Design Project 1 Report Template -- Include a page break between each numbered item below

This template will make four references to four designs that you will produce in this lab:

* An analytical design. This will consist of selecting a filter type and a filter order, then deriving the filter polynomial, then graphing the magnitude of the filter prototype transfer function. Be sure to normalize your transfer function to the power available from the source so it is consistent with S21 values later in the report.
* A simulated design with ideal components. This will consist of selecting a filter table, synthesizing the components indicated by the filter table by hand (or with a computer program / spreadsheet that you write), entering those component values into ltSpice, then simulating the S21 and S11. You may use an AC simulation instead of an S parameter simulation here, but be careful of how you define S21 and S11 in that case. You may use online filter calculators to check your work for this design (see example link below), but you must do the calculations on your own before referring to them.  
  <https://markimicrowave.com/technical-resources/tools/lc-filter-design-tool/>
* A simulated design with real components. We won’t have your ideal component values in lab, so this design setup will consist of selecting components available in lab to build your filter, possibly arranging them in series or parallel to better match your ideal values, entering those component values into ltSpice, and simulating the resulting filter.
* Measurements of your assembled filter.

1. The following table

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Parameter | Analytical | Simulated w/ ideal components | Simulated w/ real components | Measured |
| Filter type (Butterworth, Chebyshev I, etc.) |  | NA | NA | NA |
| Filter order |  | NA | NA | NA` |
| Pass Band Edge  (defined as exceeding 1dB ripple) |  |  |  |  |
| Stop Band Start  (defined @20dB of rejection) |  |  |  |  |
| Insertion Loss |  |  |  |  |
| In-Band Ripple |  |  |  |  |

2. Pictures and schematics: The schematics must be legible, and ltSpice exports often won’t be, so consider redrawing them or adjusting the ltSpice export settings.

* A schematic with ideal components
* A schematic with real components
* A picture of your assembled circuit

3. 1-2 pages of hand calculations and tables showing the following. You may include source code here if it is extremely legible. You may not just paste a spreadsheet here, but you can include it as a supplementary file for the report.

* How you picked your filter type and order including showing
  + Your in-band ripple is achievable by your design
  + Your stop-band rejection is achievable by your design
  + For Butterworth filters: how you found wp for an in-band ripple of 1dB
* The filter table you used (include a citation showing where you found it)
* How you synthesized the ideal simulation components using your filter table
* Calculation showing power delivered to a 50 Ohm if your filter were driven by a 1Vpp, 0VDC offset, 50 MHz sine wave from a voltage source w/ 50 Ohm output impedance. You will need your measured insertion loss to complete this calculation, and you may refer to the page in your report where I can check it.

4. Magnitude of S21 in your pass band for all four designs

* Use the frequency range 70MHz-130MHz. Display in on a linear scale.
* Use dB as your y-axis units
* Do not overlay these graphs. Please include four of them in a 2x2 grid.
* Each representation needs to include annotated markers that show the magnitude and frequency of
  + The maximum value in the pass band
  + The minimum ripple value in the pass band
  + The pass band edge. (In a Butterworth or Chebyshev II filter, this might be the same marker as the minimum ripple value.)

5. Phase of S21 in your pass band for three designs: the ideal simulation, the real simulation and the measured design.

* Use the frequency range 70MHz-130MHz. Display in on a linear scale.
* Use degrees between -180/+180 as your y-axis units (i.e.: provide a wrapped phase plot)
* Overlay these graphs on one frequency axis.
* Each representation needs to include one annotated marker at the band edge (which you found from your magnitude plot) that shows the phase and frequency.

5. Magnitude of S21 from DC to your stop band for all four designs

* Use the frequency range 0Hz to 300MHz (or as low as the instrument will go for measurements). Display your frequency range on a log scale.
* Use dB as your y-axis units.
* Do not overlay these graphs. Please include four of them in a 2x2 grid.
* Each representation needs to include annotated markers that show the magnitude and frequency of
  + The value of insertion loss in the pass band (i.e.: the “DC” value of S21)
  + The pass band edge
  + The stop band edge.

6. Magnitude of S11 from DC to your stop band for all four designs. Note that for the analytical design you will need to derive this from your S21 magnitude and power conservation.

* Use the frequency range 0Hz to 300MHz (or as low as the instrument will go for measurements). Display your frequency range on a log scale.
* Use dB as your y-axis units.
* Do not overlay these graphs. Please include four of them in a 2x2 grid.
* Each representation needs to include annotated markers that show the magnitude and frequency of
  + The pass band edge
  + The stop band edge.

7. Smith Charts for S11 and S21 from DC to your stop band for three designs: the ideal simulation, the real simulation and the measured results. Use the frequency range 0Hz to 300MHz and do not overlay the graphs, instead arranging them in a 3x2 grid with S11 on the left.

8. Discussion of discrepancies between analytical, simulated and measured results. Quantitatively justify differences between them, including any modifications you made to your models to make your simulations match your measurements better (e.g.: board parasitics). Refer to prior figures in your report for supporting evidence in this discussion.

9. One paragraph about one thing you learned about RF design doing this project.