Powering Xilinx™ Kintex® UltraScale+™
Reference Design for Kintex® XCKU15P

Introduction
This reference design provides a solution to power Kintex® XCKU15P based applications. Using ABB Power Modules ensures a dense, high performance and a cost-effective short design time cycle. ABB Power Modules are designed and tested to comply with IPC9592 standards and have millions of hours of Field Reliability.

Features
▪ Digital interface through the PMBus™ protocol
▪ Tunable Loop™ to optimize dynamic output voltage response
▪ Fixed switching frequency with capability of external synchronization
▪ Output over current protection (non-latching)
▪ Over temperature protection
▪ Remote On/Off
▪ UL® 60950-1 2nd Ed. Recognized, CSA® C22.2 No. 60950-1-07 Certified, and VDE® (EN60950-1 2nd Ed.) Licensed

Applications
▪ NIC Cards
▪ Data accelerator

Powertree

Figure 1 – ABB Module Solution for key power rails for XCKU15P configuration based on Upper Load Consumption
XCKU15 Power Rail and ABB Module Specifications

<table>
<thead>
<tr>
<th>RAIL</th>
<th>VOLTAGE</th>
<th>ABB MODULE</th>
<th>MODULE OUTPUT</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>VCCINT</td>
<td>0.72/0.85/0.9V, ±3%</td>
<td>MDT040</td>
<td>40A</td>
<td>SETPOINT ±1%, Balance Load Step + Ripple + Regulation</td>
</tr>
<tr>
<td>VCCBRAM/INT_IO</td>
<td>0.85/0.9V, ±3%</td>
<td>PDT003</td>
<td>3A</td>
<td>SETPOINT ±1%, Balance Load Step + Ripple + Regulation. Rail can be tied to VCCINT if both set to same voltage.</td>
</tr>
<tr>
<td>VCCaux/ADC</td>
<td>1.8V, ±3%</td>
<td>PDT003</td>
<td>3A</td>
<td>SETPOINT ±1%, Balance Load Step + Ripple + Regulation</td>
</tr>
<tr>
<td>VMGTAVTT</td>
<td>1.2V, ±3%</td>
<td>PJT007</td>
<td>7A</td>
<td>SETPOINT ±0.5%, Balance Load Step + Ripple + Regulation, &lt;10mV pk-pk ripple</td>
</tr>
<tr>
<td>VMGTvCAUX</td>
<td>1.8V, ±3%</td>
<td>APXS002 or PDT003</td>
<td>2A / 3A</td>
<td>SETPOINT ±1%, Balance Load Step + Ripple + Regulation, &lt;10mV pk-pk ripple</td>
</tr>
<tr>
<td>VMGTAVCC</td>
<td>0.9V, ±3%</td>
<td>PDT003</td>
<td>3A</td>
<td>SETPOINT ±1%, Balance Load Step + Ripple + Regulation, &lt;10mV pk-pk ripple</td>
</tr>
</tbody>
</table>

ABB Reference Solutions

ABB’s products used in these reference designs are fully integrated Point-of-Load power modules providing a high reliability (IPC9592 qualified), easy-to-use, fast time-to-market, high efficiency, small footprint, and excellent thermal derating option for powering FPGAs. ABB’s reference designs use digital power modules with PMBus™ making sequencing easy. Reference designs do not include a power management IC but any external PMBus compliant controller or the external I2C/PMBus based system controller can be used to sequence and monitor the rails.
ABB Module Description

MDT040 – The MDT040 is a dense single phase Buck Converter with PMBus communications support for start-up and sequencing control. This high-power, full-featured module operates from 4.5-14.4 Vin and provides an output of 40A over an adjustable output voltage range of 0.45 to 2.0Vdc. It has low output noise and offers Tunable Loop Control for tight load response. It is compliant to Category 2 of IPC-9592. Detailed Datasheet available at https://www.geindustrial.com/products/embedded-power/dlynx

PJTO07 – The PJTO07 provides 7A of output in a DOSA compliant PICO footprint. This single-phase Buck Converter operates from 4.5 -14.4 Vin and provides an output of 7A over an adjustable output voltage range of 0.51 to 5.5Vdc. It has a PMBus interface for start-up and sequencing control; and Tunable Loop™ to ensure a tight load transient performance. It is compliant to Category 2 of IPC-9592. Detailed Datasheet available at https://www.geindustrial.com/products/embedded-power/dlynx

PDT003 – The PDT003 provides 3A of output in a DOSA compliant PICO footprint. This single-phase Buck Converter operates from a wide 3 -14VIN and provides an output of 3A over an adjustable output voltage range of 0.45 to 5.5Vdc. It has a PMBus interface for on/off control; and Tunable Loop™ to ensure a tight load transient performance. It is compliant to Category 2 of IPC-9592. Detailed Datasheet available at https://www.geindustrial.com/products/embedded-power/dlynx

APXS002 – The APXS002 provides 2A of output in a DOSA compliant PICO footprint. This single-phase Buck Converter operates from a wide 3 -14VIN and provides an output of 2A over an adjustable output voltage range of 0.6 to 5.5Vdc. It has an analog interface for on/off control; and Tunable Loop™ to ensure a tight load transient performance. It is a cost-effective solution where digital communication is not required or is not available. Detailed Datasheet available at https://www.geindustrial.com/products/embedded-power/tlynx

Hardware for Testing

The main hardware used was the XCKU15P evaluation board and associated test equipment

Figure 2 – Evaluation Board Top and Bottom View
Test Equipment

<table>
<thead>
<tr>
<th>Function</th>
<th>Make</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC Power Supply</td>
<td>Chroma</td>
<td>62050P-100-100</td>
</tr>
<tr>
<td>DC Load 1</td>
<td>Chroma</td>
<td>63205A-150-500</td>
</tr>
<tr>
<td>DC Load 2</td>
<td>Agilent</td>
<td>N3300A</td>
</tr>
<tr>
<td>Oscilloscope</td>
<td>Teledyne Lecroy</td>
<td>HDO6104</td>
</tr>
<tr>
<td>Scope Probe (Voltage)</td>
<td>HP</td>
<td>10070A</td>
</tr>
<tr>
<td>Scope Probe (Current)</td>
<td>Teledyne Lecroy</td>
<td>AP015</td>
</tr>
<tr>
<td>Function Generator</td>
<td>Agilent</td>
<td>22310A</td>
</tr>
<tr>
<td>Bode Plots</td>
<td>Venable</td>
<td>Model 350 system</td>
</tr>
</tbody>
</table>

Tests

Module Output On-Off Sequencing
Module output was turned on and off using PMBus for those rails that needed a specific sequencing order as specified in the Xilinx™ documentation. An external computer running ABBs DPI-ProGUI software was used to turn on modules in sequence. A free version of the software is available here [http://go.ge-energy.com/DigitalPowerInsight.html](http://go.ge-energy.com/DigitalPowerInsight.html).

Efficiency
Module Efficiency was measured on individual evaluation boards which provided better access to individual module input and output points to get an accurate readback of efficiency. Efficiency curves have been generated from fixed measurements at standard interval point through a standardized test equipment setup and then data interpolated to provide the efficiency at specific output voltages.

Output Ripple Voltage
The Output Ripple Voltage was measured using Tektronics probe connector (Part No 131-4353-00) mounted close to the load terminations on the evaluation board. Measurements were done for the upper load specified by Xilinx™ for each rail in the XCKU15P configuration.

Load Transient
For the VCCINT rail a simple power FET circuit was added to the evaluation board to generate the fast rise time demanded by the rail. The output voltage was measured at the same point where the
output ripple was measured. For other rails the a short connection to the Chroma Load was made to enable the appropriate step load and slew rate for each rail.

**Bode Plots**

Loop Gain Measurements were done on the individual rails at upper load levels specified by Xilinx™

**Load Regulation**

Measurement at the load of the variation in output voltage with Sense Line from modules connected to the Output Load

**Thermal**

A Thermal image using an IR Camera was captured of the board after running all the modules on the board at Xilinx specified upper load for each rail for 20 minutes.
Module Output On-Off Sequencing Curves

**Figure 3** – ON Sequence – VCCINT (Yellow), VCCBRAM (Red), VCCAUX (Blue) (Axis Scale: 500mV(y), 1s(x))

**Figure 4** – OFF Sequence – VCCINT (Yellow), VCCBRAM (Red), VCCAUX (Blue) (Axis Scale: 500mV(y), 500ms(x))

**Figure 5** – ON Sequence – VCCINT (Yellow), VMGTAVCC (Red), VMGTAVTT (Blue) (Axis Scale: 500mV(y), 500ms(x))

**Figure 6** – OFF Sequence – VCCINT (Yellow), VMGTAVCC (Red), VMGTAVTI (Blue) (Axis Scale: 500mV(y), 500ms(x))

**Note:** For full-size plots, download complete report. Go to [Test Report](#).
Efficiency Curves

Figure 7 – VCCINT Efficiency – MDT040 (0.72Vout)

Figure 8 – VCCBRAM/IO Efficiency – PDT003 (0.85Vout)

Figure 9 – VCC AUX Efficiency – PDT003 (1.8Vout)

Figure 10 – VMGTA VCC Efficiency – PDT003 (0.9Vout)

Figure 11 – VMGTA VTT Efficiency – PJ007 (1.2Vout)

Figure 12 – VMGTVCCAUX Efficiency – APXS002 (1.2Vout)
Output Ripple – All measurements at Upper Load specified by XILINX™

Figure 13 – VCCINT–MDT040 (Axis Scale 5mV(y), 1us(x))

Figure 14 – VCCBRAM/IO–PDT003 (Axis Scale 5mV(y), 1us(x))

Figure 15 – VCCAUX–PDT003 (Axis Scale 5mV(y), 1us(x))

Figure 16 – VMGTAVCC–PDT003 (Axis Scale 10mV(y), 1us(x))

Figure 17 – VMGTAVTT–PJ007 Axis Scale (5mV(y), 1us(x))

Figure 18 – VMGTVCCAUX–APXS002 (Axis Scale 5mV(y), 1us(x))
Transients –

- Figure 19 – VCCINT – MDT040 (0.72Vout)
- Figure 20 – VCCBRAM/IO – PDT003 (0.85Vout)
- Figure 21 – VCCAUX – PDT003 (1.8Vout)
- Figure 22 – VMGTAVCC – PDT003 (0.9Vout)
- Figure 23 – VMGTAVTT – PJT007 (1.2Vout)
- Figure 24 – VMGTVCCAUX – APXS002 (1.2Vout)

Note: For full-size plots, download complete report. Go to Test Report.
Bode Plots

Fig. 25 – VCCINT, MDT040 (0.72Vout), 47kHz BW, 41°PM

Fig. 26 – VCCBRAM/IO, PDT003 (0.85Vo), 46kHz BW, 52°PM

Fig. 27 – VCCAUX – PDT003 (1.8Vol), 43kHz BW, 56°PM

Fig. 28 – VMGTAVCC – PDT003 (0.9Vo) 65kHz BW, 61°PM

Fig. 29 – VMGTAVTT – PJT007 (1.2Vol), 38kHz BW, 67°PM

Fig. 30 – VMGTVCCAUX-APXS002 (1.2Vol), 42kHz BW, 86°PM

Note: For full-size plots, download complete report. Go to Test Report.
Load Regulation – All measurements at 12Vin, Upper Load

**Figure 31**: VCCINT – MDT040 (0.72Vout), ∆ = 1mV

**Figure 32**: VCCBRAM/IO – PDT003 (0.85Vout), ∆ = 0.5mV

**Figure 33**: VCCAUX – PDT003 (1.8Vout), ∆ = 1.2mV

**Figure 34**: VMGTAVCC – PDT003 (0.9Vout), ∆ = 0.9mV

**Figure 35**: VMGTAVTT – PJT007 (1.2Vout), ∆ = 0.83mV

**Figure 36**: VMGTVCCAUX – APXS002 (1.2Vo), ∆ = 0.27mV

**Note**: For full-size plots, download complete report. Go to [Test Report](#).
Thermal Image

Figure 47 – Thermal image of the board after running all the modules on the board at full load for 20 minutes. Captured using an IR camera.

Design Files and Reference Data

Schematics
To download the schematics, use the following link XCKU15P Schematic.

Bill of Materials
To download the bill of materials (BOM), use the following link XCKU15P BOM.

Evaluation Board Layout
Xilinx has specific instructions in their FPGA Layout guidelines. To download the Layout used on the evaluation board use the following link XCKU15P Layout.
Guidelines for Layout of all ABB DLynx and DLynxII modules are available here: Module Lay-out.
Complete Test Report
Detailed Test Report of testing of ABB Modules on Xilinx Evaluation Board is available. Go to Test Report.

Online Simulation Tool
ABB provides a free, cloud-based simulation tool. Reference Designs in this document are available for simulation. Go to Power Module Wizard.

PMBus Tool and GUI
ABB provides a free downloadable GUI which works with the ABB USB to I2C adapter to allow users to command and monitor ABB Modules. Go to Digital Power Insight.

OnLine Materials
Detailed Datasheet of modules used in this reference design and other Reference Material is available at ABB Modules.