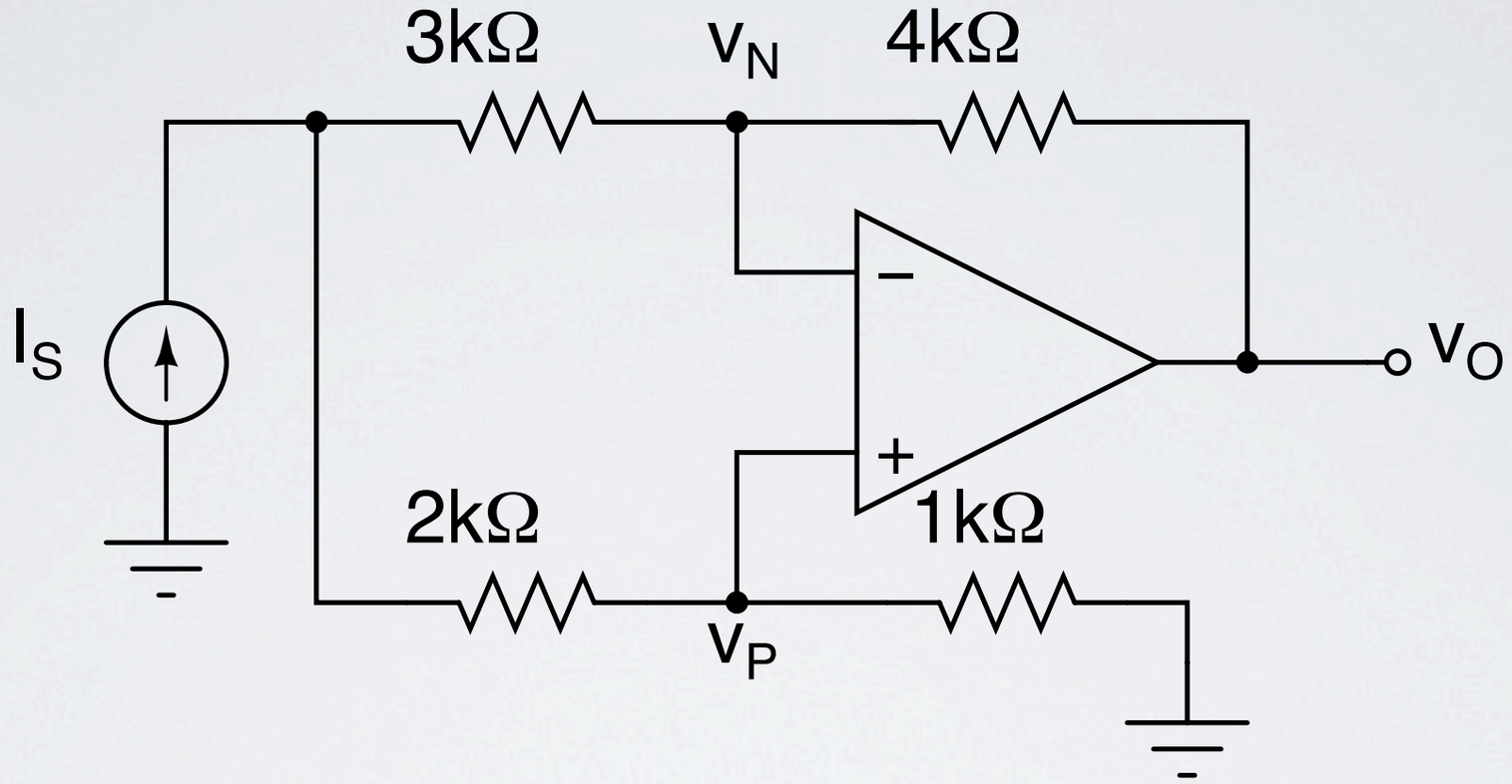
REVIEW PARTIAL EXAM 3

INEL 4202 Electronics II

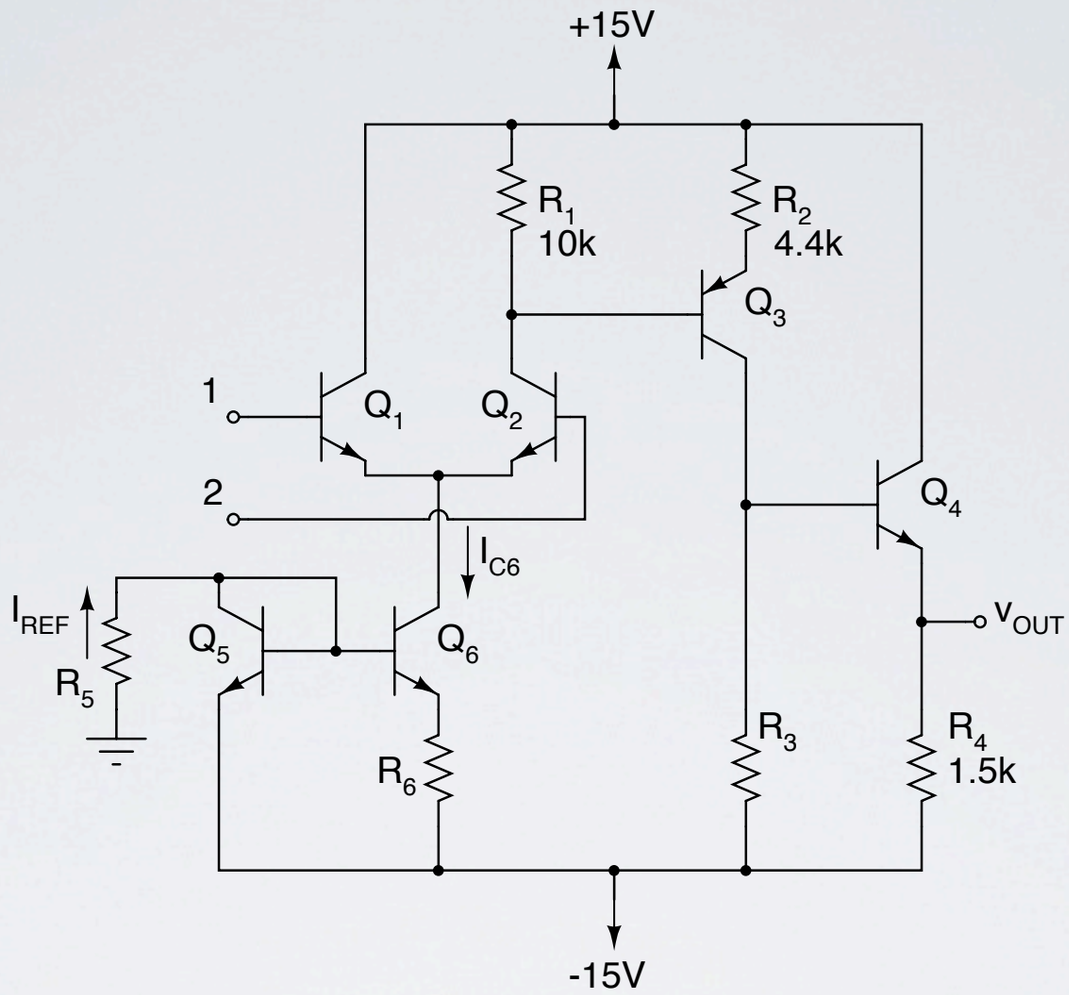
Spring 2013

TOPICS

17 (3/19)	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)
18 (3/21)	Integrators and differentiators, Applications	2.5	2.79, 2.80
19 (4/2)	Current sources	7.(4,5)	7.(46, 47, 48, 55, 56, 58, 67, 70, 76, 77, 78)
20 (4/4)	The differential amplifier	8.(1-3, 5)	8.(1, 2, 9, 25, 27, 29, 32, 33, 53, 60, 61, 62, 63, 64, 85, 91, 94, 102)
21 (4/9)	DC analysis of the 741 opamp	12.(3,4)	12.(23, 24, 25, 28, 29, 37, 39)
22 (4/11)	AC analysis of the 741 op-amp	12.5	12.(42, 43, 47, 50)
23 (4/18)	Frequency response and slew rate	12.6	12.(59, 62, 63)
24 (4/23)	CMOS opamp DC and AC analysis	12.1	12.(2, 3, 5, 6)
25 (4/25)	Freq. resp. and slew rate of CMOS opamp		12.(9, 10, 11)
26 (4/30)	Folded cascode opamp	12.2	12.(15, 16, 18, 19)


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 $i_{C6}=I_{REF}/5=0.2mA$ and equal areas for Q_5 and Q_6
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.

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

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

$$I_{C_2} = \frac{1}{2} I_{C6} = 0.715\ mA \longleftarrow$$

$$\therefore V_{C_2} = 15 - 10K\,(.715mA) = 7.85V$$

$$I_{C_3} = \frac{15V-(V_{C_2}+.7)}{4.4K\Omega} = \frac{15-(7.85+.7)}{4.4K} = 1.47\ mA$$

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

$$= \underline{-0.3V}$$

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

From this we can find the g_m's

$$g_{m_2} = \frac{.715mA}{25mV} = 0.0286\ A/V$$

$$g_{m_3} = \frac{1.47mA}{25mV} = 0.0588\ A/V$$

$$g_{m_4} = \frac{9.3mA}{25mV} = 0.372\ A/V$$

The load at the collector of C_2 is

$$R_{C_2} = R_3 // (r_{\pi 3} + (\beta+1)\,4.4K)$$

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

$$\therefore \frac{v_{C_2}}{v_1 - v_2} = +\frac{1}{2} g_{m_2} R_{C_2} = \frac{1}{2}(0.0286A/V)(9.78K\Omega) = 140\ V/V$$

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

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

$$= 10k // (151.8k\Omega = 9.38k\Omega \quad \text{◁}$$

$$\frac{v_{c3}}{v_{c2}} = \frac{-.0588 \times 9.38k\Omega}{1 + .0588 \times 4.4k} = -2.12\,V/V \quad \text{◁}$$

$$\frac{v_{eq}}{v_{c3}} = \frac{+g_{m4} R_4}{1 + g_{m4} R_4} = \frac{.372(1500)}{1 + .372 \times 1500} = 0.998 \quad \text{◁}$$

$$A_d = (+140 V/v)(-2.12 V/v)(.998 V/v) = \boxed{-296.3\,V/v} \quad \text{◁}$$

(b) $R_{in} = 2r_\pi = 2 \times \frac{100}{g_{m_2}} = 2 \times \frac{100}{.0286 A/V} \simeq \boxed{7k\Omega}$

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

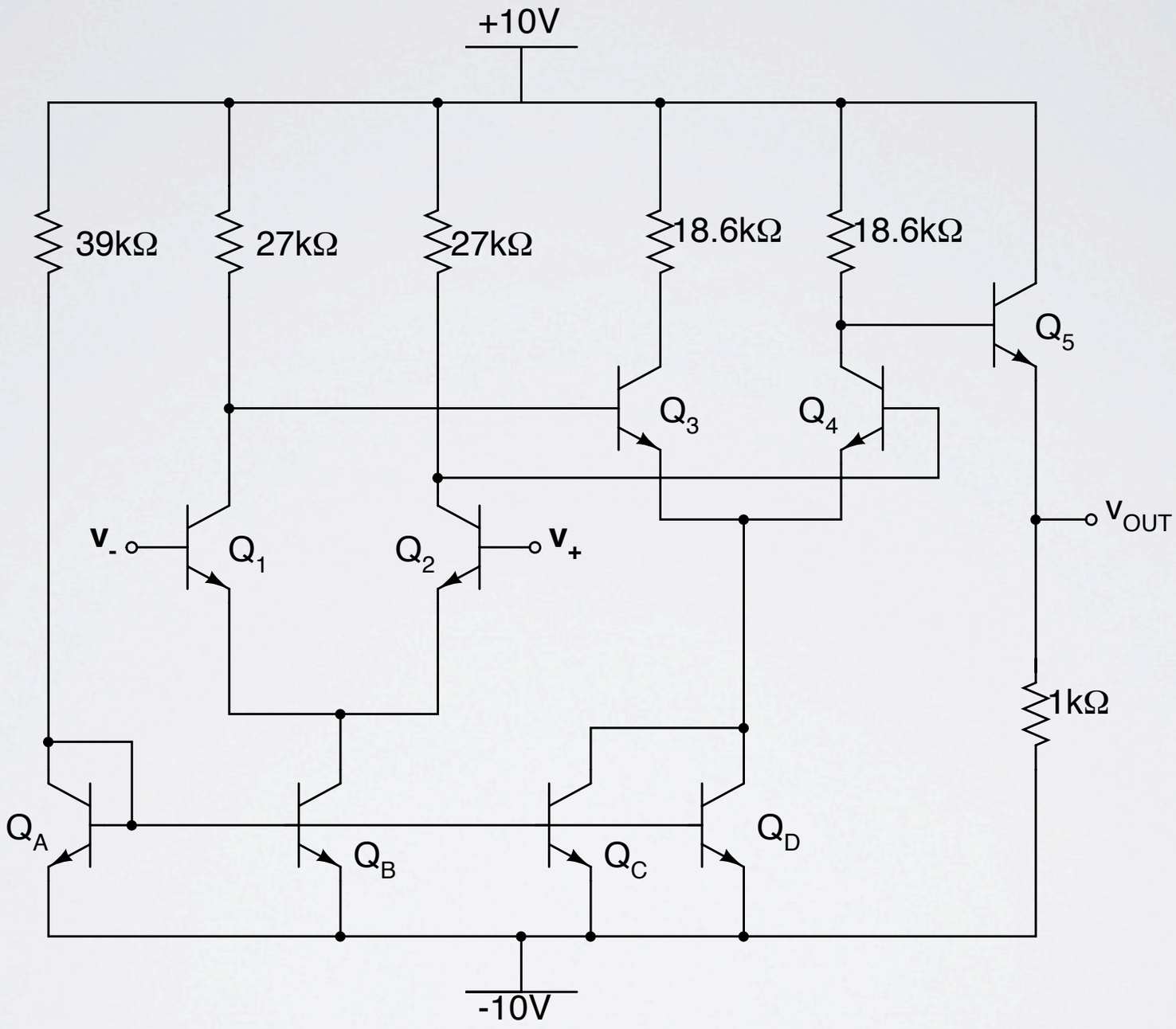
For $V_{out} = 0$, $V_{C3} = +0.7V$; $\therefore R_3 = \frac{15.7V}{.98mA} = \boxed{16k\Omega}$

3) $R_5 = (15V - 0.7)/1mA = 14.3k$; $R_6 = (V_T/I_{C6}) * \ln(I_{REF}/I_{C6}) = (0.025V/0.2mA)\ln(5) = 201$ Ohms.

4) $R_{CS} = r_{O6}(1 + g_{m6} \text{ x } R_6) = (100V/0.2mA)\{1 + (0.2mA/0.025V)201\} = 1.3$MOhms

$|A_{CM}| = g_{m2}R_{c2}/(1 + 2g_{m2}R_{CS}) \simeq R_{c2}/2R_{CS} = 10k/2.6M = 0.00192V/V$

Re-calculate A_{dm} with the new I_{C6}=0.2mA and calc. CMRR=20xlog($|A_{dm}/A_{cm}|$)


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