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# MANUFACTURING TEST OVERVIEW FOR THE EMBER<sup>®</sup> EM250, EM260, AND EM35X

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(Formerly document 120-5074-000)

Most customers have standard product manufacturing test flows, but some do not incorporate RF testing. This document describes the different options for integrating RF testing and characterization into your standard test flows. This application note is intended for Silicon Labs customers who are moving from the early prototype development stage to the manufacturing production environment and need assistance with manufacturing test. The specific target audience is senior manufacturing engineers and manufacturing managers who are investigating test processes for their Ember-enabled products.

For more details regarding Silicon Labs' recommendations for manufacturing test, refer to document AN700, *Manufacturing Test Guidelines*.

## New in This Revision

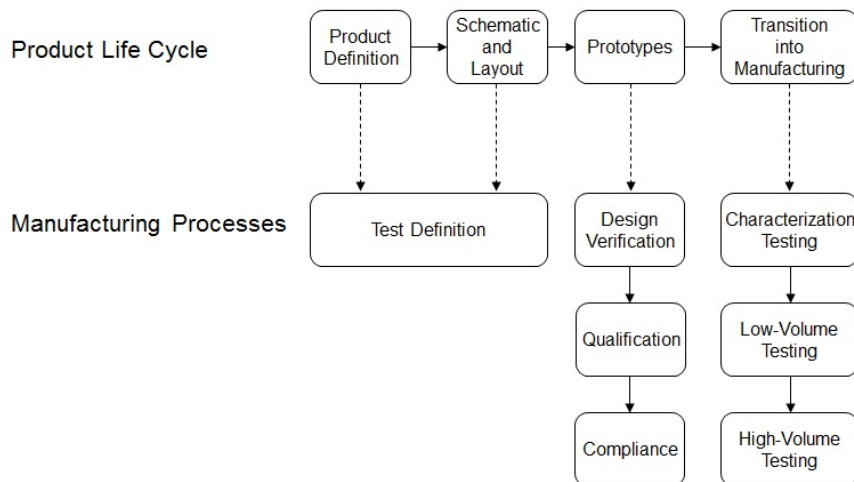
Reformatting to Silicon Labs standards.

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## 1 Manufacturing Test Flow

PCB manufacturing testing has two primary objectives: verifying components are placed properly on the boards and verifying functionality of the boards. The overall goal is to maximize test coverage while minimizing test costs. Manufacturing testing parallels the product lifecycle in that each phase is unique and builds on the previous phase. Figure 1 shows the traditional product lifecycle and how the different phases of the manufacturing process align with it.



**Figure 1. Product Lifecycle**

Silicon Labs recommends four phases of testing products according to the product lifecycle. Each phase has a purpose and builds off the previous stages.

1. Prototype: The objective of this phase is to fully verify the design on a small number of devices.
2. Characterization: This phase verifies the functionality of the product.

Once the product has been fully characterized, volume testing is next. The two phases of volume manufacturing testing are low-volume and high-volume.

3. Low-volume: This phase contains a subset of the tests run during the characterization phase but with reduced test time and coverage.
4. High-volume: This phase is a much faster test, which allows for ease of test and scalability.

The objective of these manufacturing test phases is to verify that components are placed properly on the boards. The tradeoffs for these phases discussed the next sections are the type of testing, test coverage, data collection, test application, test time, and test cost.

### 1.1 Phase I - Prototype Testing

The first phase of manufacturing test involves initial prototype testing, also known as design verification/validation. This involves product that has gone through its “first build” on a new product introduction (NPI) assembly line. This phase incorporates bench tests with test equipment and usually is not automated. Prototype testing usually involves the engineering design team. Therefore it is time consuming and expensive, but it is very important in verifying the product functionality.

As part of design verification, the product should be tested over the full environmental product requirements including temperature range and voltage supply range. The product should also be subjected to certification and compliance testing, which may include FCC, ETSI, CE, and ZigBee compliance testing. Finally, this phase includes general qualification testing, according to JEDEC standards.

Phase I tradeoffs are as follows:

- Volume: First 5-50 boards
- Type of Testing: Bench test with test equipment, not necessarily automated
- Test Coverage: Full design verification
- Data Collection: Not necessarily automated but very detailed
- Test Application: Standalone application (for example, the Ember nodetest application)
- Test Time: Hours per device (or months for some qualification tests)
- Test Cost: Expensive

## 1.2 Phase II - Characterization Testing

The second phase of testing in the product lifecycle is characterization testing. The objective of this phase is to verify functionality and repeatability. During this phase, the hardware is manufactured in higher volume (on an NPI line or production assembly line). The assembled product is fully characterized with automated test programs to determine design performance and manufacturability, as well as to collect valuable test data to be used to help with setting test limits in later phases. This phase also provides yield expectations and provides valuable design for manufacturability (DFM) and design for test (DFT) feedback to the engineering design team.

Phase II tradeoffs are as follows:

- Volume: Next 500 to 1,000 boards, depending on the customer
- Type of Testing: Automated with test equipment
- Test Coverage: Full design verification
- Data Collection: Automated, datalogs
- Test Application: Standalone application or application test mode
- Test Time: 10–30 minutes per device
- Test Cost: Expensive

## 1.3 Phase III - Low Volume Manufacturing Testing

The third phase is low-volume manufacturing. The objective of the volume manufacturing test phases (Phase III and IV) involves the verification of component placement. During this phase, a subset of the characterization testing may be performed. Test data from the characterization stage is used to help determine which tests may be reduced or eliminated. Test time during this stage is more important than the characterization stage because volumes are increased, but is still not crucial. In addition, yield analysis should be done on a continual basis with appropriate feedback provided to the engineering design team.

Phase III tradeoffs are as follows:

- Volume: Next 1,000 boards
- Type of Testing: Automated with subset of test equipment
- Test Coverage: Subset of characterization tests
- Data Collection: Automated, datalogs
- Test Application: Standalone application or application test mode
- Test Time: 2–5 minutes per device
- Test Cost: Moderate

## 1.4 Phase IV - High Volume Manufacturing Testing

The fourth and final phase is high-volume manufacturing. During this phase, test time is crucial and only minimal testing may be required depending on the customer and the application. A Golden Node application (a known good device that can be used in test for repeatable measurements) can be developed to transmit and receive packets to

and from a device under test to verify basic functionality. To further reduce test time, a manufacturing library can be used to allow for a test mode within the application itself, thus avoiding multiple programming steps.

Phase IV tradeoffs are as follows:

- Volume: After 1,000 to 2,000 boards
- Type of Testing: Automated with subset of test equipment
- Test Coverage: Minimal, basic functionality
- Data Collection: Minimal data, still automated
- Test Application: Application test mode
- Test Time: Less than 1 minute per device
- Test Cost: Minimal

**Note:** Automated test is defined as a test method where test equipment and Device Under Test (DUT) are controlled by a PC. A test program on the PC controls the test equipment and DUT. The DUT is loaded with embedded software that allows the radio to be configured for particular tests. This embedded software application could be a standalone test application or the customer's own application with a test mode included. Silicon Labs provides a standalone application, *nodetest*, for customers to use and modify. These applications are discussed in detail in document AN700, *Manufacturing Test Guidelines*.

## 2 Test Definitions

To communicate with the DUT and control various device test modes by automated test software, Silicon Labs provides embedded software applications to allow for both serial communication as well as Over-the-Air (OTA) communication to automated test software. Both of these interfaces enable configuring an Ember device for receive or transmit modes, turning on peripherals (if applicable), reading Analog to Digital Conversion (ADC) pins on the micro (if applicable), putting the radio and/or microprocessor to sleep, and similar control functions.

The tests can be divided into different types of tests— RF testing, DC testing, and peripheral testing.

- RF testing is any test specific to the operation and functionality of the radio (for example, transmitting and receiving ZigBee packets).
- DC testing is any test related to the voltage and current characteristics of the device or board (for example, active and sleep currents).
- Peripheral testing is any test not specific to RF or DC, like a sensor or an external crystal.

For more details on the specific recommended tests, refer to document AN700, *Manufacturing Test Guidelines*.

## 3 Test Recommendations

This section summarizes the functionality that should be tested on the hardware product, depending on the phase.

### 3.1 Prototype Testing

Prototype testing is necessary for all product designs. In this phase of testing, the design is verified across the full environmental product requirements, including temperature range and voltage supply range, as well as humidity range in some cases. This level of environmental testing may occur over several months, depending on the qualification requirements of the product. Certification and compliance testing may also be necessary in this phase of testing. External test houses are likely to be involved to support this testing. This phase fully verifies the design of the hardware and product that is being developed, and helps identify any design issues that need to be corrected before proceeding to the characterization testing phase.

### 3.2 Characterization Testing

Characterization testing is recommended for early production stages. In this phase of testing, the RF functionality (transmit and receive) should be characterized on all 16 ZigBee channels or a subset of these channels, as well as at various transmit output power levels or receiver input power levels. This phase fully characterizes the hardware that is being developed, determines the tests to be executed in manufacturing test, determines the test limits of these tests, and flushes out any manufacturing or process issues that might be present.

### 3.3 Low Volume Manufacturing Testing

Low-volume manufacturing testing is usually a subset of the characterization testing. A subset of the 16 ZigBee channels or transmit output power levels can be tested to reduce the test time without compromising test coverage. For example, one channel/power level combination (likely mid-band at max power) can be measured for transmit and receive functionality.

The results from the characterization phase of testing help determine not only what should be tested in the manufacturing phase but also the test limits to be applied to certain tests. For example, if a particular test does not fail at all during the characterization phase, it can be omitted from the manufacturing phase altogether. Also, if it is determined that a particular test will fail all channels if it fails at all, testing can be reduced from all channels to a single channel, most likely mid-band.

### 3.4 High Volume Manufacturing Testing

High-volume manufacturing testing is much simpler than characterization testing or low-volume manufacturing testing. The hardware design and manufacturing process have already been proven, so the product now just requires a quick “go/no go” transmit and receive functional test to verify operation.

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