

AME 3623 Real-Time Embedded Systems
Midterm
March 9, 2017

General instructions:

- Please wait to open this exam booklet until you are told to do so.
- This examination booklet has 11 pages. You also have been issued a bubble sheet.
- Write your name, university ID number and date, and sign your name below. Also, write your name and ID number on your bubble sheet, and fill in the bubbles for your ID.
- The exam is closed book, notes and electronic devices. The exception is that you may have one page of personal notes (double sided).
- The exam is worth a total of 137 points (and 10% of your final grade).
- You have 1.25 hours to complete the exam. Be a smart test taker: if you get stuck on one problem go on to the next.
- Use your bubble sheet to answer all multiple-choice questions. Make sure that the question number and the bubble row number match when you are answering each question.

On my honor, I affirm that I have neither given nor received inappropriate aid in the completion of this exam.

Signature: _____

Name: _____

ID Number: _____

Date: _____

Question	Points	Score
Binary Representations and Mathematical Operators	33	
Circuits	30	
Digital/Analog Systems	20	
Motor Control	16	
Digital I/O	25	
Serial Processing	13	
Total:	137	

A B B D B C C B D A

Part I. Binary Representations and Mathematical Operators

1. (4 points) What is the binary representation of c after the following code is executed?

```
uint8_t a = 0x67;  
uint8_t b = a << 3;  
uint8_t c = b >> 5;
```

- A. 0000 0000 **B. 0000 0001** C. 0001 1001 D. 0011 0011
E. Answer not shown
2. (4 points) What is the decimal representation for the binary digits 0110 0010? Assume an unsigned, 8-bit integer.
A. 48 B. 50 **C. 98** D. 194 E. Answer not shown
3. (4 points) What is the decimal representation of b after the following code is executed?

```
uint8_t a = 27;  
uint8_t b = (a / 32) << 2;
```

- A. 0** B. 3 C. 3.375 D. 4.741 E. Answer not shown
4. (4 points) What is the binary representation of a after the following code is executed?

```
uint8_t a = 52;
```

- A. 0011 0010 **B. 0011 0100** C. 0101 0010 D. 0101 0100
E. Answer not shown
5. (4 points) What is the decimal value of c after the following code is executed?

```
uint8_t a = 7;  
uint8_t b = 10;  
uint8_t c = a & b
```

- A. 0 B. 1 **C. 2** D. 15 E. Answer not shown

6. (4 points) What is the binary representation of c after the following code is executed?

```
uint8_t a = 0x42;
uint8_t b = 42;
uint8_t c = a + b;
```

- A. **0110 1100** B. 1000 0110 C. 1000 0100 D. 0101 0100
E. Answer not shown

7. (4 points) What is the hexadecimal representation of c after the following code is executed?

```
uint8_t a = 0x27;
uint8_t b = 0x42;
uint8_t c = a || b;
```

- A. 0x0 **B. 0x1** C. 0x10 D. 0x67 E. Answer not shown

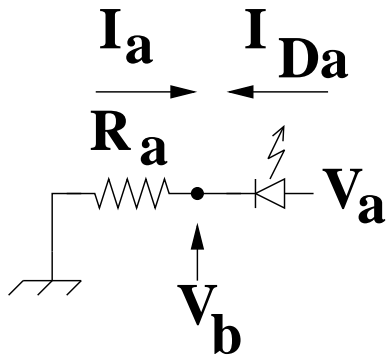
8. (5 points) What is the hexadecimal representation of c after the following code is executed?

```
uint8_t a = 0x28;
uint8_t b = 0x30;
uint8_t c = b - a;
```

- A. 0x2 B. 0x6 **C. 0x8** D. 0xF8 E. Answer not shown

Part II. Circuits

Consider the following circuit:



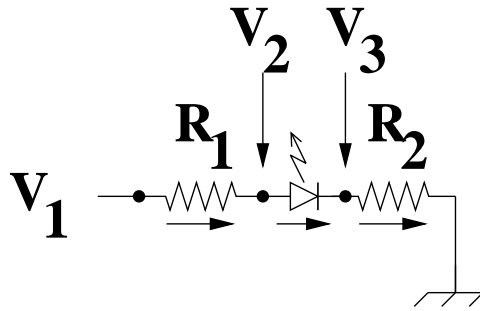
Assume $R_a = 500\Omega$ and $V_{f_a} = 1.5V$.

9. (5 points) Given that $V_a = 10\text{ V}$ What is V_b ?
 A. 0 V B. 1.5 V C. 8.5 V D. 10 V E. Answer not shown
10. (5 points) Given that $V_a = 2\text{ V}$ What is I_a ?
 A. 0 mA B. 1 mA C. 4 mA D. 5 mA E. Answer not shown

Solution: $I_a = -1\text{ mA}$

11. (5 points) Given that $V_a = -2\text{ V}$ What is V_b ?
 A. 0 V B. -0.5 V C. -1.5 V D. -2 V E. Answer not shown

Consider the following circuit:



Assume $R_1 = 400 \Omega$, $R_2 = 600 \Omega$ and $V_f = 2 V$.

12. (5 points) Given that $V_1 = 4V$. What is I_{R_1} ?
A. -4 mA B. 0 mA C. **2 mA** D. 4 mA E. Answer not shown
13. (5 points) Given that $V_1 = 3 V$. What is V_2 ?
A. $0 V$ B. $0.4 V$ C. $0.6 V$ D. $3 V$ E. **Answer not shown**
14. (5 points) Given that $V_1 = 1 V$. What is V_2 ?
A. $0 V$ B. **$1 V$** C. $2 V$ D. $3 V$ E. Answer not shown

Part III. Digital/Analog Systems

15. (5 points) Assume an 8-bit analog-to-digital converter that uses the successive approximation algorithm, and has a range of 0 to 5 volts. If $V_{in} = 1.1 V$ and the first guess by successive approximation is 1000 0000, what is the fourth guess?
A. 0011 0000 B. 0011 0010 C. 0011 0011 D. 0011 1000
E. Answer not shown
16. (5 points) Assume a 3-bit analog-to-digital converter that uses the successive approximation algorithm, and has a range of 0 to 10 volts. What is the binary value that corresponds to $V_{in} = 4 V$?
A. 0000 0001 **B. 0000 0010** C. 0000 0011 D. 0000 0111
E. Answer not shown

Solution: $V_{out} = \frac{10}{7}(D_0 + 2D_1 + 4D_2)$

The sequence of guesses is:

$100 \rightarrow 40/7V = 5R5$ (too high)

$010 \rightarrow 20/7V = 2R6$ (too low)

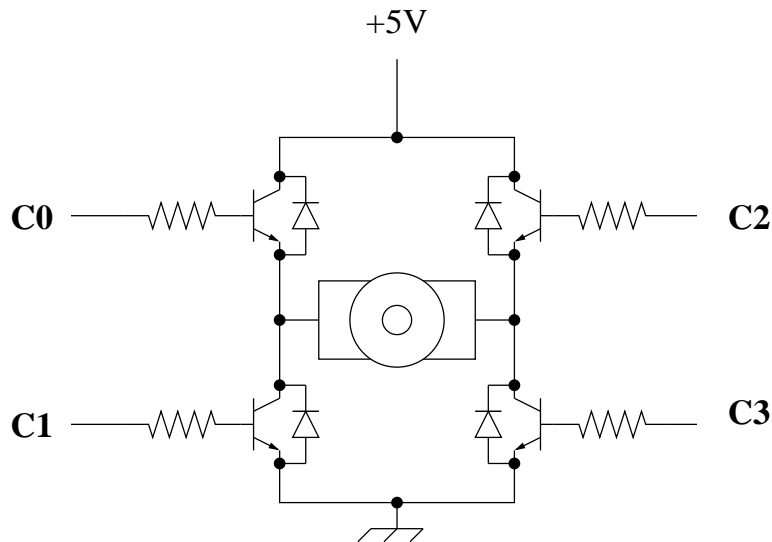
$011 \rightarrow 30/7V = 4R2$ (too high)

The choice made by the successive approximation algorithm is therefore 010 (even though 011 is closer to V_{in})

17. (5 points) Assume an 4-bit analog-to-digital converter that uses the successive approximation algorithm, and has a range of 0 to 5 volts. What is the digital representation of $V_{in} = 4.1 V$ in binary?
A. 0000 0100 B. 0000 0101 **C. 0000 1100** D. 0000 1110
E. Answer not shown
18. (5 points) Assume an 6-bit digital-to-analog converter that has a range of 0 to 3.3 V. What is the resolution of this converter (i.e., how much does the voltage change with one increment of the digital value)?
A. 33/2550 V B. 33/1270 V **C. 33/630 V** D. 33/310 V
E. Answer not shown

Part IV. Motor Control

Consider the following circuit:

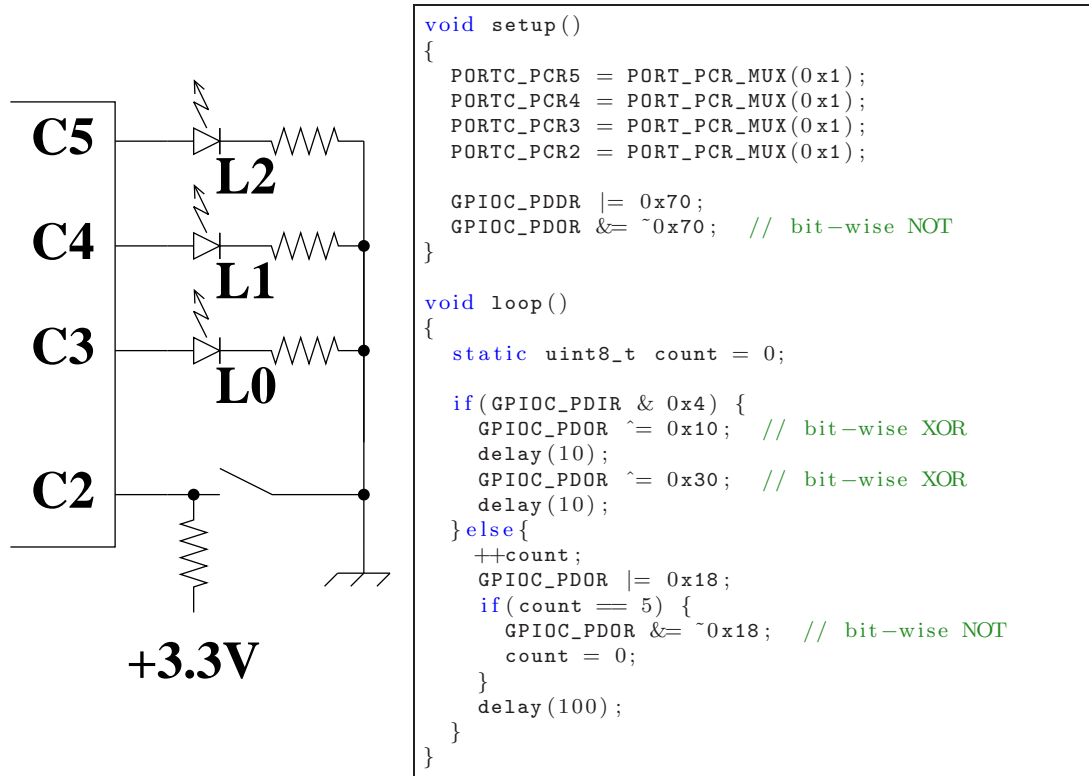


19. (4 points) When $C[3210] = [1, 0, 0, 1]$, what is the best description of what happens?
- A. A short circuit occurs
 - B. A torque is generated**
 - C. No torque is generated
 - D. The motor dynamically brakes
 - E. Answer not shown
20. (4 points) When $C[3210] = [0, 0, 0, 1]$, what is the best description of what happens?
- A. A short circuit occurs
 - B. A torque is generated
 - C. No torque is generated**
 - D. The motor dynamically brakes
 - E. Answer not shown
21. (4 points) When $C[3210] = [1, 0, 1, 0]$, what is the best description of what happens?
- A. A short circuit occurs
 - B. A torque is generated
 - C. No torque is generated
 - D. The motor dynamically brakes**
 - E. Answer not shown

22. (4 points) When $C[3210] = [1, 0, 1, 1]$, what is the best description of what happens?
- A. **A short circuit occurs**
 - B. A torque is generated
 - C. No torque is generated
 - D. The motor dynamically brakes
 - E. Answer not shown

Part V. Digital I/O

Consider the following circuit and code:



23. (5 points) When the switch is open, what is the flashing frequency of L1?
 A. 10 Hz B. 25 Hz C. 50 Hz D. 100 Hz E. The LED does not flash

Solution: When the switch is open, the test is true. The body of the “if” case requires a total of 20ms to complete. Within the body. So, we require one pass through loop() for one full flash cycle. 20ms period == 50Hz.

24. (5 points) When the switch is closed, what is the duty cycle of L0?
 A. 50% B. 75% C. 80% D. 100% E. The LED does not flash

Solution: The DDR for this bit was left at logic zero. Therefore, it is not a digital output and the LED cannot turn on.

25. (5 points) When the switch is open, what is the duty cycle of L2?
 A. 50% B. 75% C. 80% D. 100% E. The LED does not flash

26. (5 points) When the switch is closed, what is the flashing frequency of L1?
A. 2 Hz B. 2.5 Hz C. 5 Hz D. 10 Hz E. The LED does not flash

Solution: When the switch is closed, we are in the “else” case. At the beginning of the else block, count will be one of 0, 1, 2, 3 or 4 (so 5 different values are possible). At the beginning of the `count == 0` case, C4 is brought high (for cases 1, 2 and 3, it is also set to high, but the state does not change). For `count == 4` (beginning of the else), C4 is brought low.

So, there are 5 passes through `loop()` with each reset of count, for a total period of $100\text{ ms} \times 5$. Furthermore, C4 is high for 4 of the 5 passes. This gives us a flash frequency of 2 Hz.

27. (5 points) When the switch is open, what is the flashing frequency of L2?
A. 10 Hz B. 25 Hz C. 50 Hz D. 100 Hz E. The LED does not flash

Solution: When the switch is open, the test is true. The body of the “if” case requires a total of 20ms to complete. Within the body, C4 is turned on and then turned off, however the state of C5 is only flipped. So, we require two passes through `loop()` for one full flash cycle. $40\text{ms period} == 25\text{Hz}$.

Part VI. Serial Processing

Consider the following code block:

```
1 int transform (char c)
2 {
3     if(c >= '0' && c <= '9'){
4         return c - '0';
5     }
6     else if(c >= 'a' && c <= 'f'){
7         return c - 'a';
8     }
9     else {
10        return -1;
11    }
12 }
```

28. (5 points) The above function is to return the value of a character that is interpreted as a hexadecimal digit, and -1 if the character is not a hexadecimal digit. On which line is the bug? (assume that it is only necessary to capture lower-case letters)
- A. 3 B. 4 C. 6 **D. 7** E. There is no bug
29. (4 points) True or False: in an asynchronous serial protocol, the sender of the data exclusively determines the rate at which bits are sent.
- A. True **B. False**

Solution: In an asynchronous serial protocol, each side (sender and receiver) have their own clocks that they must maintain (including setting the bit rate). This is done (in RS232) by agreement of the programmers of the two sides.

30. (4 points) True or False: a start bit is used in a synchronous serial protocol.
- A. True **B. False**