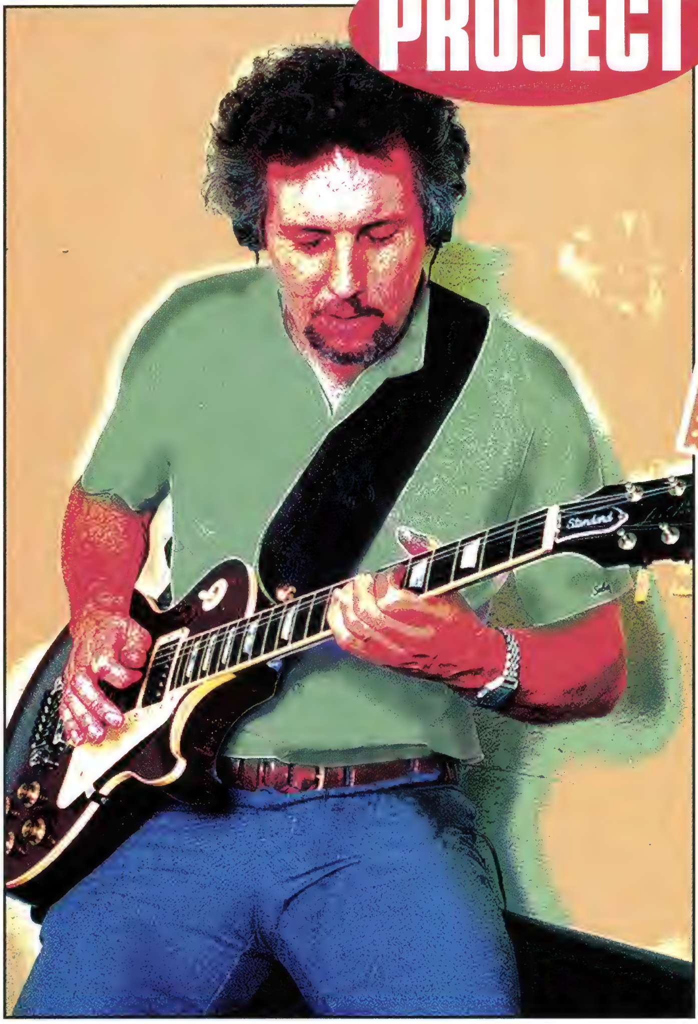


Guitar Amplifier WITH EFFECTS

PART 2

In part 2, Gavin Cheeseman gets down to construction

Introduction

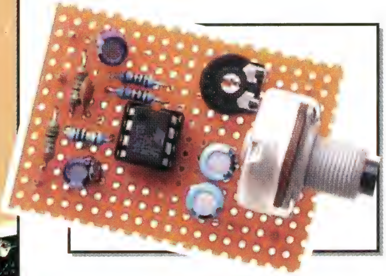
This month we look at building a home guitar practice amplifier with integral Fuzz and Wah Wah effects.

Input Stage

The circuit diagram of the input stage is shown in Figure 1. Based around a single operational amplifier, this circuit acts as a buffer providing a high impedance at the input to interface to a guitar transducer and a low output impedance suitable for driving effects circuits etc. The stage can also provide a level of gain when required, controlled by variable resistor VR1. Resistors R1 and R2 provide a half supply reference level for the non-inverting input of the op-amp via R3 which is the main factor that determines the input impedance. The gain of the stage at audio frequencies is set by resistors R4, R5 and VR1. Capacitor C4 provides a low frequency roll off and C5 reduces gain at high frequencies. Supply decoupling is provided by C3 and C6. The output of IC1 is coupled to Output Level Control VR2 via C7. The output is made available on terminal P5.

Fuzz Effect

The Fuzz Effect circuit is shown in Figure 2. In common with the input stage this section also uses a single op-amp but this time the inverting configuration is used. As described last month, this type of effect is produced by clipping the signal. Signals are coupled to the input of the amplifier via C2. The maximum gain of the stage is set by the values of R3 and R4, however, when the output signal (IC1 pin 6) swings high or low enough for any of the diodes (D1 - D4) to conduct, further signal swings in that direction are severely limited. The overall effect is to produce a clipped waveform rich in harmonics. The type of clipping produced by the circuit is determined by the diode configuration and this is controlled by switch S1. When S1 is closed only D1 and D2 are effectively in circuit (D3 and D4 are bypassed). This results in a waveform that is clipped symmetrically (at approximately the same point on each half cycle). With S1 set to the open position the effect is slightly different. In this mode the onset of clipping occurs at different levels on the positive and negative parts of the cycle. The effect is a modified harmonic response and a different (perhaps less harsh) sound. Capacitor C5 limits the high frequency response of the circuit and C6 couples the output signal to terminal P5.



Wah Wah Effect

The Wah Wah effect can be configured for either automatic or manual operation. Figure 3 shows the circuit. The stage comprising IC1, with R1, R2 and C2 providing a half supply reference for other relevant parts of the circuit. Supply decoupling is important in this circuit and is provided by C1, C3, C4, C7 and C8. The heart of the circuit is IC4, the popular LM13700 transconductance op-amp configured as a voltage controlled filter. Input signals are applied to terminal P3 and the output is available at P7. The centre frequency of the filter is determined by a positive voltage applied to P6 (this must not exceed the positive supply voltage). A variable voltage (for example, from a potentiometer) may be connected to P6 to allow the centre frequency to be manually swept. This creates the well known Wah Wah effect.

The filter may also be swept automatically. Op-amp IC2 and associated components form a simple low frequency oscillator. The switching threshold of the oscillator and ultimately the output amplitude is determined by VR1 and R5 and the oscillator frequency is set by R6, VR2 and C5. The output of the oscillator is buffered by IC3 and made available on terminal P5. The filter may be automatically swept by connecting the output at P5 directly to P6. This results in a variety of Wah Wah type effects depending on the settings of VR1 and VR2.

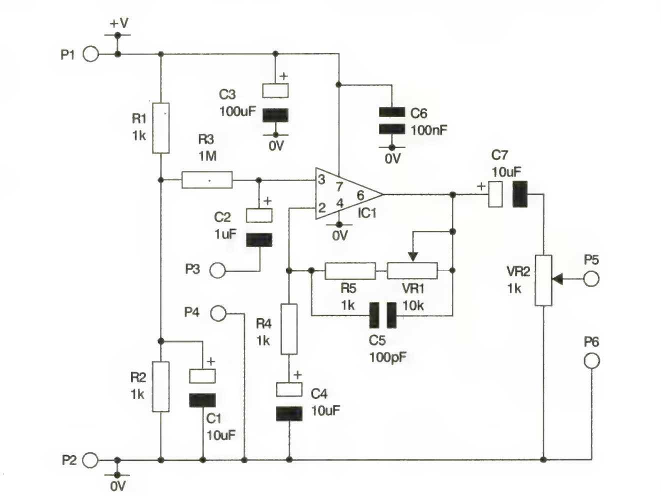


Fig 1 Input stage circuit diagram

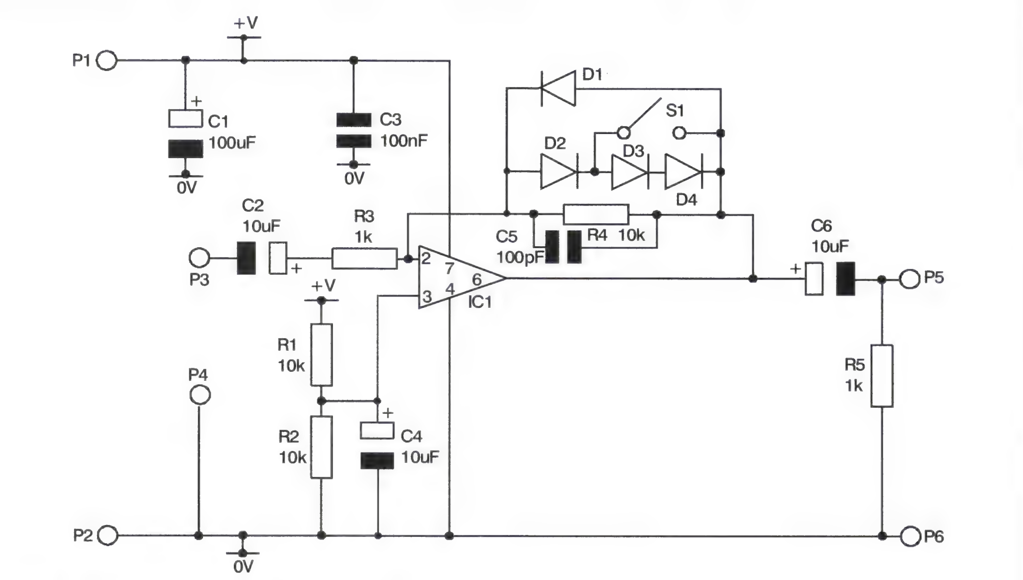


Fig 2 Fuzz effect stage circuit diagram

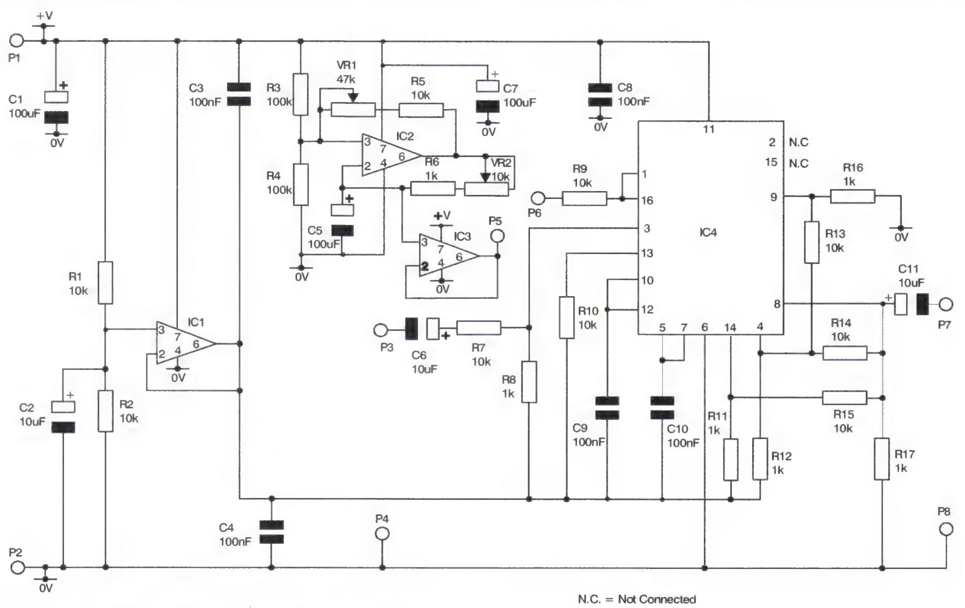
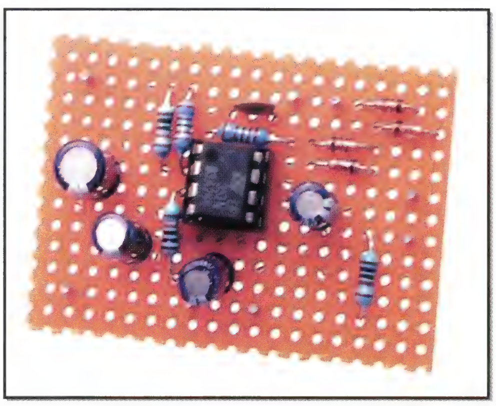
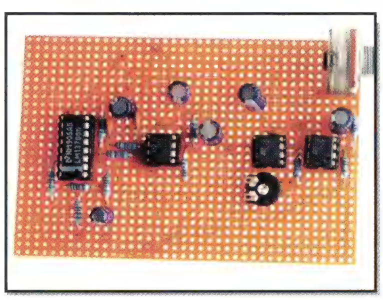


Fig 3 Wah Wah effect circuit diagram



Tone Controls and Power Amplifier

Referring to Figure 4, the tone control stage comprises C1 - C3, C7, C8, R2 - R4, VR2 and VR3. VR2 controls the treble and VR3 affects the bass although there is inevitably some interaction between the two controls. The input to the tone control circuit is applied on terminal P3. R1 and VR1 set the input level. The output of the tone control stage is available at P5 and is coupled to one input of power amplifier IC1 via capacitor C5. IC1 is configured to provide two individual channels. The input on IC1 pin 1 is connected via the tone control stage and would normally be used as the main input channel. The corresponding output is available at P10. Alternatively an input signal may be applied directly to P6 with the corresponding output on P9. This input has no level or tone controls and is an entirely separate channel. For convenience we will call this the auxiliary channel. Either output may be used to drive a suitable 4 or 8Ω loudspeaker connected between the relevant output terminal and 0V. The power handling capability of the loudspeaker should be suitable for output level. Capacitors C13 and C16 are included to reduce the gain of the amplifier at high frequencies and values are typically in the order of a few pF. The actual value chosen depends on the required response. In practice these components can usually be omitted but may be required if instability or high frequency pick-up is a problem.



Constructing the Modules

All four circuits are capable of exhibiting gain and are therefore prone to unwanted noise and earth loop problems if an unsuitable component layout is used. Problems mainly occur where earth returns are connected incorrectly and where excessive lengths of unscreened lead are used to connect to sensitive inputs. Where signal connections exceed a couple of cm screened leads should be employed. Separate sets of power supply connections (+V and 0V) should be used for inputs and outputs and all 0V connections should be connected back to one single point (star earth). High frequency decoupling capacitors (100nF) should be connected as close to the relevant active components as possible. This helps to reduce any high frequency noise on the supply rails which can be coupled back to the circuit input.

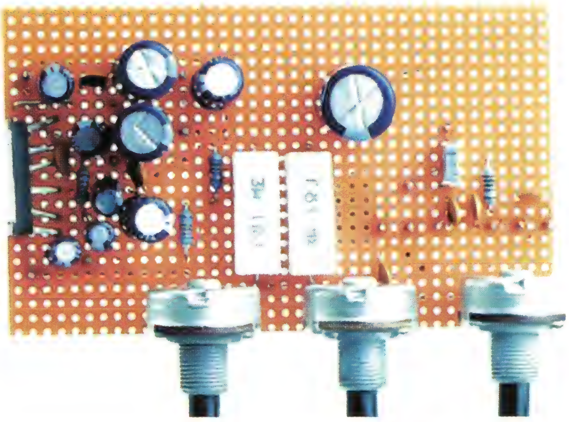
Where possible, it is recommended that DIL sockets are used for the ICs, so as to avoid damage during soldering. Of course this does not apply to the power amplifier IC (tone control/power amplifier circuit IC4) as this does not use a DIL pinout. Furthermore, this device can operate at a relatively high temperature when fully driven and normally requires heatsinking. These points must be borne in mind when the deciding on the physical orientation of the IC, and most importantly, there must be adequate air flow around the device. As a precautionary measure, the IC case should not be allowed to come into direct contact with the circuit board and cable insulation should be kept clear, although when correctly heatsinked the temperature should remain within acceptable levels.

It is normal to mount the device in the upright position perpendicular to the PCB. If you are using matrix board, it may be necessary to slightly rearrange the lead positioning to correspond with the holes in the circuit board; however, the leads must not be allowed to short together as this could be disastrous . Remember to allow enough room for the heatsink. Power supply leads, both on and off board, should be suitable for the current drain of the amplifier IC (see power supply considerations).

Similar considerations apply resistors R10 and R12 of the power amplifier circuit. These normally run cold except under certain fault conditions but it is sensible to mount the two resistors such that the component bodies are raised slightly above the PCB.

Variable resistors can be mounted on or off board. Wiring the controls off board

Tone control stage.



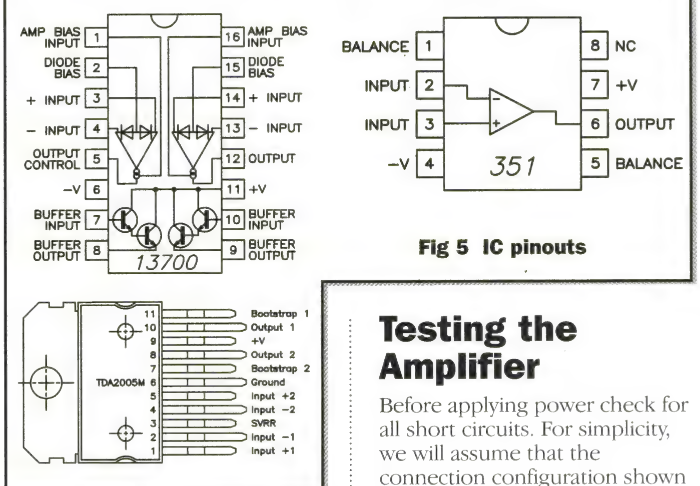


Fig 5 IC pinouts

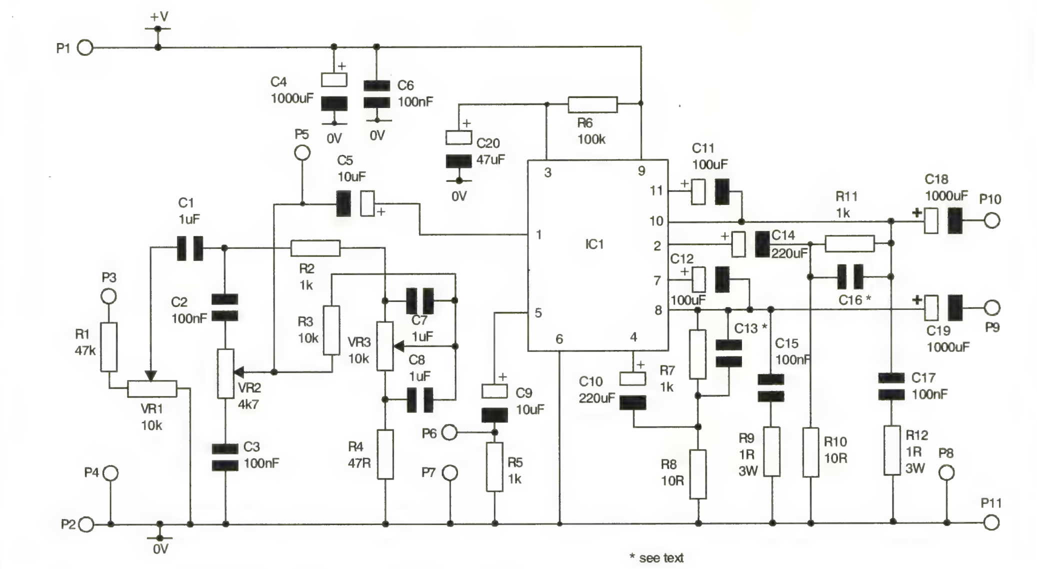


Fig 4 Tone control/power amplifier circuit diagram

may make panel mounting easier but can result in instability or noise pickup if lead lengths are excessive.

The pinout information for the main semiconductors used is shown in Figure 5.

Connections

There are various ways to connect the modules. A suitable configuration using all four circuits is shown in Figure 6. The arrangement shown allows different effects to be switched in and out. Terminal designations for each circuit are shown in Figure 7 - Figure 10 for reference. Connections between the modules should be kept very short as far as possible. Of course, there is no reason why all four modules cannot be built as a single unit offering the advantage of minimising off board connections.

Power Supply Considerations

All circuits are designed to operate from a 12V DC power supply. The power supply must be capable of delivering enough current for the power amplifier stage. The actual current consumption depends on the loudspeaker impedance, how hard the amplifier is being driven and how many channels are in use. When driving a 4_ loudspeaker from one channel a 1A power supply is adequate. If both amplifier channels are in use a higher current supply may be required.

For safety reasons, it is essential that the power supply is suitably fused so as to minimise any damage should a short circuit occur. A degree of protection is provided by the power amplifier IC itself, but this only applies to specific fault conditions such as output short circuit or thermal overload. Sometimes the power supply used may not be capable of delivering enough current to blow the fuse. If this is the case, check that the necessary short circuit protection is provided within the power supply itself. Of course, it goes without saying that the 12V power supply output must be fully isolated from the mains supply. Never attempt to use a power supply that does not provide the appropriate protection.

Testing the Amplifier

Before applying power check for all short circuits. For simplicity, we will assume that the connection configuration shown in Figure 6 is used and that the mode selection switch is set such that all four modules are connected in series and active.

The power supply terminal connections for each of the four modules are the same. The fused +12V connection is made to terminal P1 and 0V is connected to P2. A multimeter set to read current (amps) may be connected in series with the positive power supply rail so as to monitor the current consumption. It is sensible to set all variable resistor level controls to the minimum position to start with. This particularly applies to VR1 on the tone control/power amp module.

In order to test the unit a signal source is required. Initially, this may take the form of a signal generator or a guitar with a suitable pickup. An oscilloscope is also useful if available but is by no means essential.

Apply power to the guitar amplifier. With no input signal present, the current consumption should not exceed 200mA total. If a higher current drain is measured, this suggests there is a problem. In this case, switch off immediately and re-check all connections. Typical causes are incorrect connections, short circuits or instability. To provide additional protection when power is applied to the circuit for the

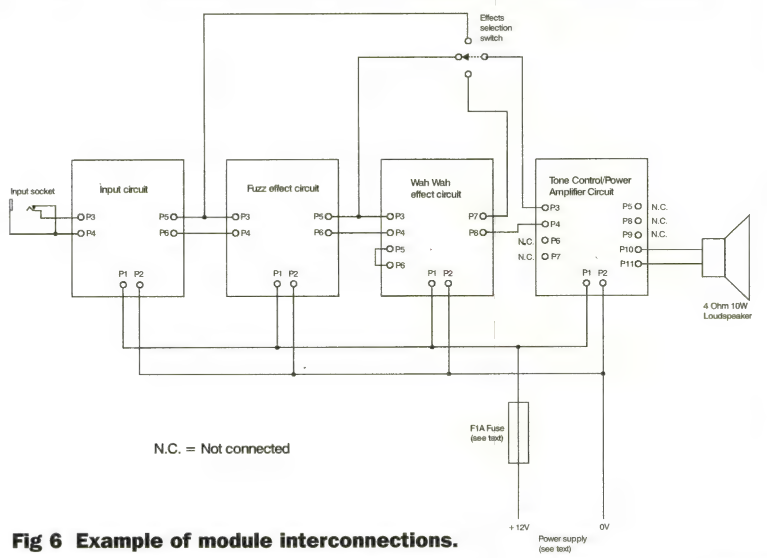


Fig 6 Example of module interconnections.

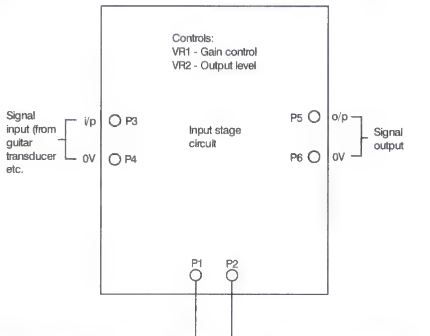


Fig 7 Input circuit terminal connections

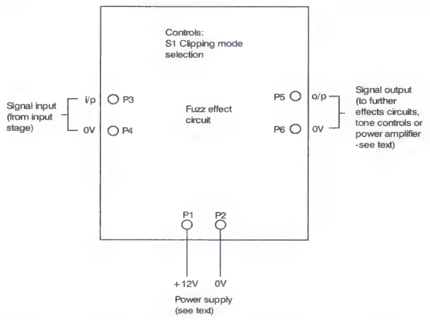


Fig 8 Fuzz effect circuit terminal connections

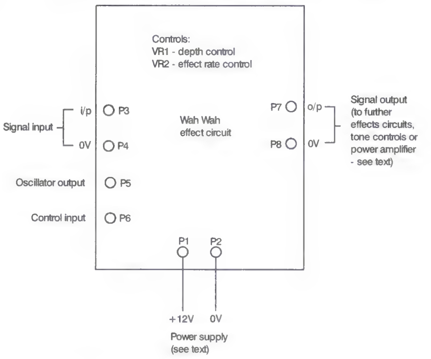


Fig 9 Wah Wah circuit terminal connections

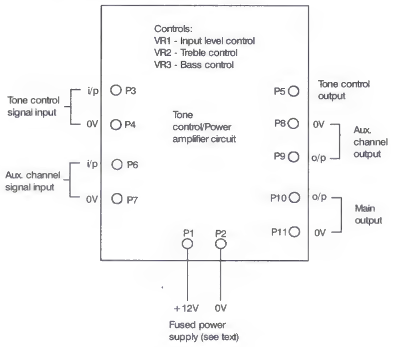


Fig 10 Tone control/power amplifier terminal connections

first time, you may wish to connect a lower rated fuse in series with the positive supply rail (e.g. F200mA). This fuse should be replaced with the standard rating, once it is determined that the current drain is within the correct limits.

Assuming that everything appears to be correct, slowly increase the setting of level control VR1 on the tone control/ power amp module. With no signal applied, this should result in very little increase in supply current. It should be possible to hear noise from the loudspeaker as the volume is increased. Set tone controls VR2 and VR3 on the same module to centre position. Adjusting these controls will normally result in a variation in the output noise level. If available an oscilloscope may be connected to the power amplifier output terminals to check that no unwanted high frequency oscillation is present. Reduce the setting of VR1 such that the wiper is set to approximately central position.

Apply a suitable signal source between P3(i/p) and P4(0V) of the input module. Set VR2 on the input module to approximately half way position. If you are using a signal generator, the amplitude should be set to the lowest level to start with. Slowly increase the input signal level. An oscilloscope may be used to check that an output is present at input module terminal P5. An output should also be audible from the loudspeaker.

Adjusting input module gain control VR1 or level control VR2 should affect the level at the final output. If you have an oscilloscope, connect this to the output of the Fuzz effect stage (P5) and note the effect of adjusting the input level. At low levels the signal should remain relatively undistorted but as the level is increased, distortion (clipping) should be introduced. The onset of distortion should be audible at the output but if the Wah Wah effect is in line this will be less noticeable due to the filtering effect of this stage. With S1 closed, clipping should be fundamentally symmetrical. Opening the switch contacts should result in a greater signal amplitude and loss of symmetry.

When the Wah Wah effect is switched in and configured to operate in automatic mode the swept filter effect is clearly audible at the amplifier output. Check that adjusting Wah Wah module controls VR1 and VR2 results in a variation to the depth and rate of the effect.

Once everything appears to be working correctly connect a guitar if you have not done so already and carry out any final checks to ensure that all sections of the guitar amplifier are operating.

Housing

The sound of the amplifier is, to a large degree, as much dependant on the acoustic characteristics of the loudspeaker housing as it is on the electronics. Loudspeaker cabinet design is a complex subject but in general terms you cannot expect the same performance from a small box of random dimensions as you will achieve using a purpose designed cabinet. Although the tonal requirements for guitar amplifiers are probably somewhat different to those of hi-fi speakers, a little time planning and experimenting can pay dividends in terms of achieving the sound you want. For those interested, a number of books are available covering speaker cabinet design (see Books Section of the current Maplin Catalogue). It is not by any means essential for the guitar amplifier to form part of the loudspeaker cabinet. The amplifier can be mounted in a separate case with an output socket to allow connection of an external loudspeaker. For example, although perhaps not ideal, a hi-fi speaker could be used, as long as it has a suitable impedance and power rating.

Using the Guitar Amplifier

The modules described provide a low cost method of producing an amplifier for use with a range of guitars. The system is well suited to use with add on guitar transducers such as stock code BM97F. These provide a simple method of driving an amplifier from an acoustic guitar and are ideal for beginners. However, one characteristic of some types of transducer is that they are quite prone to acoustic feedback. When switching off the amplifier it is always a good idea to reduce the output volume control, so that next time you switch the unit on you are not deafened by a sudden blast of noise and howl round.

Although the design does not generally provide the same level of performance as can be expected from a commercial amp and effects pedals, a useful range of effects can be produced. By varying the settings of the Fuzz and Wah Wah circuits a number of interesting sounds can be created.

Input Level

Because each of the modules is active and exhibits gain it will usually be necessary to adjust the level controls when switching from one effect to another. Always check that anything you intend to connect to the amplifier is fully compatible. The input stage is designed for relatively small signals in the order of a few mV and high level signals (e.g. line level) should not be used as these will result in overload. Also the input of the amplifier should not be connected to devices with a DC offset as this may overvoltage or reverse polarise the input coupling capacitor.

Gain Setting Depending on the signal input level driving the guitar amplifier, it may be necessary to adjust the gain of some of the stages. Level controls have been included to allow the gain to be reduced where the signal level is too high but if the input signal is insufficient to drive the Fuzz effect stage fully it may be necessary to increase the gain. Probably the easiest way to achieve this is to increase the value of R4 in the Fuzz effect circuit. It is recommended that the value does not exceed 100k.

The input level to the tone control stage can be increased by reducing in value or linking out R1 in the tone control/power amp circuit. The power amplifier will then be driven harder resulting in increased volume.

Circuit Modifications and Experimentation

As mentioned earlier, the circuits described in this article are designed with experimentation in mind and the component values and circuit configurations are intended to provide a starting point. The circuits are functional but are not necessarily fully optimised. More experienced constructors may wish to make modifications to improve or change the operation of the circuit. Also it is possible to connect the circuits in a different order or leave a module out if not needed. For example you may not require the Wah Wah stage. This is not a problem as long as input and output levels for each stage are correctly set up. This is partially determined by the output level produced by the guitar pickup.

Some readers may be interested in adding further effects circuits to the existing configuration. For example a compressor/limiter could be connected between the input stage the Fuzz effect stage to provide a relatively constant input level. A simple experimental circuit is shown in Figure 11 as an example.

The variable resistors specified in the parts lists are a mixture of

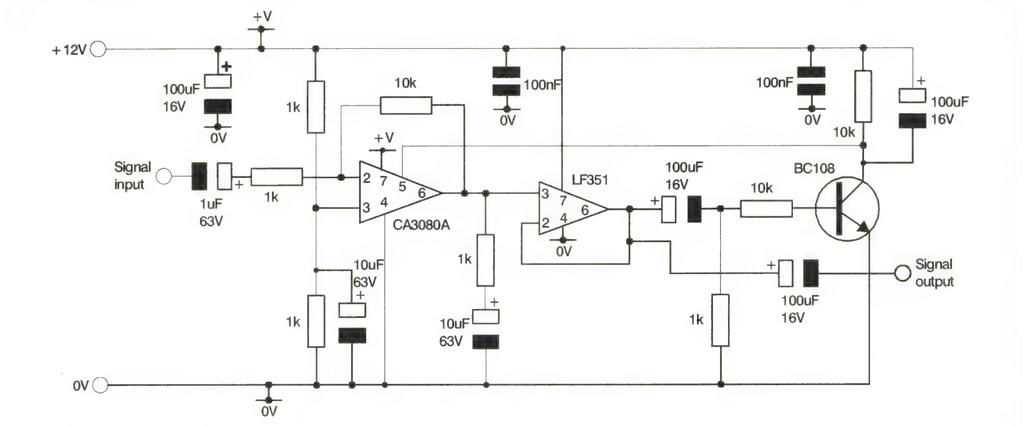


Fig 11 Experimental limiting circuit

preset and panel mounting types depending on function. For example, the input stage gain control (input circuit VR1) is specified as a preset variable resistor. This is because regular adjustment will not normally be necessary once the most appropriate gain is set. Conversely input circuit level control (VR2) has been specified as a panel mounting device as adjustment of this control will probably be more frequent (to change the input level to the following Fuzz effect stage). As long as lead lengths are kept short there is no reason why panel mounting potentiometers cannot be used in place of the preset types to allow easy access. Alternatively you may wish to minimise the number of panel mounted controls by replacing some of these with preset types. Suitable holes may be drilled in the guitar amplifier housing to allow access where necessary. Ultimately the choice is entirely down to the constructor.

Controlling the Wah Wah Circuit Manually

If required, the Wah Wah circuit may be operated manually by disconnecting P5 from P6 on the Wah Wah effect module and applying a variable control voltage to P6. The control voltage, which should not be allowed exceed the positive supply voltage (+12V) may be derived from a potentiometer. When set up correctly this allows a conventional foot pedal (with an internal potentiometer) to be used to control the effect. A switch may be used to select between automatic and manual settings (see Figure 12).

Other possible modifications include changing the response of the tone controls and modifying the frequency range of the wah wah circuit sweep oscillator. The latter may be achieved by changing the value of C5 in the Wah Wah circuit.

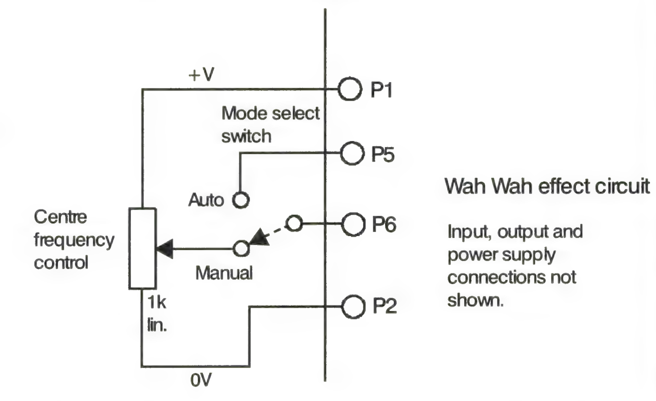


Fig 12 Using a switch to select between automatic and manual Wah Wah effects.

PROJECT PARTS LIST

INPUT STAGE

RESISTORS			
R1, 2, 4, 5	1k Min Res	4	M1K
R3	1M Min Res	1	M1M
VR1	Hor Encl Preset 10k	1	UH03D
VR2	Pot Lin 1k	1	FW00A
CAPACITORS			
C1, 4, 7	Gen Elect 10μF 63V	3	AT77J
C2	Gen Elect 1μF 63V	1	AT74R
C3	Gen Elect 100μF 16V	2	AT40T
C5	Ceramic 100pF	1	WX56L
C6	Minidisc 0.1μF 16V	1	YR75S
SEMICONDUCTORS			
IC1	LF351N	1	WQ30H
MISCELLANEOUS			
P1-6	Pin 2145	6 pins	FL24B
	DIL Socket 8-Pin	1	BL17T

FUZZ EFFECT

RESISTORS			
R1, 2, 4	10k Min Res	2	M10K
R3, 5	1k Min Res	1	M1K
CAPACITORS			
C1	Gen Elect 100μF 16V	2	AT40T
C2, 4, 6	Gen Elect 10μF 63V	3	AT77J
C3	Minidisc 0.1μF 16V	1	YR75S
C5	Ceramic 100pF	1	WX56L
SEMICONDUCTORS			
IC1	LF351N	1	WQ30H
D1-4	1N4148	4	QL80B
MISCELLANEOUS			
P1-6	Pin 2145	6 pins	FL24B
	DIL Socket 8-Pin	1	BL17T

WAH WAH EFFECT

RESISTORS			
R1, 2, 5, 7, 9, 10, 13-15	10k Min Res	9	M10K
R3, 4,	100k Min Res	2	M100K
R6, 8, 11, 12, 16, 17	1k Min Res	6	M1K
VR1	Hor Encl Preset 47k	1	UH05F
VR2	Pot Lin 10k	1	FW02C
CAPACITORS			
C1, 5, 7	Gen Elect 100μF 16V	2	AT40T
C2, 6, 11	Gen Elect 10μF 63V	3	AT77J
C3, 4, 8	Minidisc 0.1μF 16V	3	YR75S
C9, 10	Poly Layer 0.1μF	2	WW41U
SEMICONDUCTORS			
IC1-3	LF351N	3	WQ30H
IC4	LM13700N	1	YH64U
MISCELLANEOUS			
P1-6	Pin 2145	8 pins	FL24B
	DIL Socket 8-Pin	3	BL17T
	DIL Socket 16-Pin	1	BL19V

TONE CONTROL/POWER AMPLIFIER MODULE

RESISTORS			
R1	47k Min Res	1	M47K
R2, 5, 7, 11	1k Min Res	4	M1K
R3	10k Min Res	1	M10K
R4	47R Min Res	1	M47R
R6	100k Min Res	1	M100K
R8, 10	10R Min Res	2	M10R
R9, 12	1R 3W W/W	2	W1R
VR1	Pot Log 10k	1	FW22Y
VR2	Pot Lin 4k7	1	FW01B
VR3	Pot Lin 10k	1	FW02C
CAPACITORS			
C1, 7, 8	Poly Layer 1μF	3	WW53H
C2, 3, 15, 17	Poly Layer 0.1μF	2	WW41U
C4, 18, 19	Gen Elect 1000μF 16V	3	AT44X
C5, 9	Gen Elect 10μF 63V	2	AT77J
C6	Minidisc 0.1μF 16V	1	YR75S
C10, 14	Gen Elect 220μF 16V	2	AT41U
C11, 12	Gen Elect 100μF 16V	2	AT40T
C13, 16	See Text		
C20	Gen Elect 47μF 16V	1	AT39N
SEMICONDUCTORS			
IC1	TDA2005M	1	YY70M
MISCELLANEOUS			
P1-11	Pin 2145	11 pins	FL24B