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# Extended Temperature Support for Cyclone Devices

## Introduction

Semiconductor devices undergo at least two types of testing: *device characterization* and *production testing*. Device characterization is used to verify the performance of a semiconductor design and its physical implementation. Production testing is used to find manufacturing defects that randomly occur during the manufacture of all semiconductor devices. This white paper describes these testing methods and the roles they play in supporting extended temperature Cyclone™ devices.

## Testing

Device characterization is performed on a small sample of devices to characterize performance and performance variations across process, voltage, and temperature changes. Once device characterization has been performed, the operation of the device is well understood across a variety of operating conditions including commercial, industrial, and extended temperatures. Device characterization allows Altera® to determine if a product can be utilized in commercial, industrial, and extended temperature conditions.

Production testing is used to identify manufacturing defects in devices prior to shipment to customers. There are two key stages for production testing: wafer sort and post device assembly (packaging). Wafer sort identifies good die which continue in the manufacturing process to device assembly. After assembly, additional testing is performed to verify device functionality and determine performance binning (speed and temperature grades).

## Temperature Grades

Cyclone devices are available in three different temperature grades, each guaranteed to work within specifications at the specified temperature range:

- Commercial – 0 C to 85 C
- Industrial – -40 C to 100 C
- Extended – -40 C to 125 C

Altera has characterized Cyclone devices across the commercial, industrial, and extended temperature ranges and verified that they perform within our stringent specifications. However, note that while commercial-grade devices have been production tested and screened at commercial temperatures, and industrial-grade devices have been production tested and screened at the industrial high-end temperatures, Altera does not perform production screening for extended temperature operation. Thus, manufacturing device errors that may manifest themselves at extended temperature extremes will not have been identified during production testing.

For extended temperature operation, Altera supports the use of industrial-grade Cyclone devices when compiled to a slower speed-grade (see *Extended Temperature Support*), but cannot guarantee those devices to be free from temperature-related manufacturing defects under extended temperature operation.

## Performance as a Function of Temperature

An important aspect of semiconductor device operation is that its performance is inversely correlated to operating temperature. Estimates identified through characterization of Altera Cyclone devices indicate a fraction of a percent reduction of  $f_{MAX}$  change per degree C. Thus, at higher temperatures the  $f_{MAX}$  is decreased while at lower temperatures the  $f_{MAX}$  increases. This characteristic is automatically taken into account in Altera software when implementing a design on a specific device, speed-grade combination such that across its intended operating temperature range (for example 0 C to 85 C for commercial operation), adequate timing margin is included so that no timing violations occur in synchronous designs.

## Extended Temperature Support

Extended temperature operation requires additional timing margin over industrial temperature operation to compensate for the potential increased variation of  $f_{MAX}$ . With Altera devices, increased timing margin is achieved by compiling the design to a slower speed-grade in Quartus® II. For example, one can increase timing margin for a -6 device by utilizing a -7 device setting in Quartus II. This technique can be utilized to increase the timing margin of an industrial device to meet the constraints of extended temperature range operation (see the “Using Extended Temperature Devices in the Quartus II Software” whitepaper for more information). A specific list of industrial-grade Cyclone devices supporting extended temperature operation when compiled to a slower speed-grade is posted at [www.altera.com](http://www.altera.com).



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