ECE 321 - Solutions to the Final

Spring 2018

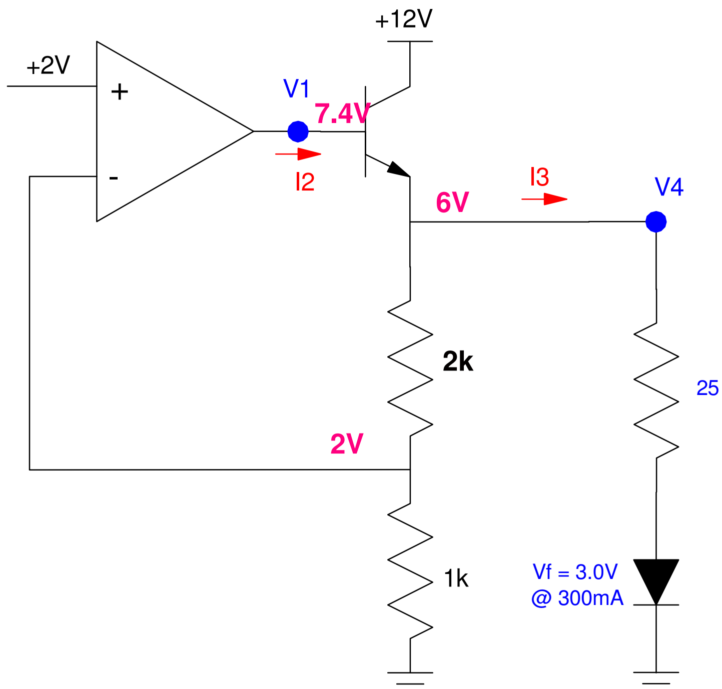
1) Determine the voltages and currents for the following push (pull) amplifier. Assume for the transistor

- $\beta = 1000$
- $V_{be} = 1.4V$

Assume for the LED

- Vf = 3.0V @ 300mA:

V1	I2	I3	V4
7.4V	**124.9uA**	**120mA**	**6V**



V+ equals V- . This means V4 must be 6V for V- to be +2V

V1 = V4 + 1.4V (Vbe) = 7.4V

$$I_3 = \left(\frac{6V - 3.0V}{25\Omega}\right) = 120mA$$

$$I_e = I_3 + \frac{6V}{3k} = 125mA$$

$$I_b = \frac{I_e}{1+\beta} = \frac{125mA}{1001} = 124.9\mu A$$

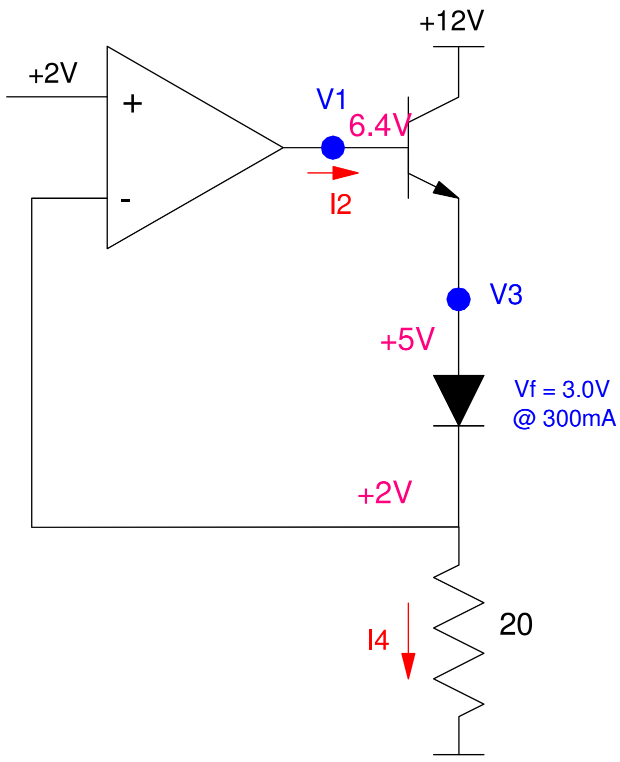
2) Determine the voltages and currents for the following push (pull) amplifier. Assume for the transistor

- $\beta = 1000$
- $V_{be} = 1.4V$

Assume for the LED

- Vf = 3.0V @ 300mA:

V1	I2	V3	I4
6.4V	**99.9uA**	**5.0V**	**100mA**



V+ = V- = 2V

$I_4 = \frac{2V}{20\Omega} = 100mA$

$V_3 = 2V + 3V = 5V$

$I_2 = I_b = \frac{I_e}{1+\beta} = \frac{100mA}{1001} = 99.9\mu A$

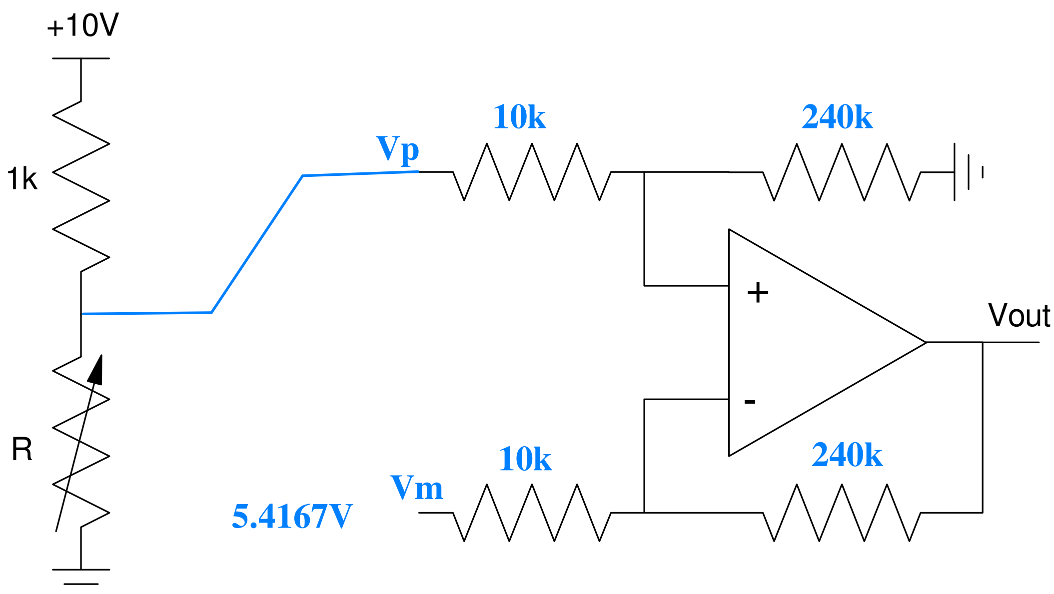
$V_1 = V_3 + V_{be} = 6.4V$

3) Design an instrumentation amplifier so that the output is

- -10V when R = 1000 Ohms
- +10V when R = 1400 Ohms

For your circuit, what is the output voltage (Vout) when R = 1100 Ohms?

Vout when R = 1100: **Vout = -4.2865V**



R = 1000 Ohms (Vo = -10V)

$$V_a = \left(\frac{R}{R+1000}\right) 10V = 5.00V$$

R = 1400 Ohms (Vo = +10V)

$$V_a = \left(\frac{R}{R+1000}\right) 10V = 5.833V$$

Gain:

$$gain = \left(\frac{10V-(-10V)}{5.833V-5.000V}\right) = 24.0$$

The output goes up as the input get larger. Connect to the plus input

$$Y = gain(V_p - V_m)$$

$$+10V = 24.0(5.8333V - V_m)$$

$$V_m = 5.4167V$$

At 1100 Ohms

$$V_p \approx \left(\frac{R}{R+1000}\right) \cdot 10V = 5.2381V$$

$$Y = 24(5.2183 - 5.4167) = -4.2865V$$

4) Give the transfer function for a low-pass filter which comes close to meeting the following requirements

- $0.9 < \text{Gain} < 1.1$ frequencies less than 500 rad/sec
- $\text{Gain} < 0.2$ frequencies above 600 rad/sec

You are free to choose any type of filter you like (Chebychev, Butterworth, Elliptic, etc.)

The number of poles you need are

$$\left(\frac{500Hz}{600Hz}\right)^N = 0.2$$

$$N = 8.82$$

Round up to N = 9

Assume a Butterworth filter. For 9 poles, the angle between poles is

$$\theta = \left(\frac{180^0}{N}\right) = 20^0$$

Place the corder at 500 rad/sec (may need to adjust with Matlab)

Make the numerator whatever it takes so that the DC gain is 1.000

$$G(s) = \left(\frac{500^9}{(s+500)\left(s+500\angle\pm 20^0\right)\left(s+500\angle\pm 40^0\right)\left(s+500\angle\pm 60^0\right)\left(s+500\angle\pm 80^0\right)}\right)$$

5) A 3rd-order Butterworth low-pass filter has the following transfer function:

$$Y = \left(\frac{250}{(s+5)(s^2+5s+25)}\right)X = \left(\frac{250}{s^3+10s^2+50s+125}\right)X$$

a) What is the differential equation relating X and Y?

$$(s^3 + 10s^2 + 50s + 125)Y = 250X$$

'sY' means 'the derivative of Y

$$y''' + 10y'' + 50y' + 125y = 250x$$

b) Determine y(t) assuming

$$x(t) = 3\sin(7t) + 5\cos(8t)$$

Use super position

x(t) = 3 sin(7t)

$$X = 0 - j3$$

$$s = j7$$

$$\left(\frac{250}{s^3+10s^2+50s+125}\right)_{s=j7} = 1.8492\angle -3.30^0$$

$$Y = (1.8492\angle -3.30^0)(0 - j3)$$

$$Y = 5.5476\angle -93.30^0$$

$$y(t) = 5.5476\cos(7t - 93.30^0)$$

x(t) = 5cos(8t)

$$X = 5 + j0$$

$$x = j8$$

$$(-)_{s=j8} = 1.1849\angle 32.03^0$$

$$Y = (1.1849\angle 32.03^0)(5 + j0)$$

$$Y = 5.9199\angle 32.03^0$$

$$y(t) = 5.9199\cos(8t + 32.03^0)$$

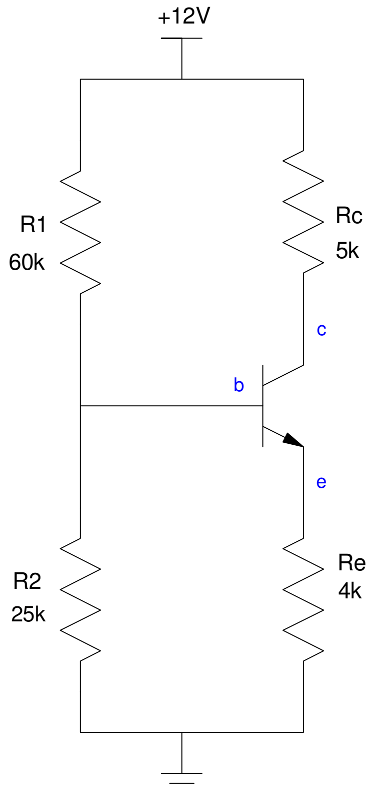
The total answer is the sum of the two parts:

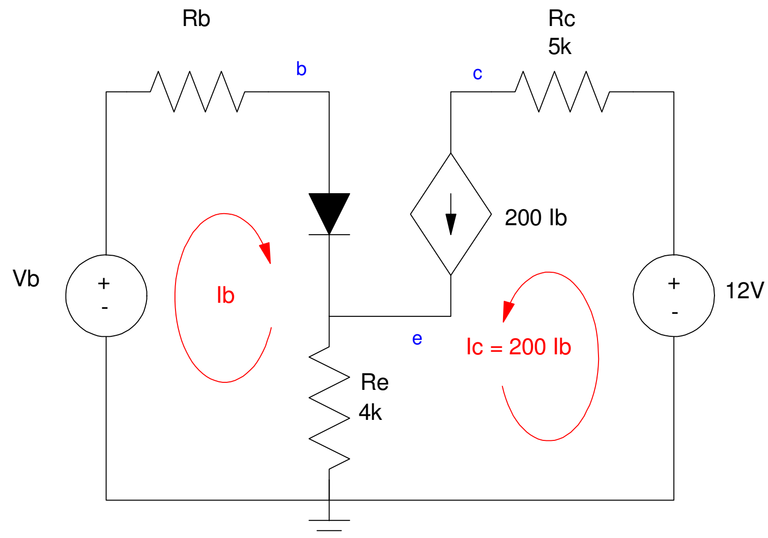
$$y(t) = 5.5476\cos(7t - 93.30^0) + 5.9199\cos(8t + 32.03^0)$$

6) Find the Thevenin equivalent of R1, R2 (Vb, Rb), and the Q-point (Ic, Vce) for the following transistor circuit. Assume a 3904 transistor:

- $\beta = 200$
- $V_{be} = 0.7V$

Vb	Rb	Ic	Vce
3.5294V	**17,657**	**688.7uA**	**5.788V**





$$R_b = R_1 || R_2 = 17,647\Omega$$

$$V_b = \left(\frac{R_2}{R_1+R_2}\right) 12V = 3.5294V$$

$$I_b = \left(\frac{V_b - 0.7V}{R_b + (1+\beta)R_e}\right) = 3.4436\mu A$$

$$I_c = \beta I_b = 688.7\mu A$$

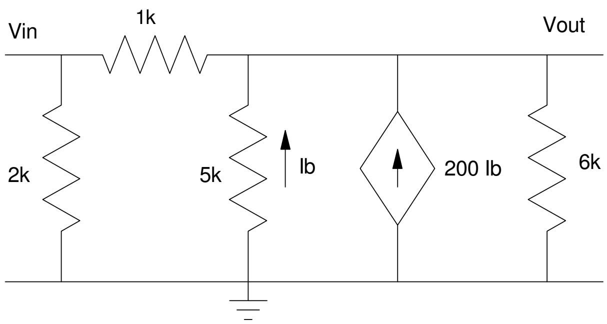
$$V_e = R_e(I_b + I_c) = 2.769V$$

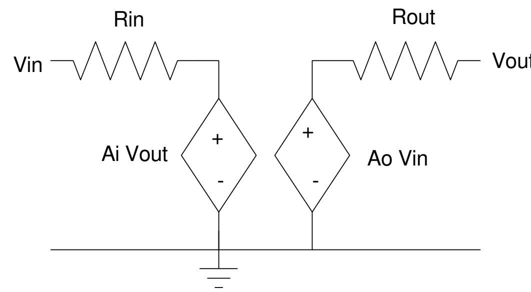
$$V_c = 12 - 5000 I_c = 8.556V$$

$$V_{ce} = V_c - V_e = 5.788V$$

7) Find the 2-port model for the following circuit:

Rin	Ai	Rout	Ao
667 Ohms	**0.667**	**186.3 Ohms**	**0.02417**





Rin: Short Vout. Apply 1V to Vin. Compute Rin.

$$R_{in} = 2k||1k = 667\Omega$$

Ai: Apply 1V tgo Vout. Measure Vin

$$A_i = \left(\frac{2k}{2k+1k}\right)1V = 0.667V$$

Rout: Short Vin. Apply 1V to Vout. Comptue the current draw

$$I = \left(\frac{1V}{1k}\right) + \left(\frac{1V}{5k}\right) + 200\left(\frac{1V}{5k}\right) + \left(\frac{1V}{6k}\right) = 5.367mA$$

$$R_{out} = \left(\frac{1V}{5.367mA}\right) = 186.3\Omega$$

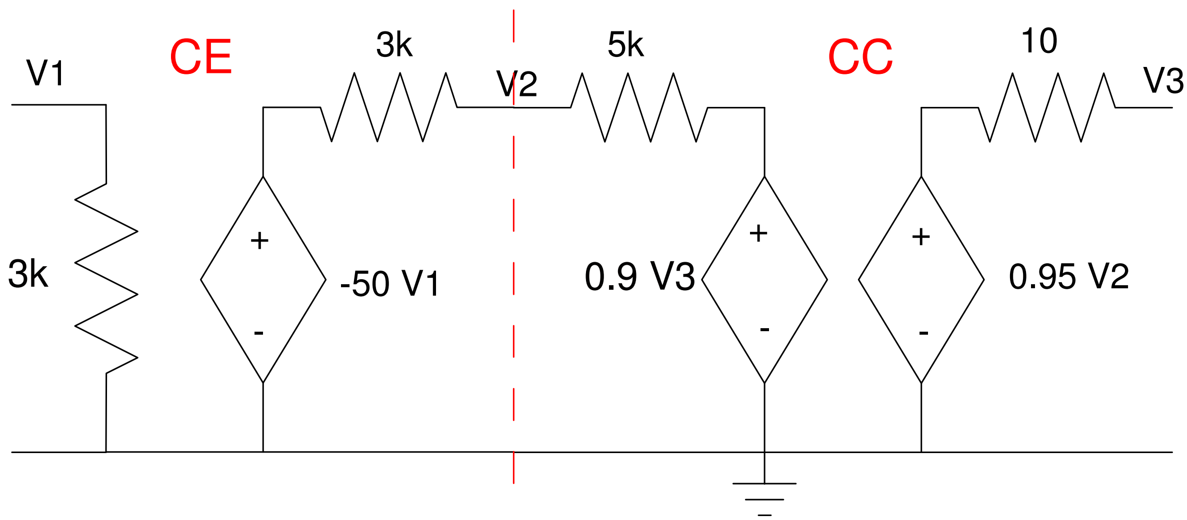
Ao: Apply 1V to Vin. Compute Vout

$$\left(\frac{V_{out}-1}{1k}\right) + \left(\frac{V_{out}}{5000}\right) + 200\left(\frac{V_{out}}{5000}\right) + \left(\frac{V_{out}}{6000}\right) = 0$$

$$V_{out} = 0.02417$$

8) Find the 2-port model for the following CE : CC amplifier

Rin	Ai	Rout	Ao
3k	**0**	**14.72 Ohms**	**-43.70**



Rout: Short V1. Apply 1V to V3. Compute the current

$$V_2 = \left(\frac{3k}{3k+5k}\right) \cdot 0.9 = 0.3375V$$

$$I = \left(\frac{1V - 0.95 \cdot 0.3375V}{10\Omega}\right) = 67.94mA$$

$$Rout = \frac{1V}{67.94mA} = 14.72\Omega$$

Ao: Apply 1V to Vin. Compute V3

$$V_2 = \left(\frac{5k}{3k+5k}\right)(-50V) + \left(\frac{3k}{3k+5k}\right)(0.9V_3)$$

$$V_3 = 0.95V_2$$

$$V_2 = -46.00V$$

$$V_3 = 0.95V_2 = -43.70V$$