Analyzer tests reverse-recovery behavior of diodes

Louis Vlemincq - July 19, 2007

Testing the reverse-recovery behavior of diodes normally requires complex testing gear. You must be able to establish the forward-conduction conditions, the blocking state, and the transition between the two. You also need a means of extracting the characteristics from the resulting waveform. In short, a specialist should handle this complex job; it is not something you routinely control in the field. This fact explains why engineers generally prefer to rely on published data.

Checking the reverse-recovery time yourself could be advantageous, however, if testing were simple and straightforward. Such a setup would enable you to compare devices from different manufacturers under identical conditions and test devices having no such specification, such as substrate diodes of driver ICs, zener diodes, and standard rectifiers. (Because of the number of combinations of the test parameters, a direct comparison of the data is rarely possible.) Note that shorter reverse-recovery time is not necessarily better. Slow diodes can be useful, too. They can generate small dead times, improve the efficiency of converters, and provide other benefits (Reference 1).

This Design Idea presents a tester that, using only a handful of inexpensive, standard components, allows you to check reverse-recovery time. The test conditions are fixed for simplicity, to normalize the tests and to provide a common standard for comparison purposes. These conditions are compatible with 99% of the devices susceptible to test. The tester’s forward current is just low enough to be safe with small switching diodes but high enough to overcome the capacitive effects in larger devices.

A diode-resistor AND gate lies at the heart of the circuit; the gate’s diode is the DUT (device under test, Figure 1). IC1 buffers flip-flop IC2A, which derives the antiphase square waves that drive this gate. R35 sets the DUT’s forward current to approximately 75 mA. With an ideal diode, the gate’s output would always stay low, because one of the inputs is always low. But a real diode remains conductive after the transition, generating a positive pulse across R35. Instead of using the brute-force approach of directly measuring this pulse width, the circuit uses a subtler scheme. The R19/C15 network averages the pulse and amplifies and displays the resulting voltage. Because the measurement frequency is fixed at 50 kHz, a correct scaling factor is all that is necessary.
Figure 1 This diode-recovery test setup allows you to compare devices from different manufacturers under identical conditions.

A real diode also has a forward voltage, which you would average with the result. $Q_3$ takes care of this problem by sampling this forward voltage through $IC_{4A}$ and subtracting it from the output voltage through $R_{32}$. Varying the gain of amplifier $IC_{4C}$ sets the various ranges. In this case, the ranges are in a 1, 2.5, 5 sequence, which suit the salvaged galvanometer this circuit uses as an indicating device. You could easily create other ranges by adapting the values of $R_8$ through $R_{22}$. The big advantage of this measuring method is that it handles only dc or low-frequency signals, requiring no fast comparators or samplers, yet it can resolve a few hundreds of picoseconds.

The built-in oscillator of $IC_3$ generates the clock. The clock frequency is 800 kHz and divides down to produce the 50-kHz reference at $Q_3$. An optional slow mode is available for those needing to test devices slower than 5 µsec. The insertion of coil $L_1$ decreases the clock frequency to 80 kHz and enables you to measure reverse-recovery time as fast as 50 µsec. $IC_2$ generates the test waveforms and shifts the 50-kHz signal at the clock rate. The leading and trailing states then exit through the $D_2/R_6$ AND gate to produce a sampling pulse that centers on the conduction period. Because the sampling occurs far from any transitions, it need not be particularly fast or accurate. $C_1$ transfers the sampling pulse and provides a convenient pretrigger signal, which $Q_1$ buffers. This option enables a comfortable observation of the waveform when you connect an oscilloscope to the anode of the DUT.

The unused output, Pin 8 of $IC_{1B}$, feeds a negative-voltage generator, serving as a bias source for the outputs of $IC_4$ to let them reach a true zero. The measurement circuits receive power from a 9V battery by a supply encompassing $IC_{1D}$. An LED serves as a reference to the 5.5V and provides some temperature compensation because the reverse-recovery time depends highly on ambient temperature.
You can make some adjustments to the circuit. For example, with no diode inserted, you can short the Adjust testpoint 1 to 4. In the 10- or 25-nsec range, $R_{v2}$, which is 0 nsec in the range, to get a midscale reading. Move the short to Adjust testpoint 3, $R_3$, and $R_{v1}$, thereby providing $V_F$ cancellation, to read the same value. Repeat the procedure until the reading is independent of the position of the short. The adjustment interacts with the zero due to the offset of the amplifiers.

Now, you have eliminated the effect of $V_F$. You can adjust the 0 nsec by shorting Adjust testpoints 1 and 4 and adjusting $R_{v2}$ to read zero on the 10-nsec range. This adjustment yields 0 nsec with a typical offset of 1 to 2 nsec in the positive direction. Residual skew in the timing and charge-injection effects cause this offset. Normally, this offset should not be a problem, because it is small, stable, and constant. If you need an absolute accuracy down to the picosecond, you have to test a known, ultrafast diode, such as an FD700 or a BAY82, and adjust the 0 nsec to read the actual value. If you lack access to such a diode, you can always arbitrarily shift the value by 1.5 nsec. This adjustment is normally sufficient to reach a ±500-psec accuracy. Schottky diodes are unsuitable. Despite their low recovery time, they generate a nonzero reading because of their relatively high capacitance and non-negligible leakage currents. Low-capacitance, mixer-type diodes are too fragile for this tester.

**Reference**