

Digilent Cerebot Plus™ Board Reference Manual

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www.digilentinc.com

215 E Main Suite D | Pullman, WA 99163
(509) 334 6306 Voice and Fax

Overview

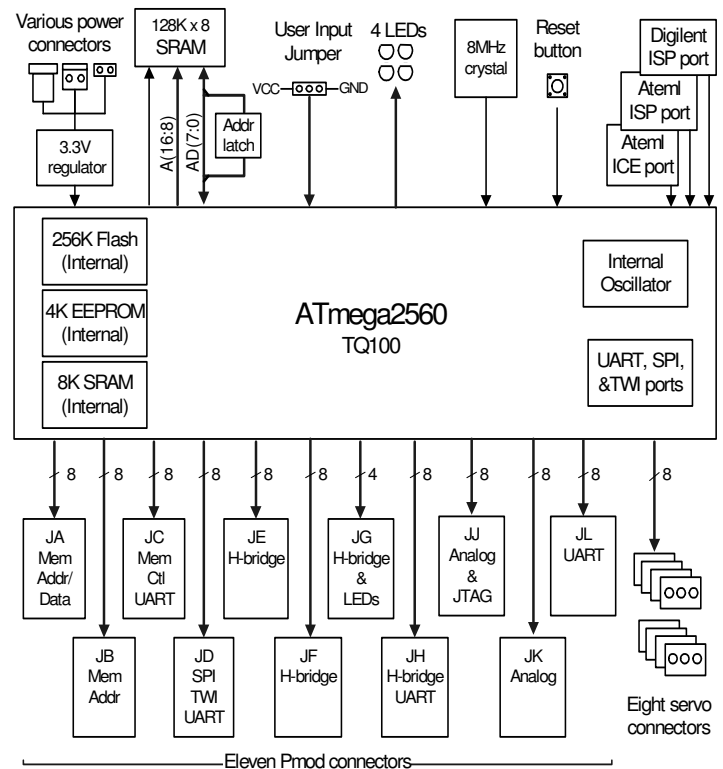
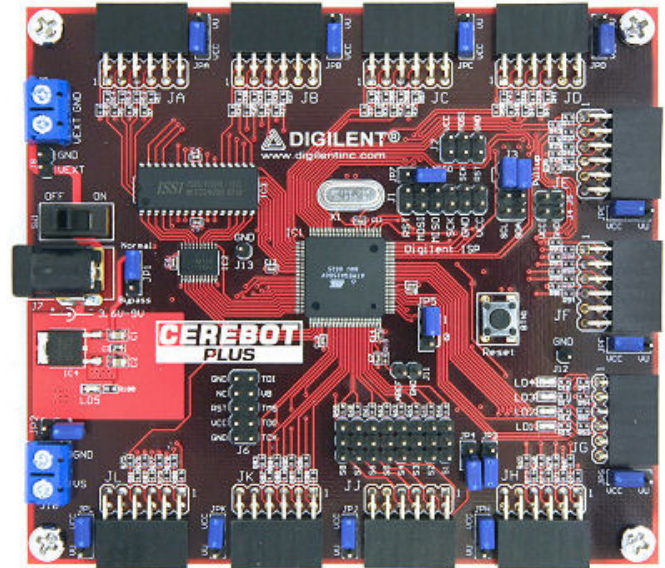
The Digilent Cerebot Plus Board is a useful tool for embedded control and robotics projects for both students and hobbyists.

The Cerebot Plus Board's versatile design and programmable embedded microcontroller lets you add different devices and program the board for multiple uses. The board has many I/O connectors and power supply options and supports a number of programming options including ATMEL AVR® STUDIO 4, and WINAVR.

The Cerebot Plus has a number of connections for peripheral devices. Digilent peripheral modules include H-bridges, analog-to-digital and digital-to-analog converters, a speaker, switches, buttons, LEDs, as well as converters for easy connection to RS232, screw terminals, BNC jacks, servo motors, and more.

Features include:

- an ATmega2560 microcontroller
- 128KB expansion memory
- eight hobby RC servo connectors
- eleven Pmod connectors for Digilent peripheral module boards
- an on-board voltage regulator
- multiple flexible power supply and jumper options
- support for the Atmel AVRISP in-system programmer
- support for the Atmel AVR JTAGICE mkII
- support for the Digilent Parallel and USB AVR in-system programmers
- ESD protection for all I/O pins.



Cerebot Plus Circuit Diagram

Features of the ATmega2560 include:

- a serial peripheral interface (SPI)
- two USART serial interfaces
- ATMEL TWI serial interface
- eight 10-bit analog inputs
- two 8-bit timer counters
- two 16-bit timer counters
- 256KB program flash
- 4KB user EEPROM
- 4KB internal RAM
- an analog comparator.

Functional Description

The Cerebot Plus is designed for embedded control and robotic applications as well as microprocessor experimentation. Embedded firmware suitable for many applications can be downloaded to the Cerebot Plus board's programmable ATmega2560 microcontroller.

The Cerebot Plus has a number of connection options, and is specially designed to work with the Digilent line of peripheral modules (Pmods) which provide various input and output functions. For more information, see www.digilentinc.com.

The Cerebot Plus has two programming interface options: The Digilent in-system-programming option is accessed via connector J1. A Digilent USB-JTAG/SPI cable or JTAG3 parallel programming cable can be attached to connector J1. The Digilent AVR Programmer application, available from the Digilent Web site, can be used to program the board via the Digilent programming cable. Alternatively, the Atmel AVRISP in-system programmer can be used. The AVRISP is connected to connector J2 and programming is done using the Atmel in-system-programming application built into the Atmel AVR Studio software. The Cerebot Plus also provides the ability to use the Atmel AVR JTAG ICE mk-II debugging tool for programming the board and debugging the user firmware. The JTAG ICE is connected using J6.

The Cerebot Plus features a flexible power supply routing system with a number of options for powering the Cerebot Plus as well as peripheral modules that connect to the board.

For more information on the ATmega2560 microcontroller, refer to the data sheet available at www.atmel.com.

Pmod™ Connectors

The Cerebot Plus has eleven Pmod connectors for connecting to Digilent Pmod peripheral modules. There are two styles of Pmod connector. The original Pmod connector standard uses a six-pin-header style of connectors providing four I/O signals, ground and a switchable power connection. The power connection is switchable between the regulated 3.3V main board supply and the unregulated input supply.

The newer Pmod connector standard uses a 12-pin (2x6) header connector and provides eight signal pins, two grounds, and two switchable power connections. The pin arrangement is such that the new connector is equivalent to two of the older connectors.

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

See the “Pmod Headers and SPI Connection” section below for more information about connecting peripheral modules and other devices to the Cerebot Plus. It lists the header connectors with their designed base function and a mapping to the Atmega64L I/O register ports. All pins can be used as general-purpose digital I/O ports.

Power Supply Connectors

The Cerebot Plus may be powered via dedicated power supply connectors, or it can be powered through any of the board's Pmod connectors. The Cerebot Plus can also be powered through the servo power connector.

The Cerebot Plus is rated for external power from 3.6 to 9 volts DC. Using voltage outside this range could damage the Cerebot Plus and connected devices.

There are three different dedicated power supply connectors on Cerebot Plus for board/processor power: J7, J8, and J9.

The barrel connector, J7, is useful for desktop development and testing where use of batteries is cost- or time-prohibitive. J7 is the connector used by the AC supply adapter available from Digilent. J7 is a 2.5mm x 5.5mm coaxial connector wired with the center terminal as the positive voltage.

J8 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 J8.

J9 is a screw terminal connector for an alternative battery supply or bench top power supply connection.

Connectors J7, J8, and J9 are wired in parallel and connect to one terminal of the power switch, SW1. The other terminal of SW1 connects to the main unregulated power bus VU. The VU power bus connects to the center terminal of the voltage regulator input jumper JP1 and also connects to the VU terminal of the power select jumper associated with each Pmod connector.

Jumper JP1 is used to select the voltage for the main board power bus VCC. When JP1 is in the 'normal' position, the VCC power bus is powered by the output of the on-board 3.3V regulator. When JP1 is in the 'bypass' position, the on-board voltage regulator is bypassed and the VCC bus is connected directly to the VU bus. In this case, the AVR microcontroller and other on-board electronics are powered directly from the voltage supply connected to VU. In this case, the input voltage must be in the range 2.7V – 3.3V. A supply voltage outside this range can permanently damage the board.

You can also power the Cerebot Plus from any Pmod connector. Place the power select jumper associated with the Pmod connector in the VU position to supply power to the VU bus, or the VCC position to supply power to the VCC bus. If power is being supplied to the VU bus, JP1 should be in the 'normal' position so that the on-board regulator will be able to regulate the supplied voltage to the 3.3V board operating voltage. If the Pmod connector power routing jumper is in the VCC position, the shorting block on JP1 should be placed in the 'bypass' position or removed.

The Cerebot Plus 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 Cerebot Plus. This can be useful when using servos that draw large amounts of power.

The Cerebot Plus can provide power to any peripheral modules attached to the Pmod connectors and to TWI devices powered from the TWI power daisy chain connectors, J4 and J5. Each Pmod connector provides power pins that can be powered by either unregulated voltage, VU, or regulated voltage, VCC, by setting the voltage jumper block to the desired position. The TWI power connectors only provide regulated voltage, VCC.

The regulated voltage on the VCC bus is provided by an on-board voltage regulator. This regulator is capable of providing a maximum of 500mA of current. The ATmega2560 microcontroller will use approximately 15mA when running at 8MHz. The external SRAM memory uses approximately 90mA when operating and 1mA when in standby mode. The remaining current is available to provide power to attached Pmod and TWI 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.

For information on how to set the jumper blocks for VU and VCC, see Table 2.

Power Supply Monitor Circuit

The Atmega2560 microcontroller on the Cerebot Plus can measure the power supply voltage on the 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 zener diode to clamp the resulting voltage to no greater than 3.3V. Jumper JP3 enables the supply monitor circuit for VU power, and jumper JP4 enables the supply monitor circuit for VS power. The analog to digital converter built into the ATmega2560 is used to measure the power supply voltages. ADC channel 0 is used to measure VU and ADC channel 1 is used to measure VS.

When the power supply monitor circuit is enabled the maximum safe voltage on VU is 9V and the maximum safe voltage on VS is 12V.

RC Servo Connectors

The Cerebot Plus provides eight 3-pin RC hobby servo connectors for direct control of servos in robotics and embedded hardware actuator applications. The connectors share I/O pins with Pmod connector JJ on the lower side of the board. Individual I/O pins may be accessed through the JJ header if they're not in use by a servo. Refer to the ATmega2560 data sheet for information on how to access the I/O pins.

The I/O pins shared between the servo connectors and connector JJ are also analog to digital converter inputs on the ATmega2560 microcontroller. If servos are being driven on

some channels and analog voltages are being read on other pins simultaneously, it is possible for digital switching noise to reduce the accuracy of the analog to digital conversions. If this is an issue, perform the analog-to-digital conversions at times when the servo pins are not switching. In normal applications, there will be a great deal of dead time when the servo pins are not switching.

There are three power options for servo connections: a common power bus (VU) for the Cerebot Plus and servos, separate on-board power busses (VU and VS) for the Cerebot Plus and servos, and an external power bus for servos.

Install the shorting block on JP2 to connect the VS servo power bus to the VU power bus. The VU bus can be powered from the coax power connector, J7, the screw terminal connector, J9, or the 2-pin battery connector, J8.

The VU bus can also be powered from any of the Pmod header interface connectors by setting the corresponding power jumper block to the VU position. This option is not suitable for providing power for large numbers of servos or servos that have a high current demand.

Remove the shorting block from jumper JP2 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 current applications, a separate power bus external to the Cerebot Plus can be used to provide servo power. In this case, remove the shorting block on JP2, tie the external servo power bus ground to the Cerebot Plus 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.

Programming Options

The Cerebot Plus provides two in-system programming connections, J1 and J2.

Connector J1 is the Digilent ISP connector. This provides for in-system programming using a Digilent JTAG3 parallel port cable or a Digilent USB-JTAG/SPI cable. When connecting the Digilent JTAG/SPI cables, ensure that the VCC and GND pin labels from the cable match to the VCC and GND pins on the Cerebot Plus. When using a Digilent programming cable, use the Digilent AVR Programmer application available for download from the Digilent web site (www.digilentinc.com) to program the board.

Connector J2 is a 6-pin (3x2) header for in-system programming using the Atmel AVRISP (Atmel P/N ATAVRISP) programmer. When connecting to the Cerebot Plus, the red indicator line on the AVRISP connection plug must be aligned with the top pins MISO and VCC on J2.

Programming can be accomplished using several AVR programming applications including the Digilent AVR Programmer (AVRP), AVRDUDE from the WinAVR tool set, and Atmel's AVR Studio. Programming via AVR Studio requires use of the Atmel AVRISP programmer hardware. See the user's documentation for each of these applications for more information on board programming.

Debugging with the Atmel JTAG ICE mk-II

Connector J6 on the Cerebot Plus is provided for the Atmel JTAG ICE mk-II (ATJTAGICE2) in-circuit emulator for debugging purposes. The JTAG ICE works with the debugger in Atmel's AVR Studio product.

The JTAG port on the ATmega2560 must be enabled when using the JTAG ICE. The Cerebot Plus is shipped with the JTAG port disabled. This port can be enabled or disabled

using a fuse bit which can be set with any of the supported in-system programmers described above.

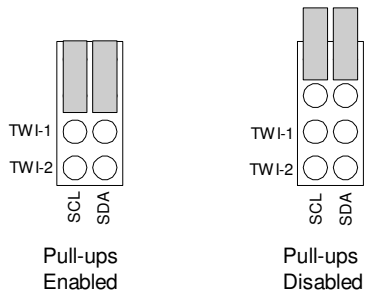
Two Wire Serial Interface

The Atmel Two Wire Serial Interface (TWI) provides a medium speed (400K bps) synchronous serial communications bus. The TWI interface provides master and slave operation with up to 127 devices on the bus. 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. See the ATmega2560 data sheet for detailed information on configuring and using the two wire interface.

The Cerebot Plus provides two ways to connect to a TWI bus. The TWI signals (SCL and SDA) are available on Pmod connector JD or on the TWI daisy chain connector J3.

Connector J3 provides two positions for connecting to the TWI signals. By using two-wire cables (available separately from Digilent) a daisy chain of multiple Cerebot Plus boards or other TWI-capable boards can be created.

The TWI bus is an open-collector bus. Devices on the bus actively drive the signals low. The high state on the TWI lines is achieved by pull-up resistors when no device is driving the lines low. One device on the TWI bus must provide the pull-up resistors. The Cerebot Plus board provides pull-up resistors that can be enabled or disabled via jumper blocks on the "pullup" positions on J3. The pull-ups are enabled by installing shorting blocks on the "pullup" positions and are disabled by removing the shorting blocks. Only one device on the bus should have the pull-ups enabled.



Jumper Settings for TWI Pull-Up Resistors

Connectors J4 and J5 are provided for daisy-chaining power along with the TWI signals. These can be used to pass power from the Cerebot Plus to other devices on the TWI bus. Either of these connectors could also be used to provide power to the Cerebot Plus from some other board on the TWI bus.

External SRAM

The ATmega2560 microcontroller has 8KB of internal data memory and provision for up to 56KB of external expansion memory.

The Cerebot Plus contains a 128KB external SRAM, providing two pages of 56KB each. Before this memory is accessible, the external memory interface must be enabled. See the ATmega2560 data sheet for information on how to enable the external memory interface.

I/O pin PG3 (port G, bit 3) is connected to the high order address line on the external memory. To access both pages of the external memory, configure pin PG3 as an output and set this pin low to access the lower page and set this pin high to access the upper page. This line is pulled low on the board, so that the lower page will be accessed by default if PG3 is not used.

Although there are two pages of 64KB each in the external memory, the lower 8KB of memory addresses access the internal memory and so the lower 8KB of each external memory page are not accessible.

Crystal Oscillator

The ATmega2560 microcontroller supports numerous clock source options for the main processor operating clock. The Cerebot Plus has an 8MHz oscillator crystal for use with the crystal oscillator option. The Cerebot Plus comes from the factory with the external crystal oscillator source selected.

The ATmega2560 microcontroller also provides an internal RC oscillator that operates at a nominal frequency of 8MHz. This internal oscillator has a frequency variability of approximately 2-3%, which is suitable for many applications. There is also a “Divide clock by 8” option that can be selected via a fuse bit to divide the processor clock by 8.

The RC oscillator’s nominal frequency assumes operation at 5V. The Cerebot Plus normally operates at 3.3V. See the oscillator frequency vs. supply voltage chart in the ATmega2560 data sheet to determine the nominal frequency at 3.3V.

Although the Cerebot Plus will normally be operated using the 8MHz crystal oscillator, the internal oscillator can be selected to operate the board at a lower frequency if desired. The clock source to be used by the board is chosen using the fuse settings in the in-system programmer.

When changing the clock source fuse settings, it is extremely important to ensure that the clock source chosen actually exists on the board (i.e., only choose the crystal oscillator or internal oscillator). The ATmega2560 internal in-system-programming state machine operates from the selected clock source and if an unavailable clock source is selected, the board may no longer be programmable.

In some cases, it is possible to recover the board if an improper clock source is chosen, but not always. There is an applications note “Cerebot Clock Source Fix” (available from www.digilentinc.com) that explains the procedure for recovering a board that has had an improper clock source programmed.

User I/O Devices

The Cerebot Plus board has a two-position jumper for user input and four LEDs for output. The user input jumper, JP5, is connected to I/O port G, bit 4. To read this jumper, bit 4 of port G must be set as an input by clearing bit 4 in the port G data direction register (DDRG) and reading the pin register for port G (PING). When the shorting block is in the '0' position, bit 4 in the pin register will be 0. When the shorting block is in the '1' position, bit 4 will be 1.

The four LEDs are connected to bits 4-7 of I/O port E. LED 1 is connected to bit 4, LED 2 is connected to bit 5, and so on. These four bits are also shared with the four I/O signals on Pmod connector JF. To use the LEDs, set the desired bits as outputs by setting the corresponding bits in the port E data direction register (DDRE) and set the bits to the desired level in the port E output register (PORTE). Setting a bit to 1 will illuminate the LED and setting the bit to 0 will turn it off.

Pmod Headers and SPI Connection

Pin	Description *All Pmod headers can be used as general purpose IOs or for the following specific purposes.	Cerebot Plus Pmod header pins to Atmega64L ports / bit		
JA	External memory bus These pins connect to the multiplexed Address/Data line of the ATmega2560 external memory bus interface.	Pin	Function	Port/ bit
		1	AD0	PA0
		2	AD1	PA1
		3	AD2	PA2
		4	AD3	PA3
		5	GND	
		6	VCC	
		7	AD4	PA4
		8	AD5	PA5
		9	AD6	PA6
		10	AD7	PA7
		11	GND	
		12	VCC	
JB	External memory bus These pins connect to the higher order address pins of the ATmega2560 external memory bus interface.	1	A8	PC0
		2	A9	PC1
		3	A10	PC2
		4	A11	PC3
		5	GND	
		6	VCC	
		7	A12	PC4
		8	A13	PC5
		9	A14	PC6
		10	A15	PC7
		11	GND	
		12	VCC	
		JC	Serial port communications Connection to UART0. A PmodRS232™ can be used on this connector for an RS232 serial interface. JC shares the RXD0 and TXD0 pins with the ISP ports. No device can be connected to JC during in-system programming. External memory bus Pins 7-9 connect to the control signals of the ATmega2560 external memory bus interface.	1
2	OC3A/ AIN1			PE3
3	RXD0/ PDI			PE0
4	TXD0/ PDO			PE1
5	GND			
6	VCC			
7	WR			PG0
8	RD			PG1
9	ALE			PG2
10	TOSC2			PG3
11	GND			
12	VCC			

Pin	Description *All Pmod headers can be used as general purpose IOs or for the following specific purposes.	Cerebot Plus Pmod header pins to Atmega64L ports / bit		
JD	<p>SPI interface The SPI interface on JD is used for synchronous serial communication of host processor and peripherals or for a connection of two processors. Master or slave modes are selected as part of the software.</p> <p>Serial port communications and interrupts Asynchronous serial port, UART1, as well as the Atmel TWI interface can be accessed on JD. These pins can also be used as external interrupt sources.</p>	Pin	Function	Port/ bit
		1	SS	PB 0
		2	MOSI	PB 2
		3	MISO	PB 3
		4	SCK	PB 1
		5	GND	
		6	VCC	
		7	SCL/ INT0	PD 0
		8	SDA/ INT1	PD 1
		9	RXD1/ INT2	PD 2
		10	TXD1/ INT3	PD 3
		11	GND	
		12	VCC	
JE	<p>H-bridge connection with input capture This port can be used to provide multiple pulse width modulated outputs to run motors. It can be used with PmodHB3 or PmodHB5 modules to run up to two motors with feedback encoding, or to run up to four motors without feedback encoding.</p>	1	T1	PD 6
		2	OC1A	PB 5
		3	ICP1	PD 4
		4	OC1B	PB 6
		5	GND	
		6	VCC	
		7	T0	PD7
		8	OC2A	PB4
		9	XCK1	PD5
		10	OC0A/OC1C	PB7
		11	GND	
		12	VCC	
		JF	<p>H-bridge connection with input capture This port can be used to provide multiple pulse width modulated outputs to run motors. It can be used with PmodHB3 or PmodHB5 modules to run up to two motors with feedback encoding, or to run up to four motors without feedback encoding.</p>	1
2	OC5A			PL3
3	ICP5			PL1
4	OC5B			PL4
5	GND			
6	VCC			
7	PL6			PL6
8	OC5C			PL5
9	ICP4			PL0
10	PL7			PL7
11	GND			
12	VCC			
JG	<p>H-bridge connection, interrupts, and on-board LEDs Use this port to run two motors without encoder input, or a motor with input sensing for a shaft encoder or other sensor. All of the pins on this header give access to interrupt inputs, providing flexibility for application development. JG can be used as a motor controller or interrupt source. The onboard LEDs also share pins with this connector.</p>			1
		2	OC3B/INT4	PE4
		3	CLKO/ICP3/I NT7	PE7
		4	OC3C/INT5	PE5
		5	GND	
		6	VCC	

Pin	Description *All Pmod headers can be used as general purpose IOs or for the following specific purposes.	Cerebot Plus Pmod header pins to Atmega64L ports / bit		
JH	<p>H-bridge connection with input capture This port can be used to provide multiple pulse width modulated outputs to run motors. It can be used with PmodHB3 or PmodHB5 modules to run up to two motors with feedback encoding, or to run up to four motors without feedback encoding.</p> <p>Serial port communications Pins 3 & 4 provide connection to UART2. A PmodRS232™ can be used on this connector for an RS232 serial interface.</p>	1	XCK2	PH2
		2	OC4A	PH3
		3	RXD2	PH0
		4	TXD2	PH1
		5	GND	
		6	VCC	
		7	T4	PH7
		8	OC4B	PH4
		9	OC2B	PH6
		10	OC4C	PH5
		11	GND	
		12	VCC	
JJ	<p>Analog input Inputs to the analog to digital converter of the Atmega2560. ADC0 and ADC1 are connected to the Cerebot Plus board's voltage monitoring circuits. ADC0 is the input for monitoring VU board power and ADC1 is connected to VS for monitoring the independent servo power.</p> <p>Analog or JTAG input The default fuse setting for the Cerebot Plus is to disable the JTAG input and provide analog inputs. The Atmega2560 fuse settings have to be changed to enable the JTAG interface to use JJ as a JTAG device input (e.g., to use the Atmel JTAGICE mkII).</p> <p>Servo connectors The pins on JJ are shared with the servo connectors S1-S8.</p>	1	ADC0	PF 0
		2	ADC1	PF 1
		3	ADC2	PF 2
		4	ADC3	PF 3
		5	GND	
		6	VCC	
		7	ADC5/ TMS	PF 5
		8	ADC7/ TDI	PF 7
		9	ADC6/ TDO	PF 6
		10	ADC4/ TCK	PF 4
		11	GND	
		12	VCC	
JK	<p>Analog input Inputs to the analog to digital converter of the Atmega2560.</p> <p>Pin change interrupt All of the pins on this connector can be used as interrupt sources for pin change interrupts.</p>	1	ADC8	PK 0
		2	ADC9	PK 1
		3	ADC10	PK 2
		4	ADC11	PK 3
		5	GND	
		6	VCC	
		7	ADC12	PK 4
		8	ADC13	PK 5
		9	ADC14	PK 6
		10	ADC15	PK 7
		11	GND	
		12	VCC	
JL	<p>Serial port communications Pins 3 & 4 provide connection to UART3. A PmodRS232™ can be used on this connector for an RS232 serial interface.</p> <p>Pin change interrupt All of the pins on this connector, except pin 10, can be used as interrupt sources for pin change interrupts.</p>	1	XCK3	PJ 2
		2	PCINT12	PJ 3
		3	RXD3	PJ 0
		4	TXD3	PJ 1
		5	GND	
		6	VCC	
		7	PCINT13	PJ 4
		8	PCINT14	PJ 5
		9	PCINT15	PJ 6
		10	PJ7	PJ 7
		11	GND	
		12	VCC	

Table 1: Jumper Blocks

Jumper Label	Function
JP1	<p>Servo power bus</p> <p>Connect the RC hobby servo power bus to the unregulated supply bus VU. When a connector block is in place on this jumper, servo power is supplied from VU on the Cerebot Plus. If the jumper block is removed, the RC hobby servo power bus must be supplied with a source connected to the screw terminal block J14.</p>
JP2	<p>Off-board regulated power supply selection</p> <p>To connect external regulated power on a Rev E version board, a single wire jumper may be connected to the positive pin of J5 (the battery connector) and the VCC pin of any of the JPA-JPH 6-pin header power selection jumpers. Alternatively, any of the JPA through JPH VCC pins can be connected to the positive screw terminal J5. Additionally, off-board regulated power can be brought onto the board via any of the Pmod header connectors.</p>
JP3	<p>VU voltage sense circuit enable</p> <p>When JP3 is installed the VU voltage monitor circuit is connected to ADC0. See page 3 of this reference manual for a description of the voltage monitor circuit.</p>
JP4	<p>VS voltage sense circuit enable</p> <p>When JP4 is installed the VU voltage monitor circuit is connected to ADC1. See page 3 of this reference manual for a description of the voltage monitor circuit.</p>
JP5	<p>User Input Jumper</p> <p>The setting of this jumper can be read from Port G, Pin 4.</p>
JP7	<p>USB Cable Power</p> <p>This jumper is used to enable powering the board from a Digilent USB cable that supports powering attached boards. Insert a shorting block to enable powering the board from USB cable power. Remove the shorting block to disable this option</p>
JPA - JPL	<p>Pmod headers</p> <p>Any of the eleven Pmod headers as well as the SPI header 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 VU.</p>