Cerebot MX4cK™ Board Reference Manual

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Note: This document applies to REV C of the board.

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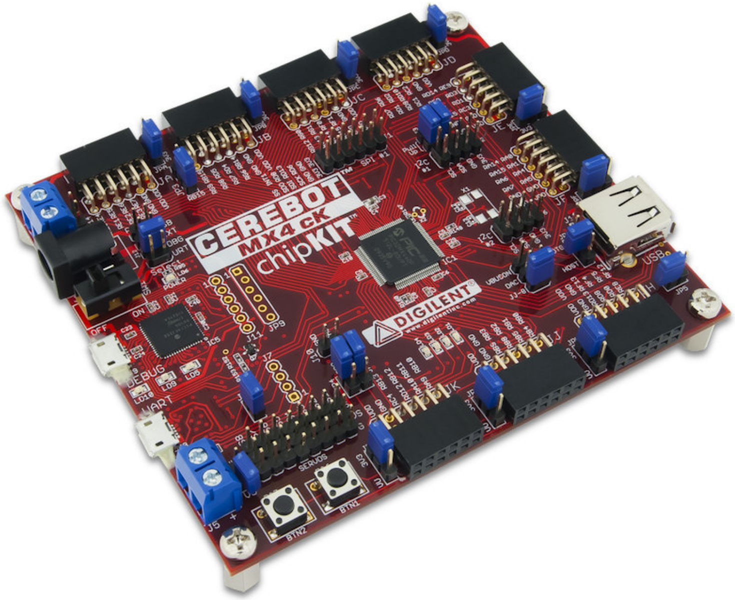
Overview

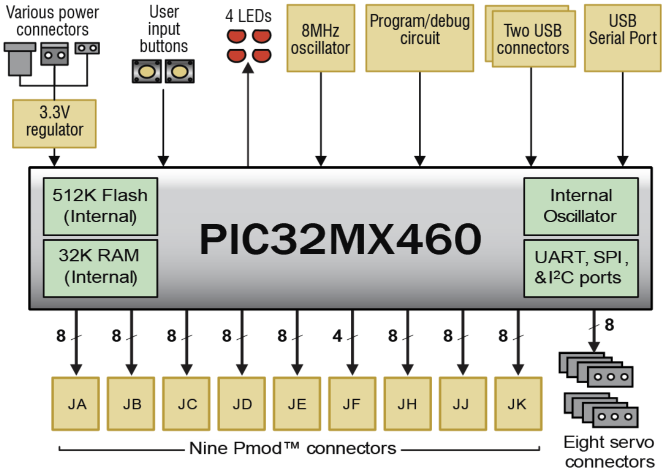
The Cerebot MX4cK is a microcontroller development board based on the Microchip PIC32MX460F512L, a member of the 32-bit PIC32 microcontroller family. It is compatible with Digilent's line of Pmod™ peripheral modules, and is suitable for use with the Microchip MPLAB® IDE tools. The Cerebot MX4cK is also compatible for use with the chipKIT™ MPIDE development environment. ChipKIT and MPIDE is a PIC32 based system compatible with many existing Arduino™ code examples, reference materials and other resources.



The Cerebot MX4cK is designed to be easy to use and suitable for use by anyone from beginners to advanced users for experimenting with electronics and embedded control systems. A built in programming/debugging circuit compatible with the Microchip MPLAB® IDE is provided on the board, so no additional hardware is required for use with MPLAB. The kit contains everything needed to start developing embedded applications using either the MPLAB® IDE or the MPIDE.

The Cerebot MX4cK provides 74 I/O pins that support a number of peripheral functions, such as USB controller, UART, SPI and I^{2}C™ ports as well as five pulse width modulated outputs and five external interrupt inputs. Fifteen of the I/O pins can be used as analog inputs in addition to their use as digital inputs and outputs.

The Cerebot MX4cK can be powered via USB, or an external power supply that may be either an AC-DC power adapter, or batteries.



Cerebot MX4cK Circuit Diagram

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Functional Description

The Cerebot MX4cK is designed for embedded control and robotics control applications as well as for general microprocessor experimentation. Firmware suitable for many applications can be downloaded to the Cerebot MX4cK's programmable PIC32 microcontroller.

Features of the Cerebot MX4cK include:

- a PIC32MX460F512L microcontroller
- support for programming and debugging within the Microchip MPLAB development environment
- nine Pmod connectors for Digilent peripheral module boards
- eight hobby RC servo connectors
- USB 2.0 Device, Host, and OTG support
- two push buttons
- four LEDs
- multiple power supply options, including USB powered
- ESD protection and short circuit protection for all I/O pins.

Features of the PIC32MX460F512L include:

- 512KB internal program flash memory
- 32KB internal SRAM memory
- USB 2.0 compliant full-speed On-The-Go (OTG) controller with dedicated DMA channel
- two serial peripheral interfaces (SPI)
- two UART serial interfaces
- two I2C serial interfaces
- five 16-bit timer/counters
- five timer capture inputs
- five compare/PWM outputs
- sixteen 10-bit analog inputs
- two analog comparators

The Cerebot MX4cK has a number of input/output connection options, and is specially designed to work with the Digilent Pmod™ line of peripheral modules to provide a variety of input and output functions. For more information, see www.digilentinc.com. In addition to the Pmod connectors, the board provides eight connectors for RC hobby servos, two push button switches, and four LEDs, as well as providing connections for two I2C busses. A serial EEPROM and a 12-bit digital to analog converter are provided on one of the I2C busses.

The Cerebot MX4cK features a flexible power supply system with a number of options for powering the board as well as powering peripheral devices connected to the board. It can be USB powered via either the debug USB port or the USB device port, or it can be powered from an external power supply or batteries.

Programming Tools

The Cerebot MX4cK can be used with either the Microchip MPLAB® development environment or the chipKIT MPIDE development environment. When used with the MPLAB IDE, in-system-programming and debugging of firmware running on the PIC32MX460 microcontroller is supported using an on-board programming/debugging circuit licensed from Microchip.

The Cerebot MX4cK is immediately useable with either the MPLAB IDE or the chipKIT MPIDE. No additional hardware is required to use the board with the Microchip MPLAB tools.

Using the Cerebot MX4cK with Microchip Development Tools

The Microchip MPLAB® IDE or the MPLAB® X IDE can be used to program and debug code running on the Cerebot MX4cK board using a built-in programming/debugging circuit licensed from Microchip.

The MPLAB programs can be freely downloaded from the Microchip web site. These software suites include a free evaluation

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copy of the Microchip C32 compiler for use with the PIC32 microcontroller family. The licensed debugger is compatible with the MPLAB IDE version 8.63 or later.

When creating a new project, use the "Configure.Select Device…" menu to specify the PIC32 device being used. Ensure that the device is set to PIC32MX460F512L.

In order to use the on-board program/debug circuit it must be selected as the debugger or programmer within the MPLAB IDE. Use the "Debugger.Select Tool" menu, or the "Programmer.Select Tool" menu, and select "Licensed Debugger" as the programmer or debugger.

The licensed debugger interface uses USB connector J9, labeled DEBUG. Connector J9 is a USB micro-B connector. Use a USB-A to micro-B cable (provided with the board) to connect to an available USB port on the PC.

When the licensed debugger is selected as the programming or debugging device, the MPLAB IDE will check the version number of the firmware running on the debugger and offer to update it if is out of date with the version of MPLAB being used.

The in-system programming/debugging interface uses two pins on the PIC32 microcontroller. The PIC32 devices support two alternate pin pairs for this interface: PGC1/PGD1 or PGC2/PGD2. PIC32 devices use PGC2/PGD2 by default. The Cerebot MX4ck is designed to use PGC2/PGD2. It is not normally necessary to select the use of PGC2/PGD2 for the debugging interface, as this should occur automatically.

If for some reason, it is necessary to select the correct pins for the programming/debugging interface, this can done using configuration variables set using the `#pragma config` statement. The following statement can be used to configure the microcontroller for use with the on-board licensed debugger circuit:

```
#pragma config ICESEL = ICS_PGx2
```

The MPLAB IDE may report an error indicating that the device is not configured for debugging until the first time a program is loaded onto the board.

The MCLR pin on the PIC32 microcontroller is used by the hardware programming/debugging interface to reset the processor. This same pin is used by the USB serial converter to reset the processor when using the MPIDE. It is possible that the reset function from the USB serial interface can interfere with correct operation of the Microchip programming and debugging tools. If this happens, jumper JP8 can be used to disconnect the USB serial converter reset circuit. Remove the shorting block from JP8 to disable the reset circuit. If the shorting block has been removed, it is necessary to reinstall it on JP8 in order to use the Cerebot MX4cK board with the MPIDE again.

Using the Microchip development tools to program the Cerebot MX4cK will erase the chipKIT boot loader. To use the board with the chipKIT MPIDE again, it is necessary to program the boot loader back onto the board. The programming file for the boot loader programmed into the board by Digilent at the factory is available for download from the product page for the Cerebot MX4cK on the Digilent web site. Additionally, the boot loader source code is available in the chipKIT project repository at www.github.com/chipKIT32/pic32-Arduino-Bootloader.

To reprogram the boot loader using MPLAB, perform the following steps:

- Use the "Configure.Select Device …" menu to select the PIC32MX460F512L
- Use the "Programmer.Select Programmer" menu to select the "Licensed Debugger".

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- Use the “File Import…” dialog box to navigate to and select the boot loader programming downloaded from the Digilent web site. The file name will be something like: chipKIT_Bootloader_MX4cK.hex
- Use the “Programmer.Program” command to program all memories on the device.

Using the Cerebot MX4cK with the chipKIT MPIDE

ChipKIT and the MPIDE is a PIC32 based hardware and software system compatible with many existing Arduino™ code examples, reference materials and other resources. The MPIDE development platform was produced by modifying the Arduino™ IDE and is fully backward compatible with the Arduino IDE. The Cerebot MX4cK board is designed to be fully compatible with the chipKIT MPIDE system, version 20111209 or later.

The MPIDE uses a serial communications port to communicate with a boot loader running in the target board. The serial port on the MX4cK board is implemented using an FTDI FT232R USB serial converter. Before attempting to use the MPIDE to communicate with the MX4cK, the appropriate USB device driver must be installed.

The USB serial converter on the Cerebot MX4cK board uses USB connector J8, labeled UART on the board. This connector is a micro-USB. Use a standard USB-A to mini-B cable (provided with the board) to connect the board to an available USB port on the PC.

In the MPIDE, use the “Tools.Board” command to select the Cerebot MX4cK from the list of available boards. Use the “Tools.Serial Port” command to choose the appropriate serial port from the list of available serial ports on the PC.

When the MPIDE needs to communicate with the MX4cK board, the PIC32 microcontroller is reset and starts running the boot loader. The MPIDE then establishes communications with the boot loader and downloads the program to the board.

When the MPIDE opens the serial communications connection on the PC, the DTR pin on the FT232R chip is driven low. This pin is coupled through a capacitor to the MCLR pin on the PIC32 microcontroller. Driving the MCLR line low resets the microcontroller, restarting execution with the boot loader.

Once the MPIDE has established communication with the boot loader, it transfers the user’s program to the boot loader, which programs it into the flash memory in the Microcontroller.

The automatic reset action when the serial communications connection is opened can be disabled. To disable this operation, remove the shorting block from jumper JP8. The shorting block is reinstalled on JP8 to restore operation with the MPIDE.

Two red LEDs (LD7 and LD8) will blink when data is being sent or received between the Cerebot MX4cK and the PC over the serial connection.

The header connector J7 provides access to the other serial handshaking signals provided by the FT232R. Connector J7 is not loaded at the factory but can be installed by the user to access these signals.

Additional Reference Documentation

For additional information about the Cerebot MX4cK board and the use and operation of the PIC32MX460F512L microcontroller, refer to the following documents in addition to this reference manual.

The Cerebot MX4cK Schematic, available on the Cerebot MX4cK product page on the Digilent web site: www.digilentinc.com

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The PIC32MX3XX/4XX Family Data Sheet and the PIC32MX Family Reference Manual available from the Microchip web site:
www.microchip.com

Additional reference material for the chipKIT MPIDE system is included in the MPIDE software download, and on-line in the chipKIT wiki. Help with questions and problems using the board with the chipKIT MPIDE software can also be obtained in the chipKIT forums:

www.github.com/chipKIT32 (software download)

www.chipKIT.org/wiki
www.chipKIT.org/forum

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Board Hardware Description

The following describes the various hardware features of the Cerebot MX4cK board and the PIC32XM460F512L microcontroller.

Power Supply

Switch SW1, in the lower left corner of the board is the power switch. Place this switch in the ON position to turn on board power and in the OFF position to turn off board power.

The Cerebot MX4cK may be USB powered via either the USB debug port, the USB UART port, or the USB device port. Alternatively, the board may be powered via dedicated, “external”, power supply connectors.

Jumper block J12 is used to select the power source used to provide power to the board. This jumper block provides the following four positions:

- USB – power is supplied by USB device connector J15. This is used when the Cerebot MX4cK is used to implement a USB bus powered device.
- EXT – Power is supplied by one of the external power connectors.
- DBG – Power is supplied by DEBUG USB connector J9.
- URT – Power is supplied by UART USB connector J8.

Place the shorting block in the appropriate position on J12 for the desired power source for the board.

The Cerebot MX4cK is rated for external power from 3.6 to 12 volts DC. Using a voltage outside this range could damage the board and connected devices. If operating the board at a voltage higher than 5V, it is necessary to remove the shorting block on jumper JP10 to protect the USB load switch, which is limited to a maximum voltage of 5.5V. When operating from any of the three USB sources, the input voltage will be 5V.

The output of power select jumper block J12 is connected to the VIN power bus. The VIN power bus supplies power to Q3, a PFET load switch, and IC9, the voltage regulator for the licensed debugger circuit. The licensed debugger circuit is powered as soon as the power switch is turned on. Power to the rest of the board is controlled by Q3. The main board power supply is enabled by bringing the gate of Q3 low. When Q3 is turned on, the unregulated power bus BRD_VU is powered.

If the licensed debugger is connected to an active USB port, it enumerates with the host computer and once it has successfully been enumerated, it turns on the main board power supply by driving the PWR_ON signal high.

If the licensed debugger is not connected to an active USB port, the PWR_ON signal is ignored and board power is turned on immediately by the power switch via transistor Q4.

The main board power supply is a switch mode voltage regulator implemented using a Microchip MCP16301 switch mode step-down regulator. This regulator provides 3.3V at up to 600 mA with approximately 96% efficiency. This powers the main board regulated power bus BRD_3V3

There are three connectors on Cerebot MX4cK for connecting an external power supply: J13, J14, and J18.

The barrel connector, J13, is useful for desktop development and testing where using USB or battery power is not suitable. J13 is the connector used by the AC 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.

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Connector J14 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.

Connector J18 is a screw terminal connector for an alternative power supply connection for use with higher current battery packs, bench supplies or other power sources where use of a hard wired power supply is desirable.

Connectors J13, J14, and J18 are wired in parallel and connect to the "External Power" position on the Power Select jumper block J12. A shorting block should be placed on the "EXT" position of J12 when using this option for board power. Only one of these three power connectors should be used at a time. If multiple power supplies are connected simultaneously, damage to the board or the power supplies may occur.

The Cerebot MX4cK has a second screw terminal connector, J5 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 Cerebot MX4cK. This can be useful when using servos that draw large amounts of power.

Jumper JP1 can be used to connect the Cerebot MX4cK unregulated power bus BRD_VU to the servo power bus, VS. When no shorting block is installed on JP1, the BRD_VU and VS busses are separate. When a shorting block is on JP1, the two busses are joined and the BRD_VU bus can be powered in any of the previously indicated ways, or from connector J5.

The Cerebot MX4cK can provide power to any peripheral modules attached to the Pmod connectors and to I^{2}C devices powered from the I^{2}C daisy chain connectors, J2 and J6. Each Pmod connector provides power pins that can be powered by either unregulated voltage, BRD_VU, or regulated voltage, BRD_3V3, by setting the voltage jumper block to the desired position. The I^{2}C power connectors only provide regulated voltage, BRD_3V3.

The PIC32 microcontroller and on-board I/O devices operate at a supply voltage of 3.3V provided by the BRD_3V3 bus. The PIC32 microcontroller will use approximately 55mA when running at 80MHz. The remaining current is available to provide power to attached Pmod and I^{2}C devices.

Power Supply Monitor Circuit

The Cerebot MX4cK microcontroller can measure the power supply voltage on the BRD_VU and VS power busses using the provided power supply monitor circuits. This feature is especially useful when using batteries because it allows the microcontroller firmware to determine the charge state of the battery and potentially notify the user when a battery supply is low.

Each power supply monitor circuit is made up of a voltage divider that divides the power bus voltage by four, and a filter capacitor to stabilize the voltage. Jumper JP4 enables the supply monitor circuit for BRD_VU power bus, and jumper JP2 enables the supply monitor circuit for the VS power bus. The analog to digital converter built into the PIC32 microcontroller is used to measure the power supply voltages. ADC channel 8 is used to measure BRD_VU and ADC channel 9 is used to measure VS.

When using the Cerebot MX4cK with the chipKIT MPIDE, these are accessed using the analogRead() function using analog input A6 to read BRD_VU and A7 to read VS.

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Pmod™ Connectors

The Cerebot MX4cK has nine connectors for connecting Digilent Pmod peripheral modules. The Pmod connectors, labeled JA–JF and JH–JK, are 2x8 right-angle, female pin header connectors. Each connector has an associated power select jumper block labeled JPA–JPF and JPH–JPK.

Digilent Pmods are a line of small peripheral modules that provide various kinds of I/O interfaces. The Pmod product line includes such things as button, switch and LED modules, connector modules, LCD displays, high current output drivers, various kinds of RF interfaces, and many others.

There are two styles of Pmod connector: six-pin and twelve-pin. Both connectors use standard pin headers with 100mil spaced pins. The six-pin connectors have the pins in a 1x6 configuration, while the twelve-pin connectors use a 2x6 configuration. All of the Pmod connectors on the Cerebot MX4cK are twelve pin connectors.

The six-pin connectors provide four I/O signals, ground and a switchable power connection. The twelve-pin connectors provide eight I/O signals, two power and two ground pins. The twelve-pin connectors have the signals arranged so that one twelve-pin connector is equivalent to two of the six-pin connectors. Pins 1–4 and 7–10 are the signal pins, pins 5 and 11 are the ground pins and pins 6 & 12 are the power supply pins.

The pin numbering that Digilent uses on the twelve-pin Pmod connectors is non-standard. The upper row of pins are numbered 1–6, left to right (when viewed from the top of the board), and the lower row of pins are numbered 7–12, left to right. This is in keeping with the convention that the upper and lower rows of pins can be considered to be two six-pin connectors stacked. When viewed from the end of the connector, pin 1 is the upper right pin and pin 7 is immediately below it (closer to the PCB).

Each Pmod connector has an associated power select jumper. These are used to select the power supply voltage supplied to the power supply pin on the Pmod connector. They are switchable between either the unregulated power supply, BRD_VU, or the 3.3V main board supply, BRD_3V3. Place the shorting block in the 3V3 position for regulated 3.3V and in the VU position to use the unregulated supply.

Each signal pin on the Pmod connectors is connected to an input/output pin on the PIC32 microcontroller. Each pin has a 200 ohm series resistor and an ESD protection diode. The series resistor provides short circuit protection to prevent damaging the I/O block in the microcontroller if the pin is inadvertently shorted to VDD or GND, or two outputs are shorted together. The ESD protection diode protects the I/O block from damage due to electro-static discharge.

Although ESD protection is provided between the connector pins and the microcontroller pins, ESD safe handling procedures should be followed when handling the circuit board. The pins on the microcontroller and other circuits on the board are exposed and can be damaged through ESD when handling the board.

Digilent Pmod peripheral modules can either be plugged directly into the connectors on the Cerebot MX4cK or attached via cables. Digilent has a variety of Pmod interconnect cables available.

See the Pinout Tables in Appendix C, for more information about connecting peripheral modules and other devices to the Cerebot MX4cK. These tables describe the mapping between pins on the PIC32MX460 microcontroller and the pins on the various connectors.

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The PIC32 microcontroller can source or sink a maximum of 18mA on all digital I/O pins. However, to keep the output voltage within the specified input/output voltage range (V_{OL} 0.4V, V_{OH} 2.4V) the pin current must be restricted to +7/-12mA. The maximum current that can be sourced or sunk across all I/O pins simultaneously is +/-200mA. The maximum voltage that can be applied to any digital I/O pin is 5.5V. For more detailed specifications, refer to the PIC32MX3XX/4XX Family Data Sheet.

Digital Inputs and Outputs

The Cerebot MX4cK board provides access to 72 of the I/O pins from the PIC32 microcontroller via the Pmod connectors. Two additional I/O pins can be accessed via the I^2C connector, J6. Any of the pins on the Pmod or I^2C connectors can be individually accessed for digital input or output. Note that when the I^2C signals on J6 are being used for I^2C communications, they are not available for general purpose I/O. Note that the signals on I^2C connector J2 are shared with pins 1 & 2 of Pmod connector JF.

On PIC32 microcontrollers, the input/output pins are grouped into I/O Ports and are accessed via peripheral registers in the microcontroller. There are seven I/O Ports numbered A–G and each is 16 bits wide. Depending on the particular PIC32 microcontroller, some of the I/O Ports are not present, and not all 16 bits are present in all I/O Ports.

Each I/O Port has four control registers: TRIS, LAT, PORT, and ODC. The registers for I/O Port A are named TRISA, LATA, PORTA and ODCA. The registers for the other I/O Ports are named similarly.

The TRIS register is used to set the pin direction. Setting a TRIS bit to 0 makes the pin an output. Setting the TRIS bit to 1 makes the pin an input.

The LAT register is used to write to the I/O Port. Writing to the LAT register sets any pins configured as outputs. Reading from the LAT register returns the last value written.

The PORT register is used to read from the I/O Port. Reading from the PORT register returns the current state of all of the pins in the I/O Port. Writing to the PORT register is equivalent to writing to the LAT register.

PIC32 microcontrollers allow any pin set as an output to be configured as either a normal totem-pole output or as an open-drain output. The ODC register is used to control the output type. Setting an ODC bit to 0 makes the pin a normal output and setting it to 1 makes the pin a open drain output.

Refer to the PIC32MX3XX/4XX Family Data Sheet, and the PIC32 Family Reference Manual, Section 12, IO Ports, for more detailed information about the operation of the I/O Ports in the microcontroller.

The chipKIT MPIDE system uses logical pin numbers to identify digital I/O pins on the connectors. These pin numbers start with pin 0 and are numbered up consecutively.

On the Cerebot MX4cK, pin numbers 0–71 are used to access the pins on the Pmod connectors and pin numbers 72 and 73 are used for the two signal pins on the I^2C connector, J6. The pin numbers are assigned so that connector JA pin 1 (JA-01) is digital pin 0, JA pin 2 (JA-02) is digital pin 1, and so on.

Pins 0-7 are on connector JA, pins 8-15 on JB, pins 16-23 on JC, pins 24-31 and so on. Refer to the tables in Appendix C for detailed information about the pin mapping between Pmod connector, logical pin number, and PIC32 microcontroller pin number and pin function.

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When using the Cerebot MX4cK with the chipKIT MPIDE the functions pinMode(), digitalRead(), and digitalWrite() are used for digital pin I/O.

The pinMode() function is used to set the pin direction. Pin direction can be set to: INPUT, OUTPUT, or OPEN. OPEN is used for open-drain and implies output.

The digitalRead() and digitalWrite() functions are used to read or write the pins. DigitalRead() returns the current state of the specified pin, and digitalWrite is used to set the state of an output pin. The pin state can be either HIGH or LOW.

PIC32MX460 Pin 20

Pin 20 on the PIC32MX460 has multiple functions. It provides the VBUSON signal when the board is being used to implement a USB host. It also provides the positive input for analog comparator 1, analog to digital converter input AN5, change notice interrupt CN7 and bit 5 of general I/O Port B. In order to support all of these different functions, jumper block J16 is used to select the routing of this pin.

Normally, the shorting block will be in the JJ-8 position. This connects microcontroller pin 20 to Pmod connector JJ pin 8. This allows the use of most functions of this pin.

When the board is being used as a USB host, the shorting block is placed in the VBUSON position to allow use of the VBUSON signal to control power to the USB bus.

Placing the shorting block in the DAC position connects the output of IC3, the MCP4725 digital to analog converter to microcontroller pin 20. This allows use of the DAC output to be used as a programmable reference for analog comparator 1.

Push Buttons and LEDs

The Cerebot MX4cK board provides two push button switches for user input and four LEDs for output. The buttons, BTN1 and BTN2 are connected to I/O pins TRCLK/RA6 and TRD3/RA7 respectively. To read the buttons, pins 6 and 7 of I/O Port A must be set as inputs by setting the corresponding bits in the TRISA register. The button state is then obtained by reading the PORTA register. When a button is pressed, the corresponding bit will be high (‘1’). Note that the microcontroller pins used by the buttons are shared with pins 3 & 4 of Pmod connector JF.

The four LEDs are connected to bits 10-13 of I/O Port B. LED 1 is connected to bit 10, LED 2 is connected to bit 11, and so on. These four bits are also shared with pins 1-4 of Pmod connector JK. To use the LEDs, set the desired bits as outputs by clearing the corresponding bits in the TRISB register. The state of an LED is set by writing values to the LATB register. Setting a bit to 1 will illuminate the LED and setting the bit to 0 will turn it off.

When using the MPIDE and the chipKIT system, the buttons are accessed using digitalRead() and the LEDs using digitalWrite(). Use the following pins to access them:

- BTN1 – PIN_BTN1, pin 42, RA6
- BTN2 – PIN_BTN2, pin 43, RA7
- LD1 – PIN_LED1, pin 64, RB10
- LD2 – PIN_LED2, pin 65, RB11
- LD3 – PIN_LED3, pin 66, RB12
- LD4 – PIN_LED4, pin 67, RB13

RC Servo Connectors

The Cerebot MX4cK provides eight 3-pin RC hobby servo connectors, labeled S1-S8, for direct control of servos in robotics and embedded hardware actuator applications. The connectors share the I/O pins with Pmod connector JC. Individual I/O pins may be

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accessed through the JC connector if they're not being used to control a servo.

RC Servos use a pulse width modulated signal, PWM, to control the servo position. The 16-bit timers in the PIC32 microcontroller have the ability to generate PWM signals using the output compare registers. However, it is also possible to use timer interrupts to accomplish this same thing. Using timer interrupts allows a single timer to be used to control the signal timing for all eight servo connectors.

The servo connectors on the Cerebot MX4cK board are intended to be driven using timer interrupts rather than directly by the pulse width modulators in the internal timers. This frees the pulse width modulators for other uses, such as DC motor speed control. Digilent has a reference design available that illustrates using timer interrupts to control signal timing for the PWM signals to control RC servos.

When using the chipKIT MPIDE development environment, the Servo library can be used to drive servos attached to these connectors. The symbols PIN_S1 through PIN_S8 can be used to specify the servo connectors being used.

The following give the correspondence between servo connector, MPIDE digital pin number, and microcontroller I/O Port register and bit position:

- S1 – PIN_S1, digital pin 16, RG12
- S2 – PIN_S2, digital pin 17, RG13
- S3 – PIN_S3, digital pin 18, RG14
- S4 – PIN_S4, digital pin 19, RG15
- S5 – PIN_S5, digital pin 20, RG0
- S6 – PIN_S6, digital pin 21, RG1
- S7 – PIN_S7, digital pin 22, RF0
- S8 – PIN_S8, digital pin 23, RF1

There are three options for supplying power to the servo connections:

- A common power bus (BRD_VU) for the Cerebot MX4cK and servos
- Separate on-board power busses for the Cerebot MX4cK (BRD_VU) and the servos (VS)
- An on-board power bus for the Cerebot MX4cK (BRD_VU) and an external power bus for servos

For the first case above: Install a shorting block on jumper JP1 to connect the VS servo power bus to the BRD_VU power bus. The servo power bus is then powered from the same source as the BRD_VU power bus. Powering a large number of servos from USB power is not recommended. Pin header jumpers and shorting blocks such as JP1 are rated for a maximum of 2A of current. USB power (J12 in the USB, DBG, or URT positions) 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 JP2 to make the VS servo power bus independent from the BRD_VU bus. Attach the servo power supply to screw terminal connector J5.

Finally, for very high servo current applications, a separate power bus external to the Cerebot MX4cK 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 Cerebot MX4cK 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.

5V Signal Compatibility

The PIC32 microcontroller operates at 3.3V. And the I/O pins provide 3.3V logic levels. It is possible, in some circumstances, to use the

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Cerebot MX4cK to operate with 5V logic devices.

There are two issues to consider when dealing with 5V compatibility for 3.3V logic. The first is protection of 3.3V inputs from damage caused by 5V signals. The second is whether the 3.3V output is high enough to be recognized as a logic high value by a 5V input.

The digital I/O pins on the PIC32 microcontroller are 5V tolerant. It is safe to apply 5V logic signals directly to these pins without risk of damage to the microcontroller.

The analog capable I/O pins on the PIC32 are not 5V tolerant. The absolute maximum voltage rating for the analog pins is 3.6V. Generally, the analog pins are the pins on I/O port B, however, there are other non-5V tolerant pins on the device.

Refer to the PIC32MX3XX/4XX Family Data Sheet for more information about which pins on the device are 5V tolerant before applying input signals higher than 3.3V to any pin on the Cerebot MX4cK board.

If a 5V signal is applied to a non-5V tolerant pin, some external means must be used to limit the applied voltage to 3.6V or less. The Cerebot MX4cK board provides 200 ohm series resistors between the microcontroller pins and the Pmod connector pins. These resistors are primarily intended to provide short circuit protection on the outputs, but will also provide limited protection if a 5V signal is inadvertently applied to a non-5V tolerant pin.

One technique that can be used to limit and input voltage to a safe level is to use a 200 ohm series resistor and Shotkey diode connected to the 3.3V supply to clamp the voltage.

The minimum output high voltage of the PIC32 microcontroller is rated at 2.4V when sourcing 12mA of current. When driving a high impedance input (typical of CMOS logic) the output high voltage will be close to 3.3V. Some 5V devices will recognize this voltage as a logic high input, and some won't. Many 5V logic inputs will work reliably with 3.3V inputs.

If the 3.3V logic output is not sufficient for 5V logic input to be reliably seen as a logic high input signal, some external means must be used to raise the output level. In some cases, a pull-up resistor to 5V is sufficient. A pull-up resistor in the range of 2Kohm–10kOhm can be used. This technique should not be used with pins that are not 5V tolerant on the PIC32 microcontroller.

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PIC32 Peripheral Devices

The following describes the peripheral devices available in the PIC32MX460F512L microcontroller and how they are accessed on the Cerebot MX4cK board.

CPU Clock Source

The PIC32 microcontroller supports numerous clock source options for the main processor operating clock. The Cerebot MX4ck board is designed to support either a silicon resonator from Discera, IC8, for use with the EC oscillator option, or an external crystal for use with the XT oscillator option. Standard production boards will have an 8Mhz Discera silicon resonator loaded and the EC oscillator option should be used. If IC2 is not loaded, an 8Mhz crystal will be loaded for X1 (on the bottom of the board) and the XT oscillator option should be used. Oscillator options are selected via the configuration variables specified using the #pragma config statement. Use `#pragma config POSCMOD=EC` to select the EC option and `#pragma config POSCMOD=XT` to select the XT option.

Using the internal system clock phase-locked loop (PLL), it is possible to select numerous multiples or divisions of the 8Mhz input frequency to produce CPU operating frequencies up to 80Mhz. The clock circuit PLL provides an input divider, multiplier, and output divider. The external clock frequency (8Mhz) is first divided by the selected input divider value. This is multiplied by the selected multiplier value and then finally divided by the selected output divider. The result is the system clock, SYSCLK, frequency. The SYSCLK frequency is used by the CPU, DMA controller, interrupt controller and pre-fetch cache.

The values controlling the operating frequency are specified using the PIC32MX460 configuration variables. These are set using the `#pragma config` statement. Use `#pragma config FPLLIDIV` to set the input divider, `#pragma config FPLLMUL` to set the multiplication factor and `#pragma config FPLLODIV` to set the output divider. Refer to the PIC32MX3XX/4XX Family Data Sheet and the PIC32MX Family Reference Manual, Section 6. Oscillators, for information on how to choose the correct values, as not all combinations of multiplication and division factors will work.

In addition to configuring the SYSCLK frequency, the peripheral bus clock, PBCLK, frequency is also configurable. The peripheral bus clock is used for most peripheral devices, and in particular is the clock used by the timers, and serial controllers (UART, SPI, I2C). The PBLCK frequency is a division of the SYSCLK frequency selected using `#pragma config FPBDIV`. The PBCLK divider can be set to divide by 1, 2, 4, or 8 using the values DIV_1, DIV_2, DIV_4 or DIV_8.

The following example will set up the Cerebot MX4cK for operation using the Discrea silicon resonator with a SYSCLK frequency of 80Mhz and a PBCLK frequency of 10Mhz:

```
#pragma config FNOSC = PRIPLL
#pragma config POSCMOD = EC
#pragma config FPLLIDIV = DIV_2
#pragma config FPLLMUL = MUL_20
#pragma config FPLLODIV = DIV_1
#pragma config FPBDIV = DIV_8
```

Documentation for the PIC32 configuration variables can be found in the PIC32MX Configuration Settings guide. This is found using the "Help.Topics…" command in the MPLAB IDE. Also, refer to Appendix B for an example of setting the configuration variables.

When using the Cerebot MX4cK with the chipKIT MPIDE software, the clock source is set by the boot loader and no action is required.

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USB Interface

The PIC32MX460 microcontroller contains a USB 2.0 Compliant, Full Speed Device and On-The-Go (OTG) controller. This controller provides the following features:

- USB full speed host and device support
- Low speed host support
- USB OTG support
- Endpoint buffering anywhere in system RAM
- Integrated DMA to access system RAM and Flash memory.

The USB controller uses a phased lock loop, PLL, to generate the necessary USB clock frequency from the external primary oscillator input frequency. By default, this PLL is disabled. In order to use the USB controller, it is necessary to enable the USB PLL, and set the input divider to the correct value to generate a valid USB clock. The input to the USB PLL must be 4Mhz. The Cerebot MX4cK provides an 8Mhz clock to the PIC32 microcontroller, so a USB PLL input divider value of 2 must be used. These parameters are set in the PIC32 microcontroller configuration registers using the `#pragma config` statement. The following statements must be used to configure the PIC32 microcontroller for use of the USB controller:

```
#pragma config UPLLEN = ON
#pragma config UPLLIDIV = DIV_2
```

When using the chipKIT MPIDE development environment, these will have been set by the boot loader, so no action is needed.

When operating as a USB device, the Cerebot MX4cK can be operated as a self-powered device or as a bus powered device. To operate as a self-powered device, an external power supply should be connected to one of the external power connectors (J13, J14 or J18) and a shorting block placed on the “EXT” position of J12. The external power supply must be a regulated 5V supply. To operate as a USB bus powered device, the shorting block should be placed in the USB Device position, “USB”, on J12.

Note that when operating as a bus powered device, the Cerebot MX4cK and all devices connected to it are limited to no more than 500mA of current.

Connector J15, on the bottom of the board in the lower right corner is the Device/OTG connector. This is a standard USB micro-AB connector. Connect a cable with a micro-A plug (optionally available from Digilent) from this connector to an available USB port on a PC or USB hub for device operation.

When operating as a USB host, the Cerebot MX4cK must be externally powered. Connect a regulated 5V power supply to one of the external power connectors (J13, J14, or J18) and ensure that the shorting block is in the center, “EXT” position of J12. The power supply used must be a regulated 5V supply. The Cerebot MX4cK board provides power to the attached USB device when operating as a host, and the USB specification requires the use of a 5V power supply. NOTE: Providing a voltage greater than 5V can damage the Cerebot MX4cK board and/or the USB device being used.

Connector J17, on the top of the board in the lower right corner is the USB host connector. This is a standard USB type A receptacle. USB devices may be connected either directly or through a standard USB cable.

Jumper JP6 is used to route power to the host connector being used. Place the shorting block in the “HOST” position when using the standard USB type A (host) connector, J17. Place the shorting block in the “OTG” position for use with the USB micro-AB (OTG) connector, J15.

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When operating as a USB host, the PIC32MX460 microcontroller controls application of power to the connected device via the VBUSON control pin. Bus power is applied to the device by driving the VBUSON pin high. Power is removed from the device by driving the VBUSON pin low. The VBUSON pin is accessed via bit 3 of the U1OTGCON register.

Pin 20 of the PIC32MX460 microcontroller is used for the VBUSON function. Place the shorting block in the VBUSON position of jumper block J16 when using the Cerebot MX4cK for USB host operation.

The VBUSON pin drives the enable input of a TPS2051B Current-Limited Power Distribution Switch to control the application of USB power to the host connector. This switch has over-current detection capability and provides an over-current fault indication by pulling the signal P32_USBOC low. Jumper JP5 is used to enable monitoring of the overcurrent fault indication. The over-current output pin can be monitored via the INT2/RE9 pin on the PIC32MX460 microcontroller when a shorting block is installed on JP5. The INT2/RE9 pin is also connected to Pmod connector JE, pin 7 (JE-07). Pmod connector pin JE-07 should not be used when using INT2/RE9 to monitor the USB overcurrent fault indicator. Remove the shorting block from JP5 to restore normal operation of JE-07.

Details about the operation of the TPS2051B can be obtained from the data sheet available at the Texas Instruments web site.

Jumper JP10 can be used to disconnect the USB load switch, IC6, when the board is operating from a power supply with a higher voltage than 5V. When the Cerebot MX4cK is operating as a USB host, a shorting block must be in place on JP10.

The Microchip Applications Library, MAL, available on the Microchip web site contains USB driver code for implementing either USB host devices or USB function devices. This library contains numerous examples demonstrating both device and host operation of PIC32 microcontrollers. With minor modification or configuration, these reference designs are suitable to use for developing USB firmware for the Cerebot MX4cK board.

Digilent has USB libraries available that can be used to develop both USB device and USB host applications when using the board with the chipKIT MPIDE development environment. These libraries can be downloaded from the Cerebot MX4cK product page on the Digilent web site.

The Digilent chipKIT libraries contain examples illustrating various USB host and device applications.

UART Interface

The PIC32MX460 microcontroller provides two UART interfaces, UART1 and UART2. The UARTs can provide either a 2-wire or a 4-wire asynchronous serial interface. The 2-wire interface provides receive (RX) and transmit (TX) pins. The 4-wire interface includes request-to-send (RTS) and clear-to-send (CTS) in addition to receive and transmit.

UART1 can be accessed from Pmod connector JE and UART2 can be accessed from Pmod connector JH using the following pins:

• U1CTS	JE-01
• U1TX	JE-02
• U1RX	JE-03
• U1RTS	JE-04

• U2CTS	JH-01
• U2TX	JH-02
• U2RX	JH-03
• U2RTS	JH-04

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Detailed information about the operation of the UART peripherals can be found in the PIC32 Family Reference Manual, Section 21, UART.

The USB Serial converter is connected to UART1. The MPIDE uses this to communicate with the boot loader. This can also be used for a serial communications interface between the Cerebot MX4cK board and other software running on a PC. Resistors are used to decouple the USB serial interface and so UART1 can also be used via Pmod connector JE when it is not being used to communicate via the USB serial converter.

Note that when using the MPIDE software, devices connected to JE can interfere with the operation of the serial interface and prevent the MPIDE from successfully downloading sketches to the board. If this happens, disconnect the external device from JE until the sketch has been downloaded and then reconnect it.

When using the Cerebot MX4cK with the MPIDE and the chipKIT system, the UARTs are accessed using the HardwareSerial facility built into the system. UART1, connector JE, is accessed using the `Serial` object and UART2, connector JH, is accessed using `Serial1`.

Serial Peripheral Interface (SPI)

SPI is a four wire synchronous serial interface and SPI devices can operate as either master devices or as slave device. The PIC32 microcontroller labels the four SPI signals as Slave Select (SS), Serial Data Out (SDO), Serial Data In (SDI), and Serial Clock (SCK). A master device transmits SS, SDO and SCK, and receives SDI. A slave device receives SS, SDI, and SCK and transmits SDO. The SS signal is used to enable the slave device, and this signal is only significant for slave devices. A master device can use any general purpose I/O pin to generate SS to enable the slave.

An SPI transaction begins with the master device bringing SS low. When the slave sees SS go low it becomes enabled and waits for the master to send data. The master shifts data out on SDO and simultaneously shifts data in on SDI. The slave device receives data from the master on its SDI pin and simultaneously sends data to the master on its SDO pin. Each time the master sends a byte to the slave, it simultaneously receives a byte from the slave.

The PIC32MX460 microcontroller provides two Serial Peripheral Interfaces, SPI1 and SPI2. SPI2 is accessed via Pmod connector JB and SPI1 is accessed via connector J1. Because of the way that peripheral functions are shared the pins for SPI1, the signals on J1 are shared with various Pmod connectors around the board. For this reason, when using only a single SPI port, SPI2 is the preferred port to use.

The following gives the mapping between SPI signals and connector pins:

• SS2	JB-01
• SDO2	JB-02
• SDI2	JB-03
• SCK2	JB-04

• SS1	J1-01 (also JD-03)
• SDO1	J1-02 (also JH-08)
• SDI1	J1-03 (also JK-10)
• SCK1	J1-04 (also JD-09)

Detailed information about the operation of the SPI peripherals can be found in the PIC32 Family Reference Manual, Section 23, Serial Peripheral Interface.

When using the Cerebot MX4cK with the MPIDE and the chipKIT system, the SPI ports are accessed using either the standard chipKIT SPI library or using the Digilent DSPI library.

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The standard SPI library supports access to a single SPI port, SPI2. This is accessed using the `SPI` object.

The DSPI library supports access to both SPI ports. The `DSPI0` object class is used to create an object used to access the default SPI port, SPI2, connector JB. The `DSPI1` object class is used to access SPI1, connector J1.

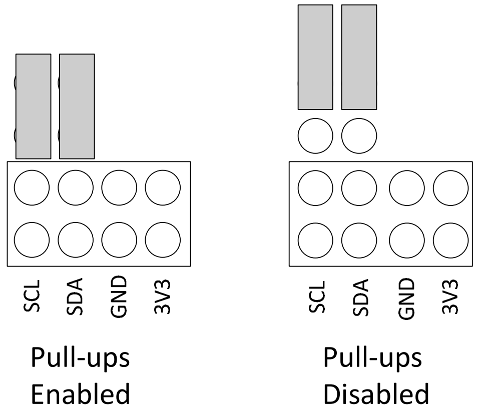
I^{2}C™ Interface

The Inter-Integrated Circuit (I^{2}C™) Interface provides a medium speed (100K or 400K bps) synchronous serial communications bus. The I^{2}C interface provides master and slave operation using either 7 bit or 10 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. Refer to the Microchip PIC32MX3XX/4XX Family Data Sheet and the PIC32 Family Reference Manual, Section 24, Inter-Integrated Circuit, for detailed information on configuring and using the I^{2}C interface.

The PIC32MX460 microcontroller provides for two independent I^{2}C interfaces. The Cerebot MX4cK is designed to provide dedicated access to one of these interfaces, I2C2, using I^{2}C daisy chain connector J6. The other I^{2}C interface, I2C1, is accessed using I^{2}C daisy chain connector J2. The signals for I2C1 are shared with Pmod connector JF, and also appear on pins 1 & 2 of JF.

The I^{2}C daisy chain connectors provide two positions for connecting to the I^{2}C signals, SDA and SCL, as well as power and ground. By using two-wire or four-wire MTE cables (available separately from Digilent) a daisy chain of multiple Cerebot MX4cK boards or other I^{2}C-capable boards or devices can be created.

The I^{2}C bus is an open-collector bus. Devices on the bus actively drive the signals low. The high state of the I^{2}C signals is achieved by pull-up resistors when no device is driving the lines low. One device on the I^{2}C bus must provide the pull-up resistors. On the Cerebot MX4cK, I2C2 has fixed 2.2K ohm pull-up resistors. I2C1 has selectable pull-up resistors that can be enabled or disabled via jumpers J3 and J4,. The pull-ups are enabled by installing shorting blocks and are disabled by removing the shorting blocks. Generally, only one device on the bus will have the pull-ups enabled.



Jumper Settings for I^{2}C Pull-Up Resistors

When using the Cerebot MX4cK with the MPIDE and the chipKIT system, the I^{2}C interfaces are accessed using the standard chipKIT Wire library, or the Digilent DTWI library.

The Wire library supports a single I^{2}C interface, I2C1 on J2. This is accessed using the `Wire` object.

The DTWI library supports both I^{2}C interfaces. The `DTWI0` object class is used to create an object for access to I2C1 and the `DTWI1` object class is used to access I2C2.
The pinouts of the I^{2}C daisy chain connectors are as follows:

Connector J2. I2C1

- J2-1 – SCL1
- J2-2 – SCL1

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- J2-3 – SDA1
- J2-4 – SDA1
- J2-5 – GND
- J2-6 – GND
- J2-7 – BRD_3V3
- J2-8 – BRD_3V3

Connector J6, I2C2

- J6-1 – SCL2
- J6-2 – SCL2
- J6-3 – SDA2
- J6-4 – SDA2
- J6-5 – GND
- J6-6 – GND
- J6-7 – BRD_3V3
- J6-8 – BRD_3V3

On-Board I^{2}C Peripheral Devices

The Cerebot MX4cK provides two on-board I^{2}C peripheral devices, a Microchip 24LC256 serial EEPROM, and a Microchip MCP4725 Digital to Analog Converter. These devices are both connected to I2C2. The 24LC256 is a 256Kbit (32Kbyte) serial EEPROM device to provide non-volatile memory storage. The MCP4725 is a single channel, 12-bit, serial digital to analog converter that provides an analog output voltage for various uses. The device address for IC2, the 24LC256 is 1010000 (0x50). The device address for IC3, the MCP4725, is 1100000 (0x60).

Refer to the Microchip data sheets for detailed information on the operation of these devices.

The analog output voltage from IC3 is available at two places on the Cerebot MX4cK board. The two pin header, J10, provides the DAC output voltage and ground for connection to off-board applications.

The DAC output signal is also available at the center, DAC, position of jumper block J16. Placing a shorting block at this position connects the DAC output to pin 20 on the PIC32MX460 microcontroller. One of the functions for this pin is as one of the inputs to analog comparator #1 on the PIC32 device. This allows the output of the DAC to be used as a programmable reference voltage for the comparator.

Analog Inputs

The PIC32MX460 microcontroller provides a 10-bit analog to digital (A/D) converter that provides up to sixteen analog inputs. The Cerebot MX4cK board provides access to 14 of them on the Pmod connectors. The converted values produced by the A/D converter will be in the range 0–1023.

For detailed information on the operation and use of the A/D converter, refer to the PIC32 Family Reference Manual, Section 17, 10-bit AD Converter.

The analog inputs are accessed using the analogRead() function in the chipKIT MPIDE software. The analog input pin number is specified using the symbols A0–A13. The digital pin numbers for the pin or the numbers 0–13 can also be used, but using the symbols A0–A13 is recommended.

The following gives the Pmod connector position, digital pin number, and microcontroller I/O port and bit number for the analog inputs:

- A0 – JJ-01, digital pin 56, RB0
- A1 – JJ-02, digital pin 57, RB1
- A2 – JJ-03, digital pin 58, RB2
- A3 – JJ-04, digital pin 59, RB3
- A4 – JJ-07, digital pin 60, RB4
- A5 – JJ-08, digital pin 61, RB5
- A6 – JJ-09, digital pin 62, RB8
- A7 – JJ-10, digital pin 63, RB9
- A8 – JK-01, digital pin 64, RB10
- A9 – JK-02, digital pin 65, RB11
- A10 – JK-03, digital pin 66, RB12
- A11 – JK-04, digital pin 67, RB13

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- A12 – JB-07, digital pin 12, RB15
- A13 – JB-10, digital pin 15, RB14

A/D Converter Reference

The PIC32 microcontroller provides two reference inputs to the analog to digital converter. Vref- is used set the lower reference level and Vref+ is used to set the upper reference level. These references can be connected to internal references or external references using two of the analog input pins.

When the internal references are being used, Vref- is connected to VSS and Vref+ is connected to VDD. This means that the voltage input range at the analog input pins is 0V–3.3V. In this case, an input voltage of 0V will convert to ~0, an input voltage of 1.65V will convert to ~511, and an input voltage of 3.3V will convert to ~1023.

Either one, or both, of the references can be connected to external reference pins. When this is done, the references can be set to voltages other than 0V and 3.3V.

If, for example, both references were selected to use external references, with 1V applied to Vref- and 2V applied to Vref+, the input voltage range at the analog input pins would be from 1V to 2V. An applied voltage of 1V would have a converted value of ~0, 1.5V would have a converted value of ~511, and 2V would have a converted value of ~1023.

When both external references are being used, Vref+ must have a higher voltage applied to in than Vref-.

The analog reference input pins appear on Pmod connector JK, pins 7 & 8. Vref- is on pin JK-07, and Vref+ is on pin JK-08. These pins are not available to be used for digital I/O when being used as an external reference.

When using the chipKIT MPIDE software, the use of external analog references is selected using the analogReference() function. The following values can be used with analogReference():

- DEFAULT – Vref- = 0V, Vref+ = 3.3V
- INTERNAL – same as default
- EXTERNAL – Vref- = 0V, Vref+ = voltage at A2
- EXTMINUS – Vref- = voltage at A3, Vref+ = 3.3V
- EXTPLUSMINUS – Vref- = voltage at A3, Vref+ = voltage at A2

Timers

The PIC32 microcontroller provides five timers that can be used for various timing functions. These timers are each 16 bits wide, although two pairs, TIMER2/TIMER3 and TIMER4/TIMER5 can be combined to produce 32 bit wide timers.

A timer consists of a control register, a counter register, and a period register. The control register is used to configure the timer for various modes of operation. The count register counts cycles of the clock source selected via the control register. This clock source can be the peripheral bus clock or a division of the peripheral bus clock via a pre-scaler divider. The period register can be used to generate an interrupt and/or reset the count register when a pre-determined value is reached.

Each timer has an associated input pin. In some operating modes, this pin can be used as an external clock input to the timer, or as a gate input to turn on/off incrementing of the counter register under control of an external signal.

The following gives the Pmod connector position, chipKIT pin number, and microcontroller I/O port and bit number for the timer input pins.

- TCK1 – not available
- TCK2 – JD-04, digital pin 27, RC01

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- TCK3 – JD-10, digital pin 31, RC02
- TCK4 – JE-10, digital pin 39, RC03
- TCK5 – JK-10, digital pin 71, RC04

For detailed information on the operation of the PIC32 timers, refer to the PIC32 Family Reference Manual, Section 14, Timers.

When using the chipKIT MPIDE software, the symbols PIN_TCK2, PIN_TCK3, PIN_TCK4, and PIN_TCK5 can be used to access the timer input pins.

Control and operation of the timers is not explicitly provided in the current version of the chipKIT MPIDE software. This capability will be added in a future version of the software. Timers are used implicitly by various core functions and libraries, however.

Output Compare

The PIC32 microcontroller provides five output compare units that can be used to control the timing of state changes on certain output pins or to generate pulse width modulated (PWM) outputs.

Each output compare unit works with a particular output pin (OC1-OC5). It can be programmed to control the pin in any of the following ways:

- PWM output
- Generate continuous pulses
- Generate a single pulse
- Toggle the output pin
- Generate falling edge
- Generate rising edge

The output compare units work in conjunction with a timer. Either Timer2 or Timer3 can be used with any of the five output compare units.

Refer to the PIC32 Family Reference Manual, Section 16, Output Compare for detailed information on the use of the output compares units.

When using the chipKIT MPIDE software, these are accessed using the analogWrite() function. The digital pin number, or preferably, the symbols PIN_OC1 through PIN_OC5 are used to specify the pin. The chipKIT MPIDE software currently only supports using the output compare units to generate PWM outputs. It uses Timer2 to control the output compares.

The following gives Pmod connector position, chipKIT pin number, and microcontroller I/O port and bit number for the output compare unit's output pins:

- OC1 – JH-08, digital pin 53, RD0
- OC2 – JD-02, digital pin 25, RD1
- OC3 – JD-08, digital pin 29, RD2
- OC4 – JE-08, digital pin 37, RD3
- OC5 – JB-09, digital pin 14, RD4

Input Capture

The PIC32 microcontroller provides five input capture units. An input capture unit works in conjunction with a timer and monitors the state of an associated pin. When the pin changes state, the current value of the timer is captured. The input capture units can be used with either Timer2 or Timer3.

The input capture unit can be programmed to be sensitive to either a rising edge, a falling edge, or both edges on the input pin. An interrupt can also be signaled when an input capture is triggered. Each input capture has a four level deep FIFO that can buffer up to four capture events.

For detailed information on the operation and use of the input capture units, refer to the PIC32 Family Reference Manual, Section 15, Input Capture.

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The following gives the Pmod connector position, chipKIT pin number, and microcontroller port and bit number for the input capture units input pins:

- IC1 – JH-09, digital pin 54, RD08
- IC2 – JD-03, digital pin 26, RD09
- IC3 – JD-03, digital pin 30, RD10
- IC4 – JE-09, digital pin 38, RD11
- IC5 – JK-09, digital pin 70, RD12

When using the chipKIT MPIDE software, the symbols PIN_IC1, PIN_IC2, PIN_IC3, PIN_IC4, and PIN_IC5 can be used to access the capture input pins.

Use of the input capture units is not currently supported in the chipKIT MPIDE software. This will be added in a future version.

External Interrupts

The PIC32 microcontroller provides five external interrupt inputs. An external interrupt input can be used to generate an interrupt to the microprocessor CPU when the pin changes state. They can be programmed to interrupt on a rising edge or a falling edge on the pin.

Refer to the PIC32 Family Reference Manual, Section 8, Interrupts for more information on the operation of the external interrupts.

These are accessed using the attachInterrupt() and detachInterrupt() functions when using the chipKIT MPIDE software,. The interrupt number is specified using the numbers 0-4, or preferably, the symbols EXT_INT0 through EXT_INT4.

The following gives Pmod connector position, chipKIT pin number, and microcontroller I/O port and bit number:

- INT0 – JH-08, digital pin 53, RD0
- INT1 – JH-07, digital pin 52, RE8
- INT2 – JE-07, digital pin 36, RE9
- INT3 – JF-01, digital pin 40, RA14
- INT4 – JF-02, digital pin 41, RA15

RTCC

The PIC32 microcontroller contains a low frequency oscillator and Real Time Clock/Calendar circuit, RTCC, that can be used to maintain time and date information. The operation of the RTCC requires a 32.768Khz frequency source. The crystal X2 position, just above and on the right of the PIC32 microcontroller, IC1, is provided for the user to solder in a 32Khz watch crystal. The Citizen CFS206-32.768KDZF-UB is a crystal part that can be used in this location.

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Appendix A: Connector Descriptions and Jumper Settings

Label	Function
J1	**SPI port #1 connector** Because of multiple uses for the pins, the signals for SPI port #1 are scattered across multiple Pmod connectors. This connector provides all of the SPI port #1 signals on a single connector. All of the signal pins on this connector are shared with pins on various Pmod connectors.
J2	**I2C port #1 daisy chain connector** This connector provides access to the I^2C signals, power and ground for I2C1.
J3 & J4	**Pull-up enable for I2C port #1** These two jumpers are used to enable/disable the pull-up resistors on I2C1. Insert shorting blocks on these two jumpers for enable the pull-up resistors. Remove the shorting blocks to disable the pull-up resistors. Only a single device on the I^2C bus should have the pull-up resistors enabled.
J5	**Servo bus power connector** This connector is used to provide power to the servo power bus, VS.
J6	**I2C port #2 daisy chain connector** This connector provides access to the I^2C signals, power and ground for I2C2.
J7	**USB Serial converter auxiliary signals** This connector can be used to access the auxiliary RS232 handshaking signals not used on the Cerebot MX4cK board.
J8	**USB Serial converter (UART) connector** This USB micro-AB connector is used to connect the FT232R serial converter to a USB port on the user PC.
J9	**Licensed Debugger USB connector** This USB micro-AB connector is used to connect the licensed debugger to a USB port on the user PC.
J10	**DAC output** The analog output voltage of IC3, the MCP4725 Digital to Analog converter, is available at this connector.
J11	**Do not use** Used for manufacturing test purposes.

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J12	**Power supply source select** This jumper is used to select the source of main board power. Place a shorting block in the USB position to have the board powered from the USB device connector, J15. Place a shorting block in the EXT position to have the board powered from one of the external power connectors, J13, J14, or J18. Place a shorting block in the DBG position to have the board powered from the debug USB connector, J9. Place the shorting block in the URT position to have the board powered from the USB serial converter connector, J8.
J13	**External power connector** This is a 5.5mm x 2.5mm coaxial power connector wired center positive. This is used to supply external power to the board.
J14	**External power connector** This is a two pin header connector that can be used to supply external power to the board.
J15	**USB OTG connector** This is a USB micro-AB connector that is used when the Cerebot MX4cK board is used to implement a USB device, or USB OTG device.
J16	**PIC32 pin 20 function select** Pin 20 on the PIC32MX460 microcontroller has multiple functions. It functions as the VBUSON control pin when acting as a USB host. It can be used as an analog input for the A/D converter or one of the analog comparators. It can also be used as a pin change interrupt input or as a general digital i/o. This jumper is used to route pin 20 to one of three places on the board: Place a shorting block in the upper, VBUSON, position when acting as a USB host to control the USB power supplied to the connected device. Place a shorting block in the middle, DAC, position to connect the output of the MCP4725 digital to analog converter to pin 20. This allows the use of the DAC output as an input to analog comparator #1. Place a shorting block in the lower, JJ-8, position to connect pin 20 to Pmod connector JJ, pin 8. This allows access to pin 20 from this Pmod connector.
J17	**USB host connector** This is a standard USB type A connector. This is used to connect a USB device when the Cerebot MX4cK is being used as a USB host.

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J18	**External power connector** This is a two pin screw terminal connector that can be used to supply external power to the board.
J19	**Auxiliary Power Out** This connector provides access to the unregulated power bus BRD_VU and GND. It can be used to distribute power to other boards from the Cerebot MX4cK.
JP1	**Connect VS bus to BRD_VU bus** This jumper is used to connect the VS bus to the BRD_VU bus. The VS bus provides power to the servo connectors, S1-S8. The BRD_VU bus is the main board power bus. Install a shorting block on this jumper to have the servo power bus powered from the main power bus. Remove the shorting block from this jumper to separate the two power busses. When using a separate servo power bus, the VS bus is powered from screw terminal connector J5.
JP2	**VS bus voltage monitor** This jumper is used to enable monitoring of the VS bus voltage. When a shorting block is installed on this jumper, the VS bus is connected via a voltage divider to analog input AN9. This can be used, for example, to monitor the state of a battery supply being used to power servos.
JP3	**Connector JB pin 7 signal select** This jumper is used to route either signal SCL1/INT3/RA14 or PMALL/AN15/CN12/RB15 to the pin 7 position of Pmod connector JB. The jumper is normally in the RB15 position. This allows connector the PIC32 Parallel Master Port to be used with connector JB. Place the jumper in the INT3 position when using JB to access an SPI device that requires an interrupt on pin 7.
JP4	**BRD_VU bus voltage monitor** This jumper is used to enable monitoring of the BRD_VU bus voltage. When a shorting block is installed on this jumper, the BRD_VU bus is connected via a voltage divider to analog input AN8. This can be used, for example, to monitor the state of a battery supply being used to power the board.
JP5	**USB over-current detect** This jumper is used to enable monitoring of the over-current detect capability of the USB bus power switch, IC6. When a shorting block is installed on this jumper, the over-current output pin of IC6 is connected to the INT2/RE9 pin of the PIC32MX460 microcontroller.
JP6	**USB host power select** This jumper is used to select which host connector is powered when host power is enabled. Place the shorting block in the “OTG” position to supply power to the USB OTG Connector, J15. Place the shorting block in the “HOST” position to supply power to the USB Host Connector, J17.
JP7	**Do not use** Used for manufacturing test purposes.

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JP8	**USB Serial converter reset disconnect** This is used to connect/disconnect the USB serial converter reset circuit from the PIC32 MCLR pin. The shorting block must be in place on this jumper when using the chipKIT MPIDE development tools. Remove the shorting block if the USB serial converter is interfering with proper operation of the licensed debugger circuit.
JP9	**Do not use** Used for manufacturing test purposes.
JP10	**USB host power disconnect** This jumper is used to disconnect the USB load switch, IC6, from the BRD_VU bus when the board is being operated from an external power supply with a voltage greater than 5V. This allows operation of the board from a higher voltage power supply.
S1-S8	**Servo connectors** These provide connection for up to 8 RC hobby servos. Each of these connectors provides a control signal: labeled S; servo power: labeled VS, and a ground connection: labeled G. The signal pins on these connectors are shared with the signal pins on Pmod connector JC.
JPA – JPF & JPH-JPK	**Pmod header power select** Any of the Pmod headers can be connected to use either regulated or unregulated power. To use regulated power, place the jumper block over the center pin and the pin marked VCC. To use unregulated power, place the jumper block over the center pin and the pin marked BRD_VU.

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Appendix B: Example of Configuration Values

The following example illustrates setting the configuration values in the PIC32 microcontroller on the Cerebot MX4cK. The microcontroller configuration should be done in a single source file in the project, and is typically done in the 'main' project source file. This example sets all configuration values to valid values for the Cerebot MX4cK board. It sets the system clock for processor operation at 80Mhz, and the peripheral bus at 10Mhz.

```
/* ------------------------------------------------------------ */
/*               PIC32 Configuration Settings                   */
/* ------------------------------------------------------------ */

/* Oscillator Settings
*/
#pragma config FNOSC    = PRIPLL    // Oscillator selection
#pragma config POSCMOD  = EC        // Primary oscillator mode
#pragma config FPLLIDIV = DIV_2     // PLL input divider
#pragma config FPLLMUL  = MUL_20    // PLL multiplier
#pragma config FPLLODIV = DIV_1     // PLL output divider
#pragma config FPBDIV   = DIV_8     // Peripheral bus clock divider
#pragma config FSOSCEN  = OFF       // Secondary oscillator enable

/* Clock control settings
*/
#pragma config IESO     = OFF       // Internal/external clock switchover
#pragma config FCKSM    = CSDCMD    // Clock switching (CSx)/Clock monitor (CMx)
#pragma config OSCIOFNC = OFF       // Clock output on OSCO pin enable

/* USB Settings
*/
#pragma config UPLLEN   = ON        // USB PLL enable
#pragma config UPLLIDIV = DIV_2     // USB PLL input divider
#pragma config FVBUSONIO = OFF      // VBUS pin control
#pragma config FUSBIDIO = OFF       // USBID pin control

/* Other Peripheral Device settings
*/
#pragma config FWDTEN   = OFF       // Watchdog timer enable
#pragma config WDTPS    = PS1024    // Watchdog timer post-scaler
#pragma config FSRSSEL  = PRIORITY_7 // SRS interrupt priority

/* Code Protection settings
*/
#pragma config CP       = OFF       // Code protection
#pragma config BWP      = OFF       // Boot flash write protect
#pragma config PWP      = OFF       // Program flash write protect

/* Debug settings
*/
//#pragma config ICESEL = ICS_PGx2  // ICE pin selection
```

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Appendix C: Connector Pinout Tables

Arranged by Microcontroller Pin Number

PIC32 Pin #	Connector Pin #	chipKIT Pin #	MCU Port Bit	PIC32 Signal Name	Notes
1	JC-04	19	RG15	RG15	also servo S4
3	JA-08	5	RE05	PMD5/RE5	
4	JA-09	6	RE06	PMD6/RE6	
5	JA-10	7	RE07	PMD7/RE7	
6	JD-04	27	RC01	T2CK/RC1	
7	JD-10	31	RC02	T3CK/RC2	
8	JE-10	39	RC03	T4CK/RC3	
9	JK-10	71	RC04	SDI1/T5CK/RC4	also J1-03
10	JB-04	11	RG06	PMA5/SCK2/CN8/RG6	
11	JB-03	10	RG07	PMA4/SDI2/CN9/RG7	
12	JB-02	9	RG08	PMA3/SDO2/CN10/RG8	
14	JB-01	8	RG09	PMA2/SS2/CN11/RG9	
17	JF-07	44	RA00	TMS/RA0	
18	JH-07	52	RE08	INT1/RE8	also J1-07
19	JE-07	36	RE09	INT2/RE9	also JP5,USB OC_SENSE
20	JJ-08	61	RB05	VBUSON/C1IN+/AN5/CN7/RB5	Selected by J16
21	JJ-07	60	RB04	C1IN-/AN4/CN6/RB4	
22	JJ-04	59	RB03	C2IN+/AN3/CN5/RB3	
23	JJ-03	58	RB02	C2IN-/AN2/CN4/RB2	
24	JJ-02	57	RB01	PGC1/EMUC1/AN1/CN3/RB1	
25	JJ-01	56	RB00	PGD1/EMUD1/AN0/CN2/RB0	
26	N/A	N/A	RB06	PGC2/EMUC2/AN6/OCFA/RB6	debug PGC
27	N/A	N/A	RB07	PGD2/EMUD2/AN7/RB7	debug PGD
28	JK-07	68	RA09	PMA7/Vref-/CVref-/RA9	
29	JK-08	69	RA10	PMA6/Vref+/CVref+/RA10	
32	JJ-09	62	RB08	C1OUT/AN8/RB8	
33	JJ-10	63	RB09	C2OUT/AN9/RB9	
34	JK-01	64	RB10	CVrefout/PMA13/AN10/RB10	also LD1
35	JK-02	65	RB11	PMA12/AN11/RB11	also LD2
38	JF-08	45	RA01	TCK/RA1	
39	JH-04	51	RF13	U2RTS/BCLK2/RF13	
40	JH-01	48	RF12	U2CTS/RF12	
41	JK-03	66	RB12	PMA11/AN12/RB12	also LD3
42	JK-04	67	RB13	PMA10/AN13/RB13	also LD4
43	JB-10	15	RB14	PMALH/PMA1/AN14/RB14	

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44	JB-07	12	RB15	PMALL/PMA0/AN15/OCFB/CN12/RB15	
47	JE-01	32	RD14	CN20/U1CTS/RD14	
48	JE-04	35	RD15	U1RTS/BCLK1/CN21/RD15	
49	JH-03	50	RF04	PMA9/U2RX/CN17/RF4	
50	JH-02	49	RF05	PMA8/U2TX/CN18/RF5	
51	N/A	N/A	RF03	USBID/RF3	USB-4
52	JE-03	34	RF02	U1RX/RF2	
53	JE-02	33	RF08	U1TX/RF8	
56	N/A	N/A	RG03	D-/RG3	USB-2
57	N/A	N/A	RG02	D+/RG2	USB-3
58	J6-1,J6-2	72	RA02	SCL2/RA2	I2C2
59	J6-3,J6-4	73	RA03	SDA2/RA3	I2C2
60	JF-09	46	RA04	TDI/RA4	
61	JF-10	47	RA05	TDO/RA5	
63	N/A	N/A	RC12	OSC1/CLKI/RC12	Primary Oscillator
64	N/A	N/A	RC15	OSC2/CLKO/RC15	Primary Oscillator
66	JF-01	40	RA14	SCL1/INT3/RA14	also J2-01,J2-02 I2C1
67	JF-02	41	RA15	SDA1/INT4/RA15	also J2-03,J2-04 I2C1
68	JH-09	54	RD08	IC1/RTCC/RD8	also J1-08
69	JD-03	26	RD09	IC2/SS1/RD9	also J1-01
70	JD-09	30	RD10	IC3/SCK1/PMCS2/PMA15/RD10	also J1-04
71	JE-09	38	RD11	IC4/PMCS1/PMA14/RD11	
72	JH-08	53	RD00	SDO1/OC1/INT0/RD0	also J1-02
73	N/A	N/A	RC13	SOSCI/CN1/RC13	Secondary Oscillator
74	N/A	N/A	RC14	SOSCO/T1CK/CN0/RC14	Secondary Oscillator
76	JD-02	25	RD01	OC2/RD1	
77	JD-08	29	RD02	OC3/RD2	
78	JE-08	37	RD03	OC4/RD3	
79	JK-09	70	RD12	PMD12/IC5/RD12	
80	JH-10	55	RD13	PMD13/CN19/RD13	also J1-09
81	JB-09	14	RD04	PMWR/OC5/CN13/RD4	
82	JB-08	13	RD05	PMRD/CN14/RD5	
83	JD-07	28	RD06	PMD14/CN15/RD6	also J1-10
84	JD-01	24	RD07	PMD15/CN16/RD7	
87	JC-09	22	RF00	PMD11/RF0	also servo S7
88	JC-10	23	RF01	PMD10/RF1	also servo S8
89	JC-08	21	RG01	PMD9/RG1	also servo S6
90	JC-07	20	RG00	PMD8/RG0	also servo S5
91	JF-03	42	RA06	TRCLK/RA6	also BTN1
92	JF-04	43	RA07	TRD3/RA7	also BTN2

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93	JA-01	0	RE00	PMD0/RE0	
94	JA-02	1	RE01	PMD1/RE1	
95	JC-03	18	RG14	TRD2/RG14	also servo S3
96	JC-01	16	RG12	TRD1/RG12	also servo S1
97	JC-02	17	RG13	TRD0/RG13	also servo S2
98	JA-03	2	RE02	PMD2/RE2	
99	JA-04	3	RE03	PMD3/RE3	
100	JA-07	4	RE04	PMD4/RE4	

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Arranged by Connector Pin Number and Digital Pin Number

PIC32 Pin #	Connector Pin #	chipKIT Pin #	MCU Port Bit	PIC32 Signal Name	Notes
93	JA-01	0	RE00	PMD0/RE0	
94	JA-02	1	RE01	PMD1/RE1	
98	JA-03	2	RE02	PMD2/RE2	
99	JA-04	3	RE03	PMD3/RE3	
100	JA-07	4	RE04	PMD4/RE4	
3	JA-08	5	RE05	PMD5/RE5	
4	JA-09	6	RE06	PMD6/RE6	
5	JA-10	7	RE07	PMD7/RE7	
14	JB-01	8	RG09	PMA2/SS2/CN11/RG9	
12	JB-02	9	RG08	PMA3/SDO2/CN10/RG8	
11	JB-03	10	RG07	PMA4/SDI2/CN9/RG7	
10	JB-04	11	RG06	PMA5/SCK2/CN8/RG6	
44	JB-07	12	RB15	PMALL/PMA0/AN15/OCFB/CN12/RB15	
82	JB-08	13	RD05	PMRD/CN14/RD5	
81	JB-09	14	RD04	PMWR/OC5/CN13/RD4	
43	JB-10	15	RB14	PMALH/PMA1/AN14/RB14	
96	JC-01	16	RG12	TRD1/RG12	also servo S1
97	JC-02	17	RG13	TRD0/RG13	also servo S2
95	JC-03	18	RG14	TRD2/RG14	also servo S3
1	JC-04	19	RG15	RG15	also servo S4
90	JC-07	20	RG00	PMD8/RG0	also servo S5
89	JC-08	21	RG01	PMD9/RG1	also servo S6
87	JC-09	22	RF00	PMD11/RF0	also servo S7
88	JC-10	23	RF01	PMD10/RF1	also servo S8
84	JD-01	24	RD07	PMD15/CN16/RD7	
76	JD-02	25	RD01	OC2/RD1	
69	JD-03	26	RD09	IC2/SS1/RD9	also J1-01
6	JD-04	27	RC01	T2CK/RC1	
83	JD-07	28	RD06	PMD14/CN15/RD6	also J1-10
77	JD-08	29	RD02	OC3/RD2	
70	JD-09	30	RD10	IC3/SCK1/PMCS2/PMA15/RD10	also J1-04
7	JD-10	31	RC02	T3CK/RC2	
47	JE-01	32	RD14	CN20/U1CTS/RD14	
53	JE-02	33	RF08	U1TX/RF8	
52	JE-03	34	RF02	U1RX/RF2	
48	JE-04	35	RD15	U1RTS/BCLK1/CN21/RD15	

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19	JE-07	36	RE09	INT2/RE9	also JP5, USB OC_SENSE
78	JE-08	37	RD03	OC4/RD3	
71	JE-09	38	RD11	IC4/PMCS1/PMA14/RD11	
8	JE-10	39	RC03	T4CK/RC3	
66	JF-01	40	RA14	SCL1/INT3/RA14	also J2-01,J2-02 I2C1
67	JF-02	41	RA15	SDA1/INT4/RA15	also J2-03,J2-04 I2C1
91	JF-03	42	RA06	TRCLK/RA6	also BTN1
92	JF-04	43	RA07	TRD3/RA7	also BTN2
17	JF-07	44	RA00	TMS/RA0	
38	JF-08	45	RA01	TCK/RA1	
60	JF-09	46	RA04	TDI/RA4	
61	JF-10	47	RA05	TDO/RA5	
40	JH-01	48	RF12	U2CTS/RF12	
50	JH-02	49	RF05	PMA8/U2TX/CN18/RF5	
49	JH-03	50	RF04	PMA9/U2RX/CN17/RF4	
39	JH-04	51	RF13	U2RTS/BCLK2/RF13	
18	JH-07	52	RE08	INT1/RE8	also J1-07
72	JH-08	53	RD00	SDO1/OC1/INT0/RD0	also J1-02
68	JH-09	54	RD08	IC1/RTCC/RD8	also J1-08
80	JH-10	55	RD13	PMD13/CN19/RD13	also J1-09
25	JJ-01	56	RB00	PGD1/EMUD1/AN0/CN2/RB0	
24	JJ-02	57	RB01	PGC1/EMUC1/AN1/CN3/RB1	
23	JJ-03	58	RB02	C2IN-/AN2/CN4/RB2	
22	JJ-04	59	RB03	C2IN+/AN3/CN5/RB3	
21	JJ-07	60	RB04	C1IN-/AN4/CN6/RB4	
20	JJ-08	61	RB05	VBUSON/C1IN+/AN5/CN7/RB5	Selected by J16
32	JJ-09	62	RB08	C1OUT/AN8/RB8	
33	JJ-10	63	RB09	C2OUT/AN9/RB9	
34	JK-01	64	RB10	CVrefout/PMA13/AN10/RB10	also LD1
35	JK-02	65	RB11	PMA12/AN11/RB11	also LD2
41	JK-03	66	RB12	PMA11/AN12/RB12	also LD3
42	JK-04	67	RB13	PMA10/AN13/RB13	also LD4
28	JK-07	68	RA09	PMA7/Vref-/CVref-/RA9	
29	JK-08	69	RA10	PMA6/Vref+/CVref+/RA10	
79	JK-09	70	RD12	PMD12/IC5/RD12	
9	JK-10	71	RC04	SDI1/T5CK/RC4	also J1-03
58	J6-1,J6-2	72	RA02	SCL2/RA2	I2C2
59	J6-3,J6-4	73	RA03	SDA2/RA3	I2C2
26	N/A	N/A	RB06	PGC2/EMUC2/AN6/OCFA/RB6	debug PGC
27	N/A	N/A	RB07	PGD2/EMUD2/AN7/RB7	debug PGD

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51	N/A	N/A	RF03	USBID/RF3	USB-4
56	N/A	N/A	RG03	D-/RG3	USB-2
57	N/A	N/A	RG02	D+/RG2	USB-3
63	N/A	N/A	RC12	OSC1/CLKI/RC12	Primary Oscillator
64	N/A	N/A	RC15	OSC2/CLKO/RC15	Primary Oscillator
73	N/A	N/A	RC13	SOSCI/CN1/RC13	Secondary Oscillator
74	N/A	N/A	RC14	SOSCO/T1CK/CN0/RC14	Secondary Oscillator

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Arranged by Microcontroller I/O Port Name and Bit Number

PIC32 Pin #	Connector Pin #	chipKIT Pin #	MCU Port Bit	PIC32 Signal Name	Notes
17	JF-07	44	RA00	TMS/RA0	
38	JF-08	45	RA01	TCK/RA1	
58	J6-1,J6-2	72	RA02	SCL2/RA2	I2C2
59	J6-3,J6-4	73	RA03	SDA2/RA3	I2C2
60	JF-09	46	RA04	TDI/RA4	
61	JF-10	47	RA05	TDO/RA5	
91	JF-03	42	RA06	TRCLK/RA6	also BTN1
92	JF-04	43	RA07	TRD3/RA7	also BTN2
28	JK-07	68	RA09	PMA7/Vref-/CVref-/RA9	
29	JK-08	69	RA10	PMA6/Vref+/CVref+/RA10	
66	JF-01	40	RA14	SCL1/INT3/RA14	also J2-01,J2-02 I2C1
67	JF-02	41	RA15	SDA1/INT4/RA15	also J2-03,J2-04 I2C1
25	JJ-01	56	RB00	PGD1/EMUD1/AN0/CN2/RB0	
24	JJ-02	57	RB01	PGC1/EMUC1/AN1/CN3/RB1	
23	JJ-03	58	RB02	C2IN-/AN2/CN4/RB2	
22	JJ-04	59	RB03	C2IN+/AN3/CN5/RB3	
21	JJ-07	60	RB04	C1IN-/AN4/CN6/RB4	
20	JJ-08	61	RB05	VBUSON/C1IN+/AN5/CN7/RB5	Selected by J16
26	N/A	N/A	RB06	PGC2/EMUC2/AN6/OCFA/RB6	debug PGC
27	N/A	N/A	RB07	PGD2/EMUD2/AN7/RB7	debug PGD
32	JJ-09	62	RB08	C1OUT/AN8/RB8	
33	JJ-10	63	RB09	C2OUT/AN9/RB9	
34	JK-01	64	RB10	CVrefout/PMA13/AN10/RB10	also LD1
35	JK-02	65	RB11	PMA12/AN11/RB11	also LD2
41	JK-03	66	RB12	PMA11/AN12/RB12	also LD3
42	JK-04	67	RB13	PMA10/AN13/RB13	also LD4
43	JB-10	15	RB14	PMALH/PMA1/AN14/RB14	
44	JB-07	12	RB15	PMALL/PMA0/AN15/OCFB/CN12/RB15	
6	JD-04	27	RC01	T2CK/RC1	
7	JD-10	31	RC02	T3CK/RC2	
8	JE-10	39	RC03	T4CK/RC3	
9	JK-10	71	RC04	SDI1/T5CK/RC4	also J1-03
63	N/A	N/A	RC12	OSC1/CLKI/RC12	Primary Oscillator
73	N/A	N/A	RC13	SOSCI/CN1/RC13	Secondary Oscillator
74	N/A	N/A	RC14	SOSCO/T1CK/CN0/RC14	Secondary Oscillator
64	N/A	N/A	RC15	OSC2/CLKO/RC15	Primary Oscillator

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72	JH-08	53	RD00	SDO1/OC1/INT0/RD0	also J1-02
76	JD-02	25	RD01	OC2/RD1	
77	JD-08	29	RD02	OC3/RD2	
78	JE-08	37	RD03	OC4/RD3	
81	JB-09	14	RD04	PMWR/OC5/CN13/RD4	
82	JB-08	13	RD05	PMRD/CN14/RD5	
83	JD-07	28	RD06	PMD14/CN15/RD6	also J1-10
84	JD-01	24	RD07	PMD15/CN16/RD7	
68	JH-09	54	RD08	IC1/RTCC/RD8	also J1-08
69	JD-03	26	RD09	IC2/SS1/RD9	also J1-01
70	JD-09	30	RD10	IC3/SCK1/PMCS2/PMA15/RD10	also J1-04
71	JE-09	38	RD11	IC4/PMCS1/PMA14/RD11	
79	JK-09	70	RD12	PMD12/IC5/RD12	
80	JH-10	55	RD13	PMD13/CN19/RD13	also J1-09
47	JE-01	32	RD14	CN20/U1CTS/RD14	
48	JE-04	35	RD15	U1RTS/BCLK1/CN21/RD15	
93	JA-01	0	RE00	PMD0/RE0	
94	JA-02	1	RE01	PMD1/RE1	
98	JA-03	2	RE02	PMD2/RE2	
99	JA-04	3	RE03	PMD3/RE3	
100	JA-07	4	RE04	PMD4/RE4	
3	JA-08	5	RE05	PMD5/RE5	
4	JA-09	6	RE06	PMD6/RE6	
5	JA-10	7	RE07	PMD7/RE7	
18	JH-07	52	RE08	INT1/RE8	also J1-07
19	JE-07	36	RE09	INT2/RE9	also JP5,USB OC_SENSE
87	JC-09	22	RF00	PMD11/RF0	also servo S7
88	JC-10	23	RF01	PMD10/RF1	also servo S8
52	JE-03	34	RF02	U1RX/RF2	
51	N/A	N/A	RF03	USBID/RF3	USB-4
49	JH-03	50	RF04	PMA9/U2RX/CN17/RF4	
50	JH-02	49	RF05	PMA8/U2TX/CN18/RF5	
53	JE-02	33	RF08	U1TX/RF8	
40	JH-01	48	RF12	U2CTS/RF12	
39	JH-04	51	RF13	U2RTS/BCLK2/RF13	
90	JC-07	20	RG00	PMD8/RG0	also servo S5
89	JC-08	21	RG01	PMD9/RG1	also servo S6
57	N/A	N/A	RG02	D+/RG2	USB-3
56	N/A	N/A	RG03	D-/RG3	USB-2
10	JB-04	11	RG06	PMA5/SCK2/CN8/RG6	

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11	JB-03	10	RG07	PMA4/SDI2/CN9/RG7	
12	JB-02	9	RG08	PMA3/SDO2/CN10/RG8	
14	JB-01	8	RG09	PMA2/SS2/CN11/RG9	
96	JC-01	16	RG12	TRD1/RG12	also servo S1
97	JC-02	17	RG13	TRD0/RG13	also servo S2
95	JC-03	18	RG14	TRD2/RG14	also servo S3
1	JC-04	19	RG15	RG15	also servo S4

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