LIGO SURF Questionnaire

Guidelines

1. You are allowed to use whatever resources you wish as long as you list all of your references. Getting help from a Professor, friend or even finding answers online, are all useful skills.
2. Answer as many questions as possible to the best of your ability. The answers are not going to be graded solely for accuracy or completeness. We are more interested in seeing how you tackle understanding a new concept.
3. You do not need to answer all parts of a problem. You can skip the ones you are not sure about. Just make sure your final submission has your answers marked correctly and are in ascending order.
4. Try to be brief in your answers. There is no strict word limit, but use a reasonable amount of words only.
5. You have 48 hours to respond to this questionnaire. Reply with a single PDF file containing all of your work. No multiple files or other formats will be entertained. You can choose to write your answers on white pages and scan them, just make sure your handwriting is legible and photos are of good quality.

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Problem 1: Black Box Circuit simulation

You measure the following frequency response transfer function of a circuit that is in a box that you are unable to open. You use a source for the small signal with a series impedance of 1 kOhm and a load of 50 Ohms at the output of the box. For the purpose of this question, use the file circuitTF.txt for the measured data.

1. Your task is to re-create a circuit that provides the same response with components (resistors, capacitors, and inductors) that you can easily find in the lab.
2. What would happen to the measured frequency response if you use a 50 Ohm source impedance and a 1 MOhm load impedance?
3. How would you change the components so that when used with the source and load impedance as in (2), the frequency response transfer function (or poles and zeros of it) remain the same as the data provided?
4. In what type of experimental situations would such a circuit be useful?
5. What is the "Quality factor" of the circuit? What can you do to improve it?

Problem 2: Temperature of a copper block

Imagine a 1 cubic meter copper block coated with a very thin Kryptonite coating that makes its emissivity 0 and conductivity from surface 0. This block is connected with the environment of the room through a copper strap of cross-sectional area 100 cm^2 and length 1m.

1. Read about the state space representation of a linear time-invariant (LTI) system and represent this copper block system in a state space model. The system has one input (the temperature of the environment), one state variable (the temperature of the copper block), and one output which is also the current temperature of the block.

2. Now, using python (preferred) or Matlab, represent this LTI state-space system. For python, we recommend using the package control that can be installed by "pip install control". Read the documentation for understanding how to use the package.

3. Simulate what would happen if the initial temperature of the block is 400 K and it is connected to a 300 K environment. Show the plot of temperature vs time. Use axis limits such that we get to see interesting stuff happening in the plot. Give us some insights on why you see this particular plot.

4. Now, simulate what would happen if the initial temperature of the block is 300 K and it is connected to a noisy environment with temperature varying as a Gaussian variable with a mean of 300 K and standard deviation of 10K. Show the plot of the temperature of the block and environment vs time. Again, give some insights on how the two plots are different (if they are) or why they are the same (if they are).

5. (OPTIONAL) If you have more time, try changing your state space model so that it represents a heater attached to your copper block. This should mean that you have a second input in your system that represents the heat transfer rate from your heater. Now you have a system with which you can play. You can drive up the temperature of the block with this new input. Can you think of a possible application here? How would you approach this application? Just a simple 2-3 sentence explanation is good enough, no need to model it.

Problem 3: Silly putty

Devise a set of experiments that will measure the mechanical properties of the so-call "Silly Putty", a silicone compound that bounces when it strikes a hard surface suddenly but flows under its own weight.