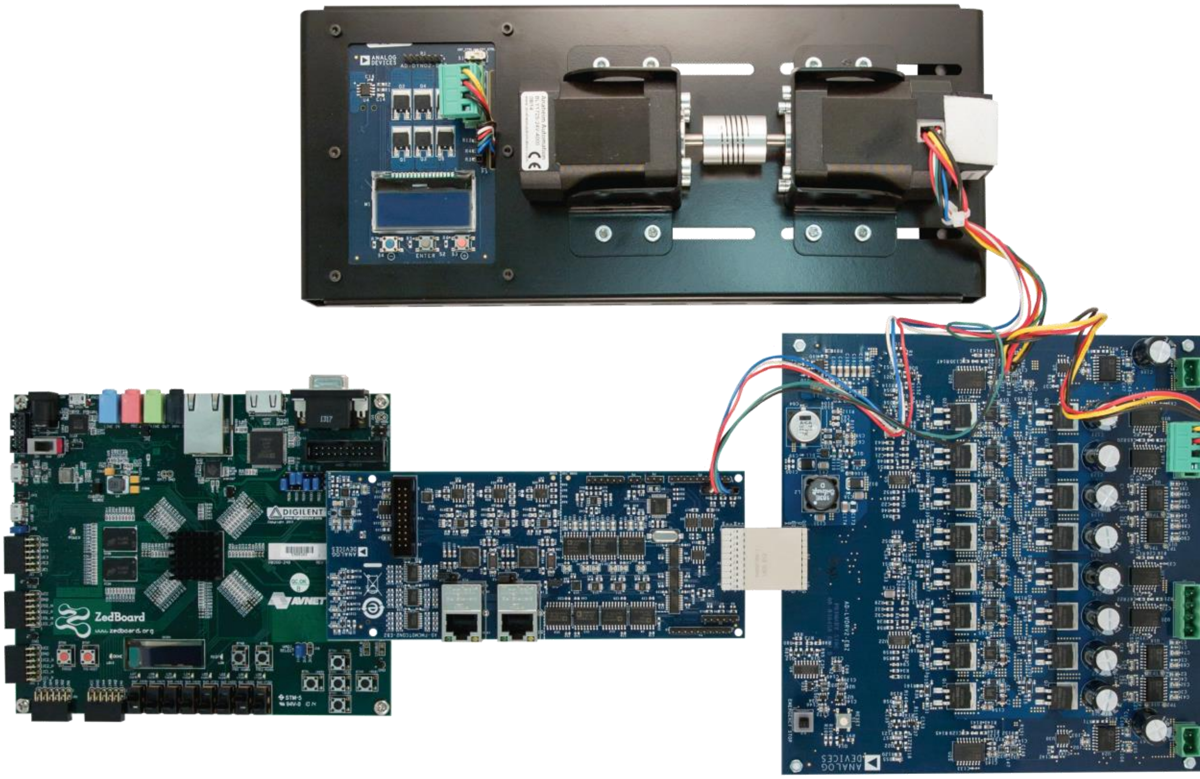
Zynq®-7000 AP SoC / Analog Devices Intelligent Drives Kit II



Getting Started Guide

Version 1.2

Revision History

DATE	VERSION	REVISION
07/31/15	1.0	First release \ MB
08/10/15	1.1	Pointed to ADI wiki for SD card image archive
10/07/15	**1.2**	**Updated broken references to figures. Added instruction to use DHCP router for connecting to the internet.**

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INTRODUCTION

The Zynq®-7000 AP SoC / Analog Devices Intelligent Drives Kit II is a flexible platform for high performance motor control and industrial networking development. The kit is based on the Avnet ZedBoard™ using the Xilinx Zynq-7000 All Programmable SoC. The kit features the Analog Devices AD-FMCMOTCON2-EBZ FMC high performance servo drive module, providing two axis motor drive up to 48 Volts at 20 Amps, precision motor phase current and voltage measurements, isolated power regulation, isolated signaling, and dual Gigabit Ethernet IEEE1588 PHYs for real-time Ethernet connectivity.

This Getting Started Guide describes the steps to set up the Zynq Intelligent Drives Kit II (ZIDK-II) and run the out-of-box demonstration.

For detailed information on ZedBoard, including tutorials, reference designs and board details please visit the website

- http://www.ZedBoard.org

For detailed information on the Analog Devices AD-FMCMOTCON2-EBZ FMC high performance servo drive module, including schematics, bill of materials, board file, and reference design source code please visit the wiki page.

- http://wiki.analog.com/resources/eval/user-guides/ad-fmcmotcon2-ebz

What's Inside the Box

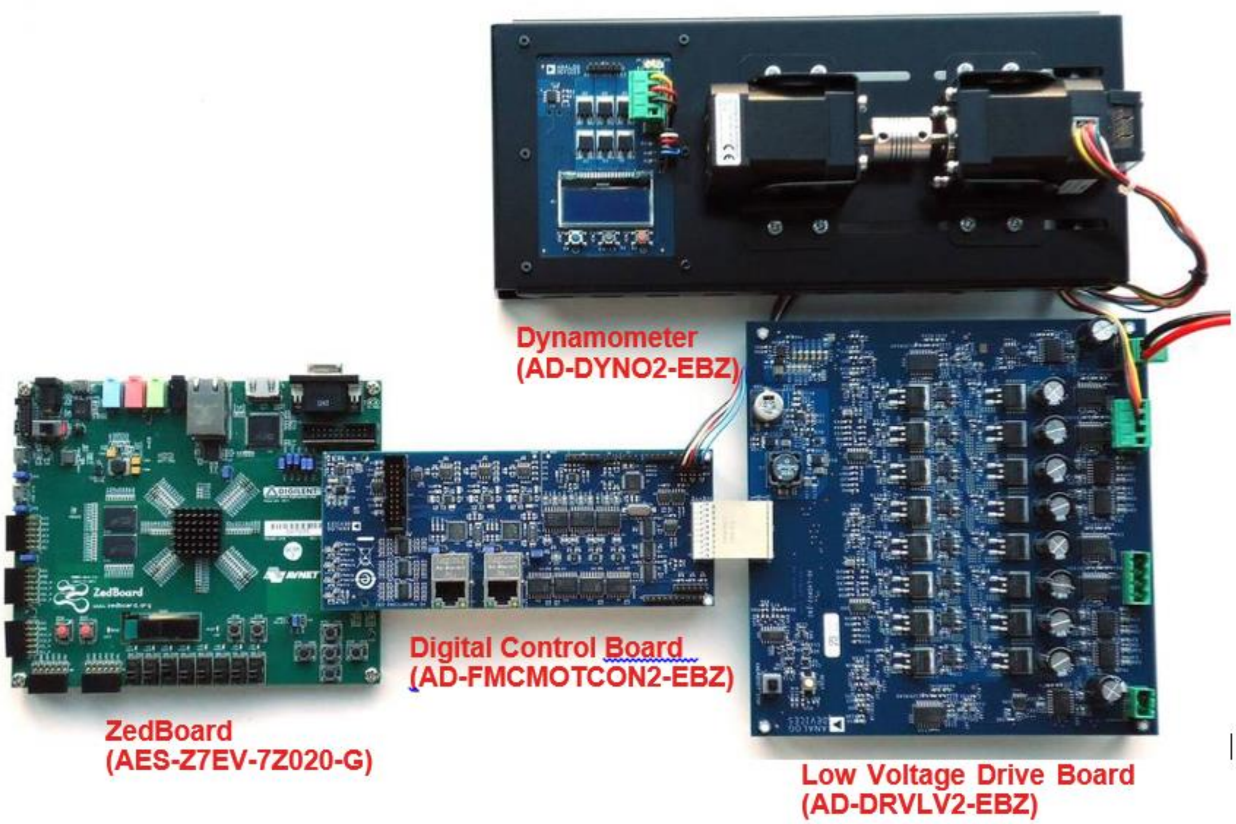
- Avnet ZedBoard 7020 baseboard
  - Zynq-7000 SoC XC7Z020-CLG484-1
  - 512 MB DDR3
  - 256 Mb Spansion® Quad-SPI Flash
  - Onboard USB-JTAG Programming
  - 10/100/1000 Ethernet
  - USB OTG 2.0 and USB-UART
  - FMC expansion (low pin count)
  - 12V power supply
  - Multiple display options (Analog Devices ADV7511 1080p HDMI, 12-bit VGA, 128 x 32 OLED)
  - 4 GB SD card programmed with a simple Linux image that demonstrates basic capabilities of ZedBoard
- Analog Devices high-performance servo FMC Module
  - Drive 2 BLDC / PMSM / Brushed DC / Stepper motors up to 48 V @ 20
  - AD7403 Isolated 20 MHz Σ-Δ modulators for precise voltage and current measurement
  - ADuM5000/7640 power and digital signal isolation
  - ADuM5230 Isolated Half-Bridge Driver for High Frequency Switching
  - Integrated over-current and reverse-voltage protection
  - Dual Gigabit IEEE1588 Ethernet PHYs for high speed industrial communication
  - Isolated Xilinx XADC interface
  - Sensored or sensoreless position measurement
  - Encoder support includes BISS, EnDAT, Hall Sensor, and resolver
  - 8 GB SD card programmed with ADI FMCMOTCON2 Base Reference Design
    - Zynq reference design for motor control featuring Analog Devices Ubuntu Linux framework

- FAT32 partition: bootloader, devicetree blob and kernel image for system boot to UBUNTU Linux
- EXT4 partition Linaro Ubuntu ARM root file system, Analog Devices IIO Oscilloscope

  - 24V power supply for FMC module motor drive stage

- Brushless DC motor
  - Hall Sensors and 1250 CPR indexed encoder
- Ethernet, HDMI, and USB cables
- USB dongle (male micro-B to female standard-A)
- Xilinx Vivado® Design Edition (device locked to XC7Z020)

- Optional Analog Devices Dynamometer
  - Included with AES-ZIDK2-ADI-DYNO-G
  - Provides a compact, dynamically adjustable load system
  - Includes one drive motor directly coupled to one load motor (generator)
  - Load motor is controlled by DYNO2 on-board electronics, or by direction connection to FMCMOTCON2



GETTING STARTED WITH ZYNQ INTELLIGENT DRIVES KIT II

The Zynq-7000 AP SoC / Analog Devices Intelligent Drives Kit II (ZIDK-II) comes with a 'Getting Started' motor control demonstration design flashed onto the 8GB SD card, which enables a single-board computer on the Avnet ZedBoard running UBUNTU desktop Linux. The system includes programmable logic-based interfaces and ARM-based Linux drivers for the Analog Devices High Performance Servo Solution on the FMC module.

Overview of the Motor Control Reference Design

The out-of-box reference design demonstrates Trapezoidal Control (6-step) of a 3-phase brushless DC motor. This controller executes in the Programmable Logic (PL) of Zynq, while Linaro Ubuntu Desktop Linux runs user applications on the Zynq ARM processors, and communicates with the Zynq PL via AXI4-Lite and AXI4 DMA channels.

Digital PWM signals are driven from the Zynq SoC to the MOSFET driver stage on the FMCMOTCON2 module in order to deliver power to the motor. For each motor, AD7403 Sigma-Delta modulators sample two analog motor phase currents and each DC voltage bus, returning serial digital bit streams to the Zynq SoC to be reconstructed with SINC3 low pass filters. The rotor position can be captured a variety of ways with the FMCMOTCON2 on-board circuitry, including rotary, Hall sensor, and resolver interfaces. In this reference design Hall Sensors communicate position to the Zynq SoC for absolute position and speed estimation. All signals between the Zynq SoC and FMCMOTCON2 are digitally isolated. Finally, an HDMI monitor, mouse, and keyboard may be connected to ZedBoard to view system signals and enter control parameters using the ADI IIO Oscilloscope Linux application. A block diagram of the system design is shown below.

More details about the design, including source code, can be found at:
http://wiki.analog.com/resources/eval/user-guides/ad-fmcmotcon2-ebz

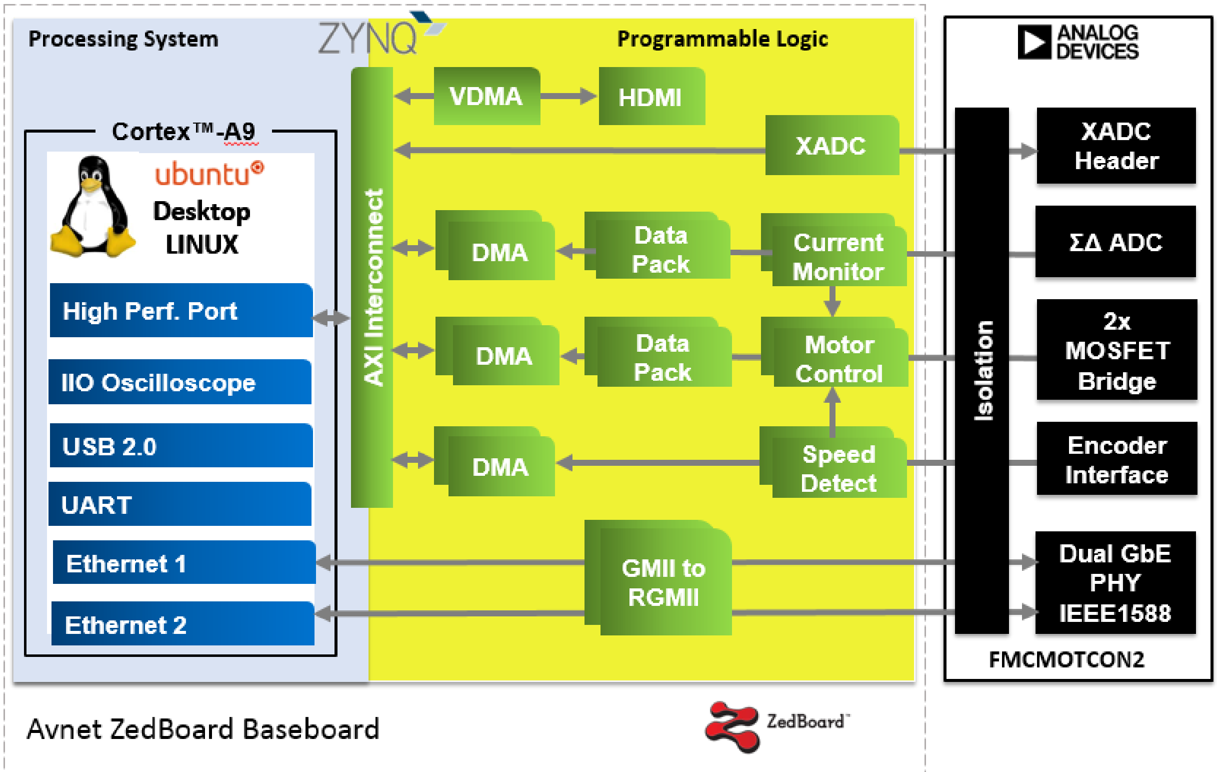


Figure 1 - Zynq Intelligent Drives Kit II Reference Design - Simplified Block Diagram

Current Monitor - Implements the communication with the AD7403 sigma delta modulators on the AD-FMCMOTCON2-EBZ and also the SINC3 filters for demodulating the 1-bit digital stream provided by these parts. This HDL block exposes a set of registers that can be accessed through the AXI Lite interface. A FIFO interface connected to a DMA controller allows the block to stream real time data to the application layer. An ADC PACK IP is used so that 1, 2 or all channels can stream data at a time.

Motor Controller - Implements the interface to the IP control blocks in the system. A FIFO interface connected to a DMA controller allows the block to stream real time data to the application layer. It implements a basic six point drive of the motor. An ADC PACK block is used so that 1, 2, 4 or all channels can stream data at a time.

Speed Detector - Implements the algorithm for converting Hall, BEMF and Encoder signals into speed and position data. This HDL block exposes a set of registers that can be accessed through the AXI Lite interface. A FIFO interface connected to a DMA controller allows the block to stream real time data to the application layer.

GMII to RGMII - Converts the GMII interface from the two Ethernet cores from the PS7 block to RGMII interface that is available on the FMC Controller Board. The IP allows for the RX pins to be on different I/O Banks.

Demo Preparations

The 8 GB SD card, labeled with Analog Devices logo, is factory-programmed with the Zynq firmware, Linux kernel image, user-space application software and file system for a stand-alone bootable system. There are several bootable Zynq designs on the SD card, so the first step is to copy the image for ZedBoard Motor Control into the boot directory.

1. Insert the SD Card labeled with Analog Devices logo into a laptop or PC.
2. Open the folder named z**ynq-zed-adv7511-fmcmotcon2**
3. Copy files **BOOT.BIN** and **devicetree.dtb** into the SD card root directory.
4. Safely eject the SD card and insert into ZedBoard (under FMC connector J1).

Note: the pre-formatted image on the SD card may be 6 or more months old. Therefore you will need to run an update script after the system is booted. This will be described in later steps.

Figure 2 - Insert the SD Card

Demo Requirements

Accessories required for this demonstration, which are not included in the kit:

- HDMI monitor and cable
- USB mouse
- USB keyboard
- USB hub (3 or more ports)

Hardware Setup

Follow these steps closely to connect and configure the hardware to run the design.

1. **IMPORTANT:** Set the ZedBoard FMC IO voltage jumper to 2.5V to avoid any damage to the AD-FMCMOTCON1-EBZ.

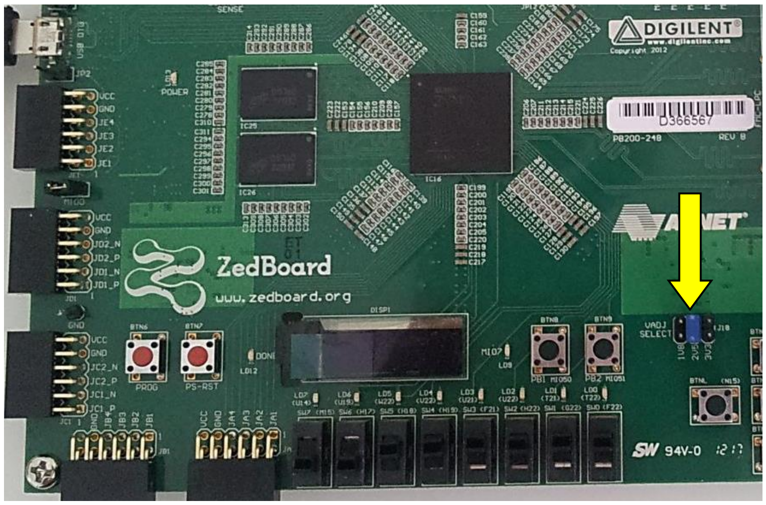


Figure 3 - Setting ZedBoard FMC IO Voltage to 2.5V

2. Set the ZedBoard boot-mode jumpers to boot from the SD card:

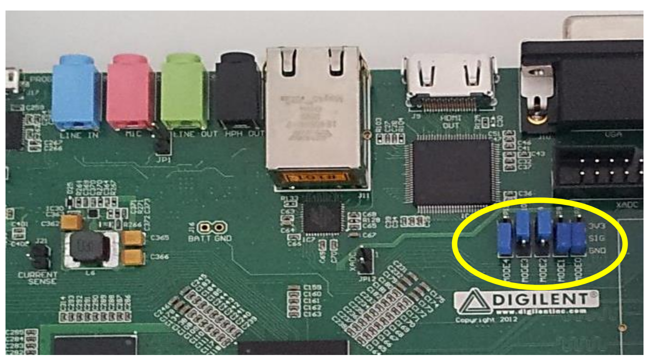


Figure 4 - Setting boot-mode jumpers to boot from the SD card

Assemble the kit as shown below:

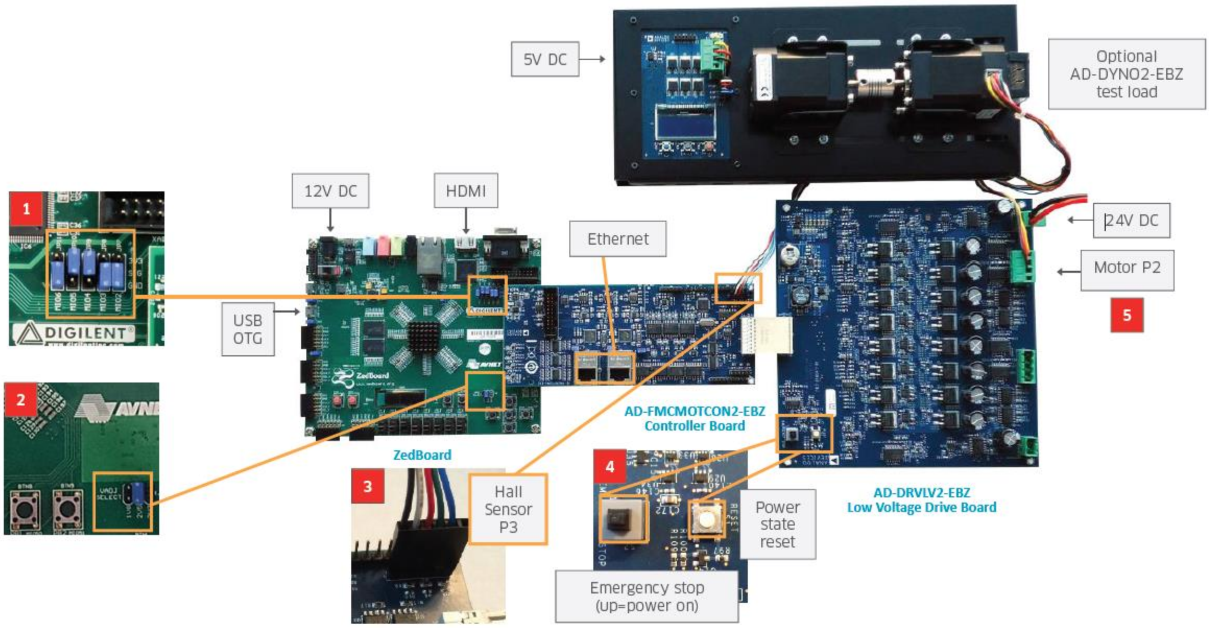


Figure 5 – Hardware Setup

3. Connect the power sources as shown
   - 12V DC plugs into ZedBoard
   - 24V DC plugs into FMCMOTCON1 module (P4)
   - optional**:** 5V DC plugs into the Dynamometer (P3 under the metal bezel)

4. Connect an HDMI cable to ZedBoard and a monitor with at least 720p resolution.

5. Connect the motor Hall Sensor and phase leads as shown in Figure 5-3. These connections are the same whether connecting a standalone motor or the motor housed in the AD-DYNO2-EBZ fixture. The 5-wire cable permanently attached the motor is connected to the internal Hall Sensors.

6. The FMCMOTCON2 emergency stop switch (S2) shown in Figure 5-4 must be toggled to the “UP” position to enable the power MOSFETs. Press the ‘Power Stage Reset’ once to clear the latch for the protection circuit.

7. Connect the included USB dongle to the USB OTG port, and then attach a USB mouse and keyboard through a USB hub (not included).

8. Provide internet connection by attaching the Ethernet cable to one of the ports on FMCMOTCON2 (P11 or P13) and a networked router with DHCP. This is required to download and install the latest design updates.

9. Turn ZedBoard power switch (SW8) to ON.

10. Wait approximately 45 seconds for Linux to boot and display on your monitor. The Analog Devices IIO oscilloscope application will launch automatically.

Updating the Reference Design [CRITICAL STEP]

The pre-formatted image on the SD card may be 6 or more months old. Therefore you will need to run a simple update script to retrieve the latest files from the ADI wiki. This will be performed in-system using Linux, which was booted on ZedBoard in the previous steps. The process takes more than a few minutes to complete, so please be patient.

The SD card contains a FAT32 partition with multiple boot files for different Zynq target platforms. The SD card also contains an ext4 partition containing the persistent Linux file system. Both partitions will be updated in the following steps.

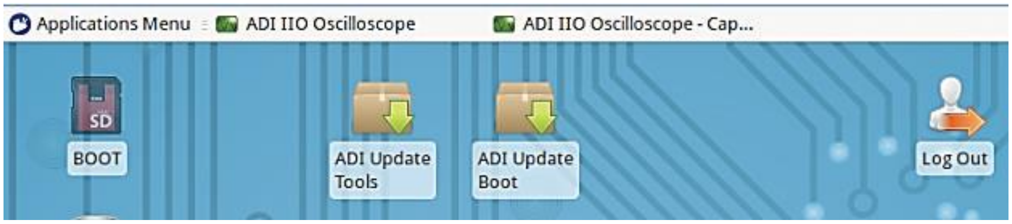


Figure 6 – Linux & Zynq Boot update application icons

1. Wait ~45 seconds for Linux to boot and display on your monitor.
2. Double-click the ADI Update Tools desktop icon to automatically download the latest version of ADI Linux applications.
3. Double-click the ADI Update Boot desktop icon to automatically download the latest version of Zynq boot files.
4. Restart the system using the Log Out desktop icon.

Note: If these steps fail it may indicate that your office firewall has blocked access to the ADI wiki site. In that case see the instructions at the end of this document for re-imaging your SD card with the most recent archive hosted on GitHub.

More details on this update process can be found on the Analog Devices wiki “Zynq Quick Start Guide” http://wiki.analog.com/resources/tools-software/linux-software/zynq_images

Running the Demo

With the ZIDK-II hardware connected and firmware updated you are ready to run the Zynq motor control design.

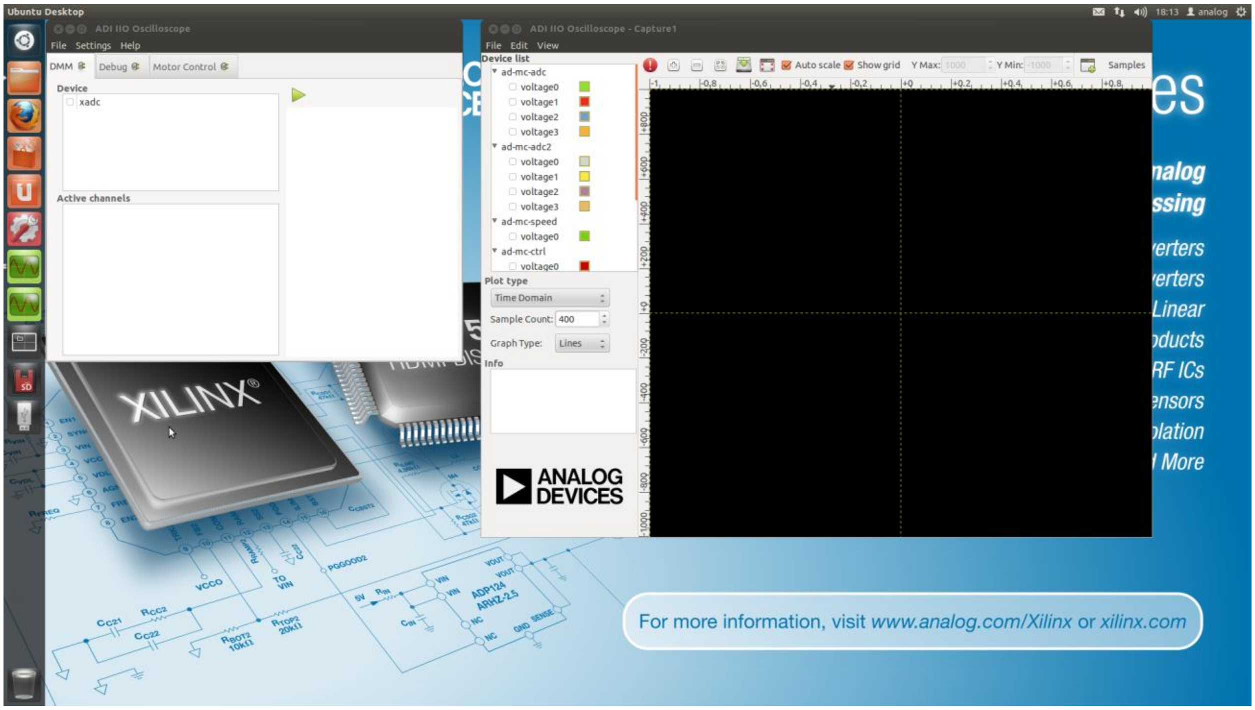


Figure 7 – Linux Desktop with ADI IIO Oscilloscope

1. In the **ADI IIO Oscilloscope** window select the **Motor Control** tab.
2. If the included BLY171 or BLY172 motor is connected, be sure to check the box for a Delta wound motor.

   Note: in this example, only one motor will be driven however 2 motors may be controlled with this design.

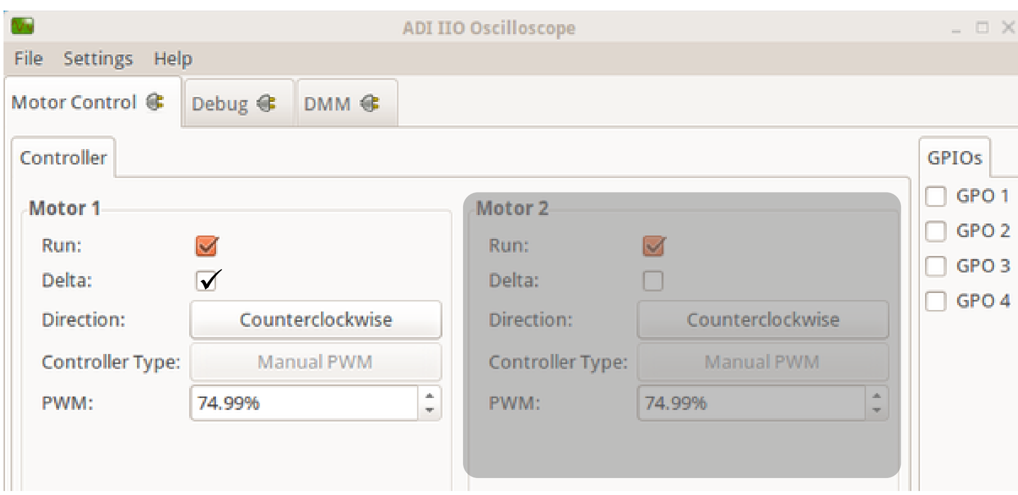


Figure 8 – Controlling the motors with IIO Oscilloscope

3. Check the '**Run**' box in the IIO Scope to start the motor spinning in open loop, under control of the 6-step HDL code running in the Zynq PS.

   NOTE: If the motor does not start spinning, verify that step 6 in *Hardware Setup* was completed (Emergency stop is UP; press Power Stage Reset once)

4. Control the PWM rate delivered to the motor by using the up/down arrows or entering a % value in the box.
5. In the **ADI IIO Oscilloscope – Capture 1** window select the voltage samples to display.

ad-mc-adc	voltage 0	Not used
	voltage 1	motor 1, phase current IA
	voltage 2	motor 1, phase current IB
	voltage 3	motor 1, DC voltage VBUS
ad-mc-speed	voltage 0	Motor 1 speed. Number of counts in 10ns units between two motor commutations. In order to display the speed in RPM, right-click on voltage 0 and check the 1/x option and multiply by 25.000.000
ad-mc-ctrl		Not used

6. Press the **Capture/Stop** button to begin sample acquisition.

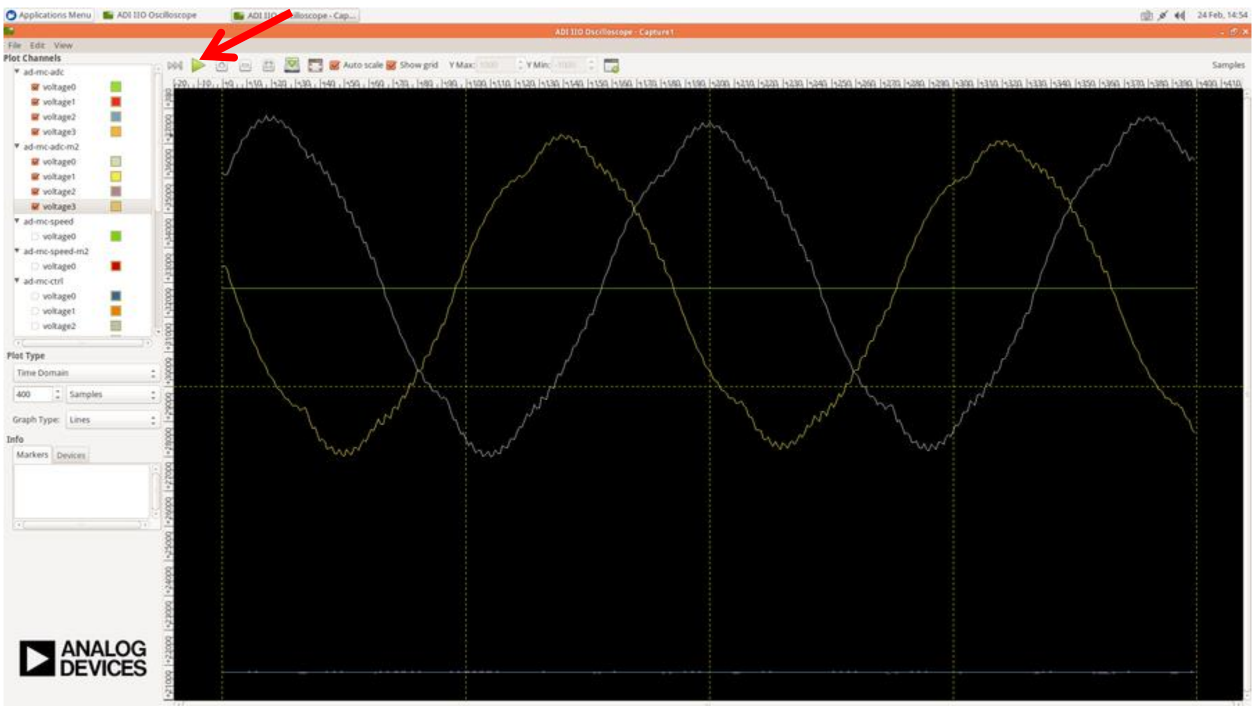


Figure 9 - ADI IIO Oscilloscope waveform viewer

Dynamometer (optional)

A compact dynamometer ("dyno") may be purchased with the Zynq Intelligent Drives Kit II. The dyno provides a test fixture to dynamically apply a load to the motor. A 3-phase MOSFET bridge, under command of an integrated digital controller, adjusts the resistance seen at the phase leads of the load motor. Optionally, the load motor may be connected to FMCMOTCON2 to be directly driven from Zynq. An LCD and 3 push buttons on board the dyno provide a user interface to dynamically change load profiles and view measurement of the load motor speed and current. More details, including schematics, bill of materials, and board files can be found at the Analog Devices wiki.

- http://wiki.analog.com/resources/eval/user-guides/ad-fmcmotcon2-ebz/hardware/dyno

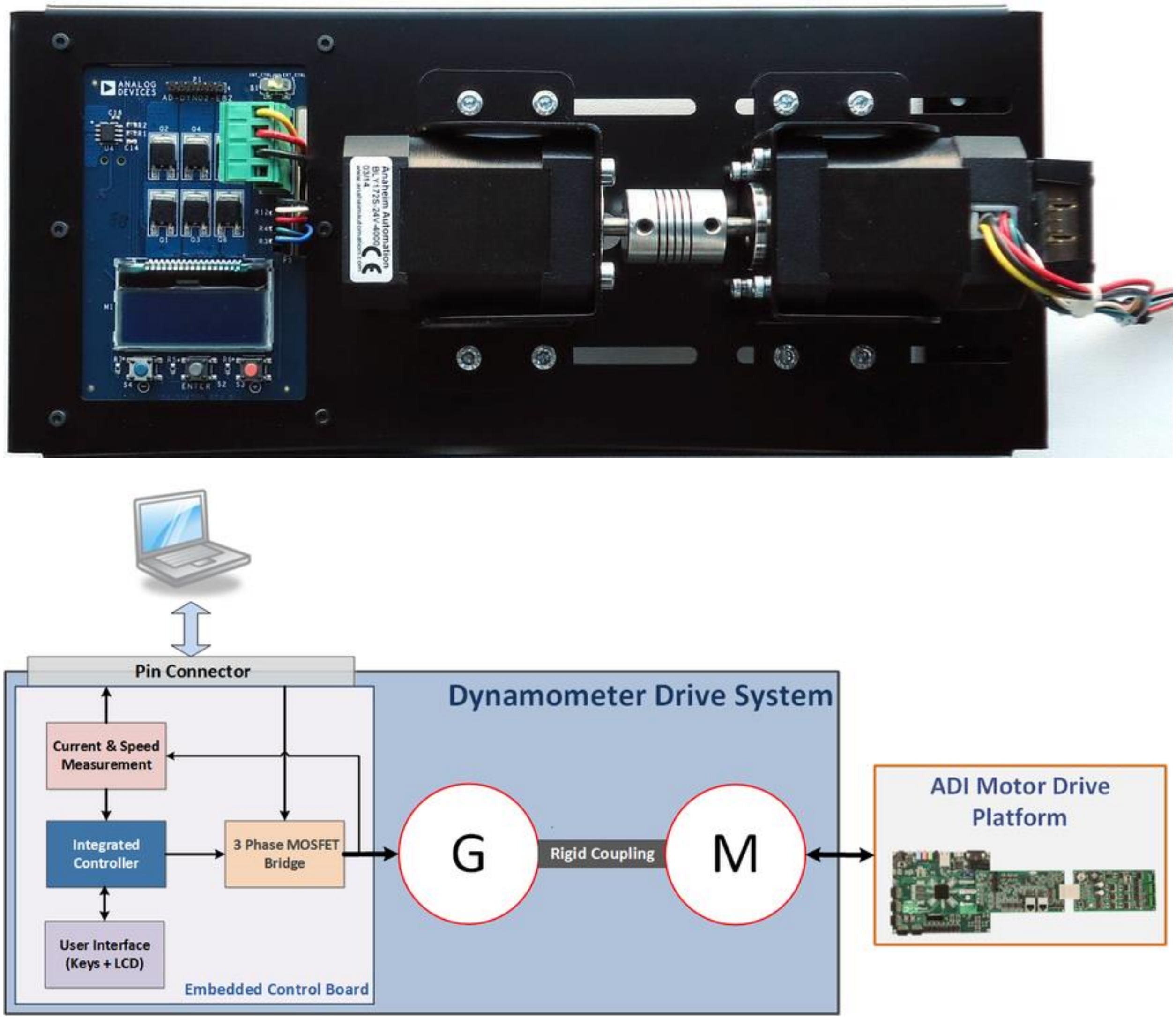


Figure 10 - Dyno2 Image and System Diagram

In order interface the Dyno with external control signals:

- Slide switch S2 to EXT_CTRL position
- Connect to the P1 header pins

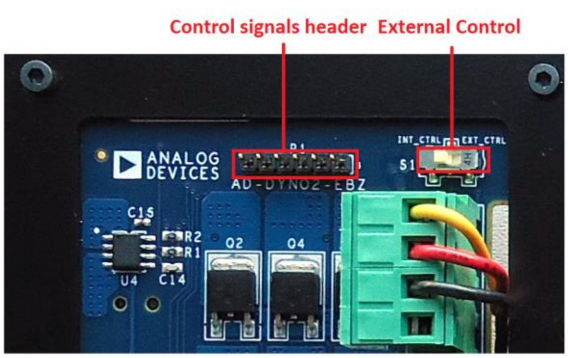


Figure 11 - Dyno2 Connections

The signals available to the Analog Discovery are:

Dyno Signal	Description
I_A	Phase A motor current (185mv/A)
I_B	Phase B motor current (185mv/A)
PWM1	Phase A PWM (3.3V levels)
PWM2	Phase B PWM (3.3V levels)
PWM3	Phase C PWM (3.3V levels)

Congratulations!

You have now run the Getting Started demonstration with the Zynq-7000 AP SoC / Analog Devices Intelligent Drives Kit II. Using this fully functional framework with embedded LINUX, you may now develop your motor control applications.

For more detailed information about the Analog Devices AD-FMCMOTCON2-EBZ module or this reference design, please visit their User's Guide wiki at:

http://wiki.analog.com/resources/eval/user-guides/ad-fmcmotcon2-ebz

Restoring the SD Card image

During the course of development, should the 8 GB SD card become corrupted or otherwise need to be restored to a known good state, the directions below will restore the factory image.

These steps will overwrite the contents of the SD card, so be certain that there is no existing data that needs to be retrieved from the SD card prior to following these steps.

The following directions were performed on a Windows 7 Professional machine, but the commands should work in a similar manner with later versions of Windows.

1. Download the image archive from the Analog Devices wiki site listed below. The instructions in this document assume that the archive is downloaded to a temporary folder which on this example system is under the **`C:\work\`** directory.

   http://wiki.analog.com/resources/tools-software/linux-software/zynq_images

2. Power down ZedBoard and remove the 8 GB SD card. Insert the SD card into the Windows PC.

   Note: The provided image file is a byte-for-byte copy of an 8 GB SD card. Ensure the size of your target SD card is an 8 GB device.

3. Open a Windows Command Prompt session with Administrator privileges by right clicking the **Start→Accessories→Command Prompt** menu item and selecting the **Run as administrator** option.

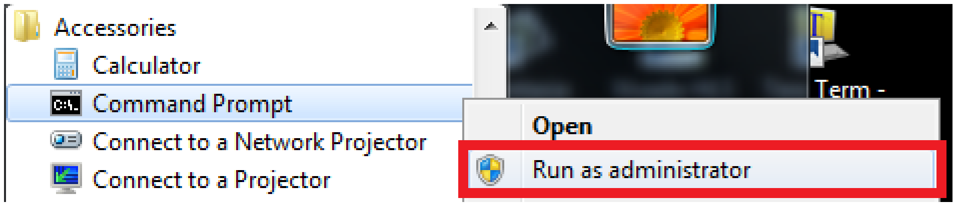


Figure 12 - Opening the Windows Command Prompt with Administrator Privileges

4. If multiple partitions exist on the SD card, each of the partitions should be removed using the **diskpart** utility. This will enable the entire SD card block range to be utilized for writing the image. Launch the **diskpart** tool from the Windows Command Prompt.

```
> diskpart
```

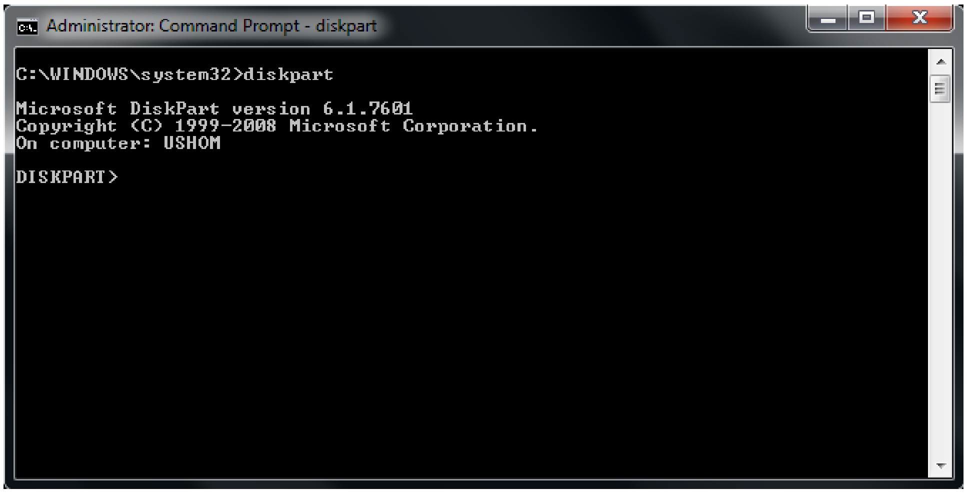


Figure 13 - Launching Microsoft DiskPart

5. Discover the disk number of the SD card device by using the **list disk** DiskPart command. In this example, the SD card device is enumerated as the **Disk 1** device.

```
DISKPART> list disk
```

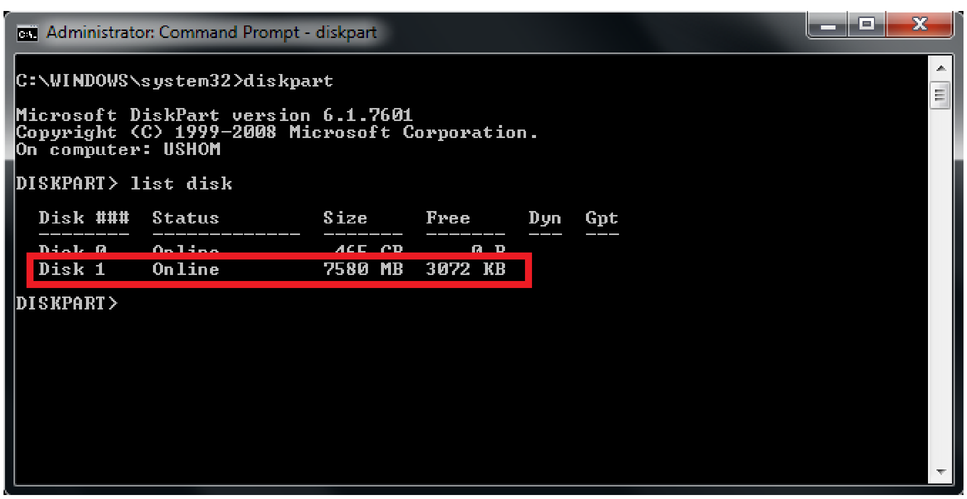


Figure 14 - Listing the Enumerated Disk Devices

6. Select the disk listing that matches the SD card device using the **select disk** DiskPart command. In this example, the SD card device is enumerated as the **Disk 1** device. If the SD card is listed as a different disk on your system, be sure to substitute the appropriate value here.

   WARNING: Selecting the incorrect disk at this point can corrupt critical data on your local machine, be sure to check that the selected disk value is the intended device.

```
DISKPART> select disk 1
```

7. List the partitions on the currently selected SD card using the **list partition** DiskPart command.

```
DISKPART> list partition
```

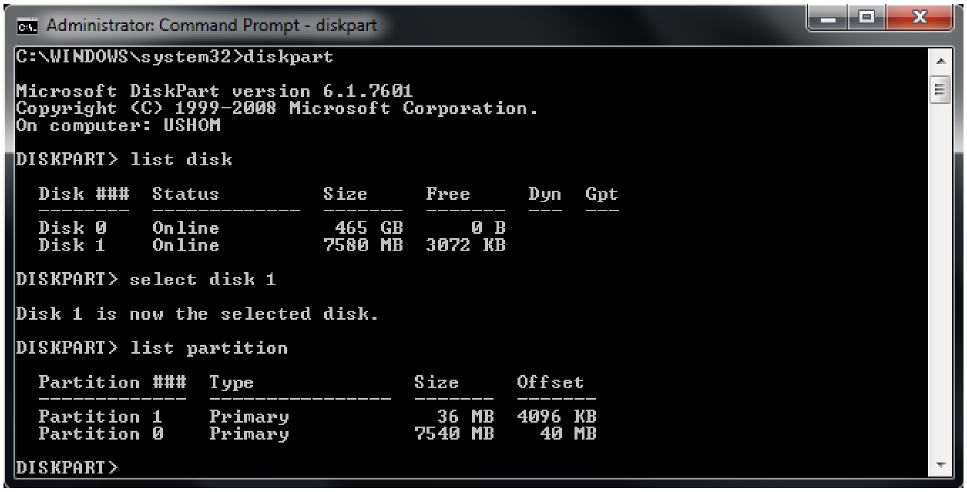


Figure 15 - Listing the Partitions on the Selected SD Card

8. Remove the partitions from the currently selected SD card using the **clean** DiskPart command.

```
DISKPART> clean
```

9. Exit the DiskPart tool.

```
DISKPART> exit
```

10. Extract the image contents of the archive obtained from Step 1 above using an **xz** compatible utility such as 7-Zip.

11. Launch a disk imaging utility such as Win32 Disk Imager.

12. Select the source image file, for example **2014_R2-2015_04_24.img,** and choose the target drive device. In this example, the image is located in the **C:\work** folder and the target SD card is assigned to the **G:** drive.

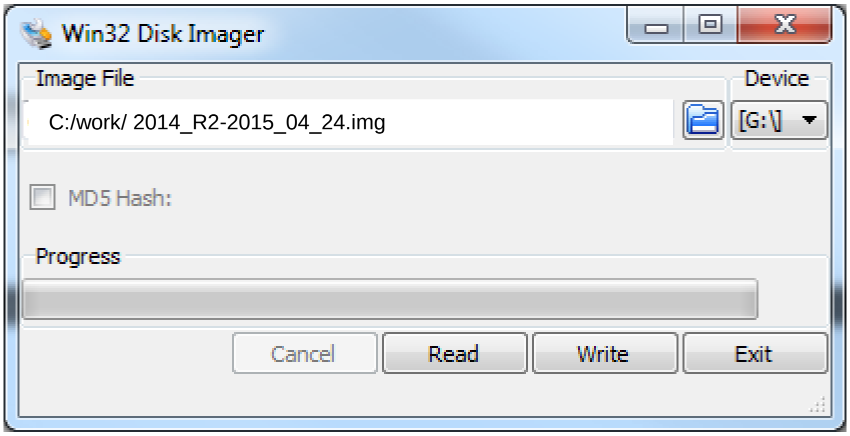


Figure 16 - Source Image File Selected

13. (Optional) Verify the integrity of the extracted image file using the Win32 Disk Imager **MD5 Hash** tool by clicking on the checkbox option. The checksum calculation may take a few minutes.
14. Click the **Write** button to begin writing the source image file contents to the SD card. The SD imaging process can take around 20 to 30 minutes to complete the 8GB transfer.
15. Use Windows "safely remove" to eject the SD card.

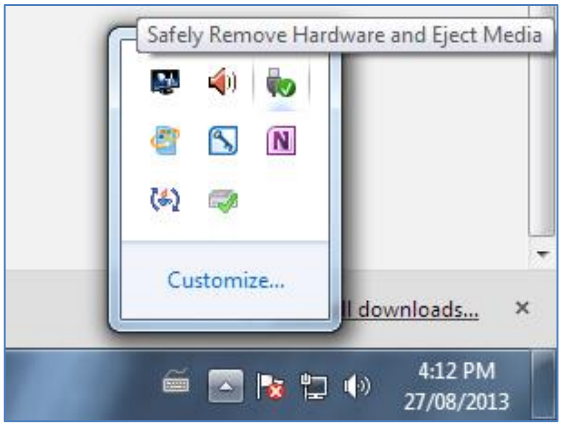


Figure 17 - Windows "safely remove" to eject the SD card

This concludes the procedure of re-imaging the SD card. Return to the beginning of this document for instructions on preparing and running the design.

Additional Documentation and Support

To access the most current collateral for the Zynq-7000 SoC / Analog Devices Intelligent Drives Kit II please visit the product website:

http://zedboard.org/product/zynq-idk-ii

http://www.em.avnet.com/zynq-idk-ii

To access the Avnet Technical Community Forums, please visit the following web page:

http://www.zedboard.org/support

Analog Devices AD-FMCMOTCON2-EBZ high-speed analog module user guide and wiki:

http://wiki.analog.com/resources/eval/user-guides/ad-fmcmotcon2-ebz

To search the Xilinx database of silicon and software questions and answers or to create a technical support case in WebCase, see the Xilinx website:

http://www.xilinx.com/support

Next Steps

Ensure Xilinx Vivado Design Edition is installed on your computer. A voucher for licensing the Xilinx software is included with this kit. For technical support, including the installation and use of a product license file, contact Xilinx Online Technical Support at http://www.support.xilinx.com

Download Zynq embedded system source files for this Getting Started demonstration design as a starting point for your system customization.[1]

http://wiki.analog.com/resources/eval/user-guides/ad-fmcmotcon2-ebz

Consult the Zynq-7000 SoC / Analog Devices Intelligent Drives Kit II product website for notification of technical training.

- http://zedboard.org/product/zynq-idk-ii

[1] Zynq embedded system source files are available for subsequent customization of the reference design, but are not required to run this Getting Started demonstration. The system is stand-alone bootable from the SD card provided with the kit, which includes the bitstream within the BOOT.BIN file in the FAT32 partition.