# E151 Lecture 25 – Oscillators

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ENGR151

## Disclaimer

These are notes for Prof. Spencer to give the lecture, they were not intended as a reference for students. Students asked for them anyway, so I'm putting them up as a courtesy. Remember that they are not intended as a substitute for attending lecture.

## Quiz Follow Up Mini-Review

- Output and input swing calculations may be rusty, esp class B/AB
- Bandwidth and/or transfer function estimation is a good skill
- Natural followup would be to use Xfer function to ask about stability
- DC coupling didn't require a level shift here, but PNP better
- Must degenerate CE stage because emitter bypass doesn't work at DC
- rin of the class AB is small … careful of loading

## Final Exam Next Friday

- Logistics: 3 hours from 9-12 on 5/3 in B445, B454 and B470
- Coverage
  - Material up to today covered, some stuff on review counts
  - Emphasis on back ½ of class, but analysis from front ½ matters
  - Special topics lecture just for fun (no quiz) ~ PLL, power converters, devices …
- Resources
  - Allowed two crib sheets (8.5x11 2-sided) and otherwise no resources
  - Use them well: back ½ of class has many odds and ends to note down
  - I've posted last year's final & solutions, also blank quizzes.
  - <u>Honor code violation</u> to share these review materials in future
- Important that you attend review … assessment & feedback there too

# Stability Analysis Practice

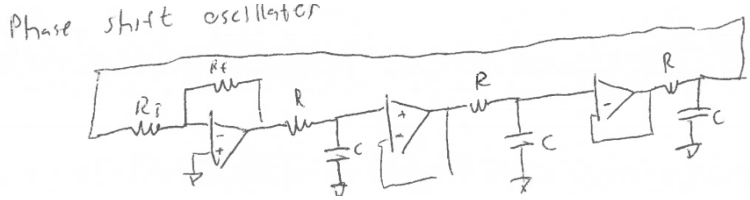
- Consider an uncompensated amplifier with two poles at p1=1MHz and p2=10MHz. What is the maximum open loop gain the amplifier can have and still be unity gain stable?

- Answer:
  - reach 180deg phase at 100MHz.
  - Have 1 decade (1MHz-10MHz) of 20dB rolloff
  - Have 1 decade (10MHz-100MHz) of 40dB rolloff
  - Therefor max stable gain is 60dB → 1000

# Knowing Stability Let's us Design Instability

- Oscillate if closed loop poles on jw axis → design L(jw)=-1 ( in -ve fb)
- Can this oscillate? (Note that all R and C are the same in each stage)

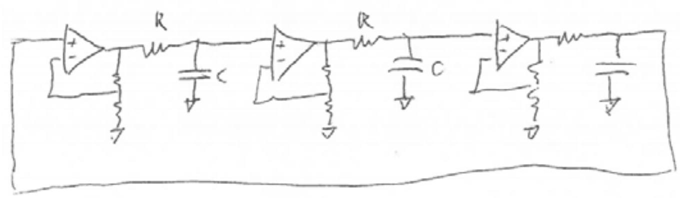
Phase shift oscillator




**Yes!**

$$L(s) = +\frac{R_f}{R_i}\frac{1}{(RCs+1)^3} \text{ in -ve fb}$$

$(-\frac{R_f}{R_i}$ in +ve$)$




**No!**

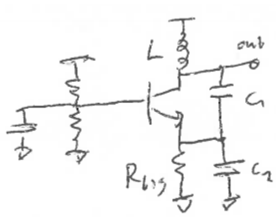
$$L(s) = \frac{\left(1+\frac{R_1}{R_2}\right)^3}{(RCs+1)^3}$$ BUT evaluate $$\frac{L(s)}{1-L(s)}$$ in +fb

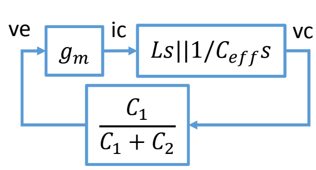
# Deeper Dive into Phase Shift Oscillator

- Frequency of Oscillation
  - Oscillate where L(jw)=-1 (phase=180) and total phase = 3*atan(wRC)
  - In other words: need 60 deg of phase from each pole
  - $\text{atan}(\sqrt{3}) = 60 \rightarrow \omega_{osc} = \frac{\sqrt{3}}{RC}$ (Recall 30 60 90 triangle → x, sqrt(3)x, 2x)
- Required gain for oscillation
  - Oscillate where L(jw)=-1 (mag = 1)
  - $\frac{R_f}{R_i}\left|\frac{1}{\sqrt{\left(RC\frac{\sqrt{3}}{RC}\right)^2+1^2}}\right|^3 = 1 \rightarrow \frac{R_f}{R_i} = 8$
- Finding frequency of osc and loop gain are standard osc problems

# Colpitts Oscillator

- Many similar LC oscillator varietals: Pierce, Clapp, Hartley, etc …
- Colpitts very easy to implement, so much so you do it by accident
- Capacitive divider feedback from b to e → eg: Cpi + big Cl + long wire
- Can Analyze w/ 1 port impedance too

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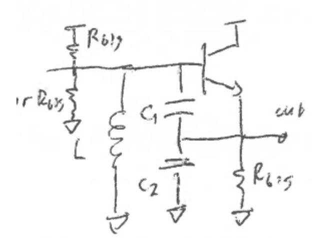


$C_{eff} = \frac{C_1C_2}{C_1+C_2}, \omega_{osc} = \frac{1}{\sqrt{LC_{eff}}}, \frac{C_1}{C_1+C_2} = \frac{1}{g_m}$

Basically the same, trickier analysis, inductor is wire from last stage

# Describing Functions

- All practical amplifiers are non-linear
- Linear 2 pole systems respond forever in response to a kick
- Real oscillators poles start RHP then non-linearity reduces loop gain
- Capture w/ describing functions → useful to evaluate osc. Spectra
  - Map gain vs. input amplitude of non-linearity for fundamental & harmonics
  - Assume system is essentially low pass so that only one tone, w, matters
  - Find amplitude at which loop gain satisfies L(jw)=-1, could vary w/ frequency
- Describing function is H(A,jw) from non-linear F(x) w/ x=A*sin(jwt)