

Crystal marker generator for receiver and CRO calibration

A simple but very useful piece of test equipment for calibrating and aligning receivers, transceivers and oscilloscopes. It is portable, battery operated and inexpensive to build.

Design: **Ray Marston**

Development: **Simon Campbell**

THIS SIMPLE piece of test gear will help you calibrate receivers or transceivers which don't incorporate a crystal calibrator, set up and calibrate low-cost oscilloscopes, and even provide an accurate calibration source for frequency/period counters (especially if you've made it yourself).

Many of the older 'budget' shortwave receivers do not have dial calibrations which are sufficiently accurate to read out to even 10 kHz, and few ever had a crystal calibrator of any sort (see 'Receivers for the Budget-Minded Shortwave Enthusiast', by Bob Padula, ETI June '80, p.26). In addition, their calibration drifts with time. This project not only allows you to set a receiver's dial calibration from time to time but you can dial up a particular frequency to an accuracy of 1 kHz.

If you're keen on VHF and operate suitable converters in front of your HF receiver then this project will be useful there too, as it provides harmonics to over 150 Mhz. (See 'Modern Solid-State Converters', by Roger Harrison, ETI Feb. '76, p.63 and 'Aircraft Band Converter', ETI March 1979, p.39).

A variety of low-cost solid-state oscilloscopes, aimed at the hobbyist, has become available recently, and while useful in a general way, suffer somewhat because they do not have a calibrated timebase. You can use this project to overcome this problem and this application was one of the reasons the 100 Hz output facility was included.

This marker generator can also be



used to calibrate the timebase oscillators of frequency counters and period timers simply by plugging the marker output into the counter's input and setting the timebase frequency to obtain the correct display!

Design

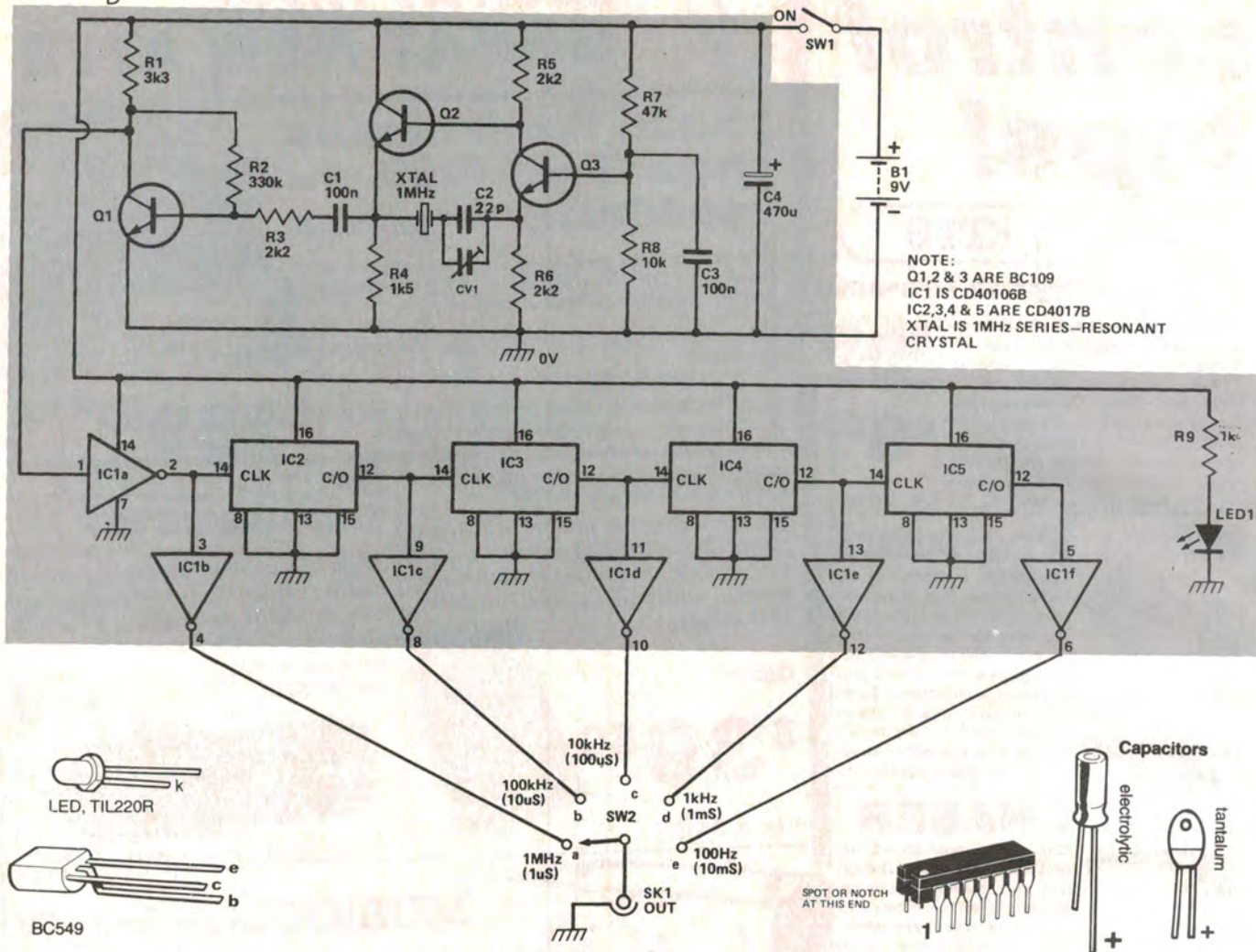
The circuit design is fairly straightforward, but quite different to our earlier crystal marker generator, the ETI-706 (Feb. '76, p.53). The latter used a 4 MHz crystal and provided fundamental outputs of 4 MHz, 2 MHz, 1 MHz, 100 kHz and 10 kHz. It had useful harmonics to 30 MHz or so.

The microprocessor industry has pro-

vided a range of components that were not common a few years ago, among them 1 MHz quartz crystals. We've used one of these as the basis of this project because they're cheap and common. As they are generally meant for series-mode operation, we've used an aperiodic Butler oscillator (for more details on crystals and crystal oscillators, see 'Modern Crystal Oscillators', by Roger Harrison, ETI Jan. '76, p.46, or ETI Circuit Techniques Vol.1).

The output of the crystal oscillator is buffered by Q1, which drives one stage from a hex Schmitt inverter (40106). This 'squares up' the signal and drives the four cascaded decade dividers (all ▶

Project 157



4017s). The first Schmitt inverter provides 1 MHz output, which is buffered by another Schmitt inverter to provide the 1 MHz output to the output selector switch. The output of each decade divider stage is also buffered by a Schmitt inverter to provide, respectively, the 100 kHz, 10 kHz, 1 kHz and 100 Hz outputs to SW2.

Construction

We constructed the project on a pc board and housed it in a conveniently sized jiffy box. The two switches, the LED and the RCA output socket we mounted on the metal front panel of the jiffy box. Layout of the panel is not important, and if you aren't going to use a Scotchcal of our panel, you can place these com-

ponents to suit yourself. Note that, whilst we used an RCA socket for the output, you could use any suitable coaxial output socket or just a pair of banana sockets, if you wished. If you are using a Scotchcal of our front panel, it can be used as a drilling template. An all-metal box, such as the K&W C642, could be used if you wish.

HOW IT WORKS ETI-157

The crystal marker generator consists of a 1 MHz crystal oscillator driving a series of four decade dividers connected in cascade. Outputs are provided at 1 MHz, 100 kHz, 10 kHz, 1 kHz and 100 Hz. As each output is essentially a square wave (but not a perfect square wave), harmonics extending into the VHF region are generated. A switch is used to select the desired output.

The crystal oscillator comprises Q2, Q3, R4 to R8 and C3. The circuit is an aperiodic Butler oscillator. Q2 and Q3 form an amplifier with the output linked to the input via the crystal. Positive feedback only occurs at the series resonant frequency of the crystal where the phase shift of the crystal is zero. Q3 is configured as a common-base amplifier. Its collector is direct-coupled to the base of Q2, an emitter follower (common-collector). The crystal is connected from the emitter of Q2 to the emitter of Q3, via a series capacitance

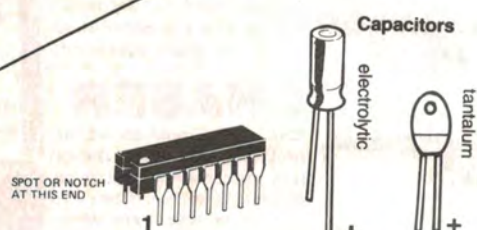
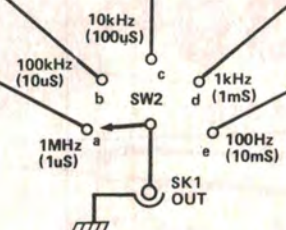
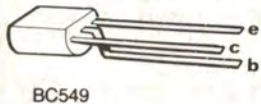
comprising C2 and CV1. Thus the output of the non-inverting amplifier formed by Q2 and Q3 is connected to the input via the crystal. When the phase shift from input to output is zero, there is positive feedback, and thus oscillation occurs. CV1 is effectively in series with the equivalent series capacitance of the crystal. Varying CV1 varies the effective phase shift between the emitters of Q2 and Q3 and thus varies the frequency of oscillation.

The output of the crystal oscillator is coupled to a buffer amplifier comprising Q1, via C1 and R3. The buffer avoids loading effects on the oscillator 'pulling' the frequency. Q1 is a common emitter amplifier. R1 is the collector load and R2 provides bias to the base. As R2 is connected between collector and base, any dc drift in the collector current changes the base current in the same direction, which then opposes the drift in collector current, affecting compensation of

any drift (dc negative feedback).

Q1 raises the oscillator output level sufficiently to provide the required drive to the input of IC1a, one stage from the 40106 hex inverting Schmitt trigger IC. This 'squares up' the signal. The output of IC1a drives the input to the first divider in the decade divider chain and the input of another stage from IC1, IC1b. This provides a buffered 1 MHz output to SW2. The divider chain consists of IC2, IC3, IC4 and IC5. Each is a 4017 decade divider, the carry output of the preceding stage driving the clock input of the next. The carry output of each stage also drives the input of a Schmitt buffer. Thus the output of IC1c provides a buffered 100 kHz output to SW2, IC1d provides the 10 kHz output, IC1e the 1 kHz output and IC1f the 100 Hz output.

Capacitor C4 provides a low frequency bypass for the supply rail, while LED1 serves as an on indicator.



SPOT OR NOTCH AT THIS END

crystal marker

PARTS LIST — ETI 157

Resistors

| | |
|--------------|------|
| all 1/2W, 5% | |
| R1 | 3k3 |
| R2 | 330k |
| R3,5,6 | 2k2 |
| R4 | 1k5 |
| R7 | 47k |
| R8 | 10k |
| R9 | 1k |

Capacitors

| | |
|--------|-------------------------------|
| C1, C3 | 100n ceramic |
| C2 | 22p ceramic |
| C4 | 470u/16 V electro. |
| CV1 | 5-40p film or ceramic trimmer |

Semiconductors

| | |
|-----------|-------------------------|
| IC1 | 40106B |
| IC2,3,4,5 | 4017B |
| Q1,2,3 | BC549, BC109 etc. |
| LED1 | TIL220R or sim. red LED |

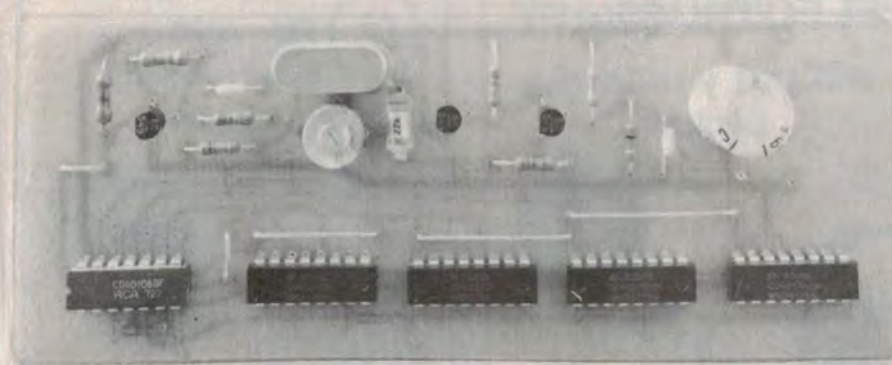
Miscellaneous

| | |
|---|--|
| XTAL | 1 MHz crystal |
| SW1 | SPST miniature toggle switch. |
| SW2 | single pole, five position rotary switch |
| SK1 | RCA coax socket |
| ETI-157 pc board; jiffy box 160 x 95 x 50 mm (or similar); knob to suit; nuts, bolts, wire etc. | |

Price estimate

\$18 - \$25

Note that this is an estimate only and not a recommended price. A variety of factors may affect the price of a project, such as — quality of components purchased, type of pc board (fibreglass or phenolic base), type of front panel supplied (if used), etc — whether bought as separate components or made up as a kit.



The finished pc board for the crystal marker generator. Note that all the ICs face the same way. Artwork for the ETI-157 pc board is reproduced on page 159, along with the full-size artwork for the front panel. The page behind is printed all in blue, so you can make a Scotchcal negative from these by exposing through the page; then use the negatives to make your pc board and panel.

Assemble the components to the pc board, resistors first, then the capacitors followed by the transistors and ICs. Leave the crystal till last. The board has been laid out to take either of the two common crystal sizes. The HC18/U style holder has a pin spacing of 12.5 mm, while the smaller HC36/U holder has a pin spacing of 5 mm. They can be obtained with pins, meant for socket mounting, or flying leads, for soldering in place. Whilst a suitable socket could be mounted on the board we soldered the crystal in place. Do it quickly to avoid possible damage to the crystal. Make sure the base of the crystal sits flat on the board, to prevent movement.

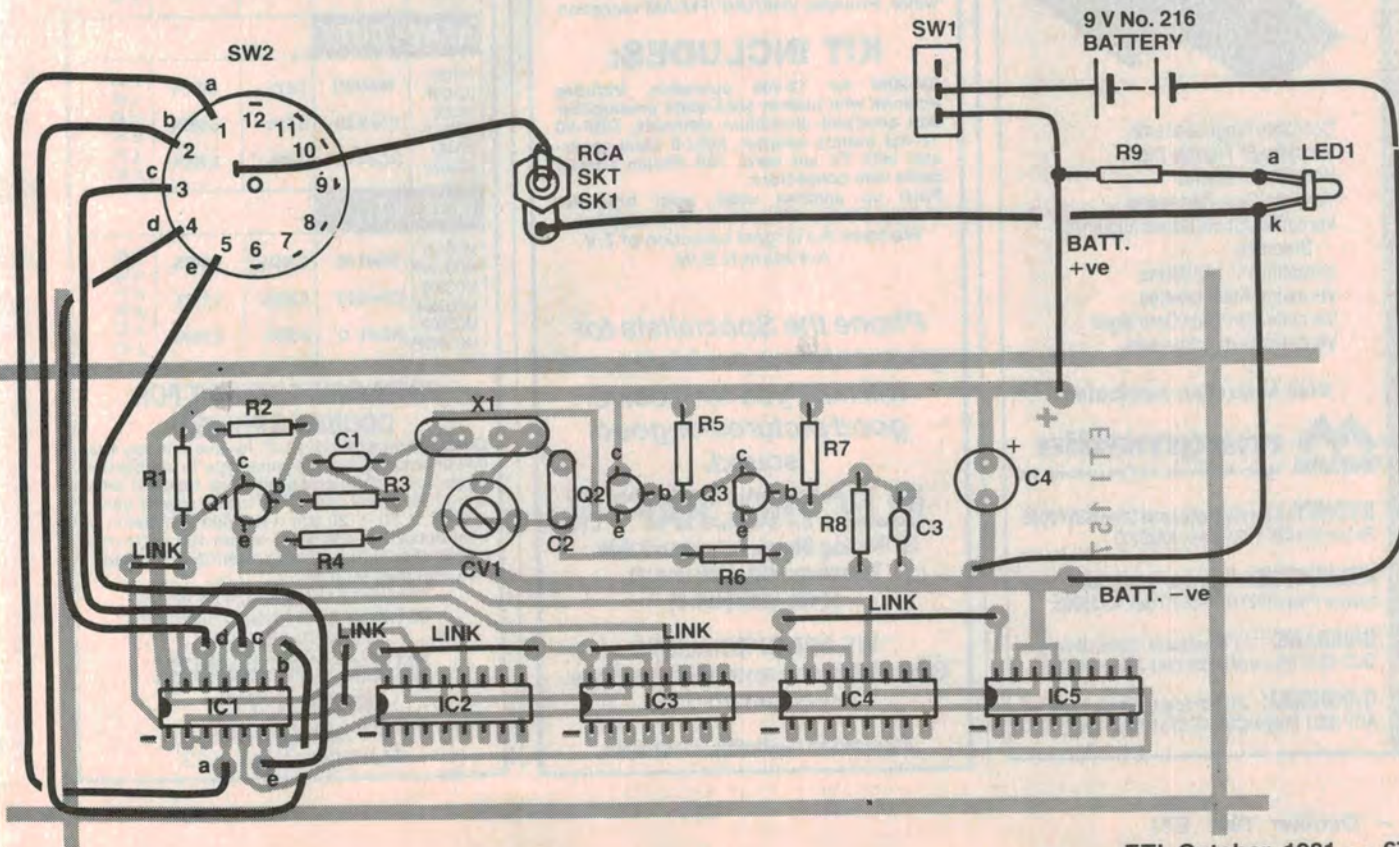
There are five links to be installed, which can now be soldered in place, along with hookup wire to go to the

switches, LED and battery. Follow the overlay/wiring diagram to complete this.

The pc board and battery we mounted in the box with double-sided sticky pads. It's simple, effective and saves drilling.

Having got it all together, connect the battery and try it out.

You can check that it's working with an ordinary broadcast band receiver, such as a transistor portable radio. Place the marker generator near the receiver and turn it on. Tune the receiver to around 10 on the dial and you should be able to hear a strong 'carrier' signal. You may hear a loud, high-pitched whistle if a broadcast station operates near this frequency in your vicinity.





Setting it up

To set the oscillator as accurately as possible to 1 MHz, a trimmer capacitor, CV1, in series with the crystal has been provided. Adjusting this will 'pull' the crystal frequency slightly. To set the oscillator you will need to have, or obtain access to, a shortwave receiver that covers the frequency range from 7 MHz to 15 MHz. A number of 'standard' time and frequency broadcasts can be received in this range. VNG Australia broadcasts on 7.5 MHz and 12 MHz within this range, while the US stations WWV and WWVH broadcast on 10 MHz and 15 MHz. The transmission frequencies are maintained to an incredible accuracy and you can use them to set your marker accurately on frequency.

Tune in one of the stations on 10, 12 or 15 MHz on the receiver. Plug a length of hookup wire into the marker's output socket and drape it near the antenna input of the receiver. Set SW2 to 1 MHz, turn the marker on and you should hear a strong whistle or 'beat' note. Using an insulated adjusting tool, adjust CV1 to decrease the pitch of the beat note until the frequency is so low you can't hear it. Doing this with headphones plugged in helps. As you approach 'zero beat', the receiver's signal strength meter will begin to oscillate, rapidly at first and then slowly. Carefully adjust CV1 until

the S-meter stops wavering or beats as slowly as possible.

This calibration method is independent of the receiver accuracy. Switch to the 10 kHz output and you should hear frequency 'pips' every 10 kHz. The 100 Hz output sounds like a 'burr' all over the dial.

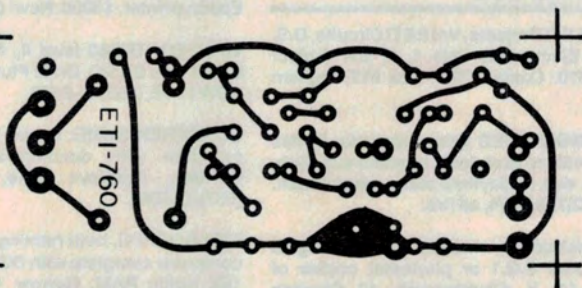
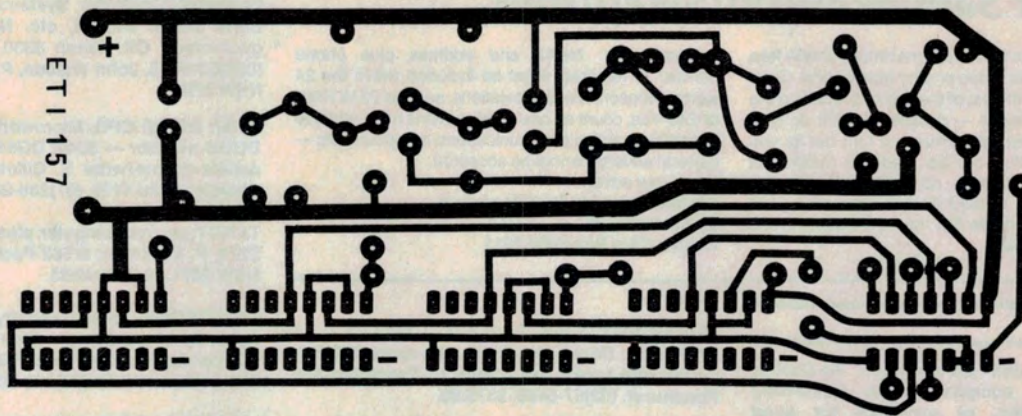
If you have access to a six or, preferably, an eight-digit readout frequency counter, it is a simple matter to set the oscillator on frequency. Connect the marker's output to the counter's input, set SW2 to 1 MHz and adjust CV1 so that the display reads 1 000 000.0! Use an insulated adjusting tool, as before. Switch through the other outputs to check that the divider is working. You can further trim the oscillator accuracy on the lower frequency output.

Say for example that you want to tune your receiver to 14 150 kHz. First select 1 MHz on SW2 and loosely couple the marker's output to the input of the receiver. Tune the receiver to the marker, which will be found at 14 MHz. If your receiver is *grossly* off calibration (or has no dial markings!), tune in one of the standard frequency broadcasts at 10 MHz or 12 MHz, and count the required number of 1 MHz markers as you tune up in frequency until you reach 14 MHz. Once located, confirm that it is indeed coming from the marker

generator by switching it on and off. Now switch to the 100 kHz markers and tune the receiver upwards to locate the first marker past 14 MHz (14 100 kHz). Now select the 10 kHz markers and tune upwards through five markers to locate 14 150 kHz. Note that if this tuning procedure is carefully carried out it is quite simple to locate any position on the dial with great accuracy.

Note that the output square wave has an amplitude of 8 V peak-to-peak and should not be directly coupled to the input socket of a receiver. Some solid-state receivers may suffer front-end damage at the lower frequencies if directly connected to the marker output. Use a coupling capacitance of several pF or loosely couple a wire from the marker output near the receiver antenna input.

To calibrate a CRO timebase, set the marker to the appropriate output range and plug the output into the Y input. Set the input attenuator to obtain a display of a convenient height. Set the CRO timebase range switch to obtain one complete cycle on the screen. One cycle of a square wave is the time between two successive rising edges or two successive falling edges. Adjust the 'fine' variable control on the CRO timebase so that the two rising (or falling) edges of the cycle are aligned on the left and right extremes of the graticule. And there you have it! ●



Instructions on how to make your own pc boards using the Scotchcal method and exposing through this page may be found on page 159 of the June '81 issue.

eti 157

CRYSTAL MARKER

100 kHz 10 kHz .1 kHz
 1 MHz .100 Hz

+
 BATTERY

+
 RANGE

+
 OUTPUT

+
 ON