

Testing Microcontrollers for ESD Immunity

Considered microcontrollers are tested for ESD immunity in EMC accredited laboratory. Testing is done for contact discharge: indirect horizontal/vertical plane and direct discharge into GND and pins. Results are summarized in Table I. The testing voltage is increased from 200 V up to 25 kV and the first occurrence of events is notified, i.e., for lower testing voltages the event was not observed, and for higher voltages the event becomes more prominent and the disturbance of normal working mode becomes more significant. For each voltage level five pulses are repeated with 1 s interval in between. The testing is done on a testing table as specified in IEC 61000-4-2. Note that results should not be interpreted as they are directly related to microcontrollers itself. Namely, microcontrollers attached to larger boards are expected to be more susceptible to ESD events used in the experiment.

All events are classified into five categories, from least significant to the most significant:

- (1) glitch – short disturbance of voltage at the output pin is recorded by the used oscilloscope,
- (2) blinking LED – LED at the microcontroller board start to abnormally blink or change state due to ESD, but no other changes in operation is observed,
- (3) soft reset – the predefined output is changed due to interruption of the code execution on microcontroller, but the microcontroller establishes normal operations without the human actions,
- (4) hard reset – the predefined output is changed and the only way to restore the normal operations is to reset the microcontroller by the human and
- (5) permanent damage – the internal hardware is damaged beyond repair, which is confirmed by multiple restarts of the microcontroller.

Table I. Results of ESD immunity testing.

Microcontroller	Indirect discharge [kV]		Direct discharge [kV]	Comments
	Vertical plane	Horizontal plane		
[1] ARDUINO NANO ATMEGA328	10 kV – glitch	10 kV – glitch 20 kV – blinking LED 25 kV – soft reset	1 kV (GND, pin) – glitch 3 kV (pin) – hard reset 4 kV (pin) – soft reset 5 kV (GND) – soft reset 5 kV (pin) – hard reset 6 kV (GND, pin) – soft reset 7 kV (GND, pin) – soft reset 8 kV (GND) – soft reset 8 kV (pin) – permanent damage of pin under test	The second most robust microcontroller within the conducted ESD testing. However, the levels that lead to undesirable events due to ESD during normal operations are at the similar level that are expected in O-ESD.

Microcontroller	Indirect discharge [kV] Vertical plane	Indirect discharge [kV] Horizontal plane	Direct discharge [kV]	Comments
[2] ARDUINO NANO EVERY	5 kV – glitch	5 kV – glitch 20 kV – blinking LED	3 kV (GND) – blinking LED 3 kV (pin) – soft reset 5 kV (pin) – glitch, blinking LED, soft reset 6 kV (pin) – glitch, blinking LED, soft reset 7 kV (GND) – blinking LED 7 kV (pin) – glitch, blinking LED, soft reset 8 kV (GND) – glitch 8 kV (pin) – glitch, blinking LED, soft reset 9 kV (GND) – blinking LED, glitch 9 kV (pin) – permanent damage of pin under test	The most robust microcontroller within the conducted ESD testing. However, the levels that lead to undesirable events due to ESD during normal operations are at the similar level that are expected in O-ESD.
[3] ARDUINO MKR ZERO	12 kV – soft reset	12 kV – soft reset	2 kV (pin) – permanent damage of pin under test	
[4] ARDUINO DUE ATSAM3X8E	25 kV – soft reset	15 kV – glitch 25 kV – hard reset	5 kV (pin) – permanent damage of pin under test	
[5] MSP430 MSP430FR6989	5 kV – glitch	5 kV – glitch	5 kV (pin) – permanent damage of pin under test	
[6] MSPM0G3507 ARM	5 kV – glitch	5 kV – glitch 20 kV – hard reset	1 kV (pin, GND) – glitch 2 kV (pin) – permanent damage of pin under test	
[7] RASPBERRY PI PICO H RP2040	5 kV – glitch 15 kV – soft reset	5 kV – glitch 15 kV – soft reset	1 kV (pin, GND) – glitch 2 kV (pin) – soft reset 3 kV (pin) – permanent damage of pin under test	

Microcontroller	Indirect discharge [kV] Vertical plane	Indirect discharge [kV] Horizontal plane	Direct discharge [kV]	Comments
[8] RASPBERRY PI PICO 2	5 kV – glitch 25 kV – soft reset	15 kV – glitch 25 kV – soft reset	1 kV (pin) – glitch 3 kV (GND) – glitch 3 kV (pin) – permanent damage of pin under test	
[9] DISCOVERY STM32F3348	N/A	10 kV – glitch 15 kV – hard reset	3 kV (pin, GND) – glitch 4 kV (pin) – permanent damage of pin under test	
[10] NUCLEO-32 STM32F031K6	5 kV – glitch	5 kV – glitch	1 kV (GND, pin) – glitch 3 kV (pin) – permanent damage of pin under test	
[11] NUCLEO-32 STM32F303K8	5 kV – glitch	5 kV – glitch	1 kV (GND, pin) – glitch 3 kV (pin) – permanent damage of pin under test	
[12] NUCLEO-32 STM32L011K4	10 kV – glitch	10 kV – glitch	1 kV (GND, pin) – glitch 2 kV (pin) – permanent damage of pin under test	
[13] NUCLEO-32 STM32L432KC	5 kV – glitch	10 kV – glitch	1 kV (GND, pin) – glitch 2 kV (pin) – hard reset 3 kV (pin) – permanent damage of pin under test	
LCD (4 rows with 20 characters) with Arduino Nano	5 kV – hard reset (Black square on display)	5 kV – hard reset (Black square on display)	400 V – hard reset	LCD seems to be the least immune part of user interface on ESD.

References

- [1] <https://www.digikey.com/en/products/detail/arduino/A000005/2638989>
- [2] <https://www.digikey.at/en/products/detail/arduino/ABX00033/10239972>
- [3] <https://www.digikey.at/en/products/detail/arduino/ABX00012/6829065?s=N4IgTCBcDaIIcCAmBXAlgOwPYAIC2A1gjfF4CmCWIAugL5A>
- [4] <https://www.digikey.at/en/products/detail/arduino/A000062/3712582>
- [5] <https://eu.mouser.com/ProductDetail/Texas-Instruments/MSP-EXP430FR6989?qs=UfUfg%2FkmHHE%252BP%2F3xbkqawA%3D%3D>
- [6] <https://eu.mouser.com/ProductDetail/Texas-Instruments/LP-MSPM0G3507?qs=17ckDYBRdenplui3wZQ%252BtQ%3D%3D>
- [7] <https://www.digikey.at/en/products/detail/raspberry-pi/SC0917/16608257>
- [8] <https://www.tme.eu/rs/hr/details/sc1631/raspberry-pi-minicomputers/raspberry-pi/raspberry-pi-pico-2/>
- [9] <https://www.digikey.at/en/products/detail/stmicroelectronics/STM32F3348-DISCO/4835708?s=N4IgTCBcDaIMoBUCyBmMxFKAsAOAtACICScAwgPIgC6AvkA>
- [10] <https://www.digikey.at/en/products/detail/stmicroelectronics/NUCLEO-F031K6/5428803?s=N4IgTCBcDaIHIFUDCAZAogeQLQDEAMAzAlwDSAbCALoC%2BQA>
- [11] <https://www.digikey.at/en/products/detail/stmicroelectronics/NUCLEO-F303K8/5428805?s=N4IgTCBcDaIHIFUDCAZAogeQLQDEDMADHgNIAcIAugL5A>
- [12] <https://www.digikey.at/en/products/detail/stmicroelectronics/NUCLEO-L011K4/5806781?s=N4IgTCBcDaIHIFUDCAZAogeQLQoAwEZ8BpAFhAF0BfIA>
- [13] <https://www.digikey.at/en/products/detail/stmicroelectronics/NUCLEO-L432KC/6132763?s=N4IgTCBcDaIHIFUDCAZAogeQLQoCwGYwBpJEAXQF8g>

Revision history

Version	Date	Author(s)	Description
1.0	20/12/2024	D.O., J.D., A.K., D.N.	Created