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Improvements in CDM Test Accuracy and Repeatability

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Our 2016 paper [1] presented many measurements of the components used in the RCDM3 tester which explained the basic causes of CDM repeatability problems. The design of the CDM test has suffered from multiple examples of poor design which have resisted accuracy improvements for too many years.

The CDM standards as originally composed required that the total CDM measurement chain be initially calibrated and periodically verified in the time domain. The 1988 current sensor design [2] produced reasonable CDM test results, but later changes to its construction introduced additional measurement errors. The causes of these errors are difficult to identify without accurate measurement of individual component responses.

The ESDA CDM working group began measuring the pulse response of ESDA current sensors in 1996 [3] with the expectation that improvements in their pulse response would be made. We followed that up in 1999 [4] with recommendations that the verification modules used as reference capacitors should use alumina ceramic instead of the FR4 printed circuit board material as the insulating dielectric. We recommended that alumina was a much better high frequency capacitor dielectric. CDM tester manufacturers never used our recommendations to improve the CDM test accuracy.

The original specifications for discharge pulse measurements in the time domain seemed to be a logical choice at the time. This was because all ESD threats occur as discharge pulses whose parameters are identified in the time domain. However, the CDM discharge test behaves much differently. The voltage threat charge is stored in the device capacitance, which is discharged through one of the device's balls or leads to a ground potential pogo pin. Its inductance (L) remains constant while different capacitance (C) values of devices or verification modules, determines the resulting CDM discharge resonant frequency. The CDM discharge circuit produces a decaying sine wave with the amount of damping determined by the combination of the discharge circuit resistive losses and spark resistance. Figure 1 shows the four components in the CDM generation/measurement chain. Figure 2 shows the high frequency elements in the CDM tester.

Figure 1. CDM Measurement Chain

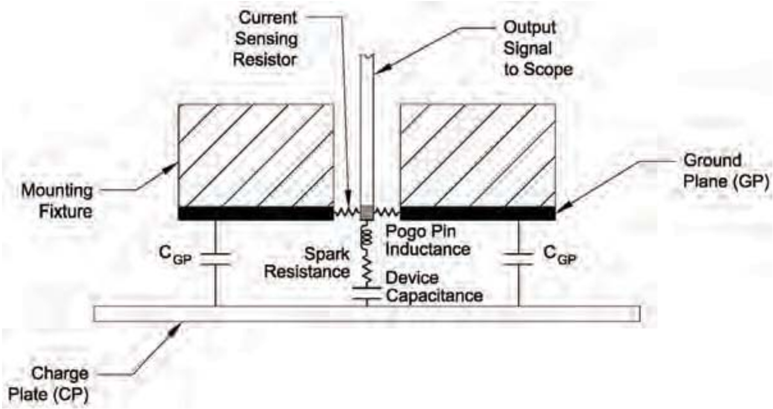

Figure 2. LRC Tester Elements

We made multiple alumina capacitors to measure the CDM resonant frequencies as each was discharged. The frequency varied from about 500 MHz for the largest devices to 2500 MHz for the smallest size and lowest (1 pF) capacitance devices. Our paper identified the long ignored CDM tester frequency domain information. CDM measurement components must provide an accurate response over this range of frequencies so the scope can accurately measure the discharge waveform in the time domain. The total CDM measurement chain accuracy can only be qualified when of each of its components is accurately measured individually. The CDM standard should be changed to specify this new measurement method.

The new JS-002 standard began improving the accuracy of the CDM test by adding 6 GHz bandwidth scope specifications and its measured data. The wider bandwidth and uniform scope frequency response over the CDM discharge frequency range was a major improvement of this component in the CDM measurement chain shown in Figure 1. Our analysis of scope bandwidth and roll–off response characteristics indicates that a 3 GHz digital scope will provide accurate CDM measurements for most packaged devices. The smallest 1.0 pF device capacitance will produce an 8% low peak current error at 2.5 GHz.

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EOS/ESD Technology

Improving CDM Test Accuracy and Repeatability continued

The accuracy of the Source (verification module) and Current Sensor in figure 1 have been not been quantified until now and have contributed unknown amounts of error to the CDM measurement chain. When the current sensor construction was changed from the reasonably accurate one ohm disk resistors to a ring of chip resistors, the JEDEC verification data did not meet the legacy peak current values.

It is not clear how the JEDEC system developed a different set of verification data values. When the design changed to a circular set of chip resistors for both the ESDA and JEDEC current sensors the JEDEC units did not meet their legacy values. Instead of identifying which design provided more accurate measurements, a "tuning" cavity was added to achieve the legacy current values measured with a 1 GHz scope.

The "tuning" cavity causes an increase in its peak current when its pulse response is measured with the 1 GHz scope. However it distorts the current sensor's frequency response by adding artificial ringing to the discharge waveform. It also inserts high impedance in front of the one ohm resistance. Impedance added to the one ohm current sensor changes the threat to the DUT which can cause errors in CDM device failure levels. Combining the "tuning" cavity correction in the JEDEC current sensor data with the more accurate ESDA current sensor data forced widening of data tolerances in JS-002.

The legacy values were so difficult to obtain with the mix of current sensors that the CDM standard recommends changing the charge voltage to obtain the required peak current values. This unusual correction method would be somewhat less questionable if the current sensors produced accurate measurements of peak current. They do not. These convoluted test voltage methods for verification and testing cry out for the return to the simple but accurate measurement components and specifications presented here.

Shortly after this new standard was finished, we produced the two new measurement components critical for accurate CDM measurements. Table 1, compares JS-002 data to the data measured with the three new uniform frequency response components.

Alumina verification module @ 500 V	6.8 pF	55 pF
JS-002 average data	7.20 A	12.10 A
New accurate average data	11.24 A	17.12 A
Percent difference	56%	41%

Table 1. JS-002 peak current vs. accurate components peak current

These are significant differences that have met early resistance in the Joint JEDEC-ESDA Working Group. The CDM test can be made more accurate by changing the new standard to incorporate both new methods to calibrate all measurement components with frequency domain specifications and accurate peak current data. Repeatable data between testers will be the result when they use accurate measurements of the CDM discharge.

We need to validate our claim that uniform frequency response current sensors and verification modules will significantly improve repeatability between test facilities. We have sent six sets of our new RCDM3 measurement components to members of the Joint JEDEC-ESDA Working Group so each can measure the discharge current parameters with wide bandwidth scopes. Comparison of the measured data at multiple sites will demonstrate if accurate measurement components can identify peak current discharge waveforms with closer tolerances. This data will be compared to that from present current sensors and verification modules. If there is reader interest we will provide the comparison in a following Threshold publication to keep the industry aware of how this improvement in CDM is developing.

A few notes of explanation will answer some questions. When current sensors with constant one ohm impedance from 500 to 2500 MHz are used, different discharge spark resistance values that cause the range of peak current tolerance will then become the largest variable in CDM testing. Coaxial cable loss is the third element in figure 1 of the measurement chain. Each cable is similar and varies between 0.5 dB (6 % Loss) at 500 MHz and 1.3 dB (16 % Loss) at 2500 MHz. This small but measurable error will not affect repeatability and can be addressed later after accurate measurement components are adopted in the CDM standard.

References:

[1] J. Barth, et. al. "Improving CDM Measurements With Frequency Domain Specifications" EOS/ESD Symposium Proceedings, 2016. Paper 4A.1

[2] R.G. Renninger, et. al., "A Microwave-Bandwidth Waveform Monitor for Charged- Device Model Simulators", EOS/ESD Symposium Proceedings, 1988. pp 162-171.

[3] L.G Henry, et. al., "Charged Device Model (CDM) Metrology: Limitations and Problems, EOS/ESD Symposium, 1996. pp 167-179.

[4] L.G Henry, et. al., "Issues Concerning CDM ESD Verification Modules - The Move to Alumina", EOS/ESD Symposium, 1999. pp 203-211.