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On the Transmission Line Pulse Measurement Technique

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ABSTRACT : *Transmission Line Pulse is a short pulse (25ns to 150ns) measurement of the current-voltage (I/V) characteristics of the ESD protection built into an integrated circuit. The short TLP pulses are used to simulate the short ESD pulse threats and integrated circuit must tolerate without being damaged. In this work the fundamental principles of how the TLP pulse is generated and used to create I-V characteristic plots will be explored. The measurement will be then used to characterize the I-V characteristics of some electronic parts to see how it can help arriving at accurate results.*

KEYWORDS–*Transmission Line Pulse, TLP, Device, Measurement*

I. INTRODUCTION

Transmission Line Pulse (TLP) measurement is an industrially accepted way for the characterization of ESD-protection devices in the high-current regime. In this technique a transmission line is charged up to an appropriate voltage and is used as a pulsed voltage source[1], [2], [3]. Once discharged a sharp pulse with very fast rise times down to 100 ps can be generated. The length of the used transmission line determines the pulse width. In 1985 Maloney and Khurana[4] introduced TLP measurements as method for characterization of ESD-protection devices in the high-current regime. Since then, TLP using a pulse width of 100 ns has become a standard practice for high-current measurements. In recent studies, the TLP method is used successfully to measure the reverse recovery phenomenon in power devices [5]. Later the method was further developed with generation of faster pulses, resulting in very fast TLP (vf-TLP) [6], which can produce pulse widths down to 1 ns.

Figure 1 shows a basic setup for a 50 ohm time-domain TLP system [4]. An approximately 10 m long 50 ohm coaxial cable, which can be charged to a high voltage, serves as the pulse source. A charged 50 ohm coaxial cable will create a rectangular pulse when discharged into a load. A switched is used to connect this transmission line to the test device. The voltage and current waveforms are monitored using high speed oscilloscopes and are sensed using special voltage and current probes.

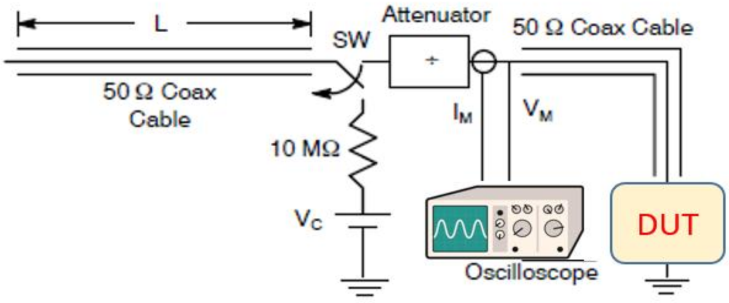

Figure 1. A 50 ohm basic TLP system

The way the TLP system works is as follows: The transmission will be charged while the switch is closed. The charged cable will act to create the voltage pulse. The pulse passes through the attenuator, travels down the coax cable to the DUT, reflects off the DUT and travels back toward the attenuator and into the pulse source transmission line. In this path, it is critical for the system to be impedance matched. Impedance matched refer to a state in which the impedance of different components of system is equal to one another. As mentioned earlier, often an oscilloscope is employed to monitor the signals during the measurement.

When a signal on a transmission line reaches a termination the reflected signal depends on the impedance of the termination as in the following equations, in which R_{DUT} is the resistance of the DUT and Z is the characteristic impedance of the transmission line.

$$V_{reflected} = V_{incident} = \frac{R_{DUT} - Z}{R_{DUT} + Z}$$

$$V_{reflected} = -V_{incident} = \frac{R_{DUT} - Z}{R_{DUT} + Z}$$

If the device has the same impedance as the measurement system then there is going to be no reflection. If the termination is open the reflected voltage is equal to the incident voltage while the reflected current is equal in magnitude but of opposite sign, since the charge is traveling in the opposite direction. For a short the reflected voltage is equal in magnitude to the incident voltage but is changed in sign. For a short the reflected current has the same magnitude and sign as the incident current. What is physically happening is that the reflected charge is traveling in the opposite direction from the incident pulse but because it was a short the charge is flowing back through the shield.

The pulse that the DUT finally sees is the sum of the incident and reflected pulses. For a TLP system with a characteristic time of 100 ns, the delay between the voltage and current probes and the DUT is much less than 100 ns, which means the incident and reflected pulses overlap at the point of the voltage and current probes. During the period of overlap between the incident and reflected pulses the oscilloscope is directly measuring what the DUT experiences. This is illustrated in Figure 2a, for an R_{DUT} with a resistance less than 50. For voltage we first see the incident pulse only, but after twice the transit time between the voltage probe and the DUT the reflected pulse arrives and adds to the incident pulse. Since R_{DUT} is less than 50 the reflected pulse is negative and the measured voltage is less than the incident pulse value. After the incident pulse has passed the voltage probe only the reflected pulse is measured and we see a negative going transient. The situation for current in Figure 2 is similar with an initial measurement of only the incident pulse, a period in which the incident and reflected pulses overlap, followed by the reflected pulse only. The major difference is that for current the reflected pulse for R_{DUT} less than 50 is positive, resulting in the measured current in the overlap region being larger than during the incident pulse only period.

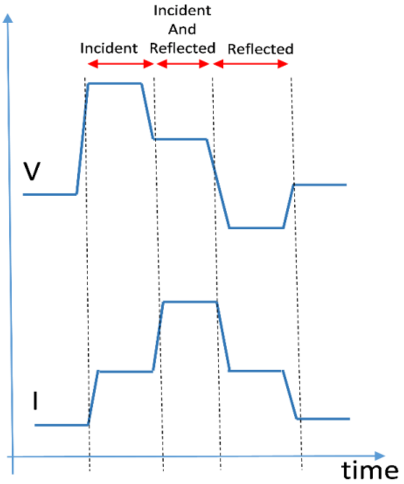

Figure 2. The incident and reflected current and voltage waveforms in the time domain

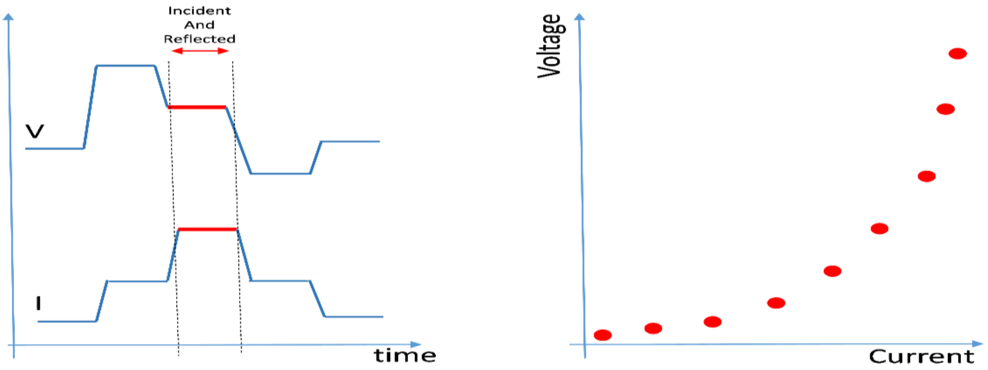

Figure 3. Demonstration of how an I-V plot is obtained from voltage and current waveforms

To obtain a current/voltage pair from the pulse measurements a measurement window is defined during the time period on the oscilloscope when the incident and reflected pulses overlap, usually toward the end of this overlap period. The voltage and current during the measurement window are plotted as a point on the I−V curve, as shown in Figure 3. To obtain a full I−V curve the process is repeated at a variety of charging voltages for the pulse source transmission line, usually starting at low charging voltages and progressing to higher voltages.

II. MEASUREMENT RESULTS - TRANSIENT VOLTAGE SUPPRESSOR (TVS) DEVICE:

Figure 4 shows a TVS device measured in Reverse Bias using the TLP technique for a TVS diode in the reverse bias direction. In this case the TLP measurements indicate that over the measured range the TVS's properties are linear and can be represented by a linear least squares fit, as shown in Figure 4. The fit yields a dynamic resistance of 1.35 and a voltage intercept of 6.49 V. (The dynamic resistance is the inverse of the slope of a current versus voltage curve over a limited range of current and voltage.) Note that the voltage intercept is not the low current breakdown voltage. The breakdown voltage of diodes is usually measured in the A or mA range, where the current is often still increasing exponentially with voltage. TLP measurements explore the high current range, which is precisely why the resistance and voltage intercept measured with TLP more accurately reflect the protection properties of a TVS device than measurements at longer time scales. Another important aspect that is demonstrated in this measurement is the suppression of the self-heating effect. During the DC measurements of power devices, the self-heating effect is always detrimental. This phenomenon can lead to erroneous results and needs to be avoided. As can be seen in the data set below, the self-heating effect is not present while the measurement is done in the pulsed form using the TLP setup. This is a great advantage of the TLP measurement over the ordinary DC measurements.

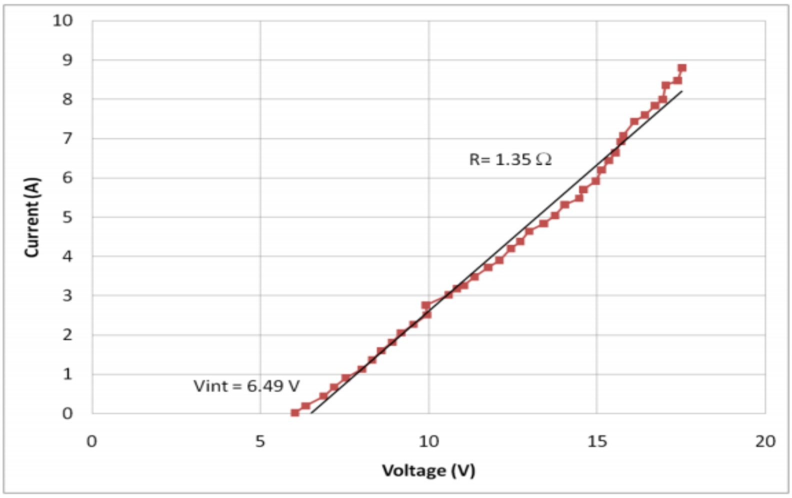

Figure 4. Sample TLP Curve of a TVS Diode

III. CONCLUSION

The Transmission Line Pulse measurement was investigated and its fundamental mechanism was explained. The benefits of using the TLP measurement over DC measurement makes it a suitable choice for measuring ESD events and power devices. This is specifically true when the gola is to avoid effects such as self-heating. The standard 100 ns, 50 ohm TLP measurement was showed to be a suitable test for studying the I-V characteristics of TSV devices.

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