2.3 Chapter Summary

- The PIC32 features a 32-bit data bus and a CPU capable of performing some 32-bit operations in a single clock cycle.
- In addition to nonvolatile flash program memory and RAM data memory, the PIC32 provides peripherals particularly useful for embedded control, including analog inputs, digital I/O, PWM outputs, counter/timers, inputs that generate interrupts or measure pulse widths or frequencies, and pins for a variety of communication protocols, including USB, Ethernet, CAN, I^2C, and SPI.
- The functions performed by the pins and peripherals are determined by Special Function Registers. SFRs are also used for communication back and forth between the CPU and peripherals.
- The PIC32 has three main clocks: the SYSCLK that clocks the CPU, the PBCLK that clocks peripherals, and the USBCLK that clocks USB communication.
- Physical memory addresses are specified by 32 bits. The physical memory map contains four regions: data RAM, program flash, SFRs, and boot flash. RAM can be accessed in one clock cycle, while flash access may be slower. The prefetch cache module can be used to minimize delays in accessing program instructions.
- Four 32-bit configuration words, DEVCFG0 to DEVCFG3, set important behavior of the PIC32. For example, these configuration bits determine how an external clock frequency is multiplied or divided to create the PIC32 clocks.
- The NU32 development board provides voltage regulators for power, includes a resonator for clocking, breaks out the PIC32 pins to a solderless breadboard, provides a couple of LEDs and buttons for simple input and output, and simplifies communication with the PIC32 via your computer's USB port.

2.4 Exercises

You will need to refer to the PIC32MX5XX/6XX/7XX Data Sheet and PIC32 Reference Manual to answer some questions.

1. Search for a listing of PIC32 products on Microchip's webpage, showing the specifications of all the PIC32 models.
   a. Find PIC32s that meet the following specs: at least 128 KB of flash, at least 32 KB of RAM, and at least 80 MHz max CPU speed. What is the cheapest PIC32 that meets these specs, and what is its volume price? How many ADC, UART, SPI, and I^2C channels does it have? How many timers?
   b. What is the cheapest PIC32 overall? How much flash and RAM does it have, and what is its maximum clock speed?
   c. Among all PIC32s with 512 KB flash and 128 KB RAM, which is the cheapest? How does it differ from the PIC32MX795F512H?

2. Based on C syntax for bitwise operators and bit-shifting, calculate the following and give your results in hexadecimal.
   a. `0x37 | 0xA8`
   b. `0x37 & 0xA8`
   c. `~0x37`
   d. `0x37>>3`
3. Describe the four functions that pin 12 of the PIC32MX795F512H can have. Is it 5 V tolerant?
4. Referring to the Data Sheet section on I/O Ports, what is the name of the SFR you have to modify if you want to change pins on PORTC from output to input?
5. The SFR CM1CON controls comparator behavior. Referring to the Memory Organization section of the Data Sheet, what is the reset value of CM1CON in hexadecimal?
6. In one sentence each, without going into detail, explain the basic function of the following items shown in the PIC32 architecture block diagram Figure 2.2: SYSCLK, PBCLK, PORTA to PORTG (and indicate which of these can be used for analog input on the NU32's PIC32), Timer1 to Timer5, 10-bit ADC, PWM OC1-5, Data RAM, Program Flash Memory, and Prefetch Cache Module.
7. List the peripherals that are *not* clocked by PBCLK.
8. 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? (It's a 10-bit ADC.)
9. Refer to the Reference Manual chapter on the Prefetch Cache. What is the maximum size of a program loop, in bytes, that can be completely stored in the cache?
10. Explain why the path between flash memory and the prefetch cache module is 128 bits wide instead of 32, 64, or 256 bits.
11. Explain how a digital output could be configured to swing between 0 and 4 V, even though the PIC32 is powered by 3.3 V.
12. PIC32's 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 in the physical memory map (for RAM, flash, peripherals, and boot flash) would have to be changed? What is the maximum amount of RAM? Give your answers in bytes in hexadecimal.
13. Examine the Special Features section of the Data Sheet.
    a. If you want your PBCLK frequency to be half the frequency of SYSCLK, which bits of which Device Configuration Register do you have to modify? What values do you give those bits?
    b. Which bit(s) of which SFR set the watchdog timer to be enabled? Which bit(s) set the postscale that determines the time interval during which the watchdog must be reset to prevent it from restarting the PIC32? What values would you give these bits to enable the watchdog and to set the time interval to be the maximum?

c. The SYSCLK for a PIC32 can be generated several ways, as discussed in the Oscillator chapter in the Reference Manual and the Oscillator Configuration section in the Data Sheet. The PIC32 on the NU32 uses the (external) primary oscillator in HS mode with the phase-locked loop (PLL) module. Which bits of which device configuration register enable the primary oscillator and turn on the PLL module?

14. Your NU32 board provides four power rails: GND, regulated 3.3 V, regulated 5 V, and the unregulated input voltage (e.g., 6 V). You plan to put a load from the 5 V output to ground. If the load is modeled as a resistor, what is the smallest resistance that would be safe? An approximate answer is fine. In a sentence, explain how you arrived at the answer.
15. The NU32 could be powered by different voltages. Give a reasonable range of voltages that could be used, minimum to maximum, and explain the reason for the limits.
16. Two buttons and two LEDs are interfaced to the PIC32 on the NU32. Which pins are they connected to? Give the actual pin numbers, 1-64, as well as the name of the pin function as it is used on the NU32. For example, pin 37 on the PIC32MX795F512H could have the function D+ (USB data line) or RG2 (Port G digital input/output), but only one of these functions could be active at a given time.

Further Reading

PIC32 family reference manual. Section 03: Memory organization. (2010). Microchip Technology Inc.

PIC32 family reference manual. Section 02: CPU for devices with the M4K core. (2012). Microchip Technology Inc.

PIC32 family reference manual. Section 32: Configuration. (2013). Microchip Technology Inc.

PIC32MX5XX/6XX/7XX family data sheet. (2013). Microchip Technology Inc.