About the Correlation of TLP with Component-Level and System-Level HBM

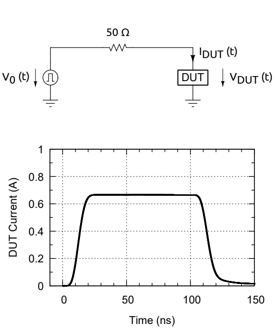
https://www.hppi.de/

December 25, 2020

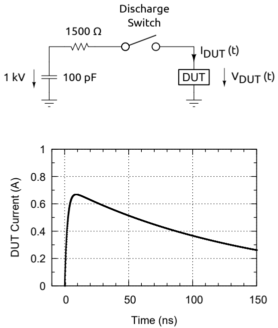
Pulse Source and Waveform Overview

TLP versus Component-Level HBM versus System-Level HBM

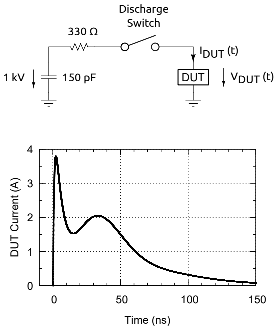
TLP



Component-Level HBM
(JEDEC/ESDA JS-001)



System-Level HBM
(IEC 61000-4-2)

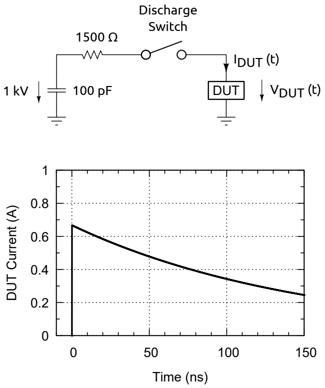


- TLP, component-level HBM (JEDEC/ESDA JS-001) and system-level HBM (IEC 61000-4-2) pulse sources have completely different source impedance

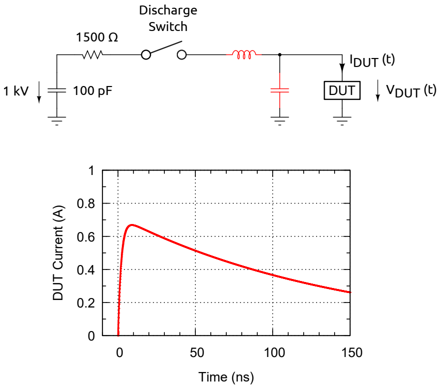
Component-Level HBM (JEDEC/ESDA JS-001)

Ideal versus Real Pulse Waveforms

Ideal



Real

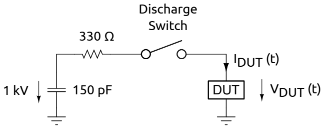


- Due to parasitics components (red) the real waveform is different

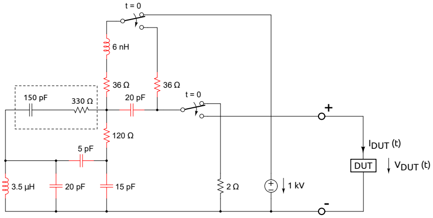
System-Level HBM (IEC 61000-4-2)

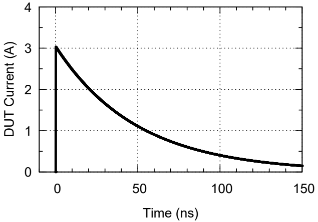
Ideal versus Real Pulse Waveforms (Contact Discharge)

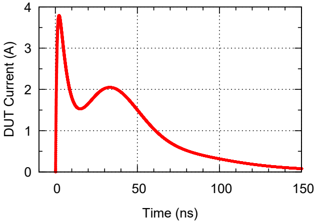
Ideal



Real







Non-Ideal Waveforms

- Real waveforms of component-level HBM (JEDEC/ESDA JS-001) test equipment as well as system-level HBM (IEC 61000-4-2) test equipment differ from ideal waveforms due to parasitic elements (RLC) in the pulse generators as well as test setup. This results in variations of the measurement results depending on equipment supplier and test setup.
- TLP does not show this non-ideal behavior because of it's clean 50 Ω source impedance. The setup is based on impedance matched transmission lines in order to avoid parasitic elements.

Pulse Energy

- In general, the DUT pulse energy is defined as:

$$E_{\text{PULSE}} = \int_{t=0}^{T} V_{\text{DUT}}(t) \cdot I_{\text{DUT}}(t) \cdot dt$$

- If the DUT is a resistor R the pulse energy results to

$$E_{\text{PULSE}} = R \cdot \int_{t=0}^{T} I_{\text{DUT}}^{2}(t) \cdot dt$$

Pulse Charge

- The total pulse charge is

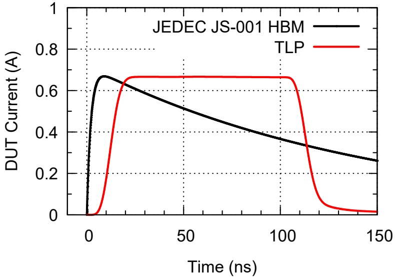
$$Q_{\text{PULSE}} = \int_{t=0}^{T} I_{\text{DUT}}(t) \cdot dt$$

- If the clamping voltage V_{CL} of a device under test (DUT) is not much depending on current, then the pulse energy is proportional to the pulse charge:

$$\begin{aligned} V_{\text{CL}} &\approx \text{const.} \\ E_{\text{PULSE}} &\approx V_{\text{CL}} \cdot \int_{t=0}^{T} I_{\text{DUT}}(t) \cdot dt = V_{\text{CL}} \cdot Q_{\text{PULSE}} \end{aligned}$$

Correlation of TLP with HBM (JEDEC JS-001)

A practical widely used rule



	HBM	TLP
Peak Current	0.67 A/kV	0.67 A/kV
Rise Time	2-10 ns	10 ns

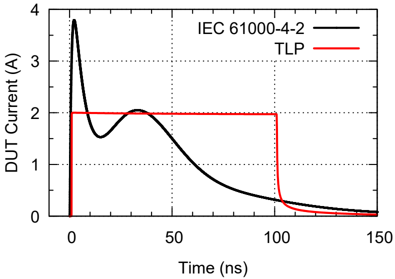
- The correlated HBM fail level can be calculated out of the fail current I_{t2} from TLP measurements:

$$\mathrm{HBM}_{\mathrm{corr.}}\ [kV] = \frac{3}{2} \cdot I_{t2}\ [A]$$

Correlation of TLP with IEC 61000-4-2

A practical widely used rule

- Contact Discharge



1st Peak Current	3.75 A/kV
2nd Peak Current (30 ns)	2 A/kV

- The correlated IEC fail level can be calculated out of the fail current I_{t2} from TLP measurements:

$$\mathrm{IEC}_{\mathrm{corr.}}\ [kV] = \frac{1}{2} \cdot I_{t2}\ [A]$$

Correlation of TLP with IEC 61000-4-2

A practical widely used rule

- Correlation of IEC with TLP is in general difficult and very dependent on the DUT.
- If the device fails due to energy the previous given rule of 2 A/kV can be applied. The TLP system should set to 100 ns pulse width and 0.6 ns rise time.
- If the device is sensitive to the first peak a correlation factor of 3.75 A/kV can be applied. The TLP system should set to 5 ns pulse width and 0.6 ns rise time.

Conclusion

- TLP, component-level HBM (JEDEC) and system-level HBM (IEC) have completely different pulse waveforms and pulse source impedance.
- In general, correlation is therefore not meaningful.
- However, in many cases correlation works quite well and can be used for device evaluation and comparison.
- For typical ESD protection devices the pulse energy is one of the relevant correlation parameters:

$$E_{\mathrm{PULSE}} = \int_{t=0}^{T} V_{\mathrm{DUT}}(t) \cdot I_{\mathrm{DUT}}(t) \cdot dt$$

- For capacitors (e.g. MIM or MOS capacitors) the maximum DUT voltage $V_{\mathrm{DUT,max}}$ is mainly relevant for the fail mode.