Understanding ESD protection device characteristics

Basic introduction

EN www.infineon.com/esd

Basic application examples

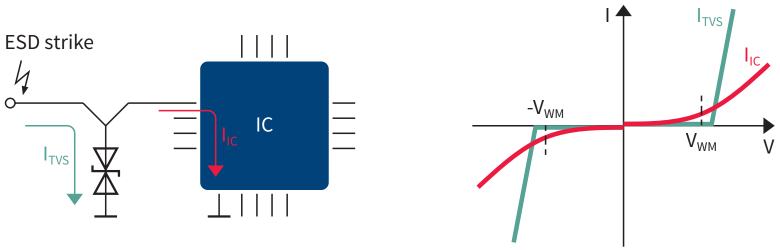

Fig. 1 Bidirectional ESD protection

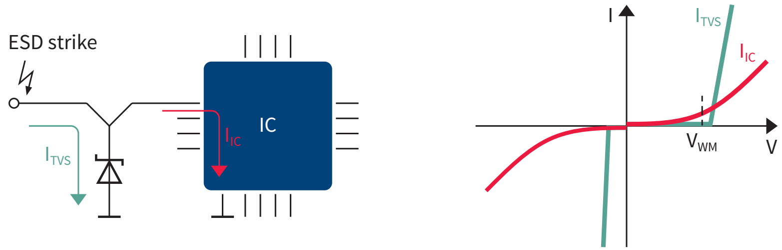

Fig. 2 Unidirectional ESD protection

Bidirectional ESD protection devices are symmetric (fig. 1). They can be used on the lines with bipolar signals ($-V_{WM} \leq V_{signal} \leq V_{WM}$) as well as with unipolar signals ($0 \leq V_{signal} \leq V_{WM}$).

Unidirectional ESD protection devices (fig. 2) are asymmetric, and can be used on lines with unipolar signals only ($0 \leq V_{signal} \leq V_{WM}$). Physically they are used in reverse direction, analogous to Zener diodes. The convention across the industry is to specify voltage and current in that direction as positive, like the voltages in the application.

Types of current-voltage (I-V) characteristic curves (not to scale)

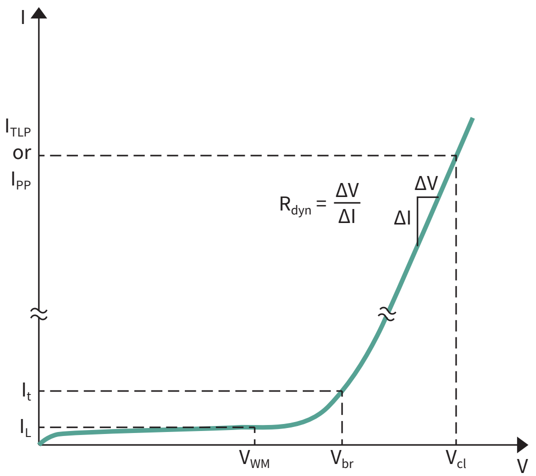

Fig. 3 Diode-like

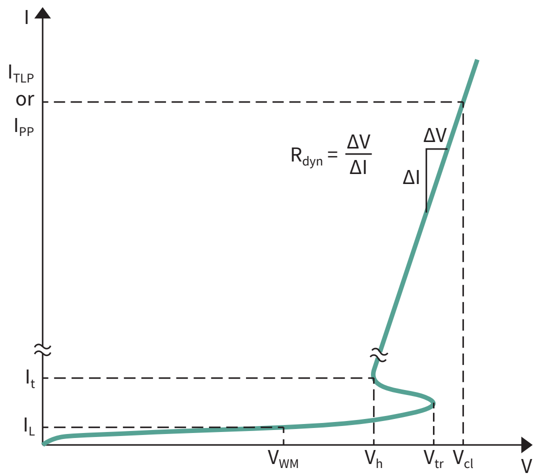

Fig. 4 Mild snapback

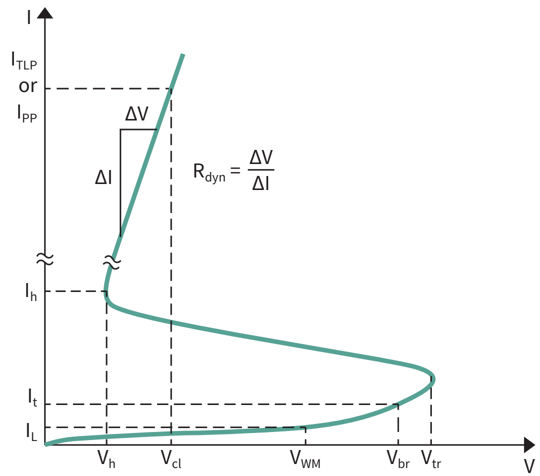

Fig. 5 Strong snapback (SCR[1]), thyristor)

1) SCR = Silicon controlled rectifier

Current-voltage (I-V) characteristic summary

I-V behaviour type	Features and benefits	Best suited for
Diode-like	› Simple behavior, easy to use › Good protection performance › Low voltage overshoot, fast turn-on	› Fast turn-on applications › Multi-purpose and low speed applications: buttons, switches, audio, GPIO, touch panels…
Mild snapback	› Improved protection performance (V_{cl}) › Enables low capacitance (**C_L**) › Excellent balance of **V_{WM}** and **V_{cl}**	Same applications as diode-like, plus › High speed I/O and RF applications
Strong snapback (SCR, thyristor)	› “Pound for pound” best protection performance (**V_{cl}**) › Enables low capacitance (**C_L**)	› RF applications › Applications with most demanding V_{cl} requirement: – High speed applications, LVDS – Super fine geometry SoC I/O with nm-scale technology

Typical first order selection parameters for the TVS

C_L – line capacitance – especially important for high speed/RF applications, less so for general purpose and low speed applications.

V_{WM} – maximum working voltage – must be chosen equal or higher than the maximum voltage on the protected line during specified operation (see fig. 6). Typical protection devices have **V_{WM}** aligned with standard system and I/O voltages (V_{IO}, V_{bus}), i.e. 2.1 V, 3.3 V, 5 V.

V_{cl} – clamping voltage – the most important parameter for protection performance. At the given stress level (**I_{TLP}, I_{PP}**)[1] **V_{cl}** must be lower than the failure voltage of the IC (if known), otherwise as low as possible.

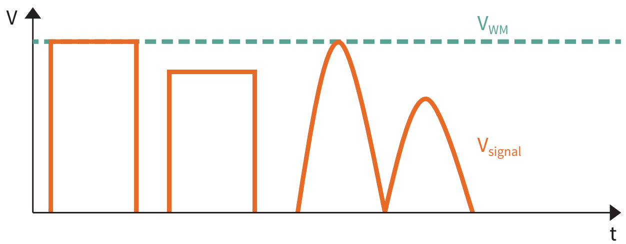

Fig. 6 V_{WM} equal or higher than V_{signal}

I-V curve parameters for advanced understanding

V_h, I_h – holding voltage, holding current

- For strong snapback devices **$V_h < V_{WM}$**. **V_h** is a local minimum of the voltage, and **I_h** is the corresponding current. **V_h** and **I_h** must be balanced with the line driver DC voltage/ current capability in order to prevent a device latch-up[2].
- For mild snapwback devices **$V_h > V_{WM}$**. **I_h** is not given in the datasheet, **V_h** is measured at a fixed testing current **I_t**.

V_{br} – breakdown voltage – measured at specified testing current **I_t**

V_{tr} – trigger voltage - maximum voltage before the device turns on (triggers) and snaps back to **V_h**. For snapback devices **V_{tr}** is slightly higher than **V_{br}**. **V_{tr}** is verified by design.

I_L – leakage current – current that flows through the device at **V_{WM}**

R_{dyn} – dynamic resistance – characterizes the steepness of the device I-V characteristic while conducting an ESD event[3]. Lower **R_{dyn}** is usually related to better protection performance, can be used to estimate **V_{cl}** at different stress levels (**I_{TLP}**) than datasheet provides.

Other device parameters/characteristics

Linearity – in applications with RF transmitters, e.g. mobile phones, EMI/EMC can be a concern due to harmonic generation from ESD protection devices on signal lines. ESD protection devices optimized for linearity generate less harmonic distortion and intermodulation.

IL – insertion loss – correlates highly with **C_L**, important only for high-speed/RF applications

V_{ESD} – maximum electrostatic discharge voltage – based on IEC61000-4-2

I_{PP} – maximum pulse current – also referred to as surge robustness, based on IEC61000-4-5

1) V_{cl} depends on the pulse width and shape: TLP, IEC61000-4-2, IEC61000-4-5
2) AN525: Latch-up prediction for SCR TVS device
3) Measured using Transmission Line Pulse (TLP) system

Low capacitance ESD protection devices

Product name	C_L typical [pF]	V_{WM} [V]	V_{cl} typical @ I_{TLP} = 16 A [V]	I_L max [nA]	R_{dyn} typical [Ω]	V_{ESD}[1] contact [kV]	I_{PP}[2] 8/20 µs [A]	Availability
ESD106-B1-W0201	0.13	5.5	25.0	20	1.10	14	1.5	Mass production
ESD107-U1-W0201	0.50	3.3	12.5/4.0[3]	50	0.40/0.20[3]	20	3.0	In planning
ESD108-B1-CSP0201	0.28	5.5	20.0	20	0.78	25	2.5	Mass production
ESD119-B1-W01005	0.20	5.5	20.0	20	0.80	25	2.5	Mass production
ESD120-B1-W0201	0.25	2.1	19.0	200	0.94	15	–	Development
ESD121-B1-W0201	0.25	7.0	24.0	200	0.90	15	–	In planning
ESD128-B1-W0201	0.30	18.0	32.0	30	0.85	15	2.0	Mass production
ESD129-B1-W01005	0.30	18.0	32.0	30	0.82	15	2.0	Mass production
ESD130-B1-W0201	0.30	5.5	20.0	20	0.80	18	2.5	Mass production
ESD131-B1-W0201	0.23	5.5	13.0	100	0.66	20	3.5	Mass production
ESD132-B1-W0201	0.45	5.5	7.0	100	0.20	30	9.0	Mass production
ESD133-B1-W01005	0.20	5.5	13.0	50	0.56	20	3.0	Mass production
ESD134-B1-W0201	0.30	2.1	7.7	20	0.28	28	7.5	Mass production
ESD144-B1-W0201	0.20	18.0	12.5	50	0.58	18	3.5	Mass production
ESD145-B1-W01005	0.20	18.0	12.5	50	0.58	18	3.5	Mass production

Nomenclature – Sales number

ESD230 – B 1 – xxx

Product series and number
ESD1xx low capacitance, C_L < 1 pF
ESD2xx multi-purpose, C_L > 1 pF

B Bidirectional
U Unidirectional

Number of lines

Package
W01005, CSP01005 wafer-level, 0.4 mm x 0.2 mm
W0201, CSP0201 wafer-level, 0.6 mm x 0.3 mm
02N plastic, 1.6 mm x 0.8 mm

Multi-purpose ESD protection devices

Product name	C_L typical [pF]	V_{WM} [V]	V_{cl} typical @ I_{TLP} = 16 A [V]	I_L max [nA]	R_{dyn} typical [Ω]	V_{ESD}[1] contact [kV]	I_{PP}[2] 8/20 µs [A]	Availability
ESD200-B1-CSP0201	6.5	5.5	13.0	100	0.20	17	3.0	Mass production
ESD202-B1-CSP01005	6.5	5.5	13.0	100	0.20	15	3.0	Mass production
ESD230-B1-W0201	7.0	5.5	13.0	100	0.22	16	3.0	Mass production
ESD231-B1-W0201	3.5	5.5	12.0	20	0.30	30	12.0	Mass production
ESD233-B1-W0201	33.0	5.5	13.0	100	0.20	20	5.0	Mass production
ESD234-B1-W0201	56.0	5.5	12.5	100	0.15	19	7.0	Mass production
ESD237-B1-W0201	7.0	8.0	13.0	100	0.21	16	3.0	Mass production
ESD239-B1-W0201	3.2	22.0	27.0	100	0.27	16	3.0	Mass production
ESD240-B1-W01005	3.0	22.0	27.0	100	0.31	16	3.0	Development
ESD241-B1-W0201	6.5	3.3	6.0	30	0.09	18	4.5	Mass production
ESD242-B1-W01005	6.0	3.3	6.0	30	0.09	18	4.5	Mass production
ESD245-B1-W0201	5.8	5.5	7.5	30	0.10	15	5.5	Mass production
ESD246-B1-W01005	5.5	5.5	7.5	30	0.10	15	5.5	Mass production
ESD249-B1-W0201	4.2	18.0	23.5	100	0.27	16	3.0	Mass production
ESD251-B1-W0201	33.0	3.3	6.0	100	0.09	25	8.0	Development
ESD252-B1-W01005	33.0	3.3	6.0	100	0.09	25	8.0	Development
ESD253-B1-W0201	2.8	24.0	31.0	100	0.30	15	3.0	Mass production
ESD254-B1-W01005	2.5	24.0	32.0	100	0.35	15	3.0	Development
ESD259-B1-W0201	4.2	16.0	24.0	500	0.29	15	2.5	Mass production
ESD307-U1-02N	270.0	10.0	17.0/2.0[3]	100	0.05/0.05[3]	30	34.0	Mass production
ESD311-U1-02N	210.0	15.0	22.0/2.0[3]	100	0.07/0.05[3]	30	28.0	Mass production

1) V_{ESD} based on IEC61000-4-2, contact discharge
2) I_{PP} based on IEC61000-4-5, 8/20 µs current waveform
3) Positive/negative direction

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