

PROGRAMMABLE STIMULI
FOR STRESS-TESTING
AND COMPONENT EVALUATION
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Introduction: Devices and Tests

Will a flash memory still be good after a hundred thousand operations? Does a switching diode switch quickly enough to avoid burning energy on the reverse part of the cycle? How much does a resistor change its value when a pulse is applied? What is the performance of a laser? and how much energy can it withstand? As a designer, you will need answers to these kinds of questions rather than risk problems surfacing later in the product cycle.

To get these answers you will need to switch fairly high voltages or currents at rates up to or beyond normal operating speed, typically measuring the results on an oscilloscope. This sounds simple, but sources must adapt to different needs if setups are not to get unwieldy when dealing with situations such as bipolar as well as unipolar pulses, different loads, and -for fatigue tests- long, accurate, pulse sequences.

At the same time, you are looking for credible, repeatable, results and fast turn-around. Programmable instruments not only meet these needs but also open the door to the statistical evaluation and automatic reports.

What this Application Note is about

This Application Note starts with a description of a concrete investigation to illustrate aspects that are common to many component evaluations. The Note explains the standard method and then suggests how today's pulse generators can contribute to better measurements.

Following this, the Note suggests some practical solutions for stimulating lasers, obtaining 3-level signals, and dealing with ringing when mismatch can't be avoided.

A typical component measurement, the reverse recovery time of a diode.....

 What is diode reverse recovery?.....

 Standardized measurements.....

 Test Condition A.....

 A better way for Test Condition A.....

 Test Condition B and an easy implementation..

Stimulating lasers.....

What if more power is needed?.....

Three-level signals.....

 Adder construction.....

Comms codes.....

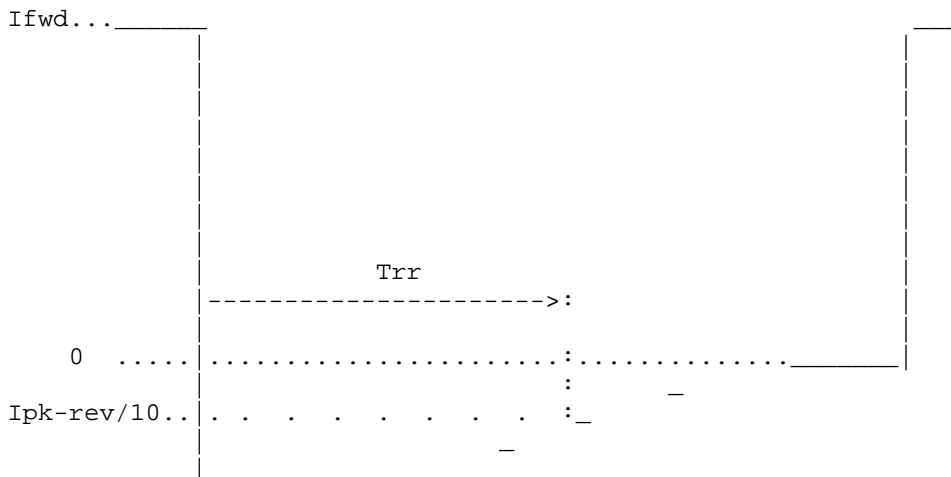
Preventing ringing.....

A TYPICAL COMPONENT MEASUREMENT:
THE REVERSE RECOVERY TIME OF A DIODE
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The application is taken from the case history of a power-supply design project. Space requirements had forced transformer size down so the switching frequency was upped to compensate for the small cores. Measurements showed that the rectifier diodes were delivering current in the REVERSE direction. At lower frequencies it was observed that the reverse current was in fact a pulse that decayed relatively slowly compared with the switching time. This reverse-recovery effect of the diodes had to be investigated before proceeding further with the design.

WHAT IS DIODE REVERSE-RECOVERY?

A diode behaves something like a capacitor when a forward bias is suddenly reversed: a transient current is rapidly built up in the reverse direction, it remains constant for a short interval, then decays exponentially to a steady reverse current value. The transient is due to the apparent charge produced by minority carriers, and is the cause of late opening in RF switches, and RFI and wasted energy in switching power supplies.



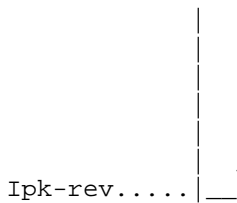


Figure 1: Typical diode behaviour under reverse bias.
 Reverse recovery time is the time (T_{rr}) taken for the reverse current (I_{rev}) to fall to one-tenth of its peak value (I_{pk-rev}).

The time taken by the diode to recover time is a function of the recovered charge and the peak reverse current. In turn, these depend on the forward current (and duration also if the duration is less than a few times the recovery time), and also on the reverse voltage and the speed with which the bias is reversed, as well as the properties of the diode itself.

STANDARDIZED MEASUREMENTS

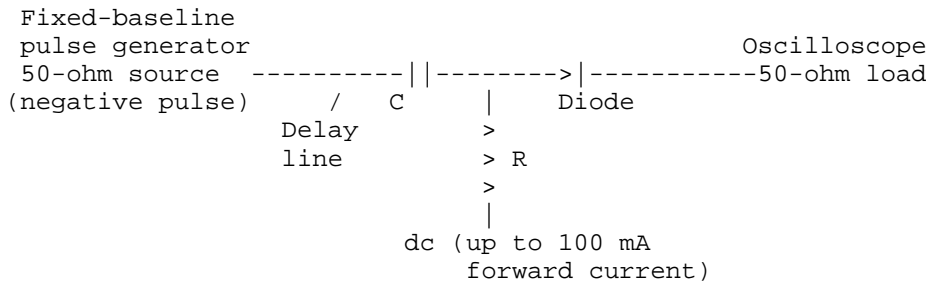
With all these parameters playing a role, manufacturers and users need defined test conditions in order to compare diode performance.

The US Department of Defense lays down tests for the reverse recovery time of diodes in MIL-STD 750, Method 4031. Two categories are defined for diodes with forward currents of 1 amp or less:

- Test condition A: forward currents up to 100 mA,
- Test condition B: forward currents up to 1 A.

Test Condition A

Ideally, a diode -especially fast ones- should be tested in a matched system as shown in the following diagram of a MIL-STD implementation. The diode is forward-biased using a dc power supply, the forward current being limited to the required value by the resistor R. When a negative pulse -coupled by capacitor C- arrives at the anode, the diode becomes reverse-biased. Depending on the duration and amplitude of the pulse, the apparent charge will be partly or fully discharged during the reverse-bias phase. Even though the circuit uses 50-ohm source, load and cables, typical diode behaviour causes the effective load resistance to increase exponentially when reverse-biased. This causes reflections which can spoil the measurement. A fairly simple solution is to add a few meters of cable between source and diode so that the reflections occur after the reverse-recovery current has decayed.



C and R decouple pulse generator and power supply.

Figure 2: Test-circuit based on MIL-STD-750 for Condition A

A disadvantage of the circuit is that the components R and C, make it difficult to achieve good repeatability.

A better way for Condition A

The above circuit simplifies if the pulse generator is able to switch from a positive to a negative level. Not only does this save a power supply, but the elimination of R and C improves repeatability.

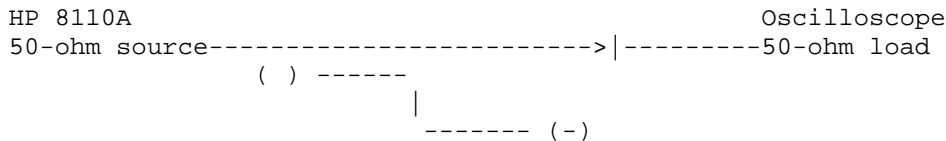


Figure 3: Alternative test circuit using a variable-baseline pulse generator.

Test Condition B

If the above method is adopted for forward currents of 1 A, the load resistor must dissipate 50 W peak power! Admittedly, the average power can be reduced by using a low duty cycle. Nevertheless, the load will warm up and present different values throughout the forward/reverse cycle. To reduce this problem, MIL-STD-750 suggests measuring the current flow into a near-short-circuit.

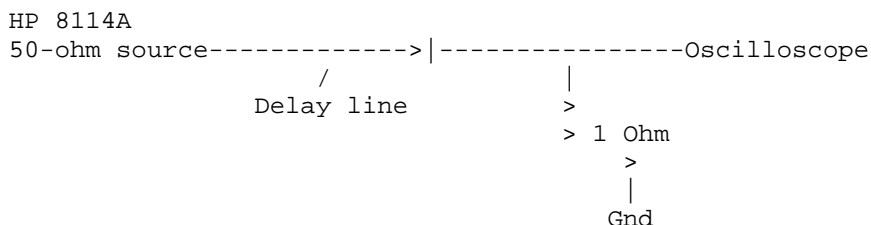


Figure 4: Adaptation of MIL-STD-750 Condition B test using a variable-baseline, high-power pulse generator.

The peak power in the 1-ohm current-sensing resistor is now just 1 W (assuming 1 A forward current) so the warming effect is much smaller. This advantage has been bought at the the cost of impedance matching -or rather, the lack of it: neither the 50-ohm source nor the 1-ohm current-sense resistor are properly terminated. Nevertheless, a delay line of several meters of cable can again be used between source and diode in order to put the reflections out of harm's way.

A PRACTICAL REALIZATION OF CONDITION B TESTING

The HP 8114A pulse generator provides currents up to 1A in forward and reverse directions. The 7 ns transitions from 1 A to -1 A are nearly linear between 10% and 90% of amplitude and are equivalent to a switching rate of more than 200 A per microsecond. MIL-STD 750 requires the switching time to be not more than 20% of the recovery time of the diode under test. This means the HP 8114A is suitable for measuring recovery times down to 35 ns.

The current-sensing resistor

To reduce temperature effects, the 1-ohm resistor can be made up from several resistors in parallel so that each resistor only disipates a fraction of the total power. A warm up time should be allowed so that a constant temperature is achieved. For accurate current measurement, the sensing resistor should be measured warm with a precision resistance meter.

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Whereas mismatch may be tolerable in the circuits used for testing power diodes, lasers can be destroyed by overshoot and ringing. A solution is to use a series resistor and allow a small current to flow in the forward direction before the main pulse is applied. This avoids the abrupt resistance change when switching from off to on because the laser is always conducting.

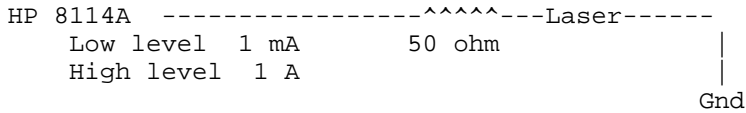


Figure 5: Near-constant load conditions for laser test. Usually, the series resistor would be somewhat less than 50 ohm to allow for the laser's forward resistance. Note that the resistance must dissipate a peak power of 50 W.

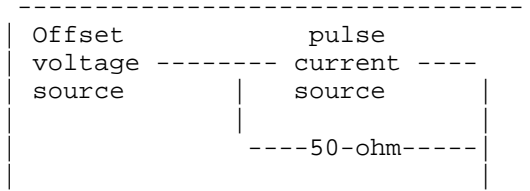
WHAT IF MORE CURRENT IS NEEDED?

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For 50-ohm loads, currents up to 2 A can be generated by the HP 8114A if Hi-Z source is selected. Disadvantages: slower transitions (12 ns), no offset. Hi-Z source should only be used with a 50-ohm load.

If offset is needed, or loads other than 50-ohms are driven, the source resistance must be 50-ohm. However, higher currents are feasible by adding co-incident pulses from two synchronized HP 8114A, the addition being done simply with a direct connection between the outputs. The load current is then the sum of the currents supplied by the two HP 8114As. Remember, though, that the load iR product cannot exceed the voltage limit of a single HP 8114A. Example: 2 A can be set up across a load <25 ohm because the voltage across the load is <50 V.

8114A No.1



8114A No.2

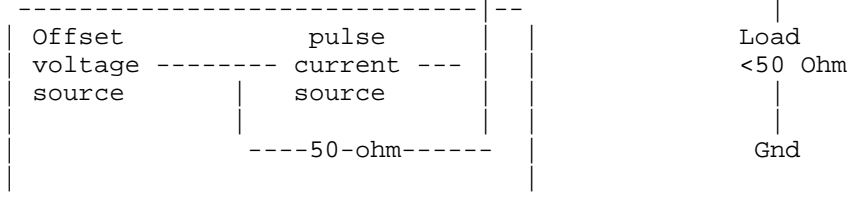


Figure 6: A dual generator solution for currents up to nearly 2 A, with baseline offset if required. Note that the generators load each other so that the load current is less than the sum of the generator currents.

THREE-LEVEL SIGNALS

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Of course, if the pulses from the two HP 8114As overlap,

three or four output levels can be obtained. For better matching, a passive adder network is recommended instead of the direct connection although this does of course mean a 3 dB power loss. Both HP 8114As can then work from 50-ohm and so provide optimal pulse timing performance. However, as the adder halves the signal, direct connection may be essential for higher currents.

ADDER CONSTRUCTION

A suitable adder can be constructed from three equal resistors star or delta connected (16.67-ohm resistors for the star, 50-ohm for the delta connection), dimensioned to carry the required power (up to 50 W peak).

COMMS CODES

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3-level comms codes such as HDB3 can be generated with the 8110A by adding the outputs of the two data channels (Internal addition can be used for frequencies up to 50 MHz. For higher frequencies, use an external 50-ohm resistive pulse adder such as HP 15104A.

For signals greater than about 14 Vpp (i.e., +/-7 V window), use the HP 8110A channels to trigger a pair of HP 8114As.

PREVENTING RINGING

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Minimum overshoot and ringing are achieved when operating from 50-ohm into 50-ohm. If the load is not 50-ohm, a series or parallel resistor should be added close up to the DUT so that a properly-terminated connection can be achieved.

If a 50-ohm termination is impracticable, reflections can often be drastically reduced by slowing transitions with the help of a low-pass filter at the 8114A output. In an application requiring 2 A into a 6-ohm load, the 26% overshoot was reduced to 8% by slowing the edges to 17 ns. This was achieved using a pi-filter (Figure 7) at the outputs of the HP 8114As (two being used to obtain the required current of almost 2A).

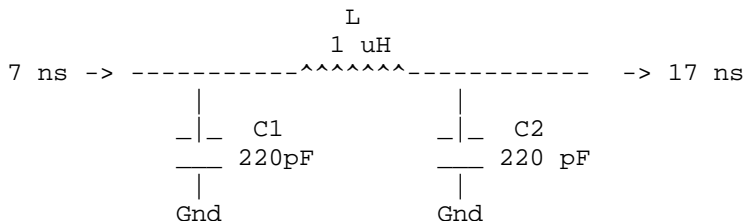


Figure 7: Simple filter to increase transition times and hence reduce mismatch effects.

Further improvement could be obtained by using multi-segment filters and including a Collins element to match source and load impedance.

Approximation of low-pass pi-filter (Figure 7) component values

1. Determine cut-off frequency, fo
Divide 350 by the required transition time Tr.
Example: for required Tr of 20 ns, fo=17.5 MHz.
2. Calculate ac impedance, Zo=0.8R. Assuming source and load resistance are 50 ohm, Zo= 40 ohm.
3. Calculate capacitor values C=1/2pi fo Zo
For fo=17.5 MHz and Zo=40 ohm, C=200 pF
4. Calculate inductance value L=2C Zo^2.
Using the foregoing values for C and Zo, L=640 nH

Approximation of Collins values for L and C

1. Calculate C1 value from $C1 = 1 / \{2\pi f_0 [R_s + (R_i + R_l)^{0.5}]\}$

Where R_s and R_l are the source and load values.

Assuming $R_s = 50$ ohm, $R_l = 10$ ohm,

$C1 = 110$ pF

2. Calculate $C2 = 1 / \{2\pi f_0 [R_l + (R_i + R_l)^{0.5}]\}$
 $= 247$ pF

3. Calculate L from $1 / \{(2\pi f_0)^2 C_{eff}\}$, where C_{eff} is the series equivalent of C1 and C2, 76 pF.

Hence $L = 1$ uH