SUMMARY

Electrostatic discharge may occur from the human body or from nearby objects which has been electrically charged due to friction, airflow or material flow across their surface. The purpose of this test is to expose the RoboteQ Controllers to Electrostatic Discharges using the direct and air-gap discharge methods. The governing specification is the IEC 61000-4-2 (indicated as the specification in this document) to which the tests here described adhere.

Specifically testing was performed to IEC Standard 61000-4-2, "Electromagnetic Compatibility (EMC), Part 4-2: Testing and Measurement Techniques, Electrostatic Discharge Immunity Test".
All units passed test within the stipulations exposed in this article.

TEST ACCEPTANCE RESULTS

RoboteQ controllers are used for battery operated systems and as such they fall in the category 7.1.3 of the specification.

Controllers are components part of a system; since a controller can be used with a large variety of different batteries, battery chargers, motors and mechanical loads, the load has been simulated with resistors/inductor combinations, which are more stringent than a real system and allow to observe better any possible malfunctions.

To be more specific testing of the UUT (Unit Under Test) was performed while powered with a battery, using the RoboteQ standard controlled test setup consisting of a combination of resistive and reactive loads.

This is a much more severe test as it will indicate even the smallest glitches which would not be visible when driving a motor due to mechanical inertia of the motor and mechanical load combination. The bandwidth of a motor as a combination of inertia and high winding inductance makes the motor unresponsive to the glitches observed.

The main requirement is that the UUT must never fail as described at performance level (d), which means no unrecoverable damage is tolerated. All UUT's tested do meet these requirements. For further reference see section 9 of the IEC specification.

The stipulations (a) are met with occasional glitches as described in (b). These occasional glitches are of very short duration (<35 milliseconds) so they are of no consequence when driving a motor or lighting an indicator LED in which only a short blinking can be observed.

TEST PROCEDURE

1. Visual check - Subject the controller to a full test.
2. Initialize controller - Load script, check output pattern
3. Mount the UUT in the Mounting Orientation specified in the Test Conditions if applicable.
4. Load the discharge network specified in the Test Conditions.
5. Apply the pulse to the UUT in the sequence specified in the Test Conditions.
6. Perform functional check after each exposure.
7. Perform the Visual check after exposure.
8. Validate proper function and calibration using RoboteQ ATE afterwards.

Brushless controllers which necessitate a proper sequence at the inputs of the Hall phase sensors were driven either by an internal script simulating the sensors or an internal script driving the Hall inputs.

Tests were performed in accordance to section 7.1.3 while live testing the UUT. The controller conduction plate was connected to the ground reference plane with a 1MΩ bleeder resistor. An additional 1MΩ bleeder cable was connected between the ground reference plane and the direct discharge pins under test.
As the specification details, this is because the system is ungrounded so it is necessary to prevent additive voltage charging during the test due to slow dissipation of the charge and therefore exceeding the test voltage. This has also the effect of accelerating the time between successive discharges during testing.

DESCRIPTION OF THE SETUP

A script was uploaded to the UUT to provide independent controlled operation while under test. The ESD source was a Thermo Keytek MZ-15/EC ESD Simulator serial #102255 with TPC-2A IEC Contact tip 150pf/330 ohm serial# 9904175.

RoboteQ controllers are components to be installed and maintained by professional technicians trained in implementing ESD protections; the environment is an industrial environment and the installation of the system is done utilizing anti-static techniques and material. Therefore we have chosen Class 2 of Table A-1 which corresponds to the highest level for this environment of 4kV for both contact and air discharge.

The test setup was powered during test by a standalone 12 Volt deep cycle battery. All outputs were connected to a RoboteQ standard R-L simulator consisting of 6 channels of four 10 ohm resistors in series and two 150nH inductors on each load in series with the resistors. This emulates a motor load in a controlled repeatable laboratory test environment. This procedure included: Proper setup of the Unit Under Test (UUT) and test system according to IEC61000-4-2 standards prior to testing, application of ESD disturbance signals to the UUT components, acquisition of UUT operational parameters during testing, and evaluation of acceptable UUT performance during and after testing.

Fig. 1 - An example floor-standing model which complied with applicable standards.

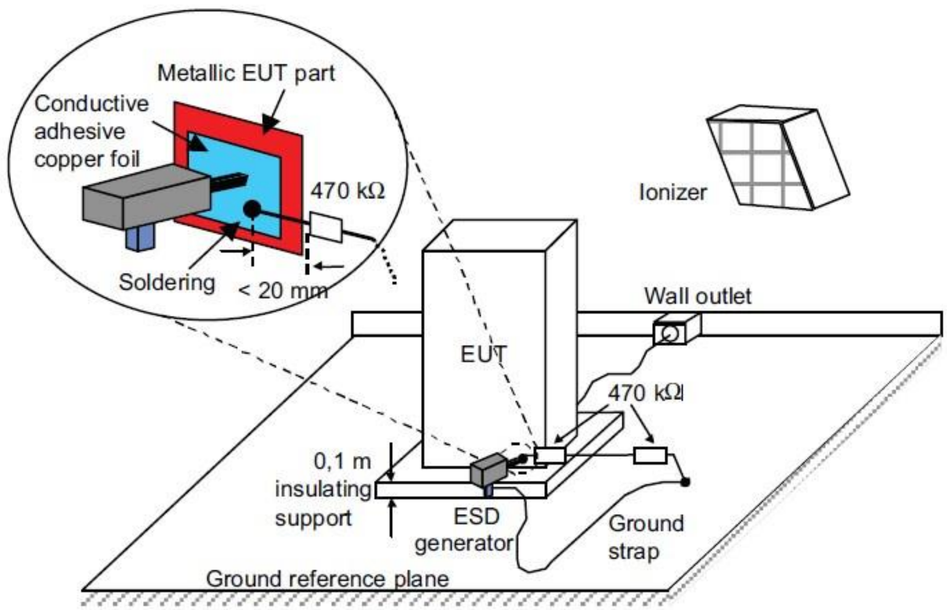


Fig 1

Environmental

Testing was performed indoors in a controlled laboratory environment at a room temperature of 25°C and relative humidity of 32%. Barometric pressure was 29.86in/hg.

Test Sequence Locations (See Appendix A for details)

Note: Contact discharge was applied only to conductive surfaces of the UUT.
Air discharge was applied only to non-conductive surfaces of the UUT.

Contact Discharges at 4KV

- All four corners of metal cases or bottom conduction plates
- Each corner of D-Sub connector cable shell
- USB connector cable shell
- Controller output terminals and cables connected to loads

Air-Gap Discharges at 4KV

- Plastic enclosure each corner and center top of case
- Plastic shell of each connected cable each corner and center

Test Results

Controller Model	Notes	Class	Result
SDC2160	Small <33ms glitch in motor output pattern	B	Pass
MBL1660		A	Pass
MDC1460		A	Pass
MDC2460		A	Pass
FBL2360		A	Pass
HBL1660		A	Pass
HBL2360		A	Pass
HBL2396	Intermittent blink of USB light during discharge	B	Pass
HDC2460		A	Pass
HDC2496	Small <33ms glitch in motor output pattern	B	Pass
XDC2460		A	Pass
RGBL1860		A	Pass
RGBL1896		A	Pass

The test results concluded that all tested units did continue to work without interruption after the application of the ESD voltage and passed the ATE tests after completion. Some units had short glitches during the discharge and one unit showed blinking at a USB indicator light. The glitch was of such a short duration that, with a real motor, it would have been of no consequence.

The installation, maintenance, and repair of the machine into which the controller is integrated must be done using antistatic material and must be conducted by qualified technicians trained in preventing the negative effects of ESD.

Use in a consumer environment by an untrained professional (Classes 3 and 4 of table A.1) where synthetic materials such as carpeting, plastic flooring, ceramic or otherwise insulated floors might be used is discouraged and has not been investigated.

Conclusions

While the graph on the right represents HBM (Human Body Model) discharge waveform characteristics, it still remains a simulated charge derived by a power supply with a specific impedance and voltage curve. Specific precautions should be made in the product design stage to prepare for the ingress of uncontrolled discharges to external interfaces on the device. TVS diodes and R/C snubber networks are only a first line of defense against ESD damage. Thought has to be given to the discharge path internally when an ESD event is received and where that current will go once received. ESD protection is a multi-level approach. Efficient design starts at the component level up to the system level. This is commonly referred to as SEED or System Efficient ESD Design. Peak uncontrolled discharge events can go as high as 35kV and 60A or more. The overall health of a system is dependent on a comprehensive approach to the protection methodology that includes a number of factors including but not limited to: On board protection components, optimized board signal routing, component packaging and, as a last line of defense, the component level protection.

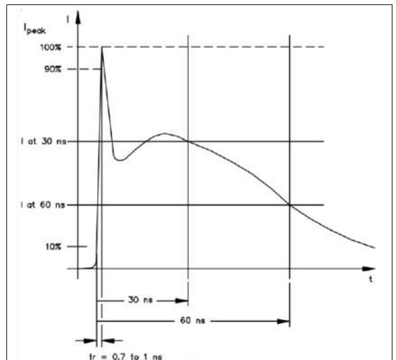
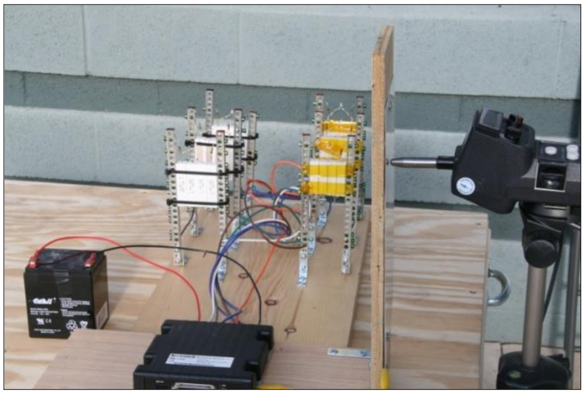


Figure 3. IEC 61000-4-2 ESD Pulse Waveform

References

1. IEC61000-4-2 Standards Edition 1.2:1995 consolidated with amendments 1:1998 and 2:2000
2. IEC61000-4-2 Emulation and Simulation, In-Compliance magazine, December 2017

Appendix: A



Reference Plane Test Setup

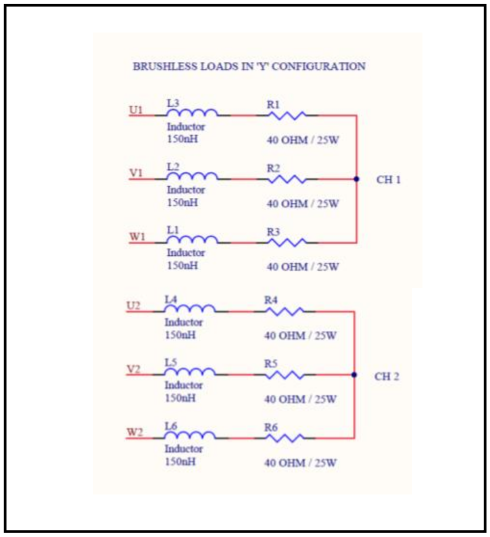
MBL Series Rear Test Points

VCP Zap In Progress

MBL Series Front Test Points

RGBL Test Points

HBL Series Front Test Points



Load Schematic

Bleeder resistor connecting conduction plate to reference plane

Bill of Materials

- Combination resistive / inductive load
    - Qty 4 pcs of Xicon 10 ohm / 25W Cement wire wound axial power resistors for total 40 Ohm DC resistance in series with:
        - Epcos BC series RF/VHF chokes.
        - Wire wound ferrite inductors 150nH / 6.5A 17 milliohm axial leaded inductors.
        - DigiKey part number 495-6932-1-ND manufacturer part number B78108E1151M000

- Bleeder resistor cable
    - Generic test leads with alligator clips at each end modified with two 470K ½ Watt metal oxide resistors in series.

- 12 Volt Sealed lead-acid battery
    - Casil CA1240, 12 Volt, 4A.

Test Equipment used:

- ESD power Source
    - Thermo Keytek MZ-15/EC ESD Simulator #102255 with TPC-2A IEC Contact tip 150pf/330 ohm #9904175.