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SINCE 1975

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AVTECH TECHNICAL BRIEF 15 (TB15)

A COMPARISON OF REVERSE RECOVERY MEASUREMENT SYSTEMS

INTRODUCTION

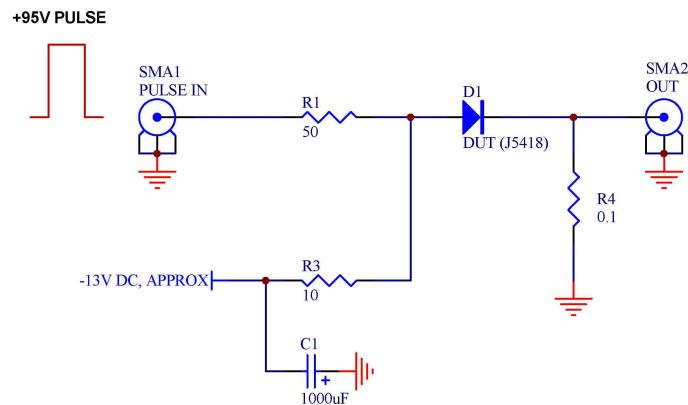
A manufacturer of semiconductor devices had built a number of different reverse recovery time (t_{RR}) measurement systems over the years. Some of these had been built with Avtech pulse generators as part of the system, and others used older equipment from other suppliers.

This manufacturer noticed that the different measurement systems were giving different results, even though the settings (forward and reverse current) were nominally the same. In particular, the test set-up that used the Avtech pulse generator tended to yield higher reverse recovery time (t_{RR}) measurements than the older systems. The manufacturer's clients were also reporting that some devices were marginal – that is, the t_{RR} times were longer than expected.

The manufacturer contacted Avtech, to see if we could offer any insights as to the relative accuracy of the different systems.

THE ORIGINAL TEST APPROACH

One of the older test systems was configured as shown below:



A DC power supply keeps the DUT reverse-biased in the quiescent state. A pulse is then applied which forward biases the diode briefly (5 μ s, in our tests). The pulse ends, and the diode switches back to reverse bias, conducting briefly as the stored charge is removed.

The diode current is “sensed” by the 0.1 Ohm resistance (R4). The voltage across this resistance is measured by an oscilloscope, which is connected used coaxial cable. The oscilloscope input impedance is set to 50 Ohms. No probe is used. With a -13V DC input and a +95V pulse input, a forward current of 500 mA and a reverse current of 1 A (approximately) are obtained.

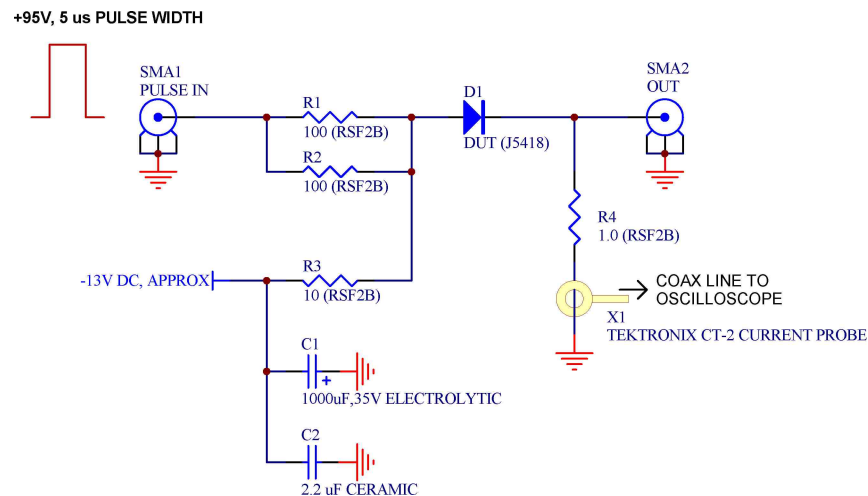
There are two major flaws with this circuit, however:

- 1) The sensed voltage across R4 is tiny ($1A \times 0.1\Omega = 100 \text{ mV}$) compared to the input pulse voltage ($\approx 95 \text{ V}$). This makes it extremely difficult to avoid interference between the two signals. Interference “spikes” are virtually guaranteed to appear on the output signal, due to signal coupling and grounding effects.
- 2) The inductive voltages caused by parasitic inductance in the sensing resistance will be comparable to the resistive voltages, severely distorting the waveform. For instance, if the forward-to-reverse transient (from $+0.5A$ to $-1.0A$) occurs in 10 ns , and the parasitic inductance is conservatively estimated to be 10 nH , inductive voltage spikes on the order of $V = L \, di / dt = 10 \text{ nH} \times 1.5A / 10 \text{ ns} = 1.5 \text{ Volts}$ can be expected. This will completely dwarf the resistive voltage change ($1.5A \times 0.1\Omega = 150 \text{ mV}$)!

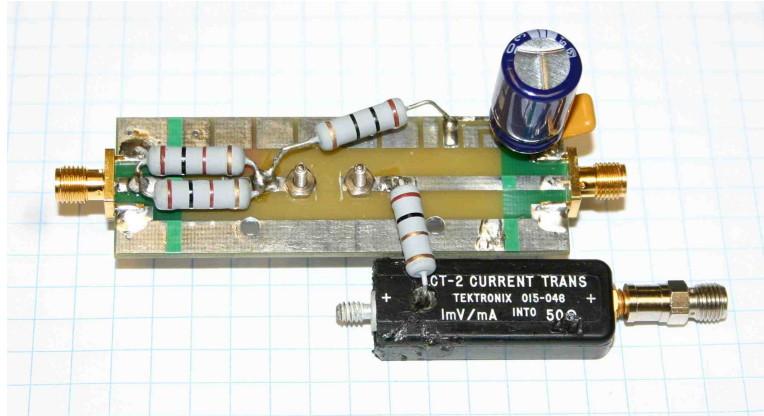
In fact, Avtech attempted to duplicate this circuit as shown above, but it was impossible to obtain clean, useful waveforms.

Instead, R4 was boosted from 0.1Ω to 1.0Ω . This reduces the problems by a factor of ten, but it does not eliminate them entirely (e.g., the inductive voltage will still be $1.5V$, but the resistive voltage change is closer to $1V$ now).

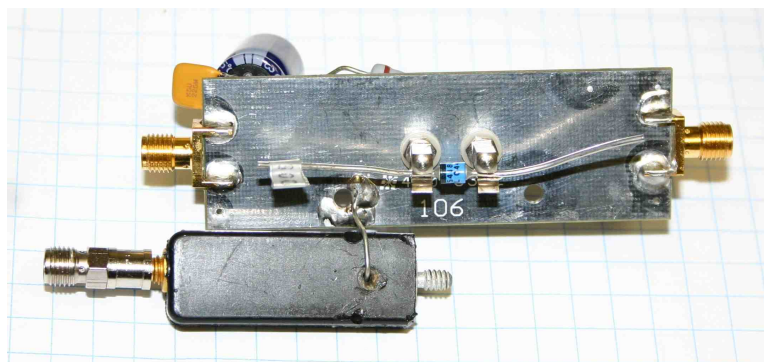
Also, to confirm the problems with R4, a Tektronix CT-2 current probe was added in series with R4. This probe is connected to a second oscilloscope input using coaxial cabling and a 50Ω termination. The circuit as tested by Avtech is shown below:



An Avtech AV-1011-B pulse generator (with 10 ns rise and fall times) was used as the pulse source. Low-inductance RSF2B-series resistors from RCD Components were used. A J5418 device was used as the DUT. It was installed in clip-posts. The circuit was constructed on a small piece of microstrip circuit board, with connectorized inputs and outputs. The circuit board is shown below:

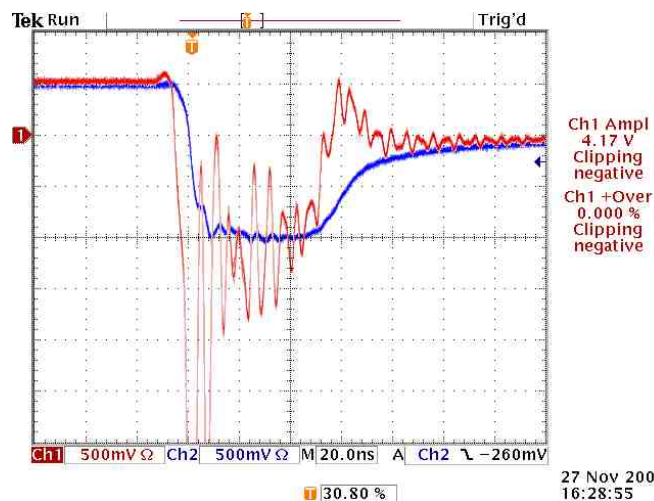


Microstrip View

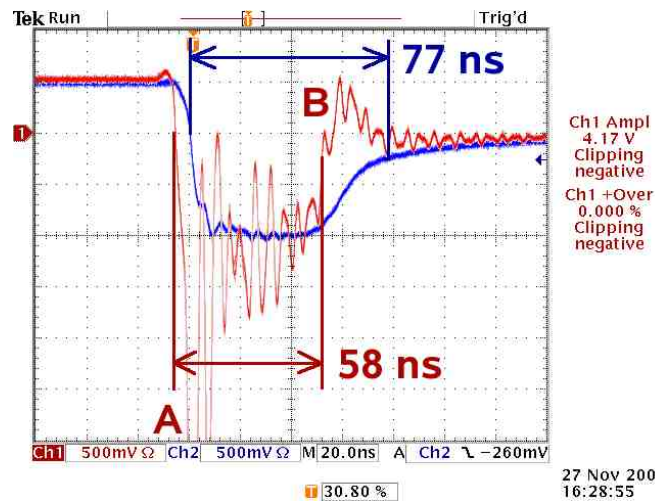


Ground Plane View

With this setup, the following two output waveforms were obtained:



The red waveform is the voltage measured across R4. The blue waveform is the output of the current probe. The t_{RR} values that can be calculated from these waveforms are shown below, assuming that t_{RR} is measured as the time between the zero-crossing and the fall-back to 25% of the nominal peak reverse current (25% of 1A = 0.25A):



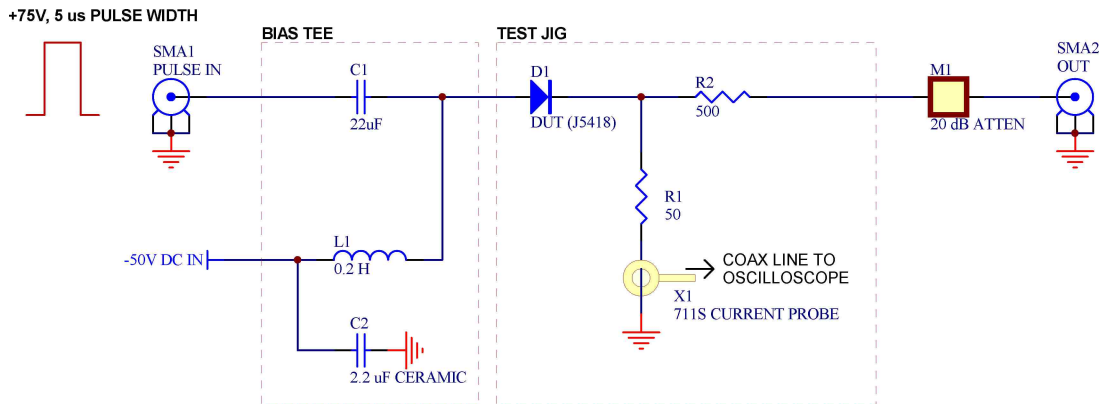
The R4 voltage waveform shows extremely large ringing, caused by the input-output interference (see the “A” area above). Also, the end of the reverse transient is obscured by a large inductive spike (in the “B” area), which causes the resistor voltage rise to a positive value for a time, which obviously does not reflect the true current flow through the diode! This spike “hides” the true current “tail”, which is accurately measured by the CT-2 current probe. The R4 waveform is so noisy that it is difficult to even measure the true peak reverse current.

The CT-2 probe waveform provides a t_{RR} measurement of 77 ns. The resistor voltage waveform provides a more optimistic, but incorrect, measurement of 58 ns.

These waveforms show that the output of low-value sensing resistors CAN NOT be used for t_{RR} measurements of modern ultra-fast devices. This circuit could be used for devices with microsecond-scale t_{RR} ratings, but it is not appropriate for faster devices unless a current probe is used to replace the sensing resistor.

THE NEWER TEST APPROACH

The device manufacturer also had another system, which had been designed in-house and made use of an Avtech pulse generator and a bias tee. This is a fundamentally different circuit. An approximation of this circuit was constructed at Avtech, using the following setup:

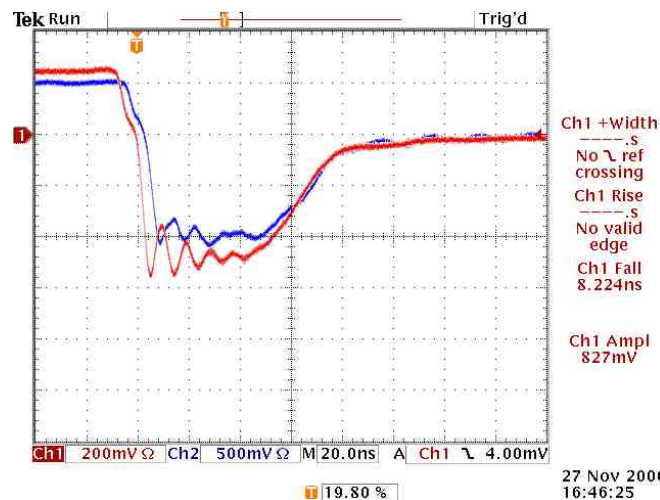


Again, a DC power supply reverse biases the DUT in the quiescent state, and a positive pulse from a pulse generator similar to the Avtech AV-1011-B or AVR-3-B models is used to briefly forward-bias the diode.

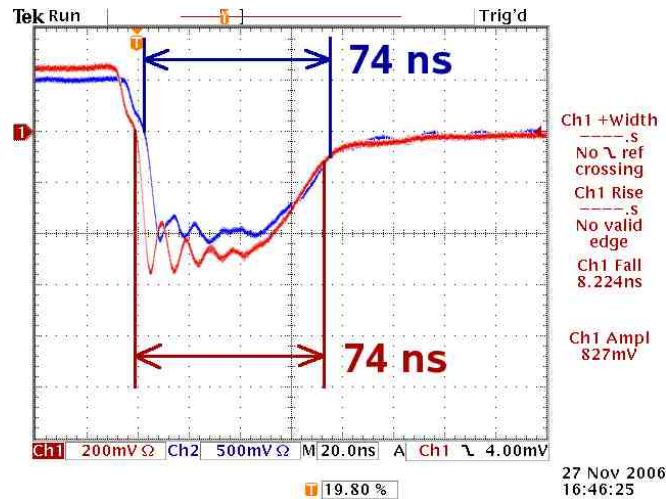
The key difference compared to the previous circuit is that the sensing resistor is 50 Ohms. The relative size of the inductive effects will be reduced by a factor of 500 compared to the 0.1Ω resistance (since $50\Omega / 0.1\Omega = 500$, and the parasitic inductance is unchanged, approximately).

A current transformer is again used to provide a second sensing method. This time, a model 711S current probe from Integrated Sensor Technologies is used.

With this approach, the following waveforms are obtained:



The red waveform is the voltage measured across R1 (attenuated by R2 and an external 20 dB attenuator). The blue waveform is the output of the current probe (at 1V per Amp). This time, the two sensing methods are in agreement, indicating that inductive effects are not distorting either measurement. The measured values of t_{RR} are shown below:

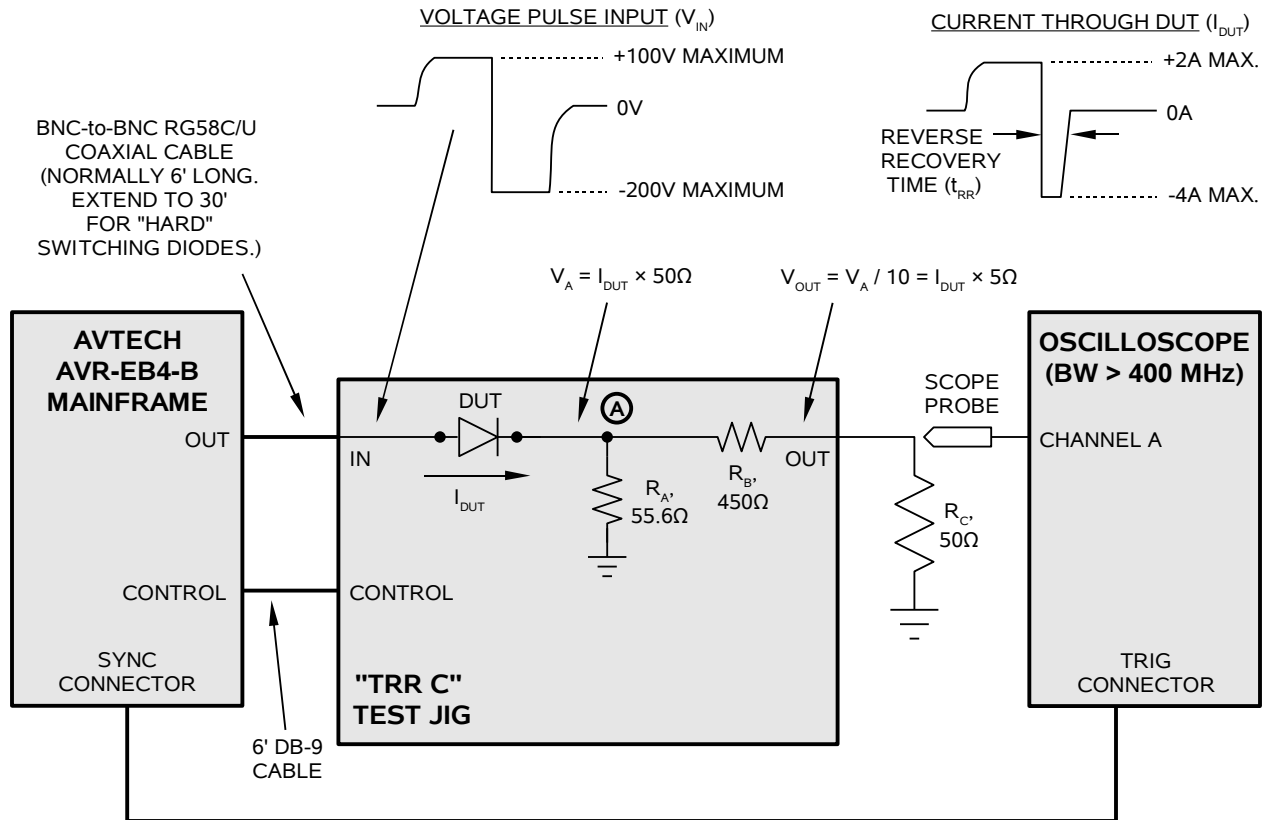


Some slight ringing is still present on the resistor voltage waveform, due to the small parasitic inductance and transmission line effects, but it is minor compared to the ringing observed with the older set-up.

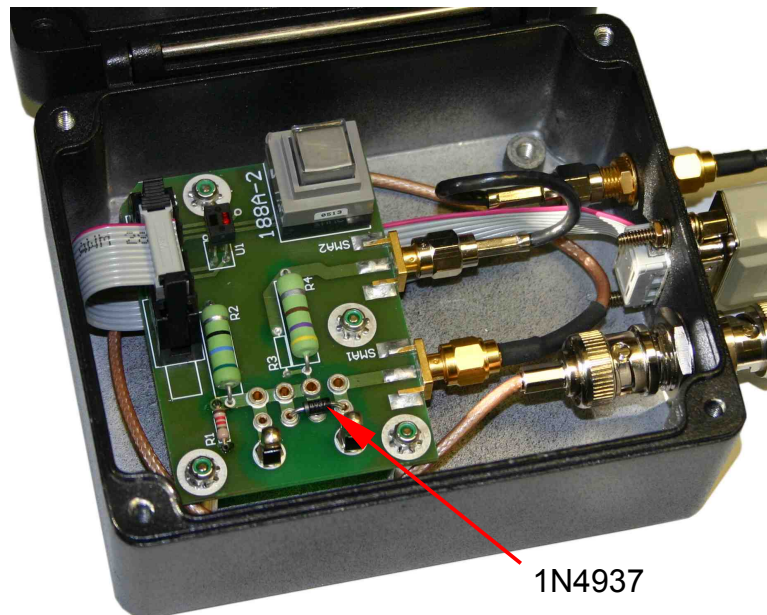
THE AVR-EB4-B SYSTEM

The previous two systems were developed largely in-house at the device manufacturer, useful pulse generators from Avtech (and other suppliers) simply as the pulse source.

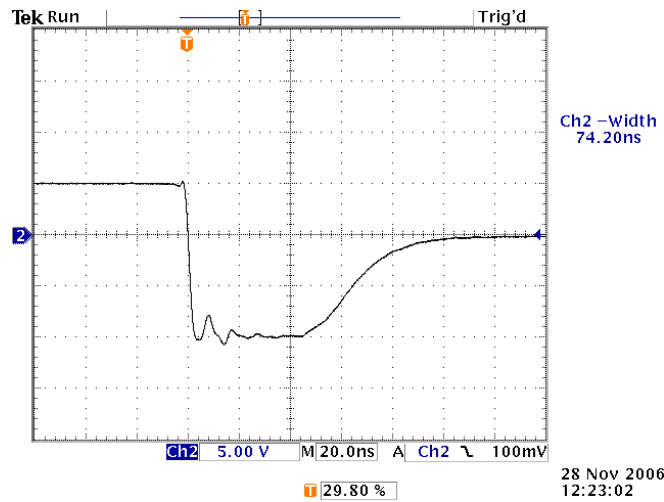
Avtech also produces more complete systems, such as the AVR-EB4-B. This particular model generates a positive pulse (forward biasing) followed immediately by a negative pulse (reverse biasing) on a single output. There is no need for bias tees or other signal combiners. The best arrangement is shown below:



A standard test jig (customized ones are available) is provided. This jig includes a pattern of pins sockets and clip posts to allow most common axial devices to be easily plugged in. The photo below shows a 1N4937 installed in the test jig:



Using the AVR-EB4-B, the following output waveform was obtained for the J5418 ($I_F = 0.5A$, $I_{RM} = -1A$, and $I_{R(REC)} = -0.25A$):



The oscilloscope measures a t_{RR} time of 74.2 ns, at the -0.25A level. This result is consistent with the previous results!

For maximum simplicity and repeatability, the manufacturer should consider using the AVR-EB4-B for their t_{RR} measurements. Further information is available at <http://www.avtechpulse.com/semiconductor/avr-eb4>. In particular, the manual at <http://www.avtechpulse.com/manuals/AVR-EB4-B.ed1.pdf> contains a considerable amount of useful information!

Avtech models in the AVR-TRA3-B or AVR-TRA4-B families (see <http://www.avtechpulse.com/semiconductor/avr-tra3> and <http://www.avtechpulse.com/semiconductor/avr-tra4>) may be suitable for the devices of interest.

CONCLUSIONS

The “old” test approach is not usable for modern ultra-fast devices. It is only suitable from devices with microsecond-scale reverse recovery times. The low ohmic-value sensing resistors introduce far too much inductance to be useful. These systems generate overly optimistic estimates of t_{RR} .

A configuration that relies on a larger sensing resistance (50 Ω , for example), should be used to avoid inductive effects. The “new” Avtech-based test system at the customer's facility does do this, providing accurate measurements.

A current probe can be used to provide a way of verifying the resistive waveforms.

Avtech can provide standard and customized systems (including pulse generators and test jigs) to achieve these goals. The manufacturer should consider using the AVR-EB4-B to replace the older systems.

Based on the results obtained here, the reverse recovery time of the J5418 diode is estimated to be ≈ 74 ns, with $I_F = 0.5A$, $I_{RM} = -1A$, and $I_{R(REC)} = -0.25A$.