Smart Diode Recovery Analyzer

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

Checking the t_{rr} (reverse recovery time) could be advantageous however, if it could be made simple and straightforward: this would enable you to compare devices from different manufacturers under identical conditions (due to the huge number of combinations of the test parameters, a direct comparison of the data is rarely possible), and test devices having no such specification (substrate diodes of driver ICs, Zener diodes, standard rectifiers, etc).
Note that shorter t_{rr} are not necessarily synonymous with better: slow diodes too can be useful: they can generate small dead times, improve the efficiency of converters, etc: see this article for further details:
http://www.edn.com/article/CA450598.html
The tester presented here does just that, using only a handful of cheap, standard components. The test conditions are fixed, for obvious reasons of simplicity, but also to “normalize” the tests and provide a common standard for comparison purposes. These conditions have been choosen to be compatible with 99% of the devices susceptible to be tested: in particular, the forward current is just low enough to be safe with small switching diodes, but high enough to overcome the capacitive effects in larger devices.

At the heart of the circuit (fig. 1) is a diode-resistor AND gate, whose diode is the DUT. This gate is driven by antiphase squarewaves, derived from the flip-flop U2A, and buffered by U1; the forward current is set by R35 and is about 75mA. With an ideal diode, the gate’s output would always stay low, as one of the inputs is always low. But a real diode remains conductive after the transition, generating a positive pulse across R35. Instead of opting for the “brute force” approach of directly measuring this pulse width, a more subtle scheme is used: the pulse is averaged by the R19/C15 network, and the resulting voltage is amplified and displayed; because the measurement frequency is fixed at 50KHz, all that is needed is a correct scaling factor.
A real diode also has a forward voltage, which would be averaged with the result; this problem is taken care of by Q3, which samples this voltage via U4A and substracts it from the output voltage via R32. The various ranges are then created by varying the gain of the amplifier U4C. In this case, the ranges are in a 1 : 2.5 : 5 sequence, suited to the salvaged galvanometer used as indicating device; other ranges could easily be created by adapting R8 to R22.
The big advantage of this measuring method is that it only handles DC or low-frequency signals, requiring no fast comparators or samplers, yet being able of resolving a few 100’s of picoseconds.

Let’s now look at some more details:
The clock is generated by the built-in oscillator of U3; the frequency is 800KHz, and is divided down to produce the 50KHz reference at Q3. An optional “slow mode” is also included for those needing to test devices slower than 5µS: the coil L1 is inserted, bringing the frequency to 80KHz, and enabling t_{rr} up to 50µs to be measured.
U2 generates the test waveforms, and also shifts the 50KHz at the clock rate; the leading and trailing states are then removed via the D5/R6 AND gate to produce a sampling pulse centered on the conduction period; because the sampling is performed at a “quiet” time, far from any transition, it doesn’t need to be particularly fast or accurate. The sampling pulse is transferred by C1, and also provides a convenient pretrigger signal buffered by Q1. This option enables a comfortable observation of the waveform when an oscilloscope is connected to the anode of the DUT.
The unused output 8 of U2B feeds a negative voltage generator, serving as a bias source for the outputs of U4, in order to let them reach a true zero.
The measurement circuits are powered from a 9V battery by a supply built around U4D; an LED serves as a reference to the 5.5V, and provides some temperature compensation (the t_{rr} is highly dependent on ambient T°).

Adjustments:
With no diode inserted, short Tp1 to 4 (GND); in the 10 or 25ns range, adjust RV2 (zero) to get a midscale reading; move the short to Tp3 (R1) and adjust RV1 (Vf cancellation) to read the same value; repeat the procedure until the reading is completely independent of the position of the short (the adjustment interacts with the zero due to the offset of the amplifiers).
Now, the effect of Vf has been eliminated; the zero can be adjusted by shorting Tp1 and 4 and adjusting RV2 to read zero on the 10ns range.
This will yield a zero with a typical offset of 1 to 2ns in the positive direction (residual skew in the timing, and charge injection effects cause this offset); normally, this should not be a problem, as this offset is small, stable and constant. If you need an absolute accuracy down to the ps, you have to test a known, ultra-fast diode (f.e. FD700 or BAY82), and adjust the zero to read the actual value. If you don’t have access to such a diode, you can always arbitrarily shift the value by 1.5ns: this will normally be sufficient to reach a +/-500ps accuracy.
Schottky diodes are not suitable: despite their absence of recovery time, they will generate a non-zero reading due to their (relatively) high capacitance and non-negligible leakage currents (low-capacitance, mixer-type diodes are too fragile for this tester).

A note about the calibration.
No provision has been made to calibrate the scale-factor; this is partly because it is more or less arbitrary, and depends on the conditions and criteria of measurement. In this tester, the conditions are that of “mirroring”, ie. conditions before and after the transition identical, but with an opposite sign, and the criterion is along the same lines: the recovery ends when the voltage reaches the Vf level of the forward phase (fig. 2).
Three reasons have inspired this particular choice:
-It is coherent and easy to correlate with oscilloscope observations
-It is logical and self-consistent
-It correlates well with typical data published by manufacturers

You are, of course, perfectly free to adopt a different factor: this can easily be done by altering the clock frequency or the gain of the amplifier.

Some additional thoughts:
-The effect of the forward recovery has not been discussed so far; it is normally minor compared to the reverse recovery. In this tester, it will simply account for a somewhat increased reading, until it is large enough to impinge on the Vf-cancellation period. It is, in my opinion, no problem since it participates to the “perceived slowness” of a diode.
-If a higher testing current is needed, it is always possible to stack (litterally) additional 74AC244’s on the top of U1, and reduce R35 accordingly.
-You are free to use any output device; here, an analogue meter is shown, but it could be built with a panel millivoltmeter module, or as a multimeter plug-in.
-Due to the measurement principle, two diodes with very dissimilar recovery profiles could (and in fact can) show an identical t_{rr} . Is this a problem? No, the physical parameter actually measured is the reverse recovery *charge*, formatted to be displayed as a time; this charge reflects the power losses in an actual circuit, meaning that those two diodes will in fact perform very similarly in the real world. You could, for that matter, display the value in nano-Coulomb, if you find this unit more relevant. And anyway, you can always connect an oscilloscope to view the actual waveshape.
-There is an alternative calibration method requiring no high-speed diode or oscilloscope, but it is too long to include here. If enough people show an interest, I may write a follow-up to this article.