OSCILLATORS

INEL 4202

REVIEW

- Feedback method: Find β, R_{11} and R_{22} and then use feedback formula $A_f = A/(1 + A\beta)$ to find feedback gain.
- Stability: Loop gain $A\beta$ determines stability of feedback amp.
  - $\Phi_M = 180° - \sum \arctan(f_{0dB}/f_{p,i})$: $f_{0dB} = f$ at which $|T|=1$ V/V
  - gain margin $= -|T(f_{-180°})|_{dB}$: $f_{-180°} =$ f at which $\Phi = -180°$
  - $|T|_{dB} = |A\beta|_{dB} = |A|_{dB} - |1/\beta|_{dB}$: can be subtracted graphically
  - graphical/approximate method using magnitude bode plot and phase equation
  - exact method using magnitude and phase equations
  - Phase equation: phase (at freq. f) $= \Phi = - \sum \arctan(f/ f_{p,i})$; sum is over all poles at freqs $f_{p,i}$.

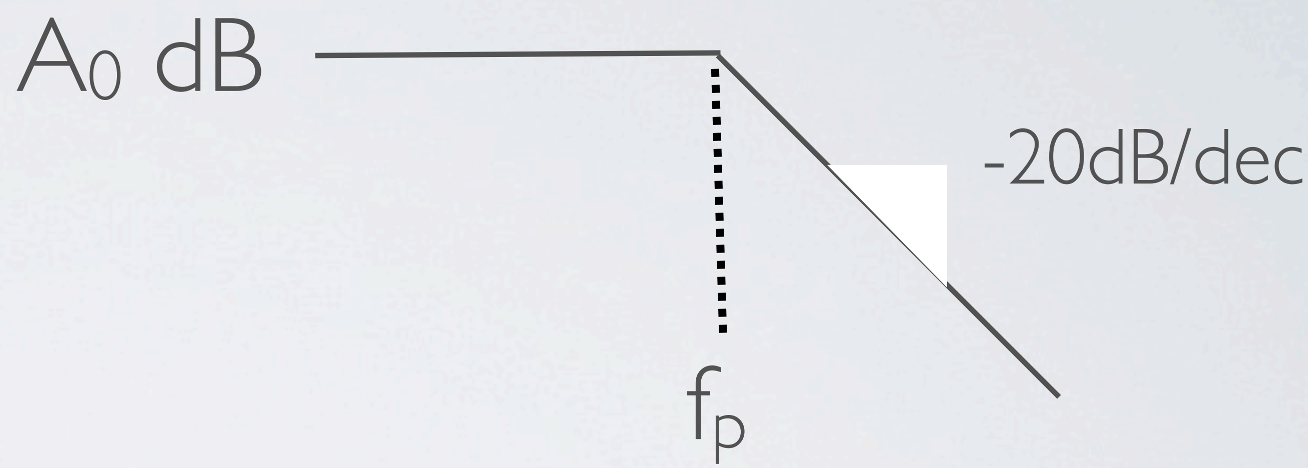
$A_{dB} = 20 \log A$

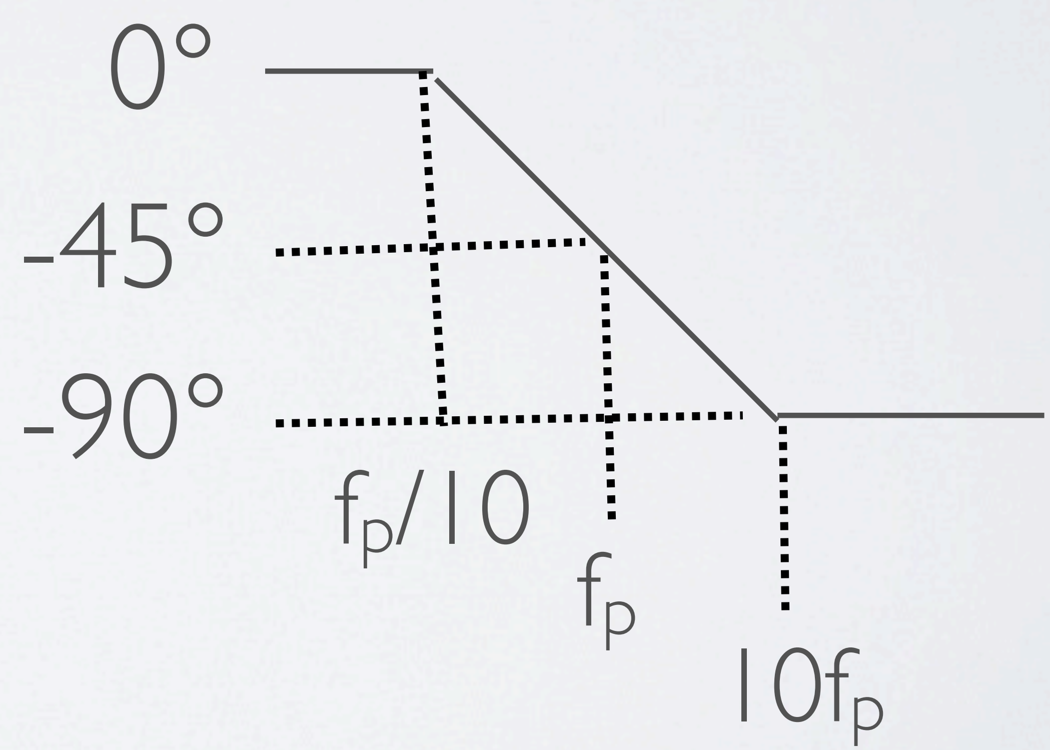
$$\frac{A_0}{1 + j\frac{f}{f_p}}$$

f/f_p	ϕ
0.1	5.7°
1	45°
10	84.3°

1 decada = 10*frec.

1 octava = 2*frec





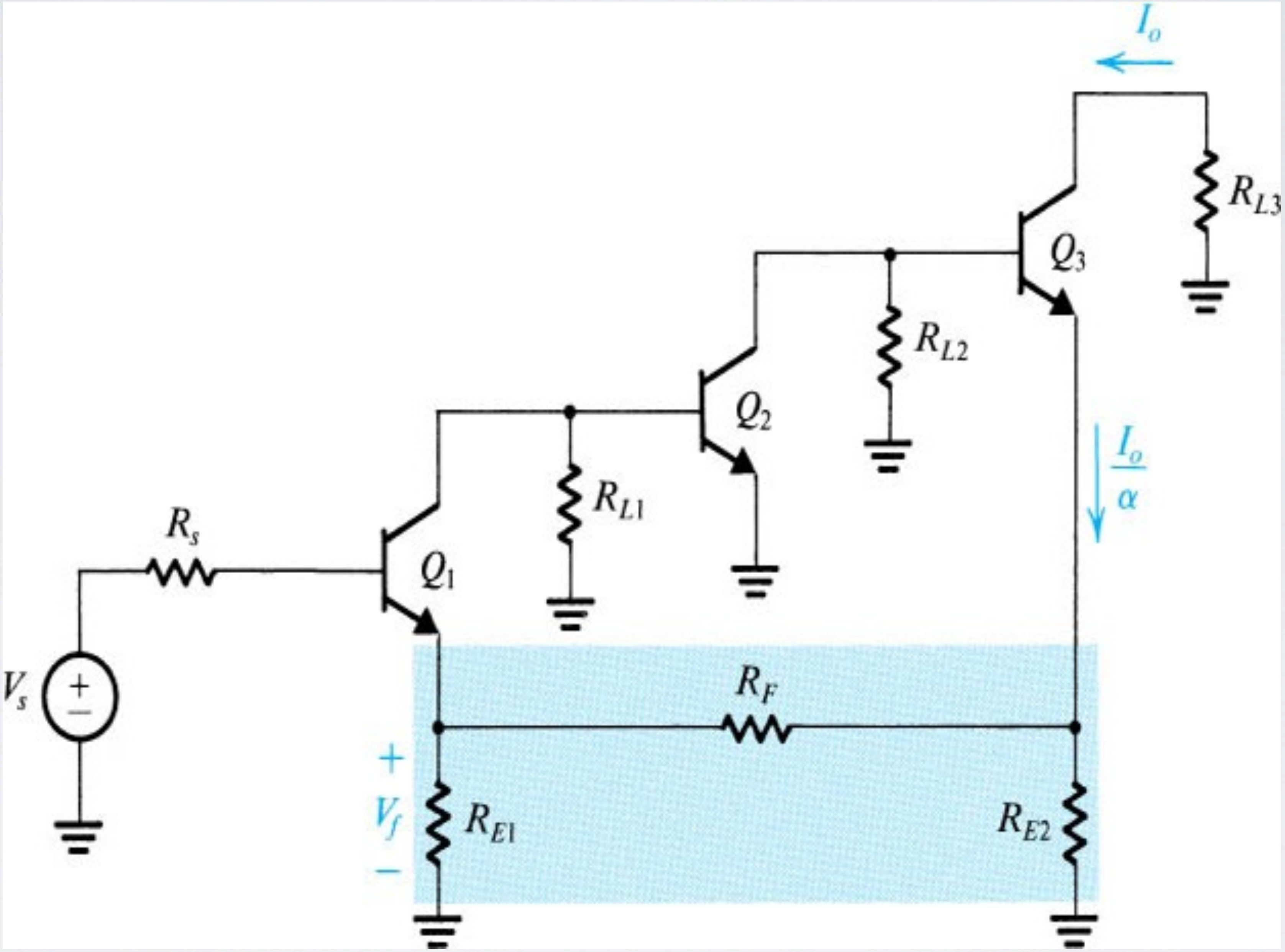
Algebraic or exact method

$$
\begin{aligned}
|A(f)| &= \frac{A_0}{\prod_{\forall i} \sqrt{1 + \left(\frac{f}{f_{p,i}}\right)^2}} \\
\phi(f) &= -\sum_{\forall i} tan^{-1}\left(\frac{f}{f_{p,i}}\right)
\end{aligned}
$$

The response of an op amp can be approximated with a dominant pole frequency f_1 and a high-frequency pole f_2 to account for higher order roots. (a) Assuming $a_0 = 10^5$ V/V, $f_1 = 10$Hz, and $\beta = 1$ V/V, find the phase margin ϕ_m if $f_2 =$ 1MHz. (b) Find f_2 for $\phi_m = 45°$ and for $\phi_m = 60°$.

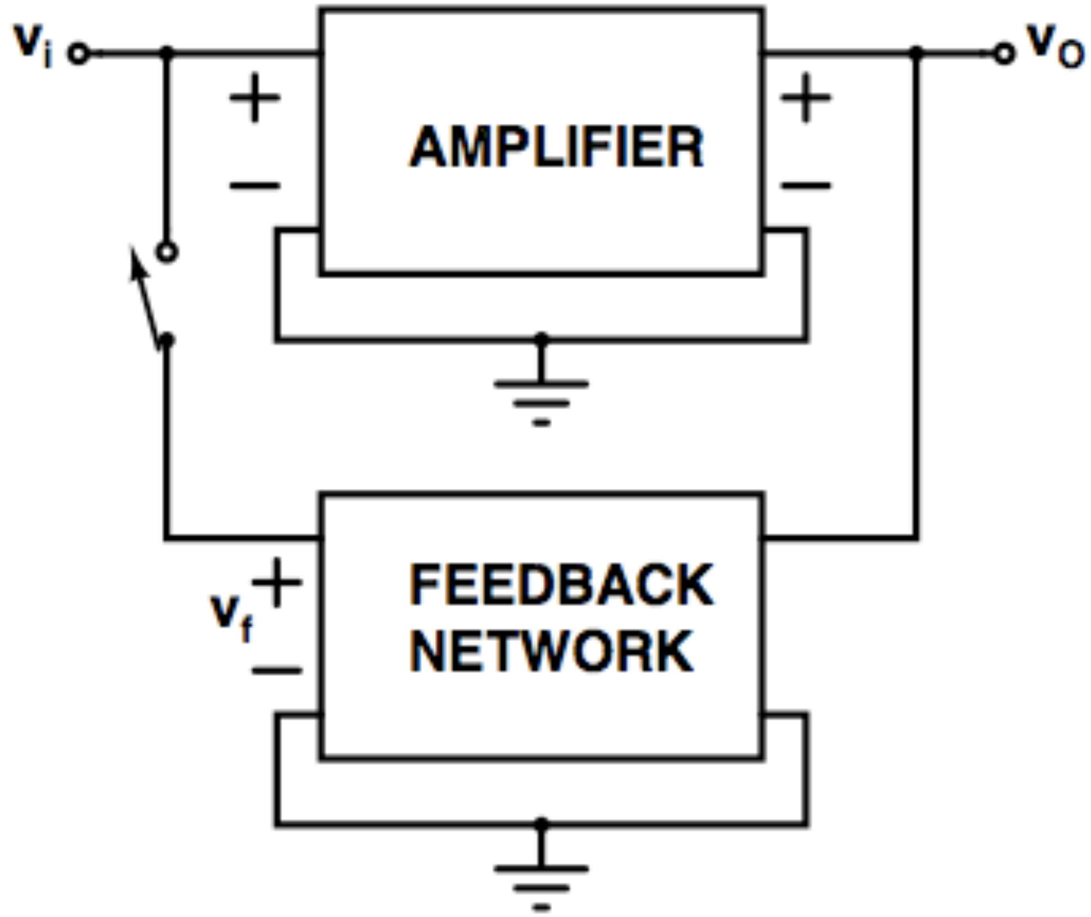
Finding Aβ by opening the loop

- Given a circuit with feedback, you can calculate the loop gain $T=A\beta(s)$ by
  - finding A and β and multiplying, or
  - opening the loop at a convenient point, and
    - take care of including loading effects, and
    - apply a test source V_t, calculate the return's output voltage V_r and find $T = -V_r / V_t$
    - Alternatively, a current test source I_t may be applied, a return output current calculated to find $T = -I_r / I_t$



I_o
R_{L3}
Q_3
R_{L2}
Q_2
$\frac{I_o}{\alpha}$
R_{L1}
R_s
Q_1
V_s
R_F
+
V_f
−
R_{E1}
R_{E2}

1 Barkhousen Criterion



If the loop gain $L = A(\omega)\beta(\omega)$ is real and larger than one at a frequency ω_0, the circuit will produce a sinusoidal output voltage with frequency ω_0.

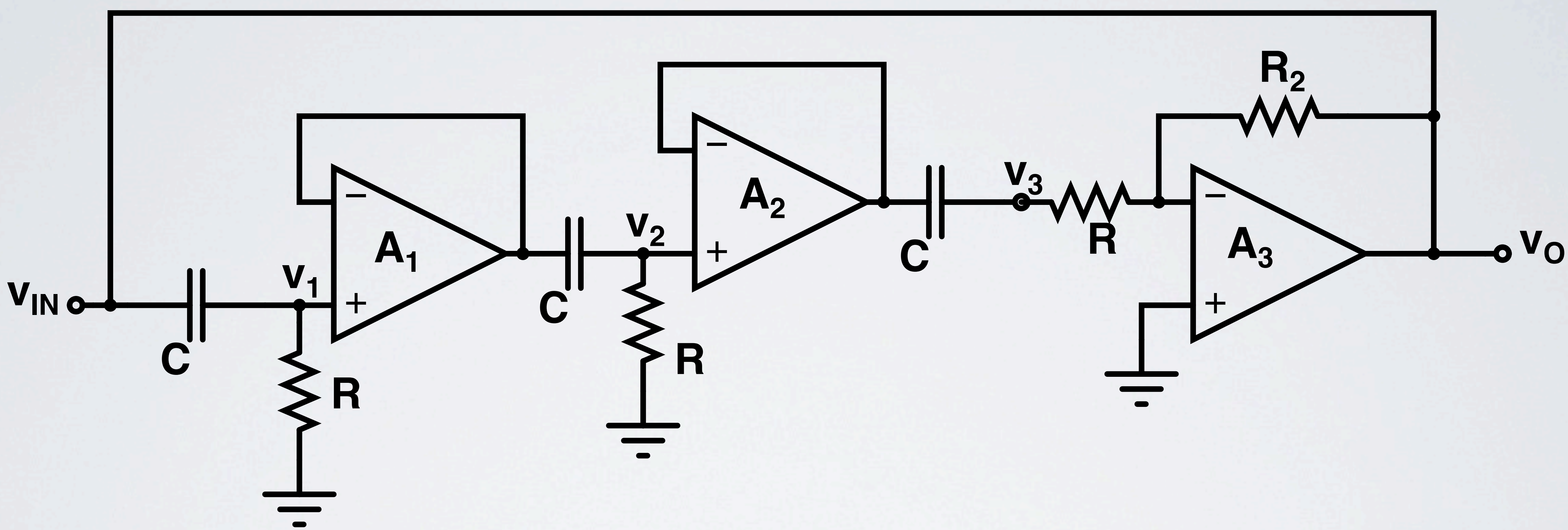
$$\frac{v_f}{v_i} = A(\omega_0)\beta(\omega_0) = M(\omega_0)\angle\phi(\omega_0) = +1$$

This means that the magnitude $M(\omega_0)$ must be unity and the phase angle $\angle\phi(\omega_0) = 0°$.

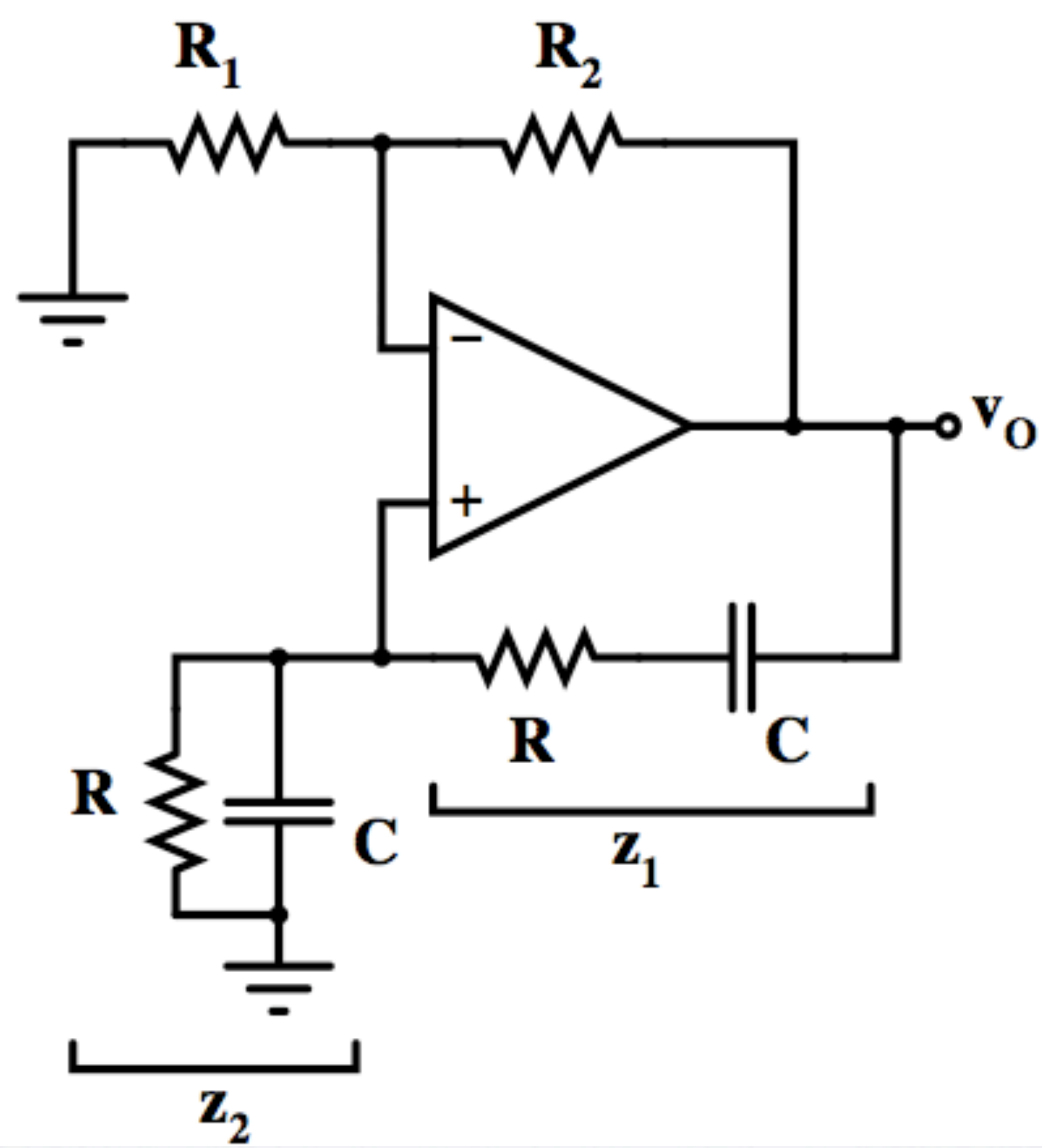
Strategy:

- find loop gain $L = A(\omega)\beta(\omega)$
- find frequency ω_0 at which the loop gain is real; the imaginary part is zero
- determine the amplifier gain required to make the loop gain larger than 1
- the criterion must be satisfied at a single, well defined ω_0
- the amplifier gain A will depend on the input impedance of the feedback network, unless the amplifier's output impedance is zero (i.e. op amps)

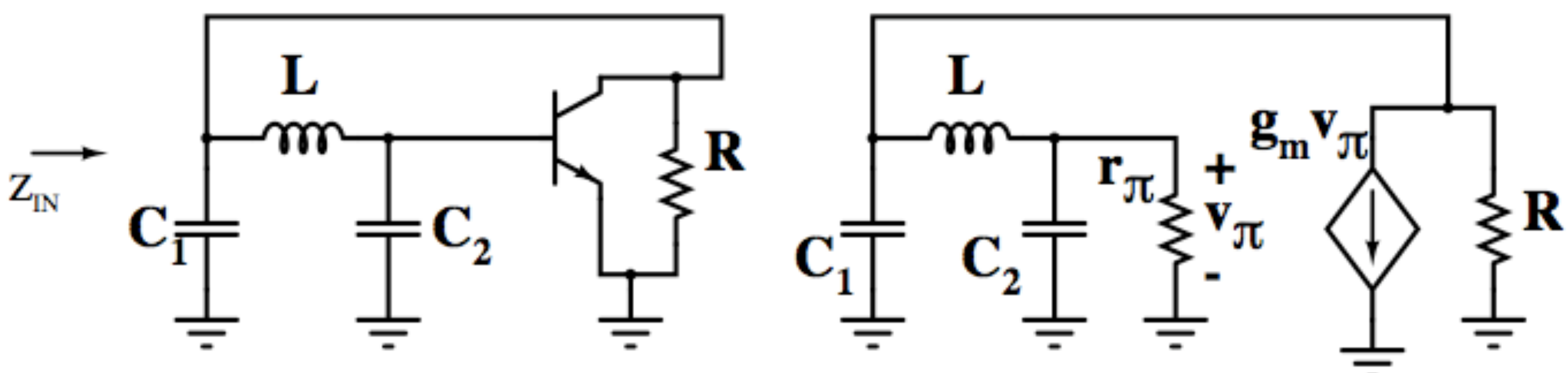
Phase-shift oscillator



Wein-Bridge Oscillator



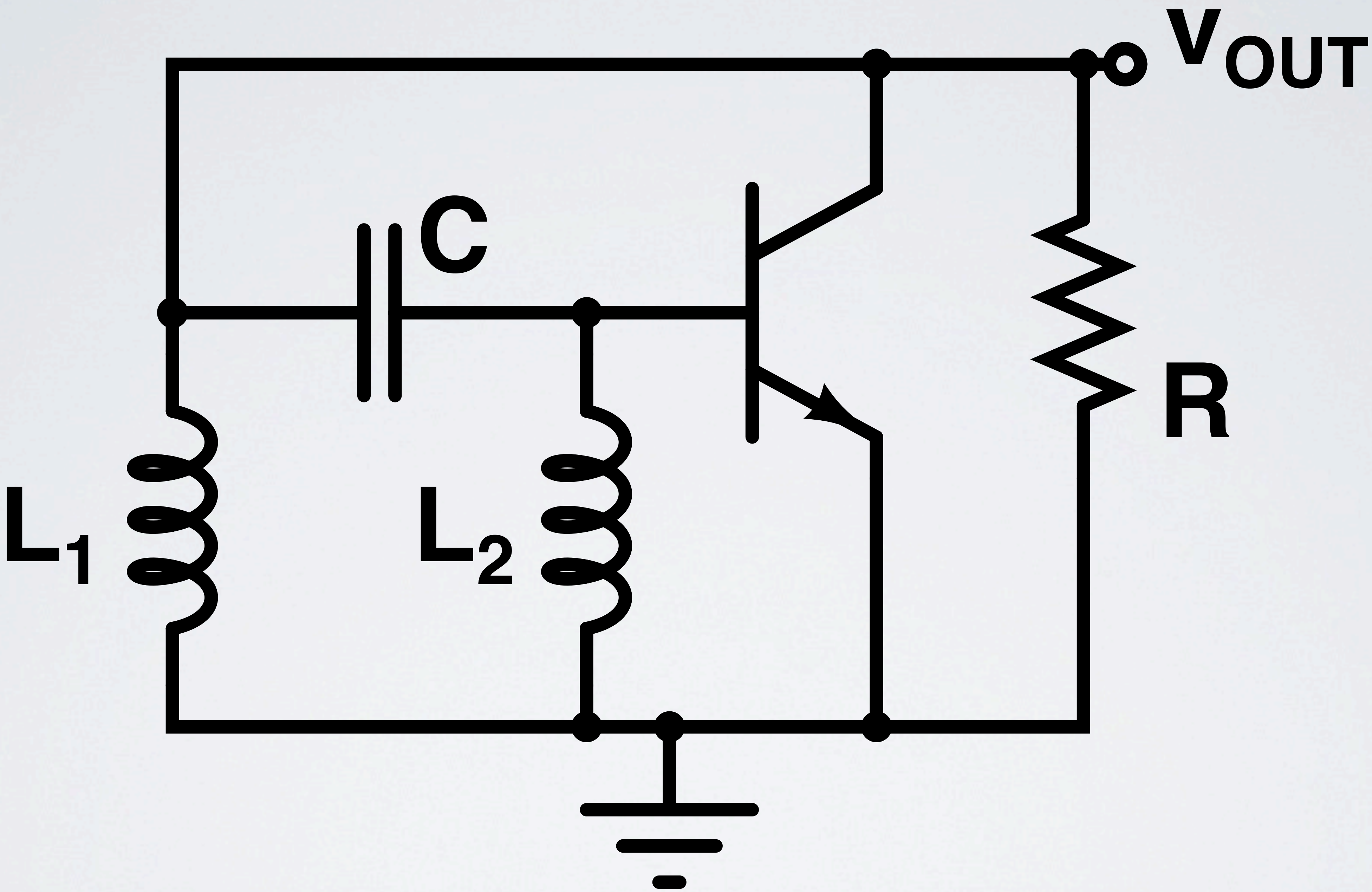
LC Oscillators: Colpitts Oscillator



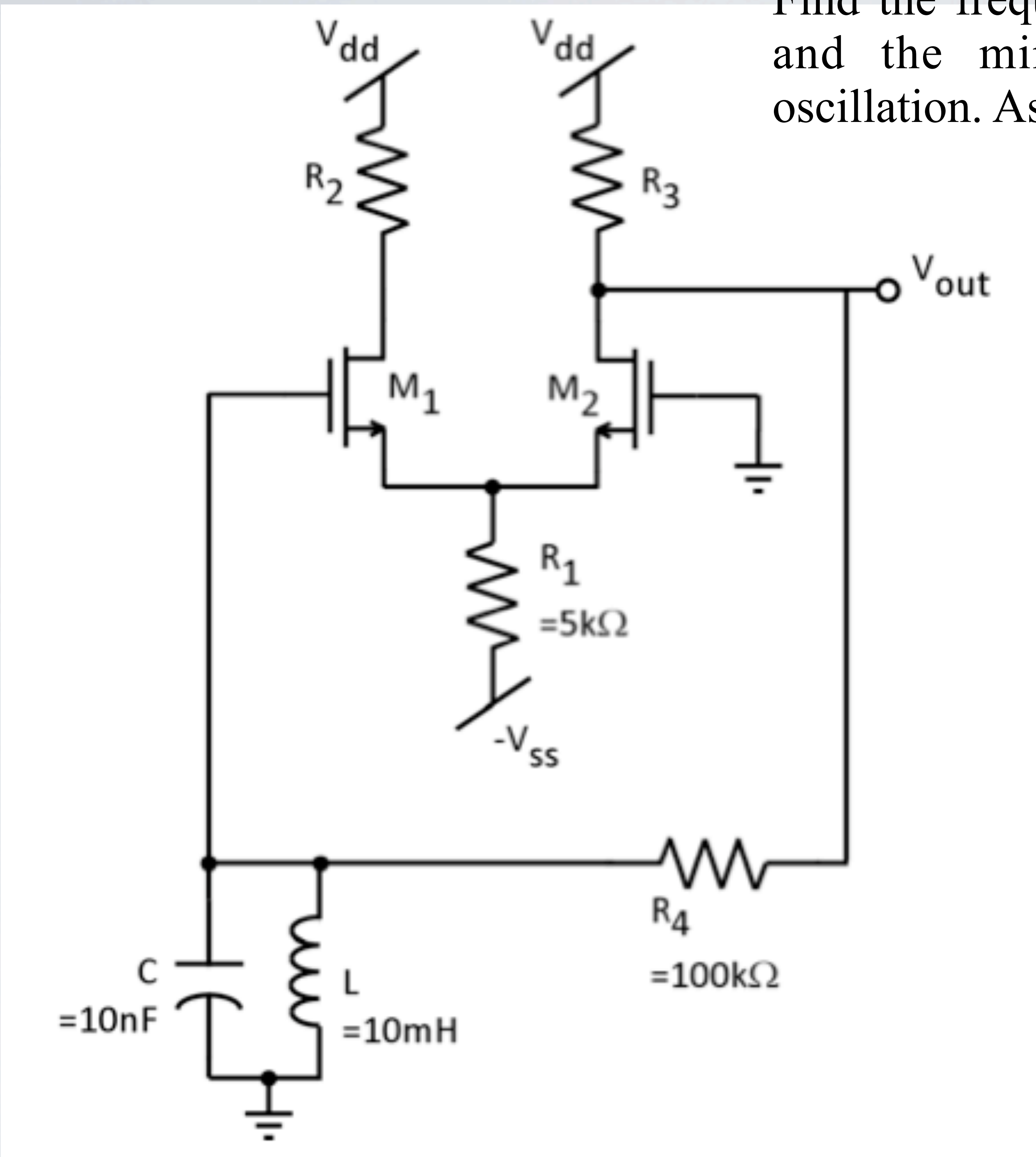
Colpitts Oscillator

Equivalent Circuit

Hartley Oscillator



Find the frequency of oscillation w_o of this circuit, and the minimum value of R_3 required for oscillation. Assume transistor g_m=45mS and $r_{ds} = \infty$.



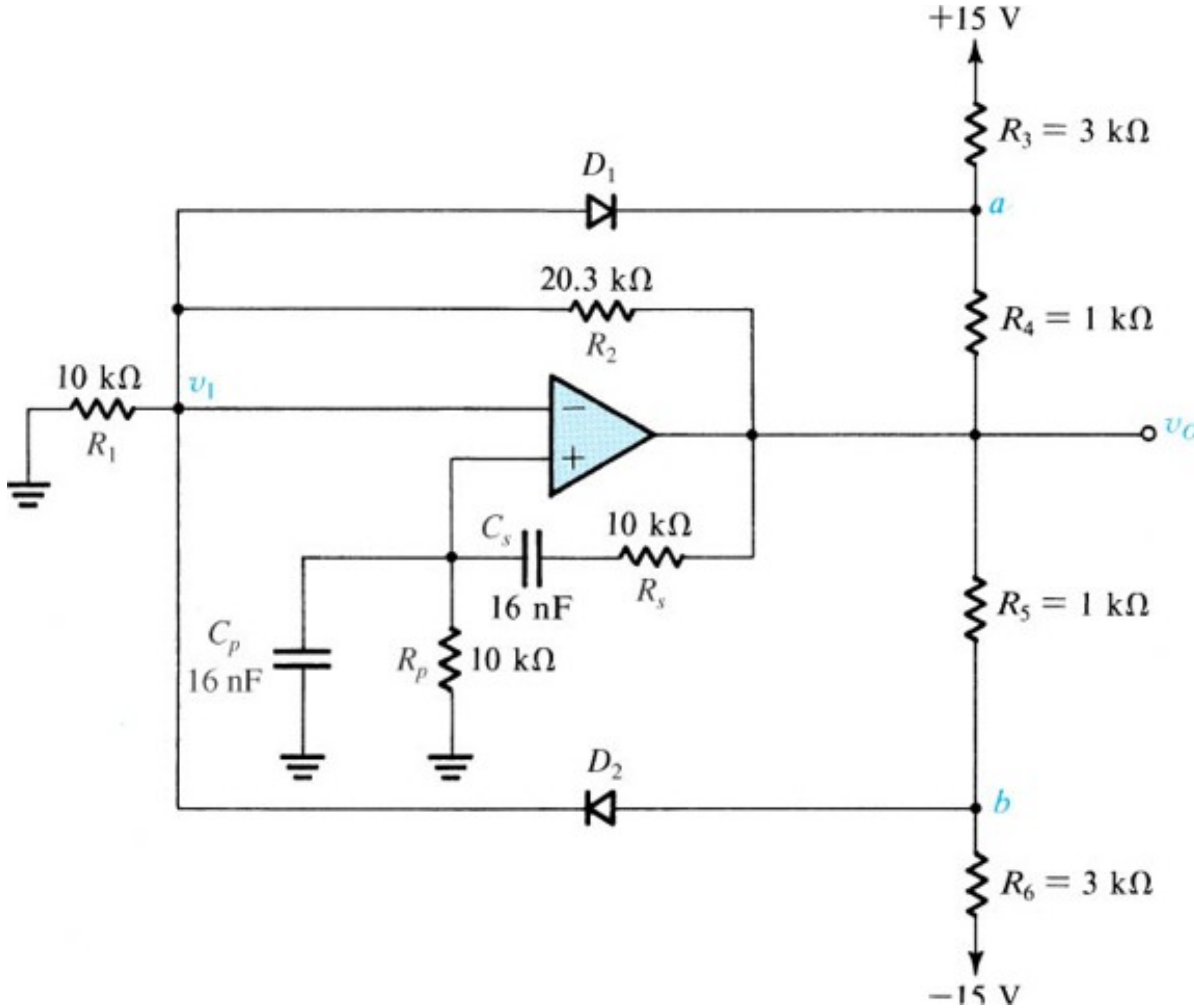


Figure 13.5 A Wien-bridge oscillator with a limiter used for amplitude control.

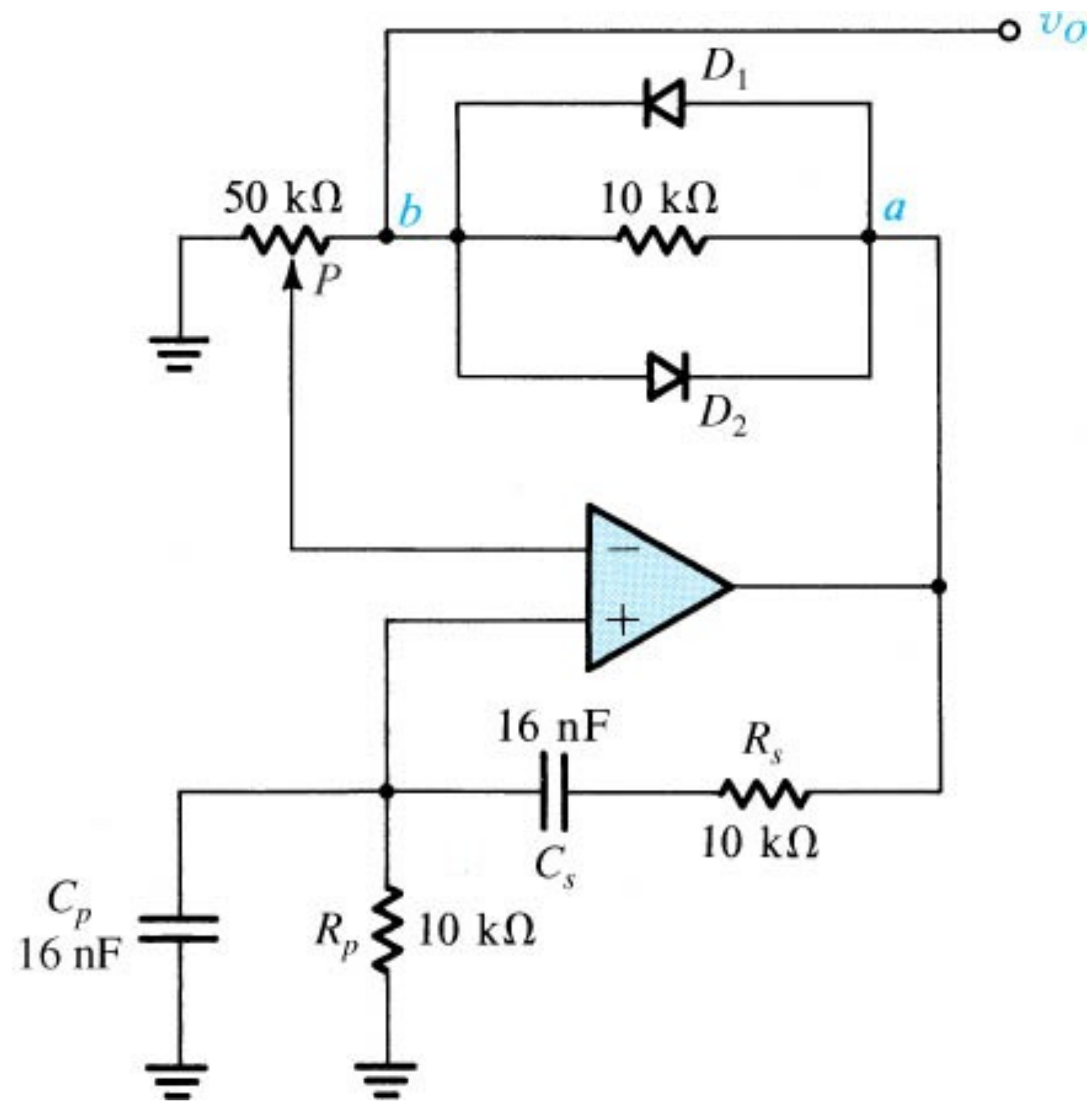


Figure 13.6 A Wien-bridge oscillator with an alternative method for amplitude stabilization.

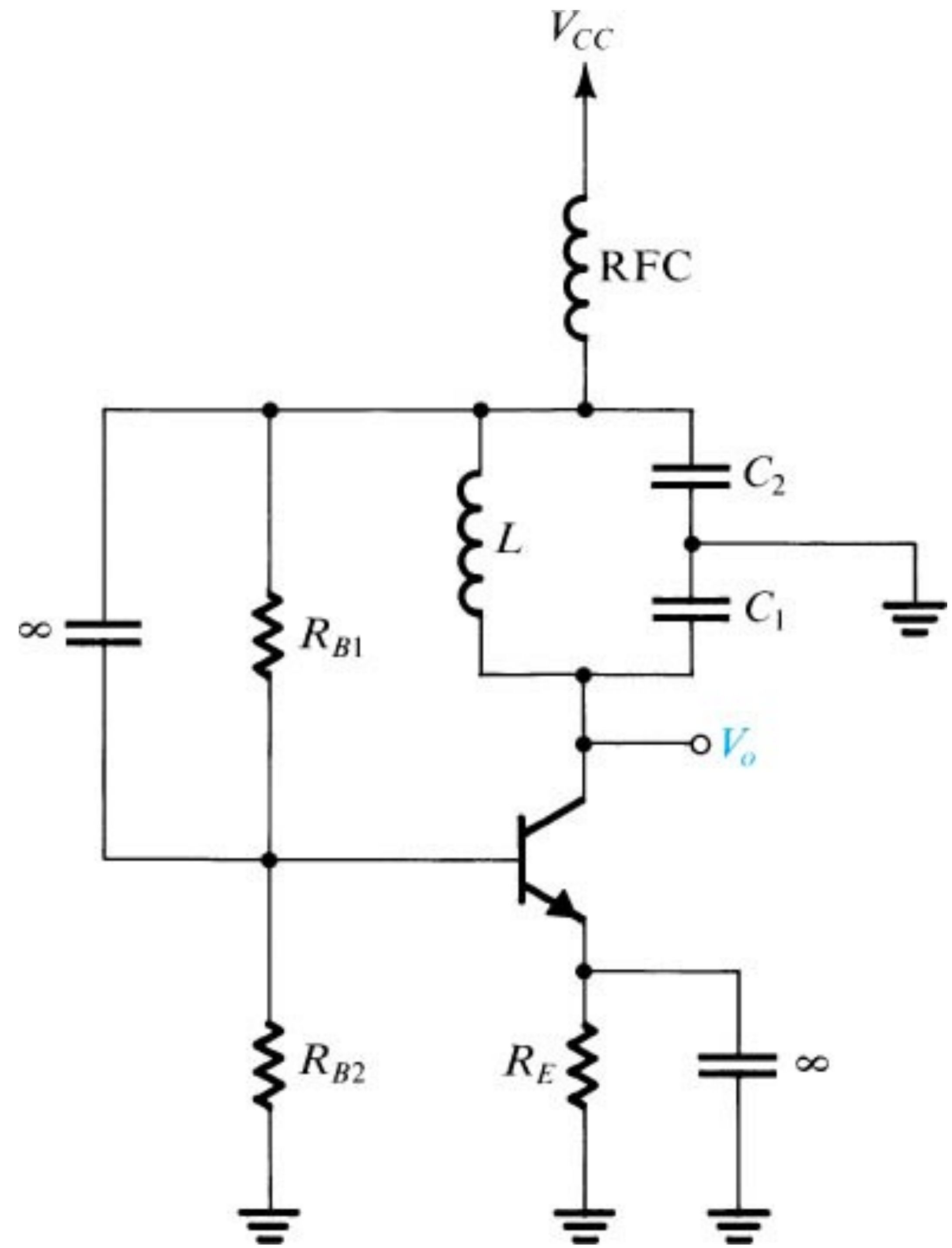


Figure 13.14 Complete circuit for a Colpitts oscillator.

13.13 For the circuit in Fig. P13.13 find $L(s)$, $L(j\omega)$, the frequency for zero loop phase, and R_2/R_1 for oscillation.

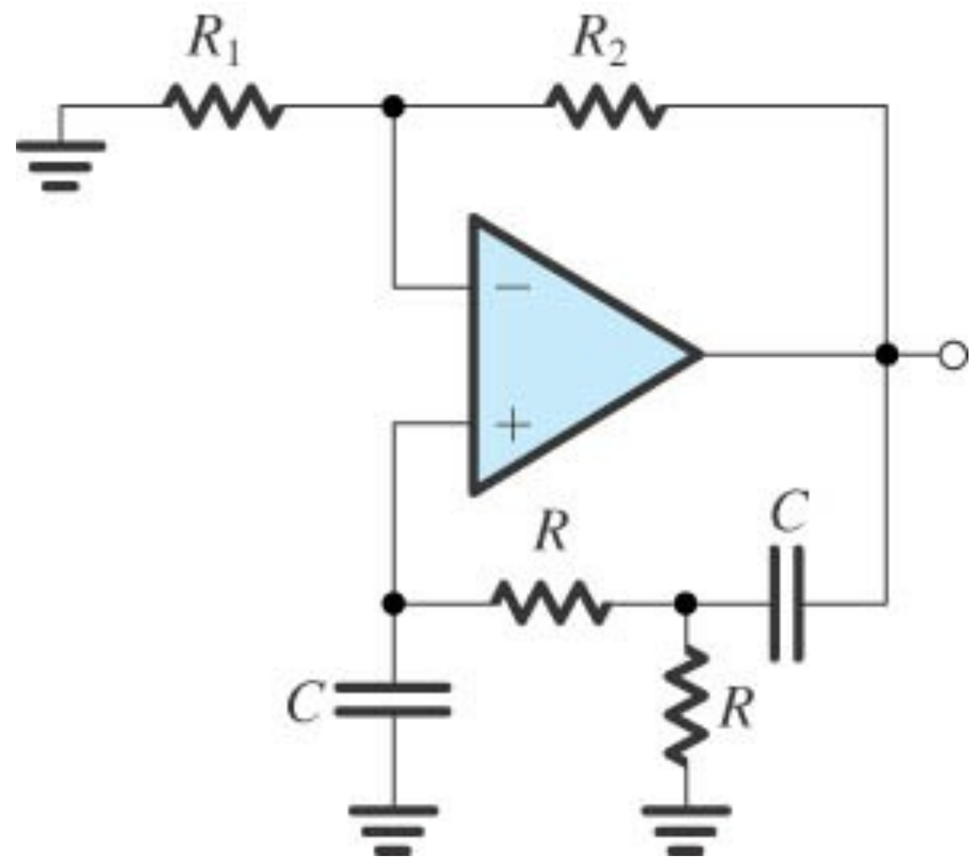


Figure P13.13

**13.21 Figure P13.21 shows four oscillator circuits of the Colpitts type, complete with bias detail. For each circuit, derive an equation governing circuit operation, and find the frequency of oscillation and the gain condition that ensures that oscillations start.

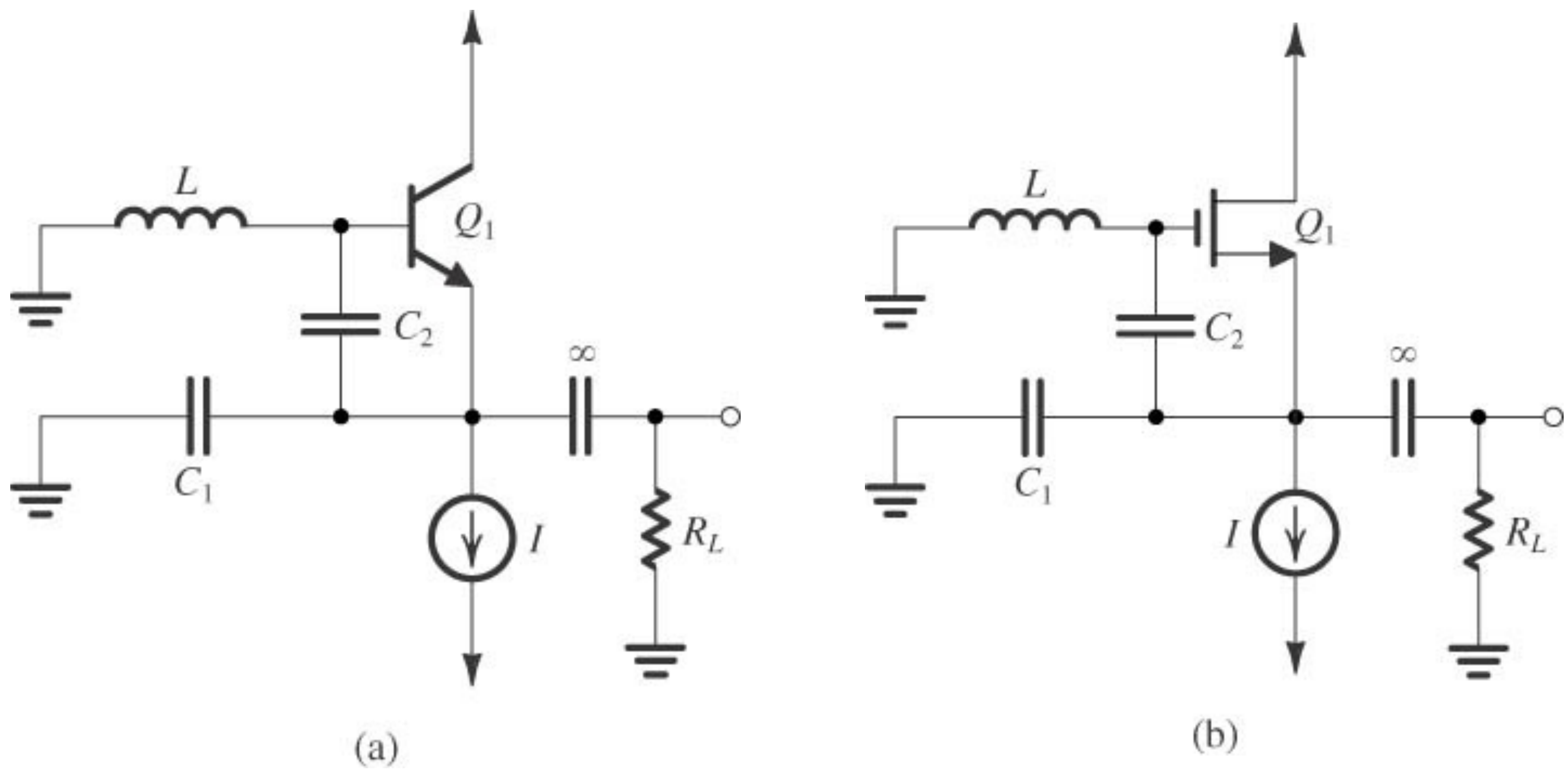
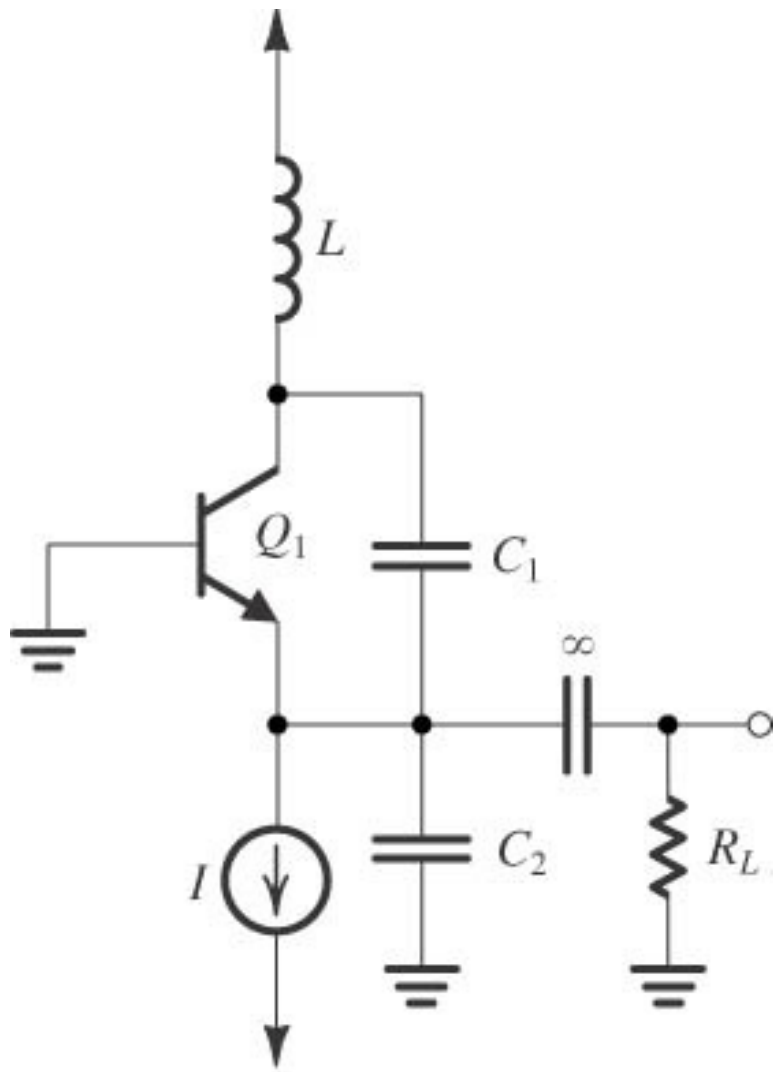
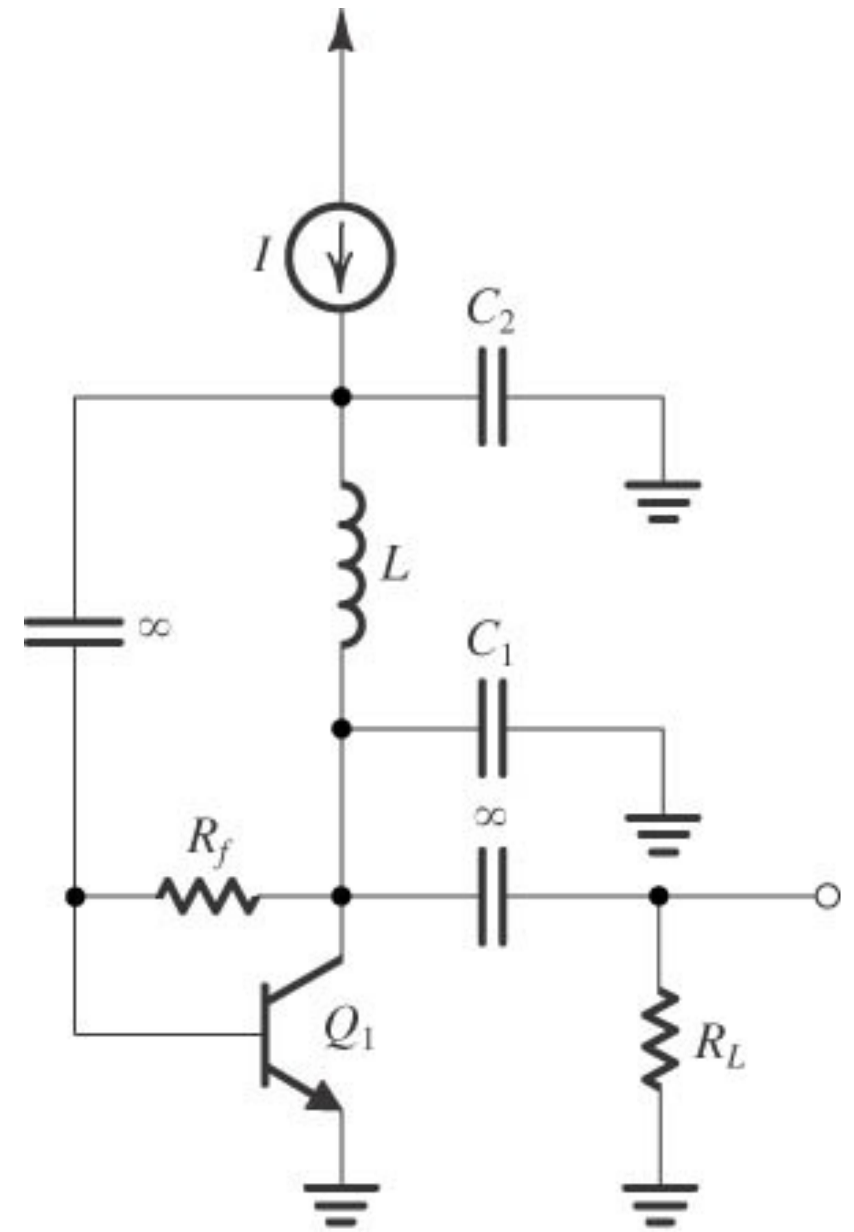


Figure P13.21



(c)



(Assume $R_f >> \omega_0 L$)

(d)

Figure P13.21 *(Continued)*

13.22 Consider the oscillator circuit in Fig. P13.22, and assume for simplicity that $\beta = \infty$.

(a) Find the frequency of oscillation and the minimum value of R_C (in terms of the bias current I) for oscillation to start.

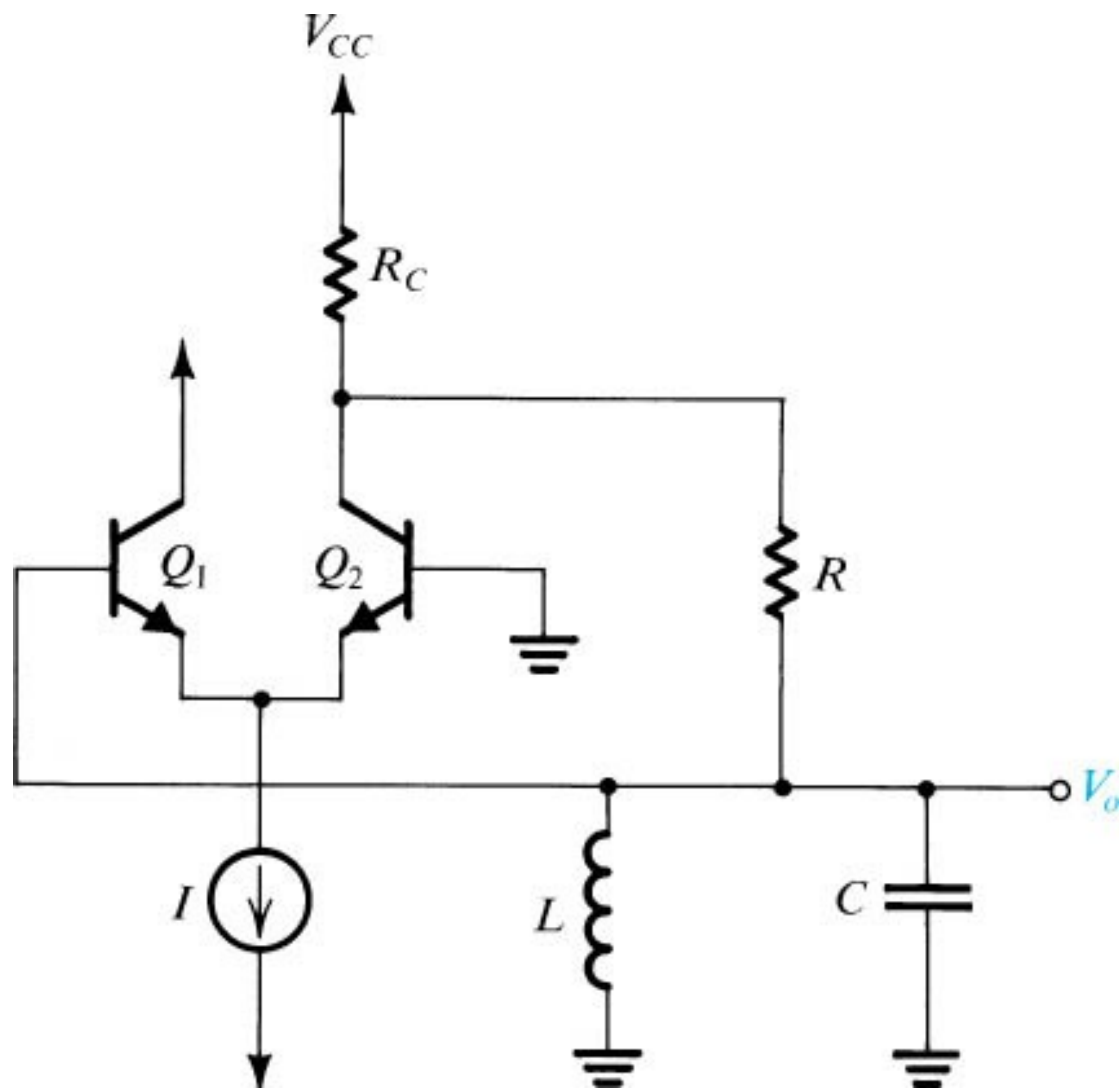


Figure P13.22