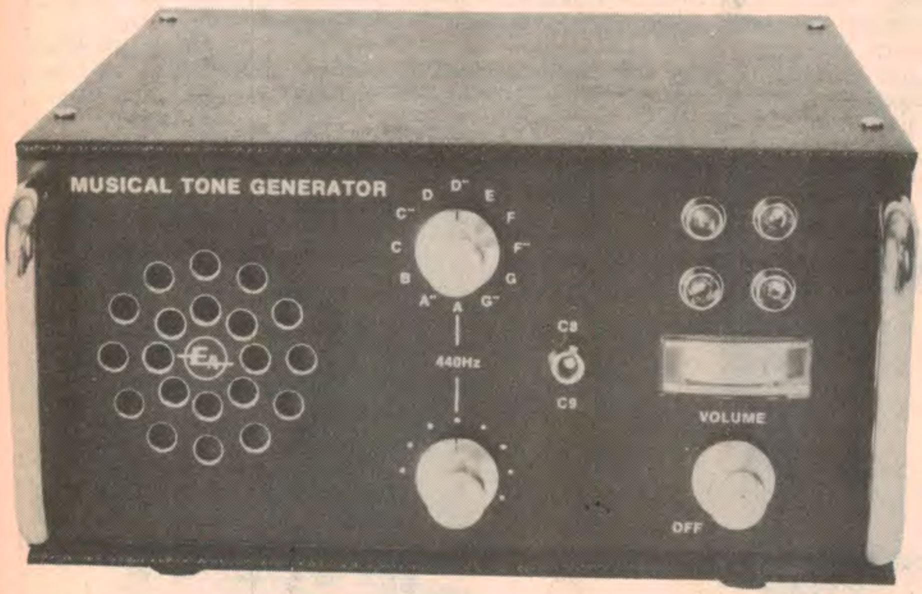
Musical Tone Generator

Crystal locked with beat frequency indicator



There are still large numbers of electronic organs with free running oscillators and which need tuning from time to time. This updated version of a crystal locked musical tone generator has a built-in beat indicator, thus avoiding the need for a CRO. The design may also form the basis for a synthesiser and for the generator for an electronic organ. With a built-in speaker, it may also be used to tune acoustically other musical instruments.

By IAN POGSON & GERALD COHN

As far back as July 1965 we described an Electronic Tuning Standard. By virtue of progress, this unit has long since been superseded. In August 1974 we described a Crystal Locked Musical Tone Generator. This was a giant step forward and indeed, it is still in current use.

However, we felt that the time had come to present an updated version of the latter unit. In retrospect, we considered that the latter unit had a couple of deficiencies which should be avoided if possible. For the normal tuning process, it was necessary to feed the outputs of the tuning device into a CRO, using the well known Lissajous pattern method. Also, when any acoustic tuning was undertaken, some difficulty was experienced due to the fact that the audio tones from the built-in speaker were substantially square waves.

Our new tuner was therefore to have some sort of built-in indicator and so avoid the need for an external CRO. Also, the tones should be filtered so as to approximate a sine wave, thereby making acoustic tuning adjustments easier.

A rather more important problem than those just mentioned, was the question of a suitable top-octave synthesiser IC consistent with a reliable source of supply. After giving this question careful consideration, we found that a suitable IC was available through the Tandy organisation. The IC is type 50240 and is available in a 16-pin DIL package.

A desirable feature of the 50240 is that it requires only a single polarity power supply, compared with the AY-1-0212 as used in our design of August 1974. The latter device requires −15V DC in addition to the +12V.

And so we had established the basis for our new version of the musical tone generator. All other components at the time of writing are readily available. More will be said about components and places of availability later on.

A look at the block diagram will show the general principle of operation. A 2MHz crystal oscillator drives the top-octave synthesiser. This divides the input 13 ways and by whole numbers to give the top notes required. These include two Cs, C8 and C9. Because whole numbers are used to divide the clock frequency, the resultant outputs are not necessarily precise but very closely approximate those laid down for the equal tempered scale.

S1, a single-pole 12-position switch, selects the required synthesiser output to be fed into a seven-stage binary counter/divider from which any one of eight octaves are available. C8 and C9, are selected by S3. The divider outputs are fed via eight low-pass filters to S2 which feeds the LED beat frequency indicator and the audio amplifier.

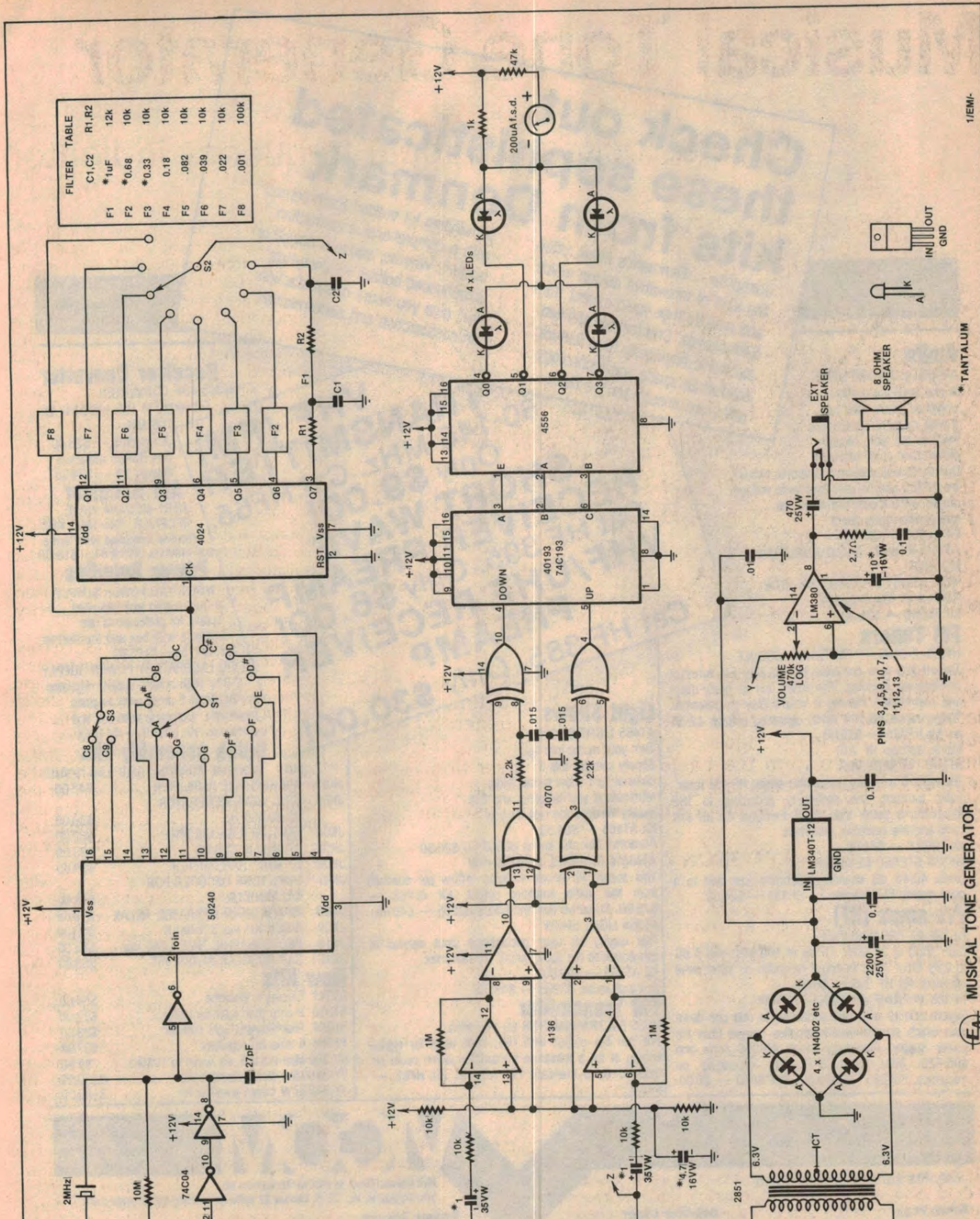
So far, we have referred to the crystal oscillator as being on 2MHz. This is a nominal frequency and much has been said about precisely what frequency should be used.

In addition to the tempered scale concept, we also have the matter of pitch to consider. This has been more or less universally accepted as fixing A above middle C on a frequency of 440Hz. The divisor of A on our top octave synthesiser is 284. Now if we divided 2MHz by 284, we get 7042.2535Hz. This is the frequency of the top available A for the instrument. Now if we divide this frequency down by octaves, we find that A is equal to 440.14082Hz, which is very close.

If we reverse the process, starting with 440Hz precisely, instead of 2MHz we get 1999.36kHz and this is the frequency required for the crystal for an exact A440.

If we adopt an exact A440, this will be coincident with the tempered scale requirement but it will be achieved at the expense of other notes being further removed from the tempered scale figures. Another school of thought seems to be that if a particular crystal frequency is adopted, giving a sort of "middle-of-the-road" for all notes of the scale, that this would be the best compromise. This crystal frequency works out to 2000.24kHz and when compared with the tempered scale figures, the maximum error is plus or minus .069%.

For the prototype, we fitted a 2MHz crystal and provided an adjustable trimmer in the oscillator circuit so that readers may make precise adjustments against a frequency counter or some other reference. We set our oscillator to 2000.24kHz. However, for average use the trimmer could be dispensed with and a 33pF NPO ceramic capacitor subsituted.



MUSICAL TONE GENERATOR

Now let us look at the circuit and describe each section in detail. The crystal oscillator uses three inverters in a standard configuration which, by virtue of the propagation delay around the loop, prevents operation of the crystal in a spurious overtone mode. An additional inverter in the same 4069/74C4 package is used to buffer the oscillator output as it feeds into the 50240 top-octave synthesiser.

No buffering is required for the outputs of the 50240 as they are compatible with the following 4024 CMOS counter/divider.

Eight passive low-pass filters are used to change the square wave outputs from the 4024 to a rough approximation of sine waves. To save space, the component values for the filters are tabulated on the circuit diagram. Each of the filter outputs is selected by switch S2 and then fed to the audio amplifier and the beat frequency indicator.

The audio amplifier is simple enough. Output from switch S2 is coupled to the 470k volume control via a 0.1uF capacitor and thence to the LM380 14-pin amplifier IC. This drives a miniature loudspeaker or an external loudspeaker via a jack socket on the rear panel. Power output is about two watts maximum.

The beat frequency indicator employs four ICs and is based on a TTL circuit featured in our "Circuit and Design Ideas" pages from the January 1975 issue. What the circuit does is to give a revolving display of four LEDs. If the frequency being compared is higher than the standard generator frequency, then the LEDs will appear to rotate in one direction. If the frequency being checked is lower, the LEDs rotate in the other direction.

Finally, if the two frequencies are exactly the same the LEDs will stop rotating and extinguish.

This method of indication is very good in its own right but it does take time to make a precise adjustment, particularly at low frequencies. As there is a varying DC condition in the supply to the LEDs, a small meter has been added which follows the slow current changes which still exist at near to zero beat. Precise zero beat can be achieved very quickly by adjusting for a stationary meter needle.

Although we have provided an effective zero beat indicating system, some readers may have access to a CRO and may prefer to use it as the zero beat indicator. We have provided for this in that there are outlet sockets on the back of the case so that a pair of patch cords may be connected across to a CRO.

A 4136 quad operational amplifier IC is used to amplify the signals to a sufficient level to operate the following CMOS circuitry. All four op amps are referenced to +6V via a voltage divider comprising two 10k resistors. The output signal from S2 is fed to an op amp configured as an inverting amplifier with a nominal gain of 100. Following that is another op amp which is a comparator. The result of the gain of these two op amps is that the previously rounded signal from the output of S2 is amplified and squared up again. An identical pair of op amps similarly treats the external input signal. These squared-up signals are then fed to a 4070/4030 quad exclusive-OR gate which frequency-doubles both signals. The two output signals from the XOR gate are then fed to a 74C193 up/down counter. The processed external input signal is fed to the count-down input while the processed internal signal is fed to the count-up input.

The output of the up-down counter drives half of a 4556 two-to-four-line

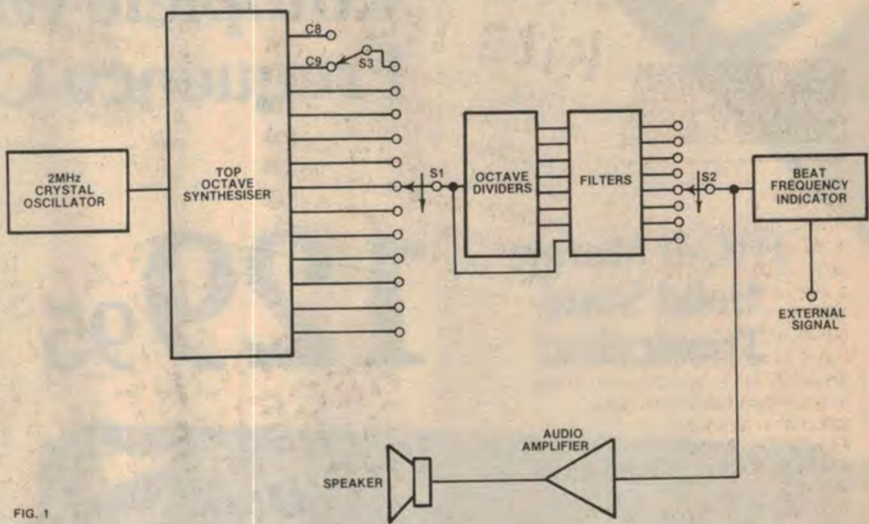
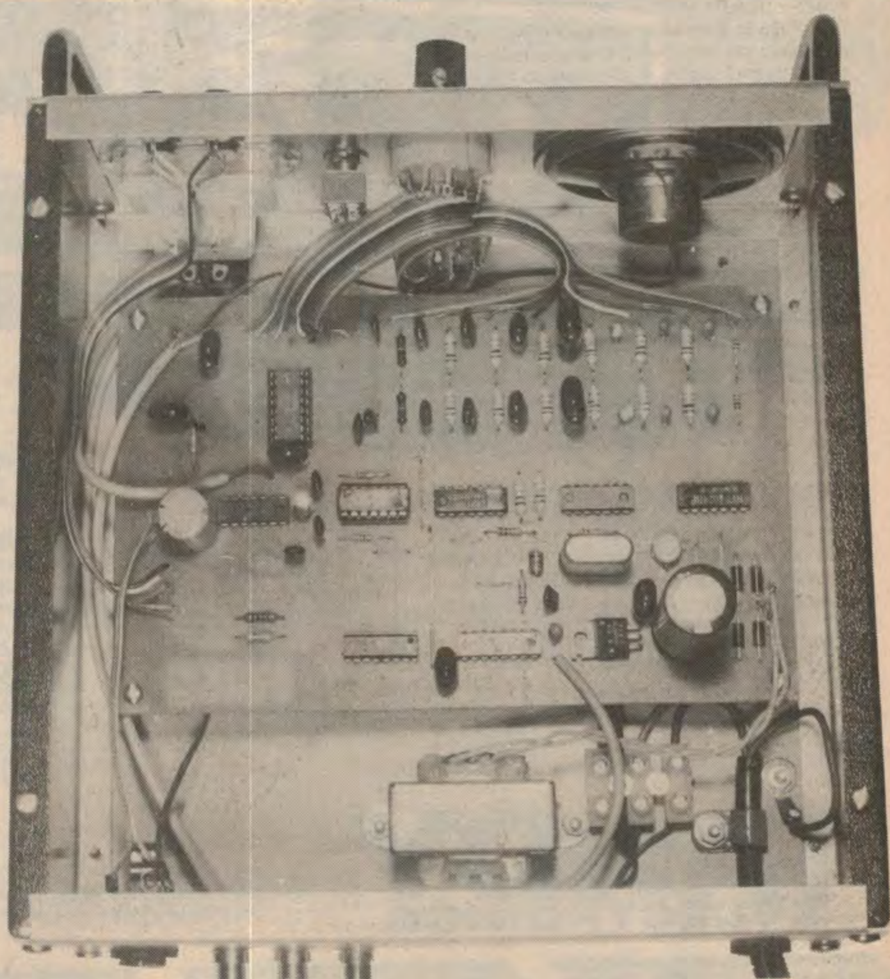
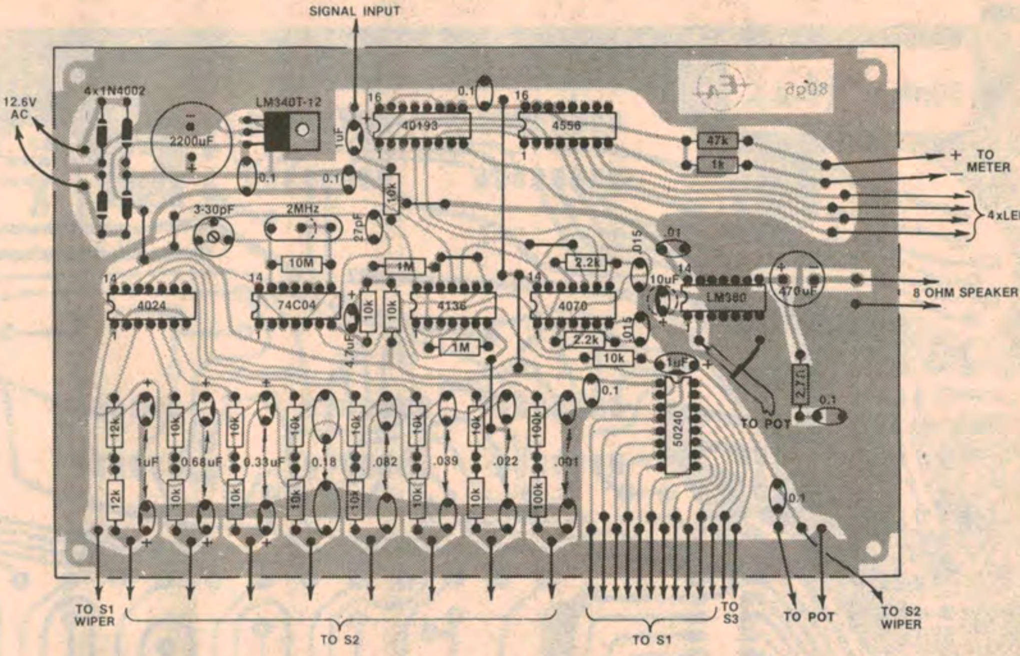


FIG. 1

This diagram shows the major features of the complete circuit which uses 13 ICs.



MUSICAL TONE GENERATOR — continued



Use ribbon cable to the switches to keep the wiring tidy.

PARTS LIST

- 1 Horwood instruments case, 204 x 100 x 210mm (W x H x D)
- 1 Front panel overlay, 204 x 90mm
- 4 rubber feet
- 2 single-pole, 12-position rotary switches (see text)
- 1 SPDT miniature toggle switch
- 1 edge-reading meter scaled 0-10
- 3 knobs
- 1 miniature 8 ohm loudspeaker
- 2 metres of 3-core mains cord and 3-pin plug
- 1 mains cord clamp and grommet
- 1 three-way insulated terminal block
- 1 6.5mm jack socket
- 3 RCA sockets, single-hole mounting
- 1 PCB, 177 x 110mm, code 80g6
- 1 transformer, 12.6V secondary, Ferguson 2851, A&R 6474, DSE 2851 or equivalent
- 1 2MHz crystal, 20pF ambient HC-33/U (see text)
- 4 PCB spacers

SEMICONDUCTORS

- 4 1N4002 rectifier diodes
- 4 red LEDs with bezels
- 1 LM340T-12, uA7812 12V 3-terminal regulator
- 1 50240 top-octave synthesizer
- 1 4069, 74C04 unbuffered hex inverter
- 1 4030, 4070 quad exclusive-OR gate
- 1 40193, 74C193 up-down binary counter
- 1 4556 dual 2-to-4-line decoder
- 1 4024 7-stage ripple counter
- 1 uA4136 quad op amp
- 1 LM380 14-pin power amplifier

CAPACITORS

- 1 2200uF or 2500uF/25VW PC electrolytic
- 1 470uF/16VW PC electrolytic
- 1 10uF/16VW PC electrolytic
- 1 4.7uF/16VW tantalum electrolytic
- 4 1uF/35VW tantalum electrolytic
- 2 0.68uF/35VW tantalum electrolytic
- 2 0.33uF/35VW tantalum electrolytic
- 2 0.18uF/100VW metallised polyester (greencap)
- 6 0.1uF greencap
- 2 .082uF greencap
- 2 .039uF greencap
- 2 .022uF greencap
- 2 .015uF greencap
- 1 .01uF greencap
- 2 .001uF greencap or polystyrene
- 1 27pF polystyrene or NPO ceramic
- 1 3-30PF Cermet or Philips trimmer

RESISTORS

(5% tolerance, ¼ or ½W rating)
1 x 10M, 2 x 1M, 2 x 100k, 1 x 47k, 16 x 10k, 2 x 12k, 2 x 2.2k, 1 x 1k, 1 x 2.7 ohms
1 470k (log) potentiometer with switch

MISCELLANEOUS

Solder, solder lug, hookup wire (various colours), screws, nuts.
NOTE: Ratings are those used on the prototype. Components with higher ratings may generally be used providing they are physically compatible. Components with lower ratings may also be used in some cases provided the ratings are not exceeded.

decoder. This has four mutually exclusive outputs which drive the four LEDs. Even though the outputs are mutually exclusive, there is still a fluctuation in the LED current through the common 1k resistor. This fluctuation is monitored by the meter to give a better indication of very low frequency beats.

Power supply requirements are quite modest. All the CMOS circuitry runs from +12V provided by a three-terminal regulator, LM340T-12 or uA7812. The LM380 amplifier IC runs directly from the unregulated DC of approximately 18 volts provided by the bridge rectifier, 2200uF/25VW capacitor and 12.6V transformer.

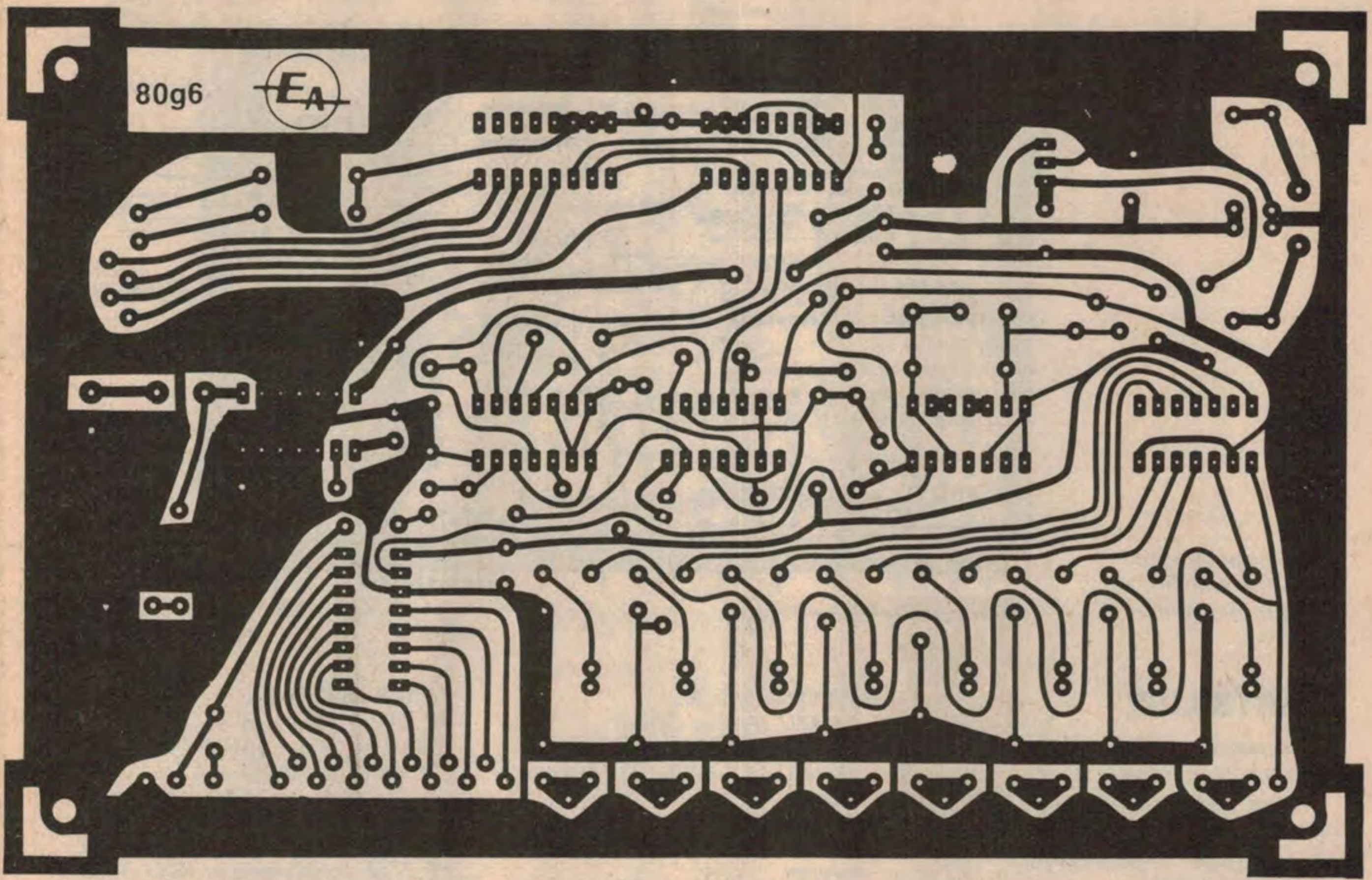
CONSTRUCTION

All the circuitry, with the exception of the switches and other hardware is mounted on a PCB measuring 177 x 110mm and coded 80g6.

The printed circuit board should be available from the usual outlets by the time this appears in print. The box which houses the instrument is made by Horwood and should be available from most stores.

The Scotchcal label for the front panel is obtainable also from Radio Despatch Services, as is the Horwood box.

The meter is also a common type and no trouble should be experienced here. The LEDs which we used on the prototype have chrome plated bezels and are rather expensive. However, other types may be used.



This is the full size PCB artwork.

Construction should begin with the assembly of the PCB. In carrying out this task, the usual precautions should be taken. A good soldering iron with a bit suited to small work is a must and care should be taken not to overheat components during soldering. Also, care should be taken to be sure that every soldered joint is a good one and that the solder has flowed properly. Resin cored solder ONLY should be used. It has come to our notice recently that some builders in their keenness to do a "good" job have used corrosive fluxes. This practice should be strictly avoided.

The use of sockets is optional. We used a socket for the most expensive chip but soldered the rest directly into circuit. If you elect to solder the ICs directly to the board, the barrel of the soldering iron should be connected with a clip lead to the "earthy" copper of the board. In any case, MOS ICs should only be removed from their packing immediately prior to fitting them to the board.

It is generally convenient to start the board assembly by fixing the smallest components first. There are seven jumpers on the board and they should be fitted first, using some 22 gauge tinned copper wire. These may be followed by the resistors, small capacitors, diodes, ICs or sockets, checking carefully for dry joints. Care should be taken to observe the polarity of components where this applies. At this stage, the PCB may be put aside until later on.

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

$85

This includes sales tax.

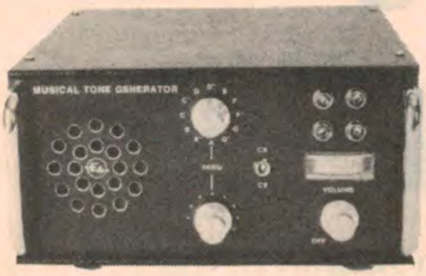
Fitting the Scotchcal overlay to the front panel is a tricky job and calls for some care. This done, all the holes should be drilled, taking care not to damage the panel. All components may then be fitted to the panel. Provided a very neat fitting hole is cut for the meter, it may be made a push fit, without any other fixing. Alternatively, some judicious use of a suitable adhesive could suffice.

There is no direct means of fitting the miniature loudspeakers to the panel. We solved the problem by fixing it with four spots of Araldite epoxy adhesive, allowing it to set overnight.

Two one-pole, 12-position rotary switches will be required. If C&K Lorlin switches are purchased, one may be modified to operate as an eight-position switch for the octave selector. Otherwise, just ignore the unused four positions. The two switches should be oriented so that their knobs point to the correct markings on the panel. The stop for the note selector is between B and C.

The back panel of the box requires five holes, three for the RCA sockets, one for the external speaker jack and one for the mains lead rubber grommet. The bottom of the box requires four holes for mounting the PCB, four for fixing the mains lead terminal strip and transformer, and one for the mains lead clamp. The PCB should be located so that there is about equal space between the board edges and the front and back panels.

Before fitting the PCB to the box, there are some preparatory matters to be dealt with. The sockets and rubber grommet are now fixed to the back panel. The mains cord may also be fitted and terminated and clamped. The green or earth lead should be terminated on a



solder lug held with one of the back panel fixing screws.

Before the PCB is fitted, all leads destined for external points must be added. Those leads to the two rotary switches should best be made with rainbow cable to help with identification. In the prototype, we used shielded audio leads from the input to the LM380 and from the volume control to the RCA socket on the back panel.

With the PCB fully prepared, mount it in the box, using four tapped spacers and suitable screws. Do not attempt to wire the rotary switches at this stage. Rather, push the relevant cables out of the way so that the rest of the wiring may be done. Wire the volume control first, terminating the shield leads on the appropriate lug. This lug is also connected back to the board via an earth lead. The other ends of the shielded leads have the shields cut off. The switch on the volume control may now be wired.

When you are satisfied that all the wiring is complete it should be thoroughly checked to make sure that there are no errors. This check should include the PCB as well. Components should be checked for correct placement and value, as well as correct polarity. Satisfied that all is well, it is ready to be given its initial tests.

If you have a frequency counter and you intend to set the crystal to the frequency of your choice, then now would be a good time to do it. The crystal signal may be taken off between a ground point and pin 6 of the 74C04. Switch on and if all is well the crystal frequency should appear on the counter. Set to the wanted frequency with the trimmer capacitor.

AUDIBLE CHECKS

It should now be possible to make some audible checks. A good place to start would be with A440. Set the two switches to this position and advance the volume control. The 440Hz tone should be heard from the speaker. Now rotate the upper switch right across the scale from C to B and all notes should be heard and in their right order. If the order is not right, there is a switching problem to be corrected. Now rotate the octave selector and the various octaves of the note selected should be heard, again in their respective order. The toggle switch selects C9, top C available.

Due to the inability of the small speaker to reproduce the lower frequencies, it may not be possible to hear anything in the lower couple of octaves or so. This may be remedied by plugging in a larger enclosed speaker into the jack provided.

During these tests, the four LEDs should appear to be on and the meter should read about half scale. With C selected on the upper switch, C8 on the toggle switch and the lowest octave on the lower switch, the LEDs will appear to be flickering. Actually, the LEDs are not all on at the one time but they are rotating, at a low speed for the low frequencies, increasing as the frequency is increased.

If you have observed all the above, it is a good bet that your Musical Tone Generator is working properly and ready for service.

HOW TO USE IT

The method of using the generator for tuning a musical instrument will depend largely on the type of instrument being tuned. If it is an acoustic instrument such as a piano, then the sound from the speaker will be used to bring the corresponding tone of the instrument to zero beat. An external speaker will of course be necessary for a job such as this one. The LEDs and the meter will be ignored for this type of operation. Another method of tuning an acoustic instrument would involve the use of a microphone so that the LED beat indicator could be employed. This would require a suitable microphone preamplifier.

If you wish to tune an electronic organ, the output from an appropriate speaker on the organ will be patched to the input of the generator. A stop will be chosen which is not too loaded with harmonics, such as a flute or tibia and the volume set at a low level so as not to be annoying in its own right. The input preamplifier of the generator will perform satisfactorily with levels ranging from about 50mV to 10V rms.

The note to be adjusted is selected on the keyboard and the corresponding note and octave is also selected on the generator. The LEDs will appear to be rotating if the organ note is off tune, the rotation direction will depend on whether the note is higher or lower than the generator. The note is adjusted so that the LED rotation stops and then the needle of the meter may still be moving slowly and adjustment is then made until the needle remains stationary.