ECE137A Notes Set 3:
Basic Common-Emitter Amplifier

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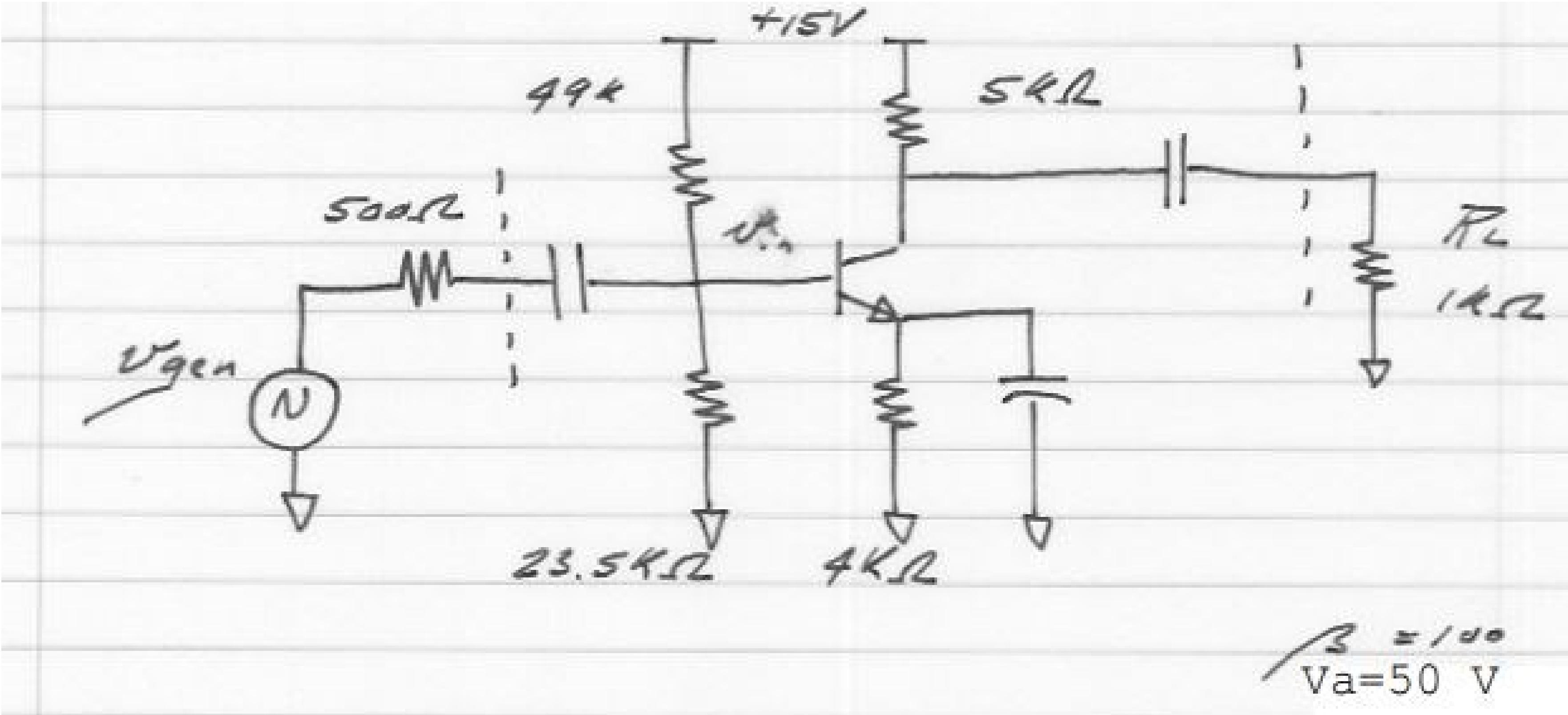
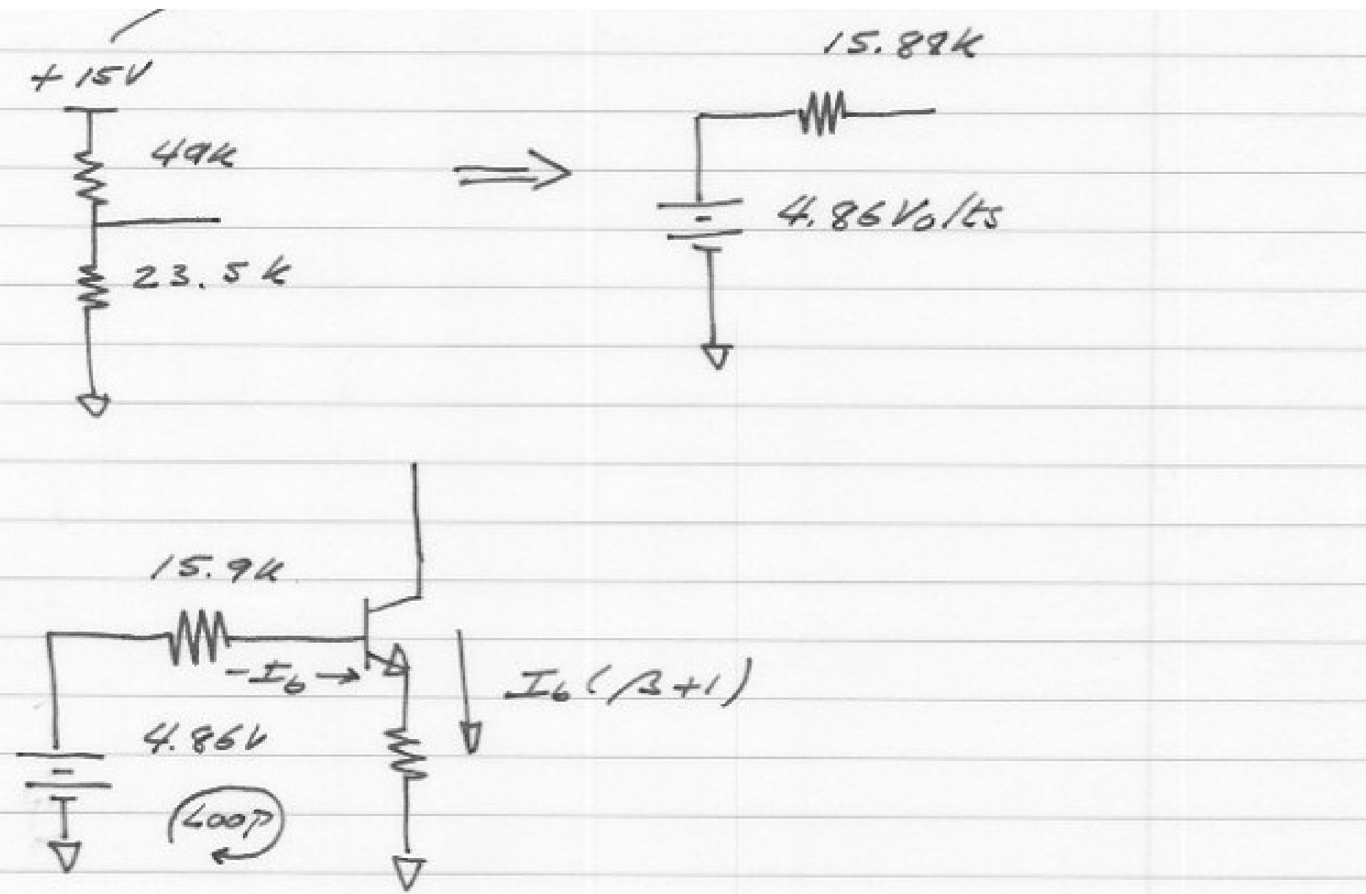
Common-Emitter Amplifier: 1950's-style



DC bias analysis: exact (slow) method

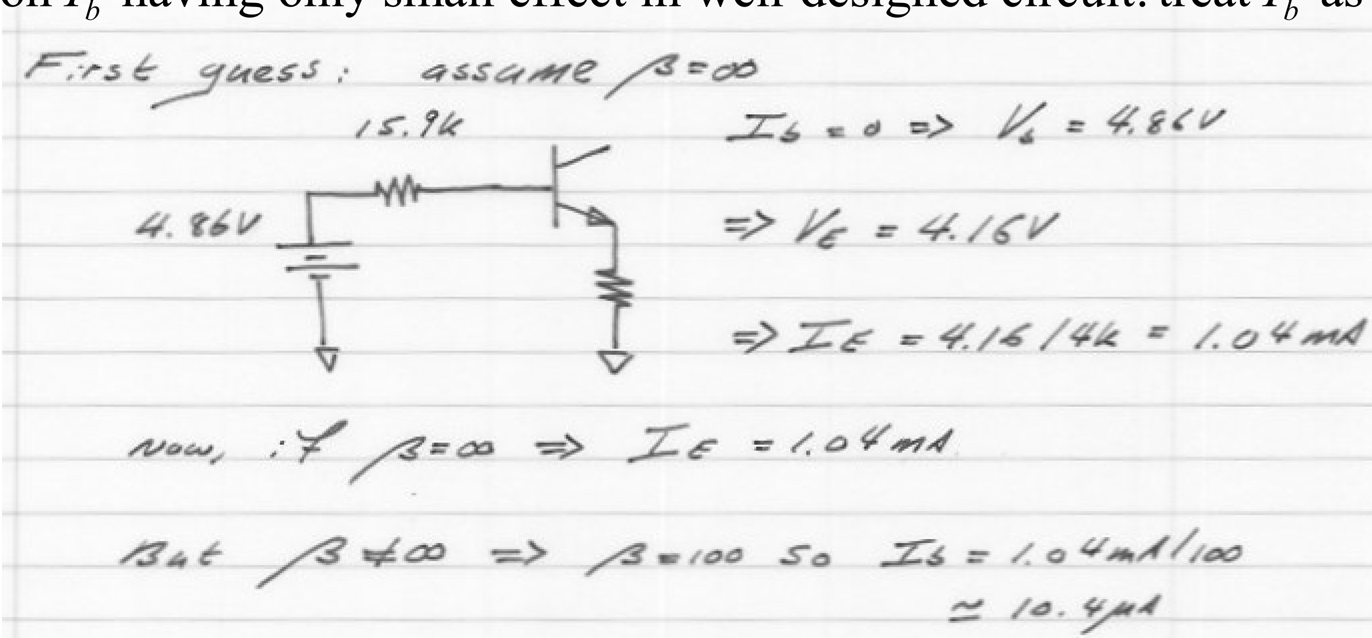


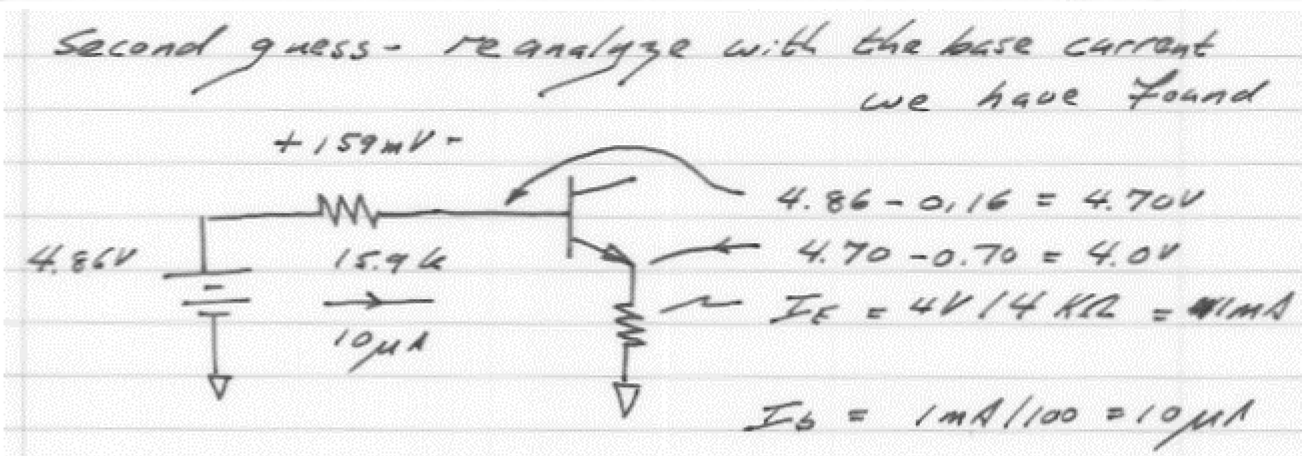
by KVL: $4.86\,V = I_b(15.9k\Omega) + 0.7\,V + (\beta+1)I_b \cdot 4k\Omega$

$\Rightarrow I_b = 10\,\mu A$ and $I_c = \beta I_b = 1\,mA$

fast DC bias analysis: iteration

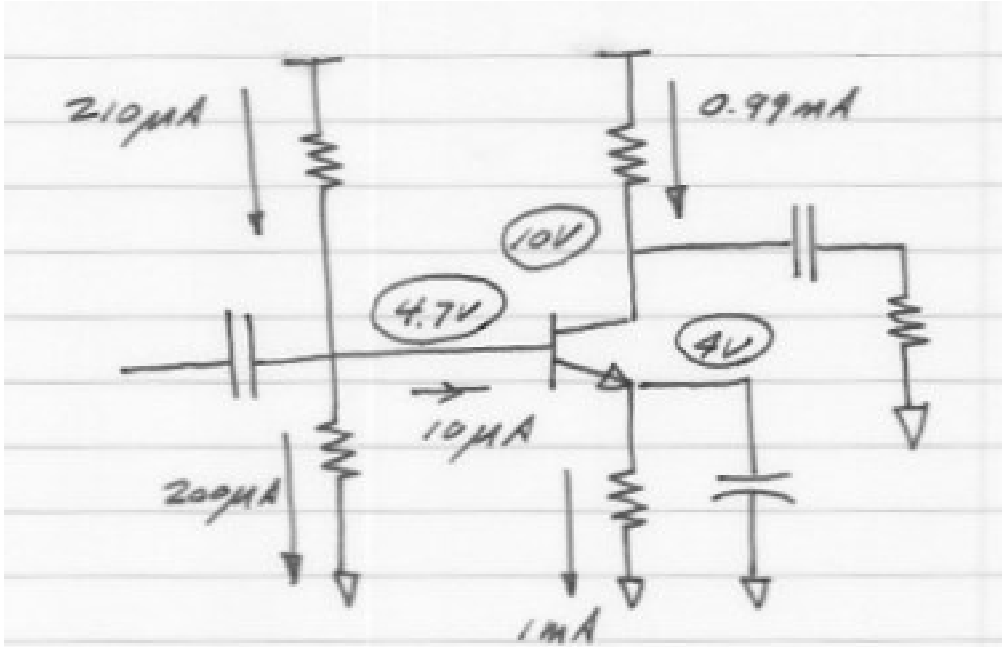
Relies on I_b having only small effect in well-designed circuit: treat I_b as a *perturbation*





Iteration can be repeated if necessary

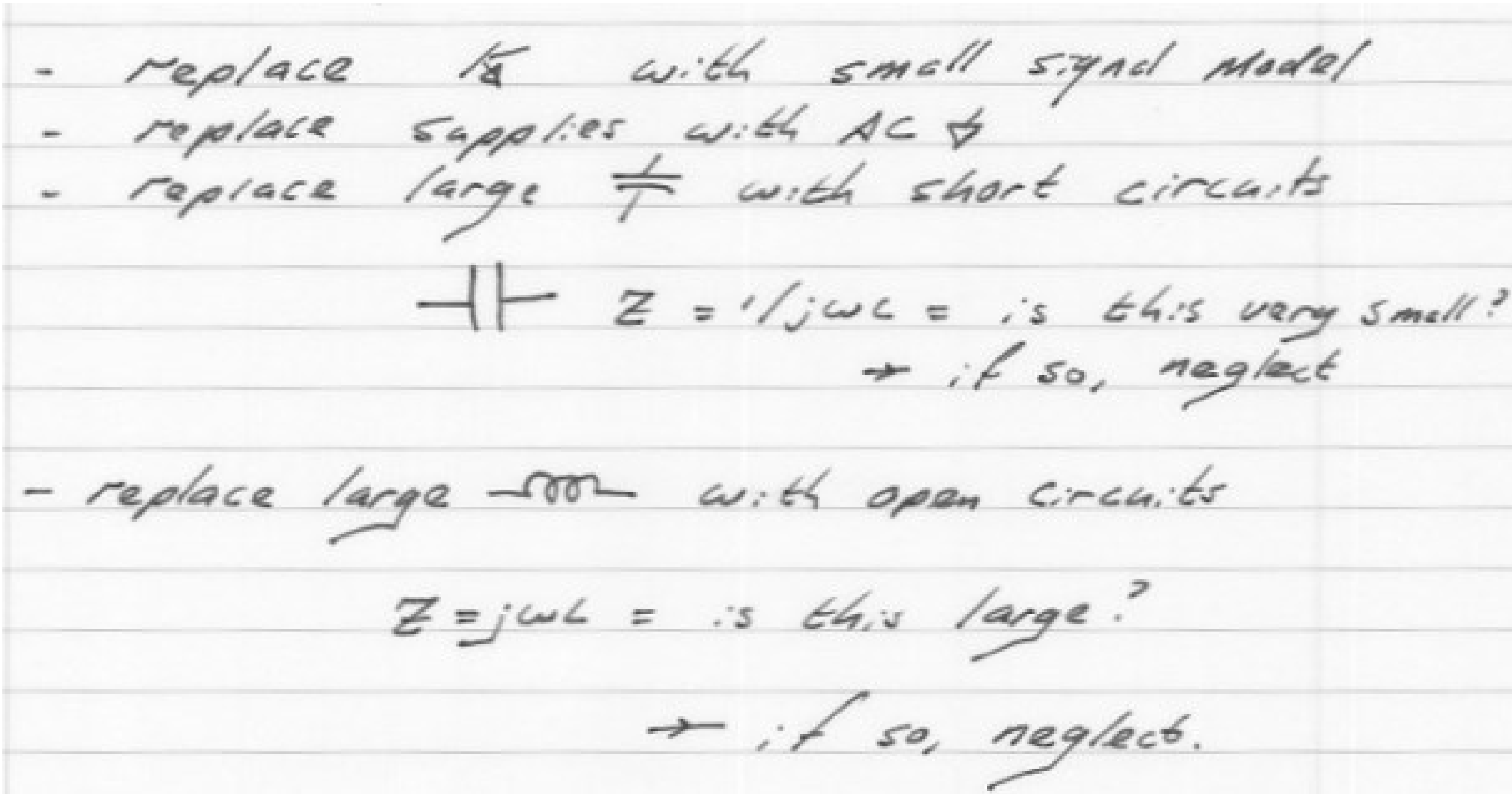
DC bias solution



This circuit is AC coupled with RC bias network. Why teach such old-fashioned techniques ? (1) As we progress from single-transistor to multi-stage designs, it is easier to progress from AC to DC coupling than to start with DC-coupled designs. (2) AC coupled designs are easier for the first 1-2 lab projects. (3) Even modern RF gain stages *are* AC coupled.

Above all (4), we will quickly transition in the next 3 weeks to DC coupling.

AC small signal analysis.



ω is the signal frequency.

At some low ω, $1/j\omega C$ and $j\omega L$ become sigificant.

We treat this in ece137B

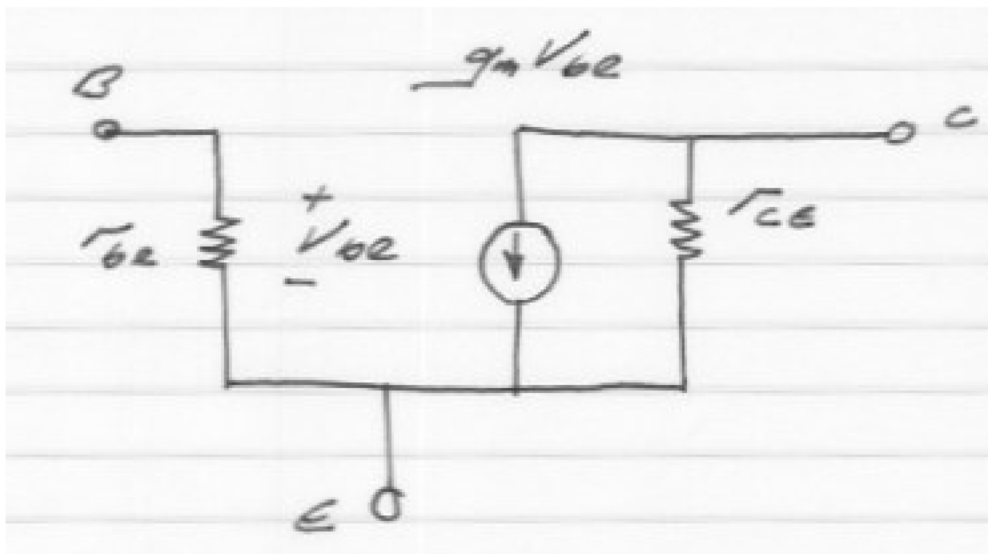
Small-signal model

$$r_e = V_t/I_E = 26\,mV/1\,mA = 26\,\Omega$$

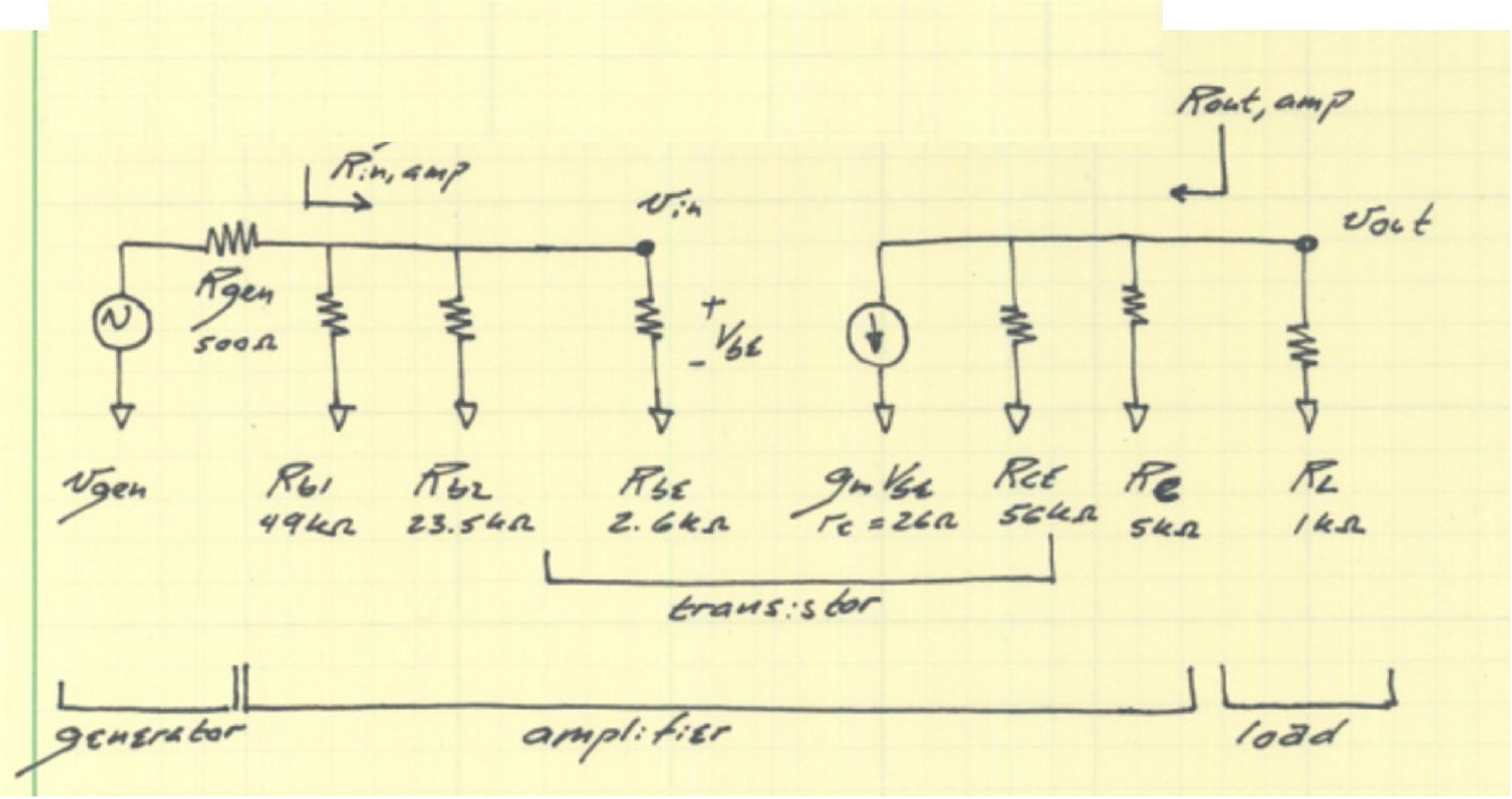
$$g_m = \alpha/r_e \cong 1/26\,\Omega \qquad (\alpha = 0.99)$$

$$r_o = r_{ce} = (V_{CE}+V_A)/I_C = 56\,V/1\,mA = 56\,k\Omega$$

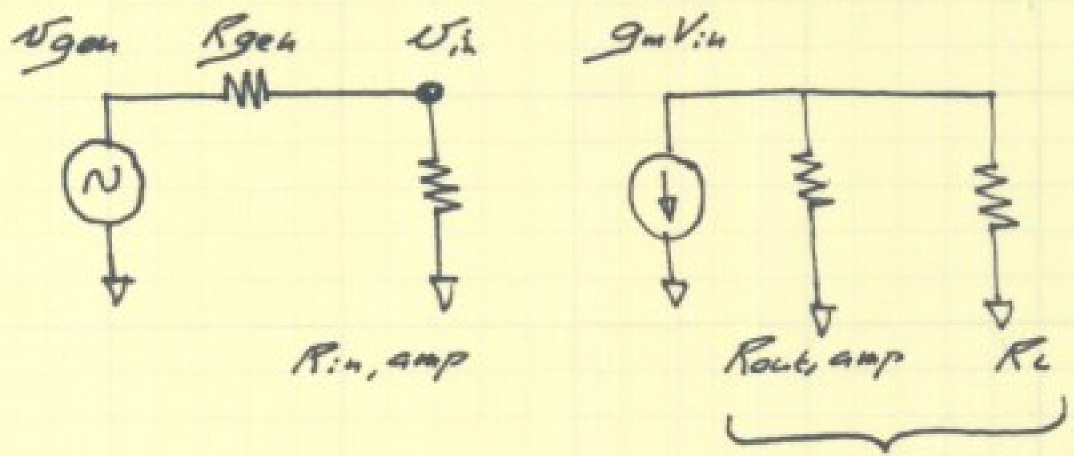
$$r_\pi = r_{be} = (\beta+1)r_e \cong \beta r_e = 100(2.6) = 2.6\,k\Omega$$



Circuit diagram: small-signal



Small-signal analysis



$$R_{Leq} = R_{out,amp} \| R_L = 820\,\Omega$$

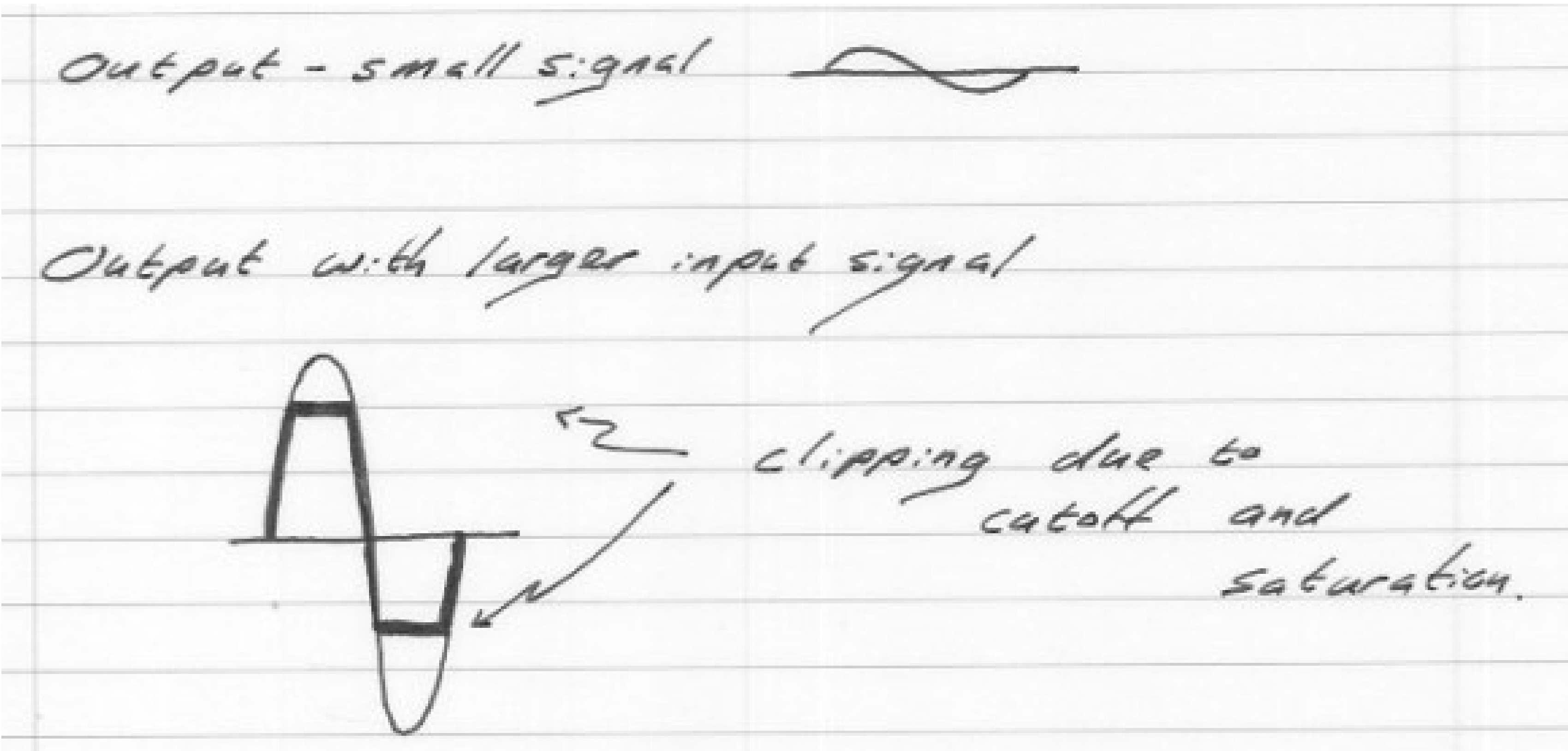
$$R_{in,amp} = R_{B1} \| R_{B2} \| R_{BE} = 2.23\,k\Omega$$

$$R_{out,amp} = R_{CE} \| R_C = 4.60\,k\Omega$$

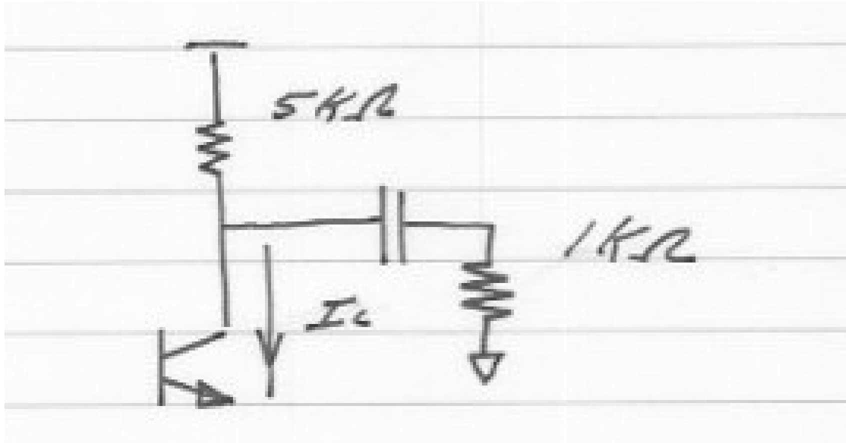
$$v_{in}/v_{gen} = R_{in,amp}/(R_{in,amp} + R_{gen}) = 0.817$$

$$v_o/v_{in} = -g_m \cdot R_{Leq} = -31.5$$

Limits on output swing



Limits on output swing: cutoff



Clipping is large-signal, but AC, not DC.

$\rightarrow$ Capacitors remain AC short-circuits.

$$R_{Leq} = 5\text{k}\Omega \,||\, 1\text{k}\Omega = 800\Omega$$

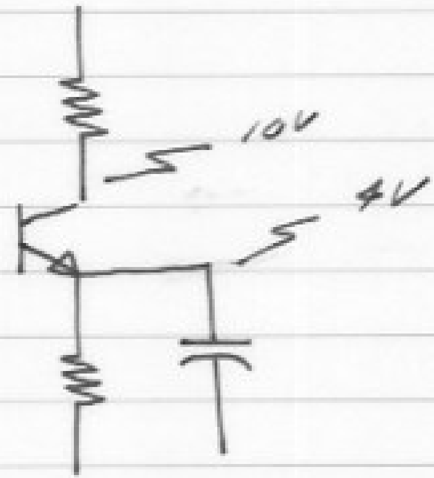
$$I_{CQ} = 1\text{mA but } I_{C,\min} = 0\text{mA} \rightarrow \Delta I_C \downarrow_{\max} = 1\text{mA}.$$

We can decrease I_C by at most 1mA.

$$\Delta V_{out} \uparrow_{\max} = 1\text{mA} \cdot R_{Leq} = 0.8\text{V}.$$

V_{out} can increase by at most 0.8V.

Limits on output swing: saturation



under bias: $V_{CEQ} = 10 - 4 = 6V$

Minimum : $V_{CE\,min} = V_{CE\,sat} \cong 0.5V$

$\Delta V_{CE} \downarrow_{max} = 6 - 0.5 = 5.5$ Volts

Since there is no ac voltage on the emitter,

this corresponds to $\Delta V_{out} \downarrow_{maximum} = 5.5$ Volts.