Review for Final

One question from each lab +1 extra (?)

Lab #1 RLC circuit analysis

know low-pass, band-pass, high-pass, band-reject
know what kinds of circuits produce these
know how to find transfer function from circuit
know how to find ω_0, ζ from 2nd order transfer function
know how to find peak : $\frac{\partial}{\partial \omega}\left(\frac{1}{|H(\omega)|^2}\right) = 0$
know how to find 3dB bandwidth
know how to draw Bode plots by hand
- remember magnitude and phase!
- may ask for straight-line approximation
- may ask for mag/phase behavior dependence on ζ (e.g. peaks)

Butterworth filters
- form of transfer function $|H(\omega)|^2 = \frac{1}{1+\left(\frac{\omega}{\omega_0}\right)^{2n}}$ ← order
- value of ζ for 2nd order : $\zeta = \frac{1}{\sqrt{2}}$
- shape of transfer function with increasing order → steeper roll-off

Some things to remember for Bode plots:
- phase changes by $\pm 90°$ per zero/pole
- normally phase takes 2 decades to change (straight-line approx.)
- can be faster for 2nd order with low ζ
- mag changes by ± 20dB/decade for each zero/pole
- find starting value at $\omega = 0$ or some low frequency

Lab #2 Active filter design

Know how to design a filter to meet specs

- could be low, high, band-pass, or band reject
- could be Butterworth, or general 2nd order

Know how to find peak value of $|H(\omega)|^2$, DC value, etc

Find ζ and ω_0, translate into component values

Know Sallen-Key filter topology

- how to translate C, R values into ζ and ω_0
- how to reduce number of variables (time saver)
  - e.g. set Cs or Rs the same, define $R_1 = Rx$, $R_2 = \frac{R}{x}$, etc.

High frequency response: Cs appear as shorts

- effect of resister values, Rout of op-amp on high freq. response
- how to design for high frequency specs

Laplace transform - how to use it

- know simple transforms: $\delta(t)$, $u(t)$, integral, derivative, convolution
- you will be given a table if you need more complicated transforms

Poles and Zeros

- conditions for stability: no poles in RHP
- relationship between pole location and time domain impulse response

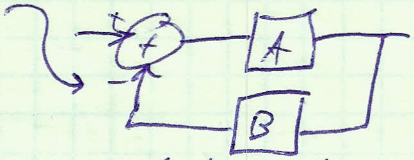
Lab #3 Voltage follower circuit

Feedback concept → $1+AB$ in denominator

Be comfortable with op-amp models:
- ideal model
- input/output resistance
- $A = G/s$ or $A = \frac{A_0}{1+s\tau_A}$

Be able to find B from circuit: $\frac{V_-}{V_{out}}$ (or V_+/V_{out})

watch out for negative sign that must be assigned somewhere



Find transfer function for op-amp circuits based on given op-amp model
- find ω_0, ζ
- determine if circuit is unstable or will ring, based on ζ
- understand how compensation resistor reduces ringing (raises ζ)

How to find input impedance from op-amp model, feedback circuit

How to find output impedance: $Z_{out} = V_{oc}/I_{sc}$

Equivalent circuit at input or output
- inductor or capacitor
- series or parallel

Lab #4 Differentiator

Know general stability theory

- feedback gives $1+AB$ in denominator
- how to find gain and phase margin from Bode plot
- Nyquist stability criterion - must not encircle -1 (clockwise)
- How to generate Nyquist plots from Bode plots
- How to find where Nyquist plot crosses real axis
- Effect of compensation: add a zero to loop gain

Design of differentiator

- How to find transfer function

  $H_{ideal} = \frac{-Z_f}{Z_i}$ and $H_{real} = H_{ideal} \cdot \frac{AB}{1+AB}$
- How to find phase margin
- With op-amp model $A = G/s$, H is 2nd order, find ω_o, ζ
- how compensation reduces ζ

Lab #5 Wien-Bridge Oscillator

Understand op-amp as amplifier, find K: gain of amp

How to find feedback term $B = \frac{-V_{in}}{V_{out}}$, watch negative sign

- when attached to V_+, we need an extra negative sign
- when attached to V_-, not necessary

How to find ω_0 of oscillator from circuit parameters

Conditions for oscillation $AB = -1$ at ω_0

How to find value of K based on circuit topology

Why limiters are used

- start oscillation with higher gain
- reduce gain after oscillation established
- soft limiters to reduce harmonics

Know other oscillator topologies:

- LC circuits (either at input or in feedback path)
- phase shift oscillator
- time delay

Lab #6 System Analysis + Design

Applying feedback concept to other systems
- mechanical, etc.
- variables may not be voltage or current

Calculate step response or impulse response

Effect of time delay
- adds phase without reducing gain, can lead to instability
- all-pass response $e^{-s\tau} \simeq \frac{1 - \frac{\tau}{2}s}{1 + \frac{\tau}{2}s}$ or $\frac{1 - \frac{\tau}{2}s + \frac{\tau^2}{12}s^2}{1 + \frac{\tau}{2}s + \frac{\tau^2}{12}s^2}$

You will not need to remember complicated equations but you should remember a few general forms
- 2nd order response, high, low, bandpass, band reject, all-pass

Determine stability of general (ie non-electrical) system

Know signal flow graphs, Mason's gain formula
- read through the examples we did in class
  - Microwave circuit
  - Ladder network
- you will not be asked to do something excessively complicated but you will have to be able to build signal flow graph for arbitrary system

Know how to implement generic transfer function with integrators

Lab #7 Oscillators

Know general behavior of inverter and ring oscillator

Know how to find time delays in inverter circuits
and how they translate to oscillation frequency

Know how to calculate gain requirement for oscillation
- find where Nyquist plot crosses real axis
- does it encircle −1 ?

Relaxation oscillator:
- understand how Schmitt trigger works
- understand how integrator works
- know how they work together to form an oscillator
- where do the transitions occur? What is the frequency?

Possible topics for 8th question:

Sensitivity analysis: $\frac{\partial\omega}{\omega_0}$ vs $\frac{\partial L}{L}$ or $\frac{\partial C}{C}$, etc

Switched capacitor circuits

Current drivers

Power supplies

Anything else from anywhere in the notes