Constructional Project

ELECTRIC GUITAR TUNER

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Strike a chord with your group!

GUITAR tuner projects range from simple devices having l.e.d. displays to highly complex units using signal processing stages, frequency to voltage converters, and sophisticated displays. This unit is very much in the "cheap and cheerful" category, but it nevertheless works very well.

Guitar tuning is an application where the more sophisticated approaches tend to generate problems that take ever more electronics to solve. Most problems stem from the fact that the output waveform from a guitar tends to change quite dramatically during the course of a sustained note, with some of the harmonics becoming very strong at times.

True frequency measuring devices can have problems due to harmonics (multiples of the fundamental frequency) being measured at times, rather than the fundamental frequency itself. Without suitable signal processing the tuning indicator can jump around, making precise adjustment very difficult.

IN COMPARISON

The guitar tuner featured here uses a very simple frequency comparison circuit that works just as well whether the input to the comparator is at the fundamental frequency or a harmonic. This avoids the need for any signal processing other than a simple input amplifier.

The display is just a single l.e.d. (light emitting diode) that flashes at a rate equal to the difference between the guitar's frequency and the correct frequency. Correct tuning is therefore indicated by a steady state from the l.e.d. indicator. The unit is powered from a small 9V battery and it is fully portable.

This project is simple enough to be tackled by a complete beginner at electronic project construction. No test equipment is needed to set-up the finished unit, but an accurately tuned instrument or pitch-pipes are needed to provide reference frequencies.

HOW IT WORKS

The block diagram for the Electric Guitar Tuner project appears in Fig.1, and as will be apparent from this, the circuit is basically just an amplifier and an audio oscillator. An l.e.d. is connected between the outputs of these two stages. The amplifier has a high level of voltage gain so that its output signal will normally be a squarewave signal.

The audio oscillator also has an output waveform that is more or less square. A simple *CR* oscillator is used, and this has six switched resistors that provide output frequencies that are the same as the six open-string notes of a guitar.

The polarity of the indicator l.e.d. is such that it is switched on when the output of the amplifier is low and the oscillator's output is high. It is switched off with any other set of output states.

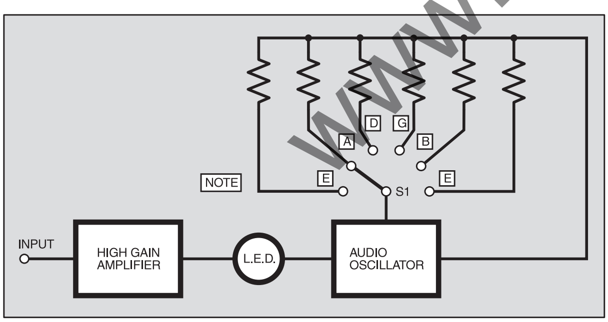


Fig.1. Block diagram for the Electric Guitar Tuner.

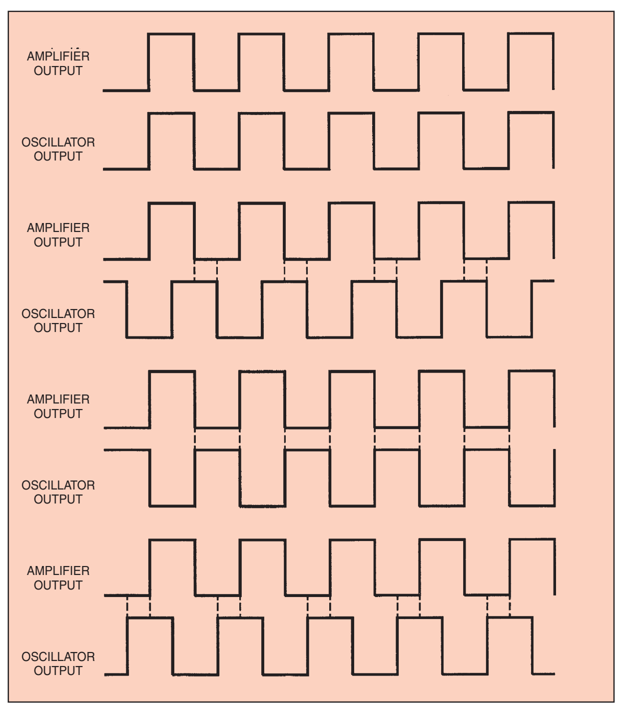


Fig.2. Output waveforms with various phase relationships between the two output signals. The dotted lines indicate when the l.e.d. is turned on.

In Fig.2, the top pair of waveforms represents the output signals from the amplifier and oscillator with the same output frequencies and the two signals in-phase. With the two signals always at the same state the l.e.d. is never switched on.

In the next pair of waveforms the two signals are still at the same frequency, but they are now 90 degrees out-of-phase. This results in the l.e.d. being switched on for 25 per cent of each cycle. The pulses from the l.e.d. are at too high a frequency for the individual pulses to be perceived, and the l.e.d. seems to be switched on continuously, but at less than full brightness.

In the third pair of waveforms the signals are 180 degrees out-of-phase, and the l.e.d. is now switched on for 50 per cent of each cycle. Again, the individual pulses cannot be seen, and the l.e.d. appears to be switched on continuously. It is at less than full brightness, but it is much brighter than with the signals 90 degrees out-of-phase. The drive current is set high enough to give reasonable brightness with the l.e.d. switched on for 50 per cent of the time.

In the final pair of waveforms the signals are 270 degrees out-of-phase, and the l.e.d. is again switched on for 25 per cent of the time. A further phase shift of 90 degrees would take things back to the beginning with the signals in-phase and the l.e.d. switched off.

With the guitar slightly off-tune so that there is a small mismatch in the two frequencies, the output signals gradually slip in and out of phase. As they do so, the l.e.d. varies from maximum brightness with the two signals 180 degrees out-of-phase, to fully switched off with the signals in-phase.

This produces the flashing from the l.e.d. at a rate equal to the difference in the two frequencies, or the "beat rate" as it is known. A lack of activity from the l.e.d., whether it is fully switched on, turned off, or anywhere in between, indicates that the two frequencies are accurately matched.

CIRCUIT OPERATION

The full circuit diagram for the Electric Guitar Tuner is shown in Fig.3. The amplifier uses operational amplifier IC1 in the standard non-inverting configuration. Some guitar pickups produce much higher output levels than others, and the closed loop voltage gain of IC1 has therefore been set very high so that strong clipping is produced at the output even when it is used with a low output pickup.

Negative feedback resistors R4 and R5 set the voltage gain at just over 60dB (1000 times). Resistors R1 and R2 bias the input of the amplifier and set the input impedance at just under 20 kilohms (20k). This produces a good match for most guitar pickups.

The oscillator uses IC2 in the standard 555 oscillator mode. A low-power version of the 555 timer i.c. is used in order to keep the battery drain quite low, and the total current consumption of the circuit is only about 8mA.

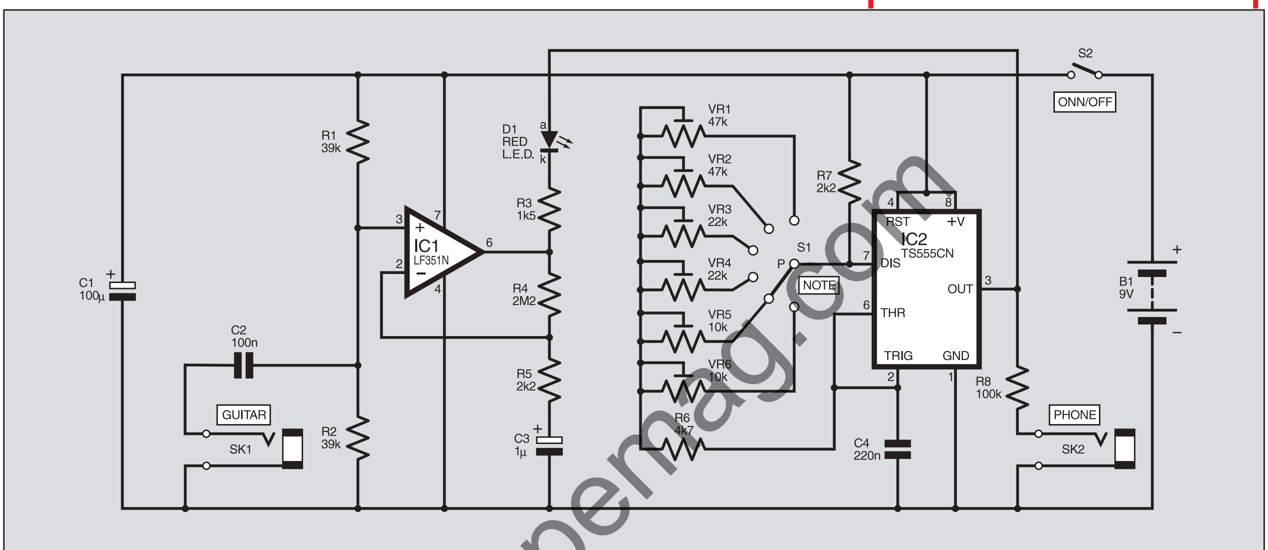


Fig.3. Complete circuit diagram for the Electric Guitar Tuner.

Resistor R7 provides one of the timing resistances, and the other one is made up from series resistor R6 and whichever of the six preset potentiometers (VR1 to VR6) is switched into circuit using rotary switch S1. The six presets provide the six reference frequencies, with VR6 and VR1 being used for the top and bottom *E* notes respectively. The value of R7 is kept low in comparison to the other timing resistances in order to give an output waveform at pin 3 of IC2 that has a mark-space-ratio of approximately 1-to-1.

Indicator D1 is the l.e.d. and R3 is the current limiter resistor. The l.e.d. current is about 4mA, but as the l.e.d. is never switched on for more than about 50 per cent of the time the average current never exceeds about 2mA. It is, therefore, advisable to use a high-brightness l.e.d. that is designed for operation on low currents.

Socket SK2 can be used to monitor the output of IC1 using a crystal earphone, and resistor R8 attenuates the output signal to a suitable level. The circuit can drive medium impedance headphones, as used with personal stereo units, if R8 is reduced to a value of 10 kilohms. For best results the phones should be driven in series.

The actual voltage from a 9V battery varies significantly during its operating life, but there is no need to power the

COMPONENTS

See SHOP TALK page

Resistors

R1, R2	39k (2 off)
R3	1k5
R4	2M2
R5, R7	2k2 (2 off)
R6	4k7
R8	100k

All 0·25W 5% carbon film

Potentiometers

VR1, VR2	47k min enclosed carbon preset, horiz. (2 off)
VR3, VR4	22k min enclosed carbon preset, horiz. (2 off)
VR5, VR6	10k min enclosed carbon preset, horiz. (2 off)

Capacitors

C1	100µ radial elect. 10V
C2	100n polyester, 5mm lead spacing
C3	1µ radial elect. 50V
C4	220n polyester or polycarbonate, 5mm lead spacing

Semiconductors

D1	5mm or 3mm low-current (2mA) red l.e.d., with panel mounting clip
IC1	LF351N bi-f.e.t. op.amp
IC2	TS555CN low-power timer i.c.

Miscellaneous

S1	6-way 2-pole rotary switch (only one pole used)
S2	s.p.s.t. min. toggle switch
SK1	standard 6·35mm mono jack socket
SK2	3·5mm mono jack socket
B1	9V battery (PP3 size), with connector clips

Small instrument case, size to suit; 0·1-inch stripboard, having 32 holes by 28 strips; 8-pin d.i.l. socket (2 off); control knob; multistrand wire; solder pins; solder; etc.

Approx. Cost Guidance Only £11 *excluding batt. & case* circuit by way of a voltage regulator. One advantage of a 555 oscillator is that its method of operation ensures that there is no significant change in output frequency even with quite large variations in the supply potential.

CONSTRUCTION

The Electric Guitar Tuner circuit is buillt on a piece of stripboard and the topside component layout, interwiring and details of breaks required in the underside copper tracks are shown in Fig.4. A board having 32 holes by 28 copper strips is required, and this is not one of the standard sizes. A larger piece of stripboard must therefore be trimmed to size using a small hacksaw.

The breaks in the copper strips can be made with a handheld twist drill bit of about 5mm in dia. Make sure that the strips are cut properly, with no fine tracks of copper left behind. The two mounting holes are 3mm in diameter and they will accept M2·5 mounting bolts.

The board is now ready for the components and link-wires to be added. Neither of the two integrated circuits are sensitive to static charges, but it is still a good idea to fit them on the board via i.c. holders.

Ideally the six preset potentiometers would be multi-turn "trimpots", which have better resolution and are easier to adjust accurately than "bog standard" presets. It should not be difficult to modify the layout to accept vertical trimpots, but six of these components will substantially boost the cost of the project. Ordinary miniature preset potentiometers will suffice, and are used on the prototype, but they must be adjusted very carefully.

In order to fit into the layout easily capacitors C2 and C4 should be types that have 5mm (0·2-inch) lead spacing. It is preferable to use a high quality component

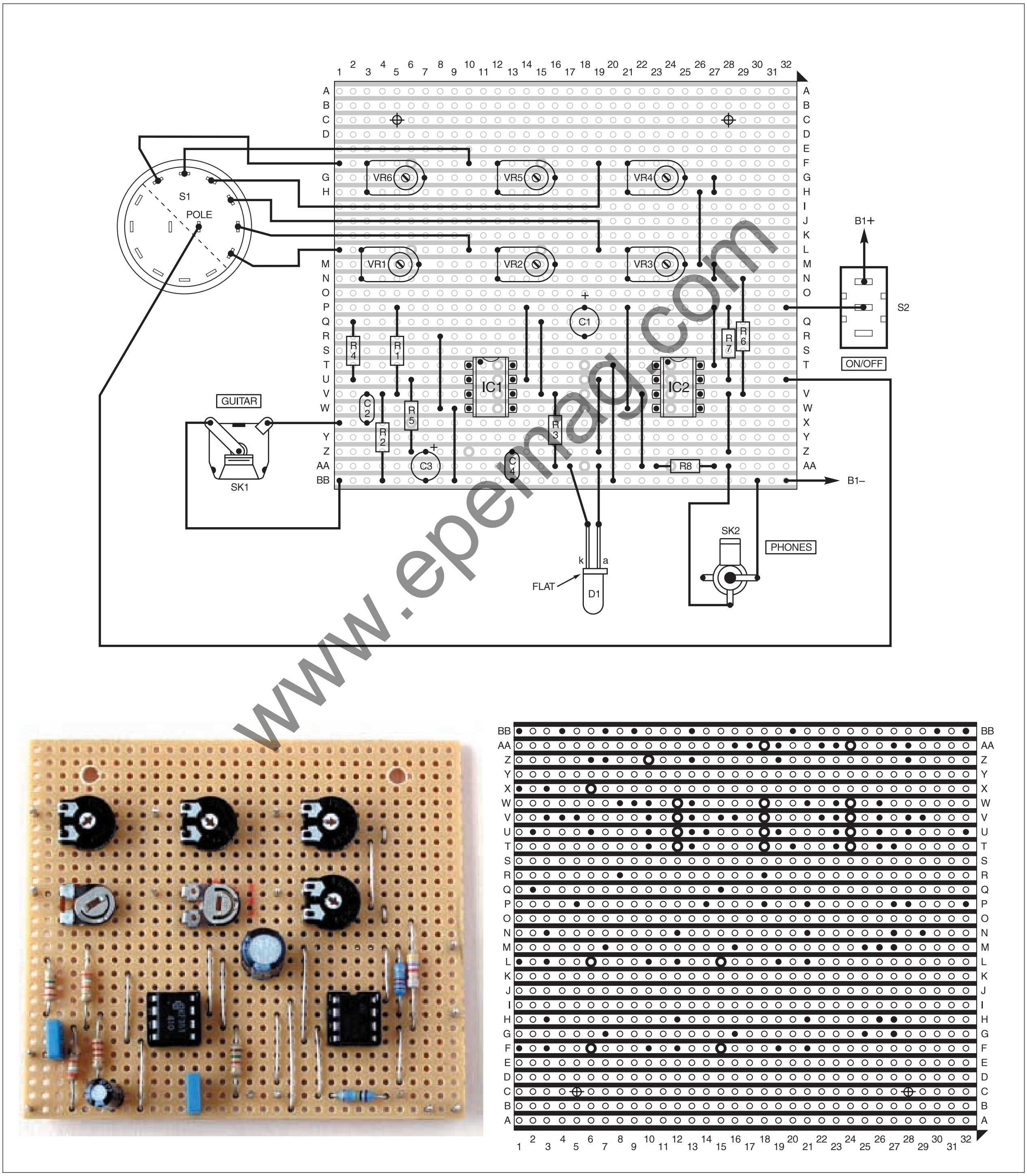


Fig.4. Electric Guitar Tuner stripboard topside component layout, interwiring to off-board components and details of breaks required in the underside copper tracks. The complete circuit board is shown above left.

for C4 so that any frequency drift with changes in temperature is minimised. A polycarbonate capacitor is probably the best choice, but a good quality polyester component should give good results. Most ceramic types have inadequate short and long term stability and should *not* be used.

Practically any small or medium size instrument case is suitable for this project. Alternatively, a diecast aluminium box is a good choice if maximum toughness is required. The exact layout of the unit is not important, but try to arrange things so that the wiring from socket SK1 to the circuit board is no more than a few centimetres long.

Due to the high gain of IC1, plus the fact that its input and output are in-phase, stray feedback to long input wiring could cause severe instability. A ***screened cable must*** be used to connect SK1 to the circuit board if this cable is more than a few centimetres long.

TUNE SWITCH

Switch S1 is a 6-way 2-pole rotary switch, but in this circuit only one pole is used. Consequently there are no connections to seven tags of this switch. Modern switches of this type invariably have an adjustable end-stop, and in this application the end-stop should obviously be set for 6-way operation.

The circuit board is bolted in place on the base panel of the case. If a metal case is used it is ***essential*** to use spacers of at least 6mm in length over the mounting bolts, between the case and the board. This will keep the connections on the underside of the board well clear of the metal case.

Even if a plastic case is used it is still necessary to use spacers, washers, or a couple of extra nuts to provide at least a small stand-off between the case and the board. Most makes of stripboard are quite brittle, and there is otherwise a risk of the board buckling and cracking as it is bolted in place.

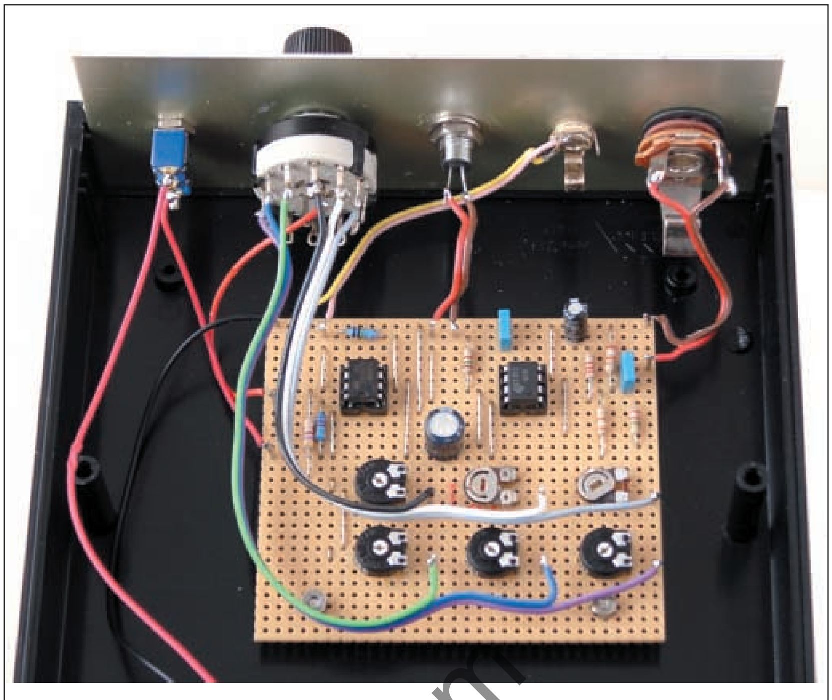
Details of the hard wiring are also included in Fig.4, and this is largely straightforward. The polarity of l.e.d. D1 is unimportant in this case. If it is connected the wrong way round the on and off states will be swapped, but this is of no consequence and the unit will still work perfectly.

ADJUSTMENT AND USE

If a suitable frequency meter is available it can be used to set the correct output frequencies from IC2. In order to obtain adequate accuracy an instrument having a gate time of 10 seconds and a resolution of 0·1Hz is required. The correct output frequencies to the nearest 0·1Hz are shown in Table 1.

Table 1: Output Tuning Frequencies

Note	Frequency	Preset
E	82·4	VR1
A	110	VR2
D	146·8	VR3
G	196	VR4
B	246·9	VR5
E	329·6	VR6



Interwiring from the circuit board to the front panel mounted components.

Another method is to monitor the output of IC2 using an earphone connected to socket SK2 and then tune the presets "by ear". Either pitch pipes or an accurately tuned instrument is needed to provide reference notes that the unit can be tuned against.

A third method is to connect an accurately tuned guitar to socket SK1 and then use this as the tuning reference. An electronic keyboard instrument can be used in the same way, but make sure it is set for a normal musical scale with middle *A* at 440Hz. A normal screened jack lead is used to connect the electric guitar or other instrument to SK1.

With preset potentiometer VR1 selected using rotary switch S1, play the lower *E* note and adjust VR1 for the lowest flash rate from the l.e.d. indicator D1. If the output frequency of IC2 is well away from the correct figure the flash rate will be so high that the l.e.d. will seem to light up continuously. Adjust VR1 to produce a perceptible flash rate first, and then carefully adjust it for the lowest possible rate.

The same basic procedure is then used to give the other five preset potentiometers suitable settings. There should be no difficulty in matching the frequency of IC2 to within 0·1Hz of each reference note.

In use the Electric Guitar Tuner is used in much the same way, but each note of the guitar is adjusted for the lowest possible flash rate. The initial tuning error might be quite large when a new string is fitted, and the guitar must then be adjusted to produce perceptible flashing from the l.e.d. indicator first. It can then be adjusted for the lowest flash rate.

The simple flashing light indicator does not show the direction of any tuning error, but with a little practice it is still quite easy to home in on the correct setting. □