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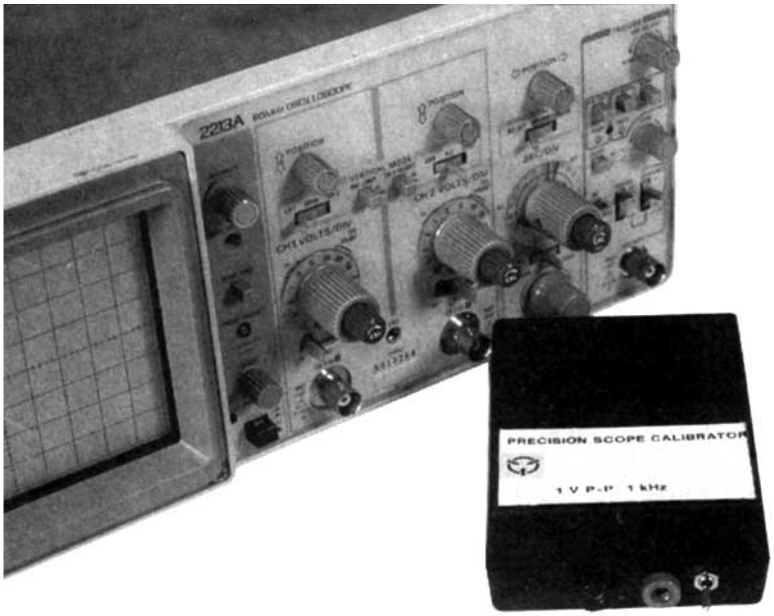

Oscilloscope Calibrator

Use it to check your scope's vertical gain and horizontal time base.

BY CHARLES HANSEN

Many oscilloscopes do not have an internally generated calibration signal. Sure, some older models have 1-volt, peak-to-peak, 60-Hz calibrator outputs; however, those outputs are little more than clipped, 60-Hz sinewaves, and are not precise enough for calibration purposes. For that reason, you might want to build and use the *Oscilloscope Calibrator* described in this article. The unit provides an accurate squarewave of 1-volt-DC peak-to-peak, at a frequency of 1 kHz. which can be used to check the vertical gain and horizontal time base of your oscilloscope.

The Calibrator can also be used to adjust scope-probe compensation and can serve as a signal source for checking the transient response of audio equipment. It is battery powered for portability. The circuit is relatively insensitive to voltage

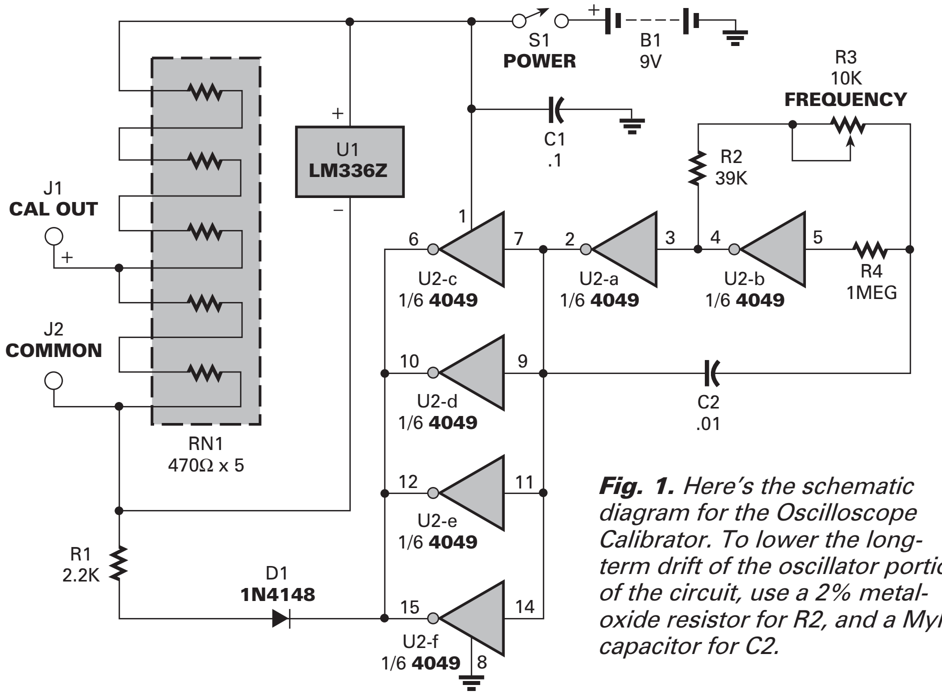

Fig. 1. *Here's the schematic diagram for the Oscilloscope Calibrator. To lower the long-term drift of the oscillator portion of the circuit, use a 2% metal-oxide resistor for R2, and a Mylar capacitor for C2.*

fluctuation; the frequency output remains constant at a battery voltage of anywhere from 7.7- to 9.8-volts DC. Also, the minimal 2-mA current drain ensures long battery life.

Circuit Description

Figure 1 shows the schematic diagram for the Calibrator. The oscillator portion of the Calibrator consists of two sections of a 4049 CMOS hex inverter (U2-a and U2-b), and timing components C2, R2, R3, and R4. That portion of the circuit determines the output frequency. The exact frequency value can be found using the formula:

$$f = 2.2(C2)(R2 + R3)$$

Assume that pin 5 of U2-b is initially low, causing the output at pin 4 of U2-b to be high. Because the input at pin 3 of U2-a is also high, the output at pin 2 of U2-a is therefore low. The high output at pin 4 charges C2 through R2 and R3. When the voltage across C2 gets to the high input threshold at pin 6 of U2-c, the output at pin 4 and the input at pin 3 will go low. That causes the output of pin 2 to go high. Because the voltage across C2 cannot change instantly, the voltage at the input of U2-b is greatly increased to approximately 150% of battery voltage. That positive feedback reverses the logic level at the maximum rate that the CMOS gate is capable of achieving.

the logic levels reversed on U2-a and U2-b, C2 is charged in the other direction, with the voltage at pin 5 decreasing. When the C2 voltage gets to the low input threshold at pin 6, the output at pin 4 and the input at pin 3 will go high. That causes the output at pin 2 to go low. Again, the voltage across C2 cannot change instantly, and the voltage at the input of U2-b is reduced to about 50% of battery voltage. That, once again, reverses the logic level at the maximum rate.

Resistor R4 limits the input current to U2-b when the voltage across C2 exceeds that of the power-supply output, thereby protecting the gate-input diodes. The resistor also prevents the RC-timing circuit from being loaded down by those internal diodes, which would tend to round off the edges of the squarewave. That results in a 50% duty-cycle squarewave whose frequency is relatively independent of the battery voltage.

The squarewave output from pin 2 is connected to the parallel-connected inputs of the four remaining inverters in the 4049, whose outputs are also connected in parallel. When the squarewave output of the 4049 is low, U1, the LM336Z 2.5-volt DC reference (available from several hobbyist sources, including Digi-Key, PO Box 677, Thief River Falls, MN 56701-0677; Tel. 800-344-4539) is turned on through R1 and D1. That causes the Calibrator's output squarewave to go high.

The combined current-sink capability of U2-e through U2-f is over 14 mA. Only 2 mA of that capability is used, assuring a very fast rise time for the output squarewave. In order to provide the 1-volt-DC, calibration output voltage, a 2% resistor network, RN1, is used. Each of the five elements in RN1 is rated at 470 ohms.

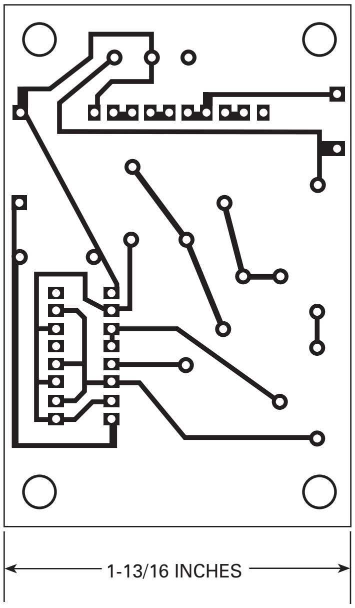

Fig. 2. *Use this template to etch your own Calibrator PC board.*

The network is tapped at 40% of its overall resistance to provide the desired 1-volt-DC output at jack J1 (CAL OUT); jack 52 is the COMMON.

When the squarewave output is high, the cathode of D1 is pulled to within 1/2-volt of the 9-volt DC supply. Therefore, no residual current flows through RN1 or U1, and the Calibrator output is a true zero. Waveform flatness is more than adequate due to both the 0.2-ohm, dynamic, "on" impedance of the LM336Z, and the complete turn-off of the drive current during a high output from the four drivers. U2-c-U2-f.

The voltage accuracy of the squarewave is maintained within 1% by U1. While the value of the network resistance is specified at 2%, the variations between each resistor element in the network are much smaller. That accurate voltage division provides a precise output-voltage level. Output impedance is approximately 1000 ohms.

The output squarewave depends greatly on the current through RN1, so a large filter capacitor is not required for the 9-volt battery, B1. Capacitor C1 is used to provide glitch filtering for U2 during logic transitions.

Construction

The author's prototype circuit was wire-wrapped on a perforated board. Layout of the parts is not critical, and for that reason, any standard project-building method can be used. However, for those who wish to build the Calibrator on a printed-circuit board, a foil pattern is shown in Fig. 2. Follow the parts placement diagram shown in Fig. 3 if you choose to make your own PC board.

In keeping with good assembly practice, install the least-sensitive parts. Install the battery connector, an IC socket for U2, and the switch, followed by the potentiometers and jacks. Next, mount the other passive parts; resistors first, then capacitors. To keep long-term drift in the oscillator portion of the circuit to a minimum, C2 should be a Mylar capacitor, R2 should be a 2% metal-oxide timing resistor, and R3 should be a wire-wound multi-turn trimmer potentiometer. Finally, install D1, U1, and U2. Double check the orientation of the polarized components, and if you aren't using a PC board, double check your wiring.

Depending on the sensitivity of your

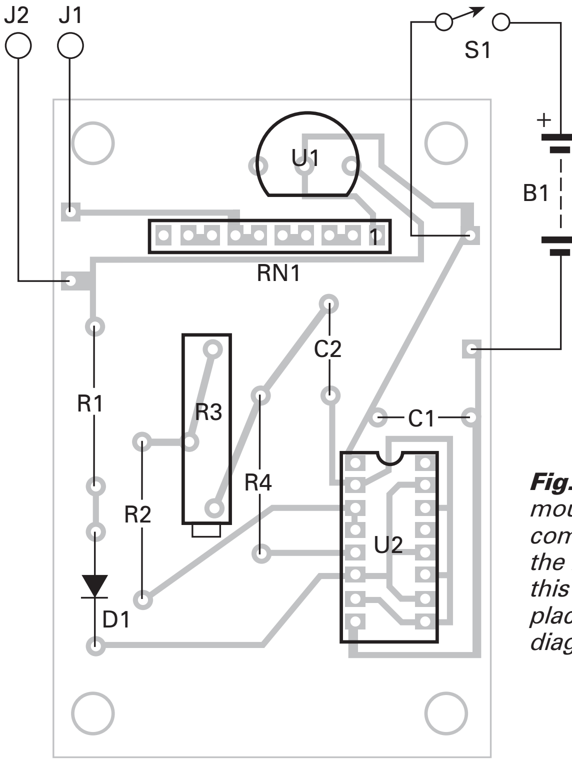

Fig. 3. *When mounting the components on the board, use this parts-placement diagram.*

scope, you might need a higher reference voltage for the Calibrator, If that is the case, keep the following possible customizing concept in mind when building the unit. Connect two LM336Zs in series, and use a reduced value resistor for R1 to maintain 1 mA in the divider and the LM336Zs. That will provide a reference based on 5-volts DC.

Checkout and Calibration

The output voltage of the Calibrator can be checked with any good-quality digital multimeter. Temporarily connect a jumper from the junction of R1 and D1 to ground. That will hold the calibrator output at exactly 1-volt DC. Check to make sure that is so.

To check the output frequency, you could use a digital frequency counter, but there is another very accurate method you can try. Acquire an audio-test CD and use the l-kHz sinewave track as a frequency standard. With the calibrator output connected to one channel of the stereo, and the CD playing on the other channel, adjust the calibrator frequency for a near-zero audible-beat frequency. That process of sound-matching is familiar to anyone who's used a piano or guitar tuner.

Using The Calibrator

A scope's vertical amplifier gain can be checked by using the 1-volt-DC height of the Calibrator squarewave and comparing it with the vertical display graticule. The time base can be checked by comparing the 1-millisecond cycle time for the squarewave against the horizontal display graticule. It's also easy to check passive, high impedance scope probes (x10, x100) against the Calibrator's squarewave output. Because the Calibrator rise time is very fast, any distortion in the waveform is due to a mismatch of probe compensation. The compensation should be adjusted until the squarewave is restored on the scope's display.

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PARTS LIST FOR THE OSCILLOSCOPE CALIBRATOR

SEMICONDUCTORS

U1—LM336Z precision 2.5-volt, DC-reference, integrated circuit (Jameco 23771 or equivalent)
U2—4049 CMOS hex-inverter integrated circuit
DI—1N4148 silicon diode

RESISTORS

(All fixed resistors are 1/4-watt, 5% units unless otherwise noted.)
R1—2200-ohm
R2—39,000-ohm, metal-oxide, 1%
R3—10,000-ohm trimmer potentiometer (see text)
R4—I-megohm
RN1—470-ohm x 5, 2% resistor network

ADDITIONAL PARTS AND MATERIALS

C1—0.1-µF ceramic-disc capacitor
C2—0.01-µF Mylar capacitor
S1—SPST miniature toggle switch
J1, J2—Binding post (red and black)
B1—9-volt battery
Printed-circuit materials, project enclosure, battery snap connector with leads, wire, solder, hardware, etc.