EECS 473 Midterm Exam

Fall 2021

Name: ______________________________ unique name: ___________

Sign the honor code:

I have neither given nor received aid on this exam nor observed anyone else doing so.

____

NOTES:

1. Closed book and Closed notes
2. There are **12** pages total for the exam as well as handouts which you will need for the last question.
3. Calculators are allowed, but no PDAs, Portables, Cell phones, etc. Using a calculator to store notes is not allowed nor is a calculator with any type of wireless capability.
4. You have about 120 minutes for the exam.
5. Though the last question is worth significantly less than half the points, we expect it will take at least half of the exam time.

Be sure to show work and explain what you've done when asked to do so. That may be very significant in the grading of this exam.

1. **<u>Circle</u> the letter in front of all the true statements.** [8 points, -2.5 per wrong circle/lack of a circle, minimum 0]

   a) Compared to the PCB power/ground plane, a bypass capacitor typically has a higher capacitance, ESR, and ESL.

   b) An advantage of RM scheduling compared to EDF scheduling is that RM scheduling has static priorities, often making it easier to implement.

   c) When designing a power distribution network, very low frequency noise (say 1KHz) is primarily handled by the power supply.

   d) The "L" in "LDO" indicates that the output voltage has to be considerably lower than the input voltage.

   e) gcc (the GNU C compiler) should be avoided in commercial software because it is licensed under the GPL and thus any code generated by it must also be licensed under the GPL.

   f) Alkaline batteries are a common type of primary-cell batteries while lithium-polymer batteries are a common type of secondary-cell batteries.

2. **<u>Multiple choice</u>—write letter in blank.** [8 points, -2.5 per wrong/blank answer, minimum 0]

   a) If you have 2 capacitors that have 2μF capacitance, 4mΩ resistance and 8nH inductance and put them in parallel, then you would expect that together they would have ___________.
      a. 4μF, 2mΩ, 16nH   b. 1μF, 2mΩ, 16nH
      c. 4μF, 2mΩ, 4nH   d. 2μF, 8mΩ, 8nH

   b) On a PCB, traces on to different layers of a board are typically connected by a ______.
      a. via   b. trace c. LDO   d. capacitor   e. multiplexer (MUX)

   c) On a PCB, 40 mils is ________ 40mm.
      a. greater than   b. less than   c. equal to

   d) Priority inversion is where ___________
      a. A semaphore or other lock is used to lock a resource and that lock is not released when it should be.
      b. A semaphore or other lock is used with "1" being free and "0" being not-free, rather than the other way around.
      c. A high priority task is blocked by a medium priority task due to the high-priority task sharing a semaphore or other lock with a low priority task.
      d. Priority inheritance sets the high-priority task to the lowest possible priority.

3. Scheduling [9 points]

Say you have the following groups of tasks. For each group find the CPU utilization and identify which groups are RM and which are EDF schedulable. Indicate if you needed to do the critical instant analysis. *If needed,* ***clearly*** *show that analysis.* The following equation may prove useful.

$$\sum_{i=1}^{n} U \leq n(2^{1/n}-1)$$

Group	T1 Execution Time	T1 Period	T2 Execution Time	T2 Period	T3 Execution Time	T3 Period	% Utilization
A	1	4	3	6	1	5	
B	1	10	4	12	1	4	
C	2	5	2	6	3	11	

Group	EDF Schedulable?	RM Schedulable?	Did you need to examine the critical instance?
A			
B			
C			

4. **Linux device drivers** [10 points]

Consider the following code found as the read function member of the file_operations struct for a Linux kernel module. It is associated with the device file "/dev/txx2" (so a read of the file /dev/txx2 will result in this function being called). Assume that everything is set up appropriately beforehand. Ignore the fact that copy_to_user's return value is being ignored (it's just a warning…).

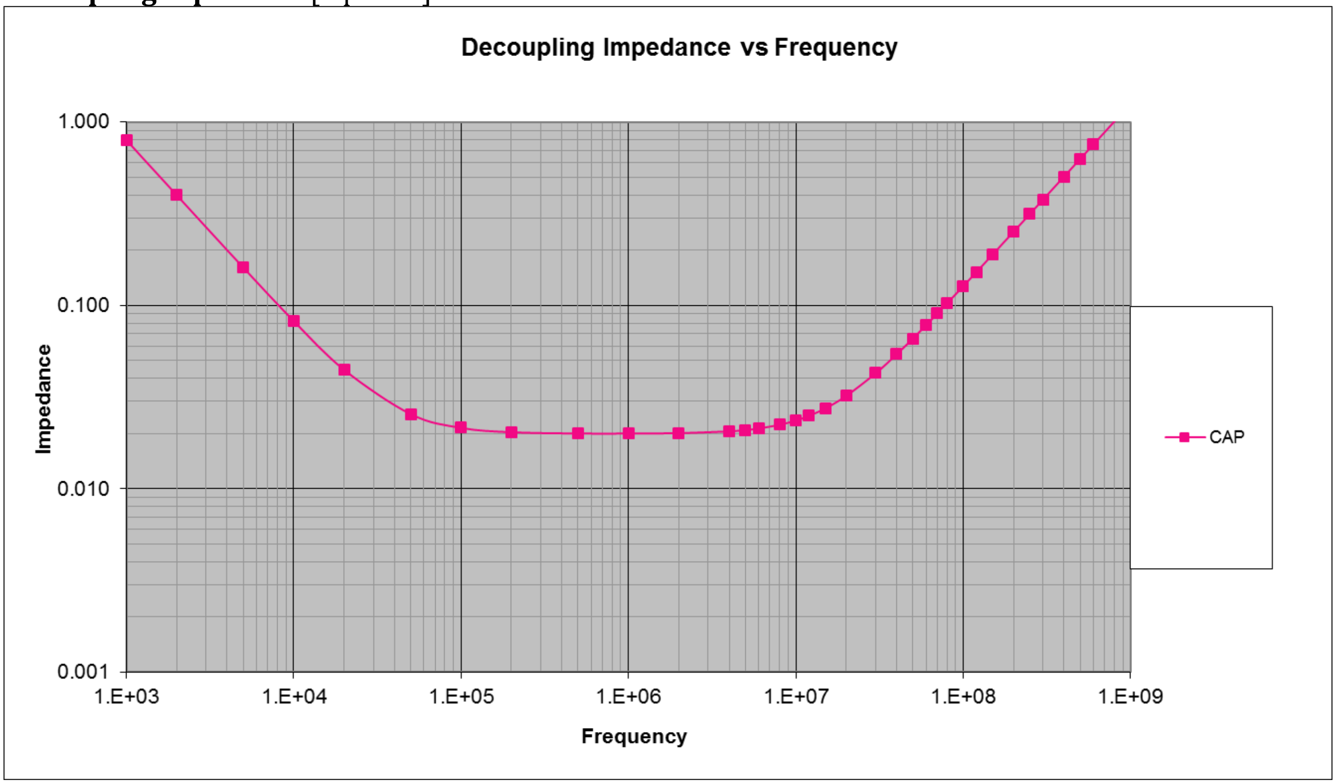
```
const char s[] = "ABCDEFGHIJKLMNOPQRSTUVWXYZ";
ssize_t memory_read(struct file *filp, char *buf,
                      size_t count, loff_t *f_pos) {


     /* Transferring data to user space */
     copy_to_user (buf, s+*f_pos, 6);

     /* Changing reading position as best suits */

     if(*f_pos>=4)
          return 0;

     *f_pos+=2;
     printk("<1> fpos= %d\n",*f_pos);

     return 4;

   }
```

Say that someone does a cat of /dev/txx2.

a) What will appear in the log file? **[4]**

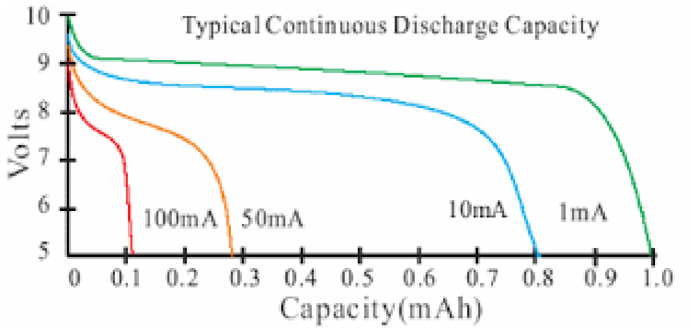
b) What will be printed by the cat command? **[6]**

5. **Decoupling capacitors** [6 points]

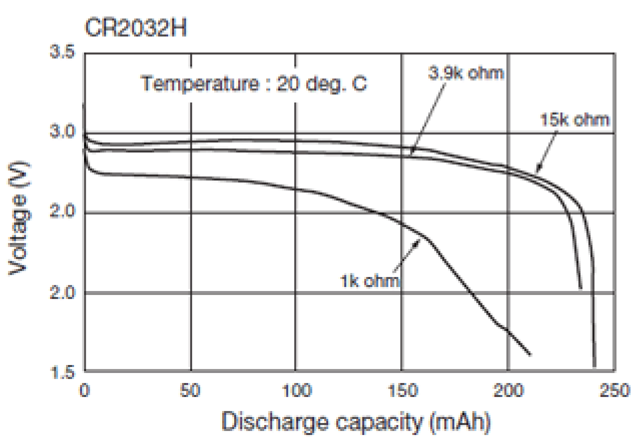


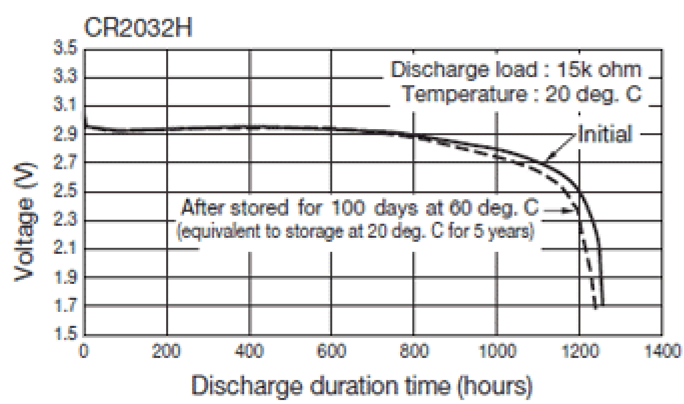
The above graph shows the frequency vs. impedance for a given capacitor. Redraw the graph showing the same information we instead put used 10 new capacitors (in parallel) which each had the same ESR and ESL but only 1/10th the capacitance.

6. **Batteries** [10 points]
Consider the following battery discharge curves from a real battery specifications. ***Clearly justify your answers.***



a) *About* how long would you expect the above battery to be able to drive 6V with a 100mA load? **[4]**





b) *About* how long could a fresh CR2032H battery drive a 1 kΩ load that requires at least 2.5 Volts? (Notice the typo in the 1st graph on the y-axis!). **[6]**

7. **Linear regulators** [6 points]
   You have a linear regulator with a 9V input, a 5V output, and a quiescent current of 5mA. If the load being driven by the regulator is a constant 100 Ohms, how much power is wasted by the regulator? You must clearly show your work.

8. **Short answer** [5 points]

Briefly define the term “power integrity” and how we achieve it on a PCB.

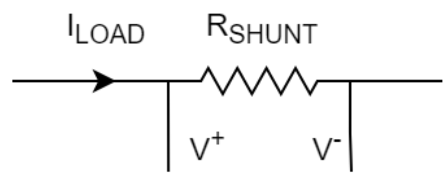
Problem 9: Design problem [38 points]

You should read the entire question before starting.

In the harsh conditions of space, electrical power is a precious resource that needs to be monitored carefully. Satellites made to orbit the earth almost always include an **Electrical Power System (EPS)** that will monitor, regulate, and control the electrical power to the satellites components. But some of these components require a lot of power, and potentially overheat the batteries or harm the power supply and thus cause a mission failure. The EPS is present to protect the integrity of the batteries and power supply.

You have been tasked to design an early prototype for a satellite EPS. This means assembling the hardware as well as writing the associated firmware. The system has the following components:

1. One Arduino Uno Board
2. One Current Sensor chip - INA219 in a 8-Pin SOT-23 package: This chip measures the voltage across a **100mΩ shunt resistor**, and uses Ohm's Law (I = V/R) to calculate the current. An abbreviated version of the data sheet has been provided.



3. One Power Distribution Switch - TPS2013A: This switch is low impedance and can pass a large amount of current. A very abbreviated version of the data sheet has been provided.
4. One Thermistor (temperature dependent resistor): Assume that this thermistor is linear, and is 5kΩ at 0°C and 2kΩ at 80°C. It should be connected in the following configuration with a 3kΩ resistor to measure the temperature of the battery.

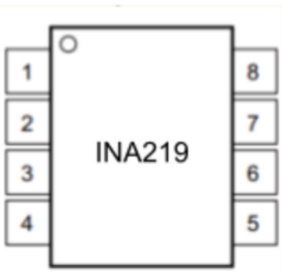
5. One Lithium Ion Battery with an output voltage of 3.7V
6. One pre-built Boost DC-DC converter with an output voltage of 5V. Assume an ideal converter with no output noise (basically, it's magic).
7. A high-power (max 5 Amp) LED with a Potentiometer to simulate a variable load.
8. Any other passives you may require.

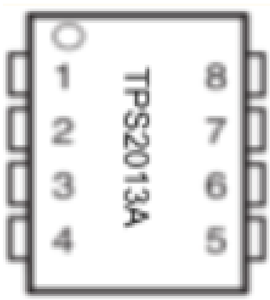
The system should have the following characteristics:

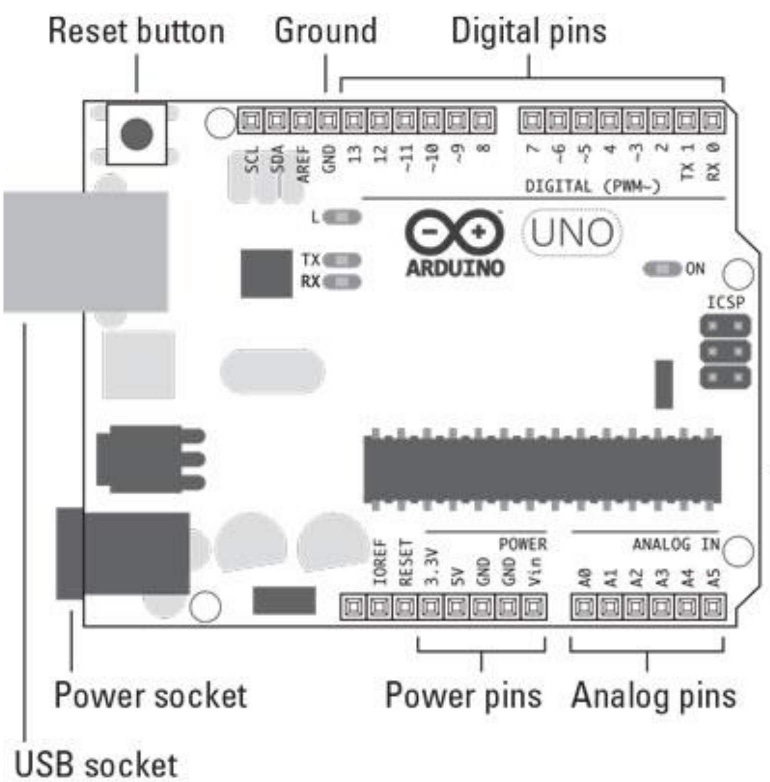
1. The batteries should provide power to the 5V voltage regulator, which provides a stable voltage for the rest of the system.
2. The LED with a Potentiometer will simulate the other components of the satellite (such as other computers, reaction wheels, thrusters, RF transceivers, etc.). The LED and potentiometer should be connected so that the potentiometer can control the brightness of the LED.
3. The Arduino should be able to **monitor the current** flowing through the potentiometer and LED. If the current **exceeds 1000mA** of current, the Arduino should switch off the power to the LED for 5 seconds. After those 5 seconds, the power should be turned back on and the current should be monitored again. You should do this measurement at least once per second. There is no need to take multiple measurements and it's fine if your shutdown current is within a few mA of 1000.
4. The Arduino should also **monitor the temperature of the batteries** that heat up due to power being and solar radiation. If the temperature of the batteries **exceeds 40℃** the power to the LED should be switched off until the temperature reaches 35°C or below.

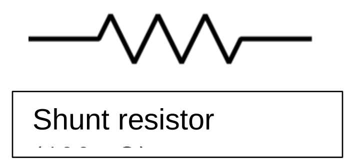
Part A: Wiring [10 points]

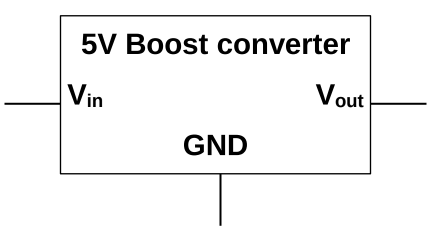
Provide the connections between the different components of the system. You should also provide power and GND to all components. Add resistors and capacitors as needed. You may use labels to make connections.

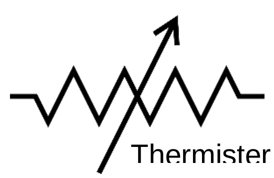












3.7V battery

Part B: I2C interfacing [5 points]

Write a two functions that will let you write and read registers on the INA219:

```
void ina219_write(uint8_t addr, unit16_t value) {







}

int ina219_read(uint8_t addr) {







}
```

Part C: Short answer [6 points]

Use formulas 1 and 2 on page 12 of the INA219 data sheet to answer the following questions:

1. What would be a reasonable value to use as the "Maximum expected current"? Briefly justify your answer.

2. Given your answer to part a, what would be the value of Current_LSB?

3. Compute the value "Cal". Show your work.

Part D: Setup [6 points]

Write a **setup** function that will initialize any inputs, outputs, and sensors you may need. The setup function should also enable the LED output. Define any variables that you may need.

```
void setup() {

}
```

Part E: Loop [10 points]

Write the **loop** function for the system. This function should monitor the temperature and the current, and control the power switch depending on the status of the system. Define any variables or helper functions you may need.

```
void loop() {

}
```