Accurate frequencies from 4kHz to 2MHz!

Quartz multiple frequency reference

This relatively simple unit will give any of a series of accurately controlled reference frequencies, derived from a 2MHz crystal via a switched binary divider arrangement. A large number of frequencies is possible, ranging from 2MHz to just under 4kHz.

by IAN POGSON

It all started several weeks ago when two members of our staff were contemplating a new project. The need for an accurate frequency reference arose, in order to follow through with the particular project. The need was met in a satisfactory way at the time, but it pointed up the need for a simple but reliable frequency reference. And so the idea of our new Quartz Multiple Frequency Reference was born.

When the idea for a project arises, quite often it goes through many phases before the final design is arrived at. This one was no exception. The idea of starting off with a 10MHz crystal seemed to be a good one. For one thing, harmonics of 10MHz could be useful well into the VHF region and this seemed to be a good enough reason for adopting this approach. Indeed, a rough prototype was produced and made to work quite satisfactorily. However, there were problems.

Right from the start the aim was to keep the circuitry as simple as possible, so maintaining a useful device at a reasonable cost. While the first prototype was relatively simple, it was not possible to use low-power CMOS devices throughout as they would not be a reliable proposition at as high a frequency as 10MHz.

This meant that we had to use a 74LS90 low power Schottky device for division from 10MHz down to say 2MHz. At this stage, we were running the CMOS devices and the 74LS90, together with a 74LS04 hex inverter, from the 5V supply.

Unfortunately this arrangement turned out to be unsatisfactory due to lack of speed in the operation of the CMOS devices when operated at 5V. Increasing the supply voltage to 12V seemed the only solution and indeed, this proved to be the case. However, this introduced the real problem of having to operate the CMOS devices from 12V and the LS devices from 5V. Furthermore, this posed the necessity of interfacing between the two different types of devices.

It was difficult to solve these problems without sacrificing simplicity, so the whole project had to be given more thought. All of the problems could be solved by dropping the idea of using a 10MHz crystal and settling for one at 2MHz. All things considered, this seemed to be the best way out and this is the method which we have adopted. While it must be conceded that harmonics of 2MHz will normally not be usable up to as high frequencies as could be expected from a 10MHz source, this seemed to be a fair price to pay. A look at the circuit will show how it has worked out.

The crystal oscillator is just about as simple as it could be, consistent with meeting the demands of a stable performance. It uses a dual gate MOSFET in a modified Pierce oscillator. Some of the output from the drain is fed back to G1 via a 120pF capacitor, with a silicon diode connected between G1 and ground. This part of the circuit comprises an AGC system, thereby controlling the output level of the oscillator, a very desirable feature. Claims for this oscillator are that there is very little change in oscillator frequency due to supply voltage and temperature changes. This virtually leaves only frequency changes due to the crystal itself.

The output from the crystal oscillator is low in harmonic content and at a fairly low level, not suitable for driving the 4013 dual D flipflop. Accordingly an interface buffer stage using a 2N706 high speed switching transistor has been added. The output of this stage drives the clock input of one half of the 4013. In addition, the 2MHz output is also fed to one of the 4009 inverters, and finds its way to the output socket via the selector switch and output level control.

Frequency	us	Switch
1MHz	1	1
500kHz	2	2
250kHz	4	4
200kHz	5	1,4
125kHz	8	8
100kHz	10	2,8
62.5kHz	16	16
50kHz	20	4,16
40kHz	25	1,8,16
31.25kHz	32	32
20kHz	50	2,16,32
10kHz	100	4,32,64
8kHz	125	1,4,8,16,32,64
5kHz	200	8,64,128
4kHz	250	2,8,16,32,64,128

This table shows the switch combinations for various frequency outputs from the instrument. Note that the delay in microseconds (us) is equal to the sum of the switch settings.

The first section of the 4013 is connected in front of a 4024 7-stage ripple-carry binary counter/divider (IC 2) to make an 8-stage system. The respective outputs are fed into a 4068 8-input NAND gate via a bank of 8 SPDT toggle switches. The output from pin 13 of the 4068 is split and one part goes via three sections of the 4009 inverters to reset the 4024 and the 4013. The other part is used to feed the second section of the 4013, which is used as a divide by 2 and squarer stage for the output from the divider system. This arrangement means that we can set the bank of switches in terms of microseconds corresponding to the period of the wanted output frequency.

The selected frequency output from pin 13 of the 4013 is buffered like the 2MHz output by feeding it through another one of the 4009 inverters. The remaining sixth inverter is not used. Either output as selected by the two-way rotary switch is fed via a protective diode and limiting resistor to a 500 ohm level control prtentiometer. The output approximates a square wave, and is about 2V peak-to-peak.

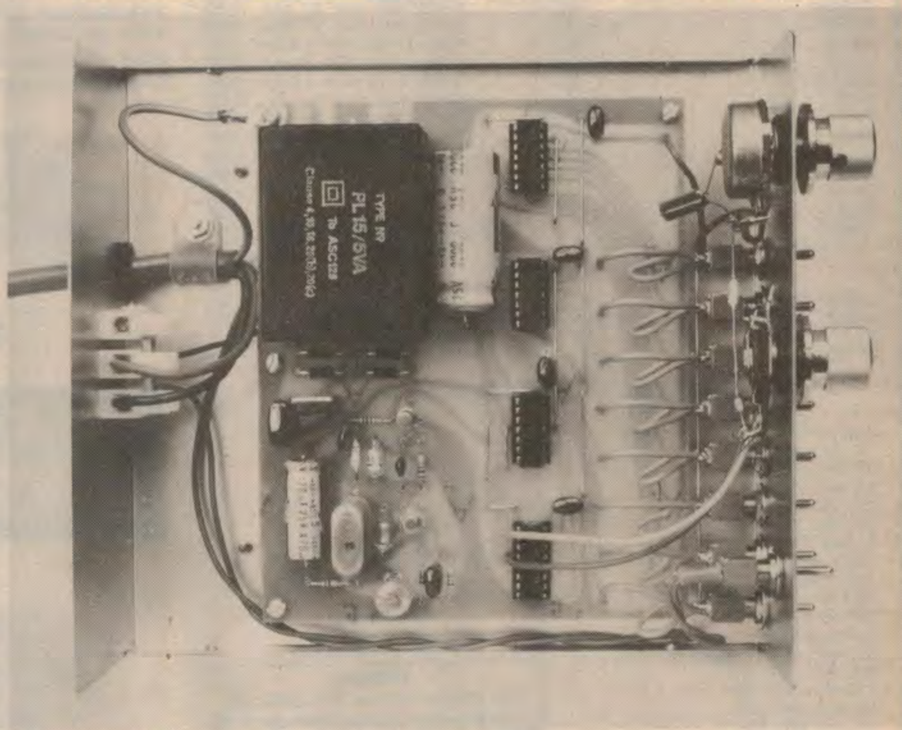
Power is derived from a type PL15/5VA PCB-mounting transformer, feeding a full-wave bridge rectifier and filtered with a 2200uF capacitor. The resultant DC voltage is regulated with an LM340T-12 IC, giving a well regulated 12V DC supply.

Components for the unit should be readily available, there being no special parts required, except possibly for the crystal. Undoubtedly, the crystal is a vital component and the overall performance of the instrument depends upon it. The crystal which we used is one which we happened to have on hand. It is a standard unit and the specifications are given in the parts list. The important question is where suitable supplies are available, and the delivery time which may be expected.

Crystals should normally be available from such people as Bright Star in Melbourne. Also, it is possible to send overseas to such suppliers as Texas Crystals, 1000 Crystal Drive, Fort Myers, Florida, USA and Interface Quartz Devices, 29 Market Street, Crewkerne, Somerset, TA18 7JU, in England. Also we understand that there is a local supplier with components off the shelf at the wanted frequency and at a reasonable price. Inquiries should be directed to D. Bowen, P.O. Box 123, Beecroft, NSW 2119.

As may be seen from the pictures, the instrument is housed in an attractive metal box. Most of the components are accommodated on a PC board, with switches, output socket and attenuator mounted on the front panel. The mains flex enters at the back and is terminated on a terminal block on the back panel. The PC board is fixed with five ½in long tapped spacers. The label on the front panel of the prototype was done with "Scotchcal".

The prototype was built into a standard metal case. Eight toggle switches and one rotary switch give accurate square wave frequencies from 4kHz to 2MHz.



A single PC board accommodates most of the components.

The printed board we have produced measures 113 x 138mm, and is coded 79fr6. It is made to take the PCB-mounting transformer made by Ferguson. This transformer is readily available and you should be able to get one through your local supplier.

General components, including transistors and ICs are standard items and are readily available at the time of writing. Details of the PCB are being made available to manufacturers as usual and supplies should be forthcoming by the time this appears in print. The box housing the unit is a popular line stocked by Dick Smith Electronics and should be available from any of their stores.

Construction of the instrument is best done by starting with the printed board assembly. The usual care should be taken. For soldering, a good hot iron is a must and all soldered joints should be done with care, making sure not to overheat any components. If you decide to use sockets for the ICs, then the only care required here is to make sure that no solder bridges are left across adjacent pin connections. On the other hand, if you wish to solder the ICs directly into the board, then the usual care should be taken when soldering CMOS devices. The barrel of the soldering iron should be connected to the earthy copper on the board via a length of flexible clip lead.

We suggest that you start off by fitting the ten tinned copper wire links.

Frequency reference

This should be followed by such small components as resistors and diodes, followed by capacitors and leading up to the larger components, finishing up with the transformer.

During this process, it is very important to observe polarities with such components as electrolytic capacitors, transistors, diodes and ICs. The correct polarity is shown in each case on the circuit diagram.

Having fitted the components to the board, it is a good idea to carefully check the work thus far, making sure that all components are in the right place and the polarities are correct. A number of lengths of hookup wire also have to be soldered to appropriate points on the board; most of them will be terminated on the various switches. Leads are also required to run from the 240V transfromer terminals to the mains switch and terminal block.

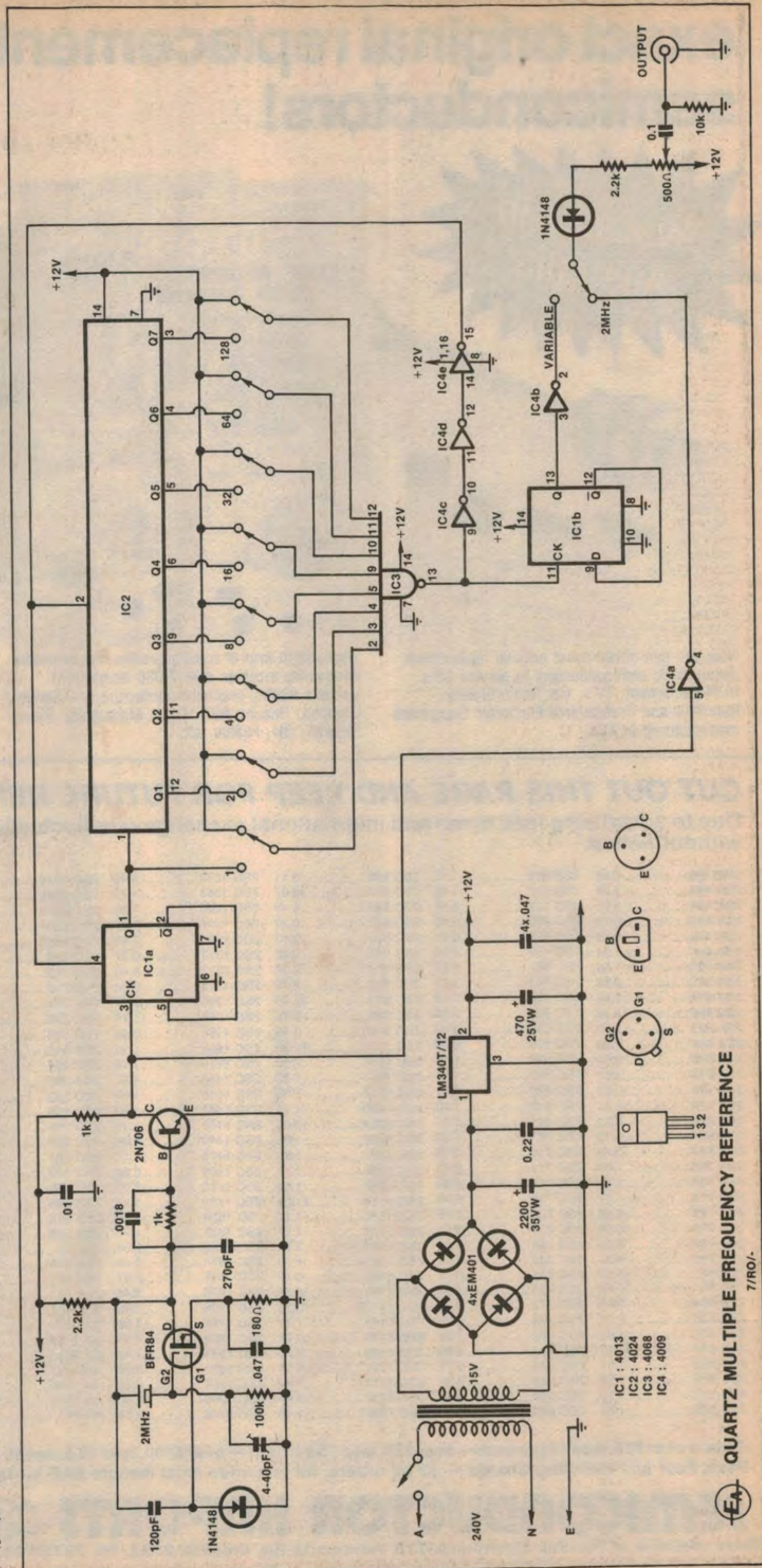
With the board assembled, it may be put aside for the time being and the various components fitted to the front and back panels. The eight toggle switches should be mounted, making sure that they are all parallel with each other. At this stage, a length of tinned copper wire is soldered along and connecting all the bottom lugs of the switches together. These will be connected to the +12V line later on.

The rest of the items may now be fixed to the front panel. A solder lug is needed under one of the fixing nuts for the coax socket, with a 0.1uF capacitor from the same point to the centre lug of the attenuator. A 2.2k resistor and a 1N4148 diode are connected in series and run between the attenuator and the common point on the "2MHz — Variable" selector switch. The junction of the resistor and the diode are soldered together, forming one continuous lead.

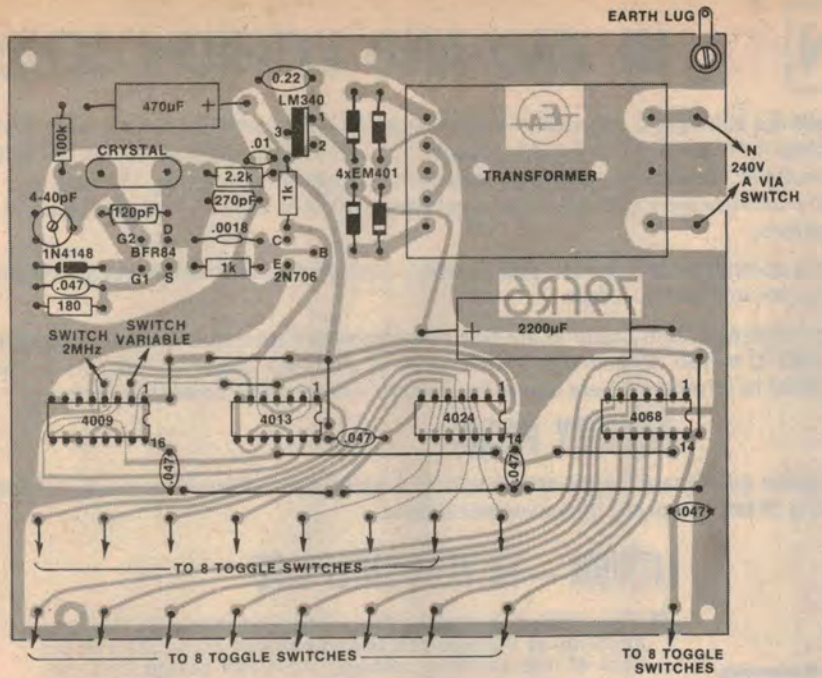
Using the five spacers, the printed board assembly may now be fixed in position. It should be so arranged that there is a space of about 2-3mm between the front edge of the board and the lugs on the row of eight toggle switches. With the board in place, the +12V lead should be terminated onto the common line of the switches. Following this, the leads nearest the edge of the board are terminated to the middle lug of each respective switch. The next row of leads are connected to the top lug of each switch. Just sufficient lead length should be left so as to make a neat gooseneck of each lead.

The two leads emerging from the board adjacent to the 4009 IC are terminated on the respective lugs of the rotary selector switch.

On the back panel, a rubber grommet should be provided for the mains lead and a three-terminal block



QUARTZ MULTIPLE FREQUENCY REFERENCE



This component overlay diagram shows the PC board as viewed from the component side of the board. Take particular care when inserting polarised components.

PARTS LIST

1 Metal box 184mm x 70mm x 160mm
9 SPDT miniature toggle switches
1 Rotary switch SPDT
1 Belling Lee coax socket
1 500 ohm linear potentiometer
2 Knobs to suit
1 Printed board 137mm x 114mm, code 79FR6
5 Brass spacers ½in long tapped ⅛in Whitworth
1 Transformer, Ferguson PL15/5VA
1 Crystal, 2000kHz, 20 to 30pF, ambient temperature, HC6/U or HC33/U holder
1 Socket to suit crystal (if required)
1 Transistor BFR84
1 Transistor 2N706
2 Diodes 1N4148
4 Diodes EM401 or similar
1 IC, LM340T-12
1 IC, 4009
1 IC, 4013
1 IC, 4024
1 IC, 4068
1 IC socket 16-pin DIL
3 IC sockets 14-pin DIL

RESISTORS (½W)
1 x 180 ohms, 2 x 1k, 2 x 2.2k, 1 x 10k, 1 x 100k.

CAPACITORS
1 4-40pF Philips trimmer
1 120pF polystyrene
1 270pF polystyrene
1 .0018uF greencap
1 .01uF greencap
5 .047uF greencap
1 0.1uF greencap
1 0.22uF greencap
1 470uF 25VW electrolytic
1 2200uF 35VW electrolytic

MISCELLANEOUS
Hookup wire, 20G TC wire, solder, solder lug, screws, rubber grommet, 3-core flex, 3-pin plug, cable clamp, cable terminal strip.

NOTE: Resistor wattage ratings and capacitor voltage 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.

for its termination. Only two of the block positions are used, the earth lead being brought directly to a lug under the screw head on the board in the corner next to the transformer. The mains lead should also be clamped just inside and near to the rubber grommet. During the wiring of the mains cord leads to the terminal block, the appropriate leads are also run to the transformer terminations on the board and to the mains switch on the front panel.

At this stage, construction is virtually complete and a careful check should be made to ensure that all is well before switching on. To make some checks on the instrument, a receiver and/or a CRO can be put to good use. Satisfied that there are no errors, power may be applied. A check on the supply voltage should verify that it is very close to 12V.

If you have a CRO, then the output of the Frequency Reference may be fed into it. Set the attenuator for full output and the selector switch to 2MHz. You should have a square wave at 2MHz on the screen. Set all the eight "microsecond" switches to the up or off position and reset the selector switch to "variable". There should be no signal on the screen. Operate the 1 microsecond switch and you should then have a 1MHz square wave on the screen. Similarly, as you operate the microsecond switches, you should get the appropriate frequency square wave displayed on the screen. It may be just as well to check that the attenuator control is working normally.

If you have a receiver capable of covering a wide range of frequencies, then this may be used to check for proper functioning of the Frequency Reference. It is a good idea to check the 2MHz output first, by setting the output to this frequency as before and by tuning the receiver to 2MHz or a harmonic thereof. Rather than connecting the output of the reference directly into the aerial terminal of the receiver, it should only be necessary to bring a lead from the output socket close to the aerial lead on the receiver.

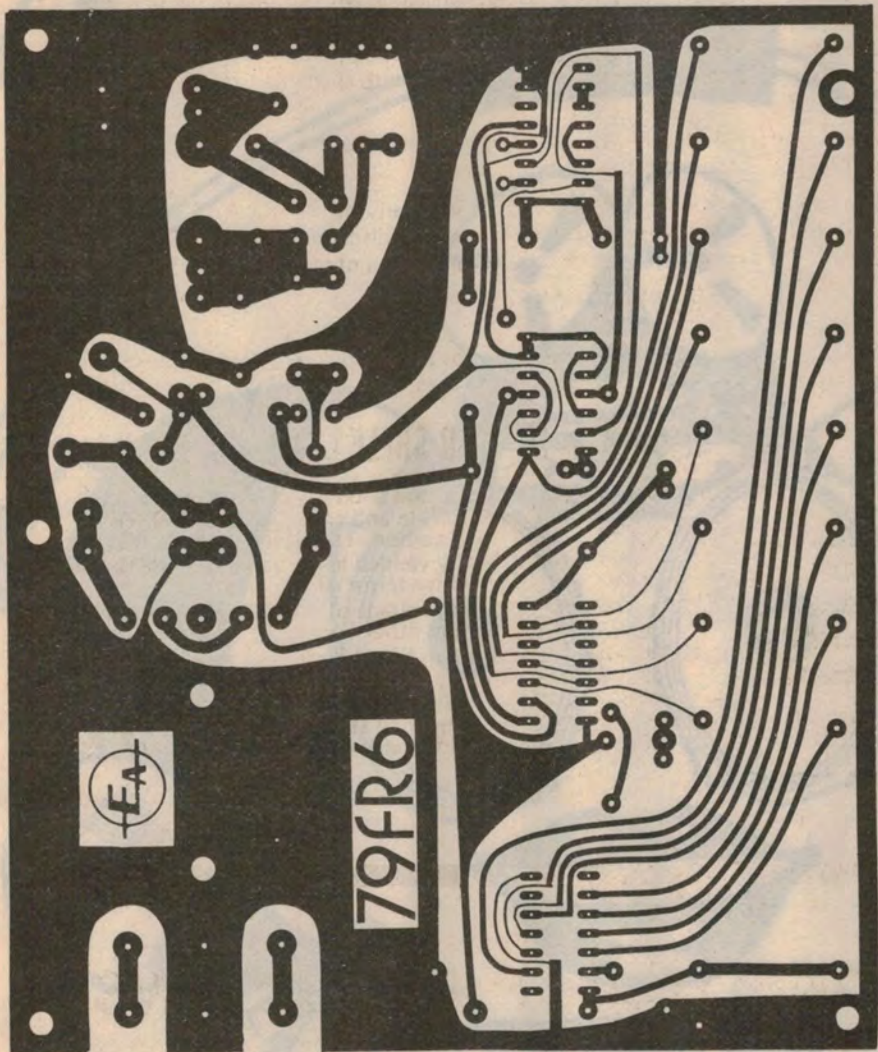
> We estimate that the current cost of parts for this project is approximately
>
> **$55**
>
> This includes sales tax.

You may then proceed to set up other frequencies and to tune in either to the fundamental or a harmonic. During this process you may take the opportunity to calibrate the crystal frequency against a standard, such as VNG, on 7.5MHz or 12MHz during daylight hours, or 7.5MHz or 4.5MHz during the hours of darkness. Other frequency standard transmissions such as WWV may also be used if convenient.

To do the calibration, first select the transmission which you intend to use. Then you must select a subharmonic from the Frequency Reference to suit. If you use VNG on 12MHz, or WWV on 10MHz, then the 2MHz output may be used. On the other hand, if you choose VNG on 7.5MHz (which is more than likely) then you will need to select say the 500kHz output from the Frequency Reference.

Having made the above choices, then the amount of signal fed into the receiver must balance the received signal so that a beat note can be readily discerned. Too strong a signal from the Frequency Reference will blanket the received frequency standard signal making the beat note hard to detect.

Assuming that all this has been done and a beat note established, then the 4-40pF trimmer of the oscillator should



be very carefully adjusted for a zero beat condition. This is not easy to do particularly if some accuracy is sought. The beat note will fall below audibility from the speaker (or headphones) and by careful adjustment, the S meter on the receiver may be used to get very close to zero beat.

With the tests and calibration completed, the instrument is ready for whatever use you may have for it. These uses may be all the way from calibrating receivers in the RF regions, down to references for audio use.

To facilitate its use, we have provided a table giving some of the more commonly used frequencies, showing how that frequency may be set up on the instrument. By way of a couple of examples, suppose that you need 200kHz. Then the selector switch will be set to "variable" and the "microseconds" switches will be set to 5, or 1 and 4. If you want 10kHz, then you will set the switches to 100, or 4, 32 and 64. And so on.

It will be readily understood that this unit will only give those frequencies which can be set up on the switches. But this is a limitation which should not cause too much inconvenience. When it is considered what the instrument will do for the amount of complexity and cost involved, it seems acceptable.

There may be times when an approximate frequency will serve the purpose quite well. If, for instance, you need about 9kHz, then this may be approximated by dividing by 111. This gives 9.009009kHz, which may be near enough for the particular purpose.

Finally, we were interested to check

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Actual size reproductions of the PC board (left) and the front panel artwork (below). The front panel may be cut out and used directly, if required.