Measure Device Capacitance

Easy Circuit Measures Voltage Dependent Capacitance

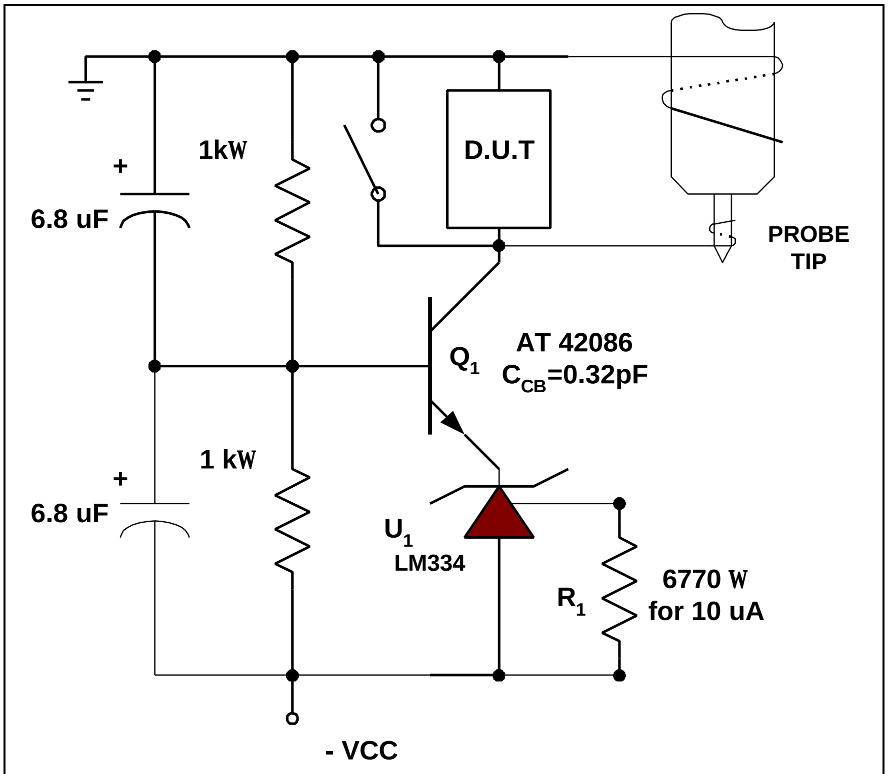

Figure 1 - Schematic of test circuit

There are many techniques for measuring capacitance. Some of these techniques require a function generator to provide either a sinusoidal, or step-function voltage source. The following design idea has the advantage of requiring no special excitation source, but rather relies on a simple test circuit, and the single-shot capture, and measurement capabilities inherent in digital oscilloscopes (DSO's). The circuit can accurately measure very small capacitances, but also has the added utility of being able to accurately measure capacitances which change as a function of applied voltage. An example of devices which have such voltage-dependent capacitance are reversed-biased pn junctions, such as the collector-base junction of a bipolar transistor. Another example is a TVS device (Transient Voltage Suppressor diode).

Test Circuit:

The test circuit (figure 1) consists of a single npn transistor (Q1) configured in a common-base connection. There is a constant current source (LM334 = U1), in the emitter leg of the transistor. The transistor exhibits very low collector-base capacitance (Ccb = 0.32pF typical). This is the specification which is critical to the design, as the actual voltage swing across the D.U.T. will occur between the collector of the transistor and ground. The base of the transistor is biased with a constant DC voltage equal to 1/2 of the supply voltage (-Vcc). Maximum Vce for the transistor used in this circuit is 12V, therefore -Vee should be limited to about -22V maximum.

The circuit works as follows. The LM334 constant-current source (U1) is programmed for a cathode current of 10uA by the selection of R1 (67mV/R1 = Icathode). The capacitance to be measured is connected between circuit ground and the collector of Q1. A low capacitance switch is used to short the collector of Q1 to ground. NOTE: I used the sharp edge of a simple clip-lead, to manually contact the ground node, to make a very low capacitance connection. A very low capacitance scope probe (FET type) is attached to the circuit as illustrated in figure 1. A digital oscilloscope is used in single-shot capture mode, to capture the falling edge of the voltage waveform which appears across the D.U.T. after the short is released, and the unknown capacitance is charged by the constant current source, through Q1. With proper triggering, the entire voltage waveform can be captured. The programmed current of the constant-current source can be changed, depending of the range of capacitance value to be measured, and is not critical. The selected value of charging current determines the slope of the displayed waveform. The voltage response (slope), can be made arbitrarily slow, so that inductances inherent in the circuit will not effect the measurement.

Analyzing The Results:
Since the D.U.T. has been charged with a constant-current, the capacitance of the device is simply:

$$C = I/(dV/dT)$$

Both the time and voltage parameters (slope of the captured voltage waveform) can be measured directly from the displayed waveform. Devices with a fixed capacitance will display a linear slope characteristic (up to the saturation voltage of Q1). Devices with capacitance which is voltage-dependent will show a varying-slope characteristic. Capacitance can be directly measured at any bias voltage, or devices which have a voltage-dependent capacitance.

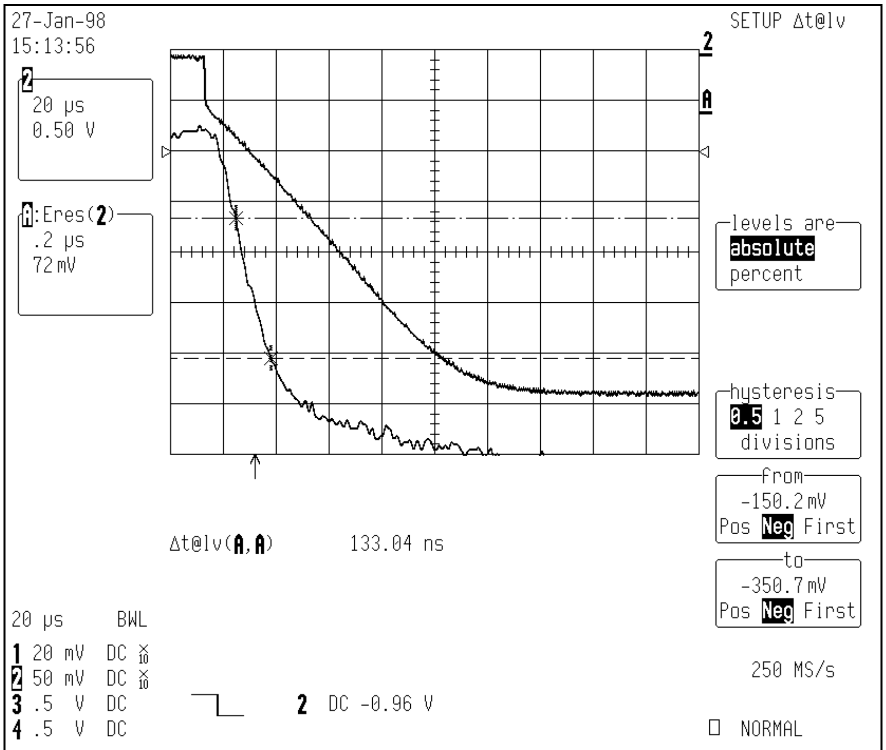

Figure 2 - Determining the region of low capacitance

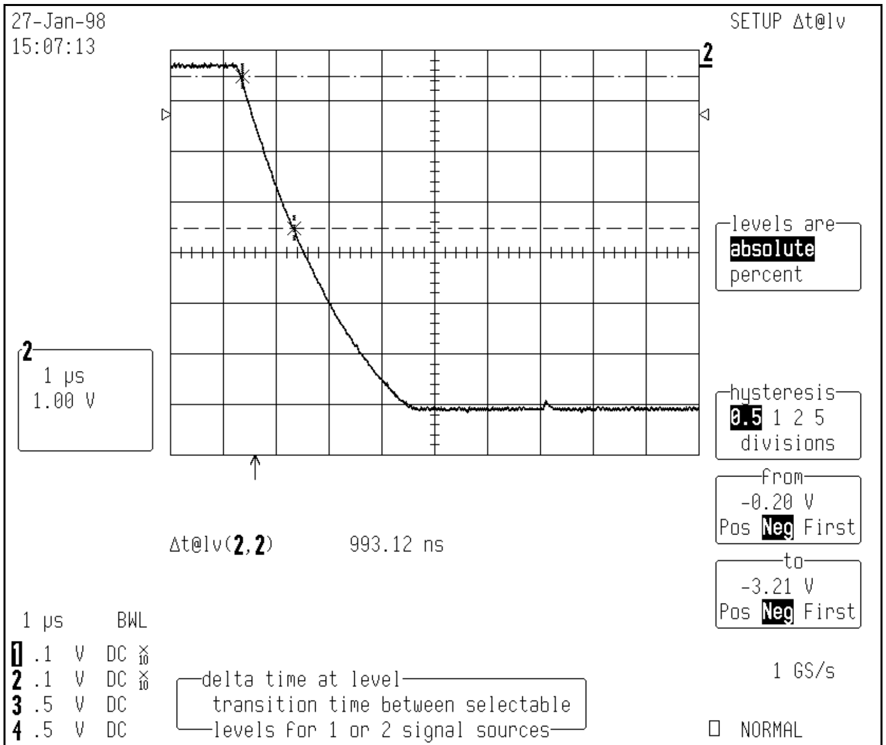

Figure 3 - Measurement of test circuit capacitance

Certain features of the modern DSO make these measurements especially convenient. LeCroy oscilloscopes have a measurement feature called “delta-time-between-levels”, which allows a direct measurement and readout of delta-time between two cursor-selected voltages on any displayed waveform (figures 2, 3 and 4). The measurement also makes use of enhanced resolution to reduce noise and improve accuracy.

The waveform displayed in figure 2 is that for the measurement circuit itself, without any D.U.T. Thus, this is a baseline measurement of the capacitance of the test circuit. This consists of the capacitance (Ccb) of Q1, the scope probe, and the parasitic capacitances of the physical test circuit. The measured value (3.3pF) will be subtracted from subsequent measurements. Figure 3 displays a waveform obtained when the D.U.T. is a TVS device. This particular device is termed a “low-capacitance” type TVS. The manufacturer achieves low capacitance by inserting a high-speed rectifier (with low-capacitance) in series with the TVS diode. What can be seen in the displayed result, is that the capacitance of the device is indeed very low (3.4pf), when the device is biased with up to 0.5V, however, above this bias voltage, the internal rectifier

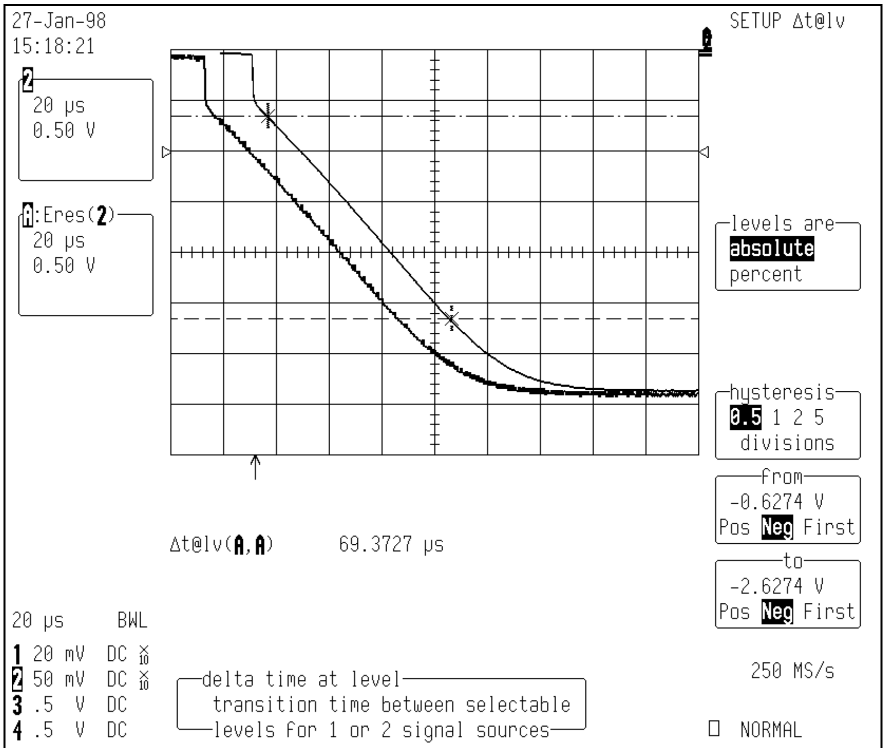

Figure 4 - measurement of the capacitance of the device at bias voltages greater than 0.5V

diode is ON, and the capacitance of the TVS device now dominates.

Figure 3 displays two waveforms. Trace 2 is the entire captured waveform showing TVS characteristics from 0V on up to its breakdown voltage with a bias current of 10uA. (This is a 3V TVS device). The expanded trace (A), is an expansion of the region from 0V to approximately - 0.5V (the region of low capacitance). Measurement on this expanded trace yields the capacitance value of 3.4pF.

Figure 4 shows the measurement of the capacitance of the device at bias voltages greater than 0.5V (347pF)

Summary:

This is a convenient technique which uses a simple, small and portable circuit to allow measurement of voltage-dependent capacitance characteristics. This circuit has also been used to measure parasitic capacitances at input connectors and other areas of PC boards, which could not easily be driven by sinusoidal voltage sources, or connected to test instruments for direct measurement.