AN-SL2001-06 Laser Emulation using Resistor

Overview

Some SL2001 and SL2002 Evaluation Boards can be ordered that replace a laser as the load with a resistor that has very low inductance and capacitance. Even though this resistor is specially designed for high frequency performance, it still doesn't act as a perfect resistor for pulse widths less than 10ns; furthermore, measuring the voltage across this resistor for pulse widths less than 10ns requires careful setup and considerations toward the bandwidth of oscilloscope and probes. This document is intended to explain the measurement set-up and calculation of the resistor current as aided by the GUI.

Resistor Load Voltage Measurement

When measuring the voltage across the resistor, care should be taken to ensure accuracy. The voltage across the resistor can be measured using 2 single ended probes and combining two sets of measurements data. It is recommended to calibrate the 2 probes prior to each measurement.

The recommended steps for measurement are provided below.

1. The SL2001/2 IC should be configured as the duty cycle mode using the GUI (Fig.1). During this mode, at the rising edge of the clock signal the Flux FET turns on and during the falling edge of the clock signal the Fire FET turns on. For this test, we recommend using at least 5µs pulse width for the clock signal. This would result in 5% duty ratio for a 100 kHz clock.

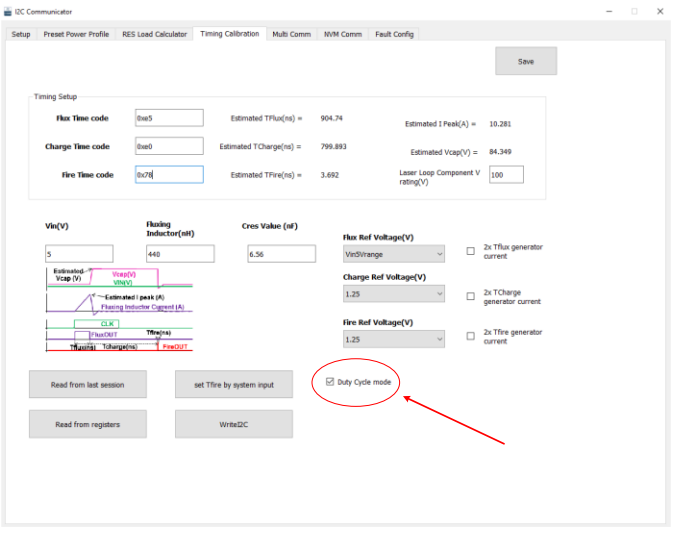

Fig.1 Selecting the Duty Cycle mode using Timing Calibration tab of the GUI

2. Using 2 single ended probes, measure R_{load} positive (+) terminal voltage with probe 1 and external clock signal from the function generator using probe 2. Trigger on the negative edge of the clock signal and capture the oscilloscope waveform in a CSV file.

3. Next, using the same 2 single ended probes, measure R_{load} negative (-) terminal voltage with probe 1 and external clock signal from the function generator using probe 2. Trigger on the negative edge of the clock signal and capture the oscilloscope waveform in a CSV file.

4. Load the csv saved waveforms into excel or another application, subtract R_{load} negative (-) terminal voltage from R_{load} positive (+) terminal voltage to calculate voltage across the R_{load} resistor.

5. Record the V_{peak} and V_{FWHM} from step 3 above.

Figure 2 below shows the positive terminal and negative terminal voltages of the load resistor, R_{load}, as well as the calculated voltage across R_{load} by subtracting them in Excel as mentioned above.

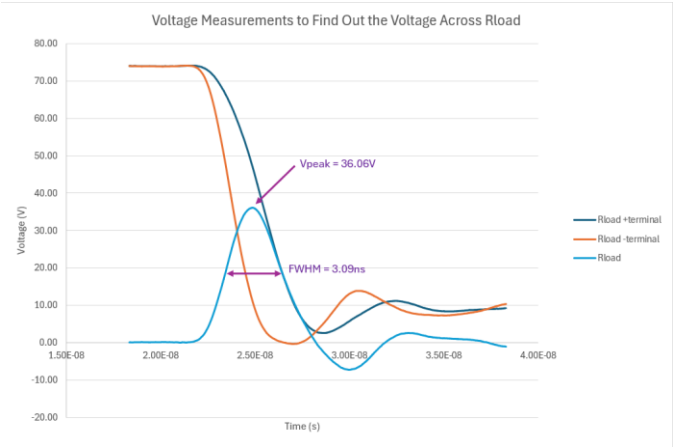

Fig.2 Voltage measurements to find out the voltage across R_{load}

Care should be taken to ensure that the bandwidth and samples per second of the oscilloscope and probes are adequately high. We recommend using a 1GHz probe and scope bandwidth with 20 Gsamples/second; however, based on our testing with lower bandwidth scope, we have noticed a 300MHz bandwidth scope and probe would result in adequately accurate voltage waveforms for FWHM > 3ns.

Note: A differential probe can be used to measure the voltage across the resistor as long as it's bandwidth is ≥300MHz, but pay careful attention to the voltage rating of the differential probe to ensure that you do not damage your equipment (note that the voltage across the resistor for the curve in Figure 2 reaches 36V).

An impedance network can be added in parallel with the Resistor Load in order to divide down the voltage, but care needs to be taken in order to maintain accuracy up to resonant frequencies of a few 100MHz.

Resistor Load Voltage Measurement using GUI

Figure 3 below shows the SL2001/2 GUI page that can be used to calculate the resistor current based upon the voltage measurement as described in the section above. The green box shows the input needed from the user, i.e. measured voltage peak and measured resonant period based on the test results. The inherent values from this EVB design and components selected are shown in the blue box for Total R (Ohm) and Total L (nH). The values in the red box are calculated by the GUI. The graph below shows the typical voltage and current waveforms where the peak of the current waveform is lagging the peak of the voltage waveform due to the parasitic inductances, e.g. ESL of the load resistors.

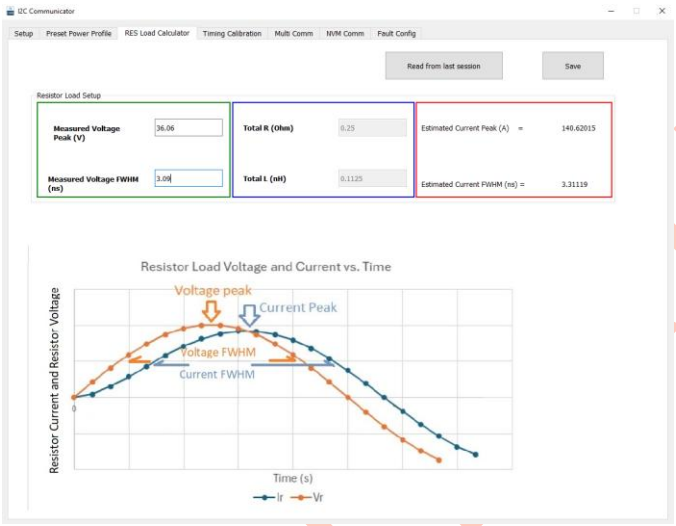

Fig. 3 RES Load Calculator tab of the GUI allows the user to estimate current peak and FWHM based on the measured voltage peak

The following section describes the calculations that are used in the GUI. Since the GUI performs all of the calculations, this section is presented purely as information for those who are interested.

Background Information regarding Calculations in the GUI

i) Impedance Description

It is possible to evaluate the performance of SL2001/2 without requiring an EEL or VCSEL laser and associated optical power measurement equipment by utilizing a low-inductance resistor load. This simplified path, as shown in Fig.4, enables for a safe and cost-effective way to evaluate the performance capabilities of SL2001/2, namely, to stress the power stage with realistic laser-equivalent peak currents and resonant frequencies.

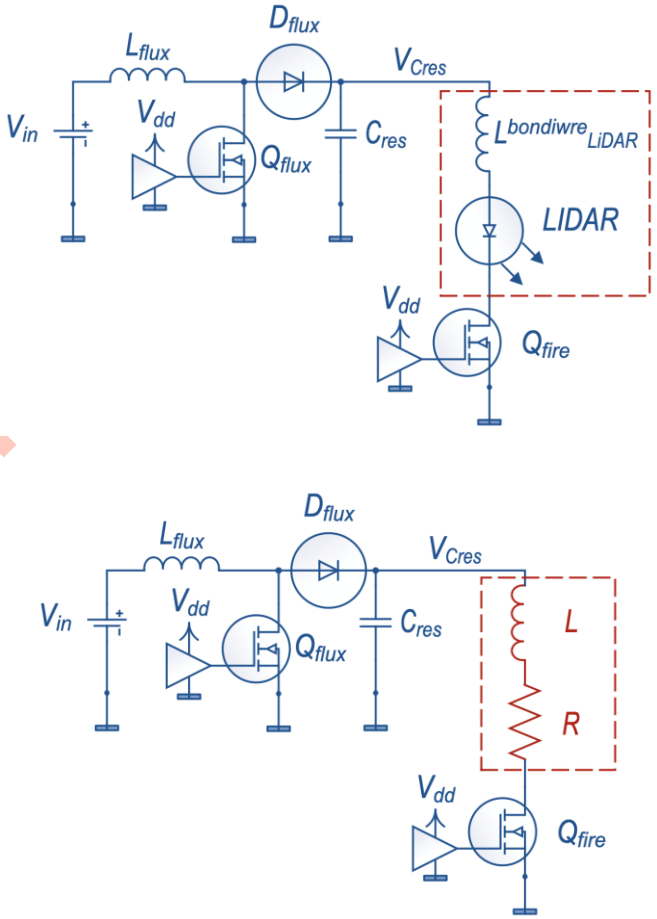

Fig.4 Typical SL2001/2 reference design top level diagram (top) and an alternative implementation which replaces the laser with resistive load for ease of evaluation (bottom).

However, it is important to keep in mind that to accurately estimate the actual current through the resistor load we cannot blindly rely on the measured voltage across the resistor load and Ohms Law. At high resonant frequencies (up to few 100MHz), which the laser and/or resistor load may operate at, the parasitic inductance of the load can effectively reduce the actual peak current by 10%-30%. The

ratio of the impedance of the resistive load relative to the dc resistance at the frequencies of interest can be approximated as (ignoring parasitic capacitance)

$$\frac{|Z|}{R} = \sqrt{1 + \left(\frac{2\pi \cdot f \cdot L}{R}\right)^2}$$

The above equation can be utilized to estimate the actual peak current through the resistor load when combined with measured differential voltage across the resistor.

The relationship between impedance and dc resistance is plotted in Fig.5 for MCT06030C1008FP500, a resistor that we have included on many evaluation boards and that we recommend due to its excellent low parasitic inductance (~450pH and in line with some of the best-in-class laser parasitic inductance values) and thin-film high peak current capabilities. This graph is created using the information from the vendor provided datasheet which is available online (https://www.vishay.com/docs/28705/mcx0x0xpro.pdf).
Note that the curve provided in the datasheet document is for a 49.9Ω resistor, while the curve for Figure 5 is for a four parallel 1Ω resistors in the configuration that has been included in Silanna's resistive load evaluation boards. By analyzing characterization data for multiple resistor values from the MCT06030C1008FP500 family, we have verified that the values for intrinsic resistor parasitic inductance and capacitance have very little variation regardless of resistor value.

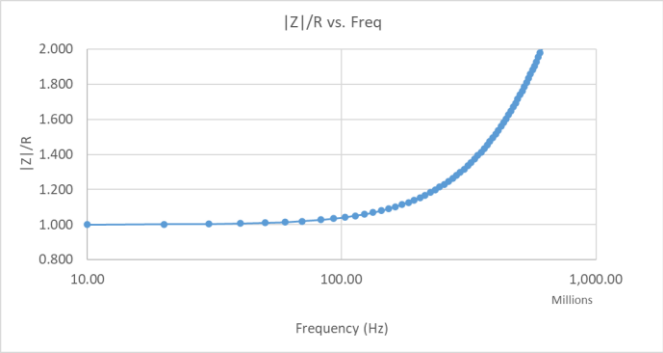

Fig.5 Impedance-to-dc resistance ratio of MCT06030C1008FP500 versus frequency.

ii) Conversion of Resistor Load Voltage Measurement to Resistor Current

Fig.6 below shows the calculated Current Waveform for the resistor differential voltage waveforms from Fig.2 using Ohm's Law (blue curve) and by modelling the extracted resistor impedance using spice simulation (orange curve).

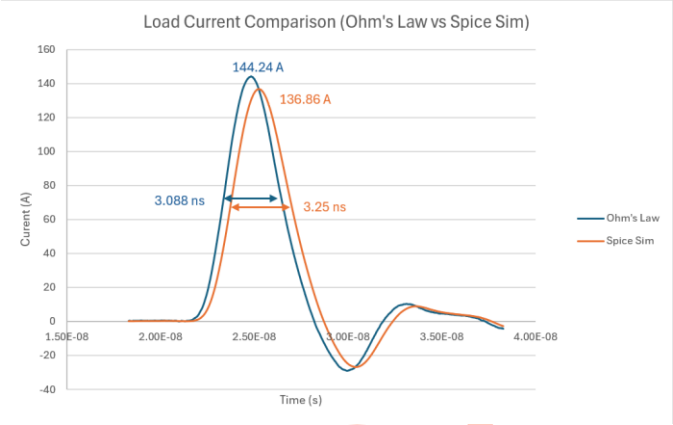

Fig.6 Load current comparison between Ohm's law and Spice simulation

iii) Measurement Approximation of Resistor Current Used by GUI

A simple measurement method is presented below to approximate the peak and the FWHM of the resistor load current:

1. Using 2 single ended probes, measure R_{load} positive (+) terminal voltage with probe 1 and external clock signal from the function generator using probe 2. Trigger on the negative edge of the clock signal and capture the oscilloscope waveform in a CSV file.
2. Next, using the same 2 single ended probes, measure Rload negative (-) terminal voltage with probe 1 and external clock signal from the function generator using probe 2. Trigger on the negative edge of the clock signal and capture the oscilloscope waveform in a CSV file.
3. Then subtract R_{load} negative (-) terminal voltage from Rload positive (+) terminal voltage to calculate voltage across the R_{load} resistor.
4. Record the V_{peak} and V_{FWHM} from step 3 above.
5. Use the following equations to calculate the I_{peak} of the resistor load using the V_{peak} from step 4.

First, calculate w in rad/sec (unit) using:

$$w = 2 * \pi \; / \; (4 * \textbf{Measured Voltage FWHM})$$

Next, calculate t_{peak} using:

$$t_{peak} \approx \frac{1}{w} \cdot \left(\pi + \tan^{-1}\left(\frac{R}{L \cdot w}\right)\right)$$

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Then, using tpeak, calculate the peak load current, ipeak using the following equation:

$$i_{peak}(t) = \frac{V_{peak} \cdot w}{L} \cdot \frac{1}{w^2 + \left(\frac{R}{L}\right)^2} \cdot \left(e^{-\frac{R}{L} t_{peak}} - \cos w \cdot t_{peak} + \frac{R}{L \cdot w} \cdot \sin w \cdot t_{peak}\right)$$

6. Finally, use the following equations to calculate the FWHM of the Resistor Load current.

$$t_{FMHW} \approx \frac{1}{2w} \cdot (\pi + \tan^{-1}\left(\frac{w \cdot L}{R}\right))$$

iv) Verification of the Accuracy of GUI Calculation to Simulated Data

I_{peak}: The I_{peak} of the Resistor Load for the voltage waveforms from Fig.6 using (A) Ohm's Law = 144.24 A, (B) Spice simulation with the Rload impedance model = 136.86 A, and (C) the approximation from this section = 140.62A (which matches the GUI calculated value in Fig.3). The delta between the GUI calculation and the simulation is <3%

FWHM: The FWHM of the Resistor Load current for the waveforms from Fig.6 using (A) Ohm's Law = 3.088 ns, (B) Spice simulation with the Rload impedance model = 3.25 ns, and (C) the approximation from this section = 3.31 ns (which matches the GUI calculated value in Fig.3).

The numbers above indicate that, while not perfect, the GUI yields a significantly closer value to the spice simulation than by just using Ohm's Law.

APPLICATION NOTE

Revision History

Revision	Date	Author	Note
0.1	6/2/2025	AR	Initial Release
0.2	7/25/2025	AZ	Updated
1.0	8/8/2025	AZ	Document Control Release

APPLICATION NOTE