

**APPLICATION NOTE**

# ESD Compliance Testing and Recommended Protection Circuits for GaAs Devices

## Introduction

Skyworks conducts ESD testing at both the device and system levels. These tests are based on the requirements outlined in:

- ESD Association 2.0 Handbook
  - Human Body Model (HBM)
  - Charged Device Model (CDM)
- IEC 61000-4-2 International Standard: Testing and Measurement Techniques
  - Electrostatic Discharge Immunity Test
- MIL-STD-1686
- MIL-HDBK-263
- Skyworks designed and tested several circuits that provide adequate ESD protection for Skyworks GaAs switches

## Device Level ESD Testing

Device level ESD classification is conducted as part of Skyworks standard qualification process, with the intent to fully characterize a component’s electrostatic discharge susceptibility.

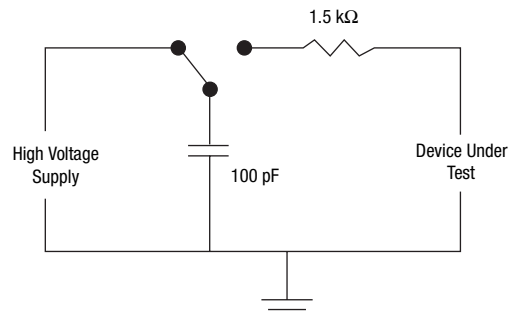
The Failure Analysis Laboratory at Skyworks utilizes an Oryx Instrument’s Bench Top ESD tester. This instrument allows Human Body Model (HBM) and Machine Model (MM) ESD events to be applied to devices. In addition, Skyworks performs ESD testing to Charged Device Model (CDM). These tests are conducted on the packaged device.

## Human Body Model (HBM)

This testing model simulates the ESD discharge delivered from the fingertip of an individual to a device. The model uses an RC circuit, such as the one shown in Figure 1, to deliver an exponentially decaying current pulse. Component ESD sensitivity levels for HBM are defined in Table 1.

The testing conducted consists of applying one positive and one negative pulse to the component, allowing a 0.3 second interval between pulses. A set of devices is exposed to these pulses at a given voltage level and pin grounding combinations, the device is tested for full static and dynamic parameters.

A typical test run consists of 20 devices. A set of five (5) devices is exposed to each level in 50 V increments. Most device level testing ranges from 150 V – 500 V.



**Figure 1. HBM Circuit for Delivering a Current Pulse to a Device.**

Class	Voltage Range
Class 0	0– ≤ 249 V
Class 1A	250– ≤ 449 V
Class 1B	500– ≤ 999 V
Class 1C	1000– ≤ 1999 V
Class 2	2000– ≤ 3999 V
Class 3A	4000– ≤ 7999 V
Class 3B	> 8000 V

**Table 1. ESD Component Sensitivity Classifications for HBM ESD Testing.**

### Charged Device Model (CDM)

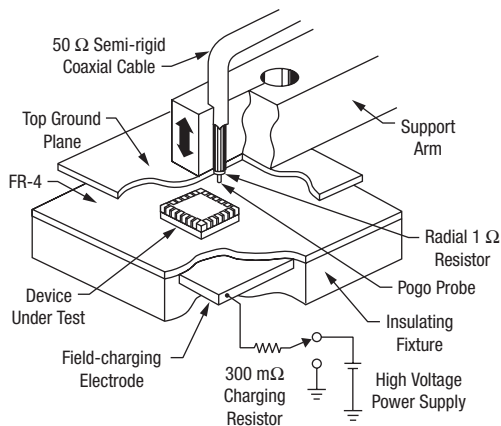
This testing model simulates the ESD discharge event that occurs as a charged component discharges to another object at a different electrostatic potential. Component ESD sensitivity levels for CDM are defined in Table 2.

Class	Voltage Range
Class C1	< 125 V
Class C2	125– < 250 V
Class C3	250– < 500 V
Class C4	500– < 1000 V
Class C5	1000– < 1500 V
Class C6	1500– < 2000 V
Class C7	> 2000 V

**Table 2. ESD Component Sensitivity Classifications for CDM ESD Testing.**

Three samples are submitted to CDM test for each voltage level. The device's potential is raised by applying a test voltage to the field charge electrode, see Figure 2 (Field Induced CDM Simulator). Five positive and negative discharges are applied to each pin, allowing enough time between discharges for the device to reach the full test voltage. Test voltages applied start at the 100 V level and are increased by 50 V increments. The device passes a voltage level when all three (3) samples stressed at this level pass. The device is tested for full static and dynamic parameters.

A typical test run consists of 20 devices. A set of five (5) devices is exposed to each level in 50 V increments.



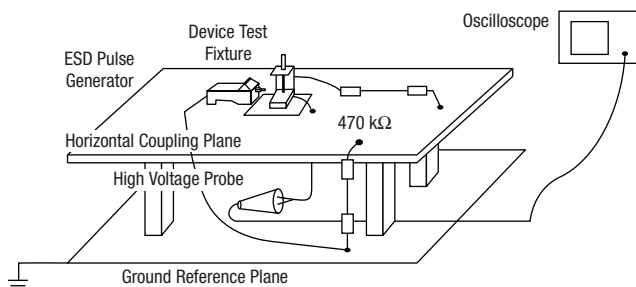
**Figure 2. Field Induced CDM Simulator.**

### System Level ESD Tests

To better understand device performance within an application, Skyworks conducts ESD testing at the system level utilizing the guidelines specified in IEC 61000-4-2. The IEC standard defines typical discharge current waveforms, range of test levels, test equipment, test configuration, and test procedure. System-level testing simulates the device in an application, such as a switch in a cellular handset. Test environment must emulate actual end-use environment.

#### Test Configuration

The test configuration used at Skyworks (Figure 3) corresponds to that outlined in the IEC Standard for tabletop equipment. The configuration consists of a 6 mm thick, 122 cm x 122 cm square aluminum plate on the laboratory floor. This plate is connected to earth ground. The discharge return cable of the ESD generator is connected to this ground reference plane.



**Figure 3. Sketch of the ESD Immunity Test Configuration.**

A wooden table 0.8 m high sits on top of the ground reference plate. A horizontal coupling plane of the same dimensions as the ground reference plane is bolted on the wooden table. The device is centrally located on this top surface. The fixture that holds the device is insulated from the horizontal coupling plane by a 0.5 mm thick, 30 cm x 46 cm insulating sheet.

An SMA cable is fed through a hole in the horizontal coupling plane in order to connect to the DUT fixture. This cable is connected to the high voltage probe that, in turn, connects to the oscilloscope. This allows the voltage at the outputs of the device to be recorded.

#### ESD Protection Circuit

GaAs devices are used in different system architectures and are applied as power amplifiers, switches, attenuators, detector/couplers, etc. In general, devices that are well embedded within the circuit are better protected, however, some applications may require an ESD protection circuit. A possible ESD protection mode utilizes a band pass filter, as shown in Figure 4.

The figure is of a Band Pass Filter (BPF) Protection Circuit for SP4T Switch IC. The BPF shown was mounted in front of a SP4T Switch IC in series.

Skyworks recommends the use of spark gap, band pass filters, and Chebyshev filters as ESD protection circuitry.

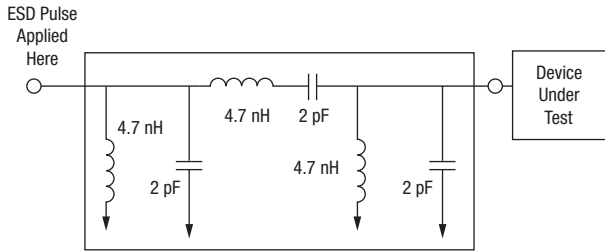
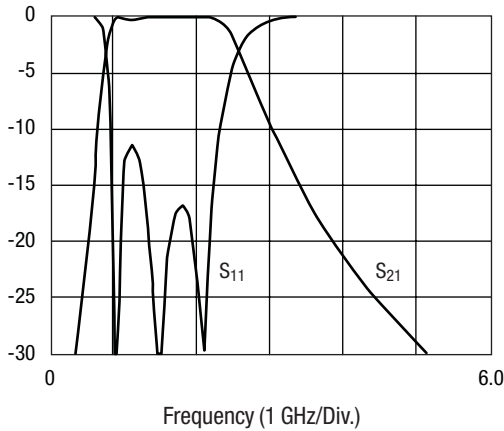


Figure 4. Band Pass Filter—ESD Protection Circuit.



Band Pass Filter Performance

**Test Procedure**

Skyworks conducts tests on devices mounted on RF test fixture boards to the electrostatic discharge as outlined in the IEC Standard. The fixture is a printed circuit board with SMA connectors to the stripline leading to the device. The device is held in place on the fixture by a spring-loaded plunger (Figure 5).

Considering the recommendation by IEC (International Electrotechnical Commission) and various individual application requirements, both contact and air discharge modes are applied to all system-level tests. The test levels used by Skyworks are outlined in Table 3.

The device is exposed to only one level of ESD energy during the test. The device is RF tested prior to the ESD test, then tested

again after the test. The unbiased device is first exposed to ESD air discharge of 16 kV. Upon passing this level of test, a device is biased in a functional state (for example, R<sub>X</sub> mode for a switch) and exposed to incrementally larger contact mode ESD pulses of each polarity.

**ESD Protection Circuit Recommendations for Portable, Handheld Devices**

Portable electronic devices, like cellular handsets, contain numerous RF and DC components, such as amplifiers, attenuators, switches and filters. Some of them may require ESD protection, some may not. However, to protect even one ESD sensitive chip, like GaAs switch, it is necessary to consider the whole handset as an ESD-sensitive system. Since the ESD pulse can leak into the switch through either one of the RF inputs, outputs, or even through the DC bias paths. Here are points to consider:

- Proper shielding of the whole handset is crucial.
- Bias source should not be located in the poorly shielded section of the board. Bias paths should not be running close to the poorly shielded sections Example: volume buttons on the side of the case can be a physical opening in the casing of the handset through which the ESD pulse can jump onto the bias path.
- Layout of the circuit board is very important, especially the location of the ESD sensitive part. There should be no other closely located components that can serve as a path for the ESD pulse into the sensitive part.
- The ESD protective circuit placed in front of the ESD sensitive part should not significantly degrade the RF performance.

Skyworks has tested several circuits that provide adequate ESD protection with various degrees of shielding. Protection circuits insertion loss varied from 0.06–0.15 dB at 0.88 GHz and from 0.05–0.1 dB at 1.9 GHz, depending on the circuit topology.

Since portable handset designs differ from manufacturer to manufacturer, the ESD protection issue has to be approached on a specific manufacturer’s design basis.

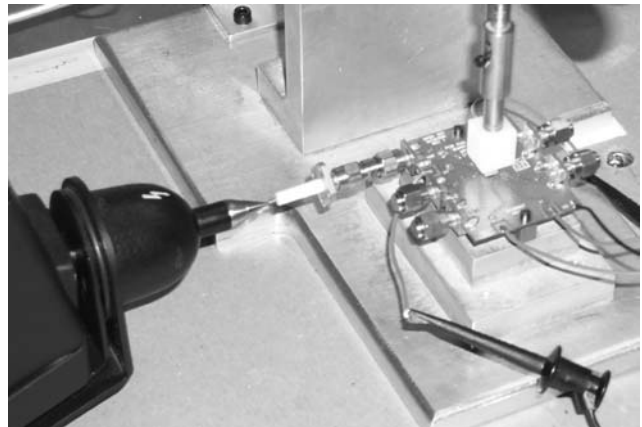


Figure 5. Photograph of the ESD Pulse Application to the Test Fixture.

Contact Discharge		Air Discharge	
Level	Test Voltage (kV)	Level	Test Voltage (kV)
1	2	1	2
2	4	2	4
3	6	3	8
4	8	4	16

Table 3. IEC Standard Defined Test Levels for Contact and Air Discharge Modes.

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