Stroboscopic Tuner for musicians

This simple circuit provides crystal-locked accuracy for tuning virtually any musical instrument, using an inexpensive LED display. It also doubles as a stable frequency reference if you prefer to tune up by ear.

by MARK CHEESEMAN

A tuning fork was usually the only way to tune a musical instrument, before the days of electronic tuners. When struck, the tuning fork emitted a tone which was then compared by ear to the sound of the instrument being tuned. The musician would then adjust the tuning of his or her instrument while listening to the beat frequency between the two sounds. When the beat frequency became too low to notice, the instrument was tuned.

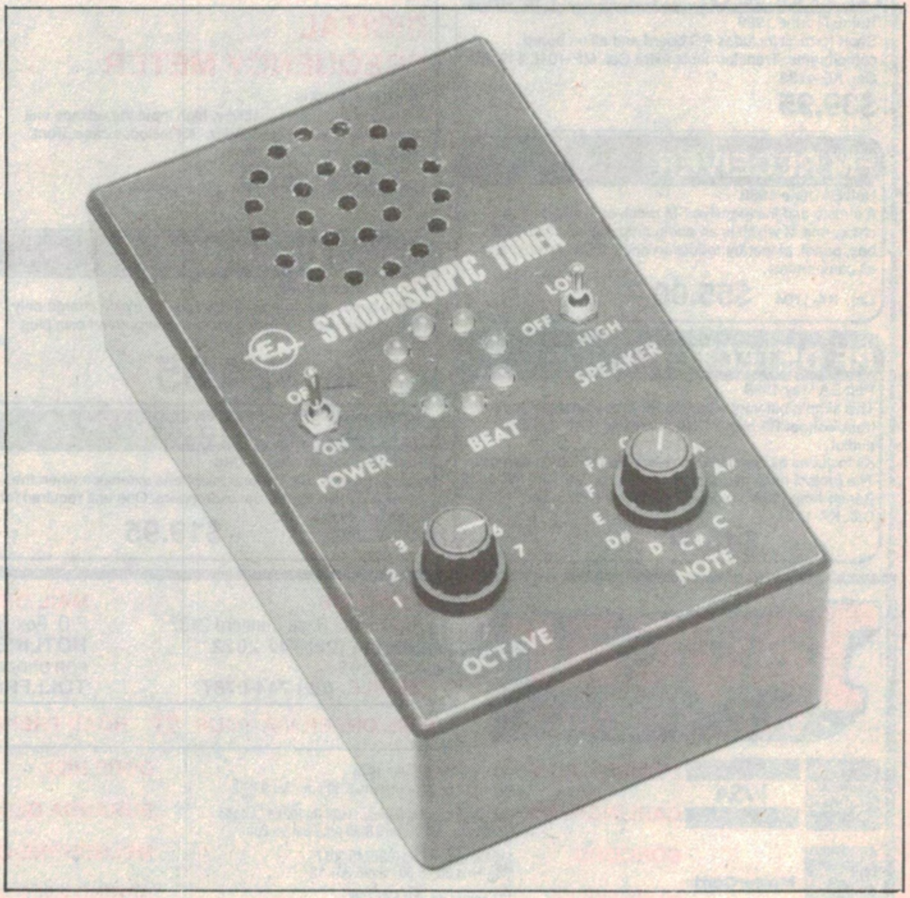
This is fine for instruments where there is only one adjustment for tuning. One simply tunes one note, and all the others follow suit. However many instruments (mainly stringed instruments) are not this easy to tune, as each note has a separate string (or even more), which need to be tuned separately. Carrying 88 tuning forks around to tune a piano would be impractical, to say the least. Not only is the sheer number rather daunting, but the size of the forks required to tune the lowest notes would be enormous, and the smallest would be so small as to be virtually unusable, if you didn't lose them first!

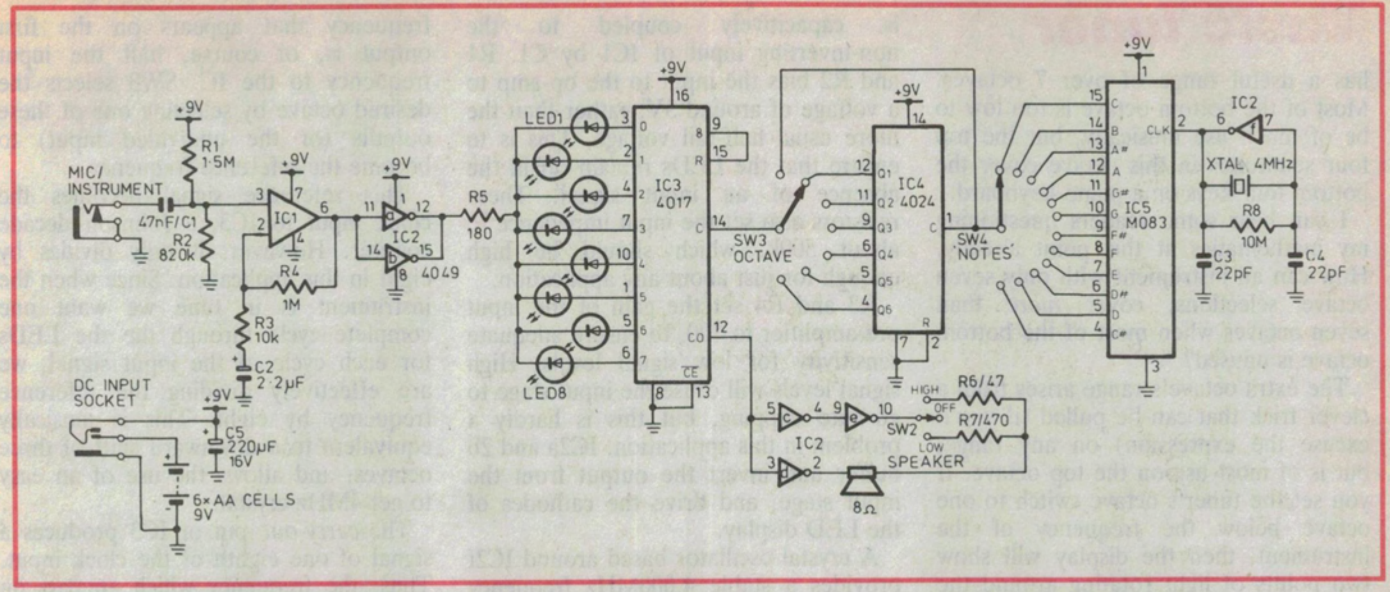
Instead, a piano tuner will usually tune one note with a tuning fork, and then uses his well-trained ears to tune the other notes so that they bear the correct relationship to the "standard". Obviously, this requires considerable experience and a lot of patience.

For those who do not trust their ears this much, an easier way is to use an electronic tuner. These usually contain an inbuilt crystal reference, which is divided down in frequency by a preset amount and compared with the incoming signal, and displayed on, say, a meter movement.

Our last musical frequency standard, published in July 1980, used a rotating LED display to show whether the two frequencies were in tune or not. The display rotates in one direction if the instrument is sharp, and the opposite way if it is flat. The faster the rotation the more out of tune the instrument is. When the display is stationary, the tuning is correct.

The primary advantage of a LED display is cost, as meter movements are getting more expensive all the time. Meters are also prone to damage unless a lot of care is taken to physically protect them. The LED display, on the other hand, is virtually roadie-proof!





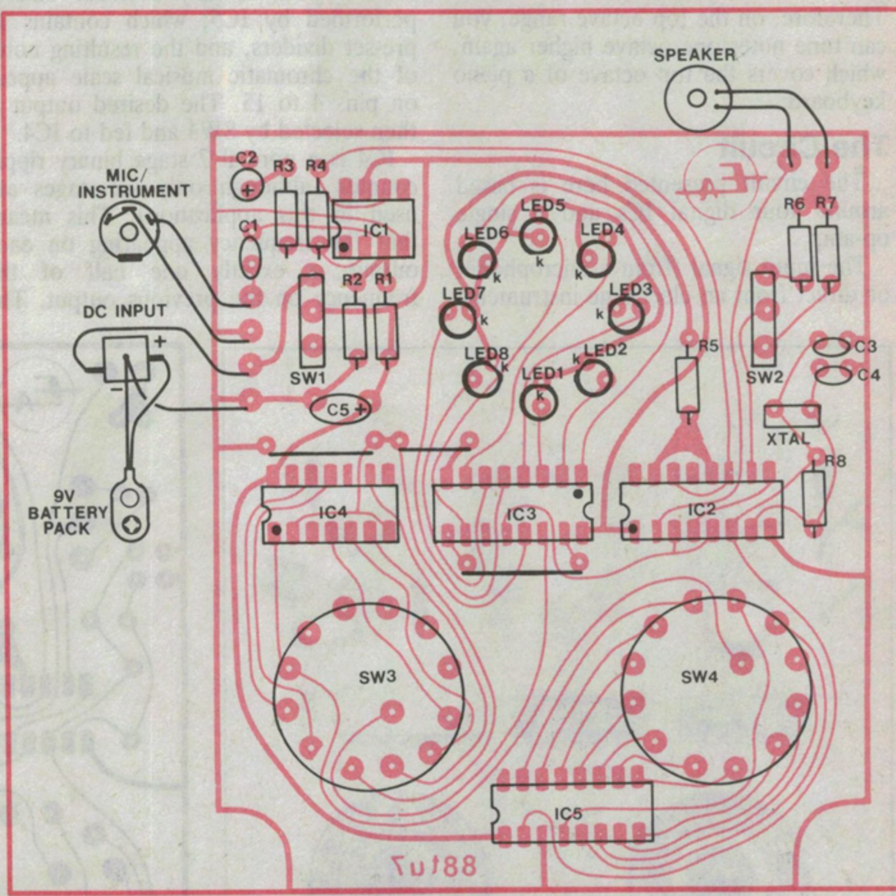
CMOS ICs are used in the circuit to minimise power consumption, allowing it to be powered by batteries.

We were considering an updated version of the 1980 design when we noticed a similar device in a recent issue of *Elrad* magazine, from Germany. What immediately grabbed our attention was the rather clever way in which the LEDs were driven. Instead of using an up/down counter as in the previous *Electronics Australia* design, the reference frequency and the unknown are both fed directly to the LEDS.

A circle of eight LEDs is used as the display. The anodes of these are driven one at a time, in sequence, by a counter clocked at eight times the frequency of the note to which the instrument is to be tuned. Thus, the light source would seem to rotate full circle once every cycle of the reference frequency. On it's own, this would not be of much use to anybody, even if your eyes were fast enough to see it!

Now for the clever bit (there's always a clever bit in electronic projects!). The cathodes of all the LEDs are connected together, and driven by the incoming "unknown" signal. This results in a visual display of the difference between the two frequencies. If the two frequencies are exactly the same, then during the time it takes for one complete cycle of the unknown signal, the counter driving the anodes will have completed one complete cycle through the eight LEDs.

Thus, the same LED or LEDs will remain alight continuously. In fact, it is being pulsed at the frequency of the relevant note, but persistence-of-vision convinces us that the LED is continuously lit (except for very low



Virtually all components mount directly on the board, greatly simplifying construction.

frequencies, which are musically irrelevant anyway).

If the frequencies are slightly different, then the display will appear to move one way or the other, depending on which frequency is the highest of the two. This is a manifestation of the same stroboscopic effect which causes moving wheels in movies to appear to rotate backwards.

In the design presented here, we have endeavoured to combine features of both the 1980 EA design and the Elrad design, to make the tuner useful to as wide a variety of musicians as possible. It covers the full chromatic scale, and

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has a useful range of over 7 octaves. Most of the bottom octave is too low to be of much use musically, but the top four semitones in this octave cover the bottom four keys on a piano keyboard.

I can hear some readers questioning my mathematics at this point already. How can an instrument with only seven octave selections, cover *more* than seven octaves when most of the bottom octave is unused?

The extra octave's range arises from a clever trick that can be pulled (if you'll excuse the expression) on any range, but is of most use on the top octave. If you set the tuner's octave switch to one octave below the frequency of the instrument, then the display will show two points of light rotating around the circle rather than one. This turns out to be just as easy to adjust as before. Therefore, on the top octave range, you can tune notes one octave higher again, which covers the top octave of a piano keyboard.

The Circuit

The circuit presented here is based around four digital ICs and a single op-amp.

The input signal (from a microphone, or direct from an electronic instrument) is capacitively coupled to the non-inverting input of IC1 by C1. R1 and R2 bias the input to the op-amp to a voltage of around 3V, rather than the more usual half-rail voltage. This is to ensure that the LEDs remain off in the absence of an input signal. These resistors also set the input impedance to about 500k, which should be high enough for just about any application.

R3 and R4 set the gain of the input pre-amplifier to 100, to ensure adequate sensitivity for low signal levels. High signal levels will cause the input stage to go into clipping, but this is hardly a problem in this application. IC2a and 2b buffer and invert the output from the input stage, and drive the cathodes of the LED display.

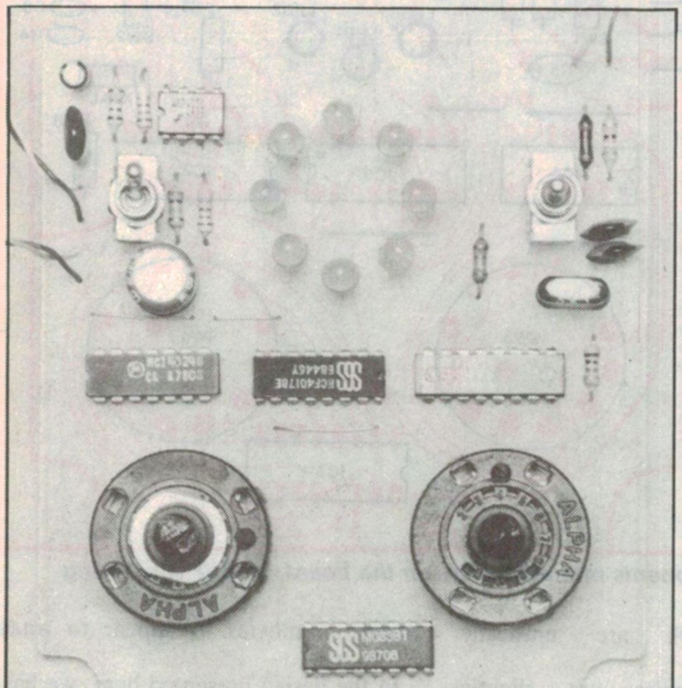
A crystal oscillator based around IC2f provides a stable 4.000MHz frequency reference from which the frequency for each note is actually derived. This is performed by IC5, which contains 12 pre-set dividers, and the resulting notes of the chromatic musical scale appear on pins 4 to 15. The desired output is then selected by SW4 and fed to IC4.

IC4 is a normal 7 stage binary ripple counter (although only six stages are used in this application). This means that the frequency appearing on each output is exactly one half of the frequency on the previous output. The frequency that appears on the first output is, of course, half the input frequency to the IC. SW3 selects the desired octave by selecting one of these outputs (or the undivided input) to become the reference frequency.

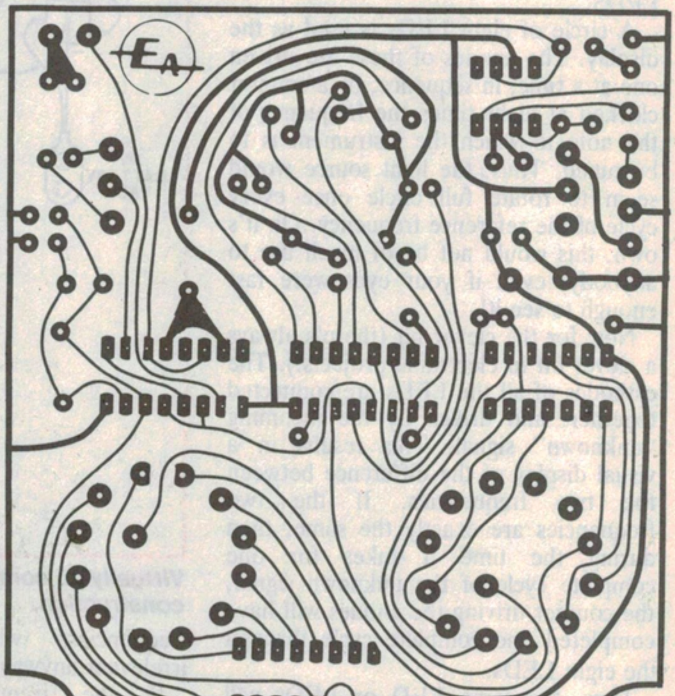
This reference signal becomes the clock input to IC3, a Johnson decade counter. However, it only divides by eight in this application. Since when the instrument is in tune we want one complete cycle through the the LEDs for each cycle of the input signal, we are effectively dividing the reference frequency by eight. This is musically equivalent to a downward shift of three octaves, and allows the use of an easy to get 4MHz crystal.

The *carry-out* pin of IC3 produces a signal of one eighth of the clock input. Thus, the frequency which appears on this pin is the true reference frequency. This is fed to the remaining three inverters in IC2, which form a crude bridge amplifier. Although the drive to the speaker is a square wave, it is still perfectly usable for tuning purposes, and the added complication of filtering was not considered to be worth the trouble.

Switch SW2 allows the internal speaker to be operated at one of two volume levels for tuning by ear, or disabled entirely if it is not required.



Note that IC3 is orientated in the opposite direction to the other ICs.



Above is the PCB pattern, and to the right is the front panel, both reproduced actual size.

Construction

The whole circuit, with the exception of the speaker and battery, is mounted on a single printed circuit board measuring 88 x 102mm, and coded 88tu7.

Begin by checking the board for shorted tracks or hairline fractures. Also, using a round file of about 10mm diameter, file out the two bottom corners in order to clear the mounting pillars in the box. Before mounting any components, check that the holes for the four switches are the correct diameter, and enlarge them if they are not.

The assembly of the PCB is pretty straightforward. Insert the three wire links first, followed by the resistors and capacitors, being careful with the polarity of the two electrolytics. Now mount the ICs, again watching their orientation carefully. Note that IC3 faces the opposite direction to the other ones.

Now mount the two toggle switches. The one with the centre-off position is mounted on the right-hand side of the board. The rotary switches may be mounted next. Both are of the single-pole, twelve-position type, but the *octave* switch should have its special washer inserted so as to restrict its movement to seven positions. The *note* switch should not have this washer in place at all, to allow the full twelve positions of movement.

The mounting of the LEDs should be left until the mechanical details are completed. The housing used for the prototype is an all-plastic jiffy box, measuring 150 x 90 x 50mm. The PCB is supported below the lid of the box by the four switches.

The 6.5mm input socket and the plug-pack connector are mounted on the top end of the base of the box. Before mounting the sockets, attach some short lengths of wire to the connectors to facilitate their connection to the PCB later on. Also connect the battery snap to the plug-pack connector.

Using a photocopy of the front-panel artwork, drill all the holes on the front panel. There are quite a lot of these, due to the presence of the speaker on the panel. It is probably best to drill a small pilot hole first and then enlarge them to the correct sizes afterwards.

When all the holes are the correct size, carefully align the *Dynamark* front panel and stick it on. Using a sharp scalpel or art knife, cut out all the holes for the switches, LEDs and speaker. The easiest way to mount the speaker is to use a strong adhesive and glue it to the back of the front panel.

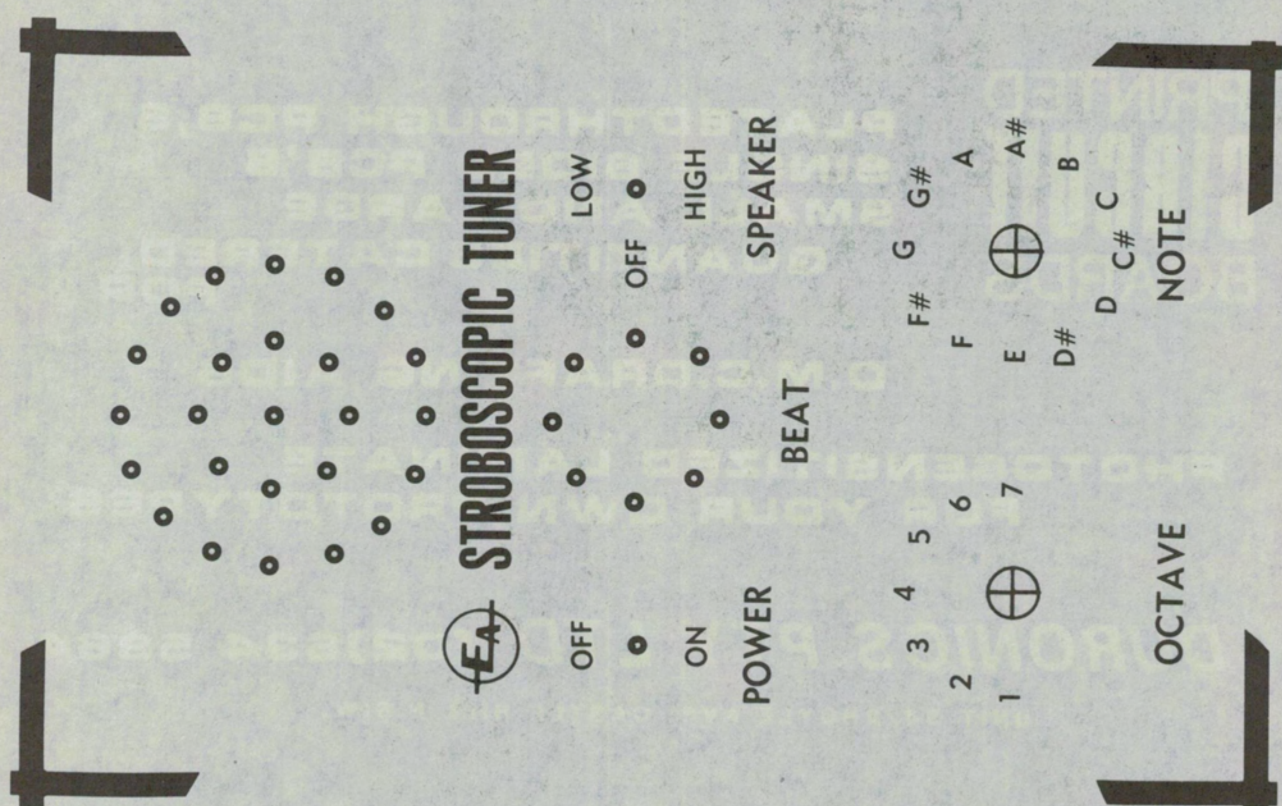
Connect the speaker to the PC board, followed by the two sockets. Also insert the eight LEDs into their holes in the PCB, taking note of polarity; but do not solder them in place yet. Remove the nuts from the four switches and attach the board to the front panel.

Now line up the LEDs with their respective holes and solder them in place one by one, so that they all protrude through the panel by the same distance. All that remains to be done now is to install the battery pack and screw the lid on the box.

Tuning up

There are basically two ways in which this tuner can be used, depending on your own ability to accurately tune one tone to the frequency of another. The first is to simply use the tuner as a frequency reference, and tune the instrument by ear. In this case, you won't need to connect a microphone to the input socket. However if you play in an orchestra/band/rock group you may have trouble doing this accurately if there are lots of people trying to do the same thing all at once.

The other way is to plug a microphone into the input jack and place the microphone as close as possible to the instrument being tuned. Alternatively, if it is an electric guitar or keyboard etc., you can connect the output directly to the tuner input. Adjust the controls on the tuner to select the note to which the instrument



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is to be tuned and play the same note on the instrument while observing the LED display.

The LED display will appear to rotate either clockwise or anti-clockwise, depending on whether the instrument is high (sharp) or low (flat) in frequency (pitch). Now all you have to do is to adjust the tuning on the instrument until the pattern remains stationary, or close to it. If the input signal is too low, then the LEDs won't light at all. However we tested the prototype on signals lower than 10mV RMS without any trouble.

Due to limitations on the maximum clock frequency of the top-octave generator chip, the tuner does not directly cover the top octave of a full 88-note piano keyboard. However if the instrument is tuned one octave higher than the tuner, then you will see two groups of LEDs on opposite sides of the circle "chasing each other around". So you can still tune the top octave of a piano in this way, by adjusting the tuning of the instrument until a stationary display is obtained as before.

Actually, tuning high frequency notes using the stroboscopic method is not as easy as for lower notes, because even a few cents difference in pitch corresponds to quite a high beat frequency, so the display will rotate quite fast even when the notes sound almost the same.

In these cases, the best way to tune the instrument is to first get it as close as possible by ear, and then adjust the last little bit using the LEDs. Bear in mind that even if the LED display is rotating a few times per second here, the relative difference in frequency is still quite small.

Now there is one less excuse for those sour notes! EA

PARTS LIST

1 PCB 88 x 102mm, coded 88tu7
1 UB1 plastic jiffy box, 150 x 90 x 50mm
1 single pole, 12 position PCB mount rotary switch
1 single pole, 7 position PCB mount rotary switch
2 suitable knobs for switches
1 SPDT miniature toggle switch
1 SPDT centre-off miniature toggle switch
1 Panel mount 6.5mm socket
1 2.5mm power socket
1 4.000MHz crystal
1 57mm speaker
1 9V battery snap
1 6xAA cell holder
6 AA cells

Resistors (all 1/4W 5%)

1 x 47ohm, 1 x 180ohm, 1 x 470ohm, 1 x 10k, 1 x 820k, 1 x 1M, 1 x 1.5M, 1 x 10M.

Capacitors

2 x 22pF ceramic
1 x 39nF metallised polyester
1 x 2.2uF 16V electrolytic
1 x 220uF 16V electrolytic

Semiconductors

1 741 op-amp
1 4017B Johnson decade counter
1 4049 hex inverter
1 4024 7-stage ripple counter
1 M083 top-octave generator
8 Red LEDS