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.

<table>
<thead>
<tr>
<th>Class</th>
<th>Voltage Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 0</td>
<td>0– ≤ 249 V</td>
</tr>
<tr>
<td>Class 1A</td>
<td>250– ≤ 449 V</td>
</tr>
<tr>
<td>Class 1B</td>
<td>500– ≤ 999 V</td>
</tr>
<tr>
<td>Class 1C</td>
<td>1000– ≤ 1999 V</td>
</tr>
<tr>
<td>Class 2</td>
<td>2000– ≤ 3999 V</td>
</tr>
<tr>
<td>Class 3A</td>
<td>4000– ≤ 7999 V</td>
</tr>
<tr>
<td>Class 3B</td>
<td>&gt; 8000 V</td>
</tr>
</tbody>
</table>

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

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 150–500 V.

![Figure 1. HBM Circuit for Delivering a Current Pulse to a Device.](image)
**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.

<table>
<thead>
<tr>
<th>Class</th>
<th>Voltage Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class C1</td>
<td>&lt; 125 V</td>
</tr>
<tr>
<td>Class C2</td>
<td>125– &lt; 250 V</td>
</tr>
<tr>
<td>Class C3</td>
<td>250– &lt; 500 V</td>
</tr>
<tr>
<td>Class C4</td>
<td>500– &lt; 1000 V</td>
</tr>
<tr>
<td>Class C5</td>
<td>1000– &lt; 1500 V</td>
</tr>
<tr>
<td>Class C6</td>
<td>1500– &lt; 2000 V</td>
</tr>
<tr>
<td>Class C7</td>
<td>&gt; 2000 V</td>
</tr>
</tbody>
</table>

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.

**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.](image-url)

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

**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 an SP4T Switch IC in series.
Skyworks recommends the use of spark gap, band pass filters, and Chebyshev filters as ESD protection circuitry.

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, \( R_X \) 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 a 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, for 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 case-by-case basis.