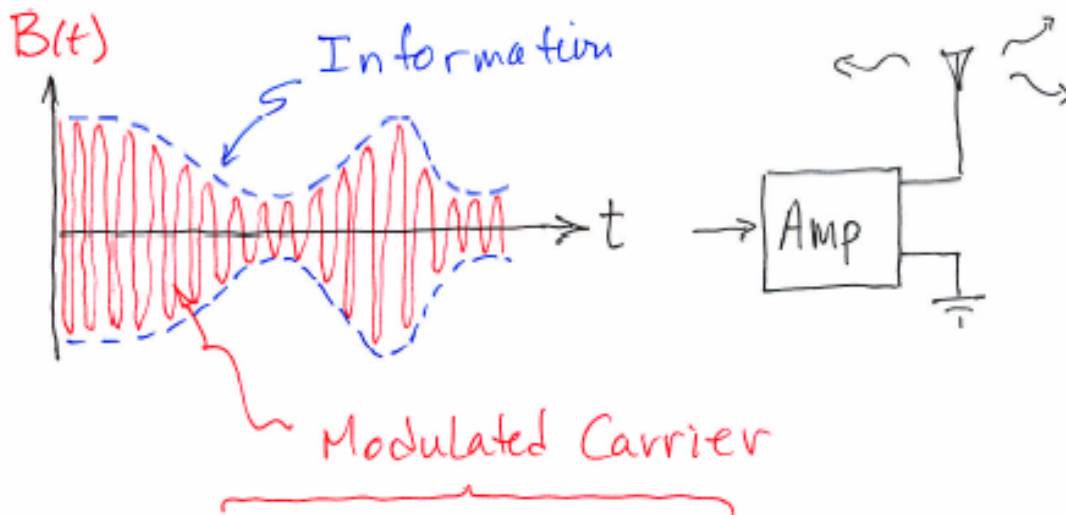


6.200 - Lecture 25

Op-Amp Systems

- Divide & Conquer
- Op-Amp Systems
- AM Radio Example

AM Radio Transmission

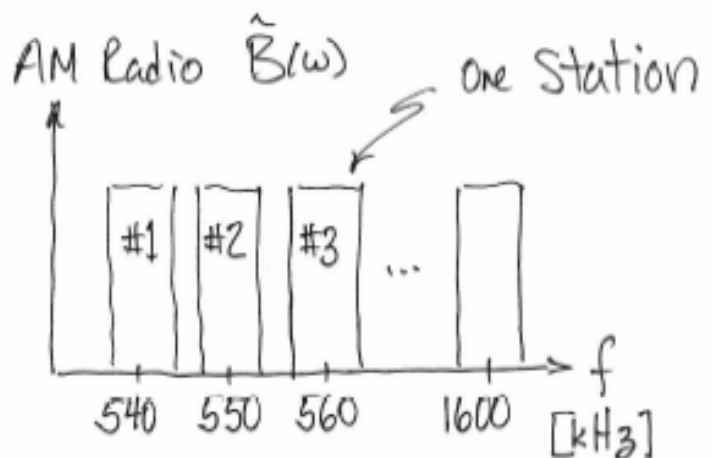
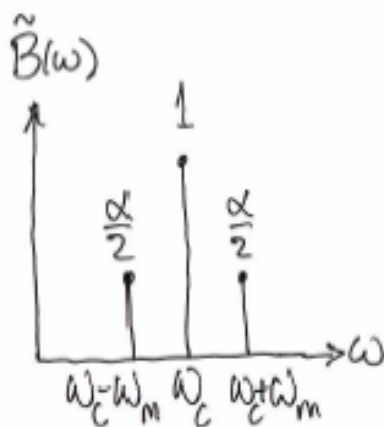


$$B(t) = (1 + S(t)) \cos(\omega_c t) \quad |S(t)| < 1$$

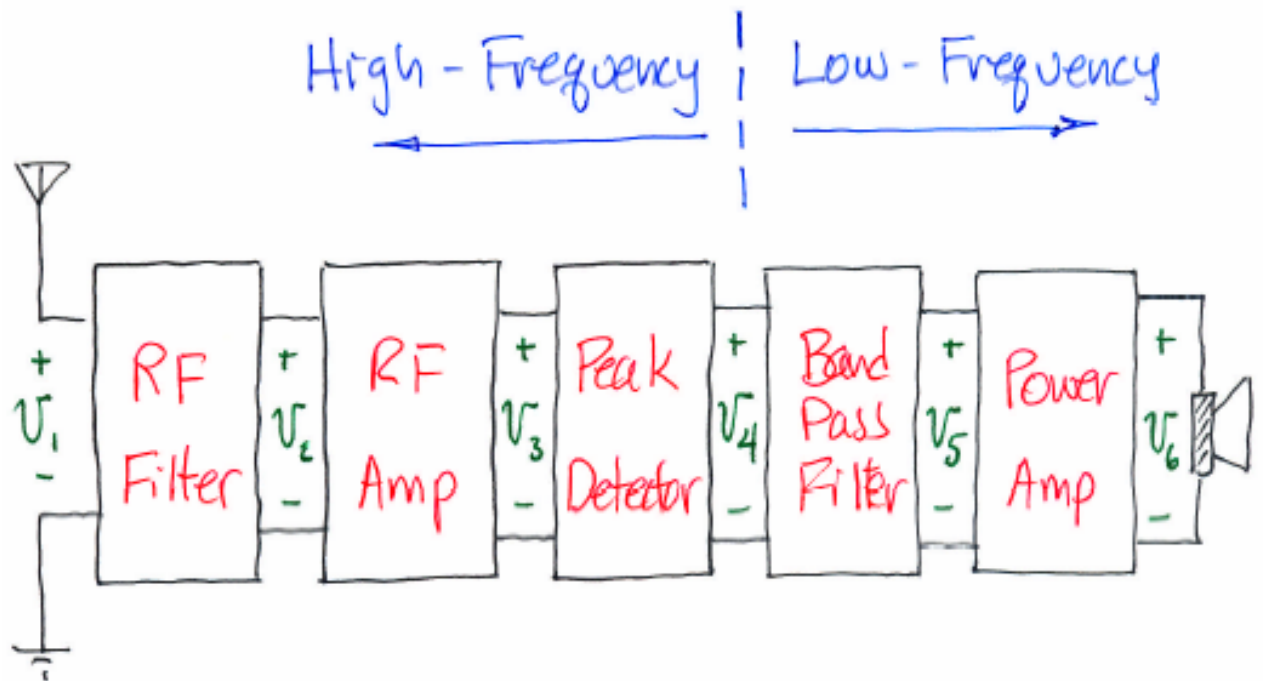
Information ↗
Carrier ↖

Suppose $S(t) = \alpha \cos(\omega_m t) \quad |\alpha| < 1$

Then $B(t) = \cos(\omega_c t) + \frac{\alpha}{2} (\cos((\omega_c + \omega_m)t) + \cos((\omega_c - \omega_m)t))$



Receiver Op-Amp System

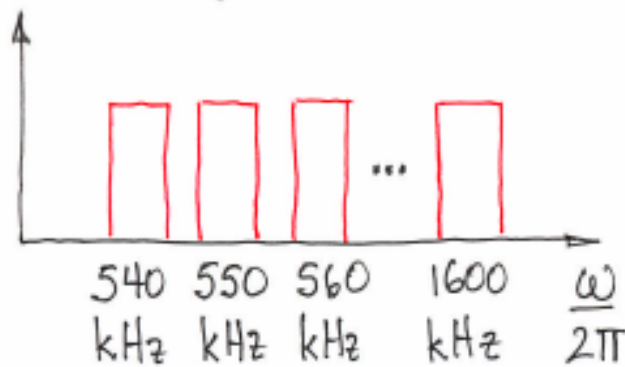


Station Selection Signal Boost Recover Info Reject "1" & ω_c Signal Boost

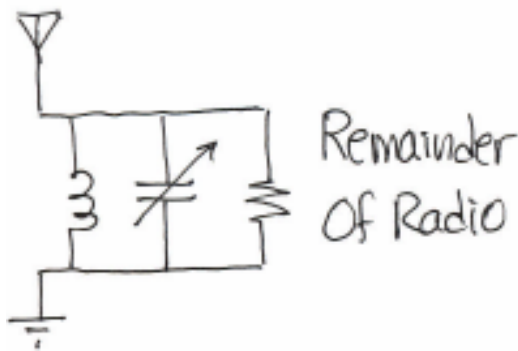
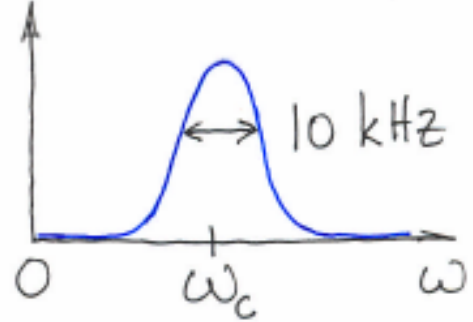
Build each block around an op-amp so as to separate functions for simplicity, as necessary.

RF Band-Pass Filter

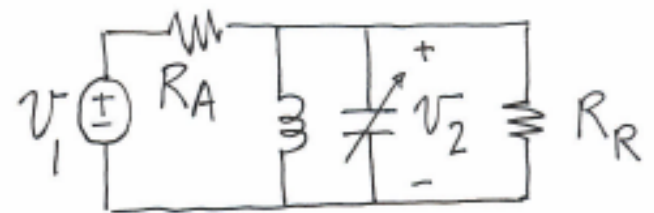
Radio Signals



Filter Gain $\left| \frac{\hat{v}_2}{\hat{v}_1} \right|$



Antenna Filter Radio



$$L = 100 \mu\text{H}$$

$$100 \text{ pF} \leq C \leq 900 \text{ pF}$$

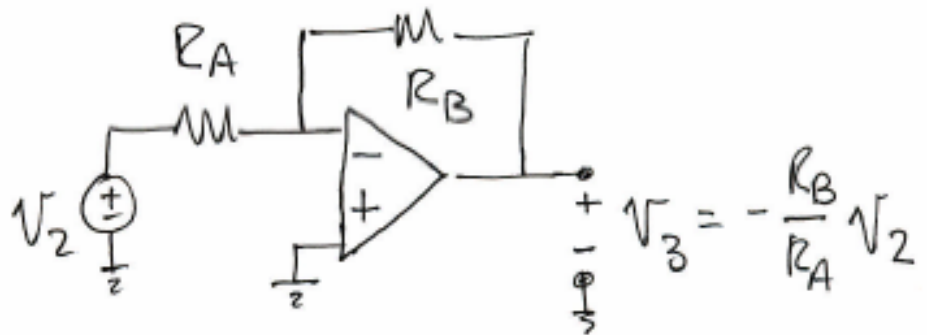
$$\begin{array}{ccc} \uparrow & & \uparrow \\ 1600 \text{ kHz} & & 540 \text{ kHz} \end{array}$$

$$Q = \frac{R_A || R_R}{\sqrt{L/C}} \approx \frac{10 \text{ kHz}}{1 \text{ MHz}} = 100$$

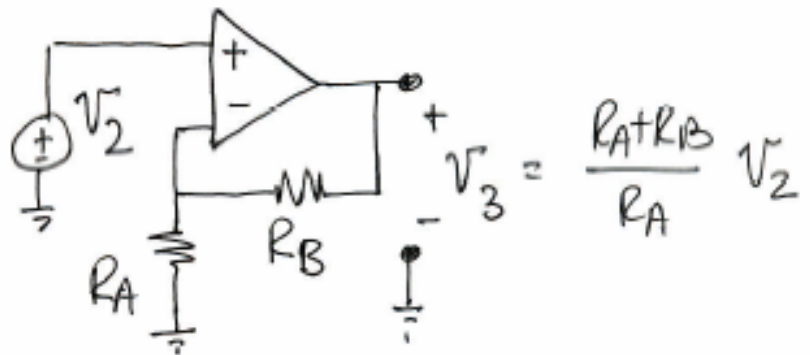
$$R_A || R_R \approx 63 \text{ k}\Omega$$

RF Amplifier

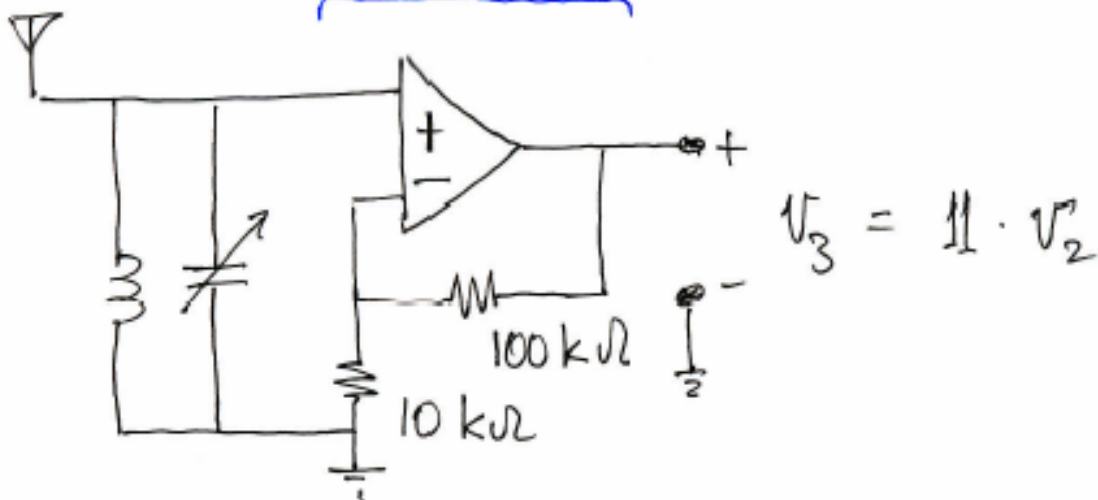
Inverting:



Non-Inverting:

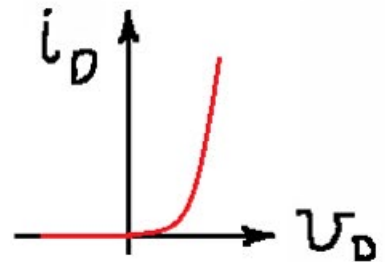
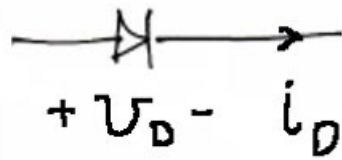


Chosen to reduce filter loading

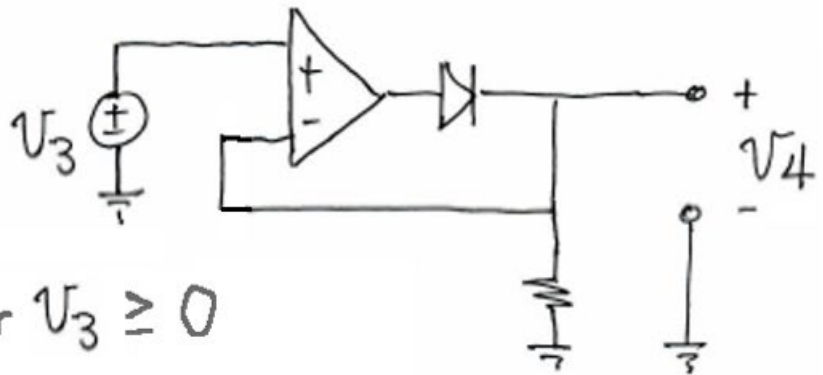


Rectifier For Peak Detector

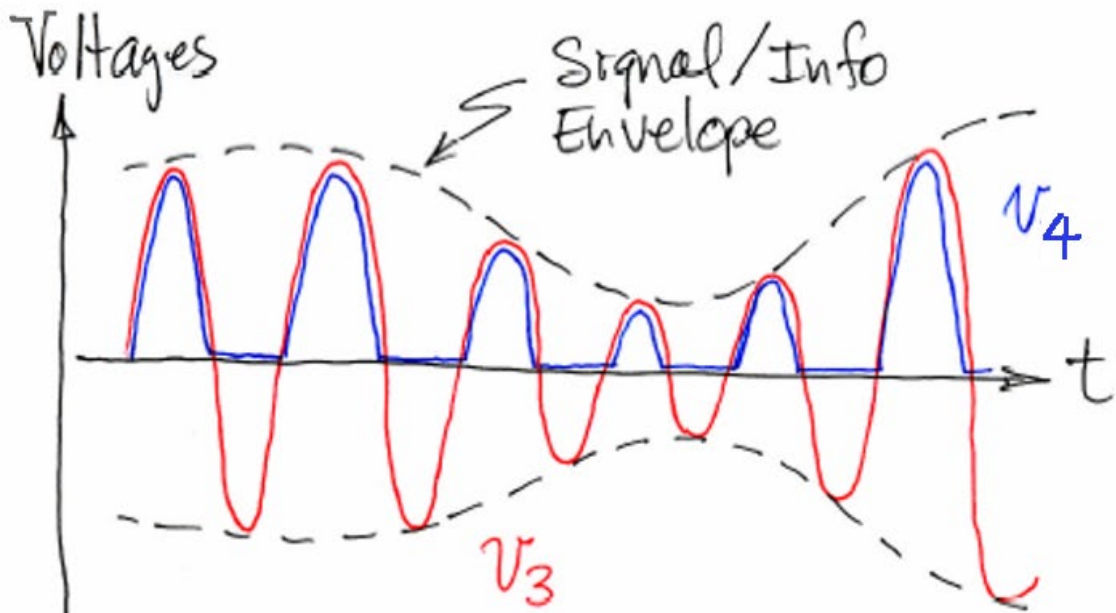
Diode:



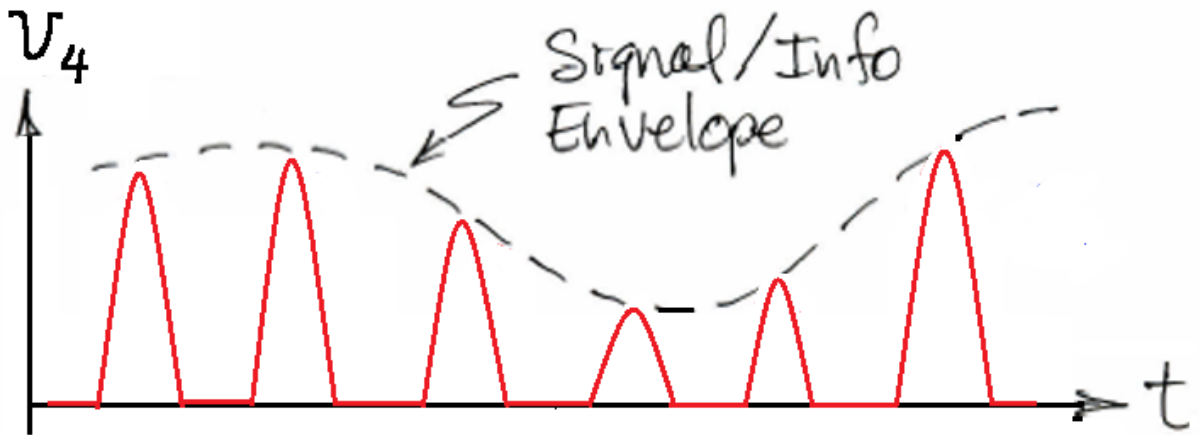
Super Diode
Rectifier:



$$v_4 \approx \begin{cases} v_3 & \text{for } v_3 \geq 0 \\ 0 & \text{for } v_3 < 0 \end{cases}$$

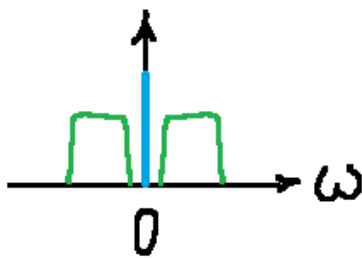


Notional Spectrum Of v_4

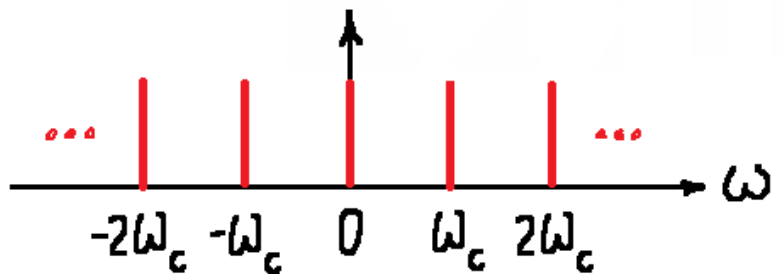


$$v_4 = \text{Gain} \cdot (1 + S(t)) \cdot \dots$$

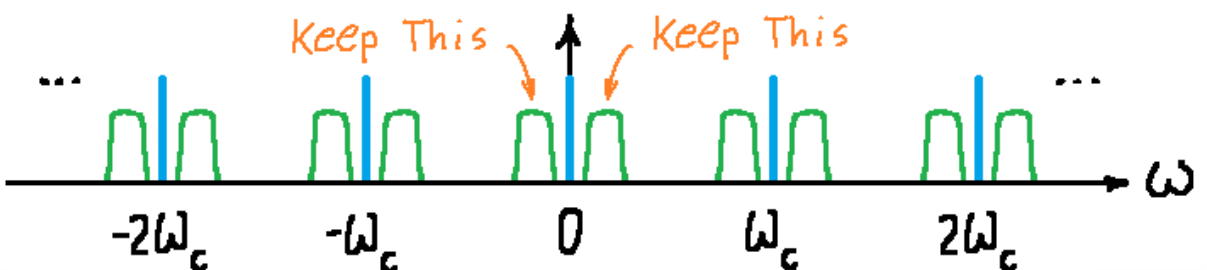
|Spectrum|



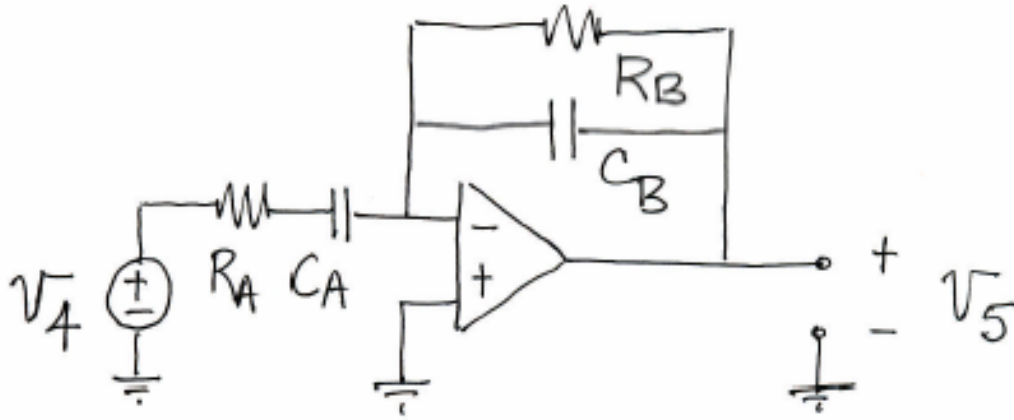
|Spectrum|



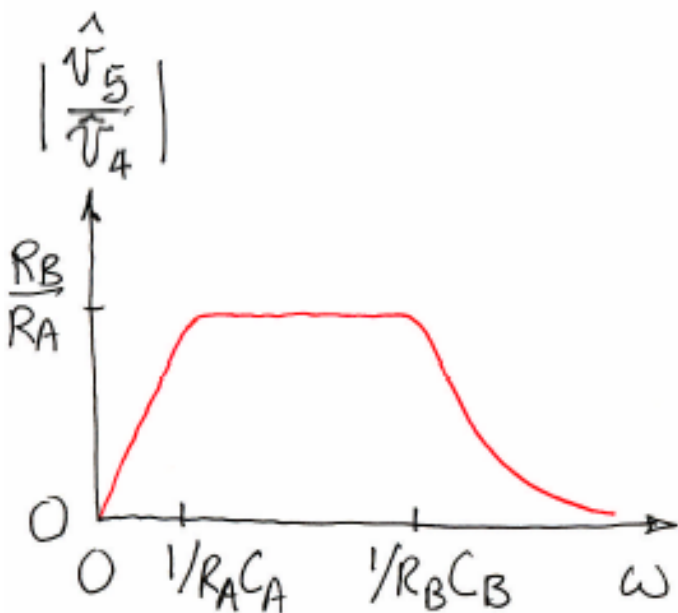
|Spectrum|



BPF To Reject "1" & " ω_c "



$$\frac{\hat{V}_5}{\hat{V}_4} = - \frac{\left(\frac{R_B \cdot 1/j\omega C_B}{R_B + 1/j\omega C_B} \right)}{(R_A + 1/j\omega C_A)} = - \frac{R_B}{R_A} \frac{1}{\underbrace{(1 + 1/j\omega R_A C_A)}_{\text{LPF}} \underbrace{(1 + j\omega R_B C_B)}_{\text{HPF}}}$$



$$R_A = 10 \text{ k}\Omega$$

$$C_A = 0.1 \text{ }\mu\text{F}$$

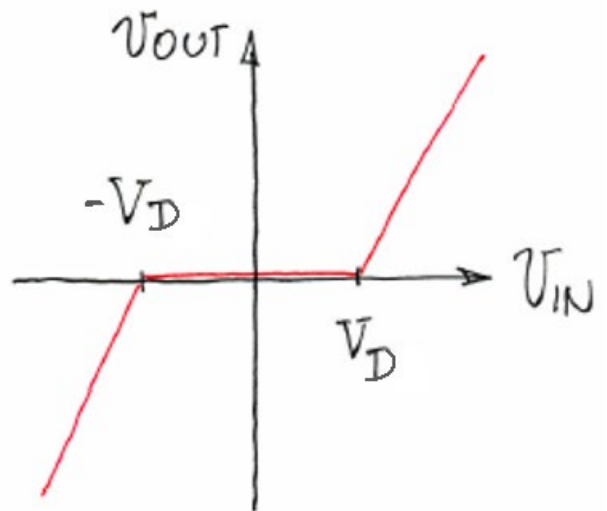
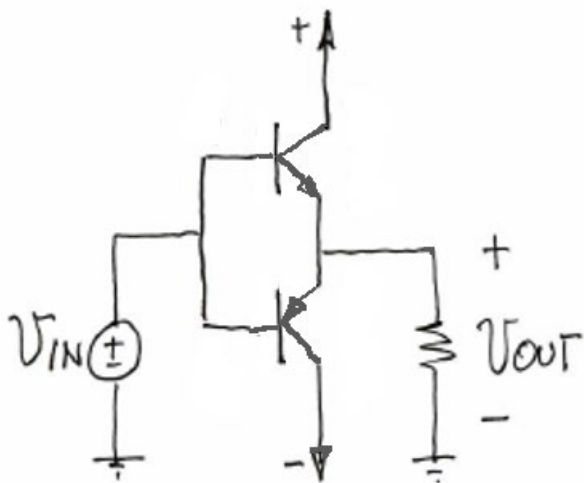
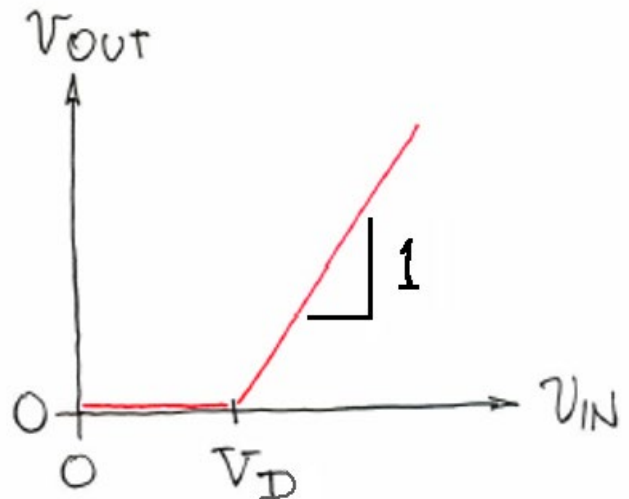
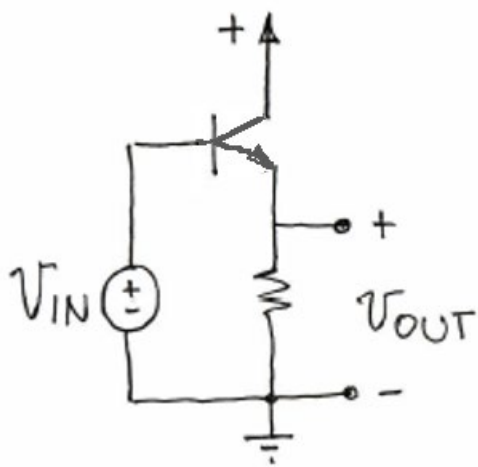
$$1/2\pi R_A C_A = 160 \text{ Hz}$$

$$R_B = 100 \text{ k}\Omega$$

$$C_B = 470 \text{ pF}$$

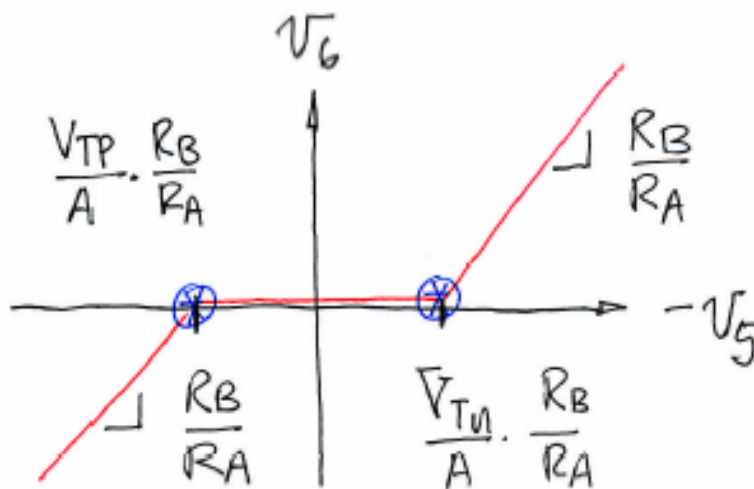
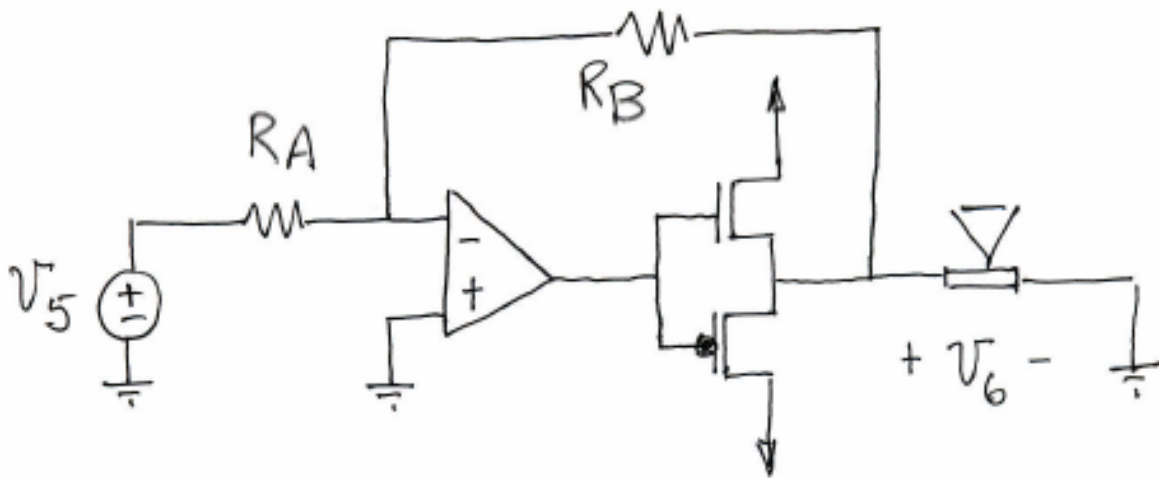
$$1/2\pi R_B C_B = 3.4 \text{ kHz}$$

Emitter Follower



Emitter followers provide current gain, and hence power gain, well beyond unity.

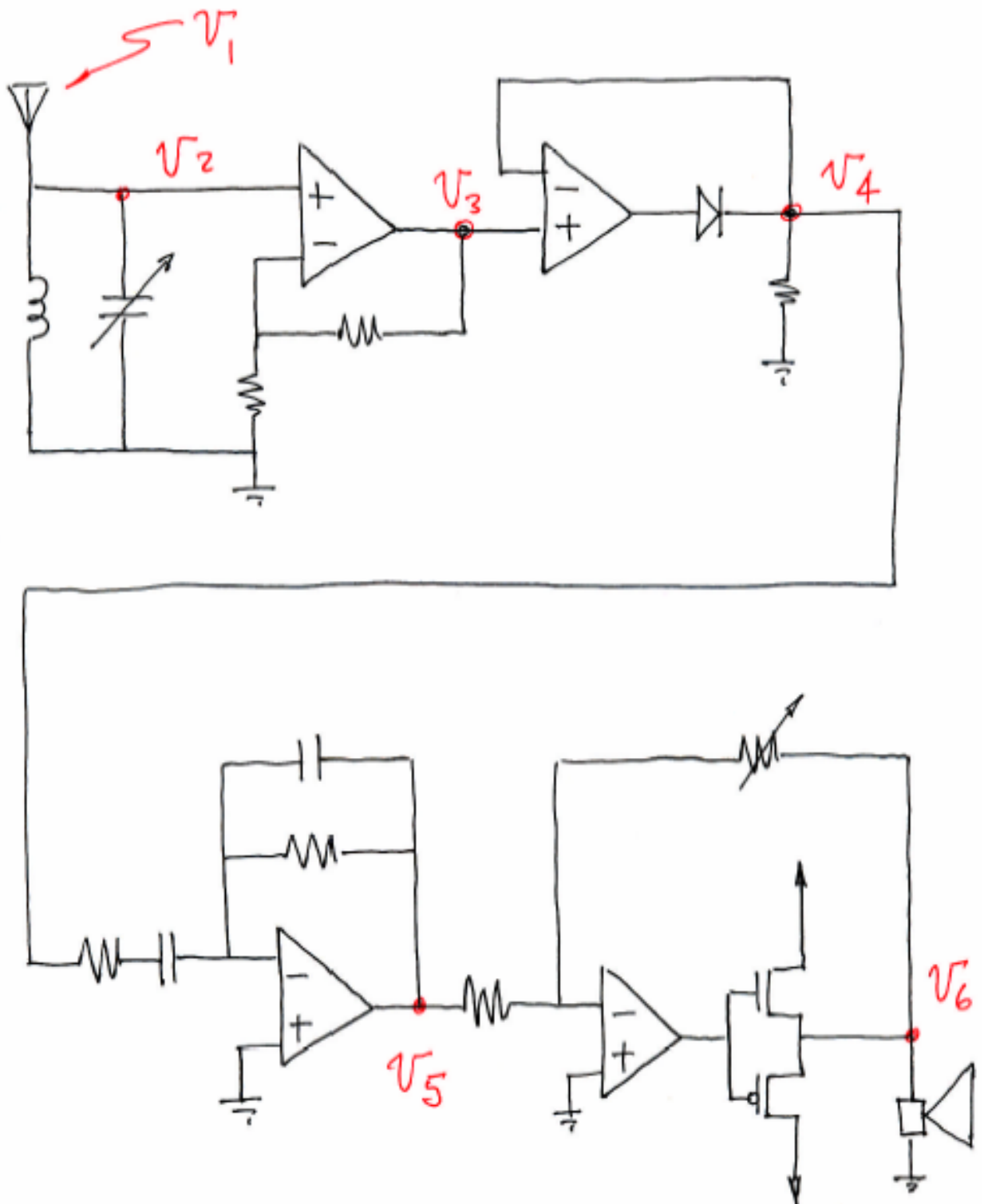
Power Amplifier



$$\otimes n: \text{KCL @ } V_- \Rightarrow \frac{V_{Tn}/A}{R_B} = \frac{-V_{Tn}/A - V_5}{R_A} \Rightarrow -V_5 \approx \frac{V_{Tn}}{A} \cdot \frac{R_A}{R_B}$$

$$\otimes p: \text{KCL @ } V_- \Rightarrow \frac{V_{Tp}/A}{R_B} = \frac{V_5 - V_{Tp}/A}{R_B} \Rightarrow -V_5 \approx \frac{V_{Tp}}{A} \cdot \frac{R_A}{R_B}$$

The Complete System



(Some) Future Subjects

- 6.203 Electronics First Lab
- 6.204 Analog Electronics Lab

- 6.208 Semiconductor Electronic Circuits
- 6.209 Solid State Circuits
- 6.250 Nanoelectronics & Nanotechnology
- 6.600 CMOS Analog & Mixed Signal Circuits
- 6.602 High-Frequency Integrated Circuits
- 6.650 Integrated Microelectronic Devices

- 6.220 Electric Energy Systems
- 6.222 Power Electronics Laboratory
- 6.620 Power Electronics