# Think Tank

# Workbench Circuits

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This month's letters are from Skip Campisi, an avid reader of, and contributor to, this column and the magazine in general. Because he sent in enough stuff for a full column, we've sent him a kit and an individually packaged, 1967, MCL1010 chip, in addition to a book. We still have chips, kits, and books for other equally ambitious participants. And remember, even if you only have one or two circuits we can use, at least you'll get a book per published circuit.

But before we get to Skip's work, let's continue our tutorial series by exploring the tantalum family of capacitors. Tantalum capacitors come in three styles: foil, wet, and solid. In the foil style, a tantalum-foil strip is used as the anode. The foil is etched to increase its surface area, and placed in a bath that forms a dielectric layer of oxide on the etched surface. That surface is placed in contact with a porous spacer containing an electrolytic solution, which forms the cathode. Sometimes, two layers of foil surround the spacer, forming a non-polarized electrolytic.

The foil design withstands high working voltages (in excess of 300 volts) and high reverse voltages. However, it has a lower capacitance-per-unit volume than the solid and wet tantalum types, so it's the least commonly used of the family.

To make a wet tantalum capacitor, tantalum powder is formed into a porous slug that acts as one plate. Oxide is electroplated inside all the pores to form a dielectric with incredible surface-area-per-unit volume. Then the assembly is sealed in a gel- or liquid-electrolyte bath in a tantalum or silver case. The case acts as the other plate. Such capacitors work at up to 150 volts and display extremely low DC leakage. Also, tantalum-case units can withstand high temperatures and significant ripple current, making them useful in aerospace and other hostile-environment applications.

The solid devices start off the same as the wet ones: a porous tantalum slug is plated with a dielectric oxide. But then the oxide is coated with manganese dioxide—the first step in creating the second electrode. A coating of graphite particles is applied to connect the manganese dioxide in all the pores to form a single electrode. A silver coating is applied to make soldering an electrode easy, and the capacitor is complete.

The enormous surface-area-per-unit volume and high dielectric strength of the tantalum oxide results in a high capacitance in a small package. The solid units can withstand more than 10% of their rated voltage in reverse polarity, and are fairly temperature stable. Also, of the three types, the solid ones are the least expensive

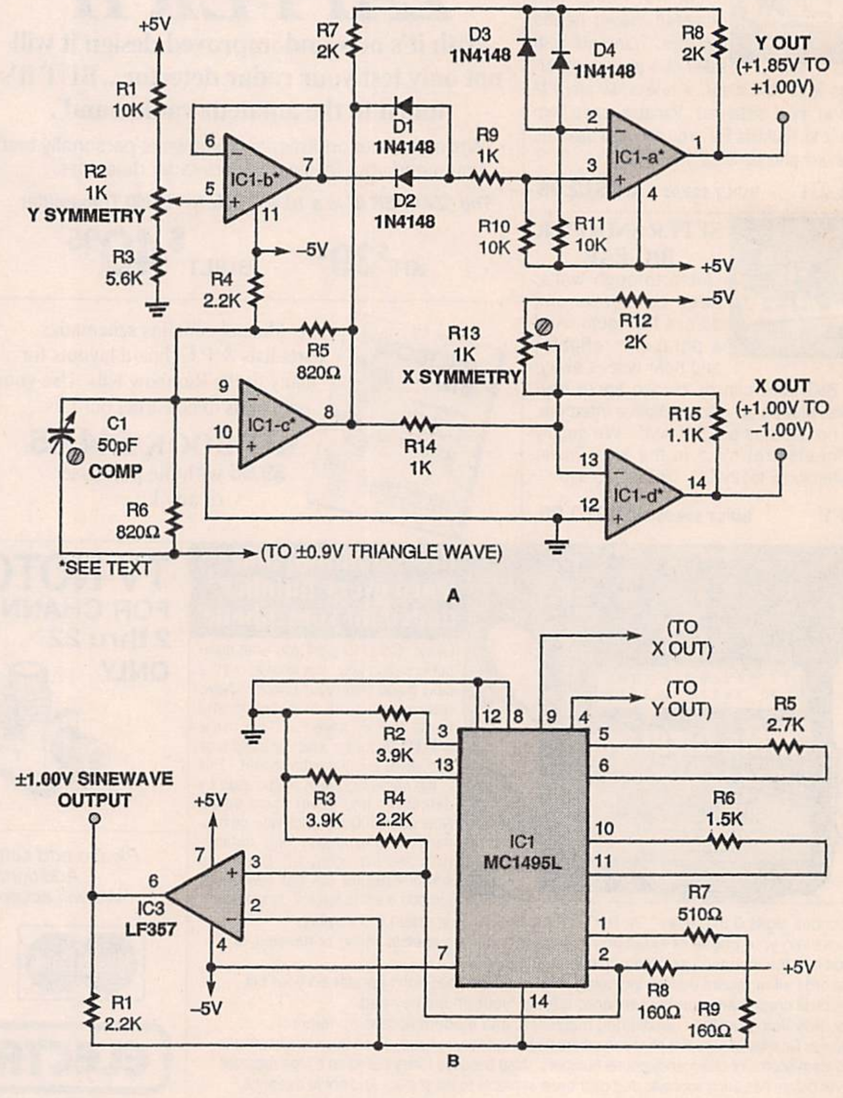
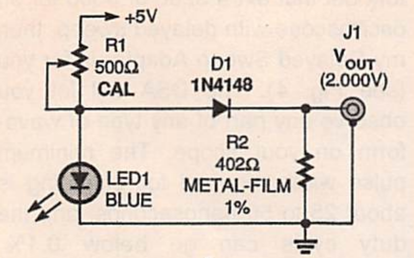


*Fig. 1. This sinewave converter (A) will work with an input ±0.9-volt triangle wave. If you need an analog multiplier as well, try this simple circuit (B).*



A

| D1 (GLASS) | $V_F$ @ 5mA |
|---|---|
| 1N34A | 0.37V |
| 1N4148 | 0.70V |

B

| LED1 (T1 TYPE) | $V_F$ @ 5mA |
|---|---|
| INFRARED | 1.20V |
| RED | 1.70V |
| YELLOW | 1.85V |
| GREEN | 2.00V |
| BLUE | 2.70V |

C

*Fig. 2. Want to design your own temperature-stable voltage references? Substituting the desired semiconductors in this circuit makes it possible.*

and the most common in hobbyist electronics.

High capacitance in a small package epitomizes the tantalum family. They are often used for AC bypass and coupling in small circuits. While they are fairly temperature stable, the more common types aren't useful in accurate timing circuits because of their dielectric absorption and high leakage.

Now, let's move on to Skip's circuits.

## NEW SINE CONVERTER

In the November 1991 issue, you were kind enough to publish my sinewave-converter circuit. I have since decided that a new high-speed design was in order—this latest circuit has a bandwidth greater than 1.0 MHz, using a similar, but more complex approach (see Fig. 1).

This design consists of a level-shifting/absolute-value circuit that drives an analog multiplier chip of your choice. As you can see in Fig. 1A, one quad op-amp, IC1, provides the functions needed to provide the proper X and Y signals to the multiplier. For lowest distortion, use metal-film, 1% resistors throughout, and match the forward voltage drop of the four diodes to within 1%. With the circuit as shown, the input requires a ±0.9-volt triangle wave, but R6 can be changed to accommodate any voltage. Use R2 to set the Y symmetry and R13 to set the X symmetry; C1 can be used to adjust for the best sinewave at 1 MHz.

Integrated-circuit IC1 should be selected for wide bandwidth and high slew-rate: I used a TLE2074 that resulted in a sine output that was down less than 1 dB at 1 MHz. An LF347 resulted in 2-dB output, and a TL084 gave a 3-dB output; an MC34084 might be a good choice, also. Remember, sinewave distortion increases with the slower amplifiers, as the output at IC1-a is double the input frequency! Use short leads when building the circuit.

If you need a good, fast, analog multiplier circuit, refer to Fig. 1B. That circuit uses an MC1495L chip (IC1) configured for a bandwidth that's much greater than 1 MHz. It accepts the input voltages from the circuit in Fig. 1A and converts them to differential output currents, where IC2 (an LF357) provides the single-ended output voltage. Integrated-circuit IC1 is available from Circuit Specialists or DC Electronics. Refer to the February 1993 *Think Tank* column for my "Function Generator" circuit if you need a 1-MHz triangle-wave generator.

*—Skip Campisi, So. Bound Brook, NJ*

*Excellent work! You've squeezed a lot out of three ICs, especially the quad op-amp. A unity-gain buffer, voltage follower, active rectifier, and amp, all out of one chip, should help keep distortion low.*

## SIMPLE REFERENCE

Here's a simple method to design your own cheap, temperature-stable voltage references. If you have a good stock of LEDs and small-signal diodes, you're ready to start right now!

Using the schematic diagram in Fig. 2A as an example, first select a diode from the choices in Fig. 2B and an LED from those in Fig. 2C so that the forward voltage difference of both semiconductors is close to the required output voltage. The diodes listed all have temperature compensations in the range of -1.8 to -2.0 mV/°C, so you can mix-and-match as needed. I wanted a 2.000-volt output, so I used a silicon-carbide blue LED (forward drop of 2.70 volts) and a 1N4148 silicon diode (0.70-volt drop).

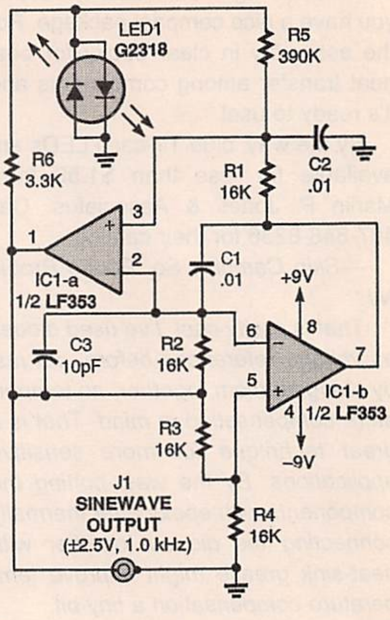


*Fig. 3. Here's an L/C oscillator without the L. The inductance is provided by IC1, R1-R4, and C1.*

Resistor R2 (402 ohms) was selected to draw 5 mA at 2.0 volts. Trimmer-potentiometer R1 was selected to drop 2.3 volts (5.0 volts minus 2.7 volts) at 10 mA, as each diode was to draw 5 mA; that would make R1 about 230 ohms, so I used a 500-ohm unit for the potentiometer. You can use any current the diodes can handle to achieve the proper voltage difference, but have each diode pass at least 2 mA to stay above their "knee" voltage. Below the knee, the temperature compensation begins to degrade. The example circuit showed less than +0.1 mV/°C temperature compensation; not too shabby!

Install the parts on a breadboard for fine tuning. Most 3-terminal, fixed-voltage regulators, such as the 78L05, have temperature compensations of about ±0.01%/C, which makes them excellent current sources for your reference. Carefully adjust R1 and trim R2, if needed, to obtain your desired output. Once you're satisfied, solder

D1 and R2 right onto LED1, so that you have a nice compact package. Pot the assembly in clear epoxy for best heat transfer among components and it's ready to use!

By the way, blue T1-case LEDs are available for less than $1.50 from Marlin P. Jones & Associates. Call 407-848-8236 for their catalog.

*—Skip Campisi, So. Bound Brook, NJ*

*That is pretty cool. I've used diodes as voltage references before, but just by stringing them together; no temperature compensation in mind. That is a great technique for more sensitive applications. By the way, potting the components with epoxy after thermally connecting the diodes together with heat-sink grease might improve temperature compensation a tiny bit.*

## "L/C" OSCILLATOR

The simple circuit in Fig. 3 provides ultra-stable, low-distortion (0.3% THD at 1.0 kHz) sinewaves when built with quality metal-film resistors and polyfilm capacitors matched to about 1%. However, even 5% components give similar results with a loss in frequency stability over temperature.

Looking at the schematic, you'll notice that there's no inductor in the "L/C" oscillator! The inductance required for oscillation at 1.0 kHz with a 0.01-µF capacitor is about 2.5 H—that's not available at Radio Shack. Instead I used a simulated inductor composed of IC1 (an LF353 op-amp), R1-R4, and C1. Those components provide an inductance, L, as follows:

$$L = C1 \times R2$$

where R1 through R4 (all equal R values) were selected to equal C1's reactance at 1.0 kHz. By adding C2 to the "inductance," you then have a tuned L/C circuit, and by applying positive feedback, the result is an L/C oscillator. Note that C2 is equal to C1 in value.

The heart of the circuit is LED1, a dual-element infrared LED, which is available from Electronic Goldmine (Tel. 602-451-7454), as part number G2318, at a cost of 3 for a $1. Both elements are matched within 1 millivolt, and the package has two long leads that you short together to form one terminal, and one stubby lead used for the other terminal. Of course, you can fabricate LED1 from two standard infrared LEDs if so desired.

The LED functions as a hard limiter to provide a squarewave to the tuned filter circuit, which has a Q of 25 (R5/R1). The Q can be raised to a maximum of about 100 for even lower distortion if desired, and the frequency can be changed by using different-value capacitors for C1 and C2. At a frequency below 100 Hz, you might have to reduce the Q to ensure start-up.

*—Skip Campisi, So. Bound Brook, NJ*

*I've seen gyrator circuits that replace inductors, but this is something special. I suppose you could use the diode trick presented in your last letter to improve the accuracy of the LED1 section in the circuit.*

## DELAYED SWEEP ADAPTER

If you're like me and don't want to fork out that extra $200 or $300 for an oscilloscope with delayed sweep, then my Delayed Sweep Adapter is for you (see Fig. 4). The DSA will let you observe any part of any type of waveform on your scope. The minimum pulse width required for triggering is about 25 to 50 nanoseconds, and the duty cycle can go below 0.1%, depending on how bright the trace is and how much jitter is in the input signal.

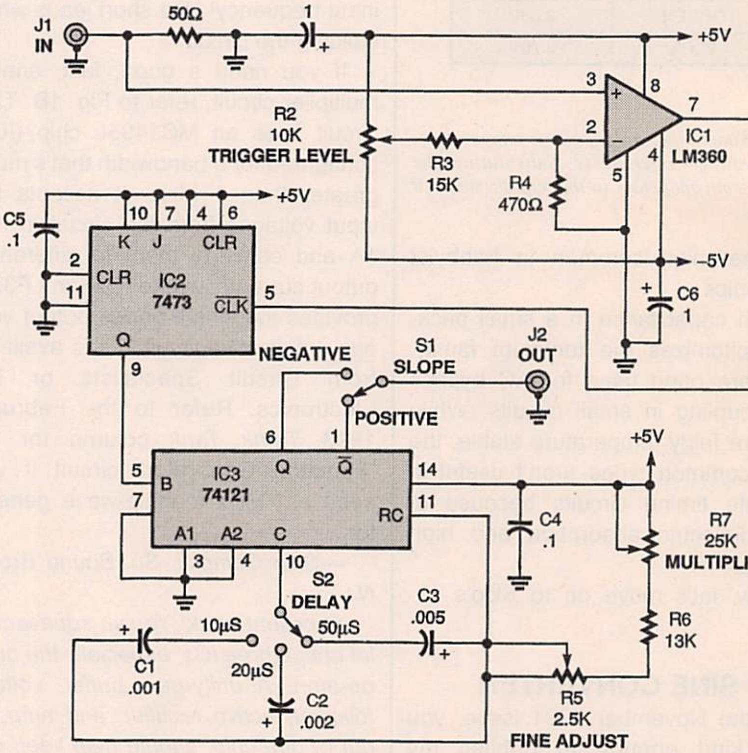


*Fig. 4. Building this delayed sweep adapter could squeeze some expanded capabilities out of an older oscilloscope, or make an inexpensive one seem worth hundreds of dollars more.*

The input to the DSA comes from your scope's channel-one output, through a 50-ohm cable terminated with a 50-ohm load (R1). The input to IC1 (LM360) has to be limited to ±5 volts, so check your scope output—mine puts out 25 mV/division, so the maximum input will only be 200 mV into 50 ohms. The output from the DSA goes through another 50-ohm cable (un-terminated) to the trigger input on your scope. Integrated circuit IC1 is a fast comparator that level-shifts the input to TTL logic levels, IC2 is a J/K flip-flop, and IC3 is a monostable multivibrator.

Only three positions are shown on the delay switch, S2, but you can use as many as you want. Use the following formula:

$$C = t/10^4$$

where C is the value in farads of the capacitor used, and t is the time in seconds.

Label the center position of R2 “0 volts” and the center position of R5 “Calibrated.” You should also label R7 “×1.0” to “×2.8” (*i.e.*, “×1.0” = 0.0 ohms, “×2.0” = 14.3k, etc.). That will help you set things up for fast pulses.

To use the DSA on narrow pulses, set your scope to internal trigger and display 2 or 3 cycles, noting the time period. Set S2 and R7 to match the time period, leaving R5 (the fine adjust) at mid position. Set S1 (the slope) to match your scope slope and switch your scope to its external-trigger mode. Adjust R2 (the trigger level) on the DSA for a steady trace, and reduce the multiplier setting, using R7, until you see a full pulse at the extreme left side of your screen. Now you can increase sweep speed while adjusting R5 and R7 to keep the pulse centered. Other types of waveforms can likewise be observed, using all of the variable controls to select any part of the waveform.

This project has to be built into a shielded cabinet, and all signal leads should be kept as short as possible, especially around IC1. Jacks J1 and J2 should be BNC connectors. Use good quality components throughout for the best stability.

*—Skip Campisi, So. Bound Brook, NJ*

*This is an excellent addition to old scopes or to today's less expensive models.*

Well, that's all for this month. Remember, if you submit enough suitable stuff for a column, you stand to win a kit, and a 1967 MCL1010 chip in addition to the usual book. Even if you only have one circuit, send it in; it could earn you one of our books. Send your circuit schematics and descriptions to *Think Tank*, **Popular Electronics**, 500 Bi-County Blvd., Farmingdale, NY 11735. ■