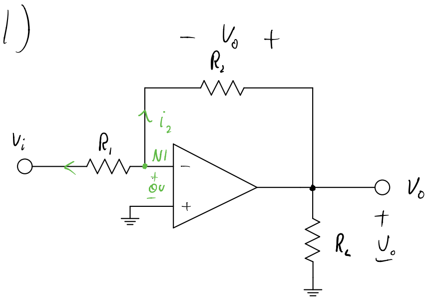
1)



$$N1: \frac{V_1 - V_i}{R_1} + \frac{V_1 - V_o}{R_2} = 0 \qquad V_1 = 0\,V$$

$$\cancel{\frac{V_1}{R_1}}^{\,0} - \frac{V_i}{R_1} + \cancel{\frac{V_1}{R_2}}^{\,0} - \frac{V_o}{R_2} = 0$$

$$\frac{V_i}{R_1} = -\frac{V_o}{R_2} \Rightarrow \frac{V_o}{V_i} = -\frac{R_2}{R_1}$$

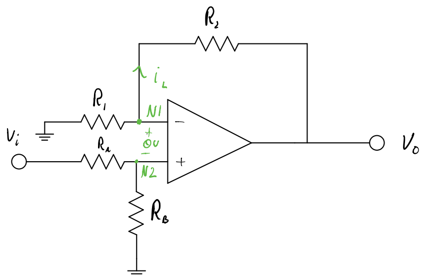
$$\boxed{A_v = -\frac{R_2}{R_1}}$$

$$\frac{V_o}{V_i} = -\frac{R_2}{R_1} \Rightarrow V_i = -V_o\frac{R_1}{R_2}$$

$$V_o = R_2\, i_2$$

$$V_i = -R_2\, i_2 \frac{R_1}{R_2} \Rightarrow \boxed{V_i = R_1\, i_2}$$

2)



$$N1: \frac{V_1 - 0}{R_1} + \frac{V_1 - V_o}{R_2} = 0$$

$$N2: \frac{V_1 - V_i}{R_A} + \frac{V_1 - 0}{R_B} = 0$$

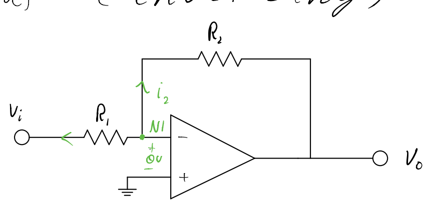
$$V_1 = \left(\frac{1}{R_1} + \frac{1}{R_2}\right)^{-1}\frac{V_o}{R_2}$$

$$V_1 = \left(\frac{1}{R_A} + \frac{1}{R_B}\right)^{-1}\frac{V_i}{R_A}$$

$$\frac{V_o}{V_i} = \frac{\left(\frac{1}{R_1} + \frac{1}{R_2}\right)R_2}{\left(\frac{1}{R_A} + \frac{1}{R_B}\right)R_A} = \frac{\frac{R_2}{R_1} + 1}{\frac{R_A}{R_B} + 1}$$

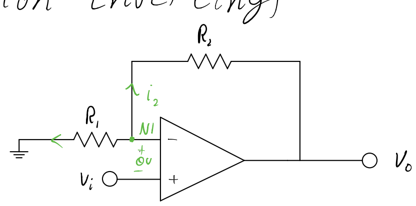
$$\boxed{A = \frac{\frac{R_2}{R_1} + 1}{\frac{R_A}{R_B} + 1}}$$

3) a) (inverting)



$$G = \frac{-R_2}{R_1\left(1 + \frac{1}{A}\left(1 + \frac{R_2}{R_1}\right)\right)}$$

b) (non-inverting)

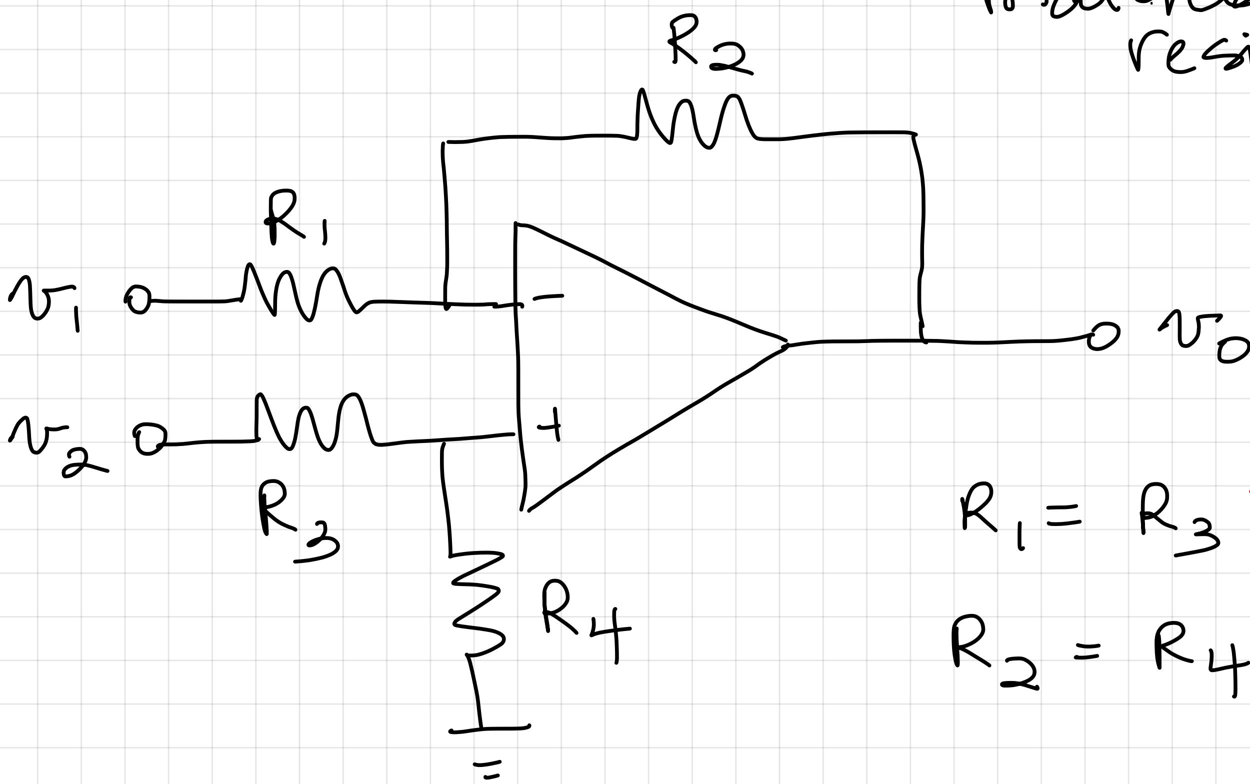


$$G = \frac{1 + \frac{R_2}{R_1}}{1 + \frac{1}{A}\left(1 + \frac{R_2}{R_1}\right)}$$

Quiz 2B - Solutions

① Difference Amp (ideal op-amp

matched resistors



$R_1 = R_3$

$R_2 = R_4$

$R_{id} = 2R_1$ $\qquad A_d = \dfrac{R_2}{R_1}$ $\qquad A_{cm} = 0$

$R_2 = R_1(A_d)$

Option 1: $R_{id} = 25\,k\Omega$ $\qquad R_1 = R_3 = 12.5\,k\Omega$

$A_d = 25\,V/V$ $\qquad R_2 = R_4 = 312.5\,k\Omega$

Option 2: $R_{id} = 50\,k\Omega$ $\qquad R_1 = R_3 = 25\,k\Omega$

$A_d = 12\,V/V$ $\qquad R_2 = R_4 = 300\,k\Omega$

Option 3: $R_{id} = 100k\Omega$ $\quad R_1 = R_3 = 50k\Omega$

$A_d = 40\ V/V$ $\quad R_2 = R_4 = 2M\Omega$

Option 4: $R_{id} = 75k\Omega$ $\quad R_1 = R_3 = 37.5\ k\Omega$

$A_d = 30\ V/V$ $\quad R_2 = R_4 = 1.13\ M\Omega$

② Instrumentation Amp (see Problem set 2B)

second stage

$$A_d = \left(1 + \frac{2R_2}{2R_1}\right)\left(\frac{R_4}{R_3}\right)$$

$2R_1 = R_f + \text{pot}$

- max gain: R_f
- min gain: $R_f + \text{pot}$

---

10 - 1000 V/V	4 - 400 V/V
$\frac{R_4}{R_3} = 4$ (lots of options)	$\frac{R_4}{R_3} = 1$ (lots of designs)
$\left(1 + \frac{2R_2}{2R_1}\right) = 2.5$ to 250	$\left(1 + \frac{2R_2}{2R_1}\right) = 4$ to 400
pot $= 10k\Omega$	pot $= 100k\Omega$
$R_2 = 7.54\ k\Omega$	$R_2 = 151.14\ k\Omega$
$R_f = 60.61\Omega$	$R_f = 757.58\Omega$

8 - 800 V/V

$\frac{R_4}{R_3} = 3$ (lots of options)

$R_2 = 8.39\,k\Omega$

$R_f = 63.13\,\Omega$

$\left(1 + \frac{2R_2}{2R_1}\right) = 2.67$ to 267.67

pot = $10k\,\Omega$

---

3 - 300 V/V

$R_2 = 100.67\,k\Omega$

$\frac{R_4}{R_3} = 1$ (lots of options)

$R_f = 673.41\,\Omega$

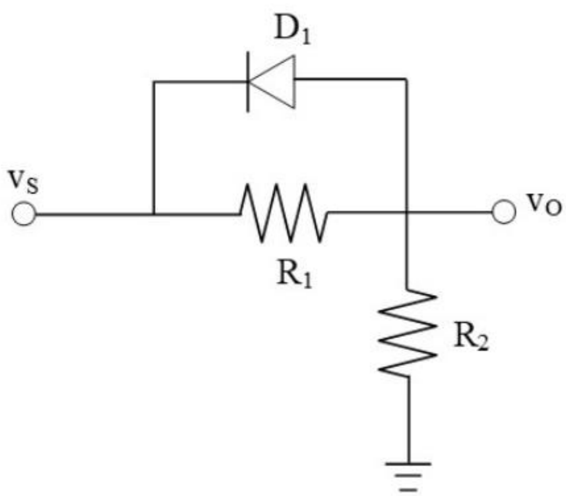
$\left(1 + \frac{2R_2}{2R_1}\right) = 3 - 300$ V/V

pot = $100k\,\Omega$

EE 315 20F Quiz 3 – Solutions/Rubric

Problem 1: 4 possible problems

Circuit 1:



If D_1 is on, v_S is less than zero such that current will flow from ground, through the diode. The diode acts like a short circuit and shorts out R_1.

If D_1 is off, then v_s is greater than zero and the diode will shut off and act like an open circuit, v_O is then determined by the voltage divider.

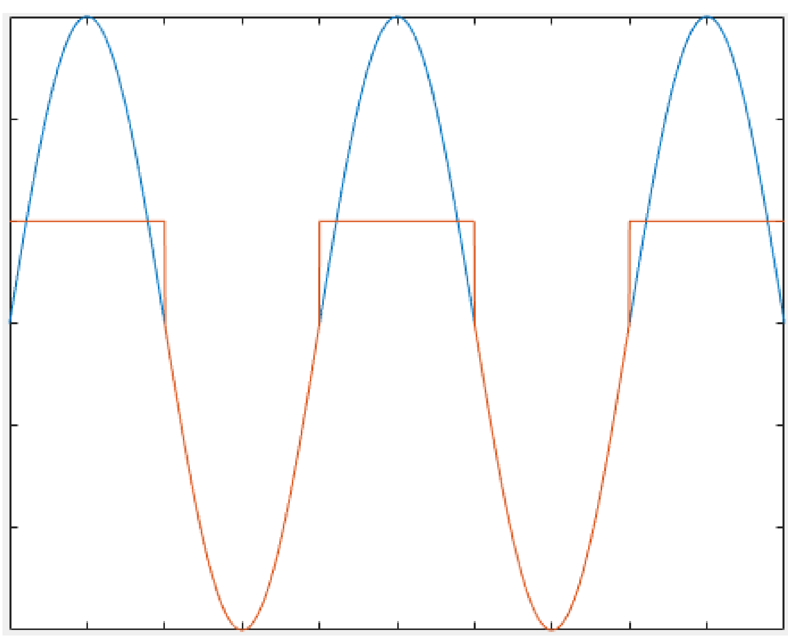
So:

$v_O = v_S$ when D1 is on for $v_S<0$

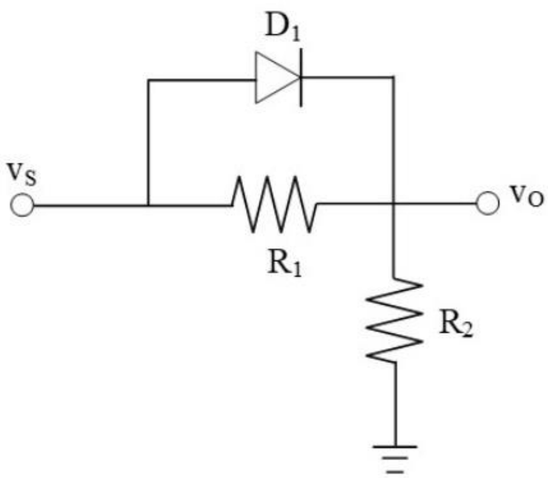
$v_O = \frac{R_2}{R_1+R_2} * v_S$ when D1 is off for $v_S>0$

v_S	R_1	R_2	v_O
+ 6V - 6V	4 kΩ	2 kΩ	2V - 6V
+ 8V - 8V	2 kΩ	6 kΩ	6V - 8V

blue = v_S and red = v_O



Circuit 2:



If D_1 is on, then v_s is greater than zero and the diode will be on and act like an short circuit. The diode acts like a short circuit and shorts out R_1.

If D_1 is off, v_S is less than zero such that current will flow from ground. v_O is then determined by the voltage divider.

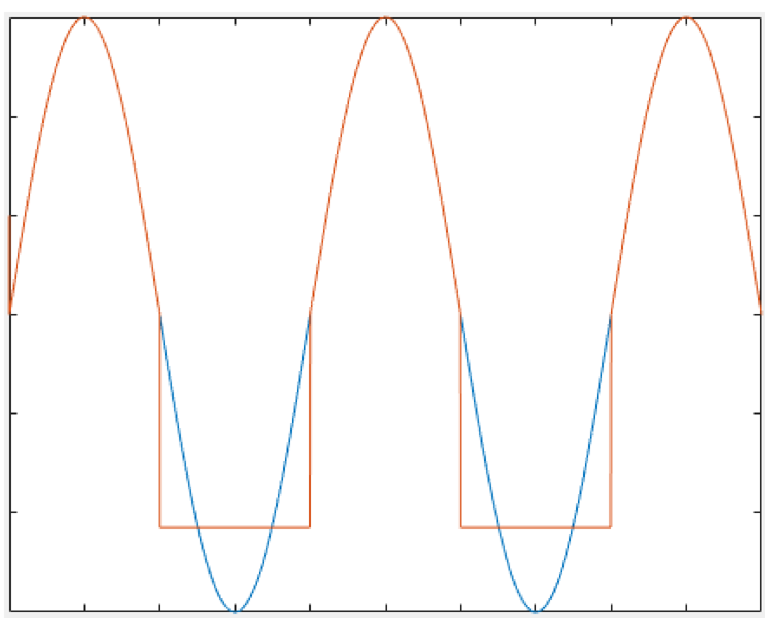
So:

$v_O = v_S$ when D1 is on for $v_S>0$

$v_O = \frac{R_2}{R_1+R_2} * v_S$ when D1 is off for $v_S<0$

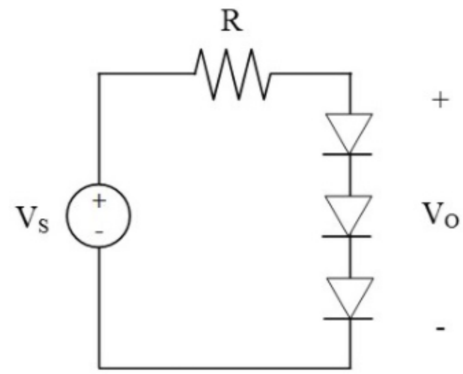
v_S	R_1	R_2	v_O
+ 2V - 2V	4 kΩ	4 kΩ	2V - 1V
+ 10V - 10V	4 kΩ	3 kΩ	10V - 4.29V

blue = v_S and red = v_O



Problem 2: 4 possible problems

These problems are all solved the same way, just the values are different.



Use the iteration method for diodes operating in the forward bias region.

Given: V_{D1} and I_{D1} and the source voltage, V_S, and output voltage across 3 diodes, V_O.

V_O represents the total voltage across three diodes so each diode will get 1/3 of the voltage. From this information, we can find V_{D2}.

$$V_{D2} = \frac{V_O}{3}$$

Now, using the forward bias equation:

$$I_{D2} = I_{D1} * \exp\left(\frac{V_{D2} - V_{D1}}{kT}\right)$$

Now that we know I_{D2}, we can find R by Ohm's Law.

$$R = \frac{(V_S - V_O)}{I_{D2}}$$

I_{D1}, V_{D1}	I_{D2}, V_{D2}	R
0.8mA, 0.7 V	11.51 mA, 0.767 V	234.51 Ω
0.9mA, 0.71 V	32.94 mA, 0.8 V	78.94 Ω
1.1 mA, 0.75 V	443.77 mA, 0.9 V	7.44 Ω
1.0 mA, 0.68 V	93.07 mA, 0.793 V	60.39 Ω

RUBRIC:

Problem 1 – 10 points

10 points	All work shown including plot (plot does not have to be perfectly labeled) and a hand sketch is fine.
Up to 4 points	Showed work such that they understood what would happen if D1 was on including the conditions and the resulting output voltage.
Up to 4 points	Showed work such that they understood what would happen if D1 was off including the conditions and the resulting output voltage
2 points (All or nothing)	Sketch of source and output waveforms – do not need to be perfect or computer generated, but should show that the student understood the circuit. If the sketch matches their work, but the work is incorrect, still give full credit.
NOTES	2 points off (each instance) if they didn't seem to understand voltage division or the passive sign convention for Ohm's law. Please check to ensure that the problem they solved was the problem they were given!

Problem 2 – 10 points

10 points	All work shown including solutions for all currents and voltages and the resistor
2 points (All or nothing)	Understood that the individual diode voltages were 1/3 of the output voltage, Vo.
Up to 5 points	Showed work such that they understood how to solve the problem using the iterative method, used the kT values correctly, and found the current ID2.
3 points	Found R using Ohm's law/KVL. If they made an error solving for ID2 or VD2 but solved for R using the correct equation, give full credit. Take 2 points off if they use Vo or Vs (alone) as the voltage across the resistor.
NOTES	Please check to ensure that the problem they solved was the problem they were given!

EE 315 – Module 5 Quiz – Solutions

1. BJT operating in active mode. You were given an operating point for (V_{BE}, I_C). Then asked to find V_{BE} for a new value of I_C.

$$V_{BE2} = V_{BE1} + V_T \cdot \ln\left(\frac{I_{C2}}{I_{C1}}\right)$$

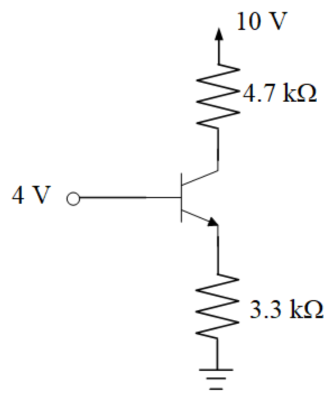
Operating Point (V_{BE1}, I_{C1})	New point (V_{BE2}, I_{C2})
(0.72V, 4.5 mA)	I_C = 6.8 mA, so V_{BE} = V
(0.75V, 2.2 mA)	I_C = 4.3 mA, so V_{BE} = 0.767 V
(0.79V, 11.4 mA)	I_C = 9.3 mA, so V_{BE} = 0.785 V

2. BJT operating in active mode. Given i_E and i_C. Solve for i_B (mA) and β and α.

$$i_B = i_E - i_C \qquad \beta = \frac{i_C}{i_B} \qquad \alpha = \frac{i_C}{i_E}$$

i_E	i_C	i_B	β	α
0.812 mA	0.8 mA	.012 mA	66.7	0.99
1.208 mA	1.2 mA	0.008 mA	150	0.99
2.767 mA	2.75 mA	0.172 mA	160	0.99

3. Given the following npn BJT with V_{BE}=0.75 V and α=.99. What are the base, collector, and emitter currents?



EE 315 Module 6 Quiz Solutions

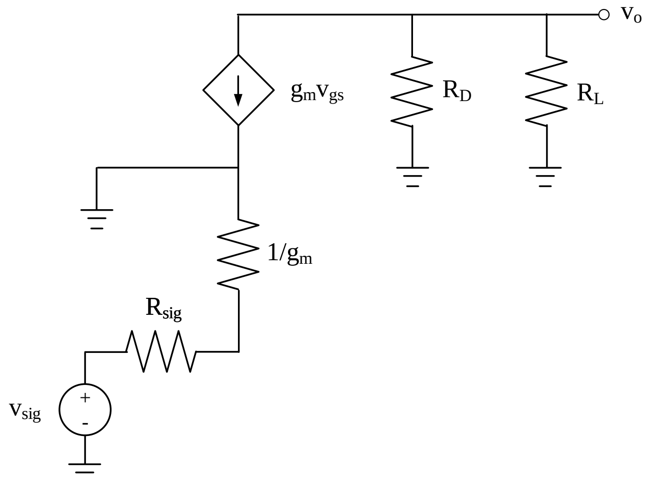
Fall 2020

1. Common Gate Amplifier

A common gate amplifier uses an NMOS transistor with a drain resistor, R_D. The amplifier has a signal resistance, R_{sig} and is terminated with a load resistor, R_L. Given the input resistance, R_{in}, find g_m and G_V.

$$g_m = \frac{1}{R_{sig}}$$

$$G_V = \frac{v_o}{v_{sig}} = \frac{(R_D||R_L)}{R_{sig} + {}^1\!/g_m}$$



Version	R_{sig} (Ω)	R_D (k Ω)	R_L (k Ω)	R_{in} (Ω)	g_m (mA/V)	G_V (V/V)
1	500	6	8	320	3.13	4.18
2	500	6	4	280	3.57	3.08
3	500	6	10	625	1.60	3.33

2. Common Source Amplifier

You are given a MOSFET (n-type) in the common source configuration with values for k_n', V_t, λ, W/L, and I_{DQ}. You were asked to solve: V_{GSQ}, r_o, and g_m.

$$V_{GSQ} = V_t + \sqrt{\frac{2I_{DQ}}{k_n' \frac{W}{L}}}$$

$$g_{m=} k_n' \frac{W}{L} (V_{GSQ} - V_t)$$

$$r_o = \frac{1}{\lambda I_{DQ}}$$

Version	k_n' (μA/V²)	V_t (V)	λ (V⁻¹)	W/L	I_{DQ} (mA)	V_{GSQ} (V)	r_o (kΩ)	g_m (mA/V)
1	300	1.0	0.045	10	0.2	1.37	111.11	1.09
2	500	0.6	0.02	10	0.6	1.09	83.33	2.45
3	200	0.8	0.04	10	0.2	1.25	125.00	0.89