A CRYSTAL-LOCKED STANDARD

for 10-100-1000KC

Our crystal standard is constructed in a compact little case made from "Lectrokit" basic parts. This form of constructon allows "add-on" units to be incorporated at a later stage, if desired.

Here is a versatile crystal standard which could be an invaluable aid in the accurate frequency calibration of communications receivers or transmitters, whether "home brew" or commercial equipment. It includes an additional oscillator arrangement which is useful for checking the activity and frequency of crystals between 1 and 15MC.

By Keith Jeffcoat

QUITE apart from their usefulness in establishing an initial calibration of a piece of equipment, crystal standards, such as the one to be described, are extremely handy pieces of equipment to have around for use in day-to-day listening around the short wave bands.

Suppose, for instance, that it is desired to receive Radio Canada on 5970KC on a receiver such as the "Communications Eight" recently described in the magazine. This receiver has quite reasonable dial calibrations but they are not good enough to allow the dial to be set exactly to this specified frequency.

By using the crystal calibrator, first in its 1MC position to locate 6MC on the receiver dial, and then in its 10KC position to locate the third 10KC marker on the low frequency side of 6MC, we will have accurately set the receiver dial to within a few hundred cycles of the desired frequency, certainly close enough to receive Radio Canada if it was on the air and putting in a strong enough signal.

The calibrator is so designed that its harmonic output on the 100KC and 10KC ranges can be heard at good strength on the average receiver up to and including 30MC; output from the 1MC crystal should be usable up to at least 50MC.

A study of the circuit diagram will show the general design of the instrument. A 6AM6 is used in a modified Colpitts oscillator circuit with a switching arrangement to select either the 1MC or 100KC crystals as desired.

Each of the crystals has across it a trimmer capacitor which allows "spot on" accuracy to be obtained. It will be noted that the crystal selector switch also changes the value of grid bias resistor and capacitive coupling, grid to cathode, of the oscillator. This change of component values is necessary because a common set of values will not suffice for both the 1MC and 100KC crystal, or even individual crystals of the same frequency.

The values given in our circuit were determined empirically for the particular crystals we used (new units supplied to order by A.W.A.) and some alteration of these values may be necessary to obtain the best results from crystals of other makes. We tried, for example, a 100KC crystal currently available from disposals sources and found that the 470pF capacitor between cathode and ground had to be increased to 1000pF before the crystal would oscillate satisfactorily.

The main components which determine whether a crystal will oscillate satisfactority in the circuit are the resistor between grid and cathode of the 6AM6 and the capacitor between cathode and ground.

In determining the correct values for these components it is not sufficient to choose a value which merely causes the circuit to oscillate at the crystal frequency; the component values must also be chosen to minimise any spurious responses the crystal may have.

It is not uncommon, for instance, to find that a crystal will oscillate at its marked fundamental frequency but produce, at the same time, a spurious oscillation somewhat higher in frequency. The presence, or otherwise, of such a spurious oscillation can be determined by feeding the output of the oscillator into a receiver, preferably on the broadcast band, and checking that only the anticipated fundamental and harmonics of the crystal can be heard.

The output from the crystal oscillator is taken, electron coupled, from the plate of the 6AM6 and fed into one half of a 12AU7 which acts as a buffer/amplifier stage. The lack of cathode bias on this amplifier stage is quite deliberate since it is intended to run class C, with grid rectification and produce output which is harmonically richer than its input.

Output from this amplifier is fed into the second half of the 12AU7, which is run as a cathode follower. The component values of this stage have been chosen, once again, to carry it toward class C operation with the object of further distorting and therefore harmonically enriching the output signal.

The main purpose of the cathode follower, however, is to provide a signal output at an impedance which is more appropriate to the average receiver on which the calibrator might be used. Taking the output from a potentiometer in the cathode return of the cathode follower also provides a convenient means of attenuating the output signal to a desired level.

The 12AV7 in our circuit is wired as a straight multivibrator with component values chosen so that, lacking an incoming synchronising signal, it will "free run" at frequencies between 6 and 12KC depending on the setting of the grid potentiometer.

The 12AV7 appeared to be the best choice for the multivibrator, with the 12AY7 a close second. The 12AT7 gave comparable harmonic content, but did not lock as easily; the 12AX7 was markedly deficient in higher order harmonics. Other VHF twin triodes could be tried, if you have them on hand, but requirements differ in regard to sockets and/or pin connections.

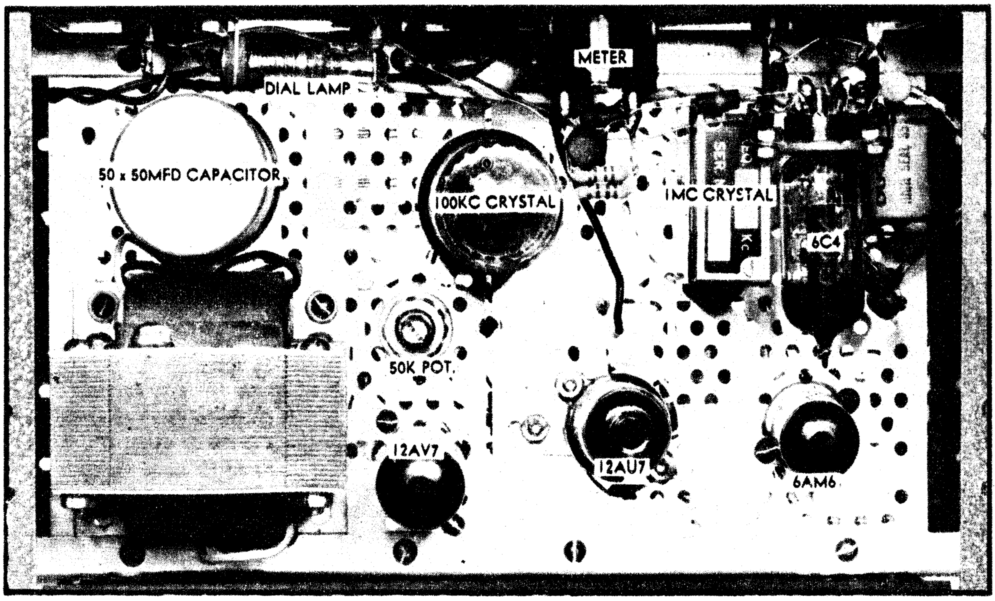
One grid of the multivibrator is coupled to the output of the crystal oscillator so that the unit can "lock on" to each tenth cycle of the 100KC crystal and thus produce an output signal at 10KC. The ability of the multivibrator to lock on the tenth and not other "subharmonics" of the crystal oscillator is determined by the setting of the grid potentiometer, but more will be said of this later in the article.

The output from the multivibrator is a square wave of roughly equal mark-space ratio, but the fairly small value of capacitor used to couple this output into the amplifier causes quite a degree of differentiation and the resultant output signal is in the form of a fairly spiky pulse.

The CRO tracings in figure 1 show,

in the upper trace, the output from the 100KC oscillator and, in the lower trace, the output from the 10KC multivibrator. These tracings were obtained on a double-beam oscilloscope with the time base set at 20 microseconds per centimetre and common to both beams. Note particularly the 10 to 1 relationship betwen the upper and lower trace. The multivibrator is being "locked on" to each tenth cycle from the 100KC crystal oscillator.

The CRO tracing in figure 2 is taken from the output terminal of the unit with the function switch in the 10KC position. The time base speed is, again, 20 microseconds per centimetre and the signal displayed shows the 100KC and 10KC fundamentals which are present plus, of course, multiple harmonics of both these frequencies.



In building the prototype unit we inadvertently placed the 1MC crystal a little close to the 6C4 valve. We suggest that, in order to keep temperature problems to a minimum, readers constructing the project should keep these components further apart.

The function switch, S1, is a double wafer four-pole five-position unit which in addition to switching crystals and component values on the crystal oscillator, is also used to apply HT voltage to appropriate stages as required.

The first position of this switch is an "off" or standby position in which all stages are disconnected from the HT line. The second position puts HT on the oscillator and amplifier/cathode follower and connects the 1MC crystal in circuit. The third position leaves HT connected to these stages and brings the 100KC crystal into circuit. The fourth position is a repeat of the third with the addition of HT applied to the multivibrator. The fifth position removes HT from the oscillator, amplifier/cathode follower and multivibrator and applies HT to only the external crystal oscillator.

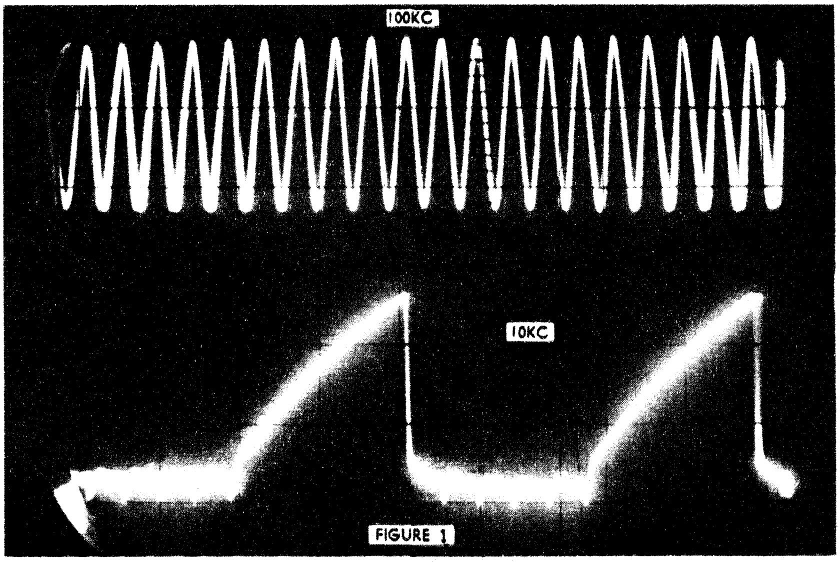
This oscillator is a 6C4 triode valve wired in a simple Pierce circuit and with a milliammeter connected to read the grid current of the valve. With the values chosen most crystals between 1 and 15MC can be made to oscillate quite easily. The output from this oscillator is connected to a separate coax. socket on the front panel of the instrument.

The purpose in including this oscillator in our instrument was twofold; (a) it provides a convenient means, along with suitable crystals, of producing fixed marker frequencies, e.g., 5.5MC for TV work; and (b) it enables crystals to be checked as to whether they will or will not oscillate, while the grid current meter gives a fair idea of the activity.

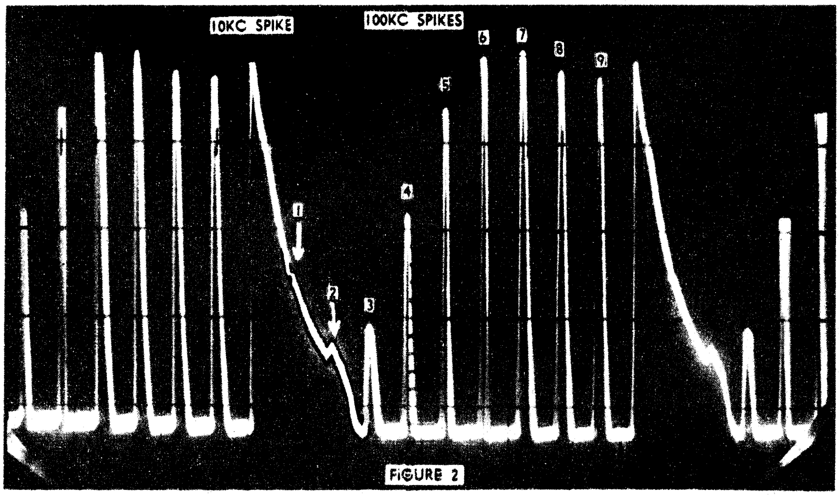
Note that other general-purpose triodes or triode-connected pentodes may be used, if desired, in place of the 6C4.

The power supply of our instrument is fairly conventional—a full-wave rectifier whose output is filtered by a simple resistance/capacitance arrangement. To prevent excessive current being drawn through the diodes at the instant of switch-on, a 22-ohm resistor is included in the centre tap return of the HT winding.

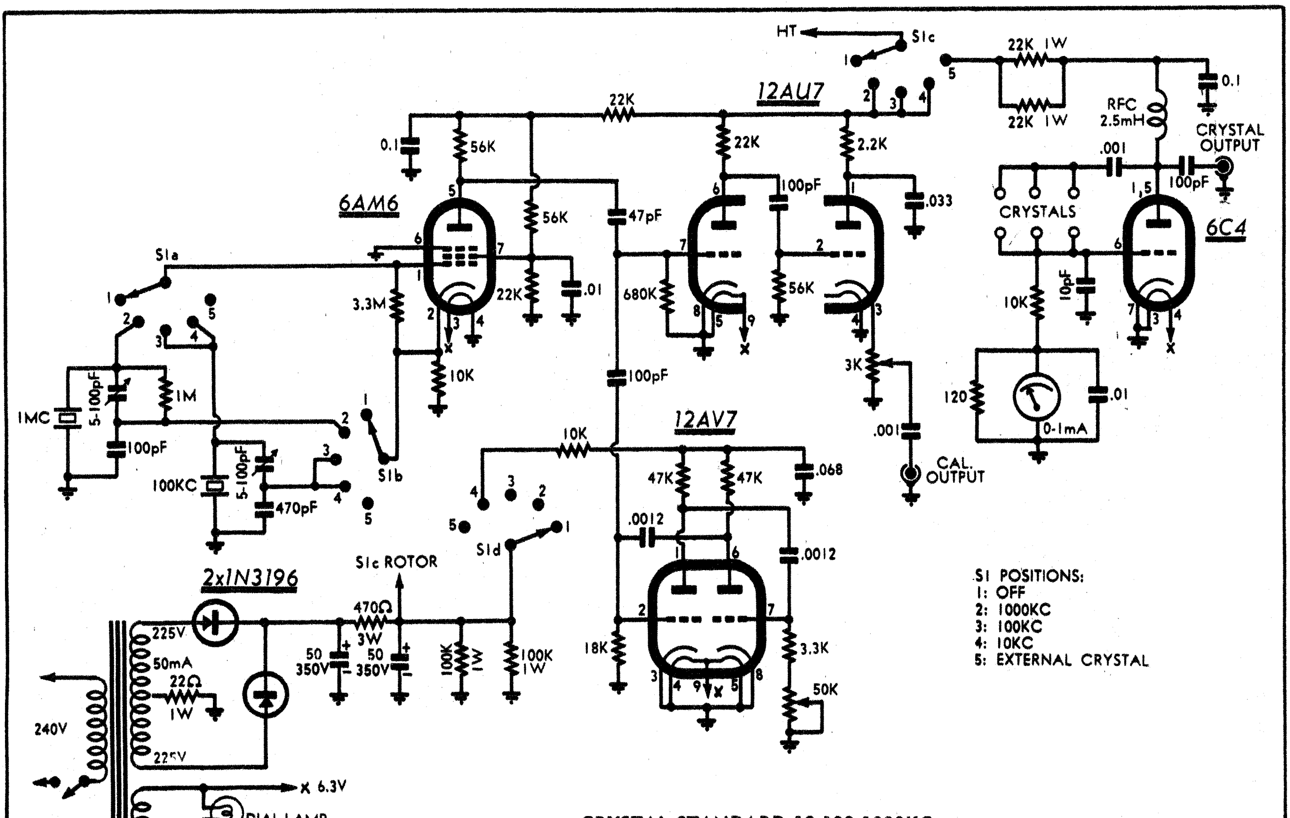
Readers with a close eye for detail will have noticed that, although only two diodes are shown in the power supply circuit, four are actually visible in our underchassis photograph of the unit. The



This CRO tracing shows, in the upper beam, the output of the 100KC oscillator and, in the lower beam, the output from the multivibrator when it is "locked on" to each tenth cycle of the 100KC oscillator.



This waveform shows the output from the unit when the function switch is in the 10KC position. The larger 10KC spike tends to obscure the following two 100KC spikes but, by careful interpolation, their position can be determined



CRYSTAL STANDARD 10-100-1000KC

Although the chassis layout of our calibrator is non-critical, circuit values should be closely adhered to if optimum performance is desired. The only exception is the power supply, which can be any arrangement that delivers approximately 250 volts DC at 40-50mA.

diodes specified in the circuit are 800PIV types but, in the prototype unit, two 400PIV diodes were used in each "leg" of the circuit. Either arrangement is satisfactory but it just happened that the 400-volt types were available to the author at bargain prices at the time the instrument was constructed.

Those who desire to do so could use a voltage doubling power supply in lieu of the one shown and, in this case, a transformer with a single 104-volt secondary winding would be required. The two diodes would only need to have a PIV rating of 400 volts.

There is little to choose here between the two arrangements since the saving in cost on the diodes is offset by the need for an additional electrolytic; the cost of the transformer would be about the same as the one used in our circuit.

As a matter of interest, our crystal standard is constructed in a type of chassis/case system not previously used in any of our projects although it was featured in the Trade Review section of the November 1963 issue.

This metalwork goes under the trade name of "Lektrokit" and is available in this country through E.M.I. (Australia) Ltd. The particular case used is a very convenient size for this instrument and the metalwork is easy to use. In the author's case, a major reason for choosing this particular metalwork was the ease with which other units may later be "added on" to the original instrument.

At some future stage the author plans to increase the versatility of the instrument by adding to it two further multivibrators with outputs of 1KC and 100 cycles, plus a complex pulse generator. These latter features are unlikely to be described in the magazine, however, and readers who plan the construction of the instrument, as is, could just as easily use one of the standard instrument cases featured on many past projects.

Whichever case and chassis is used, the layout could be the same as shown in our photographs of the unit, with one possible exception. When we made our prototype of the unit we did not include the crystal test oscillator. This section was added as an afterthought and, to keep the leads from the crystal sockets to the valve as short as possible the valve was mounted horizontally and directly behind the crystal sockets. The position of the three sockets was, in turn, governed by our desire for a symmetrical panel layout.

PARTS LIST

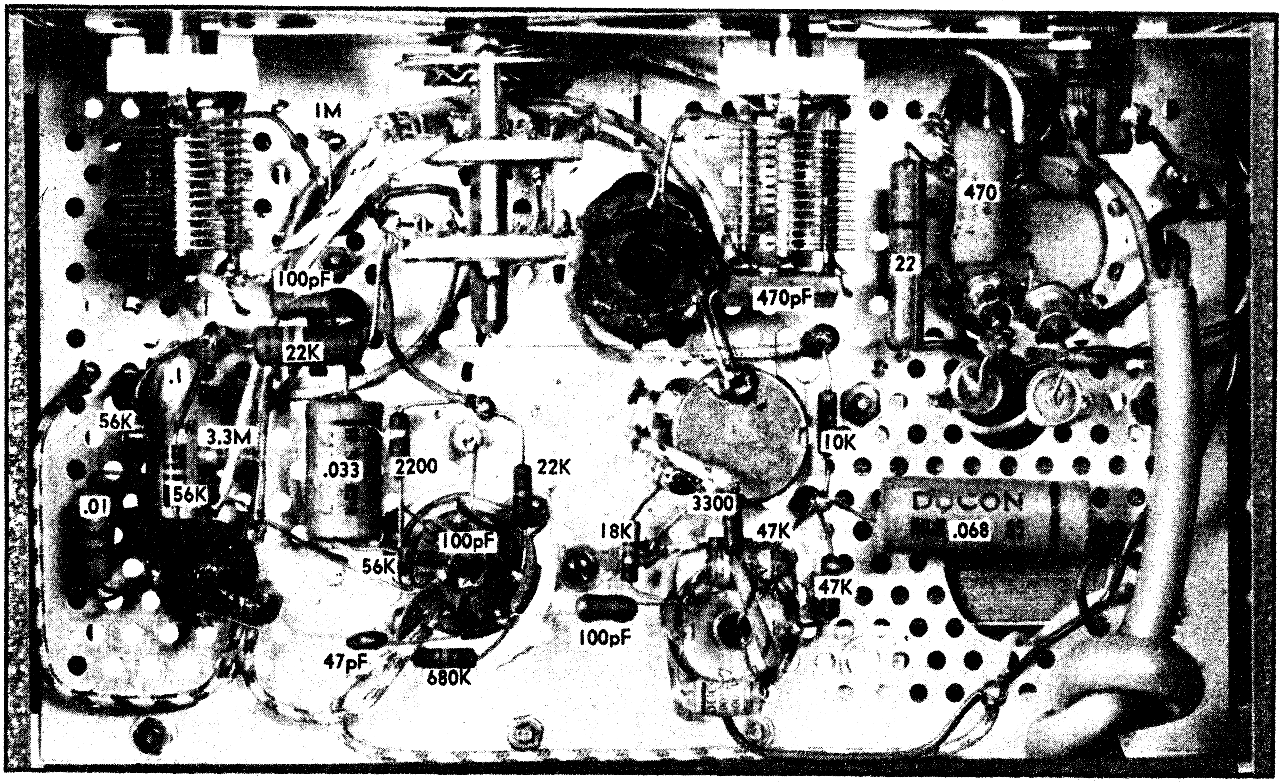
- **1 Suitable chassis and case (see text).**
- **1 Power transformer, 225/225, 50mA, 6.3V — 2A.**
- **1 6AM6 valve.**
- **1 12AU7 valve.**
- **1 12AV7 valve.**
- **1 6C4 valve.**
- **2 1N3196 silicon diodes.**
- **1 1MC crystal.**
- **1 100KC crystal.**
- **2 Suitable crystal sockets.**
- **2 5/100pF tuning capacitors.**
- **1 4-pole, 5-position switch.**
- **1 "Toggle" switch.**
- **2 Co-ax sockets.**
- **1 DC11 crystal socket.**
- **1 "D" type crystal socket.**
- **1 FT243 type crystal socket.**
- **1 0 - 1mA meter - 1" diameter.**
- **2 7-pin valve sockets.**
- **2 9-pin valve sockets.**
- **1 3-pin power plug and 3 yards of 3-core flex.**
- **1 6.3V dial lamp and lamp-holder.**
- **1 2.5mH RF choke.**
- **4 Suitable knobs.**

RESISTORS

- **1 22 ohm 1 watt.**
- **1 120 ohm ½ watt.**
- **1 470 ohm 3 watt.**
- **1 2200 ohm ½ watt.**
- **1 3000 ohm pot.**
- **1 3300 ohm ½ watt.**
- **3 10K ohm ½ watt.**
- **1 18K ohm ½ watt.**
- **3 22K ohm ½ watt.**
- **2 22K ohm 1 watt.**
- **2 47K ohm ½ watt.**
- **1 50K ohm pot.**
- **3 56K ohm ½ watt.**
- **2 100K ohm 1 watt.**
- **1 680K ohm ½ watt.**
- **1 1 megohm ½ watt.**
- **1 3.3 megohm ½ watt.**

CAPACITORS

- **1 10pF ceramic NPO.**
- **1 47pF ceramic NPO.**
- **4 100pF ceramic NPO.**
- **1 470pF silver mica.**
- **2 .001uF ceramic.**
- **2 .0012uF plastic.**
- **2 .01uF plastic.**
- **1 .033uF paper or plastic.**
- **1 .068uF paper or plastic.**
- **2 .1uF paper or plastic.**
- **1 50/50uF 350VW electrolytic.**



The layout and components positioning used in our prototype is easily seen in the above photograph but, in actual fact, the layout is not too critical and almost any arrangement which ensures low grid-to-ground capacitance for the 6AM6 would be satisfactory.

The net result is that the 6C4 winds up being a little close to the 1MC crystal and, although we have not experienced any problems of frequency drift with this crystal, due to heating, we feel that readers constructing the unit might well place this crystal a good inch away from the valve just to be on the safe side.

In line with this problem of drift caused through heating of the crystals it would be advisable, where a chassis of the conventional type is used, to drill a series of ¼in diameter holes surrounding each of the valve sockets. Ventilation should also be provided in the top and bottom of the case to ensure a free flow of air past each of the valves.

It might be mentioned that none of those steps need be taken with the "Lektrokit" metalwork since the chassis material, as supplied, already has 1/8in holes spaced ¼in apart over the entire surface of the material.

We mentioned earlier that we had no problems of frequency drift due to heating in our prototype instrument. This is mainly due to the fact that we used crystals having zero temperature coefficient. Many crystals, however, have positive or negative temperature coefficients, depending on the cut of the wafer and, in such a case, the provision of adequate ventilation which stabilises the operating temperature of the unit will do much towards stabilising the output frequency.

The three crystal sockets mounted on the front panel are types "D," "DC11" and "FT243." It will be found that these holders will accommodate the majority of crystals, disposals and otherwise, available in this country. The type "D" holder should be mounted between the DC11 and FT243 types and these latter two should be secured to the panel with 1/8in Whitworth bolts approximately 1½in in length. The 6C4 socket is mounted on the end of these bolts.

The meter used to measure crystal current is an imported, 1in diameter unit which is available at a fairly reasonable price. Some readers may feel, however, that this meter could be dispensed with because of the rather infrequent use it may get. In this case we would recommend that two terminals be placed in its position on the front panel so that the workshop multimeter can be used when crystal activity is to be gauged.

To avoid upsetting our front panel symmetry with an "odd man out" pilot light, we arranged this lamp so that it sits immediately behind the "xtal" output coax. socket. The particular type of coax. socket used is moulded from red plastic material and it makes a most convenient bezel for the lamp.

There is probably little else we need say about the construction of the unit, except the need to keep all connections as short and direct as possible and make sure that all connections associated with the grid and cathode of the 6AM6 are run with good stiff wire (18 gauge tinned copper covered with cambric sleeving) and as far from the chassis plate as possible. This latter will help to keep down the stray capacitances around the oscillator.

No difficulties should be experienced in getting the unit going, provided the previous remarks about crystals (activity, spurious signals etc) are borne in mind. Setting the multivibrator to produce the 10th sub-harmonic of the 100KC crystal can be done in several ways, depending on the choice of test equipment available to the constructor.

If an oscilloscope with a calibrated timbase is available it could bet set to a sweep of, say, 20 microseconds per centimetre and, with the output of the unit connected to the Y amplifier of the CRO, and the function switch set to 10KC, the multivibrator grid potentiometer should be adjusted until the "spikes" of the 10KC output are 5 centimetres apart.

If the oscilloscope is uncalibrated but has a triggering circuit good enough to hold the pattern steady on the screen the correct setting of the multivibrator pot. can be determined by counting the number of 100KC spikes between the two larger 10KC spikes. There should be exactly nine spikes in between.

The first two of these spikes are somewhat hard to locate but they can be identified by the slight discontinuity they produce in the trace. If not immediately obvious, note the distance between the larger, easier to identify spikes and "guesstimate" the point on the 10KC spike at which these 100KC spikes must occur. In our oscilloscope trace of figure 2 we have numbered the spikes and shown, by arrows, their exact position on the trace.

If an audio generator and a non-calbrated oscilloscope are available, the generator should be fed into the X amplifier of the CRO and the output from the multivibrator fed into the Y input. The audio generator should be set to 10KC and the multivibrator adjusted to produce a 1 to 1 lissajous pattern on the CRO screen.

Note that for this test, the audio generator need only be good enough to distinguish between signals at 9, 10 and 11KC since the frequency of the multivibrator will jump suddenly between these frequencies as it locks to the appropriate sub-harmonics of the 100KC crystal. Provided the unit is functioning as it should, there is no possiblity of the multivibrator operating at frequencies between those quoted.

Perhaps the simplest and most satisfactory method, however, is simply to feed the output from the unit into a broadcast band receiver and, with the function switch of the unit set to the

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10KC position, adjust the multivibrator until a beat note is heard on selected stations or on several stations. The method is possible because all Australian broadcast stations operate on frequencies which are multiples of 10KC.

Note that we have specified selected stations or several stations. In fact, taken singly, some Australian stations are not suitable for this calibration method, because their operating frequency, in addition to being a harmonic of 10KC, is also harmonically related to one of the other sub-harmonics of 100KC, to which the multivibrator may be locked.

A station on 550KC, for instance, will enable a beat note to be obtained when the multivibrator is set to 10KC. But a beat note can also be obtained if the multivibrator is set to 12.5KC because the 44th harmonic of 12.5KC is 550KC. The multivibrator can, in its turn, be inadvertently locked to 12.5KC because this is the 8th sub-harmonic of 100KC. It gets complicated doesn't it?

The following is a list of Australian broadcast stations which are entirely suitable for this method of calibration; 2FC (610KC), 3WV (580KC), 4QR (590KC), 5CK (640KC), 6WA (560KC), and 7NT (710KC).

Those who desire to use stations on frequencies other than the ones listed will need to divide the station frequency in turn by 12.5, 11.11, 9.09 and 8.33. If the answer is a whole number (one without a decimal place) then the station is not suitable for calibration use.

It might also be mentioned that stations whose frequency is a multiple of 100 would not be suitable for calibration purposes since they would, of course, be heterodyned by a harmonic of the 100KC cyrstal and it would be impossible to tell whether the weaker signal from the multivibrator was locked to their frequency.