Kettering University

Microcomputers I

Lab Exercise 8

Developing and Conducting Appropriate Experimentations

Validating Experimental Results

RTI Cycle-Time Measurement

Spring 2022

Prelab (10%): Go over this handout rigorously, do Assignment **1**, and then upload one handout (prelab) per group to Blackboard in **.pdf format** by **11:59 pm** on the **Tuesday** before your lab day.

Lab report: Upload one lab handout (report) per group to Blackboard (in **.pdf**) by **11:59 pm** on the **Sunday** following the lab day and **after** you have done all the assignments, answered all the questions, and shown your lab work to the lab instructor **individually**.

In the lab report, please correct your prelab incorrect answers, if any.

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Note:

Be careful when you configure a pin as OUTPUT. This may cause a short circuit, hence damaging the chip.

*We will follow the **Incremental Approach** in the Microcomputers I lab: Please start with one of your functional codes that is the closest one to today's assignment. Then add a tiny portion to that code, and test it. Continue this "increment-test" approach until you get the job done ☺*

*You may follow the opposite direction, the **Decremental Approach**, for troubleshooting purposes: if you are provided with a nonfunctional code (along with the implementation algorithm), remove a portion of the code and test the code. Continue this "decrement-test" approach until you locate the problematic portion.*

Purpose of this lab exercise:

The purpose of this lab was to improve our knowledge of RTIs and to gain experience gathering/analyzing data.

Objectives

- Strengthen your ability to develop and conduct experiments to obtain the required data and measure variables.
- Develop skills to validate experimental data, analyze the results, use engineering judgment and draw conclusions.
- Improve your programming skills.
- Better understand how Real-Time Interrupt (RTI) works.

What to hand in

- Upload this handout (report) in **.pdf**, and after you have done all the assignments and answered all the questions.
- Show your functional system in Assignment **2** to the lab instructor *individually*, and before you turn in your report.
- Also be prepared to *individually* answer the lab instructor's questions regarding today's lab exercise and what your group did.

Note

- **When single-stepping, reduce the delays, if any, to almost zero, or use breakpoints.**
- Press the reset button on the trainer board before you upload your code.
- Close the "True-Time Simulator & Real-Time Debugger" window, *before* you run the debugger again if you use the microcontroller.
- Take Code Warrior to HCS12 Serial Monitor mode when you wish to use the trainer board.
- Use single-stepping (F11) for troubleshooting/testing purposes.
- Write your programs with proper *indentation* as well as *explanatory* and *short* comments.
- In your comments, use *meaningful/descriptive* names for the register and memory locations that you use.
- Your flowchart (the *formulation* of the project) should not be too close to the word description of the problem, nor too close to the assembly program.

During your presentation, suppose that you are selling your product (software). When I ask you if your product works, please do not tell me you don't know; this is one of the worst possible answers! If you are ready to demo, you should be able to prove that your product does work!

You should work closely with your lab partner, as this will enhance your performance. You are also urged to talk to other students; teach them or learn from them; however, do NOT copy from them!

Assignments

Note: The members of each group should work on the prelab *independently* and then compare their results.

Prelab starts here:

1. Clearly, briefly, and *qualitatively* propose a method to *measure* the RTI cycle time:

We simply used a phone timer to track the amount of time it took for an LED to blink 10 times, and divided the stop time by 10 to get the amount of time for one cycle.

Prelab ends here.

2. Four values for RTICLT, the CRG RTI Control Register, are shown in Columns 1 and 2 of the following table. Using your proposal in Assignment 1, develop and conduct appropriate experiments to determine the RTI cycle time for each row, and write your results (after necessary calculations) in Column 3 of this table. You should do this assignment *empirically with the real hardware*, NOT theoretically, NOR through simulation. **Show your lab instructor how you do it.**

1 RTICLT[6:4]	**2 RTICLT [3:0]**	**3 RTI Cycle Time (ms) (Empirical)**	**4 RTI Cycle Time (ms) (Theoretical)**
5	D	30	24
6	8	40	29
6	1	10	8
3	7	4	3

Figure 1. RTI cycle times

3. Clearly, briefly, and *quantitatively* show the approach you made (including the calculations) to obtain the above values:

We recorded the amount of time between 10 cycles, divided the time by 10 and then divided again by the frequency divider.

Ex.
For an RTICLT of 5D, we measured a time of 4.76 seconds. We then divided by 10, which gave us 476 ms between each blink. We divided again by the frequency divider, which was 8. This resulted in 59.5 ms per cycle, which we rounded up to 60.

4. Copy your indented and commented codes, and paste them in the space provided on this page:

```
; Your code starts here

; Initialization
    movb  #$F, DDRP         ; configure PORT P3-0 as output
    movb  #$F,  PTP         ; disable 7-segment displays

    bset    DDRJ, #2        ; configure PJ1 as output
    bclr    PTJ,  #2        ; enable LEDs

    movb  #1,   DDRB        ; configure PORT B as output
    bset    PORTB, 1        ; Turn LED0 ON

    movb  #$7F, RTICTL      ; get max RTI period
    bset    CRGINT, #$80    ; enable RTI
    cli                     ; assert master enable

forever:
    bra forever


rti_isr:
    inc     counter         ; update Int counter
    ldaa    counter
    cmpa    #8              ; check if 8 Int occurred (almost 1 sec)
    bne     return          ; if not, too early to toggle
    clr     counter         ; otherwise, clear counter
                            ; & toggle LED0 (next 3 instructions)
      ldaa  PORTB
      eora  #1
      staa  PORTB

return:
    bset    CRGFLG, $80 ; reset RT interrupt flag (send 1 to reset)
    rti
    end
```

5. Validate the experimental results listed in Column 3 of Figure 1, and then type your findings in Column 4 of this figure. Explain your approach and show your calculations *clearly* and *legibly*:

We calculated the theoretical cycle times by using this table:

RTR[3:0]	RTR[6:4]							
	000 (off)	001 (2^{10})	010 (2^{11})	011 (2^{12})	100 (2^{13})	101 (2^{14})	110 (2^{15})	111 (2^{16})
0000 (÷1)	off*	2^{10}	2^{11}	2^{12}	2^{13}	2^{14}	2^{15}	2^{16}
0001(÷2)	off*	2×2^{10}	2×2^{11}	2×2^{12}	2×2^{13}	2×2^{14}	2×2^{15}	2×2^{16}
0010 (÷3)	off*	3×2^{10}	3×2^{11}	3×2^{12}	3×2^{13}	3×2^{14}	3×2^{15}	3×2^{16}
0011 (÷4)	off*	4×2^{10}	4×2^{11}	4×2^{12}	4×2^{13}	4×2^{14}	4×2^{15}	4×2^{16}
0100 (÷5)	off*	5×2^{10}	5×2^{11}	5×2^{12}	5×2^{13}	5×2^{14}	5×2^{15}	5×2^{16}
0101 (÷6)	off*	6×2^{10}	6×2^{11}	6×2^{12}	6×2^{13}	6×2^{14}	6×2^{15}	6×2^{16}
0110 (÷7)	off*	7×2^{10}	7×2^{11}	7×2^{12}	7×2^{13}	7×2^{14}	7×2^{15}	7×2^{16}
0111 (÷8)	off*	8×2^{10}	8×2^{11}	8×2^{12}	8×2^{13}	8×2^{14}	8×2^{15}	8×2^{16}
1000 (÷9)	off*	9×2^{10}	9×2^{11}	9×2^{12}	9×2^{13}	9×2^{14}	9×2^{15}	9×2^{16}
1001 (÷10)	off*	10×2^{10}	10×2^{11}	10×2^{12}	10×2^{13}	10×2^{14}	10×2^{15}	10×2^{16}
1010 (÷11)	off*	11×2^{10}	11×2^{11}	11×2^{12}	11×2^{13}	11×2^{14}	11×2^{15}	11×2^{16}
1011 (÷12)	off*	12×2^{10}	12×2^{11}	12×2^{12}	12×2^{13}	12×2^{14}	12×2^{15}	12×2^{16}
1100 (÷13)	off*	13×2^{10}	13×2^{11}	13×2^{12}	13×2^{13}	13×2^{14}	13×2^{15}	13×2^{16}
1101 (÷14)	off*	14×2^{10}	14×2^{11}	14×2^{12}	14×2^{13}	14×2^{14}	14×2^{15}	14×2^{16}
1110 (÷15)	off*	15×2^{10}	15×2^{11}	15×2^{12}	15×2^{13}	15×2^{14}	15×2^{15}	15×2^{16}
1111 (÷16)	off*	16×2^{10}	16×2^{11}	16×2^{12}	16×2^{13}	16×2^{14}	16×2^{15}	16×2^{16}

We looked up the RTICLT value in this table, and divided it by 8, the frequency of the CPU in MHz.
Ex.
For 5D, the value in the table is 12*2^14. (12*2^14) / 8 = ~24ms, which is the theoretical period of our RTI Cycle.

6. Analyze the results, use engineering judgment, and draw a conclusion.

We concluded that our measurement system could be improved. On average, our measured result was about 30% slower than the theoretical result. 30% is far too much, and should be improved via the methods outlined in question 7.

((30/24)+(40/29)+(10/8)+(4/3)) / 4 = 1.3 = 130%

7. Briefly but clearly explain how you may improve the accuracy of your results shown in Column 3 of Figure 1:

We could improve the accuracy of our measurements by taking more samples (i.e. 20 blinks instead of 10) and recording the blinking in slow motion to get a near-exact time. Additionally, we could use code to track the number of cycles, which would be extremely accurate, but would require extra time and labor.