

SEMI E135-0704

TEST METHOD FOR RF GENERATORS TO DETERMINE TRANSIENT RESPONSE FOR RF POWER DELIVERY SYSTEMS USED IN SEMICONDUCTOR PROCESSING EQUIPMENT

This test method was technically approved by the Global Metrics Committee and is the direct responsibility of the North American Metrics Committee. Current edition approved by the North American Regional Standards Committee on April 22, 2004. Initially available at www.semi.org on June 2004; to be published July 2004.

1 Purpose

1.1 The purpose of this document is to define a test method used to determine the transient response for an RF Generator used in RF power delivery systems for semiconductor processing equipment to support SEMI E113.

2 Scope

2.1 This document specifies the testing procedures and test equipment required for determining the transient response of an RF generator operating into a nominal 50-ohm load as a function of the change in set point level, including the time delay between the request for power (i.e., RF enable signal) and the start or stop of the RF output signal.

2.2 The primary focus for this document is semiconductor processing equipment including, but not limited to, the following tool types:

- Dry etch equipment,
- Film deposition equipment (CVD and PVD).

NOTICE: This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory or other limitations prior to use.

3 Limitations

3.1 This standard addresses RF generators used in RF systems that primarily operate in the frequency range of 0.2–100 MHz. It does not address higher frequency RF systems or microwave systems.

3.2 This standard is meant for analyzing RF generators that are designed to have a nominal characteristic impedance of 50 ohms. This standard can also be used with RF generators with a different characteristic impedance if the appropriate standard terminations are used.

3.3 International, national, and local codes, regulations and laws should be consulted to ensure that the

equipment and procedures meet regulatory requirements in each location.

3.4 This standard does not address any safety or performance issues related to RF emissions or electrical codes (e.g., Underwriter's Laboratory, Inc. (UL), the National Electrical Code (NEC®), Federal Communications Commission (FCC)). It is the responsibility of the users of this standard to conform to the appropriate local codes and regulations as applied to this type of equipment, some of which are covered by referenced documents.

4 Referenced Standard

4.1 SEMI Standard

SEMI E113 — Specification for Semiconductor Processing Equipment RF Power Delivery Systems

NOTICE: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 Abbreviations and Acronyms

5.1.1 CVD — Chemical Vapor Deposition

5.1.2 PVD — Physical Vapor Deposition

5.1.3 RF — Radio Frequency

5.1.4 VSWR — Voltage Standing Wave Ratio

5.2 Definitions of Terms

5.2.1 *cable assembly* — the section of cable (transmission line), including the connectors, used to connect various parts of the RF power delivery system.

5.2.2 *device under test (DUT)* — the RF generator to be tested.

5.2.3 *load impedance* — the load impedance is the impedance to which a generator is attached.

5.2.4 *RF enable signal* — the signal that a generator receives to turn on the output power.

5.2.5 *RF set point signal* — the signal that a generator receives that corresponds to a desired output power.

6 Test Apparatus

6.1 *Digital Oscilloscope* — The Digital Oscilloscope is used to measure the RF enable signal, the RF set point signal, and the RF power output signal. It shall have a digitization rate of at least 500 mega-samples per second per channel. The Digital Oscilloscope shall have an up-to-date calibration per the manufacturer.

6.2 *RF Rectifier/Diode Detector* — A device that converts an RF signal into a DC signal is used to measure a signal related to the output power of the RF generator. The input RF signal is produced by the RF Signal Sampler. The output DC signal goes to the Digital Oscilloscope.

6.3 *RF Signal Sampler* — A device that will detect RF voltage and/or current and produce a reduced-level RF signal is used for detection purposes. The sampler can be a non-directional coupler or a directional coupler that detects forward power. The reduced-level signal produced by the sampler is typically -40 to -50 dB (decibels) below the RF signal being detected.

6.4 *RF Set Point Signal Generator* — A device that will produce a DC signal that is used to set the desired RF generator output. The device is connected to the controller input of the RF Generator and is measured with the Digital Oscilloscope.

6.5 *RF Enable Signal Generator* — A device that will produce a DC signal that is used to turn-on and turn-off the RF generator output power. The device is connected to the controller input of the RF Generator and is measured with the Digital Oscilloscope.

6.6 *RF Power Meter* — A device that will measure the output power of the RF generator that is used. It shall have an absolute power accuracy of ± 3 percent and a measurement repeatability of ± 1 percent.

6.7 *RF Adapters and Terminations* — Various adapters may be necessary to convert between different types of coaxial connectors (e.g., type N to type HN adapters). All adapters used shall have the same nominal characteristic impedance as the system, which is typically 50 ohms. For some measurements, additional coaxial cable assemblies are used. These cable assemblies shall also be of the same nominal characteristic impedance as the system.

6.8 *High-Power RF Dummy Load* — A high power RF load is used to absorb the power produced by the generator. It shall have the same nominal characteristic impedance as the RF generator, which is typically 50 ohms. The RF dummy load shall have a power handling capability that is compatible with the RF generator being tested.

7 Safety Precautions

7.1 Work should be conducted in accordance with local safety requirements and test device manufacturer recommended safety procedures.

7.2 The area immediately surrounding the Test Setup shall be kept free and clear of unnecessary equipment and materials.

8 Test Setup for Measuring the Transient Response of the RF Generator as a Function of the Change in Set Point

8.1 The test setup for measuring the transient response of the RF generator consists of an RF Enable Signal Generator, an RF Set Point Signal Generator, a Digital Oscilloscope, the RF Generator (DUT), an RF Signal Sampler, an RF Rectifier/Diode Detector, an RF Power Meter, and a High-Power Dummy Load. A schematic of the test setup is shown in Figure 1. All signal cables that are used to connect to the Digital Oscilloscope should be of comparable length so that there is no significant time delay between the signals measured by the Digital Oscilloscope.

8.2 Prior to making any measurements, the Digital Oscilloscope and other electronic test equipment shall be turned on and allowed to warm up per the manufacturer's guidelines before the testing is to take place. This time will allow for electronics to come to a stable operating condition for the measurements.

9 Test Procedure for Measuring the Transient Response of the RF Generator as a Function of the Change in Set Point

9.1 The test procedure described below compares the change in the set point signal (produced by the RF Set Point Signal Generator) to the signal produced by the DUT. The Set Point signal is an input to the DUT and is used by the DUT to produce the desired output power level, per the DUT manufacturer's instructions. The DUT output power level is measured with the RF Signal Sampler. The signal from the RF Signal Sampler is used by the RF Rectifier/Diode Detector to produce a DC signal that corresponds to the RF output power from the DUT. The Digital Oscilloscope measures both the Set Point signal and the RF Detector signal.

9.2 *Test Method for Measuring the Transient Response of the RF Generator as a Function of the Change in Set Point*

9.2.1 Connect the outputs of the RF Enable Signal Generator and the RF Set Point Signal Generator to the controller input of the DUT. Connect the RF power output of the DUT to the input of the RF Signal

Sampler, and connect the output of the RF Signal Sampler to the High-Power RF Dummy Load. If any coaxial cable assemblies or adapters are used to make any of the connections between the output of the DUT and the High-Power RF Dummy Load, they shall have power handling capability that is consistent with the maximum output power of the DUT. Connect the reduced-level signal output of the RF Signal Sampler to the input of the RF Rectifier/Diode detector. Connect the output of the RF Set Point Signal Generator and the output of the RF Rectifier/Diode Detector to the input channels of the Digital Oscilloscope. Inspect all connections of the Test Setup to ensure proper contact.

9.2.2 Set up the Digital Oscilloscope to trigger off of the signal level change of the RF Set Point Signal Generator.

9.2.3 Turn on the RF Enable Signal Generator to a level that will allow the DUT to produce output power.

9.2.4 Change the RF Set Point Signal Generator output level to produce the desired change in RF output power. Measure and record the RF Set Point Signal Generator signal and the RF Rectifier/Diode Detector signal with the Digital Oscilloscope. Also record the indicated RF power levels from before and after the Set Point change as measured by the RF Power Meter. The measurement by the Digital Oscilloscope shall continue until the RF output power has stabilized, which typically takes a few milli-seconds.

9.2.5 The data shall be recorded and then presented in both graphical and tabular forms. An example of data collected from a Digital Oscilloscope for an RF generator test is shown in Figure 2, where the Set Point was changed from 3% to 33% of full power, and in Figure 3, where the Set Point was changed from 33% to 3% of full power.

10 Test Setup for Measuring the Transient Response of the RF Generator as a Function of the Change in RF Enable Signal

10.1 The Test Setup for the measuring the transient response of the RF generator as a function of the RF Enable signal consists of a RF Enable Signal Generator, a RF Set Point Signal Generator, a Digital Oscilloscope, the RF Generator (DUT), a RF Signal Sampler, a RF Rectifier/Diode Detector, a RF Power Meter, and a High-Power Dummy Load. A schematic of the Test Setup is shown in Figure 4. All signal cables that are used to connect to the Digital Oscilloscope should be of comparable length so that there is no significant time delay between the signals measured by the Oscilloscope.

10.2 Prior to making any measurements, the Digital Oscilloscope and other electronic test equipment shall

be turned on and allowed to warm up per the manufacturer's guidelines before the testing is to take place. This time will allow for electronics to come to a stable operating condition for the measurements.

11 Test Procedure for Measuring the Transient Response of the RF Generator as a Function of the Change in RF Enable Signal

11.1 The test procedure described below compares the change in the RF Enable signal (produced by the RF Enable Signal Generator) to the signal produced by the DUT. The Enable signal is an input to the DUT and is used by the DUT to turn on and turn off the output power. The DUT output power level is measured with the RF Signal Sampler. The signal from the RF Signal Sampler is used by the RF Rectifier/Diode Detector to produce a DC signal that corresponds to the RF output power from the DUT. The Digital Oscilloscope measures both the RF Enable signal and the RF Detector signal.

11.2 Test Method for Measuring the Transient Response of the RF Generator as a Function of the Change in RF Enable Signal

11.2.1 Connect the outputs of the RF Enable Signal Generator and the RF Set Point Signal Generator to the controller input of the DUT. Connect the RF power output of the DUT to the input of the RF Signal Sampler, and connect the output of the RF Signal Sampler to the High-Power RF Dummy Load. If any coaxial cable assemblies or adapters are used to make any of the connections between the output of the DUT and the High-Power RF Dummy Load, they shall have power handling capability that is consistent with the maximum output power of the DUT. Connect the reduced-level signal output of the RF Signal Sampler to the input of the RF Rectifier/Diode detector. Connect the output of the RF Enable Signal Generator and the output of the RF Rectifier/Diode Detector to the input channels of the Digital Oscilloscope. Inspect all connections of the Test Setup to ensure proper contact.

11.2.2 Set up the Digital Oscilloscope to trigger off of the signal level change of the RF Enable Signal Generator.

11.2.3 Turn on the RF Set Point Signal Generator to a level that will produce the desired output power.

11.2.4 Change the RF Enable Signal Generator output to a level that will turn on the DUT (per the DUT manufacturer's specification). Measure and record the time delay between the RF Enable Signal Generator signal and the RF Rectifier/Diode Detector signal with the Digital Oscilloscope. Also record the indicated RF output power level as measured by the RF Power Meter. The measurement by the Digital Oscilloscope