

ESD Association Standard Practice

ANSI/ESD SP5.5.2-2007

*For the Protection of Electrostatic
Discharge Susceptible Items*

*Electrostatic Discharge Sensitivity Testing –
Very Fast Transmission Line Pulse
(VF-TLP) – Component Level*



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for the Protection of Electrostatic Discharge Susceptible
Items –***

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Very Fast Transmission Line Pulse (VF-TLP) –
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FOREWORD

This standard practice defines a method for pulse testing to evaluate the voltage current response of the component under test. This technique is known as “transmission line pulse” (TLP) testing.

Interest in very fast transmission line pulse (VF-TLP) testing is growing rapidly in the testing of electronic components in the semiconductor industry. VF-TLP testing techniques are being used for semiconductor process development, device and circuit design. This technique or practice is being utilized on products in both wafer level and packaged environments. VF-TLP testing is used as an ESD characterization tool to obtain voltage-current pulse characterization parameters, failure levels, and ESD metrics. The VF-TLP technique is being used today as a standard measurement for ESD devices. The VF-TLP system to the ESD engineer is becoming a tool as critical as the “parameter analyzer” is to the semiconductor engineer.

Today there is no industrial standard or specification to best describe VF-TLP testing. This document is intended to serve as an interim step toward establishment of a VF-TLP specification for the industry. Today, the majority of systems are designed by engineers in a laboratory environment. As of this writing, a number of commercial VF-TLP systems have been marketed in the industry. Hence it is clear a VF-TLP specification is needed for the TLP vendors, semiconductor industry and product customers to be able to make valid data comparisons. With the usage of VF-TLP data for ESD characterization, technology benchmarking, and product quality evaluation, there is a growing need to have standard methodologies, failure criteria, and means of reporting to allow dialogue between semiconductor suppliers, vendors, and product customers.

This document defines the standard practice used today in the semiconductor industry for VF-TLP testing method and techniques in both industrial and academic institutions. (This document is intended to be used by electrical technicians, electrical engineers, semiconductor process and device engineers, ESD reliability and quality engineers, and circuit designers.) The document is to act as an educational guide, a learning document, and as a reference for the practices being used today. The values stated in the document are guidelines, not specifications. The values stated are the majority consensus of the contributors from both industry and academic environments.

The context of this document is the application of VF-TLP techniques for the electrical characterization of semiconductor components. These semiconductor components can be single devices, a plurality of devices, integrated circuits, or semiconductor chips. This methodology is relevant to both active and passive elements. This test method is applicable to diodes, MOSFET devices, bipolar transistors, resistors, capacitors, inductors, contacts, vias, wire interconnects and related components.

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This standard practice was processed and approved for submittal to the ESD Association Standards Committee by the 5.5 Device Testing (TLP) Subcommittee in 2006. At that time, the 5.5 Device Testing (TLP) Subcommittee had the following members:

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1.0 SCOPE AND PURPOSE

1.1 Scope

The scope and focus of this document pertains to very fast transmission line pulse (VF-TLP) testing techniques of semiconductor components.

1.2 Purpose

The purpose of the document is to establish guidelines and standard practices presently used by development, research, and reliability engineers in both universities and industry for VF-TLP testing. This document explains a methodology for both testing and reporting information associated with VF-TLP testing.

2.0 REFERENCED PUBLICATIONS

Unless otherwise specified, the following documents of the latest issue, revision or amendment form a part of this standard to the extent specified herein:

ESD ADV1.0, ESD Association's Glossary of Terms¹

ANSI/ESD STM5.1, Human Body Model (HBM) – Component Level¹

ESD DS5.2, Machine Model (MM) – Component Level¹

ESD DS5.3.1, Charged Device Model (CDM) – Component Level¹

ANSI/ESD SP5.5.1, Transmission Line Pulse (TLP) Component Level¹

3.0 DEFINITIONS

The following definitions are in addition to those found in ESD ADV 1.0, ESD Association's Glossary of Terms:

Very Fast Transmission Line Pulse (VF-TLP). A rectangular current pulse formed by discharging a charged transmission line cable. In this document, VF-TLP refers to any rectangular pulse formed from any pulse source with a fast rise time and short pulse width.

Very Fast Transmission Line Pulse Test System. A test system that applies a rectangular pulse to a device under test and allows measurement of device electrical characteristics during a pulsed state. The system typically measures current and voltage across the device, as well as leakage current after VF-TLP pulse application.

4.0 SAFETY

4.1 Personnel Safety

The procedures and equipment described in this document may expose personnel to hazardous electrical conditions. Users of this document are responsible for selecting equipment that complies with applicable laws, regulatory codes and external and internal policy. Users are cautioned that this document cannot replace or supersede any requirements for personnel safety.

Ground Fault Circuit Interrupters (GFCI) and other safety protection should be considered wherever personnel might come in contact with electrical sources.

¹ ESD Association, 7900 Turin Rd., Bldg. 3, Rome, NY 13440; Ph: 315-339-6937; FAX: 315-339-6793; www.esda.org

Electrical hazard reduction practices should be exercised and proper grounding instructions for equipment must be followed.

5.0 EQUIPMENT

VF-TLP systems vary in their use of equipment, configurations, and methodology to extract the current and voltage characteristics of a device. VF-TLP systems must achieve a minimum system bandwidth to achieve time resolved measurements of the device under test (DUT). System bandwidth can be limited by the lowest bandwidth component. The minimum requirements stated in Section 5 may limit total bandwidth. VF-TLP design and system configuration is contained in Annex A.

NOTE 1: All equipment within the test system must be able to withstand the maximum current for the largest pulse width applied. Additionally, all equipment must withstand the maximum voltage from the initial charge voltage (including the reflected voltage, up to 2X the pre-charge voltage) observed in the test system. Current and voltage probes must not saturate and/or fail during VF-TLP testing.

5.1 Oscilloscope

Oscilloscope requirements:

- a. A minimum single shot bandwidth of at least 2.5 GHz and a minimum sampling rate of 5 gigasamples per second.

5.2 Voltage Probe

Voltage probe requirements:

- a. A minimum bandwidth of 1 GHz. A higher bandwidth voltage probe (e.g., 3X the oscilloscope bandwidth) will prevent the voltage probe from limiting the total system bandwidth. (Note 1 applies.)

5.3 Current Probe

Current probe requirements:

- a. A minimum bandwidth of 2 GHz. A higher bandwidth current probe (e.g., 3X the oscilloscope bandwidth) will prevent the current probe from limiting the total system bandwidth. (Note 1 applies.)

5.4 Transmission Line

Transmission line requirements:

- a. Must be able to withstand the maximum current for the largest VF-TLP test pulse width without electrical damage. (Note 1 applies.)

5.5 High Voltage Power Supply

High voltage power supply requirements:

- a. Must be able to source VF-TLP test voltage levels required to evaluate the DUT. (Note 1 applies.)

5.6 High Voltage Switch

High voltage switch requirements:

- a. Must be able to withstand maximum current for the largest VF-TLP test pulse width without electrical damage. (Note 1 applies.)

5.7 Attenuator

Attenuator requirements:

- a. Must be able to withstand maximum current for the largest VF-TLP test pulse width without electrical damage. (Note 1 applies.)

5.8 Rise Time Filter

Rise time filter requirements:

- a. Must be able to withstand maximum current for the largest VF-TLP test pulse width without electrical damage. (Note 1 applies.)

Table 1. VF-TLP Pulse Parameters (at the Pulse Source)

VF-TLP Pulse Parameters (Voltage and Current Conditions)	Value	Load Condition
Pulse Width (ns)	10 ns or less	50 Ω
10 to 90% Rise Time (ns)	0.1 to 0.5 ns, typically less than or equal to 15% of the pulse width	50 Ω
20 to 80% Rise Time (ns)	Less than the 20 to 80% rise time	50 Ω
10 to 90% Fall Time (ns)	Greater or equal to 10 to 90% rise time	50 Ω
80 to 20% Fall Time (ns)	Less than the 10 to 90% fall time	50 Ω
Maximum Peak Overshoot	Less than 15% of plateau	50 Ω
Maximum Ringing Duration	Less than 20% of pulse width	50 Ω

6.0 VF-TLP WAVEFORM PARAMETERS

6.1 General Waveform Parameters

The following waveform parameters apply to the VF-TLP pulse generator output pulse and to the measured VF-TLP system incident and reflected voltage and current waveforms.

6.1.1 Pulse Plateau

The pulse plateau is the duration of the pulse over which a time-averaged maximum value is obtained. It is desirable to have the pulse plateau duration be flat and sustained as long as possible.

6.1.2 Rise Time: 10 to 90%

Rise time is the time it takes the pulse to rise from the 10 to 90% of the pulse plateau (see Annex A.1 and Figure 1).

6.1.3 Rise Time: 20 to 80%

The 20 to 80% rise time is the time it takes the pulse to rise from 20 to 80% of the pulse plateau (see Annex A.1).

6.1.4 Fall Time: 10 to 90%

The 10 to 90% fall time is the time it takes the voltage or current to decrease from 90 to 10% of the pulse plateau (see Figure 1). The fall time should be equal to or greater than the rise time (see Annex A.1).

6.1.5 Fall Time: 20 to 80%

The 20 to 80% fall time is the time it takes the voltage or current to decrease from 80 to 20% of the pulse plateau (see Figure 1). The fall time should be equal to or greater than the rise time. The 80 to 20% fall time is a more repeatable measurement than the fall time 90 to 10% (see Annex A.1).

6.1.6 Maximum Peak Overshoot

The maximum peak overshoot is the maximum allowable magnitude of the pulse immediately following the rising edge that exceeds the pulse plateau. Maximum peak overshoot is expressed as a percentage of the pulse plateau.

6.1.7 Maximum Ringing Duration

The maximum ringing duration is the length of time from when the pulse reaches 50% of the plateau magnitude to the time that the pulse settles to and remains within $\pm 5\%$ of the plateau magnitude. The ringing duration of a VF-TLP pulse that does not have an overshoot is the time from when the pulse reaches 50% of the plateau to the time when the pulse reaches 95% of the plateau. For example, a VF-TLP pulse of 5 ns duration with ringing of more than 5% of the plateau (exceeding the plateau until 1.25 ns, measured from when the pulse reaches half the plateau magnitude) has 25% ringing duration.

6.2 TLP Waveform (at Pulse Generator)

This section describes the pulse characteristics of the pulse generator. Table 1 summarizes the pulse characteristics when measured directly by an oscilloscope with a 50-ohm input impedance connected using a short length of high frequency cable. The oscilloscope bandwidth should be 2.5 GHz or greater, preferably with a rise time of less than one-third the specified pulse rise time to be measured. Cable quality should provide an insertion loss of < 1 dB at 3 GHz ($< 1.15\%$ voltage loss) for the length used.

Table 1 parameters should be verified for all combinations of pulse widths and rise time filters that are to be used. When reporting VF-TLP results the parameters of Table 1 should be noted.

6.2.1 Pulse Width

The pulse width is the full width at half maximum (FWHM). Half maximum are the points on the rising and following edges of the pulse where its magnitude is 50% of the plateau (see Figure 1).

6.2.2 Rise Time

Refer to Table 1 for the maximum peak overshoot (see Figure 1 and Annex A.1).

6.2.3 Fall Time

Refer to Table 1 for the maximum peak overshoot (see Figure 1 and Annex A.1).

6.2.4 Maximum Peak Overshoot

Refer to Table 1 for the maximum peak overshoot (see Figure 1 and Annex A.1).

6.2.5 Maximum Ringing Duration

Refer to Table 1 for the maximum ringing duration (see Annex A.1).