ME 333: Introduction to Mechatronics

Assignment 2: Solutions

Electronic submission due **before** 11:00 AM on Thursday February 2nd

1. and 2. Nearly all of you were able to get your hardware up and running. If you had trouble getting your hardware to work, please get this resolved during office hours ASAP.

3. *A Crash Course in C* describes bitwise operators. Calculate the following and give your results in hexadecimal.

(a) `0x39 | 0xA8` = 0b1011_1001 = 0xB9

(b) `0x39 & 0xA8` = 0b0010_1000 = 0x28

(c) `~0x39` = 0b1100_0110 = 0xC6

(d) `0x39>>3` = 0b0000_0111 = 0x07

4. In one sentence each, without going into detail, explain the basic function of the following items shown in the PIC32 architecture block diagram: SYSCLK, PBCLK, PORTA...G (and indicate which of these can be used for analog input on our PIC), Timer 1-5, 10-bit ADC, PWM OC1-5, Data RAM, Program Flash Memory, and Prefetch Module.

(a) SYSCLK: The system clock dictates the speed at which the CPU executes instructions.

(b) PBCLK: The peripheral bus clock, which is the clock for many of the peripherals on the PIC32.

(c) PORTA..G: The digital input/output (I/O) ports on the PIC32. The analog pins are all on PORTB.

(d) Timer 1-5: 16-bit counters that increment at some submultiple of PBCLK or whenever an external event is triggered.

(e) ADC: The ADC is a 10-bit analog to digital converter with 16 multiplexed inputs.

(f) PWM OC1-5: A square wave or single pulse generator with programmable frequency and duty cycle.

(g) Data RAM: Volatile memory (e.g. not preserved across resets) on the PIC where temporary data, like most C variables, are stored.

(h) Program Flash Memory: Non-volatile memory that retains its information after reboots, like our C programs.

(i) Prefetch Module: A module on the PIC that reads a chunk of instructions from program flash, so that the CPU can have the machine instructions at a much faster rate than reading directly from flash.

5. If the ADC is measuring values between 0 and 3.3 V, what is the largest voltage difference that it may not be able to detect? (Its a 10-bit ADC.)

With 10 bits, there are a total of $2^{10} = 1024$ different values that we can represent. With a total range of 3.3V, that means that each step in binary equates to $3.3\,\text{V}/1024\,\text{step} = 0.0032\,\text{V/step} = 3.2\,\text{mV/step}$. Thus, we will be unable to detect a voltage difference that is less than 3.2 mV.

6. Describe the four functions that pin 22 of our PIC32 can have. Is it 5 V tolerant?

Pin 22 can be the analog to digital pin (AN3), the positive input for the second analog comparator (C2IN+), change notification pin 5 (CN5), and the third digital I/O pin for port B (RB3). It is not 5V tolerant.

7. Go to the Microchip homepage, check out the Parametric Table of PIC32s (32-bit MCUs>Find Products>PIC32 Family), and find a PIC with the following specs: 80 MHz max clock speed, 512 K flash (program memory), 65 K RAM (data memory), 16 A/D channels 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, 6 UARTs, 3 SPI, and 4 I2C pins, no CAN modules, Ethernet, and 64 pins. What is the part number? What types of packages does it come in (e.g., DIP, or different kinds of surface mount packages)? How much does it cost in quantity 1? What is the difference in price and features from our PIC, the PIC32MX795F512L?

(a) Part number is PIC32MX675F512H

(b) It is available in 64-pin QFN, and TQFP surface-mount packages

(c) Depending on packaging, the price can vary from about $7.79 to $8.34

(d) Our PIC is slightly more powerful, and slightly more expensive at roughly $2 more per chip. The primary differences between ours and the PIC32MX675F512H is that ours has twice as much RAM, an extra SPI communication port, and two CAN modules compared to zero on the PIC32MX675F512H.

8. How wide is PORTG on our PIC32 (i.e., how many pins does it have)? You should use Table 1-1 in Section 1 of the Data Sheet, dont search and count for the pins in a diagram.

PORTG is 12 bits wide.

9. Check out the Special Features section of the Data Sheet. If I want my PBCLK frequency to be four times less than my SYSCLK frequency, which bits of which Device Configuration Register do I have to modify? What values do I give those bits?

Modify the "Device Configuration Word 1" (DEVCFG1). Bits 12 and 13 are referred to as the "Peripheral Bus Clock Divisor Value" bits (FPBDIV). Setting bit 13, and clearing bit 12 will accomplish this goal.

10. Referring to the Data Sheet, what is the name of the SFR I have to modify if I want to change pins on PORTC from output to input?

The SFR name is TRISC.

11. PIC32s have increased their flash and RAM over the years. What is the maximum amount of flash memory a PIC32 can have before the current choice of base addresses (for RAM, flash, peripherals, and boot flash) would have to be changed? Give your answer in bytes in hexadecimal.

Currently, the largest PIC32 has 512 KB of flash memory. With the current addressing scheme that the PIC32s are using, the starting physical address of flash memory is 0x1D000000. The next segment in the memory map is the Peripheral SFRs, and they start at 0x1F800000. That means there are a total of 0x02800000 memory addresses between them; converting to decimal, that implies there are 41,943,040 total bytes that we can address with the current addressing scheme.

12. The SFR OC2CON controls the behavior of Output Compare module 2. What is its virtual address? What is its physical address? (Section 4 of the Data Sheet may be helpful.

OC2CON is at virtual address 0xBF803200, it's physical address is 0x1F803200 (which we can get by using the fixed mapping translation formula on p. 8 of Chapter 2: Looking Under the Hood: Hardware.).

13. Your NU32 board provides 5 V output. You plan to put a resistor from that 5 V output to ground. What is the smallest resistance that would be safe? In a sentence, explain how you arrived at the answer.

In section 2.2, it says that we should never try to source more than 400 mA from the NU32 board. If the 5 V rail is tied to ground through a resistor, and we assume that we don't want to draw more than 400 mA, we can calculate the minimum resistor size using Ohm's law:

$$\frac{V}{I} = R = \frac{5\text{ V}}{0.4\text{ A}} = 12.5\ \Omega\text{ min}$$