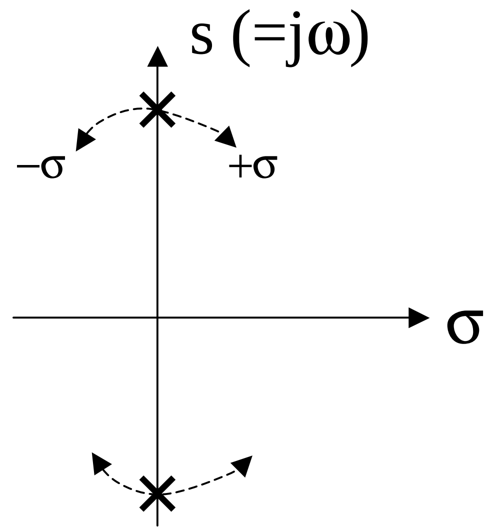
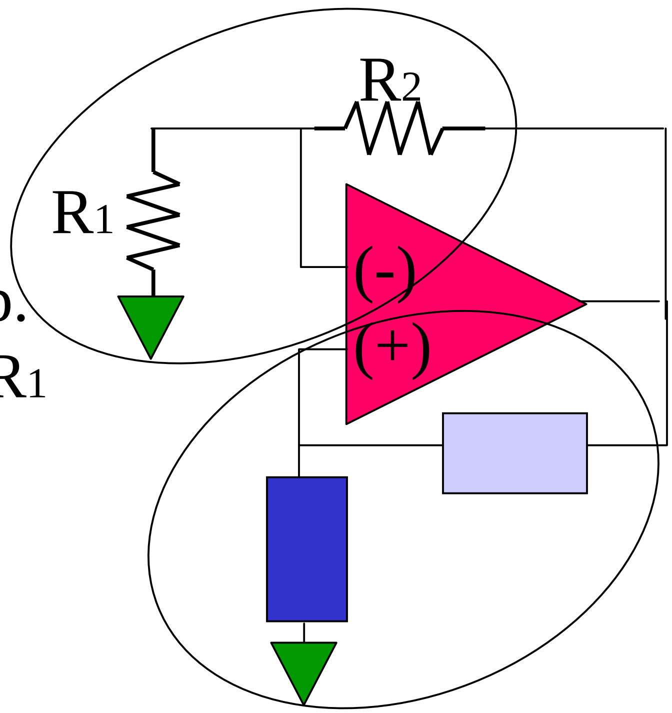
Oscillations ad Voltage-Controlled Oscillators

- Feedback perspective A=a/(1-af), if af=1 we get infinite gain…or oscillations
- From EE 122 the phase-shift oscillator specifically uses series-parallel RC network to:
  - Make |f|=1/|a| and
  - Guarantee exact 0-degree phase shift
- Timing-based oscillations--this can be "ring oscillator" type or "charge-discharge" (of C) type
- Transistor level oscillations (which we'll do now)

Reminder about
s-plane and poles
moving into either
LHP or RHP



Inverting
Gain amp.
$A_v \sim -R_2/R_1$



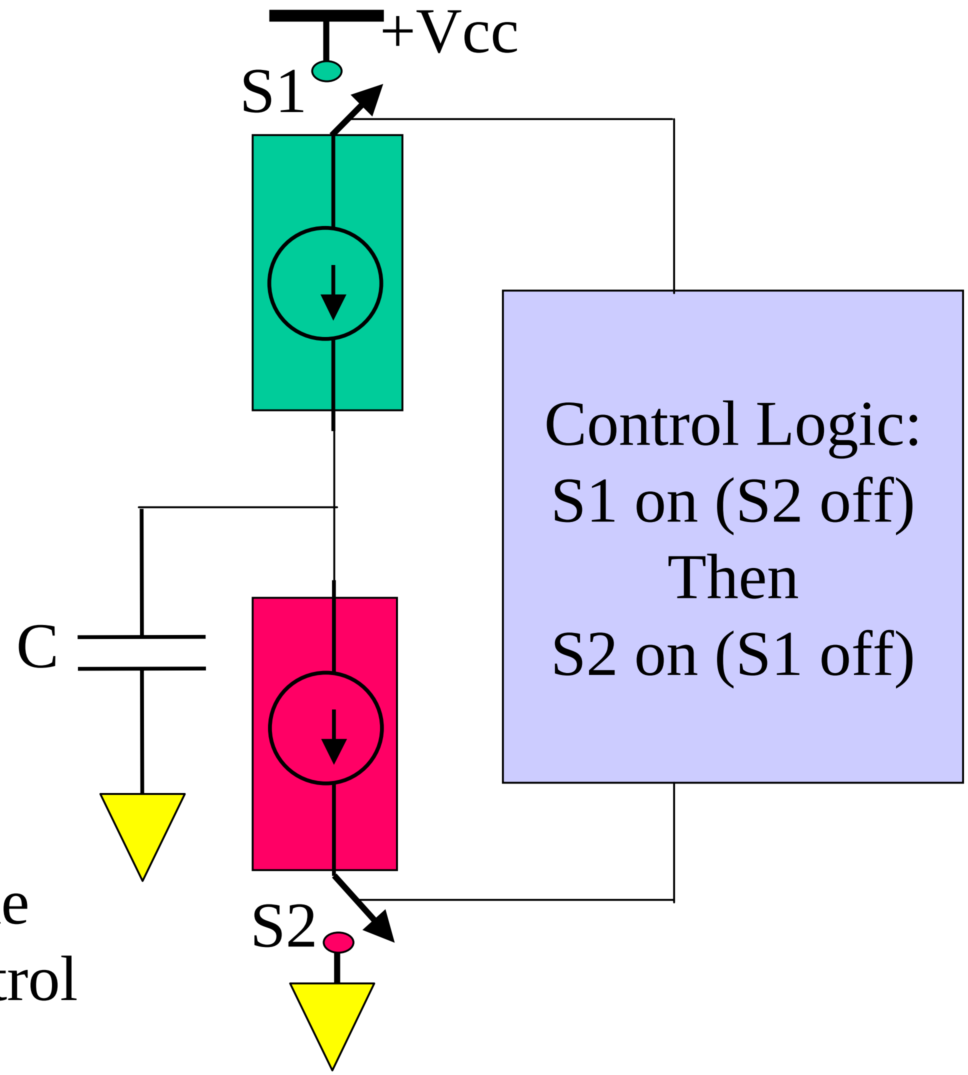
Phase-shift
Network
$\phi=0$ and f_o
and attenuating
by $1/A_v$

Timer Circuits:
- Schmitt Trigger
- 555 IC
- Many others...

$$I = C\frac{dV}{dt}$$

$$\frac{C\Delta V}{I_x} = T_x$$

"x" is the portion of the total period for which the respective "I_x" is in control

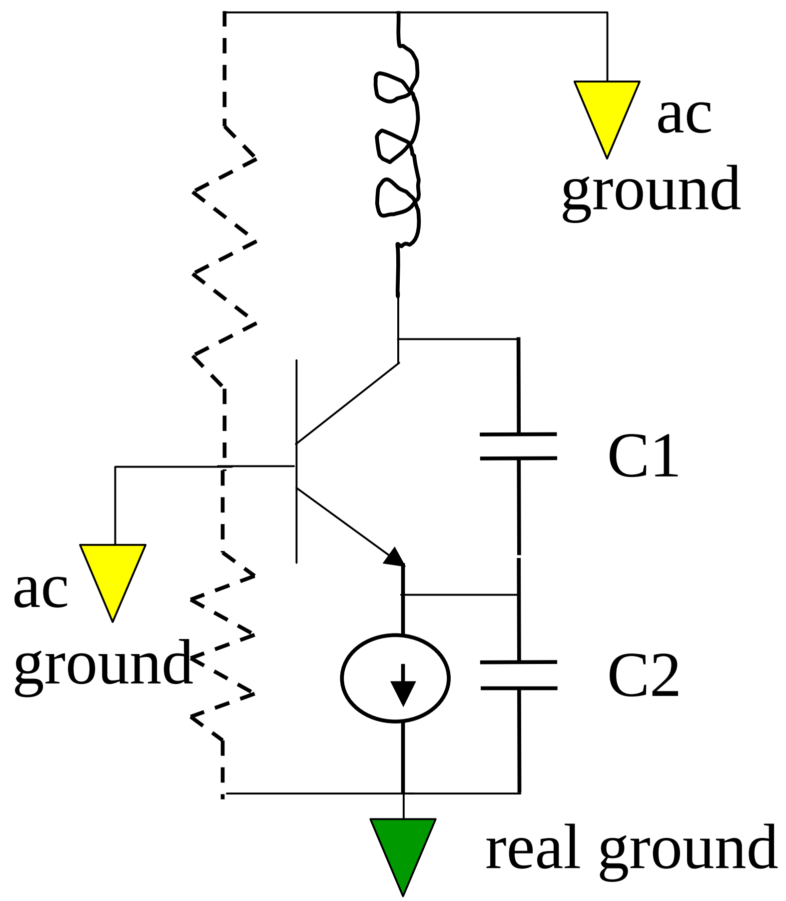


Colpitts Oscillator (Analysis and Design):

Read Chapter 5 (especially 5-5) in Krauss!

The following is a combination:

- First-order, small-signal analysis (Dutton)
- Improved "large signal" version (T. Lee)
- Discussion of Krauss' version (ala 5-5)

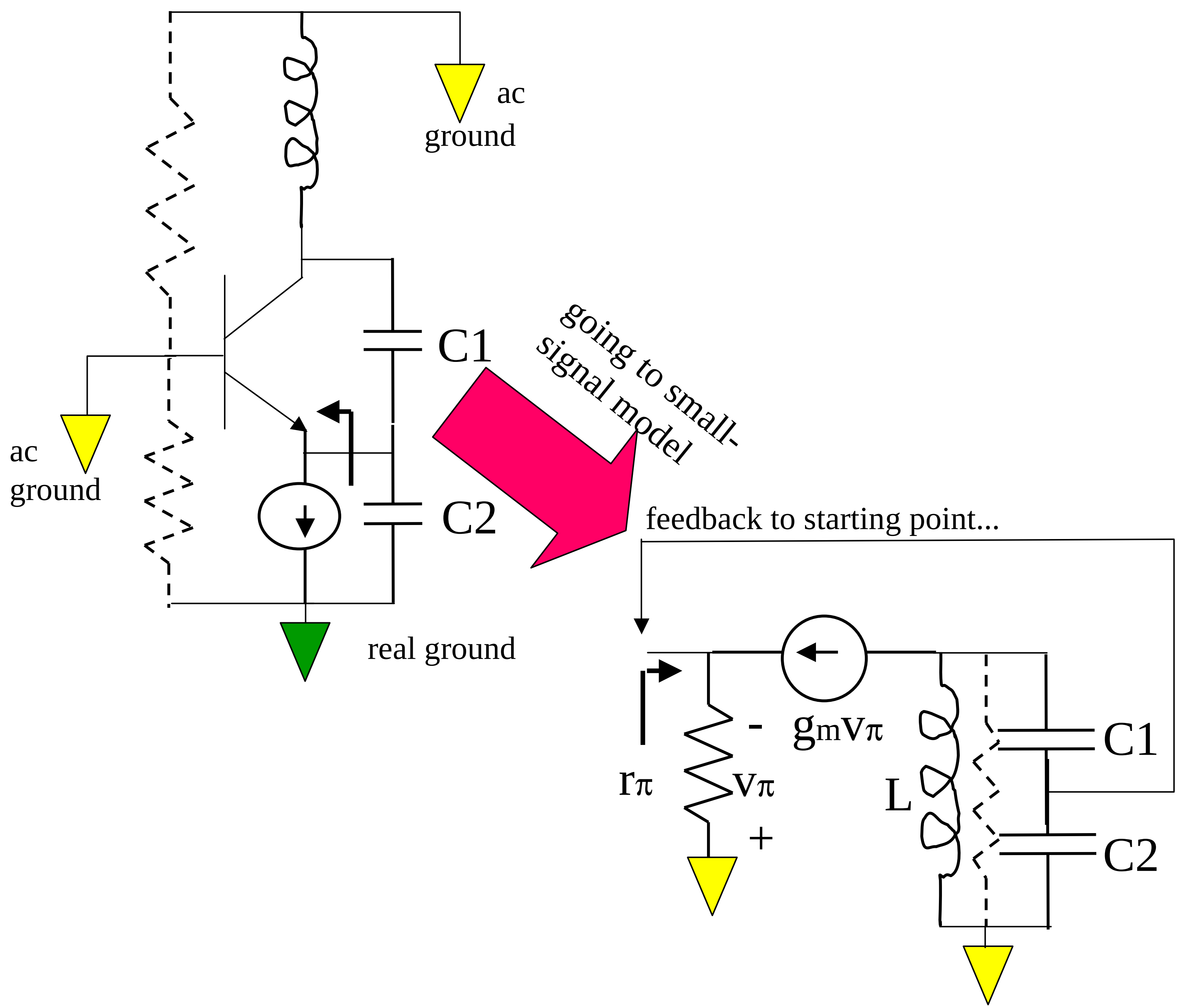


Common Base Amp.:

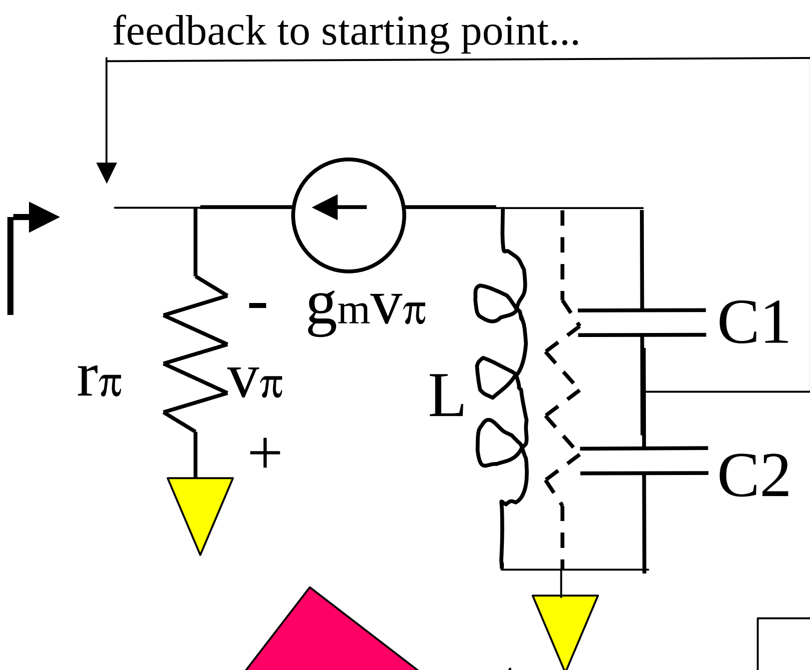
- Biasing like CE but!
- BIG Cap at base=ac ground
- Cap divider (ala Ch. 3) from collector back to emitter
- TANK circuit at collector

Bottom-line:

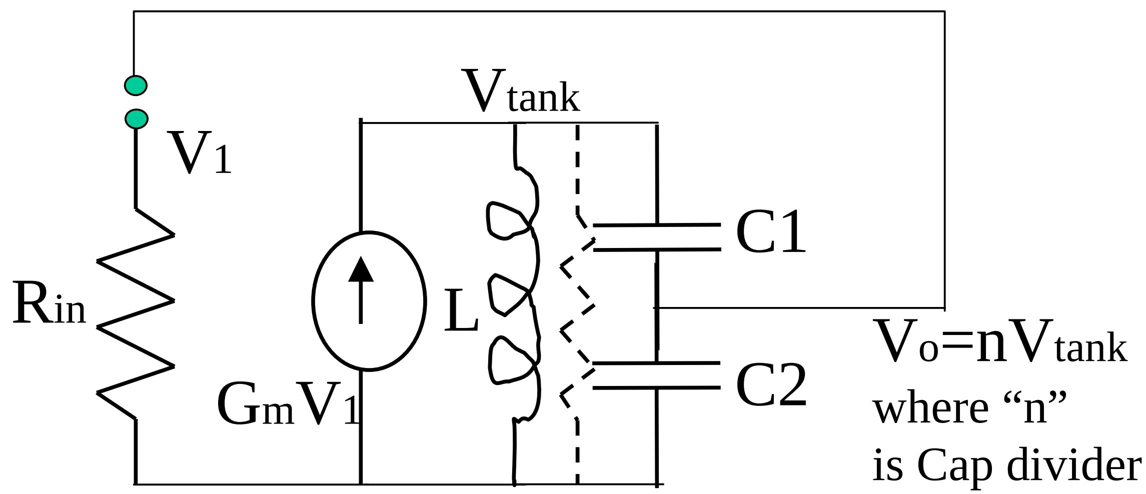
CB=>non-inverting GAIN stage + Cap divider closes loop with ϕ=0 (I.e. oscillations)



ac
ground
C1
going to small-
signal model
ac
ground
C2
feedback to starting point...
real ground
-
$g_m v_\pi$
C1
r_π
v_π
L
+
C2



And creating an equivalent two-port for transistor (which is written generally…either small-sig. or equivalent as a large-signal behavior…)



Assume a V1:

$V_{tank} = +G_m V_1 Z_{tank}$

at resonance, $Z_{tank}=R_{eq}=R_{iT} || R$
(where R is all other resistances* and R_{iT} comes from the **i**mpedance **T**ransform of R_{in} based on C1 & C2)

$V_o = n V_{tank}= [C1/(C1+C2)] V_{tank}$

and, if $V_o = V_1$ we will have condition for oscillations

*Footnote: This notation follows T. Lee (copy from text attached); Krauss uses a different notation: $R_t=R_L||R_p$ (where R_p is from inductance L and R_L is an actual LOAD) and R_i includes both the intrinsic transistor ($1/g_m$) and external added resistor R_e

At the highest level, we can use simple feedback theory to emphasize a couple of points:

$a= G_m R_{eq}$

$f=C_1/(C_1+C_2)$

$af=1$--> denominator is zero

Note*: this doesn't Specify where it Comes from...

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*Footnote: It turns out that, as shown in Fig. 16.6 (T. Lee book) the current flow in the device is highly non-linear (spiked in time as V_{BE} turns on) and we really can't use normal small-signal parameters for G_m. How to cope with that problem is discussed in Sect. 16.3.2 of T. Lee text (Ch.16)

This is a highlight summary of the T. Lee discussion, Ch. 16, Section 16.3.4...

Loading

$$\left(\frac{R_{iT}}{R_i}\right)^{\frac{1}{2}} = \frac{1}{n}$$

$$\therefore R_{iT} = \frac{R_i}{n^2} = \frac{1}{n^2 G_m}$$

$$R_{eq} = R \parallel R_{iT} = R \parallel \frac{1}{n^2 G_m}$$

$at..resonance:$

Voltage gain

$$\upsilon_{\tan k} = G_m \upsilon_1 \left(R \parallel \frac{1}{n^2 G_m} \right)$$

$$\upsilon_{\tan k} = (2 I_{bias}) \frac{R}{1 + n^2 G_m R}$$

$the..next..not - so - obvious..step..uses$

Closing the Loop... →

$$G_m = \frac{2 I_{bias}}{\upsilon_1} = \frac{2 I_{bias}}{n \upsilon_{\tan k}}$$

$$\upsilon_{\tan k} = \frac{2 I_{bias} R}{1 + \frac{n^2 \cdot R \cdot 2 I_{bias}}{n \cdot \upsilon_{\tan k}}} \Rightarrow$$

$$v_{\tan k} + n \cdot R \cdot 2 I_{bias} = 2 I_{bias} R$$

$$\therefore v_{\tan k} = 2 I_{bias} R \cdot (1 - n)$$

$$Other..notation:$$

$$C_{eq} = \frac{C_1 C_2}{C_1 + C_2};..\omega = \frac{1}{\sqrt{L\,C_{eq}}};..n = \frac{C_1}{C_1 + C_2}$$

This is the bottom-line result, giving the final tank voltage in terms of the bias current, R and the voltage divider ration n.
Incidentally, if one were using the notation from Krauss, then R would actually be given by $R_L || R_P$