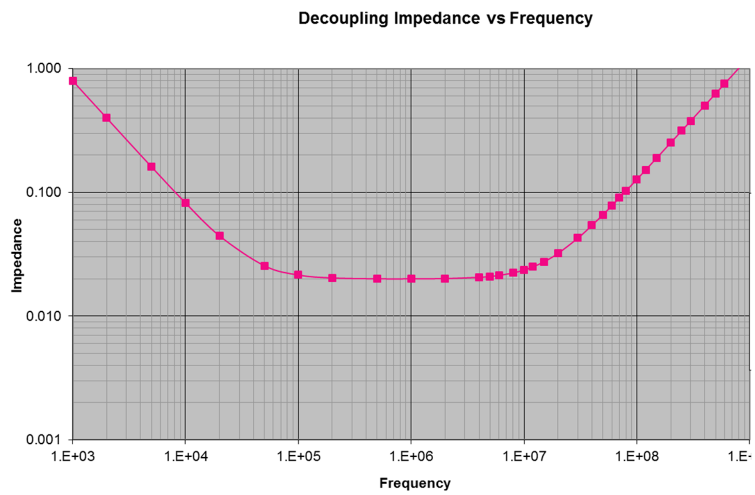
473 Fall 2023 Homework 2

Due on Gradescope by 7pm on December 8th. ~~We'll take only 5% off if turned in my 5pm on the 6th.~~ 140 points. Corrections are in red.

Review—because September was a long time ago. [25 points]

1) Capacitors and power integrity **[8 points]**
   a) In your own words, explain why we are concerned about the frequency response of the power/ground lines. **[4]**
   b) In the context of power integrity, why might it be preferable to have two capacitors in parallel rather than one capacitor of double the capacitance? **[2]**
   c) Consider the capacitor described on the right. Redraw the curve to represent ten of the same capacitors in parallel. **[2]**



2) True/False **[9 points, -2 per wrong answer, minimum 0]**
   For each statement, indicate if it is true or false. If it is false, explain what makes it false. **[9 points]**
   a) A LIPO battery is being used with a constant current draw of "5C". You would expect that the battery would last at least 12 minutes, but probably not much longer.
   b) Linux user-space programs are generally expected to use memory-mapped I/O addresses to talk with I/O devices.
   c) When designing a power distribution network, very low frequency noise (say 1KHz) is primarily handled by the power supply/voltage regulator.
   d) Given our standard assumptions about scheduling, anything that can be scheduled using EDF scheduling can also be scheduled by RM scheduling.
   e) An ideal switching power supply would waste no power. An ideal linear regular would.
   f) The "lifetime" of a primary cell has to do with the number of times you can charge it before its capacity drops significantly.
   g) On a PCB, a 20 mil-wide trace has less resistance than a 10mm-wide trace of the same length.

3) Take a look at problem 6 from our midterm. In your own words, explain the answer to problem 6b **[8 points]**

Digital Signal Processing and other specialized processors [45 points]

4) Fixed point **[16 points]**
   a) What are the primary reasons we might use fixed point rather than floating point? **[3]**
   b) Say you multiply two int8_t Q7 numbers as standard integers. What size/form will the result be assuming that the size of an "int" on your machine is 16 bits and no casting was used? Will there be any loss of data? **[2]**
   c) As b but the numbers re int16_t Q7 numbers. **[3]**
   d) Write a C function "Q15mult" which takes two values, A and B, each declared as an int16_t number and returns an int16_t number as the product of A and B. All three numbers are treated as Q15. There will be a fair bit of casting. Round to the nearest value (you can break a tie as you wish). Assume that the default "int" size on your computer is 16 bits (it does matter). **[8]**

5) One issue in modern computer architecture is that for a novel design we tend to find that the relationship between power (P) and performance (perf) is such that $P=perf^x$ where x is probably between 2 and 3. Thus, if I want to double the performance of a core with a "from scratch, redesign" we are looking at the power being 4 to 8 times as high. While this really harms high-end processor performance (too much power means it all melts), this relationship can be very helpful with respect to IoT devices. Why? **[8 points]**

6) Embedded AI overview **[13 points]**
   Read https://www.edgeimpulse.com/blog/the-embedded-machine-learning-revolution-the-basics-you-need-to-know.
   a) The author suggests that it's possible to train AI models in the cloud and execute them on embedded devices. **[4]**
      i) What is the difference between training and executing a model in this context?
      ii) Why would the training be done in the cloud rather than on the device?
   b) The author provides a list of reasons why one might choose to execute the model on an embedded system rather than in the cloud. Consider two applications: A) detecting bats and classifying them by species based on their call (should sound familiar) and B) counting the number of apples on a tree to figure out if they are ready for harvesting. For each application pick one or two of his benefits you think are most relevant to the application and justify why you picked those. **[9]**

7) List three different types of "specialized compute" processors other than a DSP and provide a link to an example processor that is that type of specialized compute. **[8]**

Wireless communications [50 points]

8) We generally think of sourcing encoding and channel encoding as very different things. **[5 points]**
   a) Define those terms in your own words. **[2]**
   b) One of them generally adds bits to the data and another one removes them. Explain how doing each of those things is useful/needed. **[3]**

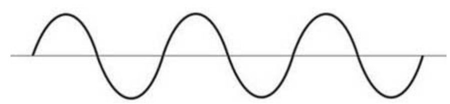
9) Using the example on slide 29 of lecture 13-15, do the following **[15 points]**
   a) Find what parity bits would be sent with the data “1011”. **[2]**
   b) Say our receiver received the following 7-bit packets (d_1, d_2, d_3, d_4, p_1, p_2, p_3 in that order) and performed error correction. For each of the data packets, show what the 4 bits of data would be after correction (if any) **[4]**
      i) 1111000
      ii) 0000001
      iii) 1100001
      iv) 1111001
   c) Using logic gates, draw a circuit that takes d[1:4] and p[1:3] as input and generates a corrected version of d[2] as output, which we will call c[2]. **[9]**

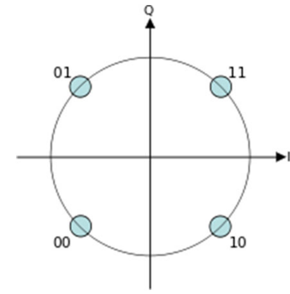
      Hint: Break this into three parts: a) figure out which parity bits don’t match (if any), b) figure out if d[2] should be flipped and c) flip it if needed. Broken down that way you should be able to manage a solution with less than 8 gates (not including negation bubbles).

10) Define the following wireless terms in your own words: **[4 points, 1 each]**
   a) Keying
   b) FSK
   c) QAM
   d) PSK

11) Consider the 4-ASK scheme shown on slide 39 of lecture 13. **[14 points]**
   a) Show how the message “1000110101” would be communicated as a wave. Draw all sinusoids that have a positive amplitude as starting at max value and ending at the max value while those with a negative amplitude start at the minimum value and end at that same value (just as is done in the example). Have each symbol last for 3 periods. **[5]**
   b) In the part above, we had each symbol last for 3 periods. If you are communicating at 1 Mbit and using 4-ASK on a 2.4GHz carrier, about how many periods would there really be? Ignore all overhead (including overhead from synchronization, error correction, and protocol). **[4]**
   c) Most schemes that rely on phase or amplitude require a message start with a fixed signal to allow for synchronization. Why do you suppose this is needed? Think about both phase and amplitude issues. **[5]**

12) Consider the 4-PSK scheme as shown in the figure on the right. Show how the message "00110111" would be communicated as a wave. Draw each sinusoid as lasting for exactly 3 periods and assume a sinusoid with a phase of zero degrees would be exactly a sine wave starting at zero and rising (as shown).
[6 points]





13) Consider the XBee modules as described at https://www.sparkfun.com/datasheets/Wireless/Zigbee/XBee-Datasheet.pdf **[11 points]**
   a) What are the primary differences between the Zigbee PRO and Zigbee in terms of transmit power and receiver sensitivity? **[3]**
   b) Assuming they are used at the 2.4 GHz range and using a Monopole (Integrated whip) antenna on both sides
      i) What is the theoretic range at which a Zigbee PRO could send to a Zigbee PRO? Show your work. **[6]**
      ii) How does your answer to i) compare to the Zigbee specification? **[2]**

Switching supplies [15 points]

14) Switching supplies **[7 points]**
   a) What are the pros and cons of switching power supplies compared to linear regulators? **[4]**
   b) Explain the terms boost, buck and boost-buck as they apply to switching regulators **[3]**

15) Answer the following **[8 points, -3 per wrong/blank answer, minimum 0]**

   a. A(n) ***LDO / buck / boost / buck-boost*** converter which converts 10V to 7V can never be more than 70% efficient.

   b. Figure #1 is a(n)
      LDO / buck / boost / buck-boost converter.

   c. What is the purpose of the diode in figure 1?
      - ***It prevents the capacitor from getting too high of a voltage.***
      - ***It gives the inductor someplace to draw current from when the transistor is off.***
      - ***It stores energy to provide power when the transistor is off.***
      - ***It controls the transistor's switching rate.***

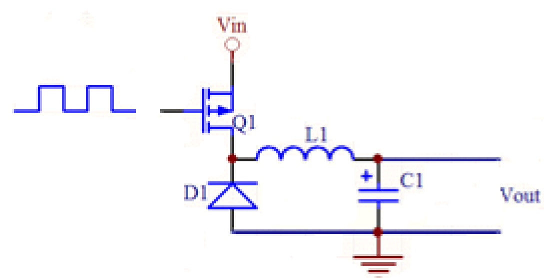


Figure 1: A voltage converter

   d. An otherwise ideal buck converter which has a quiescent current of 5mA and otherwise has an efficiency of 90% will pull ______________mA from its 12V input if it is generating 100mA at 5 volts. (Round to the nearest mA)

Final thoughts for the exam

- Consider working a number of old design problems. I'm partial to the one from Fall 2014.
- Go back and do exam 1 again. Especially the battery and linux problems.
- Take some of the old finals. More recent ones are likely more representative of current expectations.
- We expect, but do not promise, that the final exam design question will involve FreeRTOS. If so, function headers for FreeRTOS (as given in the reference for F22's final) will be provided