Add sustain to your guitar

So you've built a guitar "fuzz box" but you've had just about enough of Jimmi Hendrix impersonations. Trouble is, most of us get bored with fuzz in short order. But what about the sustain effect without the distortion? With the new EA Guitar Sustain, that's just what you get.

by COLIN DAWSON

Fuzz circuits achieve sustain simply by virtue of their vast amounts of gain. The signal is then clipped down to a fixed level with diodes to produce the familiar distortion sound. This technique is simple and effective, unless you want sustain without gross distortion. What's required is a circuit with automaticaly adjusting gain — low to start with and increasing as the signal decays.

To meet this requirement, we have designed a circuit around the Signetics NE571 compander IC. This contains two independent variable gain devices and is intended primarily for use in communications equipment. Normally, one of the devices would be set up as a compressor for outgoing signals and the other as an expander for incoming signals. However, the IC is by no means restricted to this configuration. In fact, we have used one of the devices as a normal preamplifier and the other as an automatic level control.

Basically, the Sustain operates as a compressor with a very high compression ratio. This enables it to maintain a very nearly constant output level for a wide range of input levels — an automatic level control. There are, of course, limitations. The circuit cannot increase its gain indefinitely to compensate for a decaying input. Eventually, its maximum gain will be reached.

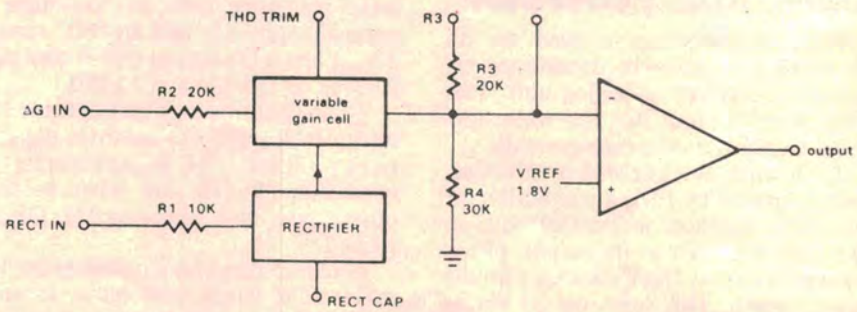
Even if infinite gain was available, each guitar note eventually reaches a practical end-point — it becomes submerged in the inherent noise of the pick-up. Beyond this point, amplification is pointless. Ideally, the compressor should reach its maximum gain before this end point is reached.

The automatic level control can both amplify and attenuate signals, as necessary to maintain a fixed output level, so the typical input signal should be at the midpoint — where unity gain occurs. This maximises the range over which compression is available. A problem arises in attempting to compress guitar signals in that the guitar output is never more than 100mV and less than 5mV towards the end of its normal decay pattern. This means that the compressor will always be amplifying (expanding) the signal, reaching its open loop gain well before the note has ended.

The obvious solution is to amplify the guitar output before compression occurs and this is exactly what our circuit does. IC1a forms a preamplifier with a maximum gain of 100. This brings the guitar output up to several volts. In fact, the output of IC1a could momentarily reach 10V peak with a firmly plucked guitar string. This provides an opportunity for the compressor to attenuate the signal.

A potential problem is inherent with input signals which very quickly reach a high level, such as a plucked guitar string. Unless the circuit has a fast response ("attack"), it will not track the signal. The signal will exceed the maximum level the control stage can handle, overloading it until the compressor has time to respond. This leads to a most unpleasant spike at the beginning of the note — clearly not desirable. The obvious solution is to provide a fast enough attack time.

Unfortunately, there is a conflicting requirement that has to be satisfied. If



The NE571 has three functional blocks.

the attack time is made too fast the compressor sees low frequencies as a variation in level, and attempts to smooth them out. This creates a particularly unpleasant form of distortion within the compressor.

In practice we have been able to select a compromise value which permits a minimum, and acceptable, distortion level due to either cause. We found that an attack time of around 1.2ms gave the best results, at least for the instrument we were using. Other instruments, or different playing styles, may call for some modification, and this is easy enough to provide.

Looking more closely at the NE571 IC we find that each section contains three main functional blocks: an op-amp, a precision rectifier, and a variable gain cell. Each of these blocks can be accessed individually, which greatly enhances the versatility of the IC.

In the control mode the variable gain cell is used as a feedback path for the op-amp. The gain cell is controlled by an input voltage derived from the rectifier output. The rectifier, in turn, may derive its input voltage from either the op-amp input or output, depending on the mode of operation.

Output from the rectifier must be filtered before being fed to the gain cell, otherwise extreme "fuzz" will result (no, that's not what we want, Jimmi). The filter capacitor to provide this is connected to pin 16 and is identified as "C Rect". Its value also controls the attack rate, as already discussed.

Actually, the attack time is determined not only by C Rect, but also an internal 10kΩ resistor. Note that the value of C Rect may need to be altered to optimize the performance for any given situation. Where the style of guitar playing is not particularly "aggro", C Rect could be increased to reduce the risk of low frequency distortion.

A foot operated bypass switch can be included in the project. This selects between sustain and non-sustain. Note that in the bypass position, the circuit is not entirely bypassed — the preamplifier is still used. Otherwise, the output level would drop from 2V to about 20mV when changing from sustain to bypass. As it is, the average level will stay at about 2V, although the peak level will be somewhat higher.

The guitar signal is capacitively coupled to the input (pin 6) of IC1a. This feeds into the inverting input of the op amp via an internal resistor. The non-inverting input is internally referenced to a fixed voltage and cannot be accessed. Feedback for this stage can occur via three different paths — one purely for DC (this provides the bias for the inverting input), one for audio frequency AC, and another for supersonic AC.

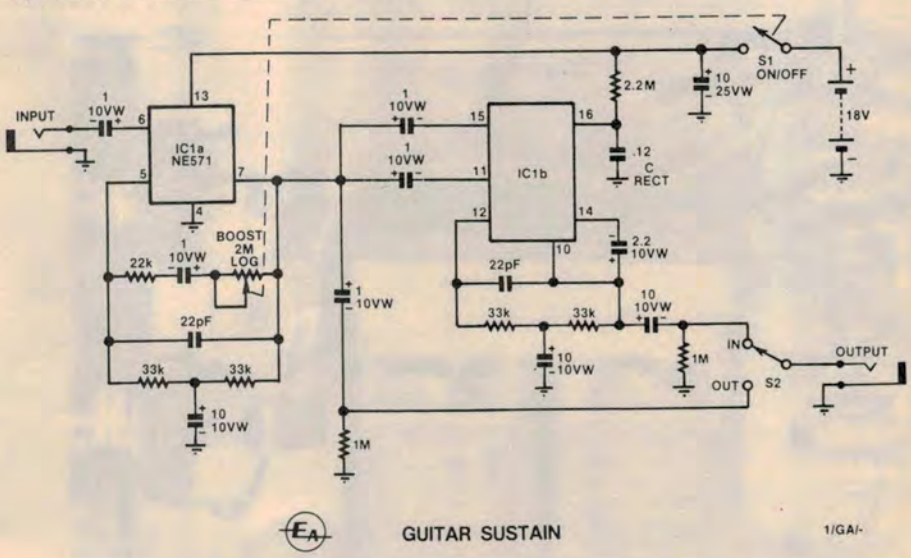
The 2MΩ potentiometer is included in the audio AC feedback path and functions as a gain control. Only AC can be controlled via this path, otherwise noisy potentiometer operation will result (hence the inclusion of the 1μF DC blocking capacitor).

DC feedback is provided by the filter consisting of two 33kΩ resistors and 10μF capacitor (negligible audio feedback occurs through this path). The 22pF ceramic capacitor provides a safeguard against high frequency oscillation.

Output from IC1a is taken from pin 7. This is connected to both the input (pin 11) and the rectifier input (pin 15) of IC1b. Additionally, the output of IC1a is available at the output socket of the project when sustain "OUT" is selected.

IC1b has the same DC and high frequency feedback arrangements as IC1a, but there is no external audio feedback circuit, as for IC1a. Audio frequency feedback (and hence volume control) is provided internally by the variable gain cell. The control voltage for

Circuit diagram for the sustain unit. IC1a is used as a preamplifier and IC1b as a compressor. S2 selects between normal and sustain modes.



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the variable gain cell is derived from the filtered output of the rectifier, fed with audio signal via pin 15. Output from IC1b is via pin 10 and goes to the ouptut socket via S2 when in the "IN" position.

The value of C Rect is shown as 0.12μF, the value we found to be the best compromise. However, the constructor can experiment with this value, in either direction, according to his taste and the requirements of his instrument.

The 2.2MΩ resistor connected between the C Rect output and the positive supply line reduces the gain of IC1b when no signal is present. This helps to eliminate the transient response problems of IC1b. When signal is present at normal levels, this 2.2MΩ resistor has little effect on the circuit (note that decreasing this resistance will provide better transient response but will also tend to reduce the overall gain).

Specifications for the NE571 indicate that it will operate on a single supply of between 6 and 18V. However, in this circuit we found performance lacking for any supply less than 7V. Although the circuit draws only about 3.5mA, a single 9V battery would not have a very long life with a 7V cut off. For this reason we suggest the use of two 9V batteries connected in series.

Construction

We chose an inexpensive folded aluminium project box to house our Sustain unit. This measures 107 × 72 × 51mm and is available from Dick Smith Electronics, although several other project boxes could be used. If the foot-operated bypass switch is not used a smaller box could be selected.

A Scotchcal front panel label, measuring 67 × 102mm, is available for this project. If you are using this, apply it first so that it can be used as a template for drilling the front panel. The "INPUT" and "OUTPUT" labels can be trimmed off the side of the Scotchcal and stuck near the appropriate sockets.

The printed circuit board (PCB) is coded 84ga6 and measures 42 × 58mm. Where PCB pins are to be used, these should be installed first.

A battery holder will be needed — we made one from a piece of scrap aluminium measuring 105 × 13mm.

Where a metal project box is used, no earth connection between the sockets and PCB need be made, but the box itself must be earthed to the PCB at some point. For plastic project boxes, use shielded hook-up wire to provide the earth for the sockets.

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

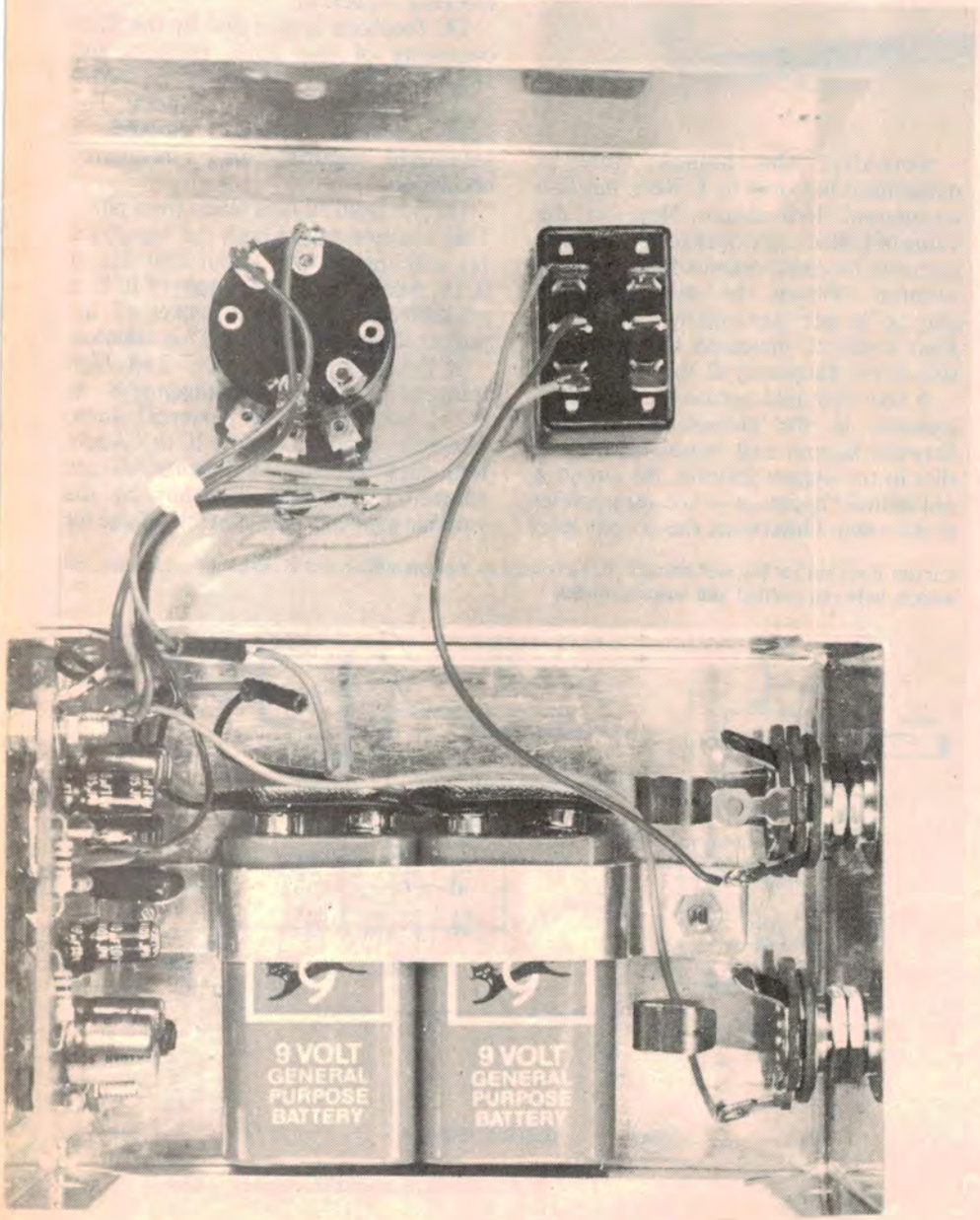
$24

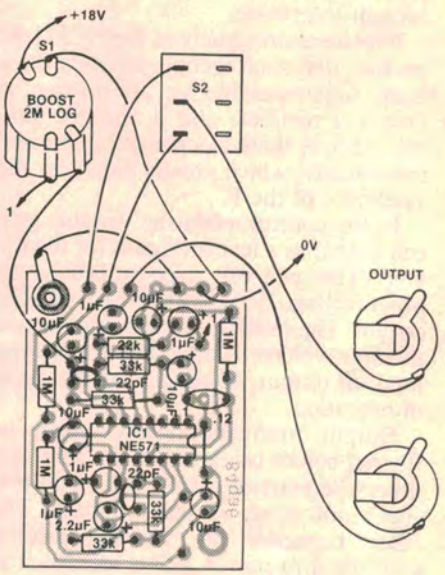
This includes sales tax, but not the cost of batteries.

Testing, testing

To test the unit, first select sustain "OUT" and set the boost to minimum. Set the amplifier volume control to a fairly low point, then switch the Sustain on. Gradually increase the boost until the amplifier output is at an acceptable level. Now select sustain "IN". The average level of any note should now be about the same, with the initial peak

Inside view, showing the vertically mounted PCB at left.





Install the parts as shown in this overlay diagram.

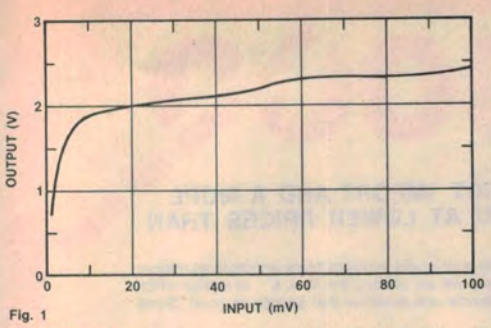


Fig. 1

Fig. 1: response curve of the Guitar Sustain (500Hz input).

lower and sustain time much longer.

The Guitar Sustain unit can maintain a reasonably constant output level with inputs down to 10mV. With input impedance of 50kΩ and output impedance of 300Ω, it can be patched into the circuit between the guitar and preamplifier, or used to replace the preamplifier entirely.

Parts List

1 NE571 Compander IC
1 Aluminium project box, 72 × 107 × 51mm (or similar)
1 PCB, 42 × 58mm, code 84ga6
1 Scotchcal adhesive label, 67 x 102mm
1 Single pole, single throw (SPST) foot operated switch
2 6.5mm jack sockets (mono)
2 9V batteries, Eveready 216 or equiv.
2 Battery connectors
4 Rubber feet for box
1 Battery holder (13 × 105mm scrap aluminium or similar)

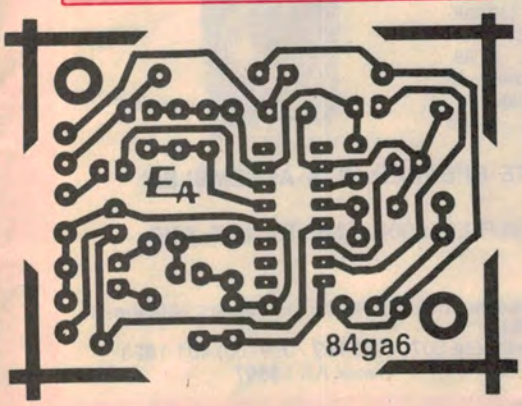
Screws, nuts, hook-up wire

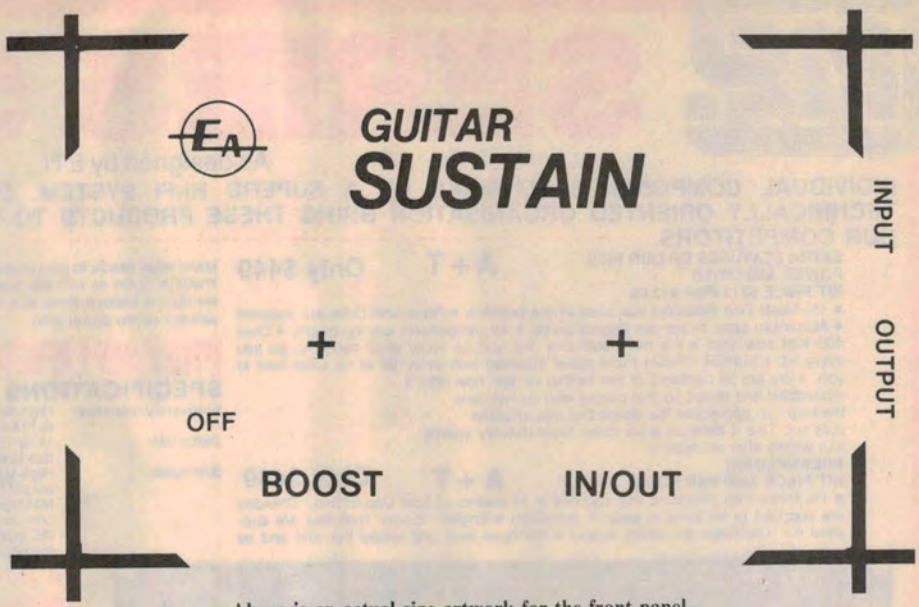
Capacitors

1 10μF/25VW electrolytic
4 10μF/10VW electrolytic
4 1μF/10VW electrolytic
1 0.12μF metallised polyester (greencap)
2 22pF ceramics

Resistors (¼W, 5%)

1 × 2.2MΩ, 2 × 1MΩ, 4 × 33kΩ,1 × 22kΩ, 1 × 2MΩ log potentiometer.





Above is an actual size artwork for the front panel.