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1/24/2011
ME 333, Assignment 2

Assignment 2: Getting to know the PIC32

1 Converting Between Different Numbering Systems

Questions

Converting decimal to binary

(a) What is 79_{10} in binary?

Divide n by 2	Quotient	Remainder
79/2	39	1
39/2	19	1
19/2	9	1
9/2	4	1
4/2	2	0
2/2	1	0
½	0	1
0/2	0	0

1001111_2

(b) What is 18_{10} in binary?

Divide n by 2	Quotient	Remainder
18/2	9	0
9/2	4	1
4/2	2	0
2/2	1	0
½	0	1
0/2	0	0

10010_2

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Questions

Converting binary to base-10

(a) What is 10110101_2 in decimal?

n = number of bits = 8 → n – 1 = 7

$$d = \sum_{i=0}^{n-1} (2^i \times b_i) = \sum_{i=0}^{7} (2^i \times b_i)$$

$= (2^7 \times b_7) + (2^6 \times b_6) + (2^5 \times b_5) + (2^4 \times b_4) + (2^3 \times b_3) + (2^2 \times b_2) + (2^1 \times b_1) + (2^0 \times b_0)$
$= (1 \times 2^7) + (0 \times 2^6) + (1 \times 2^5) + (1 \times 2^4) + (0 \times 2^3) + (1 \times 2^2) + (0 \times 2^1) + (1 \times 2^0)$
$= 128 + 32 + 16 + 4 + 1$

$= \mathbf{181_{10}}$

(b) What is the maximum number in decimal that a 10-bit number can hold?

In binary, the maximum decimal value for a 10-bit number is 1111111111 (10 bits, all of which are set to be 1).

n = number of bits = 10 → n - 1 = 9

$$d = \sum_{i=0}^{n-1} (2^i \times b_i) = \sum_{i=0}^{9} (2^i \times b_i)$$

$= (2^9 \times b_9) + (2^8 \times b_8) + (2^7 \times b_7) + (2^6 \times b_6) + (2^5 \times b_5) + (2^4 \times b_4) + (2^3 \times b_3) + (2^2 \times b_2) + (2^1 \times b_1) + (2^0 \times b_0)$
$= (2^9 \times 1) + (2^8 \times 1) + (2^7 \times 1) + (2^6 \times 1) + (2^5 \times 1) + (2^4 \times 1) + (2^3 \times 1) + (2^2 \times 1) + (2^1 \times 1) + (2^0 \times 1)$
$= 512 + 256 + 128 + 64 + 32 + 16 + 8 + 4 + 2 + 1$

$= \mathbf{1023_{10}}$

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Questions

Converting binary to hexadecimal

(a) What is 1011011_2 in hexadecimal?

$(0101)(1011)_2$

From the table:

Binary	Hexadecimal
0101	5
1011	B

1011011_2 in hexadecimal = $\mathbf{5B_{16}}$

(b) What is 80_{10} in hexadecimal?

First, convert to binary:

Divide n by 2	**Quotient**	**Remainder**
80/2	40	0
40/2	20	0
20/2	10	0
10/2	5	0
5/2	2	1
2/2	1	0
½	0	1
0/2	0	0

1010000_2

Now, convert to hexadecimal:
(0101)(0000)2

From the table:

Binary	Hexadecimal
0101	5
0000	0

80_{10} in hexadecimal = $\mathbf{50_{16}}$

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2 The C bitwise operators

Questions

(a) What are the four bitwise operators?

The four bitwise operators are:

~	**Bitwise Negation (unary)**
&	**Bitwise And**
|	**Bitwise Or**
^	**Bitwise Exclusive Or**

(b) Write the truth table for each bitwise operator.

P	**Q**	**~P**	**~Q**	**P & Q**	**P | Q**	**P ^ Q**
T	T	F	F	T	T	F
T	F	F	T	F	T	T
F	T	T	F	F	T	T
F	F	T	T	F	F	F

(where T = 1, and F = 0)

Questions

(a) What is 0x55 & 0x17?

First, convert 0x55 from hexadecimal to binary:
$5_{16} = 0101_2$ → Therefore, 0x55 = $(0101)(0101)_2 = 01010101_2$

Next, convert 0x17 from hexadecimal to binary:
$1_{16} = 0001_2$ and $7_{16} = 0111_2$ → Therefore, 0x17 = $(0001)(0111)_2 = 00010111_2$

variable	b_7	b_6	b_5	b_4	b_3	b_2	b_1	b_0
0x55	0	1	0	1	0	1	0	1
0x17	0	0	0	1	0	1	1	1
0x55 & 0x17	0	0	0	1	0	1	0	1

0x55 & 0x17 = 00010101_2

Now, we have to convert the number back to hexadecimal:
$(0001)(0101)_2$ → $0001_2 = 1_{16}$ and $0101_2 = 5_{16}$ → $(0001)(0101)_2$ = 0x15

0x55 & 0x17 = **0x15**

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(b) What is 0x55 ^ 0x17?

variable	b_7	b_6	b_5	b_4	b_3	b_2	b_1	b_0
0x55	0	1	0	1	0	1	0	1
0x17	0	0	0	1	0	1	1	1
0x55 ^ 0x17	0	1	0	0	0	0	1	0

0x55 ^ 0x17 = 01000010_2

Now, we have to convert the number back to hexadecimal:
$(0100)(0010)_2 \rightarrow 0100_2 = 4_{16}$ and $0010_2 = 2_{16} \rightarrow (0100)(0010)_2 = 0x42$

0x55 ^ 0x17 = **0x42**

(c) What is (~0x55) | 0x17?

0x55 = 01010101_2

Therefore,
~0x55 = 10101010_2

variable	b_7	b_6	b_5	b_4	b_3	b_2	b_1	b_0
~0x55	1	0	1	0	1	0	1	0
0x17	0	0	0	1	0	1	1	1
(~0x55) | 0x17	1	0	1	1	1	1	1	1

(~0x55) | 0x17 = 10111111_2

Now, we have to convert the number back to hexadecimal:
$(1011)(1111)_2 \rightarrow 1011_2 = B_{16}$ and $1111_2 = F_{16} \rightarrow (1011)(1111)_2 = 0xBF$

(~0x55) | 0x17 = **0xBF**

(d) Given a = 0xFF, c = 0x5E, what is b in c = a & b?

First, convert 0xFF from hexadecimal to binary:
$F_{16} = 1111_2$ → Therefore, $0xFF = (1111)(1111)_2 = 11111111_2$

Then, convert 0x5E from hexadecimal to binary:
$5_{16} = 0101_2$ and $E_{16} = 1110_2$ → Therefore, $0x5E = (0101)(1110)_2 = 01011110_2$

variable	b_7	b_6	b_5	b_4	b_3	b_2	b_1	b_0
a	1	1	1	1	1	1	1	1
b	**0**	**1**	**0**	**1**	**1**	**1**	**1**	**0**
c	0	1	0	1	1	1	1	0

$b = 01011110_2$

Now, we have to convert the number back to hexadecimal:
$(0101)(1110)_2 \rightarrow 0101_2 = 5_{16}$ and $1110_2 = E_{16} \rightarrow (0101)(1110)_2 = 0x5E$

b = 0x5E

3 The PIC32 Hardware

Questions

(a) What does "peripheral" mean for the PIC?

According to the wiki page, peripherals are what make microcontrollers useful for embedded control.

Peripherals include:

PORTA… PORTG (digital I/O ports)
5 16-bit counters
Analog-to-digital converter (ADC)
Real-time clock and calendar (RTCC)
2 comparators
6 UARTs
"Parallel master port" (PMP)
5 I2C modules
4 SPI modules
5 "input capture" pins
5 pulse-width modulation pins ("output compare")
22 change notification pins

(b) Go to the Microchip homepage, check out the Parametric Table of PIC32s, and find a PIC with the following specs: 80 MHz max clock speed, 512 K flash (program memory), 32 K RAM (data memory), 4 channels of DMA, 16 A/D converters with 10-bit resolution, USB capabilities, 2 comparators, 5 16-bit timers and 1 32-bit timer, 5 PWM channels and 5 input compare channels, 2 UARTs, 2 SPI, and 2 I2C pins, no CAN modules, no

Ethernet, and 100 pins. What is the part number? What types of packages does it come in (e.g., DIP, or different kinds of surface mount packages, etc.)? How much does it cost in quantity 1? What is the difference in price and features from our PIC, the PIC32MX795F512L?

The part number is PIC32MX460F512L.

It comes in 2 different package types: XBGA and TQFP. The XBGA packages contain 121 leads, while the TQFP packages contain 100 leads.

In quantity 1, it costs around $8 (the cheapest variant is $7.59 in quantity 1, and the most expensive variant is $8.03 in quantity 1).

The difference in price between the PIC32MX460F512L and our PIC is about 2 dollars (our PIC costs just under $10, and the PIC32MX460F512L costs around $8). The difference in features is as follows:

Feature	PIC32MX460F512L	Our PIC (PIC32MX795F512L)
RAM (KB)	32	128
DMA channels	4	8
SPI	2	4
I2C	2	5

(c) Refer to the "Block diagram of the PIC32MX7XX" under "PIC32 Hardware Overview" or p. 31 "Device Overview" in the DS. In one sentence each, without going into detail, explain the basic function of the following items shown in the block diagram: Timing Generation, MCLR, SYSCLK, PBCLK, USBCLK, PORTA…G (and indicate which of these can be used for analog input on our PIC), Timer 1-5, 10-bit ADC, Comparators, Ethernet, UART 1-6, I2C 1-5, SPI 1-4, IC 1-5, PWM OC 1-5, CN1-22, Data RAM, Program Flash Memory, and Pre-Fetch Module.

(NOTE: DS = Data Sheet, RM = Reference Manual)

Timing Generation: An external crystal, timing circuit, or internal circuit may be utilized for timing generation to produce SYSCLK, PBCLK, and USBCLK. (wiki page)

MCLR: The MCLR is the Master Clear (Reset) input and it allows the PIC32 to be reset. (DS p. 40, 42)

SYSCLK: The SYSCLK is the system clock, and it is responsible for clocking some of the peripherals. (wiki page)

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PBCLK: The PBCLK is responsible for clocking the majority of the peripherals on the PIC32. (DS p. 160)

USBCLK: The USBCLK is the USB clock, which operates at 48 MHz and allows full-speed and low-speed USB communication. (wiki page, DS p. 127)

PORTA…G: These are digital bidirectional I/O ports *(and PORTB is used for analog inputs -NR)*. **(DS p. 34-35)**

Timer 1-5: These are external clocks that can be used as free-running interval timers. (DS p. 131, 197)

10-bit ADC: This is a 10-bit analog-to-digital converter that translates a 10-bit result into a 32-bit output. (DS p. 149)

Comparators: A comparator is used to compare voltages, and its output will change to digital high or digital low depending on which of its inputs is larger. (RM Chapter 19 p. 7)

Ethernet: The Ethernet controller is a module that works with a Physical Layer, which is separate from the PIC32, to create an Ethernet node. (DS p. 153)

UART 1-6: A UART (universal asynchronous receiver transmitter) is a serial I/O module that corresponds with peripheral devices and computers by using protocols. (DS p. 143)

I2C 1-5: An I2C module is an Inter-Integrated Circuit module, which is responsible for exchanging information with peripheral devices and microcontrollers. (RM Chapter 24 p. 2)

SPI 1-4: An SPI module is a serial peripheral interface module, which is also capable of exchanging information with external peripherals and microcontrollers. (DS p. 139)

IC 1-5: An IC (interrupt controller) module orders the interrupt signals before sending them to the CPU unit, (DS p. 117)

PWM OC 1-5: The PWM OC (pulse-width modulation output compare) module produces pulse patterns by comparing times given by certain registers. (DS p. 137)

CN1-22: The CN (input change notification) is part of the I/O ports that permits devices to produce interrupts based on state changes on the pin. (DS p. 130)

Data RAM: Data RAM allocates memory for storing data and program information. (DS p. 51)

Program Flash Memory: Program Flash Memory is used for operating code written by a user. (DS p. 113)

Pre-Fetch Module: The pre-fetch module allows for improved performance for programs that run from Program Flash Memory. (RM Chapter 4 p. 2)

(d) Describe the four functions that pin 23 of our PIC32 can have. Is it 5V tolerant?

Pin 23 can have the following four functions:

1. **AN2: analog-to-digital input**
2. **C2IN-: comparator negative input**
3. **CN4: produces interrupts if the input changes**
4. **RB2: digital I/O pin (for PORTB)**

Pin 23 is not 5V tolerant, based on the "Pinout of the PIC32MX795F512L" diagram shown on the wiki.

(e) How many pins from the PIC32 are available on the NU32v2 board?

There are <u>82 pins</u> from the PIC32 that are available on the NU32v2 board.

(Other acceptable solutions were in the 80-90 range, like 84 and 95 -NR)

(f) What is the absolute maximum amount of current that the NU32v2 board can provide from the 9V wall plug? What are some limiting factors in drawing the full amount of current from the plug?

The 9V wall plug supplies the NU32v2 board with about <u>660 mA</u> of current.

One limiting factor is the fact that the 5V regulator will drop 4V when supplied with current from the 9V wall plug. The 5V regulator gives off heat. Another limiting factor is that the 5V and 3.3V regulator can only source about 800 mA of current. As a result, typical usage of the device should draw less than 400 mA of current.

(g) How wide is PORTG on our PIC32 (i.e., how many pins does it have)? You should use Table 1-1 in the DS, don't search and count for the pins in a diagram.

Based on Table 1-1, PORTG has 12 pins.