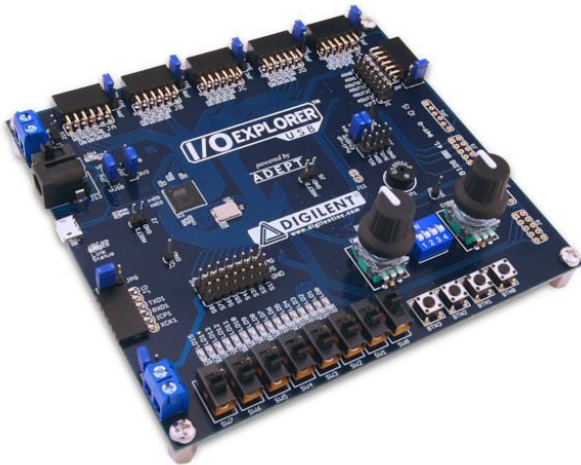# I/O Explorer™ USB Reference Manual
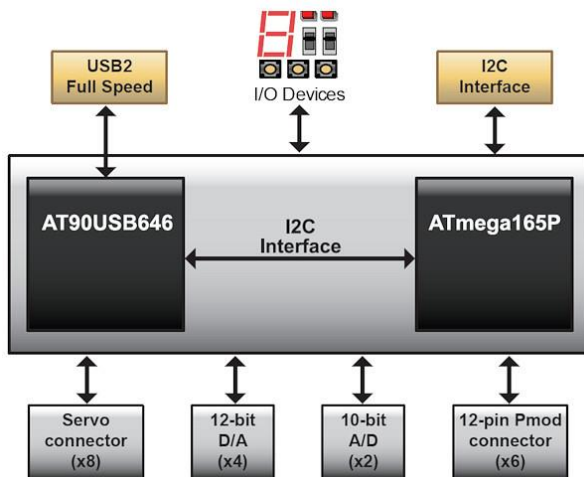
Revised April 15, 2016
This manual applies to the I/O Explorer USB rev. C

Overview

The Digilent I/O Explorer USB is a USB peripheral device that allows programmatic access from a personal computer to various external Input/Output (I/O) devices.

Features include:

- Two Atmel AVR microcontrollers: AT90USB646 and ATmega165P
- USB 2.0 Full Speed device
- Fully software compatible with the Digilent Adept Runtime system
- C/C++/C#/Visual Basic callable API set using the Digilent Adept System Software Developer's Kit (SDK)
- 5 12-pin and 1 6-pin Pmod ports
- 16 discrete LEDs
- 8 slide switches
- 4 push button switches
- 4 position DIP switch
- 2 rotary encoders with integral push button
- speaker/buzzer
- Two 10-bit A/D inputs
- Four 12-bit D/A outputs
- Up to 52 digital input/output pins
- Connectors for up to 8 RC servos
- 1 hardware SPI master port
- Up to 3 additional software SPI master ports
- UART interface port
- Provision for 4 additional RC servos using Digilent PmodCON3
- Provision for 2 additional quadrature encoders via Pmod port
- Provision for up to 8 additional 10-bit A/D inputs using servo connectors
- Multiple power supply options, including USB powered
- ESD protection and short circuit protection for all I/O pins.

The I/O Explorer board.

I/O Explorer USB block diagram.

Using the Digilent Adept Software Developer's Kit (SDK) and the Digilent Adept Runtime System it is possible to write application programs running under either the Microsoft Windows or Linux operating systems that perform

various kinds of I/O operations to devices on the I/O Explorer board itself, or through the I/O Explorer to devices external to the computer.

The I/O Explorer provides a number of I/O devices on the board itself, as well as RC servo connectors, and Digilent Pmod ports that allow access to devices external to the I/O Explorer.

In addition to its use as a dedicated USB peripheral device, the I/O Explorer can also be used as a microcontroller development board. It features two Atmel AVR microcontrollers, one having USB device capability. Digilent makes available the firmware images needed to restore it to the factory configuration as a USB peripheral device if it has been reprogrammed with user defined firmware.

1   Functional Description

The Digilent USB I/O Explorer is a microcontroller board that is designed to be used as a USB peripheral device to expand the I/O capabilities of a PC running either the Microsoft Windows operating system or the Linux operating system. The Digilent Adept Software System provides the run-time software for operation of the board, and the Digilent Adept Software Development Kit (SDK) allows the user to write custom application software to access and control its features. The Digilent Adept SDK comes with a variety of sample programs that illustrate operation of various features of the I/O Explorer.

The I/O Explorer provides a number of built-in I/O devices, such as switches, push buttons, LEDs, rotary encoders, and a speaker/buzzer. It also provides a number of connectors that allow access to and control of devices external to the I/O Explorer.

Operation of the I/O Explorer board as a Digilent Adept compatible device requires the installation of the Digilent Adept software available for download from the Digilent web site: www.digilentinc.com. In addition to downloading and installing the Digilent Adept software, the Digilent Adept SDK must be downloaded and installed in order to make effective use of the board.

In addition to the Digilent Adept SDK, the user will require some software development tool that allows writing application programs on the target operating system. The Digilent Adept System uses the C programming language calling conventions and any development tool that provides the ability to call C functions in a DLL (on Windows) or a shared library (on Linux) can be used. Some version of Microsoft Visual Studio is commonly used on Windows, and some version of the GCC tool chain is normally used on Linux.

In addition to the primary design purpose of being a dedicated USB peripheral device, the I/O Explorer can also be used as a microcontroller development board. The I/O Explorer contains two Atmel AVR microcontrollers: IC1, the primary microcontroller is an AT90USB646 AVR microcontroller with USB capability; IC2, the secondary microcontroller is an ATmega165P AVR device.

Development of custom firmware to run on the I/O Explorer requires the use of some development tool that supports the Atmel AVR microcontroller family. The most common tool used is the free Atmel AVR Studio IDE and assembler available for download from the Atmel web site. The free GCC based WinAVR C compiler system can be used with Atmel's AVR Studio and provides a very powerful C language programming environment. WinAVR is available for free download from the internet from various sources.

In addition to the development tool software, using the I/O Explorer as a microcontroller development platform requires a programming cable, or in-system-debugger to load the user firmware into the microcontroller. The I/O Explorer is designed to allow use of the Atmel JTAG-ICE mk II or the Atmel AVR Dragon for in-system debug. In-

system programming is normally accomplished using a Digilent programming cable, either the Digilent JTAG-USB Programming Cable, or the Digilent JTAG-USB Full Speed Module. The use of an Atmel ISP In System Programmer is also supported with the use of a suitable flying-lead cable (e.g. Digilent 6 Pin MTE Cable) to convert from the Digilent 1x6 programming connector convention to the Atmel 2x3 connector convention.

For additional information useful in developing custom firmware for the board, the complete schematic is available on the Digilent web site.

2   Power Supply

The I/O Explorer may be used either as a USB bus powered device or as a self powered device. Jumper JP6 is used to select between these two options. Install a shorting block in the VUSB position for USB bus power. Install a shorting block in the VEXT position for self power.

Power switch, SW10, is used to turn board power on or off. Ensure that the power switch is in the ON position to operate the board.

When operating as a bus powered device, care should be taken in powering devices external to the I/O Explorer. The 5V USB bus power supply is available at the Pmod ports and other points on the board. Care should be taken not to exceed the 500mA current limit that USB bus powered devices are allowed to consume. Care should particularly be taken not to short the USB 5V supply to ground or external voltage supplies as this could result in damage to the USB hub or PC motherboard to which the I/O Explorer is connected.

When operating as a self powered device, there are three power supply connectors on the I/O Explorer for connecting the external power supply: J13, J14, and J15. These three connectors are wired in parallel and only one of the three should be used at a time.

The barrel connector, J13, will normally be used for desktop applications as a self powered device. J13 is the connector used by the AC supply adapter optionally available from Digilent, or other sources. J13 is a 2.5mm x 5.5mm coaxial connector wired with the center terminal as the positive voltage.

J14 is a screw terminal connector for use with higher current battery packs, bench supplies or other power sources where use of a hard wired power supply is desirable.

J15 is a two-pin male header that provides easy battery or battery-pack connection. Digilent has both two-cell and four-cell AA battery holders with two pin connectors available for connection to J14.

The main operating voltage of the I/O Explorer can be selected between one of two voltages. Jumper JP7 is used to select between these two voltages. With JP7 in the 3V3 position, the main board power bus is powered from the output of the 3.3V main power supply regulator on the board. When JP7 is in the 5V0 position, the main power supply regulator is bypassed, and the main board power bus is powered directly from the applied supply voltage. When operating as a USB bus powered device, this will be the USB bus 5.0V power supply. When operating as a self powered device, this will be the voltage of the external supply. In this case, the external supply should not exceed 5.5V or damage to the board will result.

The main power supply regulator on the I/O Explorer is rated for external power from 3.6 to 9 volts DC. Using a voltage outside this range could damage the board and connected devices.

The I/O Explorer has a second screw terminal connector, J10 that supplies power to the servo power bus, VS, to power the RC hobby servo connectors. This allows servos to be powered from a separate power supply than the

one powering the electronics on the I/O Explorer. This can be useful when using servos that require large amounts of power. See the section on Servo Connectors below for a discussion of the options available for powering the VS bus.

Jumper JP3 can be used to connect the I/O Explorer unregulated power bus VU to the servo power bus, VS. When no shorting block is installed on JP3, the VU and VS busses are separate. When a shorting block is on JP3, the two busses are joined and the VU bus can be powered in any of the previously indicated ways, or from connector J10.

The I/O Explorer can provide power to any peripheral modules attached to the Pmod ports and to I2C devices powered from the I2C daisy chain connector, J12.

Each Pmod port provides power pins that can be powered from either unregulated voltage, VU, or regulated voltage, 3V3, by setting the voltage jumper block to the desired position. Note that when the operating voltage select jumper JP7 is in the 5V0 position, the USB or external power supply voltage will be supplied to the Pmod ports regardless of the position of the voltage select jumpers at the connectors.

The I2C power connectors provides 3.3V when the main board operating voltage (selected by JP7) is 3.3V, or the external supply voltage when JP7 is in the 5V0 position.

The 3.3V supply provided to the Pmod and I2C connectors is provided by the onboard voltage regulator. This regulator is capable of providing a maximum of 500mA of current. The circuitry on the I/O Explorer will consume less than 100mA in normal operation. The remaining current is available to provide power to attached Pmod and I2C devices. The regulator is on the bottom of the board, near the power connectors, and will get warm when the amount of current being used is close to its limit.

3   USB Operation

When operating using the normal factory firmware, the I/O Explorer functions as a USB 2.0 compliant full speed device. Normal operation requires installation of the Digilent Adept Runtime software system, and it is accessible to applications software developed using the Digilent Adept Software Developer's Kit (SDK). The Digilent Adept Software Developer's Kit and the Digilent Adept Runtime system is available for download from the Digilent web site: www.digilentinc.com

By replacing the factory firmware with end-user developed firmware, the I/O Explorer can function as a user defined USB device.

The primary microcontroller (AT90USB646) contains a USB 2.0 Compliant, Full Speed Device controller. Refer to the Atmel data sheet for the AT90USB646 and the USB 2.0 Specification for information on developing USB device firmware.

4   On-board I/O Devices

The I/O Explorer provides the following I/O Devices on the board:

- 8 Slide switches
- 4 Push button switches
- 4 Position DIP switch
- 16 Discrete LEDs

- 2 Rotary encoders with integral push buttons
- Speaker/Buzzer

When operating the I/O Explorer using the factory firmware, these devices are accessible using the DGIO API set as described in the DGIO Programmer's Reference Manual contained in the Digilent Adept SDK. Refer to the section Digilent Adept Port Descriptions below for details on the ports used for access to the on-board I/O devices.

5 Pmod Ports

The I/O Explorer has six Pmod ports for connecting Digilent peripheral modules. There are two styles of Pmod ports: six-pin and twelve-pin. Both ports use standard pin headers with 100mil spaced pins. The six-pin ports have the pins in a 1x6 configuration, while the twelve-pin ports use a 2x6 configuration. The six-pin ports provide four I/O signals, ground, and a switchable power connection. The twelve-pin ports provide eight I/O signals, two power, and two ground pins. The twelve-pin ports have the signals arranged so that one twelve-pin port is equivalent to two of the six-pin ports. The power connection is switchable between the regulated 3.3V main board supply and the unregulated input supply.

When operating the I/O Explorer using the factory firmware, the Pmod ports are accessible via a number of the API sets provided by the Digilent Adept SDK. In addition to the other ways that they can be used, the I/O pins on the Pmod ports can be accessed for direct pin input or output using the DPIO API functions described in the DPIO Programmer's Reference Manual contained in the Digilent Adept SDK. Refer to the section Digilent Adept Port Descriptions below for information on the various ways that the Pmod ports are used.

Digilent Pmod peripheral modules can either be plugged directly into the ports on the I/O Explorer or attached via cables. Digilent has a variety of Pmod interconnect cables available.

See the "Connector and Jumper Block Pinout Tables" section below for more information about connecting peripheral modules and other devices to the I/O Explorer. These tables describe the relationship between the various Adept software interfaces and the signals available on the connector pins.

6 Analog Inputs and Outputs

The I/O Explorer provides analog input channels and analog output channels via Analog to Digital (A/D) and Digital to Analog (D/A) converters on the board. When using the factory firmware, these analog inputs and outputs are accessed using the DAIO API functions provided by the Digilent Adept SDK and described in the DAIO Programmer's Reference Manual.

The A/D converters for the analog input channels are provided by the built-in A/D converters in the two microcontrollers.

The two analog input channels accessible through DAIO port 0 are provided by the A/D converter in the primary microcontroller. This port supports single sample input mode as well as continuous sampling input mode. These two analog input channels have input protection diodes to protect from out-of-range input voltages and band limiting input filters with a cutoff frequency of 2Khz. This port supports sample rates up to 4K samples per second.

This analog input port supports two selectable internal voltage references (2.56V and 3.3V) as well as an external reference that can be applied to the AREF1 pin on connector J2.

The analog inputs for DAIO port 0 are accessed via connectors JF and J1.

The eight analog input channels accessible through DAIO port 1 are provided by the A/D converter in the secondary microcontroller. This port supports only single sample input mode. The inputs on this port are available using the servo connectors S1-S8. These connectors and the corresponding I/O pins on the microcontroller are shared between DAIO port 0, DPIO port 6, and DEMC port 3.

This analog input port supports two selectable internal voltage references (1.1V and 3.3V) as well as an external reference that can be applied to the AREF2 pin on connector J5.

The four analog output channels accessible through DAIO port 2 are provided by a Microchip MCP4728 serial D/A converter. This port supports only single sample output mode. The analog outputs for DAIO port 2 are accessible via connectors JF and J1.

This analog output port supports two selectable voltage references (2.048V and 3.3V).

7   UART Interface

The I/O Explorer provides a Universal Asynchronous Receiver/Transmiter (UART) interface for asynchronous serial communications.

The I/O signals for the UART interface are provided on Pmod connector JG. When using the factory firmware, the UART interface is accessed using the DACI API functions provided in the Digilent Adept SDK and are described in the DAIO Programmer's Reference Manual. The UART interface is accessed as DACI port 0.

The signals provided at connector JG are logic level signals. If RS232 signal levels are required, a Digilent PmodRS232 can be attached to connector JG to provide the level translation and a DB9 connector for connection to standard RS232 serial devices.

8   RC Servo Connectors

The I/O Explorer provides eight 3-pin RC hobby servo connectors for direct control of servos in embedded hardware actuator applications. The servo connectors are labeled S1-S8 and are accessible via the Adept system DEMC servo interface. When programmed directly, the servo connectors are connected to the secondary microcontroller. The servo connectors S1-S8 are accessible via DEMC port 3.

In addition to the on-board servo connectors, a second servo port, DEMC port 4, provides four additional servo channels. This servo port can be used with a Digilent servo connector module, PmodCON3, connected to pins 7-12 of Pmod connector JE.

RC servos use a pulse width modulated signal, PWM, to control the servo position. When directly programming the secondary microcontroller, the servo connectors on the I/O Explorer board are intended to be driven using timer interrupts rather than directly by the pulse width modulators in the internal timers. Digilent has a reference design available that illustrates using timer interrupts to control signal timing for the PWM signals to control RC servos.

There are three power options for servo connections: a common power bus (VU) for the I/O Explorer and servos; separate on-board power busses for the I/O Explorer (VU) and the servos (VS); or an on-board power bus for the I/O Explorer (VU) an external power bus for servos.

For the first case above: Install a shorting block on JP3 to connect the VS servo power bus to the VU power bus. The servo power bus is then powered from the same source as the VU power bus. Powering a large number of servos from USB power is not recommended. USB should only be used to power a couple of servos to avoid exceeding the 500mA that a USB device is allowed to use.

For the second case above: Remove the shorting block from jumper JP3 to make the VS servo power bus independent from the VU bus. In this case, the VS bus is powered from screw terminal connector J10.

Finally, for very high servo current applications, a separate power bus external to the I/O Explorer can be used to provide servo power. In this case, remove the shorting block on JP1, tie the external servo power bus ground to the I/O Explorer ground through the ground terminal on J10, and use pin 1 on the servo connectors to bring the servo control signals out to the servos. The servo power and ground connections are made off-board.

The on-board servo power bus can be used to provide a maximum of 2A to each servo connector and 5A total to all servo connectors.

9   Digilent Two Wire Serial Interface (DTWI)

The Digilent Two Wire Serial Interface (DTWI) provides a medium speed serial comunications interface compatible with the Inter-Integrated Circuit (I2C™) Interface defined by Philips. The I2C interface provides master and slave operation using 7 bit device addressing. Each device is given a unique address, and the protocol provides the ability to address packets to a specific device or to broadcast packets to all devices on the bus.

Access to the DTWI bus is provided using the DTWI API functions as described in the DTWI Programmer's Reference Manual in the Digilent Adept SDK.The DTWI connector, J12, provides two positions for connecting to the I2C signals, power and ground. By using two-wire or four-wire MTE cables (available separately from Digilent) a daisy chain of multiple I2C-compatible devices can be created.

The I2C bus is an open-collector bus. Devices on the bus actively drive the signals low. The high state on the I2C signals is achieved by pull-up resistors when no device is driving the lines low. One device on the I2C bus must provide the pull-up resistors. The I2C bus on the I/O Explorer provides selectable pull-up resistors that can be enabled or disabled via jumper blocks JP4 and JP5. The pull-ups are enabled by installing shorting blocks and are disabled by removing the shorting blocks. The shorting blocks are placed so that they line up with the SCL and SDA labels on the board. Only one device on the bus should have the pull-ups enabled.
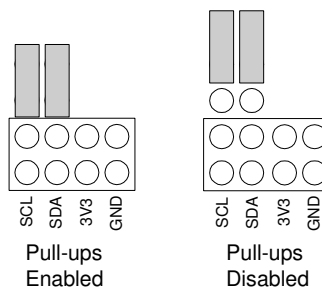
Jumper settings for I²C pull-up resistors.

10 Private I²C Bus

When the I/O Explorer is operating using user developed firmware in the primary microcontroller, there is a private I2C bus controlled by the primary microcontroller that is used to talk to two peripheral devices: The secondary microcontroller, and the Microchip MCP4728 Digital to Analog (D/A) converter.

When running the factory firmware in the secondary microcontroller, this microcontroller appears as an I2C slave device on the private bus. The command protocol for this interface is described in the document: Digilent I/O Explorer Slave Device Communications Protocol available on the Digilent web site. This document is contained in the reference design example that illustrates the used of the command protocol to talk to the secondary microcontroller. The primary microcontroller can send commands to the secondary microcontroller for access to many of the on-board I/O devices, such as the switches, push buttons, LEDs, etc.

In addition to the secondary microcontroller, there is also a Microchip MCP4728, four channel, D/A converter on the private I2C bus. When using the factory firmware in the primary microcontroller, this D/A converter provides the analog outputs accessible through the DAIO API functions. When running user defined firmware on the primary microcontroller, this device is directly accessible to the user firmware.

The AT90USB646 microcontroller has a single TWI controller. This TWI controller is used to provide the public DTWI (I2C) interface, and is not used for the private I2C bus. The private I2C bus is controlled using a 'bit-banged' software I2C implementation. Digilent provides a reference design example as part of the I/O Explorer support documentation to illustrate this 'bit-banged' I2C implementation.

11 Developing Custom Firmware for the I/O Explorer

Although the I/O Explorer is primarily intended to function as a dedicated USB peripheral device to provide I/O expansion capability for PC application programs, it can also be used as a microcontroller development platform to run user developed custom firmware.

Connectors are provided for in-system-programming and for debugging firmware running on each microcontroller. Connectors JP1 and J3 are the programming and debugging connectors respectively for the primary microcontroller, IC1, an Atmel AT90USB646. Connectors JP2 and J6 are the programming and debugging connectors respectively for the secondary microcontroller, IC2, an Atmel ATmega165P.

The programming connectors are intended for use with a Digilent JTAG/SPI programming cable, such as the Digilent JTAG-USB Full Speed Module, although other programmers can be used with a suitable connector adapter. The debugging connectors are suitable for use with an Atmel JTAG ICE mk II or an Atmel AVR Dragon for in-system programming and debugging.

In order to restore the I/O Explorer to its original functionality after having programmed it with custom firmware, it is necessary to re-program the original firmware into whichever of the two microcontrollers have been programmed with custom firmware. Digilent makes the factory firmware images available as part of the support documents for the I/O Explorer on the Digilent web site. There are two firmware image files for each microcontroller: one to restore the program flash memory, and one to restore the EEPROM. Both firmware images must be programmed into the microcontroller.

The filenames for the firmware image files for the primary microcontroller are of the form: AvrFW_29_000003F2_XXXX.hex and AvrFw_29_000003F2_XXXX.eep, where "XXXX" represents the firmware version number. The .hex file is the image for the program flash, and the .eep file is the image for the EEPROM.

Similarly, the filenames for the firmware image files for the secondary microcontroller are of the form: AvrFw_210174_0101_XXXX.hex and AvrFw_210174_0101_XXXX.eep, where "XXXX" represents the version number.

In order to completely restore the board to the correct state for use as a Digilent Adept Compatible USB device it is necessary to restore the device serial number after programming the firmware and EEPROM images into the primary microcontroller. This is accomplished using the AdeptUtil program that is contained in the Adept Command Line Utilities. These utility programs are installed when the Adept Runtime System software is installed. The correct device serial number is: "210174nnnnnnnn", where "nnnnnnnn" is the last six digits of the bar code label attached to the bottom of the board. After reprogramming the firmware onto the primary microcontroller, attach the board to a USB port on the PC, turn it on, and then use the AdeptUtil program to set the serial number. The device user name will be the default name: "ioexp".

12   Digilent Adept Port Summary

The following summarizes the ports accessible via the Digilent Adept SDK when using the I/O Explorer as a USB peripheral device using the standard firmware.

Pin Input/Output Interface (DPIO) Ports

Port 0	8 Bits IN/OUT	Pmod connector JA1-JA4, JA7-JA10
Port 1	8 Bits IN/OUT	Pmod connector JB1-JB4, JB7-JB10
Port 2	8 Bits IN/OUT	Pmod connector JC1-JC4, JC7-JC10
Port 3	8 Bits IN/OUT	Pmod connector JD1-JD4, JC7-JC10
Port 4	4 Bits IN/OUT	Pmod connector JE1-JE4
Port 5	4 Bits IN/OUT	Pmod connector JE7-JE10
Port 6	8 Bits IN/OUT	Servo connectors S1-S8
Port 7	4 Bits IN/OUT	Pmod connector JG1-JG4

General Sensor and U/I Device Interface (DGIO) Ports

Port 0

Channel 0	16 Bits, Discrete OUT	LEDs LD0-LD15
Channel 1	8 Bits, Discrete IN	Slide Switches SW0-SW7
Channel 2	4 Bits, Discrete IN	Push Button Switches BTN0-BTN3
Channel 3	4 Bits, Discrete IN	DIP Switch (SW8) positions 1-4 (DSW0-DSW3)

Port 1

Channel 0	2 Bits, Discrete IN	Rotary Encoder push buttons
Channel 1	Single value, Ranged IN	Rotary Encoder ENC1
Channel 2	Single value, Ranged IN	Rotary Encoder ENC2

Port 2

Channel 0	Single value, Ranged OUT	Speaker/Buzzer frequency

Port 3

Channel 0	Single value, Ranged IN	Quadrature encoder input on JE7-JE8
Channel 1	Single value, Ranged IN	Quadrature encoder input on JE9-JE10

Serial Peripheral Interface (DSPI) Ports

Port 0	HW SPI controller	Pmod connector JD1-JD4
Port 1	SW SPI controller	Pmod connector JA1-JA4
Port 2	SW SPI controller	Pmod connector JB1-JB4
Port 3	SW SPI controller	Pmod connector JC1-JC4

Two Wire Serial Interface (DTWI) Ports

Port 0	HW TWI controller	TWI daisy chain connector J12

Asynchronous Serial Communications Interface (DACI) Ports

Port 0	HW UART controller	Pmod connector JG3-JG4

Analog Input/Output Interface (DAIO) Ports

Port 0	2 Channels, 10-bit IN	Connector JF1-JF2, J1 pins 1,3
Port 1	8 Channels, 10-bit IN	Servo connectors S1-S8
Port 2	4 Channels, 12-bit OUT	Connector JF7-JF10, J1 pins 5,7,9,11

Electro-Mechanical Control Interface (DEMC) Ports

Port 0	Unipolar stepper motor	Pmod connector JA7-JA10
Port 1	Unipolar stepper motor	Pmod connector JC7-JC10
Port 2	Brushed DC motor	Pmod connector JB7-JB10
Port 3	8 channel servo control	Servo connectors S1-S8
Port 4	4 channel servo control	Pmod connector JE7-JE10

13 Connector Usage by Digilent Adept Port

The following summarizes the connectors on the board and how they are used by the Digilent Adept system ports.

Pmod Connector JA

DPIO	Port 0	JA1-JA4, JA7-JA10
DEMC	Port 0	JA7-JA10
DSPI	Port 1	JA1-JA4

Pmod Connector JB

DPIO	Port 1	JB1-JB4, JB7-JB10
DEMC	Port 2	JB7-JB10
DSPI	Port 2	JB1-JB4

Pmod Connector JC

DPIO	Port 2	JC1-JC4, JC7-JC10
DEMC	Port 1	JC7-JC10
DSPI	Port 3	JC1-JC4

Pmod Connector JD

DPIO	Port 3	JD1-JD4, JD7-JD10
DSPI	Port 0	JD1-JD4

Pmod Connector JE

DPIO	Port 4	JE1-JE4
DPIO	Port 5	JE7-JE10
DEMC	Port 4	JE7-JE10
DGIO	Port 3, Chan 0	JE7-JE8
DGIO	Port 3, Chan 1	JE9-JE10

Pmod Connector JG

DPIO	Port 7	JG1-JG4

Servo Connectors S1-S8

DPIO	Port 6
DAIO	Port 1
DEMC	Port 3

Connector JF

DAIO	Port 0	JF1-JF2
DAIO	Port 2	JF7-JF10

Connector J1

DAIO	Port 0	pin 1 & 3
DAIO	Port 2	pin 5, 7, 9, 11

Connector J12

DTWI	Port 0

14   Microcontroller Pin, and Connector Tables

14.1 IC1, AT90USB646 Port Connections

MCU Port Bit	Signal	Connector Pin	Notes
RA00	U1-PA0/AD0	JA-01	
RA01	U1-PA1/AD1	JA-02	
RA02	U1-PA2/AD2	JA-03	
RA03	U1-PA3/AD3	JA-04	
RA04	U1-PA4/AD4	JA-07	
RA05	U1-PA5/AD5	JA-08	
RA06	U1-PA6/AD6	JA-09	
RA07	U1-PA7/AD7	JA-10	
RB00	U1-PB0/SS/PCINT0	JD-01	
RB01	U1-PB1/SCK/PCINT1	JD-04	
RB02	U1-PB2/MOSI/PCINT2	JD-02	
RB03	U1-PB3/MISO/PCINT3	JD-03	
RB04	U1-PB4/OC2A/PCINT4	JD-07	
RB05	U1-PB5/OC1A/PCINT5	JD-08	
RB06	U1-PB6/OC1B/PCINT6	JD-09	
RB07	U1-PB7/OC1C/PCINT7	JD-10	

RC00	U1-RC0/A8	JB-01	
RC01	U1-RC1/A9	JB-02	
RC02	U1-RC2/A10	JB-03	
RC03	U1-RC3/A11/T3	JB-04	
RC04	U1-RC4/A12/OC3C	JB-07	
RC05	U1-RC5/A13/OC3B	JB-08	
RC06	U1-RC6/A14/OC3A	JB-09	
RC07	U1-RC7/A15/ICP3	JB-10	
RD00	U1-PD0/SCL/INT0	J12-1,J12-2	I2C bus SCL
RD01	U1-PD1/SDA/INT1	J12-3,J12-4	I2C bus SDA
RD02	U1-PD2/RXD1	JG-03	
RD03	U1-PD3/TXD1	JG-04	
RD04	U1-PD4/ICP1	JG-02	
RD05	U1-PD5/XCK1	JG-01	
RD06	BTWI-SCL	J11-01	Private I2C bus SCL
RD07	BTWI-SDA	J11-02	Private I2C bus SDA
RE00	U1-PE0/WR	JC-01	
RE01	U1-PE1/RD	JC-02	
RE02	U1-PE2/ALE	JC-03	
RE03	U1-PE3/UID	JC-04	
RE04	U1-PE4/TOSC1/INT4	JC-07	
RE05	U1-PE5/TOSC2/INT5	JC-08	
RE06	U1-PE6/AIN0/INT6	JC-09	
RE07	U1-PE7/AIN1/INT7	JC-10	
RF00	U1-PF1/ADC0	JF-01,J1-01	DAIO Port 0, ch 0
RF01	U1-PF2/ADC1	JF-02, J1-03	DAIO port 0, ch 1
RF02	LINK	N/A	USB Link LED
RF03	PWR_ON	N/A	Main power supply on/off control
RF04	U1-PF4/ADC4/TCK	JE-01	
RF05	U1-PF5/ADC5/TMS	JE-02	
RF07	U1-PF6/ADC6/TDO	JE-03	
RF07	U1-PF7/ADC7/TDI	JE-04	

14.2 IC2, ATmega165P Port Connections

MCU Port Bit	Signal	Connector Pin	Notes
RA00	U2-PA0	N/A	DIP Switch 1, DGIO port 0, chan 3
RA01	U2-PA1	N/A	DIP Switch 2, DGIO port 0, chan 3
RA02	U2-PA2	N/A	DIP Switch 3, DGIO port 0, chan 3
RA03	U2-PA3	N/A	DIP Switch 4, DGIO port 0, chan 3
RA04	U2-PA4	N/A	Push button BTN0, DGIO port 0, chan 2
RA05	U2-PA5	N/A	Push button BTN1, DGIO port 0, chan 2
RA06	U2-PA6	N/A	Push button BTN2, DGIO port 0, chan 2
RA07	U2-PA7	N/A	Push button BTN3, DGIO port 0, chan 2

RB00	U2-SS/PB0	N/A	Switch SW0, DGIO port 0, chan 1
RB01	U2-SCK/PB1	N/A	Switch SW1, DGIO port 0, chan 1
RB02	U2-MOSI/PB2	N/A	Switch SW2, DGIO port 0, chan 1
RB03	U2-MISO/PB3	N/A	Switch SW3, DGIO port 0, chan 1
RB04	U2-OC0A/PCIN12/PB4	JE-07	Also SPKR, Speaker/Buzzer output, DGIO Port 2, DPIO port 7
RB05	U2-OC1A/PCINT13/PB5	JE-08	DPIO port 7
RB06	U2-OC1B/PCINT14/PB6	JE-09	DPIO port 7
RB07	U2-OC2A/PCINT15/PB7	JE-10	DPIO port 7
RC00	U2-PC0	N/A	LED LD8, DGIO Port 0, chan 0
RC01	U2-PC1	N/A	LED LD9, DGIO Port 0, chan 0
RC02	U2-PC2	N/A	LED LD10, DGIO Port 0, chan 0
RC03	U2-PC3	N/A	LED LD11, DGIO Port 0, chan 0
RC04	U2-PC4	N/A	LED LD12, DGIO Port 0, chan 0
RC05	U2-PC5	N/A	LED LD13, DGIO Port 0, chan 0
RC06	U2-PC6	N/A	LED LD14, DGIO Port 0, chan 0
RC07	U2-PC7	N/A	LED LD15, DGIO Port 0, chan 0
RD00	U2-ICP1/PD0	N/A	LED LD0, DGIO Port 0, chan 0
RD01	U2-INT0/PD1	N/A	LED LD1, DGIO Port 0, chan 0
RD02	U2-PD2	N/A	LED LD2, DGIO Port 0, chan 0
RD03	U2-PD3	N/A	LED LD3, DGIO Port 0, chan 0
RD04	U2-PD4	N/A	LED LD4, DGIO Port 0, chan 0
RD05	U2-PD5	N/A	LED LD5, DGIO Port 0, chan 0
RD06	U2-PD6	N/A	LED LD6, DGIO Port 0, chan 0
RD07	U2-PD7	N/A	LED LD7, DGIO Port 0, chan 0
RE00	U2-RXD/PCINT0/PE0	N/A	Encoder ENC1, DGIO Port 1, chan 1
RE01	U2-TXD/PCINT1/PE1	N/A	Encoder ENC1, DGIO Port 1, chan 1
RE02	U2-XCK/AIN0/PCINT2/PE2	N/A	Encoder ENC2, DGIO Port 1, chan 2
RE03	U2-AIN1/PCINT3/PE3	N/A	Encoder ENC2, DGIO Port 1, chan 2
RE04	BTWI-SCL	J11-01	Private I2C bus SCL
RE05	BTWI-SDA	J11-02	Private I2C bus SDA
RE06	U2-DO/PCINT6/PE6	N/A	Enocder ENC1 button, DGIO Port 1, chan 0
RE07	U2-CLKO/PCINT7/PE7	N/A	Encoder ENC2 button, DGIO Port 1, chan 0
RF00	U2-ADC0/PF0	S1	DEMC port 3, DAIO port 1, DPIO port 6
RF01	U2-ADC1/PF1	S2	DEMC port 3, DAIO port 1, DPIO port 6
RF02	U2-ADC2/PF2	S3	DEMC port 3, DAIO port 1, DPIO port 6
RF03	U2-ADC3/PF3	S4	DEMC port 3, DAIO port 1, DPIO port 6
RF04	U2-ADC4/TCK/PF4	S5	DEMC port 3, DAIO port 1, DPIO port 6
RF05	U2-ADC5/TMS/PF5	S6	DEMC port 3, DAIO port 1, DPIO port 6
RF07	U2-ADC6/TDO/PF6	S7	DEMC port 3, DAIO port 1, DPIO port 6
RF07	U2-ADC7/TDI/PF7	S8	DEMC port 3, DAIO port 1, DPIO port 6
RG00	U2-PG0	N/A	Switch SW4, DGIO port 0, chan 1
RG01	U2-PG1	N/A	Switch SW5, DGIO port 0, chan 1
RG02	U2-PG2	N/A	Switch SW6, DGIO port 0, chan 1
RG03	U2-T1/PG3	N/A	Switch SW7, DGIO port 0, chan 1
RG04	SPKEN	N/A	Speaker/Buzzer enable, DGIO port 2

14.3 Connector Descriptions and Jumper Settings

Label	Function
JA-JE & JG	**Pmod connectors** These connectors are used to access many of the I/O functions of the board. Refer to the Digilent Adept Port Summary table and the Connector Usage By Digilent Adept Port tables for more information.
JPA-JPE & JPG	**Power select jumpers for Pmod connectors JA-JE & JG** Place a shorting block in the VU position to supply input power (normally 5V) to the Pmod connector. Place a shorting block in the 3V3 position to supply regulated power (normally 3.3V) to the Pmod connector.
JF	**Analog Input/Output Connector** This connector provides access to the analog input signals for DAIO port 0 and the analog output signals for DAIO port 2. Pin 1 AIN0 Pin 2 AIN1 Pin 3 N/C Pin 4 N/C Pin 5 GND Pin 6 VU or 3V3 Pin 7 AOUT0 Pin 8 AOUT1 Pin 9 AOUT2 Pin 10 AOUT3 Pin 11 GND Pin 12 VU or 3V3
JPF	**Power select jumper for connector FJ** This jumper selects the voltage supplied to the supply pins on JF. Place a shorting block near the board edge to select input power (normally 5V). Place the sorting block away from the board edge to select regulated power (normally 3.3V).
J1	**Analog Input/Output Connector** This connector provides access to the same signals as JF. The signal connections are labeled on the board. All even numbered pins on the connector are connected to GND. The voltage supplied on pin 13 (VJPF) is the voltage selected by JPF.
J2	**A/D Converter Reference Input** This pin is used to supply the reference voltage for the A/D converter in the primary microcontroller (used by DAIO port 0) when the port is operating using an external reference. The voltage applied at this pin must not exceed the operating voltage of the board (normally 3.3V). The reference voltage is applied to the AREF1 pin.
J3	**Primary Microcontroller (AT90USB646) Debug Connector** This connector allows use of an Atmel JTAG ICE mkII or AVR Dragon to perform in-system programming and debug of code running in the primary microcontroller. Note: the fuses must be set to enable the JTAG interface to allow in-system debug.
J4	**USB Connector** Micro B connector used to connect I/O Explorer to USB host port.
J5	**A/D Converter Reference Input** This pin is used to supply the reference voltage for the A/D converter in the secondary microcontroller (used by DAIO port 2) when the port is operating using an external reference. The voltage applied at this pin must not exceed the operating voltage of the board (normally 3.3V). The reference voltage is applied to the AREF2 pin.
J6	**Secondary Microcontroller (ATmega165P) Debug Connector** This connector allows use of an Atmel JTAG ICE mkII or AVR Dragon to perform in-system programming and debug of code running in the secondary microcontroller. Note: the fuses must be set to enable the JTAG interface to allow in-system debug.

J7-J9	**Ground Posts** These provide a GND connection for use when using external test equipment, such as an oscilloscope, to probe signals on the board.
J10	**Servo Bus Power** This screw terminal connector is used to provide power to the servo power bus VS when the servo power bus is being powered separately from the board main power bus.
J11	**Internal I2C Bus** This connector provides access to the two signals for the internal I2C bus used to communicate between the two microcontrollers and the MCP4728 DAC.
J12	**TWI BUS Daisy Chain Connector** This connector is used to connect external devices to the DTWI bus.
J13-J15	**External Power Supply Connectors** These three connectors are wired in parallel and are used to connect an external power source to the board when operating the I/O Explorer as a self-powered USB device, or when not using USB.
JP1	**Primary Microcontroller (AT90USB646) In-System-Programming Connector** This connector is used to access the primary microcontroller for in-system-programming. It is intended for use with a Digilent programming cable, although other Atmel AVR in-system programmers will work with a suitable cable adapter.
JP2	**Secondary Microcontroller (ATmega165P) In-System-Programming Connector** This connector is used to access the secondary microcontroller for in-system-programming. It is intended for use with a Digilent programming cable, although other Atmel AVR in-system programmers will work with a suitable cable adapter.
JP3	**Servo Bus Power Select** Insert a shorting block on this jumper to join the servo power bus, VS, to the main board power bus, VU. With the shorting block installed, the VS bus is powered from the main board power supply. With the shorting block removed, the VS bus is powered via connector J10.
JP4 & JP5	**TWI Bus Pull-up Enable** These jumpers are used to enable/disable the pull-ups on the DTWI bus. Installing the shorting blocks enables the pull-ups, removing the shorting blocks disables them. The pull-ups on the I/O Explorer are implemented using current mirrors, rather than simple pull-up resistors. This provides improved reliability when driving longer busses.
JP6	**Main Power Source Select** This jumper is used to select the main power source for the board. Place a shorting block in the VUSB position to power the board from the USB connector. Place a shorting block in the VEXT position to power the board from one of the external power connectors J13, J14, or J15. An external power supply should provide a regulated 5V. An external voltage greater than 5.5V should never be applied or damage to the board will occur.
J7	**Operating Voltage Select** This jumper is used to select the operating voltage for the board. Place a shorting block in the 3V3 position to operate the board from the internal 3.3V regulator. Place a shorting block in the 5V0 position to operate the board from the input supply (either USB or externally applied 5V) voltage.