**Mid-term – Part 1 Written Section (Closed Book) – 60-minute time limit**

**Instructions:** Complete your answers in the space below (do not use back of paper).

**Student Name** \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ **Final Score** out of 50: \_\_\_\_\_\_\_\_

1. Fill in the blanks for the following – some blanks may be 2 worded ones **(20%)**
	1. Capacitors are parallel conductive plates separated by an insulator
	2. Diodes allow the flow of current only in one direction
	3. Computers use a Base-2 numbering system
	4. An N-bit analog-to-digital converter has N voltage dividers
	5. A 10-bit analog-to-digital converter results in (raw) decimal values ranging from 0 to 1023
	6. In practice, an op-amp cannot have infinite gain
	7. Impedance obstructs alternating current
	8. Voltage followers are often used in instrumentation amplifiers
	9. Shannon’s sampling theorem puts a limit on the minimum sampling time
	10. Motors, relays and pneumatic valves are examples of actuators
	11. Pulse-width modulation is the ratio of times when a signal is on and off
	12. I2C is a low-speed, half-duplex data transfer between integrated circuits
	13. RS-485 is a high-speed, half-duplex data transfer between PCs and peripherals
	14. I2C has a 2-wire interface consisting of data and clock lines
	15. In integrated circuits, TTL stands for transistor-to-transistor logic
	16. Bi-directional digital lines means that the lines can be used for both input and output
	17. Like relays, transistors can act as electronic switches
	18. H-bridges are circuits that use switches to reverse the direction of current
	19. A relay is an electromechanical switch
	20. MOSFETs are voltage-driven transistors
2. Convert the following numbers. Show relevant calculations **(10%)**
	1. 67 (from base 10 to base 2)

**Answer:** 1000011

* 1. 608 (from base 10 to base 3)

**Answer:** 211112

* 1. 16 (from base 10 to base 8)

**Answer:** 20

* 1. FF (from base 16 to base 10)

 **Answer:** 255

* 1. 1101 (from base 2 to base 3)

**Answer:** 111

1. What are the 2 rules and 5 properties of an ideal op-amp? Use the 2 rules to mathematically derive the input-output relationship of the op-amp below. This op-amp circuit converts what to what? **(10%) 40% by now**



**Answer:**

Rule 1: Voltage at “+” and “-” terminals are equal

Rule 2: No current at “+” and “-” terminals



* Input impedance
* Output impedance



* Open-loop gain is





* Bandwidth is



* when

From Rule 1, we have that $V^{-}=V^{+}=GND$. From Rule 2 we have current into negative input must be 0. Hence $I\_{OUT1}-\frac{V\_{OUT}-V^{-}}{R\_{FB}}≡0$. Hence $V\_{OUT}=I\_{OUT1}∙R\_{FB}$. This is a current-to-voltage converter.

1. Sketch a non-inverting op-amp and mathematically derive its input-output relationship **(15%)**

**Answer:**

**Step 1:** Add labels to help make things clearer:



**Step 2:** Recall the 2 op-amp rules:

(1)

Rule 1: Voltage at “+” and “-” terminals are equal. Hence $v\_{α}=v\_{in}$

Rule 2: No current at “+” and “-” terminals. Hence, current at $β$ must be zero. Hence$-I\_{1}+I\_{2}≡0.$

Where we see that $-I\_{1}=\frac{v\_{α}}{R\_{1}}$ and $I\_{2}=\frac{v\_{out}-v\_{α}}{R\_{2}}$. Thus we have

(2)

$$-\frac{v\_{α}}{R\_{1}}+\frac{v\_{out}-v\_{α}}{R\_{2}}≡0$$

Substituting (1) into (2) we can rewrite (2) as

$$v\_{out}=v\_{in}+\frac{v\_{in}R\_{2}}{R\_{1}}=v\_{in}\left(1+\frac{R\_{2}}{R\_{1}}\right)=v\_{in}\left(\frac{R\_{1}+R\_{2}}{R\_{1}}\right)$$

Note that $\left(\frac{R\_{1}+R\_{2}}{R\_{1}}\right)>1$ always. Hence there’s amplification (but no inversion) i.e. **Non-inverting amplifier.**

1. For the following voltage divider circuit, suppose $R\_{B}$ is 1000 Ohms and $V\_{in}$ is 10 volts. What value should $R\_{A}$ be for V to be 3.0 volts? **(10%)**



**Answer:**

Recall that $\frac{V\_{in}}{R\_{A}+R\_{B}}=\frac{V}{R\_{B}}$ hence $(R\_{A}+R\_{B})V=V\_{in}R\_{B}$or$R\_{A}V=V\_{in}R\_{B}-R\_{B}V$.

Hence $R\_{A}=\frac{\left(V\_{in}-V\right)R\_{B}}{V}= \frac{\left(10-3\right)1000}{3}=2333Ω$

1. Consider a 4-bit Digital-to-Analog Converter (DAC) **(10 points) *80% by this point***
	1. What is the resolution in volts if the reference voltage is +5V

**Answer:** Recall that have $2^{4}-1=15, $this means that can resolve reference voltage (5V) into 16 discrete values ($\frac{5}{16}=0.3125 V$).

* 1. List all the possible analog voltages this DAC can deliver for +5V reference voltage

**Answer:** 0; 0.3125; 0.625; 0.9375; 1.25; 1.875; 2.1875; 2.5; 2.8175; 3.125; 3.4375; 3.75; 4.02625; 4.375; 4.6875; 5

* 1. Suppose you want an analog voltage of precisely 0.625V. What should the decimal number for a reference voltage of +5V?

**Answer:** $\frac{V\_{ref}}{16}=\frac{V}{Word}$ so $Word=\frac{16∙V}{V\_{ref}}=\frac{16∙0.625}{5}=2$

* 1. For the decimal number calculated above, suppose you want an analog voltage of precisely 0.6V. What should reference voltage be?

**Answer:** $\frac{V\_{ref}}{16}=\frac{V}{Word}$ so, $V\_{ref}=\frac{16∙0.6}{2}=4.8 V$

* 1. What is the resolution in volts if one uses an 8-bit DAC and +5V reference voltage?

**Answer:** Have$2^{8}=256$, so $\frac{5}{256}=0.0195 V$

1. The Fibonocci numbers have the following sequence: 1, 1, 2, 3, 5, 8, 13… You’ll note that 1+1=2, 1+2=3, 2+3=5, 3+5=8 and 5+8=13 and so on. The next number (eighth in the sequence) will be 8+13=21. Write a C program that prompts the user to enter a positive integer representing the n’th number in the sequence (n should be greater than 2). Your program should then print all the Fibonocci numbers up to the n’th. Submit both the source code and output handouts. Example output (bold is what the computer generates, non-bold is what the user typed in): (*10 points*)

# How many Fibonocci numbers do you want?

10

**The 10 numbers are**

**1, 1, 2, 3, 5, 8, 13, 21, 34, 55**

1. A store manager would like to track the number of customers that enter the store. Entrances that are busiest could then be equipped with more store promotions and eye-catching sales items. Given your experience with the 8255, the manager has contracted you to design a microcomputer solution. The store has eight possible entrances which all have swinging doors. By running your program for one day and recording which doors and how many times each door was opened, the manager would know which doors are busiest. Design a solution supported by discussion on the following *(20 points)*
	* 1. Potential sensors and where they’d be placed
		2. Diagrams (e.g. how the sensors would be interfaced to the PC)
		3. C code