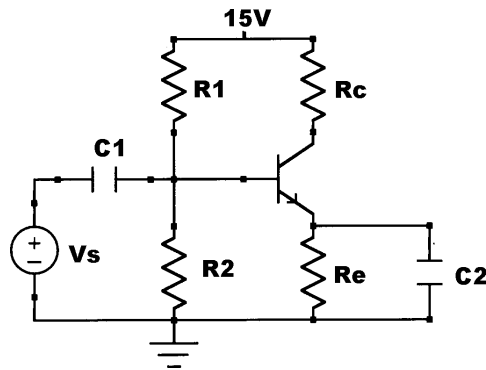


## Designing a Common-Emitter Amplifier

### Design Criteria:

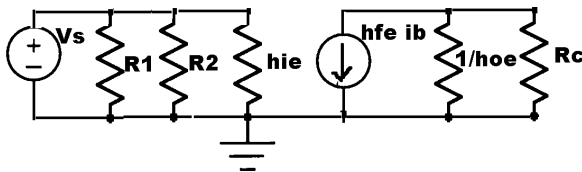
- Flat frequency response 30-10KHz
- Gain  $\cong 100$
- Input impedance  $\cong 300 \Omega$



Can choose R1, R2, Rc, Re, C1 and C2.

### AC Properties: What is voltage gain ?

Apply small signal model



$$\text{apply KVL, KCL} \rightarrow A_{vs} = \frac{V_{out}}{V_{in}} = \frac{R_c h_{fe}}{(1 + R_c h_{oe}) h_{ie}}$$

for N3904 in typical operating range

$$h_{ie} = 3K\Omega$$

$$h_{fe} = 200$$

$$h_{oe} = 1 \times 10^{-6} \Omega^{-1}$$

$$\text{so from above } 200 = \frac{R_c \cdot 200}{(1 + R_c \cdot 1 \times 10^{-6}) \cdot 3000} \text{ yields } \boxed{R_c = 1500 \Omega}$$

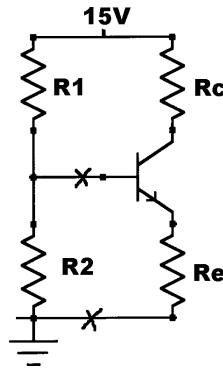
### What is Input Resistance? (A.C.)

$$R_{in} = R_1 || R_2 || R_{eq} \quad \text{Let } R_{eq} = R_1 || R_2 \quad \text{then} \quad 300 = \frac{3000R_{eq}}{(3000 + R_{eq})}$$

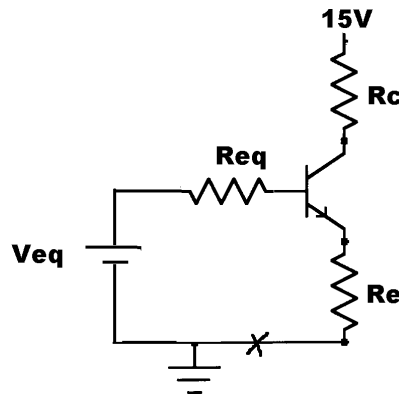
$$\rightarrow \boxed{R_{eq} = R_1 || R_2 = 333 \, \Omega}$$

*The desired AC properties are now met*

### D.C. Properties: Now bias to active region.



applying Thevenin to the left of x-x



$$R_{eq} = R_1 || R_2 = 333 \, \Omega$$

$$V_{eq} = 15 \frac{R_2}{(R_1 + R_2)}$$

KVL around input and output loops with the approximation  $I_c \approx I_e$  and  $V_{be} = .65V$  yields:

$$15 = 1500I_c + V_{ce} + I_c R_e$$

$$V_{eq} = I_b R_{eq} + .65 + I_c R_e$$

For  $I_c$  in normal (operating) range of transistor manufacturer suggests:

$$I_c \approx 0.4 \, \text{mA}$$

Since  $I_c \approx h_{fe} I_b$

$$I_b = 0.4 \times 10^{-3} / 200 = 2.0 \times 10^{-6} \, \text{A}$$

Choosing  $V_{CE} = 7.5 \, \text{V}$  exactly in the middle of the operating range

$$15 = 15020(4.0 \times 10^{-4}) + 7.5 + 4.0 \times 10^{-4} R_e$$

then

$$R_e = 17250$$

We can now determine  $R_1$  and  $R_2$ :

$$V_{eq} = (2.0 \times 10^{-6}) 333 + .65 + (4.0 \times 10^{-4}) 17250 = 7.55$$

$$7.55 = \frac{25R_2}{(R_1 + R_2)} \quad 333 = \frac{R_1 R_2}{(R_1 + R_2)}$$

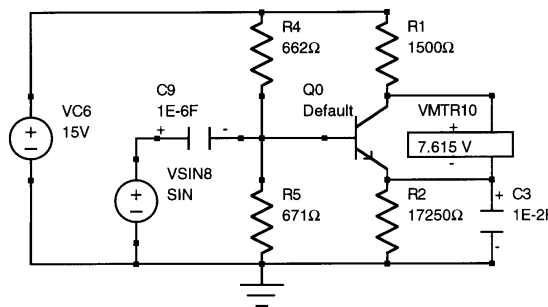
Solving these equations yields:

$$R_1 = 662\Omega$$

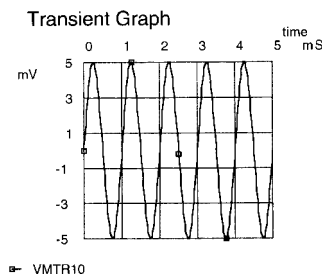
$$R_2 = 671\Omega$$

### Modeling these Parameters using BSPICE:

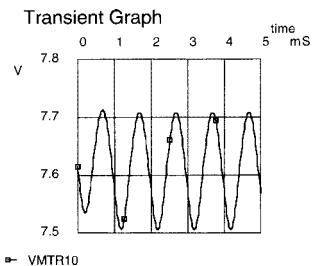
The resistors and capacitors above were entered into the BSPICE simulation program as is shown below. A DC analysis was run and  $V_{ce}$  was found to be 7.6V, very close to the 7.5 V chosen above.



A transient analysis was run with an input sine wave (VSIN8) and the output (VMTR10) waveform was plotted.



input(VSIN8)



output(VMTR10)

The gain of the amplifier can be seen to be  $1/.005 \approx 20$ . This is in poor agreement, but we have only used approximations to the small signal parameters and SPICE did not have a model for the N3904. One can put a resistor box on R4 to increase the gain.