

# 1-GHz Sampling Oscilloscope Front End Is Easily Modified

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CIRCLE 525

This sequential-sampling oscilloscope plug-in module can significantly increase the display bandwidth of an ordinary 10-MHz oscilloscope for repetitive signals (Fig. 1). Using the 5k potentiometer and oscilloscope adjustments, the time base is adjustable from 1 to 50 ns/div. For longer sweeps, the circuit should simply be bypassed, and the oscilloscope must be used directly. By adding a DSO board and computer, it can be converted into a digital sampling oscilloscope as well. Future modifications, such as the use of the strobe as a variable delay generator, are simple to put into effect. Also easily implemented is the "synchroscope" mode, with triggerable components installed within the delay line.

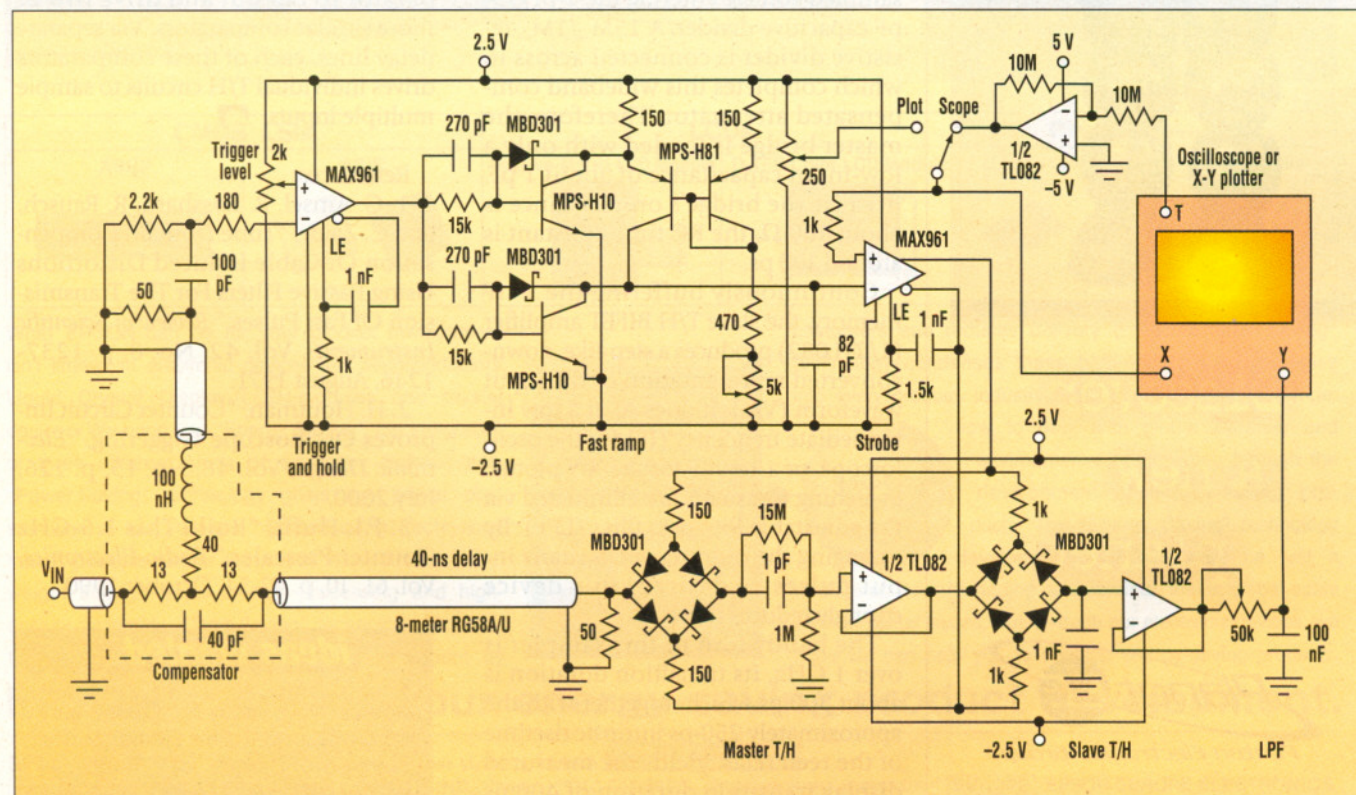
The input signal enters via the compensator box, which is a 4.6-dB pole-zero cancellation attenuator.<sup>1</sup> In essence, the 40-pF capacitor diverts fast

changes into the 40-ns RG58A/U delay line and away from the inductor arm. As was verified by using this sampler as a time-domain reflectometer (TDR), the two main ports are 50  $\Omega$  up to 1 GHz. Frequency-dependent losses in the delay cable are quite accurately compensated, as shown by the reed-relay (Radio Shack part number 275-232) step response (Fig. 2, trace A). When an ordinary 4.6-dB attenuator is implemented, a rounded step response results (Fig. 2, trace B).

Although the inductor arm derives the trigger from the input signal, other triggers can be plugged in as needed. These triggers also can be displayed by routing them to the sampler via the delay line. For each input pulse, the MAX961 trigger-and-hold comparator triggers an adjustable-rate, fast-ramp circuit by switching the two Schottky-clamped MPS-H10 transistors. At the same time, its 4-V complementary-out-

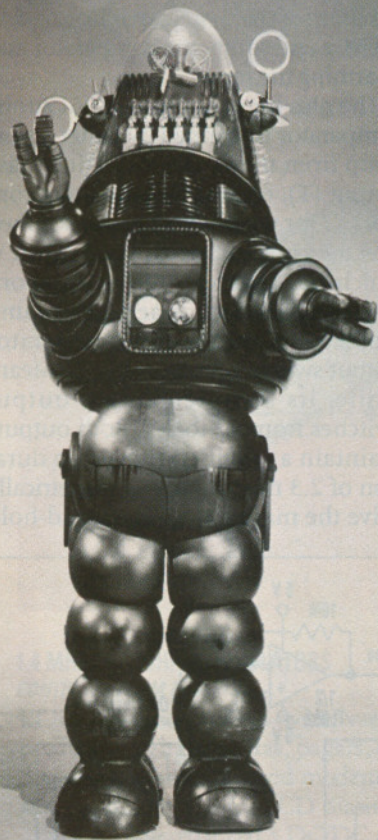
put step quickly enables its own latch (LE), locking out further changes. This locked comparator allows the switched MPS-H81 current source to ramp up the 82-pF capacitor from -2 to 2 V, without interruption. After 500 ns, the resistor discharges the 1-nF capacitor to 0 V, thereby reinstating the comparator and re-arming the ramp.

The plus input of the MAX961 strobe comparator is scanned by either a slow ramp from the oscilloscope time-base output (T), or the 250- $\Omega$  manual control (X) for the X-Y plotter. It's scanned over the same voltage range of -2 to 2 V, which also is used as the display horizontal signal. Each time the fast ramp crosses this voltage, the comparator output switches from 2 to -2 V. Meanwhile, its complementary output switches from -2 to 2 V. Both outputs maintain a specified transition duration of 2.3 ns. They also symmetrically drive the master/slave track-and-hold



1. In this sampling oscilloscope plug-in, the time base (T) or adjustable voltage (X) interferes with the triggered fast ramp at strobe to repeatedly toggle the tandem master/slave track-and-hold, acquiring samples at input Y for display of  $V_{IN}$ .

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bridges that are connected to sequentially sample  $V_{IN}$  in the delay cable.

The actual sampling event happens in the track-to-hold transition. It takes place during the few hundred picoseconds in which the master Schottky-diode bridge resistance switches from low to high. Such switching occurs within a small, central part of the full 8-V applied step.

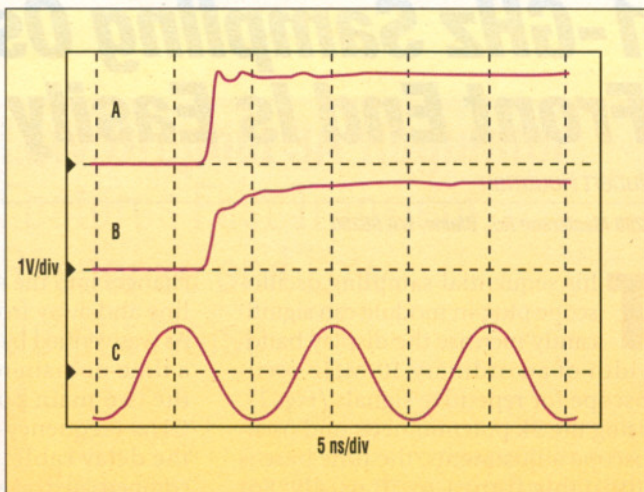
Consequently, its switching duration

must be only a small fraction of the strobe comparator transition duration. The RC delay network controls the strobe comparator's latch. While the slave is in the track mode, this latch locks the master T/H in the hold state for 650 ns.

During this 650-ns period, the master BIFET charge amplifier (1/2TL082) can buffer the sample, pulsed onto its input capacitance of about 15 pF. This voltage is a scaled-down replica of the sampled voltage entering the 1-pF/15-pF capacitive divider. A 15M<sub>Ω</sub>/1M<sub>Ω</sub> resistive divider is connected across it, which completes this wideband compensated attenuator. Therefore, the master bridge is loaded with only a low-input capacitance of about 1 pF. Because the bridge's on-resistance is about 100  $\Omega$ , the RC time constant is around 100 ps.

Continuously buffering the 1-nF memory, the slave T/H BIFET amplifier (1/2TL082) produces a step-like, down-converted representation of the input waveform ( $V_{IN}$ ). It does so at a low intermediate frequency (IF) for the oscilloscope, or a zero IF for the X-Y plotter. Switching transients are eliminated via the adjustable low-pass filter (LPF). By averaging the output over as many input pulses as desired, this device strongly reduces noise.

The bandwidth of this sampler is over 1 GHz. Its transition duration is about 300 ps which, together with the approximately 250-ps intrinsic risetime of the reed relay, yields the measured display transition duration of 400 ps (Fig. 2, trace A, again). Trace C illustrates the time-scale calibration and ver-



2. In these sampler output plots, trace A is the reed-relay step response to a 3.7-kHz signal, trace B uses a normal attenuator, and trace C is a sampler plot of a 100-MHz sine wave.

tical-scale linearity by showing a sampled 100-MHz sine wave with a sampled zero line. For this RF measurement, a countdown trigger was used, prior to the trigger-and-hold.<sup>2</sup> To display higher frequencies with this sampler, the countdown trigger should be preceded by a prescaler, such as the emitter-coupled logic (ECL) circuitry.<sup>3</sup>

Additional experiments have verified that it's fairly easy to add more synchronized channels, using the strobe comparator to fan out and drive two or more similar comparators. Via separate delay lines, each of these comparators drives individual T/H circuits to sample multiple inputs.  $\blacktriangleright$

### References:

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2. H. Houtman, "Counter Circuit Improves Oscilloscope Triggering," *Electronic Design*, Vol. 48, No. 15, p. 126, July 2000.
3. F.J. Hufft, "Build This 1.6-GHz Counter Prescaler," *Radio-Electronics*, Vol. 61, 10, p. 47-54, October 1990.

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