

The PIC32 Microcontroller—an Overview

The PIC32 is a no-nonsense microcontroller based upon the industry standard MIPS 4K 32 bit core. MIPS are leading technologies for performance driven, cost sensitive, high volume products. The technology has had an enormous impact on embedded products worldwide sales of over a billion products in the last several years. The 32 bit Experimenter uses MIPS technology with the Microchip PIC32MX695F512H 64 pin microcontroller. This MIPS based “PIC32” is a +3.3V device with low powered operation, large memory space, a generous offering of peripherals and a 5V tolerant pin set (see block diagram). The +5V tolerant pins are the only pins that the PIC32 can accept 5 volt inputs and the default for all pin is +3.3V. The PIC32 has impressive memory and speed performance, with 512KB flash, 128KB ram, and CPU clock rates of up to 80MHz. To enhance PIC32 performance Microchip includes a pre-fetch cache between PIC32 flash and MIPS core. This allows PIC32 programmed flash to keep up the high speed MIPS 4K core achieving an instruction execution rate of one instruction per clock once the internal pipeline has filled. The performance has been benchmarked at an impressive 1.56 DMIPS (Dhrystone Millions of Instruction per Second). The Dhrystone measurement represents a standard computing benchmark based upon IBM 11780 computers. This Dhrystone benchmark makes the PIC32 one of the highest performance 32 bit devices available in its class.

A block diagram of the PIC32 shows the internals of the chip. It is organized around two internal buses. The top bus is the faster of the two and runs at the system clock CPU rate. It functions as a bus matrix. As a bus matrix it allows simultaneous communications for all bus masters on this bus without any bus contention. Bus masters are the PIC32 MIPS 4K core, the 8 channel DMA (Direct Memory Access Controller), USB, and 100 MHz Ethernet Controller. Bus masters require unimpeded access to “non-master devices” like memory and peripherals to sustain PIC32 performance. The non-master devices on this bus are pre-fetch cache, ram, interrupt controller, all the digital ports and a peripheral bridge (a connection to all the on-chip peripherals). It is interesting to note that digital ports reside on the high speed bus. This means they can be toggled (on/off) at the 80 MHz rate ---able to generate digital signals of up to 40MHz if needed. With the use of the DMA bus master this port (or any other peripheral) can directly access PIC32 memory directly without CPU (software) intervention for data transfers.

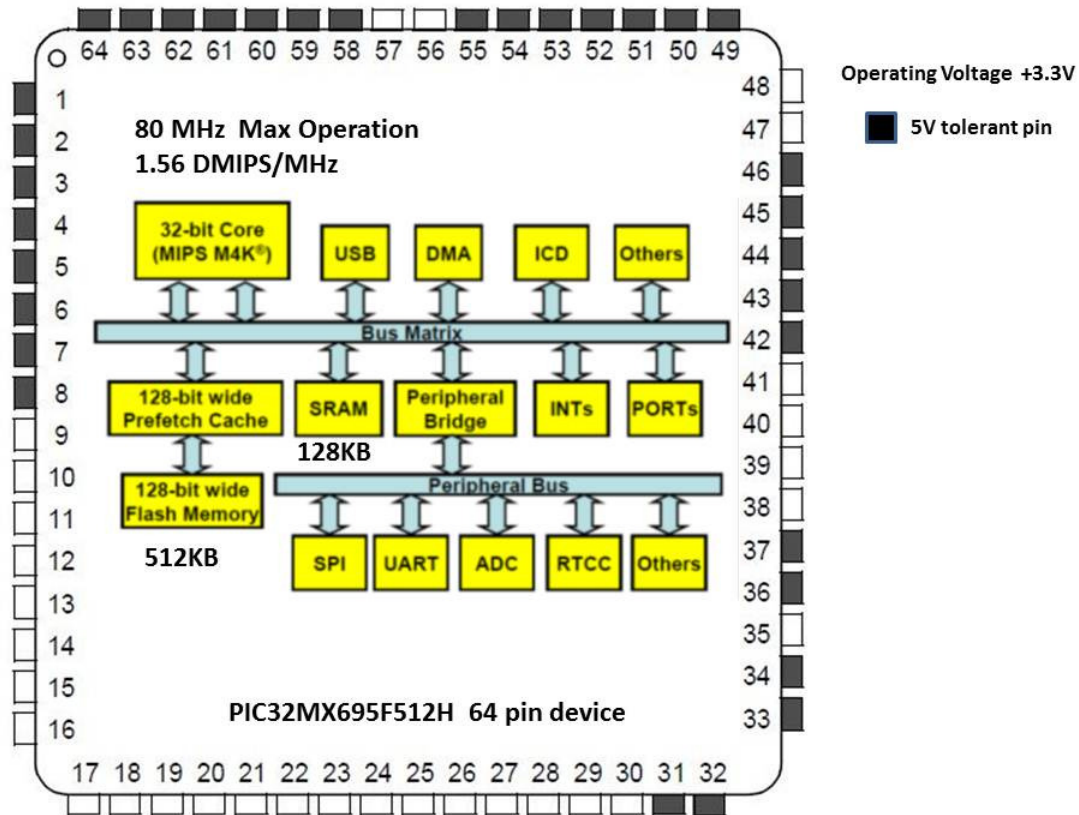


Figure 2 PIC32 Block Diagram

The other bus is the peripheral bus. This bus does not need to run as fast as the bus matrix and can be set to 1 to 8 times slower (peripheral clock rates are not required to be run as high as 80 MHz). The peripheral bus connects to all the on-chip peripherals. With the PIC32MX695F512H there are 5 16 bit Timers, a RTCC (Real Time Clock Calendar), 6 UART (Universal Asynchronous Receiver Transmitter), 3 SPI (Serial Peripheral Interfaces) , 4 I²C (Inter-Integrated Circuits) , 16 Channel 10 bit ADC (Analog-to – Digital Converter) , 1 PMP (Parallel Master Port), 5 CCP (Compare/Compare Ports), and 2 Analog Comparators. The 32 bit Experimenter interface hardware allows access to all these capabilities.

An Overview of 32 Bit Experimenter Hardware

A diagram of the Experimenter board is shown; schematics are also included at the end of this manual. The board has extensive expansion capabilities. This approach allows access to all the board Microcontroller (PIC32MX695F512H) I/O for experiments.

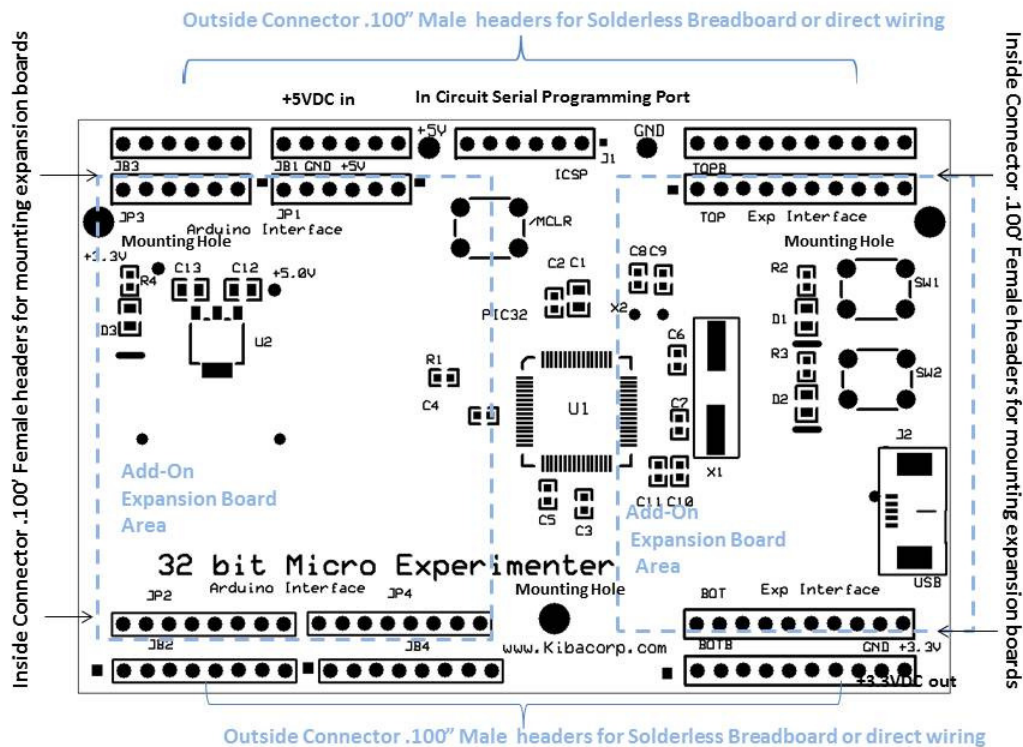


Figure 3 EXP32 Board Diagram

The Experimenter inside connectors is .100" female headers. This allows mounting expansion cards right on top of the Experimenter (vertical expansion). The left side female header top and bottom set has an "Arduino Expansion" footprint that is mechanically and electrically compatible with Arduino expansion cards, the minor exceptions to interface are shown in red (see Figure 3). These expansion cards are available from a number of vendors and this feature allows users the opportunity to integrate a number of existing Arduino expansion cards with their Experimenter applications. Keep in mind that new software drivers will have to be rewritten in Microchip 'C' to accommodate any of these boards. The Experimenter also uses an additional set of female connectors top/bottom on right side to accommodate non-Arduino expansion boards.

For horizontal expansion (typical of Solderless bread boarding) the outside connector rows sets support .100" male headers. These are used to mount the Experimenter to a large Solderless breadboard (3260 contacts) to accommodate direct wiring prototyping. Finally, the board has three mounting holes that provide mechanical support for vertical expansion or mounting the entire Experimenter to a chassis.

The male and female headers are grouped together namely six pin JP1 and JB1, 8 pin JP2 and JB2, 6 pin JP3 and JB3, 8 pin JP4 and JB4, 10 pin TOP and TOPB, 10 pin BOT and BOTB. Within these grouping all pins share common connections, pin out identifications are shown below. Pin 1 of each grouping is designated by a small rectangle near the connector pin 1 position. The "Arduino Compatible" pin set is show first

(incompatibilities with Arduino are shown in red), followed by the TOP and BOT pin set descriptions.

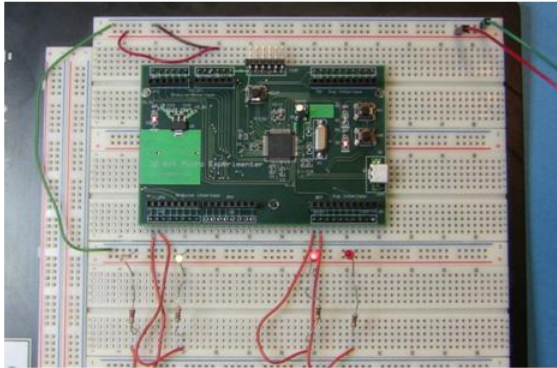
Power	JP1	ARDUINO	PIC32
		1 Reset	/MCLR (7)
		2 3.3V	3.3V
		3 5V	5V
		4 gnd	gnd
		5 gnd	gnd
		6 vin	NA
	JP2		PIC32
Digital1		1 RXD/PD0	U1ARX(50)
		2 TXD/PD1	U1ATX(51)
		3 INT0/PD2	INT0 (46)
		4 INT1/PD3	INT1(42)
		5 T0/PD4	NOT0 RE5(1)
		6 T1/PD5	NOT1 RE6(2)
		7 AIN0/PD6	ADN0 C1IN+ (11)
		8 AIN1/PD7	ADN1 C1IN-(12)
	JP3		PIC32
Analog		1 ADC0/PC0	AN0 (16)
		2 ADC1/PC1	AN1(15)
		3 ADC2/PC2	AN2(14)
		4 ADC3/PC3	AN3(13)
		5 ADC4/SDA/PC4	SDA3A(31)
		6 ADC5/SCL/PC5	SCL3A(32)
	JP4		PIC32
Digital2		1 ICP/PB0	IC3(44)
		2 OC1A/PB1	OC5(52)
		3 OC1B/SS/PB2	/SS2A (8)
		4 MOSI/OC2/PB3	SDO2A (6)
		5 MISO/PB4	SDI2A (5)
		6 SCK/PB5	SCK2A (4)
		7 GND	gnd
		8 AREF	NAREF AN8 (21)

TOP		PIC32 EXP
1	TSP1	RE7(3)
2	TSP2	RE4(64)
3	TSP3	RE3(63)
4	TSP4	RE2(62)
5	TSP5	RE1(61)
6	TSP6	RE0(60)
7	TSP7	RF1(59)
8	TSP8	RF0(58)
9	TSP9	RD7(55)
10	TSP10	RD6(54)

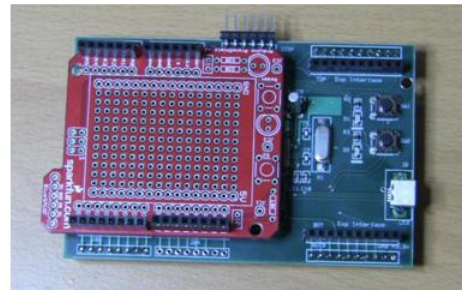
BOT		PIC32 EXP
1	BSP1	RB9(21)
2	BSP2	RB10(22)
3	BSP3	RB14(29)
4	BSP4	USBID(33)
5	BSP5	RD9(43)
6	BSP6	RD11(45)
7	BSP7	RD1(49)
8	BSP8	RD5(53)
9	GND	GND
10	3.3V	3.3V

Figure 4 Experimenter 48 pin Expansion Interface

Expansion Capabilities (48 Pins)



Using Solderless breadboard



Vertical stacking

Figure 5 Experimenter Expansion

The Experimenter requires a +5VDC input (500 ma max current) and does on-board regulation of this +5VDC to generate the necessary +3.3VDC for the PIC32. A power up LED signifies that +3.3VDC is up and running. The regulated +3.3VDC is also made available for off board use through BOT or BOTB pin 10 and GND through BOT or BOTB pin 9.

Power can be applied several ways: +5VDC through expansion connector pin 3 on either JP1 or JB1 or to the test terminal marked +5VDC next to J1, GND to expansion connector JP1 or JB1 either pins 4 or 5 or to test terminal marked GND next to J1. The Experimenter board is programmed and debugged using the standard Microchip six pin ICSP (In Circuit Serial Programming Interface). This interface directly accepts a PICKIT3 programmer/debugger or any of the other Microchip programmers/debuggers (with exception of the PICKIT2).

An 8MHz crystal serves as a CPU clock source and is electronically multiplied inside the chip for 80MHz operations and for USB clock requirements. The Experimenter also has a fully USB 2.0 compliant interface. USB applications will be covered in detail in subsequent articles.

An optional 32 KHz crystal position X2 can be added to serve as a precision clock source for the PIC32 Real Time Clock Calendar (RTCC) peripheral for accurate data/time operations.

There is a minimal user interface for manual reset (switch MCLR), two software controlled LEDs (D1 and D2), and readable pushbutton switches (SW1 and SW2) to support debugging and experiments.

Setting up your Tool Suite

This couldn't be any easier. Go to the Microchip web site and download their latest version of MPLAB

http://www.microchip.com/stellent/idcplg?IdcService=SS_GET_PAGE&nodeId=1406&dDocName=en019469&part=SW007002

And their free evaluation PIC32 'C' Compiler

http://www.microchip.com/stellent/idcplg?IdcService=SS_GET_PAGE&nodeId=2615&dDocName=en532454 .

All supplied demo should be easily built and compiled. The only choices you have are the method of programming and debugger hardware. It comes down to the following choices: PICKIT3, MPLAB ICD3, or REALICE. All choices are viable with PICKIT3 being the cheapest. The Experimenter comes pre-configured with an LED blink program that alternately turning off/on each of the two on-board LEDs. This should run "right out of the box" once you apply +5VDC and Ground to JP1 or JB1 or test point connectors. Demo Source code is available on the CD-ROM supplied with the kit. The Demos allow you to exercise your tool suite to build, compile and download working code into your Experimenter.

Experimenter Assembly Instructions

The 32 bit Micro Experimenter is a sensitive to static charge please use proper handling to avoid damage

The Experimenter is available in both kit form and fully assembled from the Nuts and Volts web store. The Experimenter is largely surface mount so in both kit and other offerings, the Surface Mount assembly is complete. The only "kit" aspects are mounting and soldering the female and male headers onto the board, as well as the 32 KHz crystal. The kit parts list and assembly instructions are given here.

Experimenter parts List

A picture of the kit and a list of all components are given

They are as follows:

- (1) SMT assembled board with ICSP soldered in place.
- (2) 6 pin .100" female headers JP1 and JP3
- (2) 6 pin .100" male headers JB1 and JB3
- (2) 8 pin .100 " female headers JP2 and JP4
- (2) 8 pin .100" male headers JB2 and JB4
- (2) 10 pin .100" female headers TOP and BOT
- (2) 10 pin .100" male headers TOPB and BOTB
- (3) pushbuttons MCLR and SW1 and SW2
- (1) red test terminal +5V (already on board)
- (1) black test terminal GND (already on board)

Power hook up and test point assembly

The kit should work out of the box with LEDs D1 and D2 blinking; however, you need to supply power to the board. The power shown is +5VDC and the supply should be at least able to supply 120ma or greater. ***Do not supply any power greater than +6.4V to the board.***

1. Solder red test point to the top of the board at the hole marked +5V. Next solder black test point to the top of the board at the hole marked GND. Apply +5VDC to the board using these test connections. You should see D3 (+3.3V power indicator lit and D1 and D2 alternatively blinking.
2. Disconnect power --next solder the MCLR and SW1 and SW2 pushbuttons to the top of the board at the designated positions marked on the board.
3. Reapply power. The LEDs should be operating as before, push and release MCLR --you should see operation briefly halting before resuming as before. You have successfully installed the reset button for the Experimenter.
4. Test SW1 and SW2. Leave power on. Connect your PICKIT3 (or equivalent --but not PICKIT2) to the Experimenter ICSP connector. Open demo project TESTSW.MCP in TESTSW folder. Build project using PICKIT3 or equivalent as programmer. Program board. Remove PICKIT3. The demo lights D1 when SW1 is depressed and D2 when SW2 is depressed. You have successfully installed SW1 and SW2 on the Experimenter.

Connector Assemblies

The Experimenter supports six female headers and six corresponding male headers. You have the optional of installing either or both. For Solderless bread boarding the male connectors is required. To utilize the full expansion features of the Experimenter it is recommend that you do both.

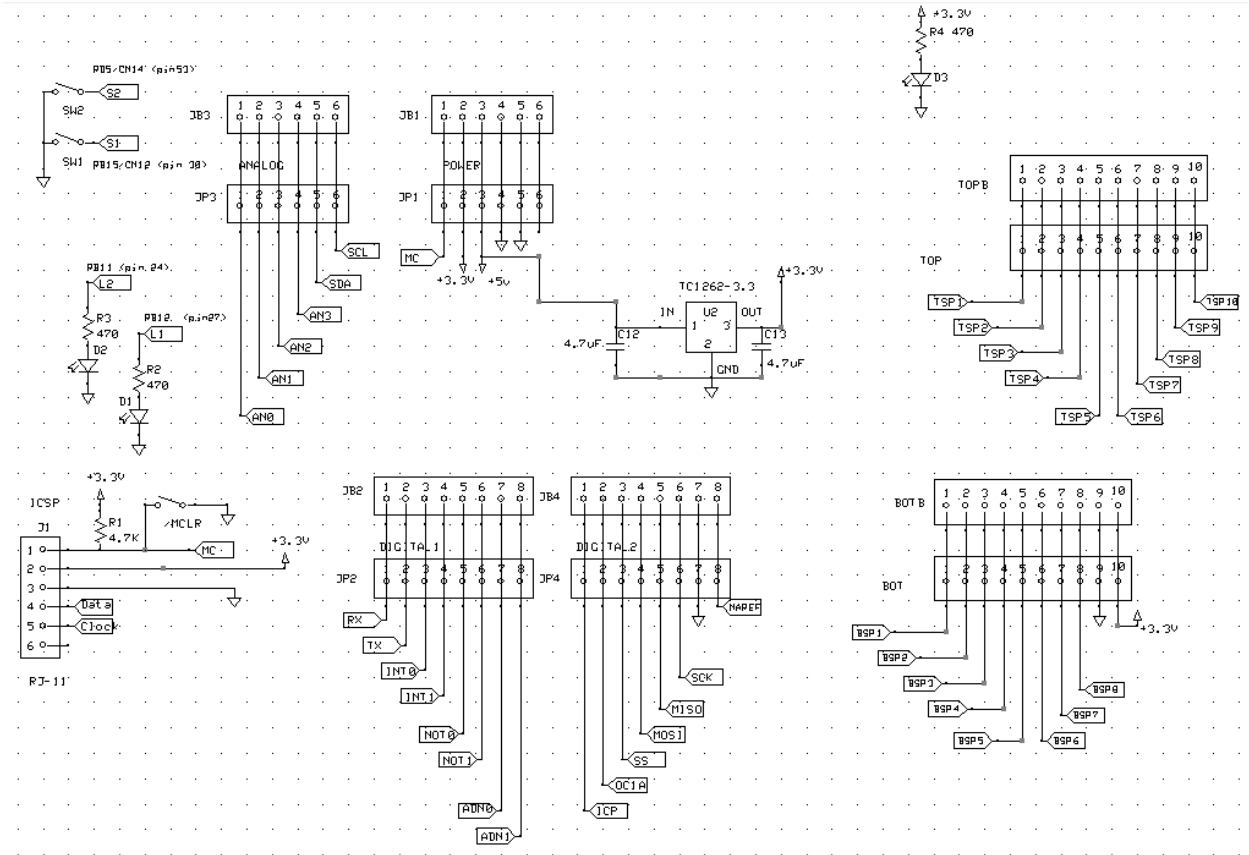
This assembly will cover the process to mount and test and connectors to the board.

1. Start with female six pin JP3 and place on top of the board at the appropriate designated mounting area. You need to solder from bottom. Flip the board (maintaining JP3 in place--insure that connector is properly align and vertical to the board. For now simply "tack" (solder one pin) to keep connector in place.
2. Flip the board to top size and insert ten pin female BOT to top of the board using same process described earlier. Again you are to solder from the bottom a single pin making sure the connector is aligned to silkscreen pattern on top of the board and is vertical.
3. Next work with ten pin female TOP. Repeat the process described in (2).
4. Next work with 6 pin female JP1. You should now have a full top compliment of female connector on the board. The reason we "tacked" single pins is to insure that all the females line up when viewing the board from both the side and the top. The single tack allows us to "adjust" ant offsets to a connector by reheating the

- solder on the single pad and realigning the connector as necessary. If you are completely satisfied with alignments that solder all remaining pins on JP1, JP3, TOP at this time.
5. To finish installing bottom female connector JP2 and JP4, repeat the process described above starting with JP2 and then JP4. If you are satisfied with final alignments of JP2, JP4 and BOT then solder at the remaining pins. At this point you should have all the female connectors installed on board and all their corresponding pins solders.
 6. Now for the male connector headers (JB3, JB1, TOPB, JB2, JB4, BOTB. The easiest way to approach this is to procure a large Solderless bread board (3260 contacts) and place the long end of the male connector header into the Solderless breadboard aligned with the silkscreen positions on those connectors. Once these headers are correctly positioned simply place the board over them and align the short end of the header (top) to the corresponding holes of the board. If done correctly the board should now be resting on these headers through their designated holes as viewed from the top side of the board. Solder the header in place from the top side of the board. At this point you should have all the connectors and header soldered and integrated on to the experimenter.
 7. To test your newly integrated connectors and headers a demo program TESTPINS.MCP is provided. Apply +5V and GND to board. Connect PICKIT3 to ICSP port of Experimenter. Open project, build, compile and download into Experimenter (configure PICKIT3 as programmer). Remove PICKIT3 and notice the LEDs are again blinking—in fact with this demo every digital pin is toggled. With a scope hook one end of your instrument to ground and the other side of your scope to any digital pin (see figure 3). You should see the pin toggle from +3.3 VDC to ground continuously indicating successful connection. Testing can be done both at the female and male pins. A meter can also be used for testing but rapid toggling may be difficult to discern.

Congratulations –your Experimenter is now fully ready for use!

Experimenter Schematics



Experimenter Schematics Processor and I/O

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