Transmission Line Pulse Methods, Test Techniques and Characterization of Low Capacitance Voltage Suppression Device for System Level Electrostatic Discharge Compliance

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Outline

- Motivation and Purpose
- System Versus Chip ESD
- The ESD Standards Gap
- Polymer Voltage Suppressor Characterization
- Bridging Standards Gap with TLP: GaAs RF Switch
- TLP for OEM Cable ESD
- Summary/Future

Motivation and Purpose

- ESD Characterization of POLYMER VOLTAGE SUPPRESSORS (PVS)
- A TLP method for specifying PVS products to improve Electronic Products:
  - Reliability
  - Mean time before failure
  - ESD Compliance

Motivation and Purpose

- Use of TLP to Bridge the Gap Between Chip and System level ESD Standards
- Increase the use of TLP for ESD equivalent test for:
  - System level ESD Failure Voltage
  - Cable ESD Failure Voltage
  - ESD Compliance using PVS components

System Level ESD Constraints

- Driven by:
  - Smaller semiconductors
  - High frequencies
  - Escalating numbers of signal lines
- ESD is a performance bottleneck
  - Limited chip area and board space
  - Capacitance loads

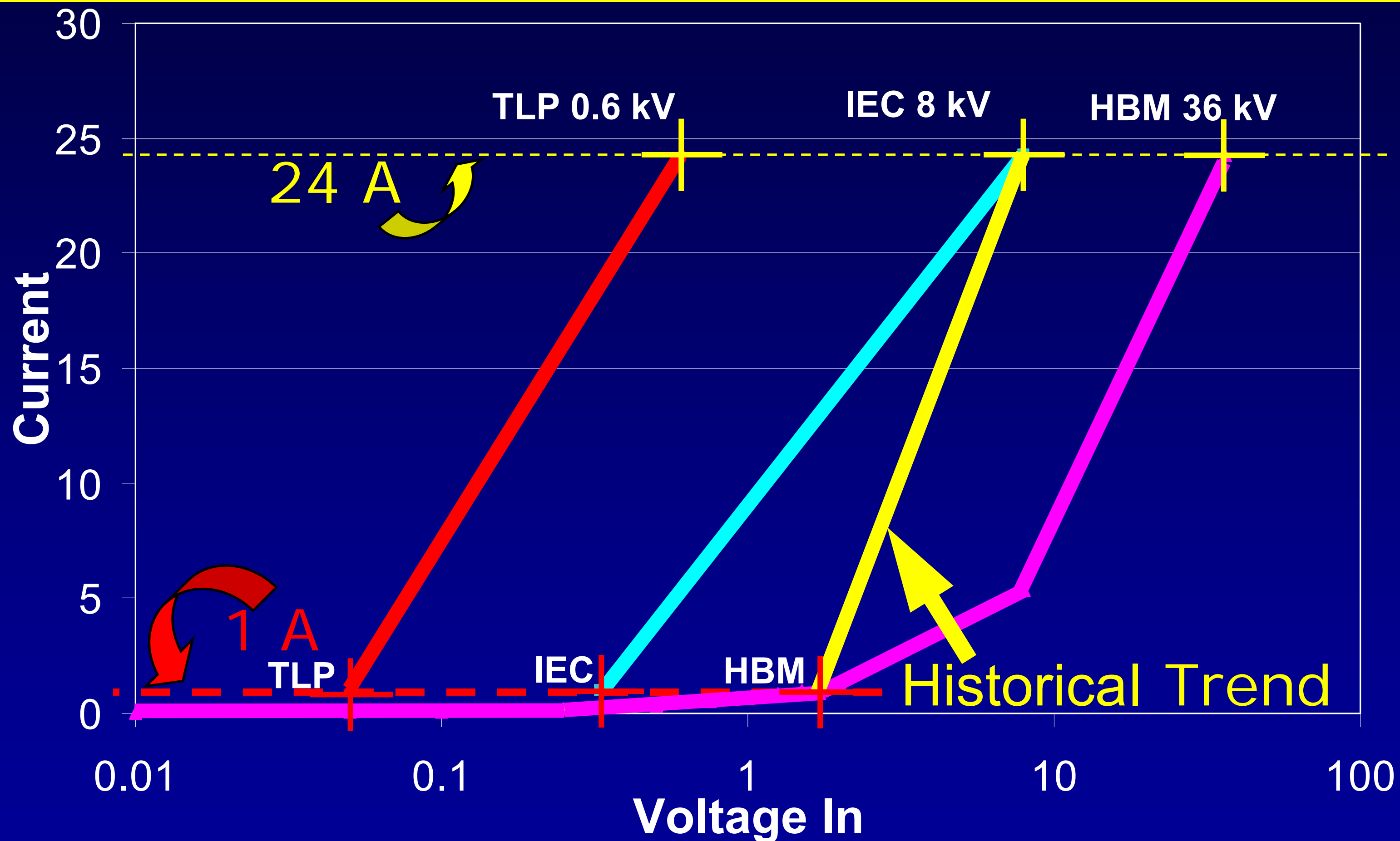
Industry ESD Constraints

- ESD is getting worse
  - On chip protection is failing system level ESD
- RF products need reliability:
  - Cell phones
  - SiGe applications
  - GHz servers
  - GaAs RF switches
  - VCSEL applications
- There is a gap between chip and board level ESD
  - 8 kV IEC has 6X more current than 8 kV HBM

The Standards Gap: On Chip Versus IEC

- Historically Chips were tested at 2000 V
  - 2000 V HBM = 1.3 Amp
  - 1.3 Amp is equivalent to 439 V IEC
- Now: 8 kV IEC is equivalent to 36 kV HBM
- 8 kV IEC = 24 Amp versus 5.3 Amp HBM
- That is the problem
- TLP bridges the gap

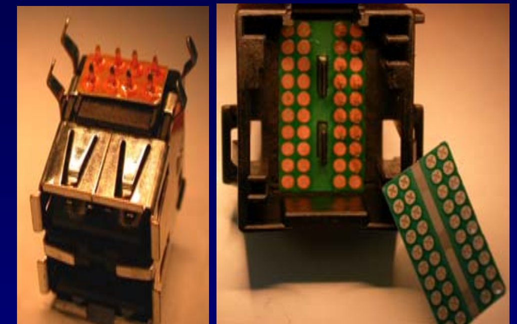
The Standards Gap: On Chip Versus IEC



TLP Bridges the Gap: TLP Correlates to Both

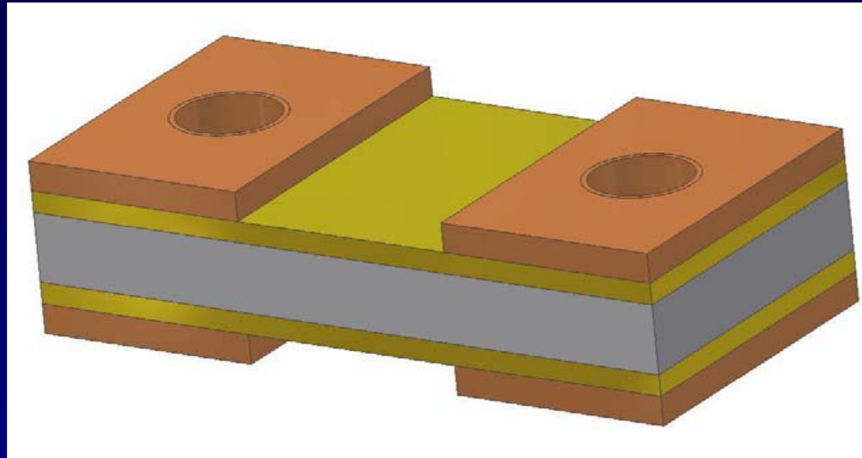
PVS Fits RF ESD Constraints

- Capacitance < 150 fF
- Multiple line ESD protection
- Bipolar
- Low profile, ≤10 mils (0.25 mm)
- Pico-second ESD response
- Zero board space on a connector
- Substrateless Surface Mount



EPI-FLO™ PVS USB and Automotive Connector Arrays

Polymer Voltage Suppression Devices



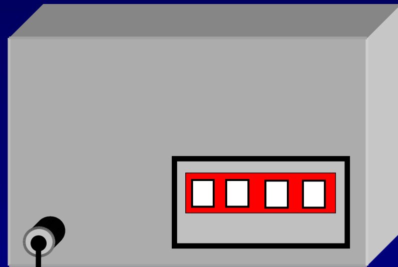
Substrateless Surface Mount Device

0603 ID#	Cp (fF)
T484A/2/7	102
T484A/2/9	107
T484A/2/45	70
T484A/2/99	118
T484A/2/98	119
T484A/2/95	115
Average	**105**

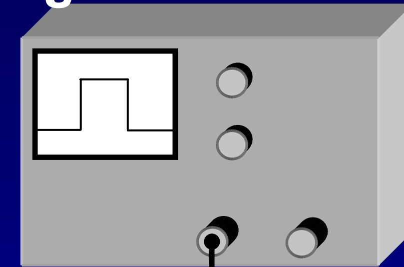
EPI-FLO™ PVS 0603 Surface Mount Device Capacitance

TLP Component Testing

ESD Signal Generator



8 GSa / Second
Digital Oscilloscope



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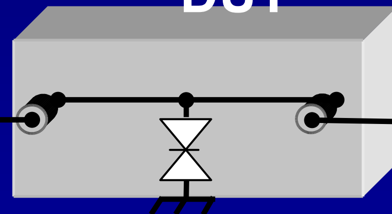
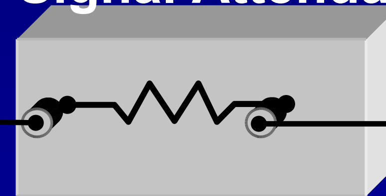
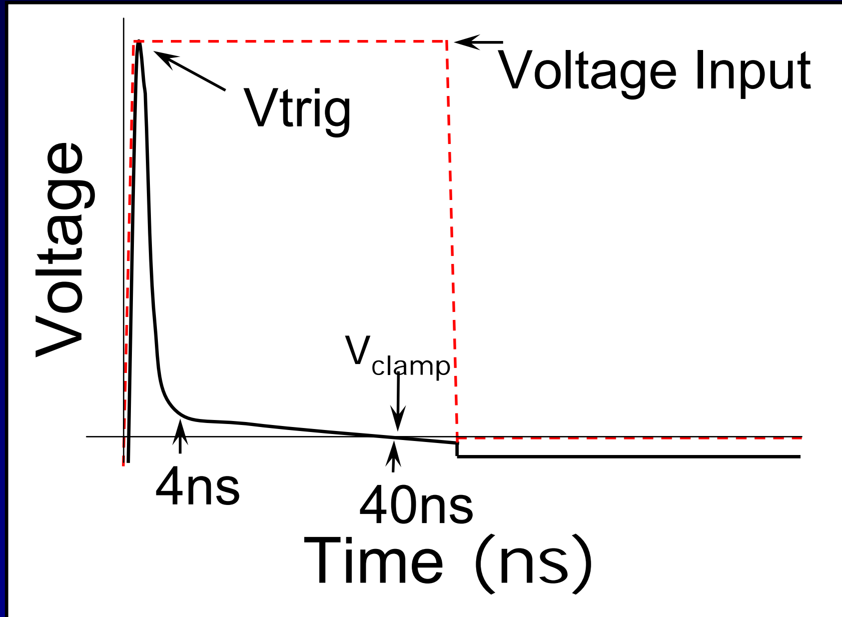


Signal Attenuator



TLP set-up for PVS and RF components

Surface Mount Voltage Characterization

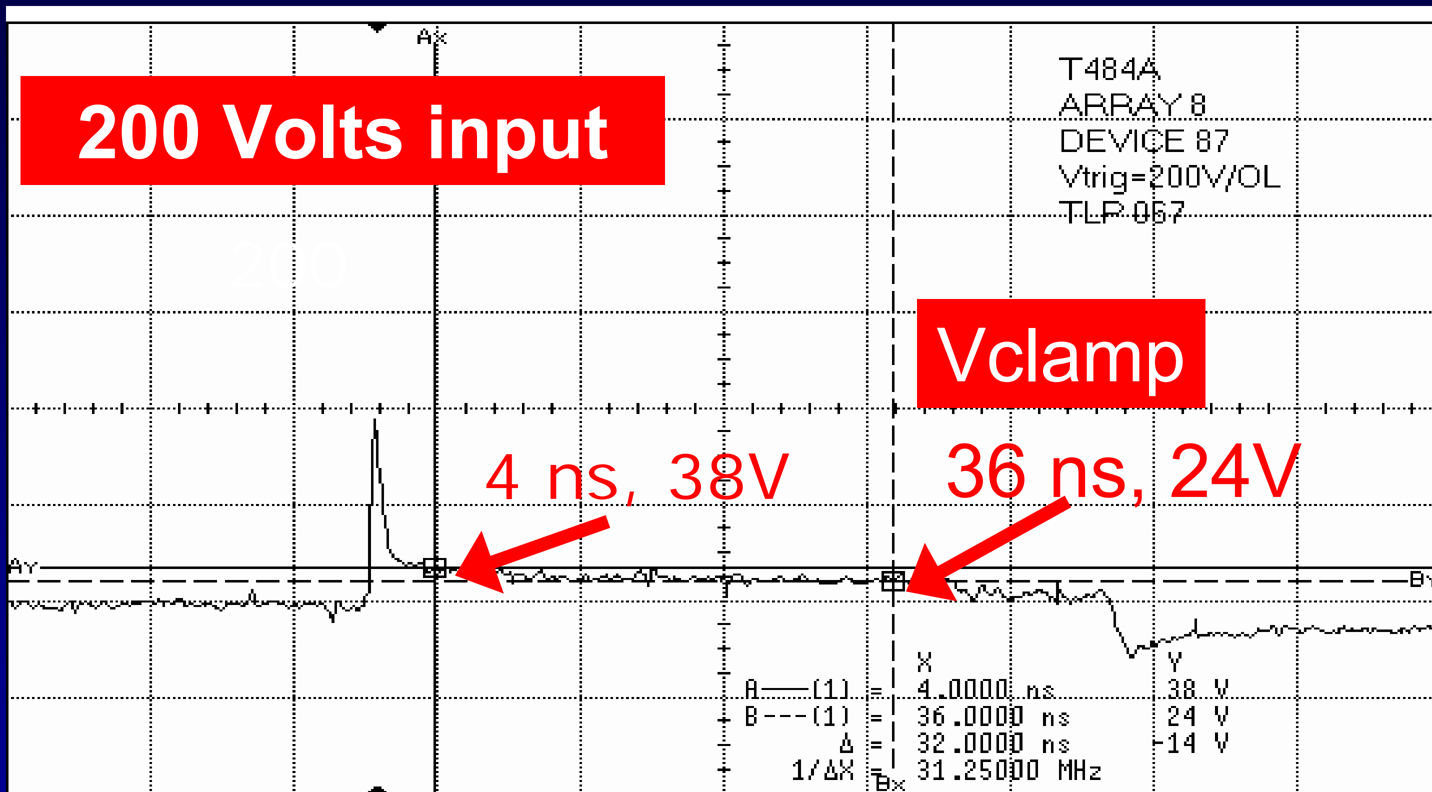


Device	Endurance Test	Vtrig Response	
Vtrig	Endurance, 600V 20th pulse, Vclamp	Vclamp at Trigger	
Volts	$V_{(40ns)}$	$V_{(4ns)}$	$V_{(40ns)}$
100	43	99	30
200	40	181	51
400	48	129	31

100, 200, 400 Vtrig Devices

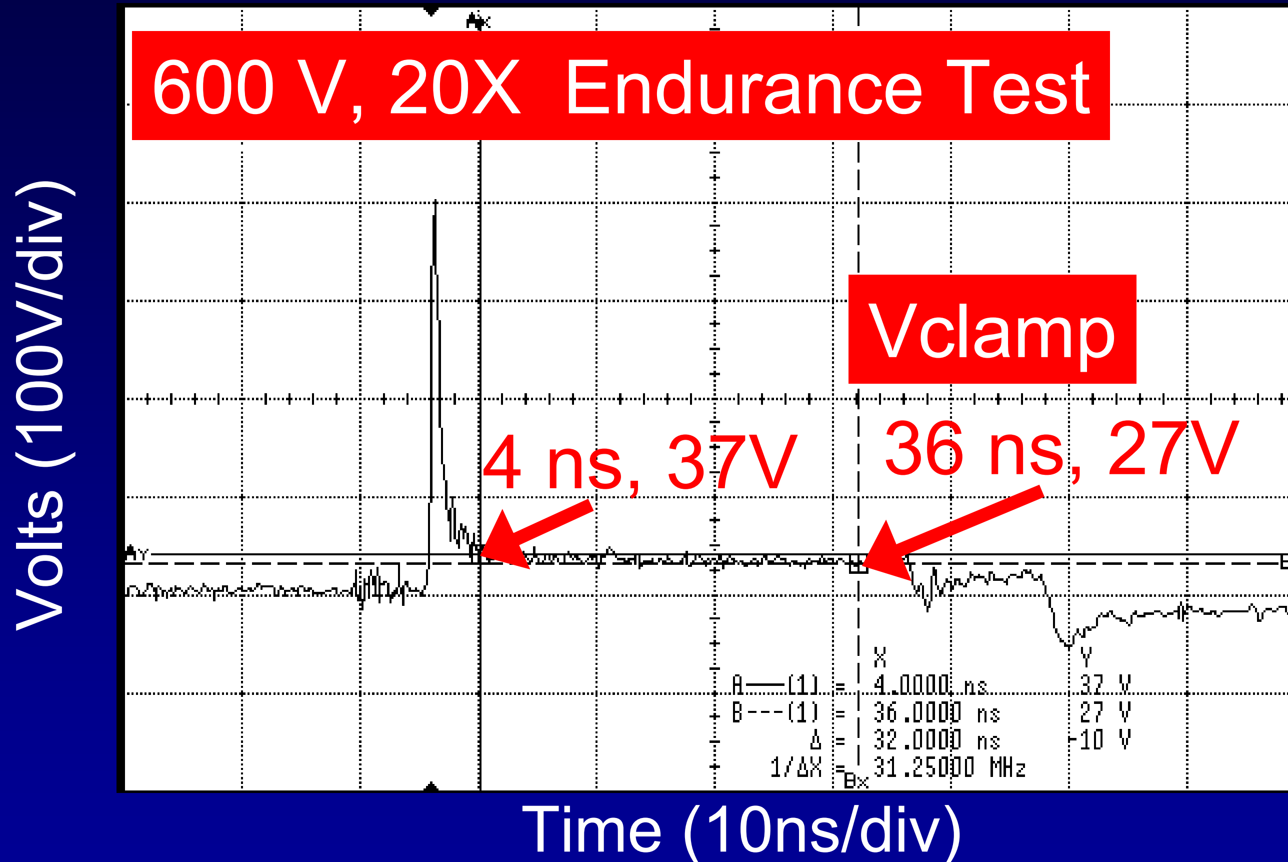
- Vtrig: Voltage is increased until device turns on
- Endurance: 20x at 600V ~ equivalent to 8kV IEC

TLP PVS Trigger Characterization



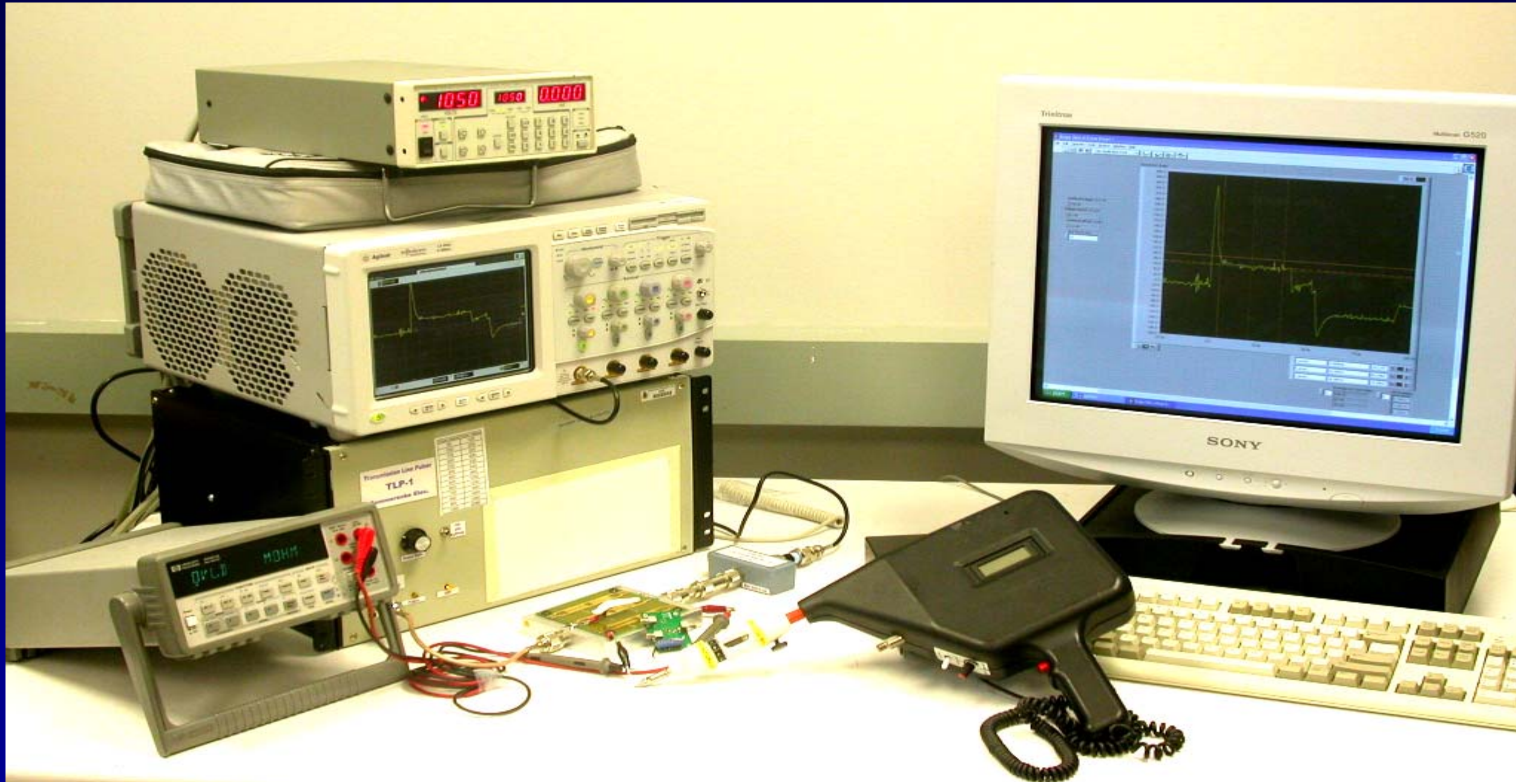
200 Vtrigger 0603 Device

600 V TLP PVS Characterization



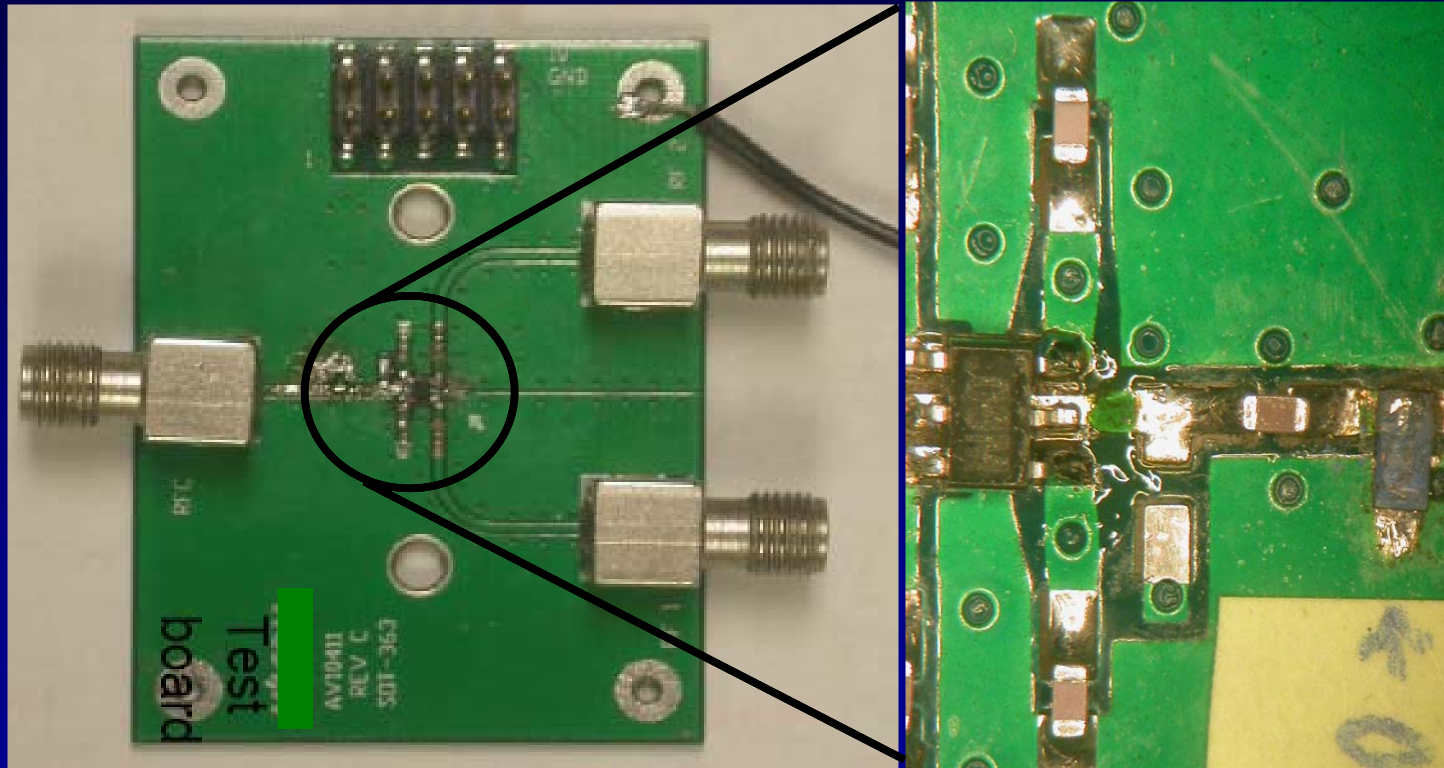
TLP .6 kV Equivalence to 8 kV IEC 6-10004-2`

TLP/ESD System Testing



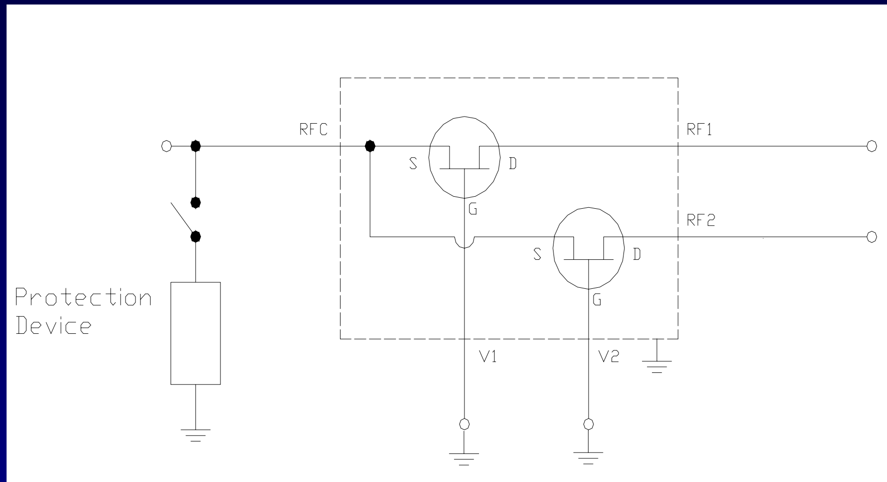
ESD Gun is Added to TLP Testing for Correlation

Cell Phone Antennae Test Board



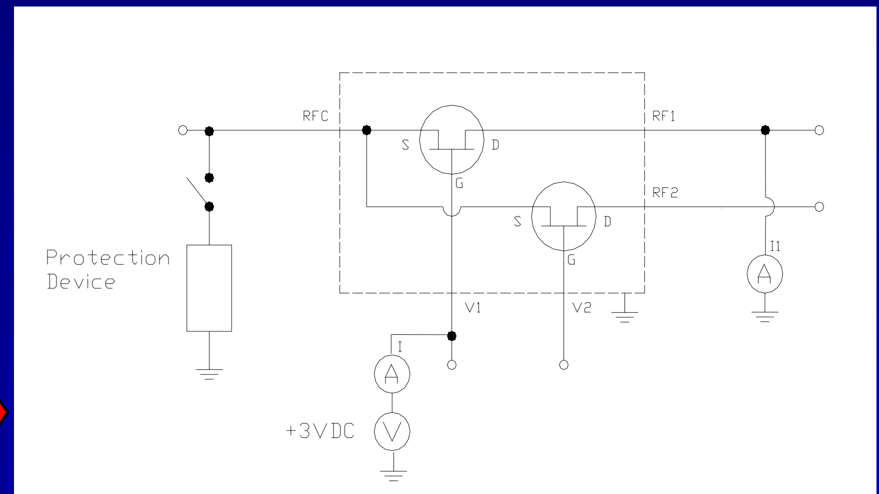
GaAS RF Switch Tested With and Without PVS

TLP/ESD Test for GaAs RF Switch



TLP/ESD gun Voltage Input on signal line with and without PVS device protection

IV Trace: Post ESD/TLP damage to switch is change in leakage current when device is powered.



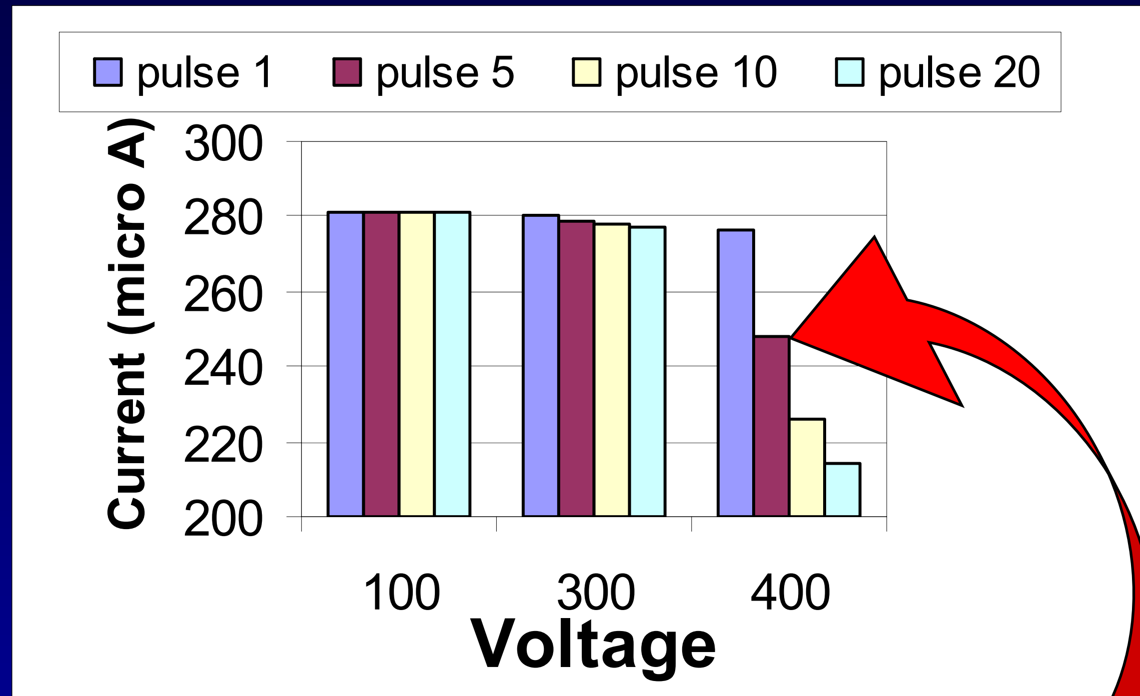
Step 1: GaAs RF Switch ESD Gun

- Zap Gun: IEC 6-10004-2
- Power device
- 10% Change in current at RFC = damaged device

Vin	Pulse #	I (µA)	I (RFC) (µA)	I (RFC1) (µA)	I (RFC2) (µA)	Open Circuit I (µA)
100V	1x	281	281	281	281	0
	5x	281	281	281	281	0
	10x	281	281	281	281	0
	20x	281	281	281	281	0
300V	1x	280	280	280	280	0
	5x	279	279	279	279	0
	10x	278	278	278	278	0
	20x	277	277	277	277	0
400v	1x	276	276	276	276	2
	2x	276	276	276	276	4
	5x	277	248	248	248	253
	10x	277	226	226	226	265
	20x	277	214	214	214	268

Step 1: ESD Gun Test GaAs RF Switch

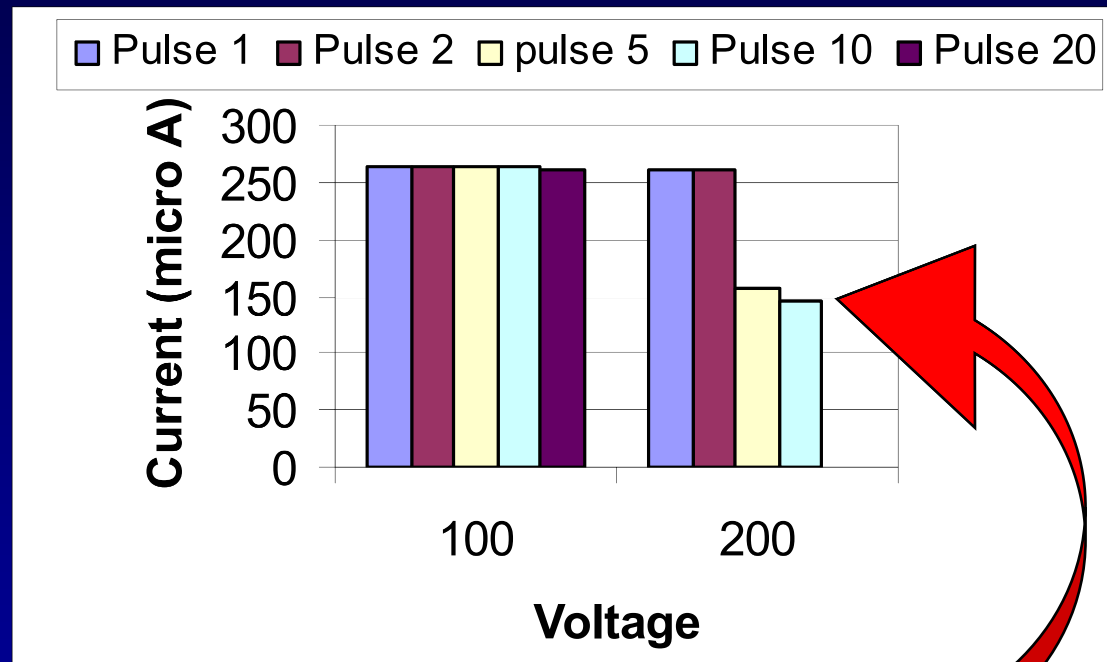
- Pulse
  - 1X, 5X, 10X, 20X
  - Ramp V by 100V
- Failure = 10% change in RFC current



Failed Current < 253 µA

Step 2: TLP Test GaAs RF Switch

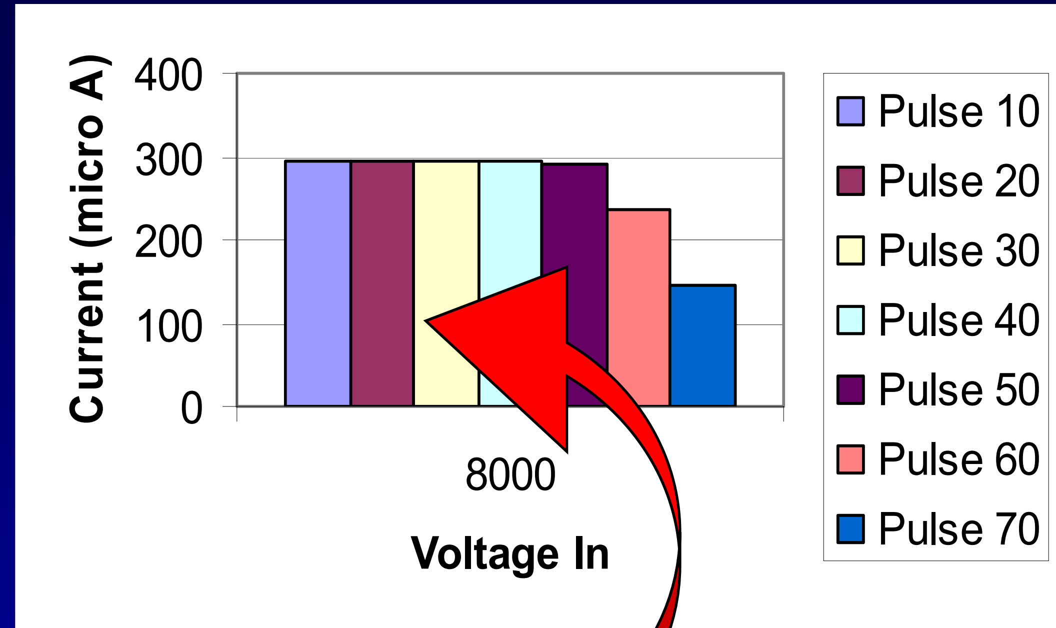
- Pulse
  - 1X, 5X, 10X, 20X
  - Ramp V by 100V
- Failure = 10% change in RFC current



Failed Current = 158 μA

Final Step: 8 kV IEC Test with PVS

- Select PVS device Vtrig<200V
- Solder PVS device on board
- Zap 20X+ at 8 kV for ESD compliance

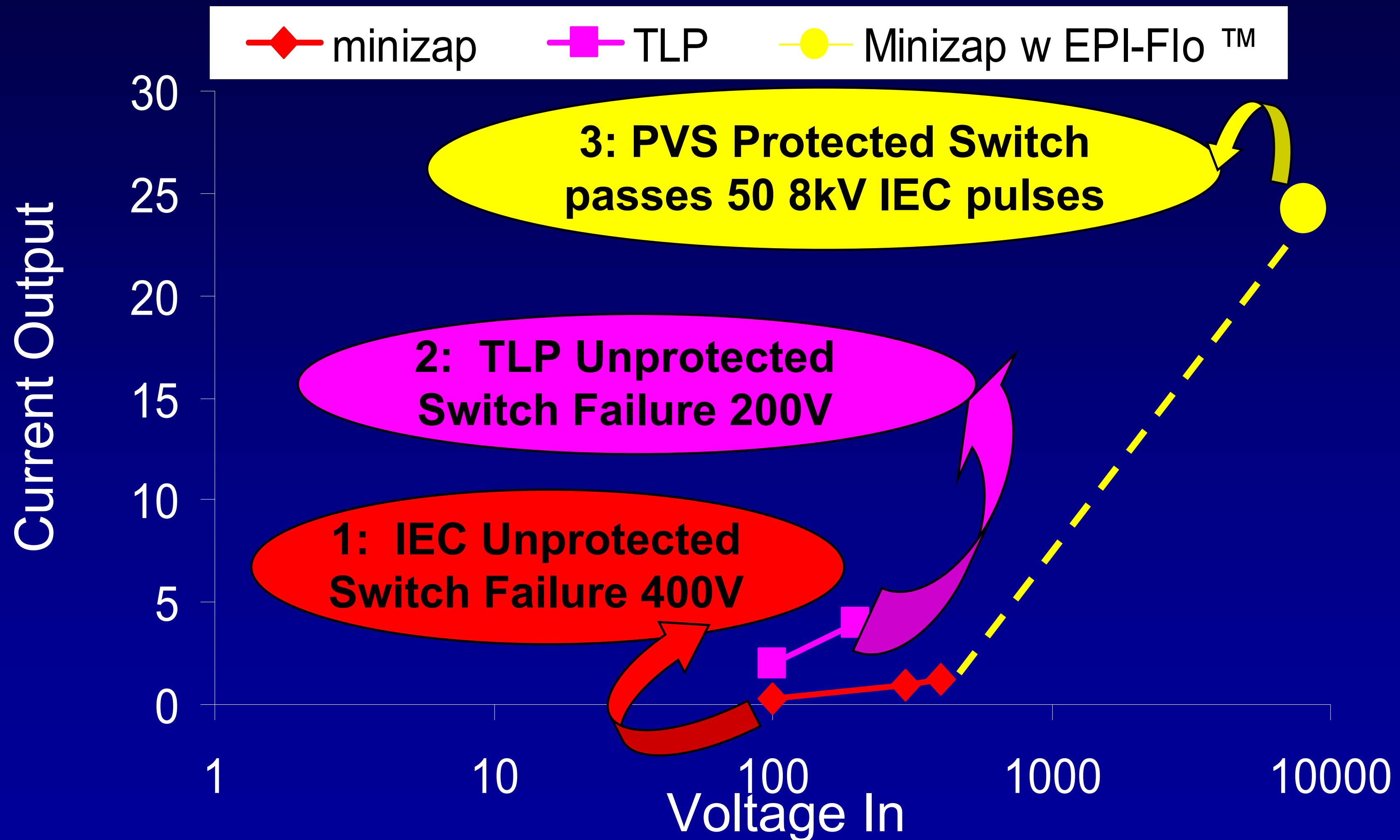


20 Pulses = IEC Requirement

Failure = 158 µA

GaAs Switch With **100Vtrig PVS Undamaged**

TLP Test Method Summary



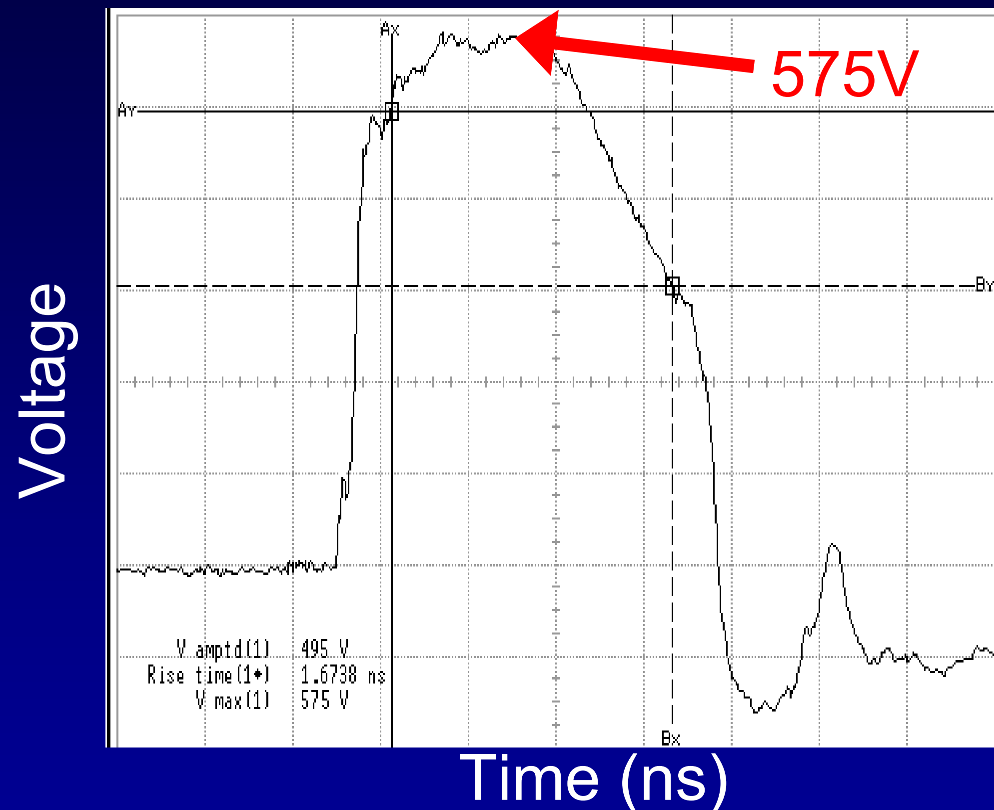
VCSEL HBM/TLP Test Result

VCEL # Avg. 5 devices									
Initial Voltage		Current In		Current Out		V4ns		V40ns	
3	V DC only	12.19	mA	332.40	μA	N/A	V	N/A	V
10	V pulse	12.00	mA	324.00	μA	9.33	V	9.69	V
15	V pulse	12.00	mA	324.00	μA	13.27	V	15.02	V
20	V pulse	12.06	mA	326.00	μA	15.52	V	18.76	V
25	V pulse	12.05	mA	326.80	μA	18.56	V	21.46	V
30	V pulse	12.06	mA	326.00	μA	21.01	V	24.20	V
35	V pulse	12.03	mA	325.00	μA	23.12	V	26.19	V
40	V pulse	12.02	mA	324.20	μA	25.06	V	27.39	V
45	V pulse	12.00	mA	324.00	μA	27.36	V	29.76	V
50	V pulse	12.01	mA	322.60	μA	29.17	V	32.46	V
55	V pulse	11.99	mA	304.40	μA	31.85	V	34.52	V
60	V pulse	12.02	mA	254.60	μA	33.69	V	36.49	V
65	V pulse	12.01	mA	149.20	μA	35.56	V	37.88	V
70	V pulse	12.02	mA	74.40	μA	37.50	V	39.23	V
75	V pulse	12.05	mA	34.65	μA	39.37	V	41.29	V

Photo Diode Current Output Showed PVS with Vtrig <60 V Required for 1000 V HBM

Cable ESD Tests Need Standards

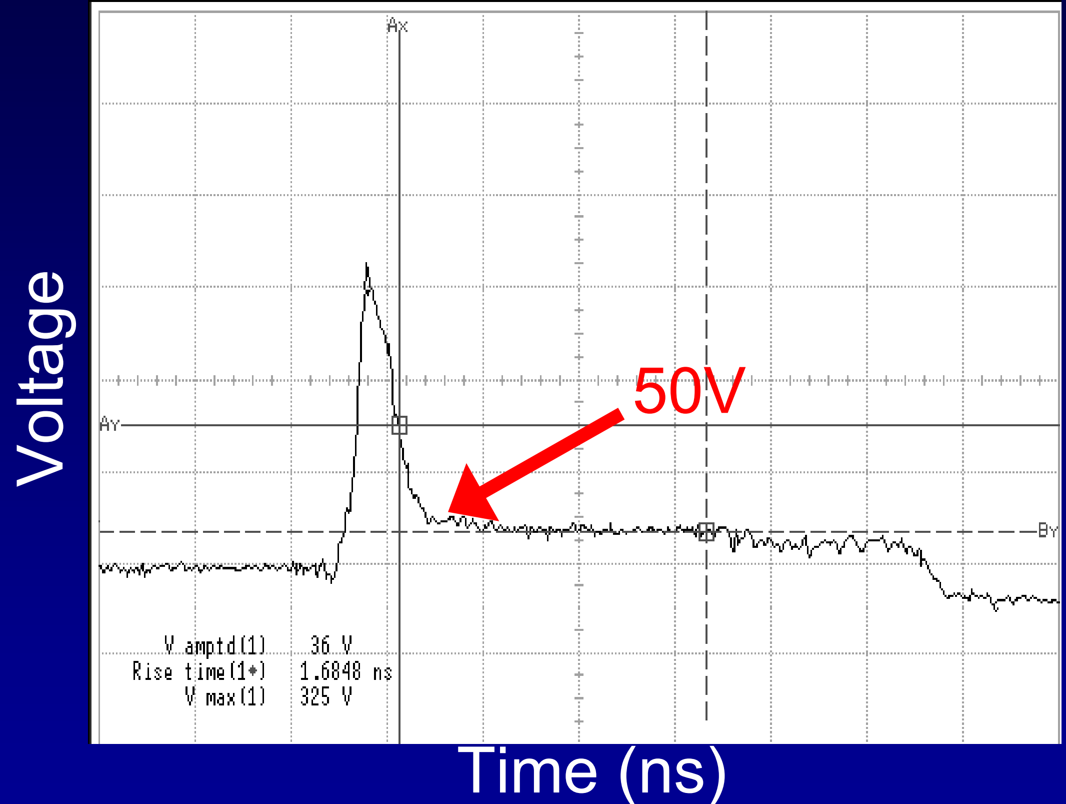
- Cable ESD varies:
  - Automotive:
    - 25 kV IEC
    - 10 kV TLP
  - Giga bit server:
    - 600 foot cable charged to 3kV



600V TLP test of RJ-45 connector with Magnetics shows no protection

Cable ESD PVS Specs ≠ IEC ESD

For Cable ESD for Server application PVS Device on RJ-45 connector needs to be tested with 600 foot cable charged to 3 kV



PVS installed on RJ-45 removes ~80% of 8 kV equivalent ESD TLP pulse

The Future

- Low Capacitance PVS devices remove performance barriers for :
  - Cell phones, Giga bit servers, PDA’s
  - SiGe, GaAs, InP, semiconductors
  - Tunneling Magneto Resistive Heads
- PVS devices open doors for future sensitive semiconductors removing ESD as a potential barrier to Market entry

Summary

- The gap between chip and system level ESD standards needs a TLP standard
- TLP/ESD characterization using femto Farad Polymer Voltage Suppression devices provides 8 kV IEC reliability for of RF products and components
- PVS devices open the door for future sensitive semiconductors removing ESD as a potential barriers to Market entry