)/(input resistor value). If we replace the feedback and input resistors with variable impedances, we find that when the feedback impedance is greater than the input impedance then the overall gain is greater than unity, and vice versa. As impedances vary with frequency, the gain at each frequency will tend to be different. The only time the gain does not vary is when the input and feedback impedances are equal whatever their magnitude. This is the general principle on which the tone control networks operate.

The final section to be considered is the power amplifier stage. Voltage amplification is provided by IC6 and the output from it drives two complementary compound Darlington pairs, Q4/Q6 and Q5/Q7. Quiescent current through the output devices is set by RV8 in conjunction with Q3, R54 and C19. R59 and R60 aid in maintaining bias stability and provide some protection to the output transistors in the event of a fault. R61 and C20 compensate for load impedance variations at high frequency and C18 reduces the high frequency gain of the power amplifier to reduce the possibility of RF oscillation. The large capacitors C21-25 are to reduce the effects of aging batteries and prevent low frequency oscillation or intermodulation distortion.

The construction details, parts list and overlays will appear next month. ETI

Playmate Part II

For aspiring artists we conclude our portable guitar amp with added ingredients fuzz and wah. Design and development by Phil Walker.



BEFORE WE CONTINUE with our analysis of the circuit theory, we have to apologize for the manpower shortage last month which meant that the Playmate circuit diagram missed out on our usual thorough checking. Naturally the perversity of the universe ensured that this was the project that had several errors, so we're reprinting the circuit diagram with mistakes and duplicate component numbers corrected and all pots marked CW or CCW to tie up with the front panel wiring diagram. Meanwhile, back to the plot . . .

The State-variable Filter

Things start getting a bit heavy now! The following equations are the transfer equations for a state-variable filter such as that in Fig. 2:

$$V_x = [(R1/R3) \times V_{in} + (R2/R3) \times V_y] + R5/(R4 + R5) \times [1 + R3(R1 + R3)/(R1R2)] \times V_o$$

If R1 = R2 = R3 = R5, then:

$$V_x = -(V_{in} + V_y) + R1(1 + 2)/(R4 + R1) \times V_o$$

$$V_x = \frac{3R1V_o}{R4 + R1} - (V_{in} + V_y)$$

$$V_o = -1/sCR \times V_x,$$

$$V_x = -sCR\,V_o$$

$$V_y = -1/sCR \times V_o$$

Substitute (2) and (3) in (1):

$$-sCR\,V_o = \frac{3R1\,V_o}{(R1 + R4)} - (V_{in} + (-1)/sCR\,V_o)$$

$$\frac{V_{in}}{V_o} = (sCR + 3R1/(R1 + R4) + 1/sCR)$$

$$= j\omega CR + \frac{3R1}{(R1 + R4)} + 1/j\omega CR$$

$(s = j\omega,\ \omega = 2\pi f,\ f = \text{frequency}$

Fig. 1. (Right) The correct version of the circuit diagram — sorry ...

Compare this with the equation for an LCR tuned circuit:

$$V_{in} = (j\omega L + 1/(j\omega C) + R)\, I_{out} \qquad \text{(Fig. 3)}$$

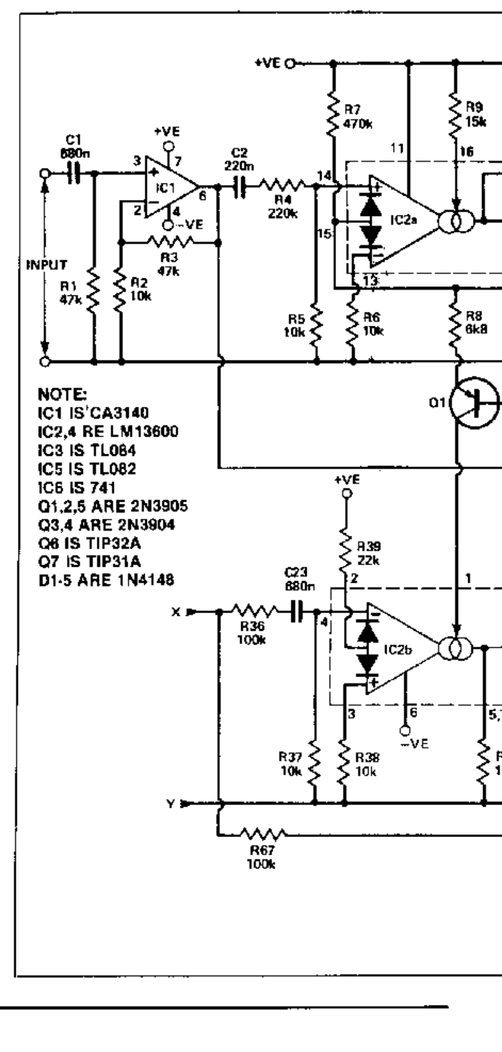
$$\frac{V_{in}}{I_{out}} = j\omega L + R + 1/(j\omega C) \quad \text{(LCR circuit)}$$

$$\frac{V_{in}}{V_{out}} = j\omega CR + \frac{3R1}{(R1 + R4)} + 1/(j\omega CR)$$

(State variable filter)

From this it is apparent that these responses are similar except that the LCR circuit gives a current output rather than a voltage. For this type of LCR circuit, the frequency of minimum attenuation or maximum gain (the resonant frequency) is given by:

$$f = \frac{1}{2\pi\sqrt{LC}}$$



For our circuit this is: —

$$\frac{1}{2\pi\sqrt{CR.CR}} = \frac{1}{2\pi CR}$$

The 'Q' factor influencing the bandwidth is given by:

$$Q = \frac{2\pi \ f \ L}{R} = \frac{2\pi \times (1/2\pi CR) \times CR}{3R1/(R1 + R4)}$$

$$= \frac{R1 + R4}{3R1}$$

Figure 4 shows the configuration necessary to use the LM13600 as a filter of this type. Last month we found that the transfer function of the LM13600 with no diode current is given by:

$$I_{out} = \frac{I_{abc}}{26 \times 10^{-3}} \times V_{in}$$

As we are using a capacitative load, this output current will generate a voltage of·

$$V_{out} = I_{out} \times \frac{1}{j\omega C}$$

$$= V \times \frac{I_{abc}}{26 \times 10^{-3}} \times \frac{1}{j\omega C}$$

$$= V_{in} \frac{R1}{R1 + R} \times \frac{I_{abc}}{26 \times 10^{-3}} \times \frac{1}{j\omega C}$$

Since we are not dealing with a normal type of op-amp, analysis of the circuit is not as easy as the normal filter, but the result is an equation of much the same form. We do not show all the derivation here as it would occupy most of a page. However, the end result is that the centre frequency of the filter pass band is proportional to the amplifier bias current. Therefore we have an easy way to control the wah wah effect.

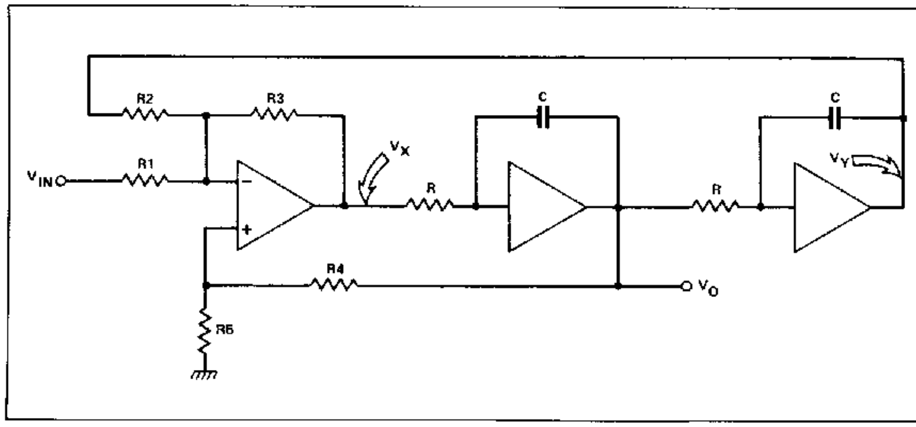
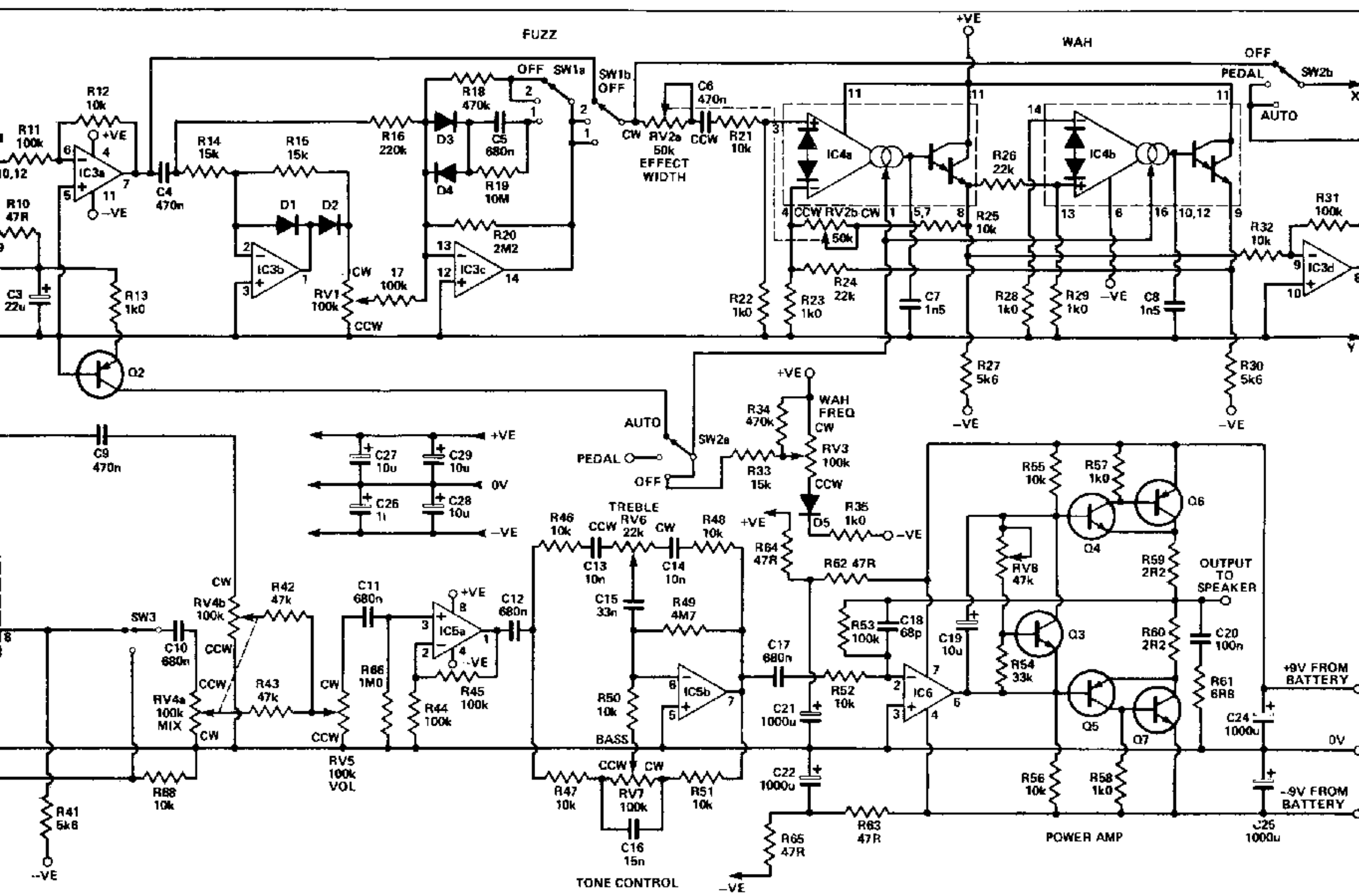
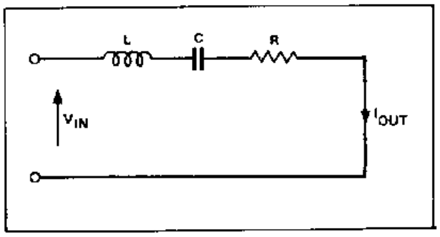
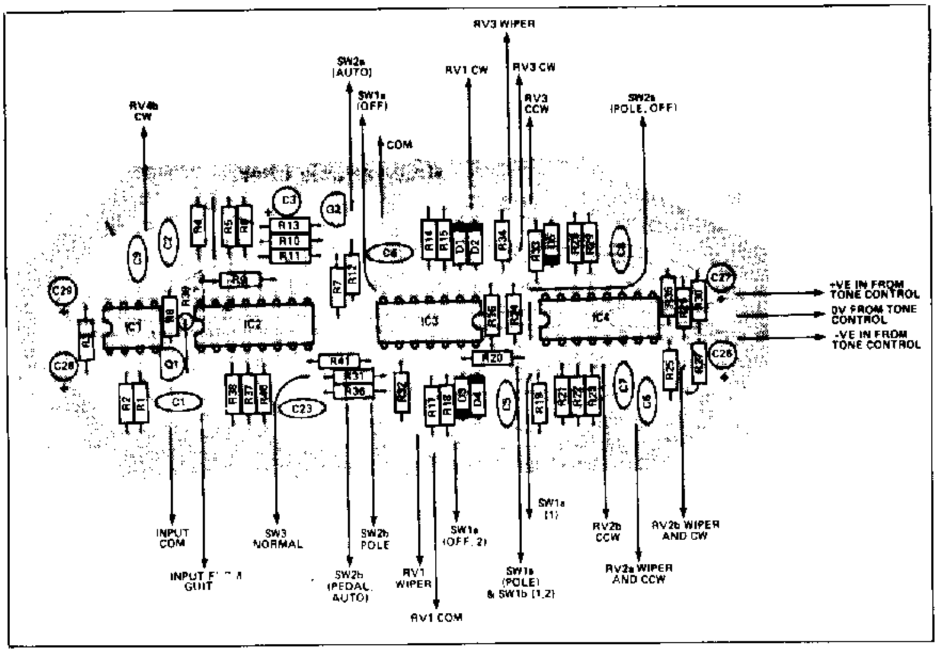
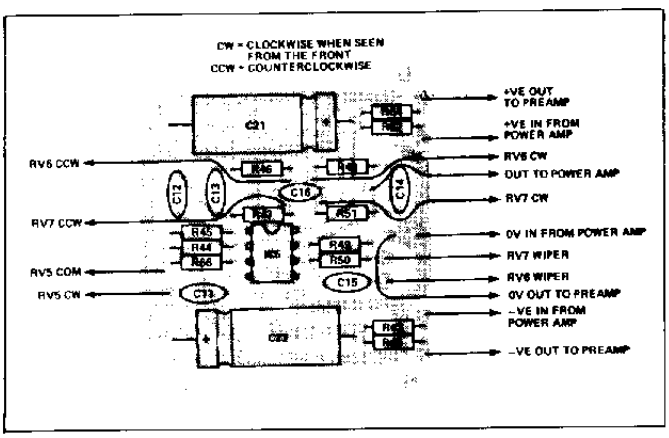


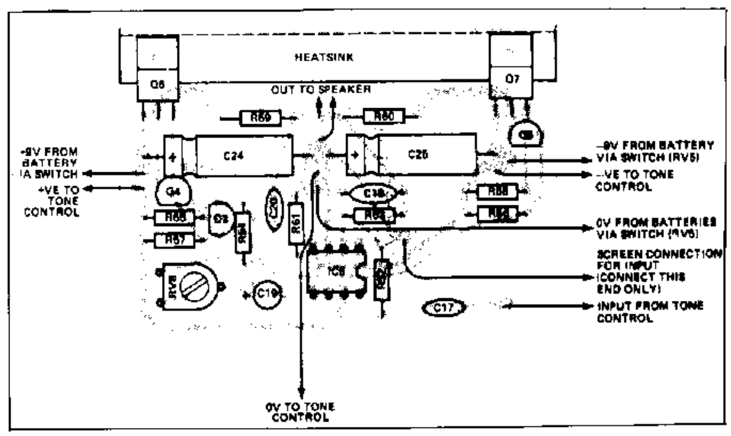
Fig. 2. Generalized state-variable filter.







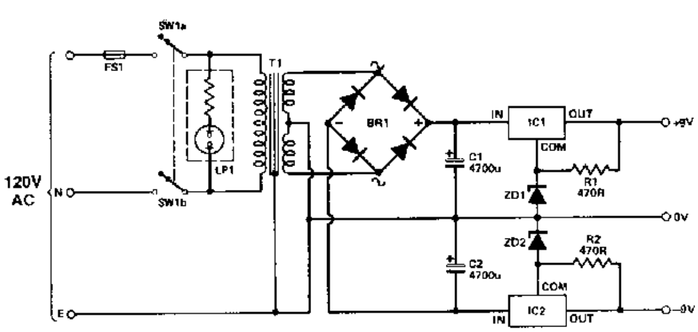




Construction

Except for the controls, almost all the components for this project are mounted on the three PCBs. The preamplifier board is the largest and most densely packed. It is advisable to use sockets for the ICs and don't forget the links. The capacitors used in the project should be as small as possible, otherwise you will have difficulty fitting them. A fine tipped soldering iron will be useful when assembling the boards and care should be taken to avoid creating short circuits between tracks with accidental solder splashes.

Ensure that all the diodes, transistors and other polarized components (especially IC3) are fitted the correct way round. On the power amplifier board the output transistors are mounted on top of a short length of ½" x ½" aluminum angle which acts as a heatsink. The transistors and the angle are held in position by the transistor mounting screws.



Parts List

R1,2	270R ¼W 5%
C1,2	4700u 25 V electrolytic
IC1	7805
IC2	7905
ZD1,2	3V9 400 mW zener
BR1	1 amp bridge rectifier
T1	9-0-9 12 VA transformer, 100 mA or more
SW1	DPDT miniature rocker or slide switch
FS1	1 A 200 mm fuse and holder
LP1	120 V panel neon with integral resistor

PARTS LIST

Resistors (All ¼W 5%)

R1,3,42,43	47k
R2,5,6, 12,21,25, 32,37, 38,46-48, 50-52,55, 56,68	10k
R8	220k
R7,18,34	470k
48	6k8
R9,14,15,33	15k
R10,62-65	47R
R11,17,31, 36,40,44, 45,53,67	100k
R13,22,23, 28,29,35, 57,58	1k0
R19	10M
R20	2M2
R24,26,39	22k
R27,30,41	5k6
R49	4M7
R54	33k
R59,60	2R2
R61	6R8
R66	1M0

Potentiometers

RV1,3,7	100k linear
RV2	50k linear dual gang
RV4	100k linear dual gang
RV5	100k logarithmic with two-pole switch
RV6	22k linear
RV8	47k miniature horizontal preset

Capacitors (All polycarbonate except where stated)

C1,5,10-12 17,23	680n
C2	220n
C3	22u 16 V tantalum
C4,6,9	470n
C7,8	1n5
C13,14	10n
C15	33n
C16	15n
C18	68p
C19	10u 35 V tantalum
C20	100n
C21,22,24, 25	1000u 10 V axial electrolytic
C26-29	47u 10 V PCB electrolytic

Semiconductors

IC1	CA3140
IC2,4	LM13600
IC3	TL084
IC5	TL082
IC6	741
Q1,2,5	2N3905 or equiv.
Q3,4	2N3904 or equiv.
Q6	TIP32 or equiv.
Q7	TIP31 or equiv.
D1-5	1N4148

Miscellaneous

SW1,2	2-pole, 3-way miniature slide switch
SW3	1-pole, 2-way miniature slide switch

PCBs; case (220 x 105 x 230mm), Vero Ref. 75-2443A; wire (single, single screened and double screened); 4" or 5" loudspeaker (8 ohms, 5 W); standard ¼" jack socket for input; stereo jack socket for foot switch (if required); 75 mm or 12 x 12 mm aluminum angle; two 9V batteries and clips.

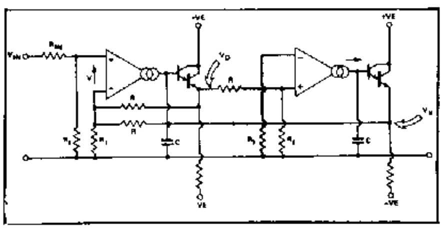
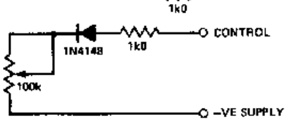


Fig. 4. Using the LM13600 as a state-variable filter.

Suggested Foot Pedal



The first diagram shows the circuit used with a three-connection (stereo) jack. This will duplicate the effect of the panel-mounted control. As the angular rotation of foot pedal controls is sometimes limited, some adjustment of position may be necessary to get best results. If the range of control isn't wide enough, change to a higher value. The link on SW2a should be removed for this circuit. The second diagram shows a simple circuit for use with ordinary jack connectors which can be used if the link between SW2a pole and off position is retained.

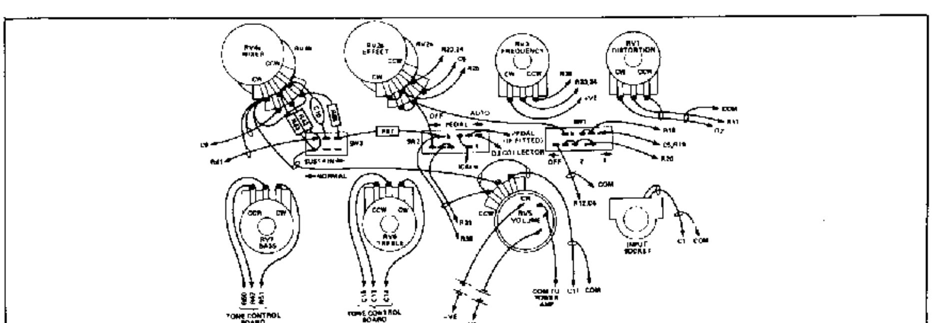


Fig. 8. How to wire the front panel. Compare with the front panel photo last month.

Mount the control switches and potentiometers on the front panel (see photo for our layout) and make the necessary interconnections and fit the three components needed around the balance control. The wiring from the front panel to the preamplifier/effects and the tone control boards should be carried out using thin flexible wire for control signals and miniature screened cable for any sound signals. These should be short, but allow enough slack to be able to fit them in position easily (it is probably easier to connect all the wires to the circuit boards first). The power amplifier board was fitted to the metal base plate of our case using the angle on which the transistors were mounted. It was positioned so that it fitted neatly between the two batteries in the bottom of the case. Together with the loudspeaker, the amplifier board holds the batteries without any further help.

The small loudspeaker for this project was mounted on the plastic case of the box through which a number of holes were drilled to let the sound out. If required, a small mains power unit capable of 9-0-9 V at 100 mA or more may be used to power the unit.

A foot pedal control for controlling the wah wah effect could be plugged into a jack socket. This would need to be one of the three-connection or stereo type so that positive and negative supplies as well as the control signal could be connected.

ETI