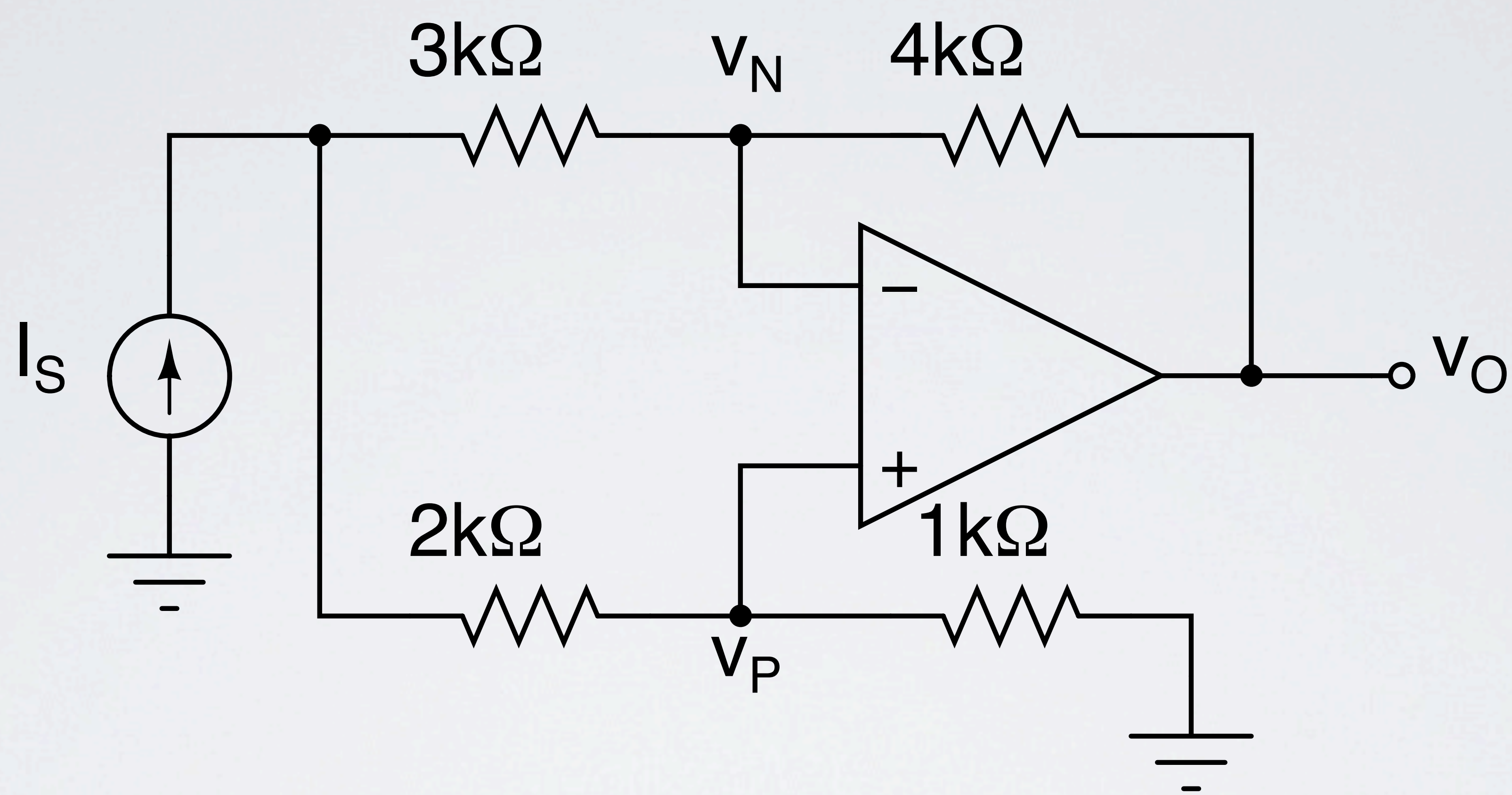
REVIEW PARTIAL EXAM 3

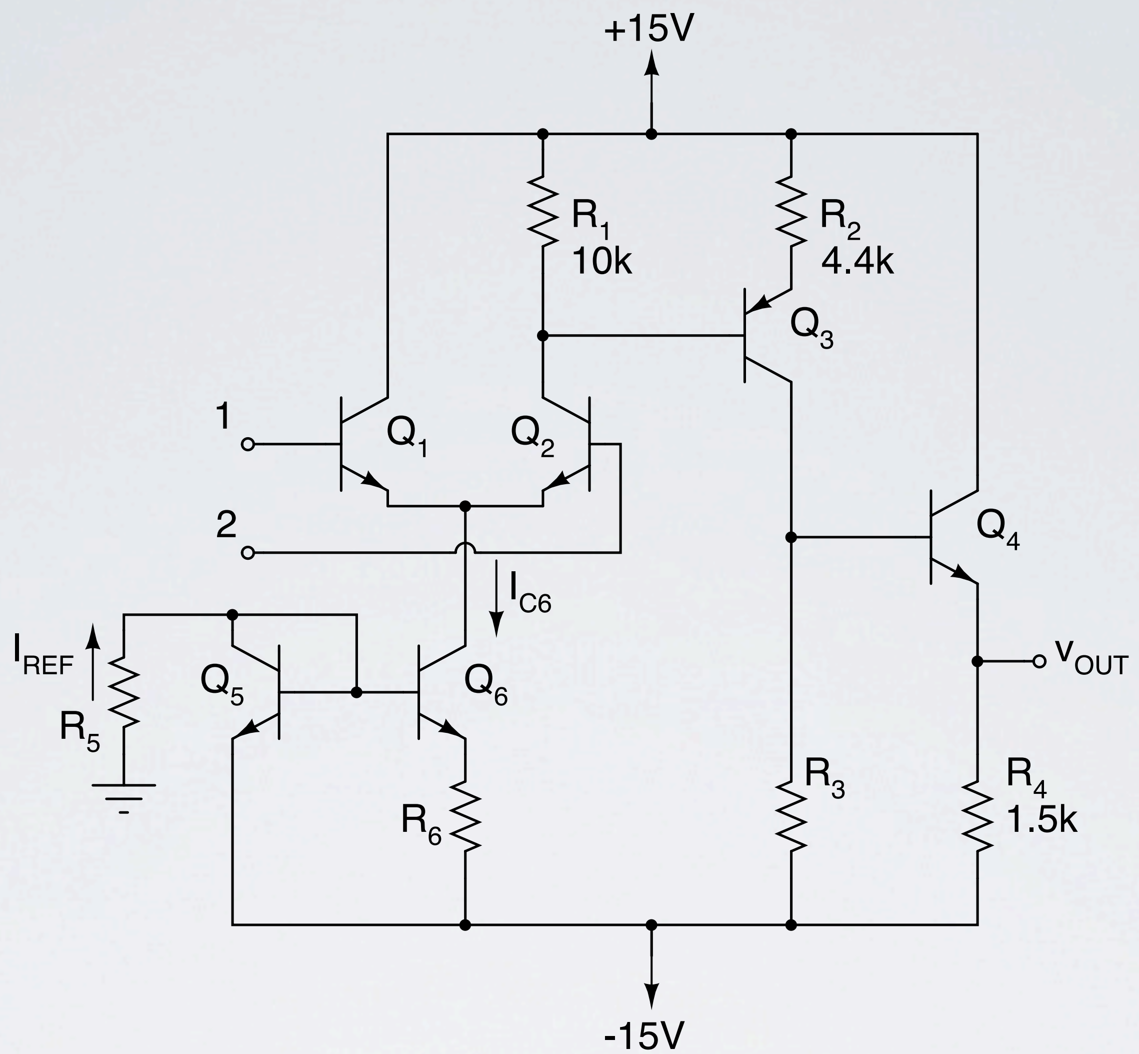
INEL 4202 Electronics II
Fall 2012

TOPICS

Topic	Section	Practice problems
Operational amplifiers, Summers, integrators, inverting and non-inverting amplifiers	2.1- 2.4	2(1, 2, 8, 9, 11, 12, 16, 20, 22, 30, 44, 46, 49, 60, 62, 72, 74)
Integrators and differentiators, Applications	2.8	2.112, 2.113
Current sources	6.3, 6.12	6.21, 6.22, 6.23, 6.30, 6.31, 6.33, 6.131, 6.140, 6.141, 6.142, 6.143
The differential amplifier	7.1-3, 7.5	7.1, 7.2, 7.11, 7.14, 7.15, 7.17, 7.20, 7.21, 7.37, 7.38, 7.39, 7.40, 7.41, 7.42, 7.62, 7.67, 7.68, 7.74
DC analysis of the 741 opamp	9.3, 9.4…	9.20, 9.21, 9.22, 9.25, 9.27, 9.35, 9.37
AC analysis of the 741 op-amp	9.5	9.40, 9.41, 9.46, 9.47, 9.48
Frequency response and slew rate	9.6	9.57, 9.60, 9.61
CMOS opamp DC and AC analysis	9.1	9.2, 9.3, 9.5
Freq. resp. and slew rate of CMOS opamp	9.2	9.7, 9.8, 9.9


3kΩ
v_N
4kΩ
I_S
v_O
2kΩ
1kΩ
v_P

$\beta = 100$



1. Assuming $R_5 = 50k\Omega$, $R_3 = 10k\Omega$, $R_6 = 0$, and that the area of Q_6 equals 5 times the area of Q_5, find:
   (a) the differential gain $A_d = \frac{v_{OUT}}{v_1 - v_2}$ (40 points)
   (b) the input resistance R_{in} seen by differential signals between terminals 1 and 2. (15 points)
   (c) the output resistance R_{out} at the output terminal. (15 points)
2. Assuming $I_{C6} = 1mA$, select R_3 so that $v_{OUT} \approx 0V$ when $v_1 = v_2 = 0V$. (15 points)
3. Select R_5 and $R_6 \neq 0$ such that $I_{C6} = 5 \times I_{REF}$ and $I_{C6} = 1mA$. (15 points)
4. Find the Common-mode rejection ratio (CMRR) for your selection of R_6 in the previous problem. Assume $V_A = 100V$. (15 points)

1.(a) To find the gain, we need to determine the bias currents.

$$I_{REF} = \frac{15-.7}{R_5} = \frac{14.3V}{50k} = 286\mu A$$

$$I_{C6} = 5 \times I_{REF} = 1.43 \text{ mA}.$$

$$I_{C2} = \frac{1}{2} I_{C6} = 0.715 \text{ mA} \leftarrow$$

$$\therefore V_{C2} = 15 - 10K(.715mA) = 7.85V$$

$$I_{C3} = \frac{15V - (V_{C2}+.7)}{4.4k\Omega} = \frac{15-(7.85+.7)}{4.4k} = 1.47 \text{ mA}$$

$$\therefore V_{B4} = -15 + (1.47mA)(R_3) = -15 + (1.47mA)(10K)$$

$$= -0.34V$$

$$I_{E4} = \frac{V_{B4} - .7 + 15}{1.5k} = 9.3 \text{ mA}$$

From this we can find the g_m's

$$g_{m2} = \frac{.715mA}{25mV} = 0.0286 \text{ A/V}$$

$$g_{m3} = \frac{1.47mA}{25mV} = 0.0588 \text{ A/V}$$

$$g_{m4} = \frac{9.3mA}{25mV} = 0.372 \text{ A/V}$$

The load at the collector of C_2 is

$$R_{C2} = R_1 // (r_{\pi 3} + (\beta+1) 4.4k)$$

$$= 10k // \left[\frac{100(25)}{1.47} + 101 \times 4.4k\right] = 9.78K\Omega$$

$$\therefore \frac{v_{C2}}{v_1 - v_2} = +\frac{1}{2} g_{m2} R_{C2} = \frac{1}{2}(0.0286 A/V)(9.78k\Omega) = 140 \text{ V/V}$$

Monday, November 19, 12

$$\frac{v_{c3}}{v_{c2}} = \frac{-g_{m3} R_{c3}}{1 + g_{m3} R_2}$$

$$R_{c3} = R_3 // (r_{\pi 4} + 101 \times 1.5k\Omega) = 10k // \left(\frac{100}{.372} + 151.5k\right)$$

$$= 10k // (151.8k\Omega = 9.38k\Omega \;\leftarrow$$

$$\frac{v_{c3}}{v_{c2}} = \frac{-.0588 \times 9.38k\Omega}{1 + .0588 \times 4.4k} = -2.12\,v/v \;\leftarrow$$

$$\frac{v_{e4}}{v_{c3}} = \frac{+g_{m4} R_4}{1 + g_{m4} R_4} = \frac{.372(1500)}{1 + .372 \times 1500} = 0.998 \;\leftarrow$$

$$A_d = (+140\,v/v)(-2.12\,v/v)(.998\,v/v) = \boxed{-296.3\,v/v} \;\leftarrow$$

(b) $R_{in} = 2 r_\pi = 2 \times \frac{100}{g_{m2}} = 2 \times \frac{100}{.0286 A/v} \doteq \boxed{7k\Omega}$

(c) $R_{out} = 1.5k // \frac{r_{\pi 4} + R_3}{101} = 1.5k // \frac{\frac{100}{.372} + 10k\Omega}{101} = \boxed{95.2\,\Omega}$

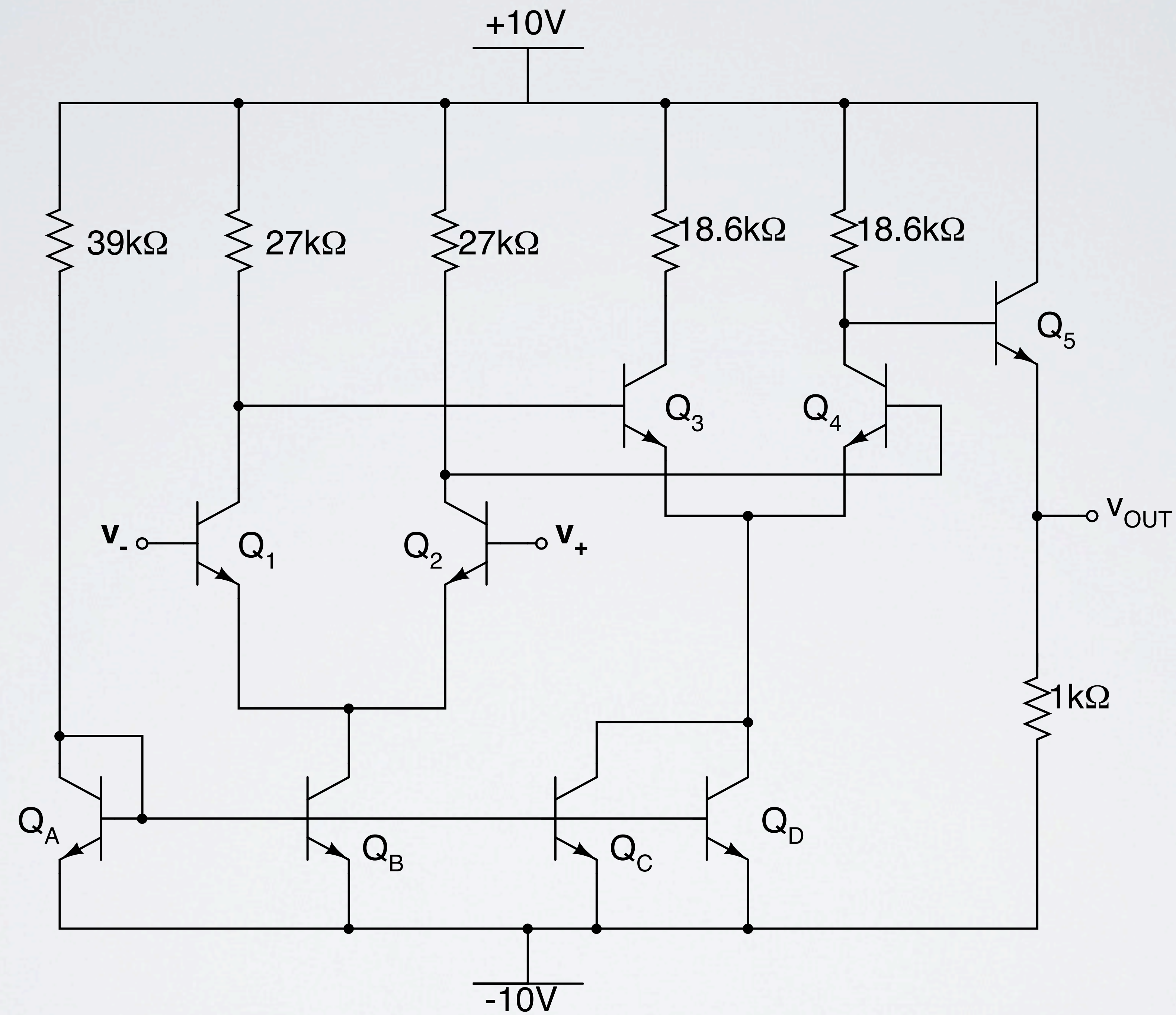
(2) if $I_{C6} = 1mA$, $I_{C2} = .5mA$, $V_{C2} = 10V$; $I_{C3} = \frac{15 - 10.7}{4.4k} = .98\,mA$

For $V_{out} = 0$, $V_{C3} = +0.7v$; $\therefore R_3 = \frac{15.7v}{.98mA} = \boxed{16k\Omega}$

(3) Widlar Current Source

$I_O R_M = V_T \ln\left(\frac{I_{REF}}{I_O}\right)$; $I_{REF} = 2mA \Rightarrow R_5 = \frac{14.3v}{2mA} = \boxed{\text{[crossed out]}}$ $= 7.15k\Omega$

$R_6 = \frac{25mv}{1mA} \ln(2) = 17.3\,\Omega$


+10V
39kΩ
27kΩ
27kΩ
18.6kΩ
18.6kΩ
Q5
Q3
Q4
v-
Q1
Q2
v+
vOUT
1kΩ
QA
QB
QC
QD
-10V