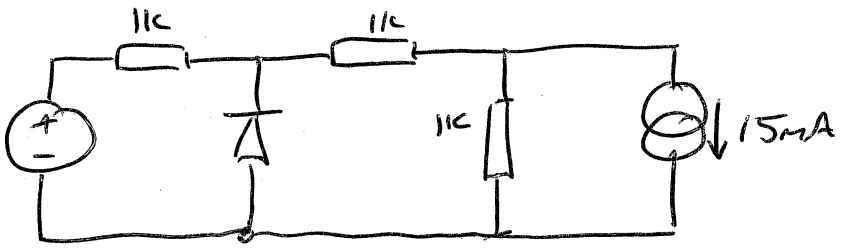
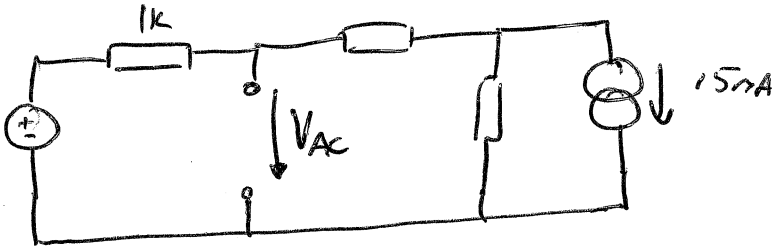
1ai

By Superposition:



If Diode not conducting...



For 6V source (15mA is o/c)

$$\therefore V_{AC} = -6 \cdot \frac{2K}{3K}$$

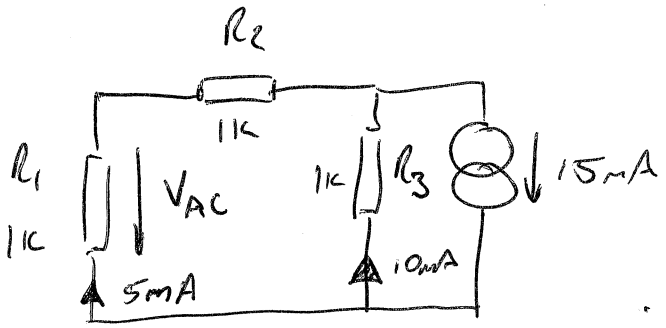
$$= \underline{-4V.}$$

From $\left[-\left(6 \cdot \frac{R_2 + R_3}{R_1 + R_2 + R_3} \right) \right]$

For 15mA source (6V is s/c)

$$\therefore V_{AC} = 15 \times 10^{-3} \cdot \frac{1}{3} \cdot 1K\Omega = \underline{5V}$$

This is because with the 6V s/c the cct becomes...

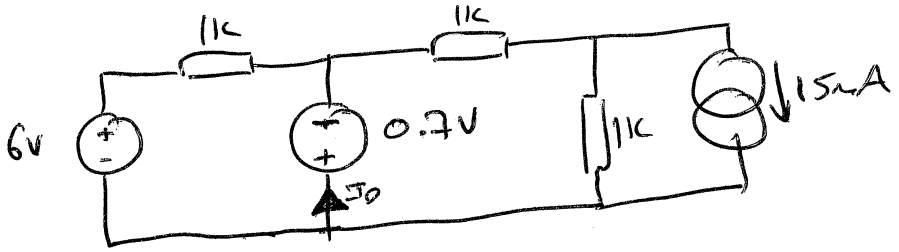


...which is a current divider circuit.

Total $V_{AC} = 5V - 4V = 1V$. $1V > 0.7V$ ∴

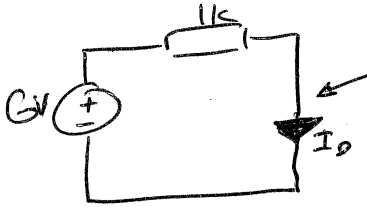
Diode conducts.

1a ii) CONDUCTION CURRENT...



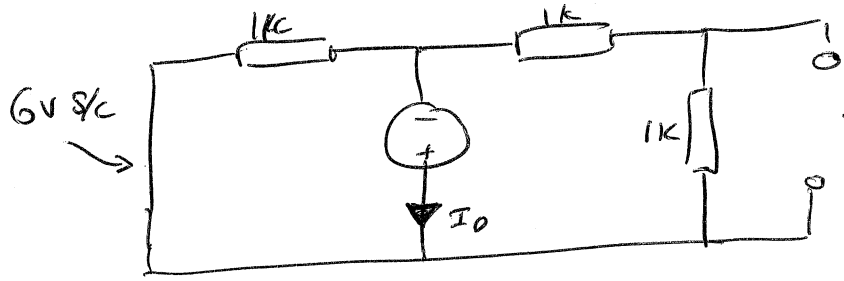
By SUPERPOSITION...

FOR 6V (V_D & 15mA S/C & O/C RESPECTIVELY)



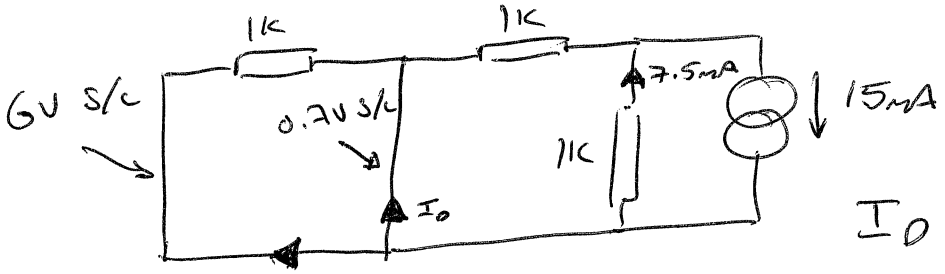
$I_D = 6mA$ (BUT LOOK AT THE DIRECTION)

FOR 0.7V (6V & 15mA S/C & O/C RESPECTIVELY).



$$I_D = \frac{0.7}{1K // (1K + 1K)} = \frac{0.7}{0.666} = 1.05mA$$

FOR 15mA (6V & 0.7V BOTH S/C)



THIS IS A CURRENT DIVIDER TOO.

$$I_D = 15mA \times \frac{1}{2} = 7.5mA$$

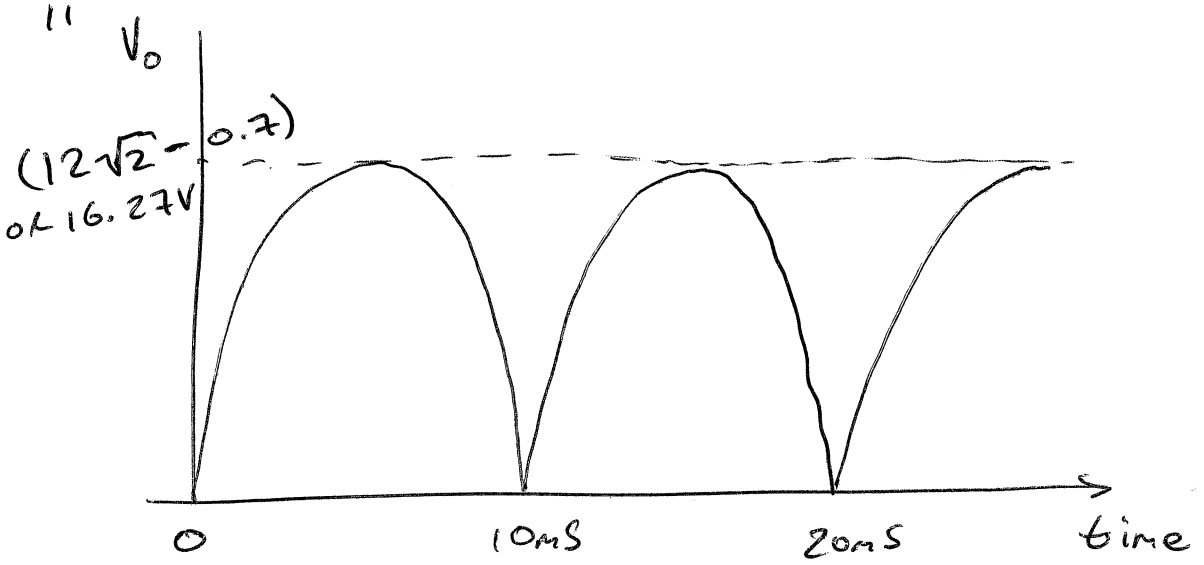
$$I_D = -6 - 1.05 + 7.5 \quad (mA)$$

$$= 0.45mA.$$

THESE SIGNS ARE FOUND BY LOOKING AT THE DIRECTION OF I_D IN EACH SUPERPOSITION CIRCUIT. THE CURRENT FLOWING ANODE TO CATHODE IS CONSIDERED POSITIVE.

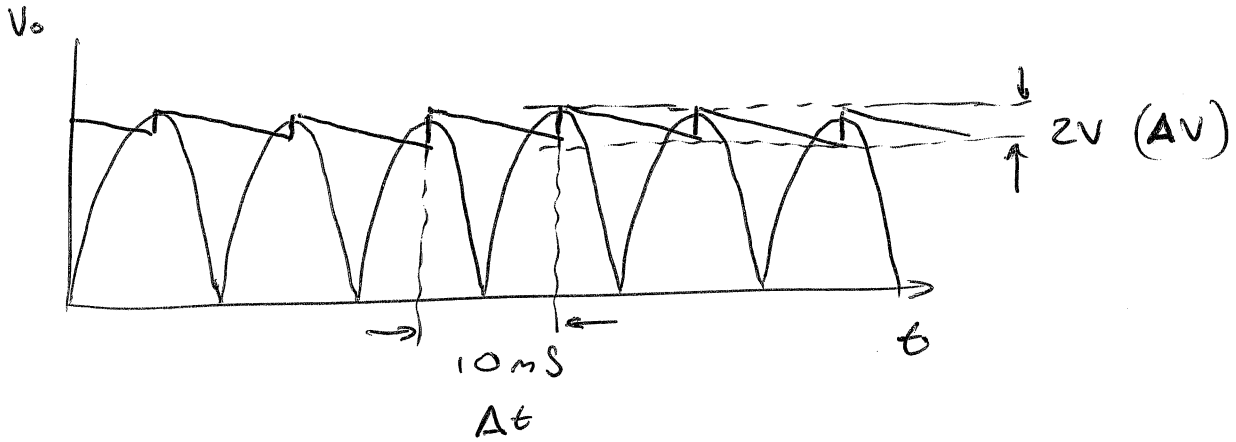
16 i FULL WAVE. (3)

ii



iii FROM ii $16.27/30$ = 542.3 mA

iv LOOKS LIKE



ASSUMING WORST CASE (PEAK CURRENT FLOWS ALWAYS)

$$I = C\frac{dV}{dt} \quad \therefore \quad C = \frac{I\,dt}{dV} = \frac{542.3\times10^{-3} \times 10\times10^{-3}}{2}$$

$$= 2{,}711.5\ \text{mF}$$

IF AVERAGE CURRENT IS USED...

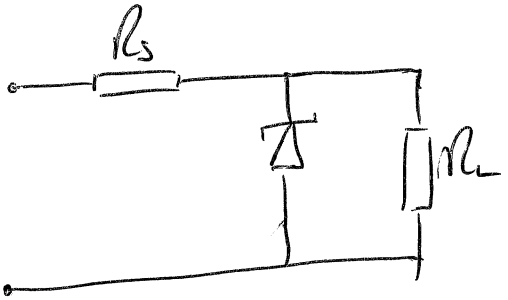
$$I_{MIN} = \frac{16.27 - 2}{30} = \underline{475.\dot{6}\,mA}$$

$$I_{AV} = \frac{542.\dot{3} + 475.\dot{6}}{2} = \underline{509\,mA}$$

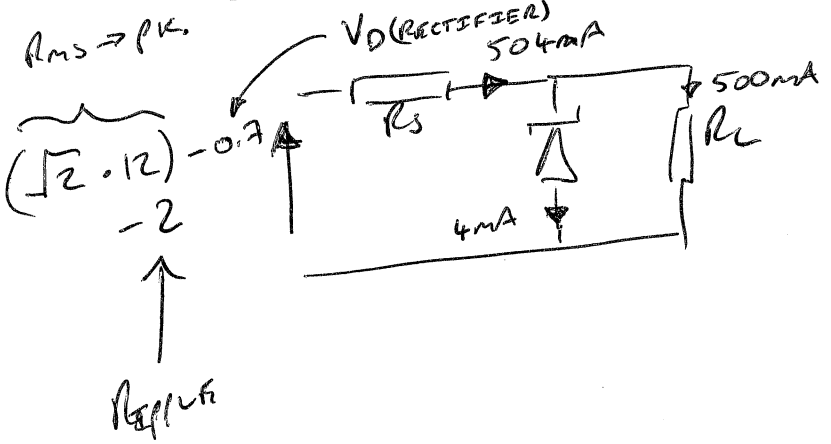
$$C = \frac{I\,dt}{dV} = \frac{0.509A \times 10mS}{2V} = \underline{2545\mu F}$$

ALL OTHER ANSWERS VALID AS LONG AS ASSUMPTIONS ARE REASONABLE AND STATED.

d i)



ii) MUST USE SMALLEST I/P VOLTAGE & LARGEST O/P CURRENT.



$$I_{R_S} = 500mA + 4mA = \underline{504\,mA}$$

$$V_{R_S} = 14.27 - 9 = \underline{5.27}$$

$$\therefore R_S = \frac{5.27}{504mA} = \underline{10.46\,\Omega}$$

iii) $P = I^2R =$ 2.65 WATTS

$\therefore$ >3 W BUT < 10 WATT. WOULD BROK.

iv) $P_D = V_D \times I_D$

↑

9V

(ZENER)

- WHEN CCT IS FULLY ON I_D IS A MINIMUM AT 4mA SO:

$P = 9 \cdot 4 \times 10^{-3} =$ 36mW

- WHEN CCT IS ON STANDBY I_D IS A MAXIMUM (ASSUMING THAT "NO LOAD" IS NOT A VALID OPTION)

$P = 9 \cdot (504 - 20)mA =$ 4.356WATTS

3ai) (6)

$$I_R = \frac{V_S - V_{CE(SAT)}}{R_L} = \frac{48 - 1.1}{10} = \underline{4.69\ A}$$

ii) $E = \frac{1}{2} LI^2 = \frac{1}{2} \cdot 80\times10^{-3} \cdot 4.69^2$

$= \underline{0.88\ J}$

iii) $P = I^2R = 4.69^2 \cdot 10 = \underline{219.96\ \text{WATTS}}$

iv) $P = IV = 4.69 \times 1.1(V) = \underline{5.159\ \text{WATTS}}$

IT IS OK TO INCLUDE B-E DISIPATION IF IT'S DONE CORRECTLY.

v) $I_B = \frac{I_C}{h_{FE}} = \frac{4.69}{100} = \underline{46.9mA}$

$V_B = V_i - 0.7$ ← $V_{BE(SAT)}$

$R_B = \frac{V_B}{I_B} = \frac{5 - 0.7}{46.9mA} = \underline{91.68\Omega}$

vi) POWER IN THE SWITCH SHOULD BE CONSTANT SO

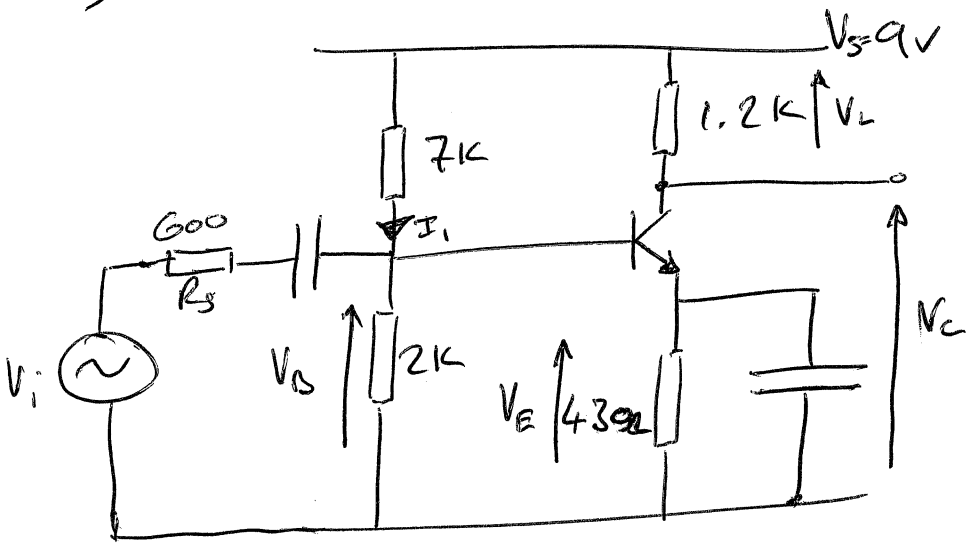
$I^2 r_{ds(ON)} = \underline{5.159\ W}$

↑

4.69A

$r_{ds(ON)} = \frac{5.159}{4.69^2} = \underline{0.235\Omega}$

c)



$$-V_B = V_S \cdot \frac{2K}{7K+2K} = \frac{2}{9} = 2V.$$

$$-I_1 = \frac{V_S - V_B}{7K} = \frac{9-2}{7K} = 1mA$$

$$-V_E = V_B - 0.7 = 1.3V$$

$$-I_E = V_E/430 = \frac{1.3V}{430} = 3.02mA$$

Assume $I_B = 0$...

$\therefore I_C = I_E$

$\therefore V_L = 1.2K \cdot 302\,mA = 3.624V$

And $V_C = V_S - V_L = 9 - 3.624 = 5.376V$

OR Assuming $I_B = 150$ (say)...

$$I_C + I_B = I_E$$

$$I_C + I_C/\beta = I_E$$

$1.006\, I_C = I_E$

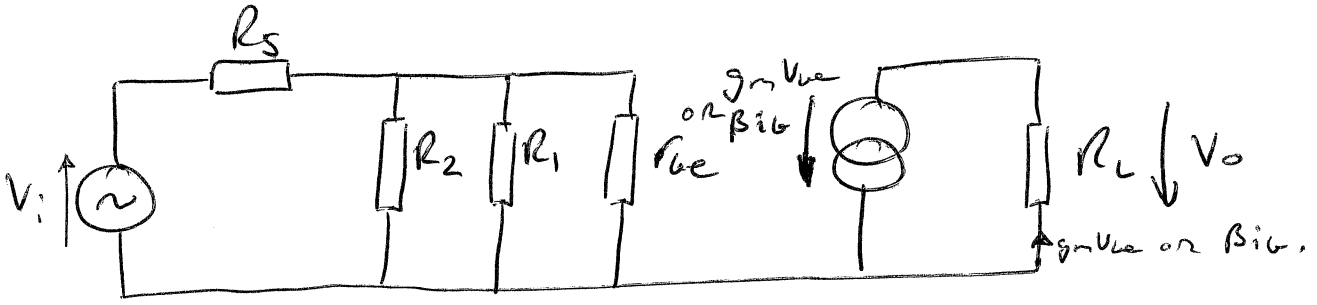
$$I_C = \frac{3.02mA}{1.006} = \underline{3mA}$$

$$\therefore I_B = I_E - I_C = 3.02 - 3\ (mA)$$
$$= \underline{20\mu A}$$

THEN $V_L = 1.2 \times 3 = \underline{3.6V}$

AND $V_C = V_S - V_L = 9 - 3.6 = \underline{5.4V}$

c)



$$V_{be} = V_i \cdot \frac{r_{be} // R_1 // R_2}{R_S + r_{be} // R_1 // R_2}$$

$$V_o = g_m r_{be} \cdot R_L$$

$$\frac{V_o}{V_i} = g_m R_L \cdot \frac{r_{be} // R_1 // R_2}{R_S + r_{be} // R_1 // R_2}$$

$$g_m = \frac{eI_C}{KT} = \frac{1.6 \times 10^{-19} \cdot 3mA}{1.38 \times 10^{-23} \cdot 300} \quad \rightarrow (\text{OR } 3.02\ mA..)$$

$$= 0.1159\ A/V$$

$$r_{be} = \beta / g_m = 150 / 0.1159 = \underline{1.2941 k\Omega}$$

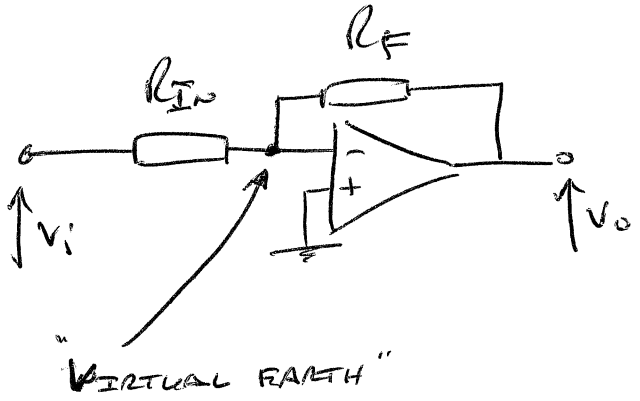
$$\frac{V_o}{V_i} = 0.1159 \cdot 1.2k \cdot \frac{(1.294k // 7k // 2k)}{600 + (1.294k // 7k // 2k)}$$

$$= 0.1159 \cdot 1.2k \cdot \frac{706.387}{1.3067}$$

$$= \underline{\underline{75.202}} \; V/V.$$

(Depends on Assumptions)

6 a i)

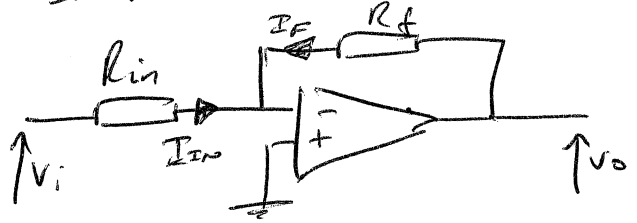


(10)

iii) THE VIRTUAL EARTH EXISTS DUE TO THE OPAMP OPERATION. THE OPAMP IS DESCRIBED BY ITS EQUATION $V_o = A_V(V^+ - V^-)$. ASSUMING A_V IS LARGE, THE OPAMP WILL, WHEN OPERATED WITH NEGATIVE FEEDBACK, ATTEMPT TO BRING ITS INPUTS TOGETHER BY ADJUSTING ITS OUTPUT VOLTAGE. SINCE THE NON-INVERTING INPUT IS GROUNDED THE OPAMP WILL ATTEMPT TO MAKE THE INVERTING INPUT GROUND TOO.

iv) BY INSPECTION THE INPUT RESISTANCE IS R_{IN}.

v)



$$I_{IN} = I_F$$

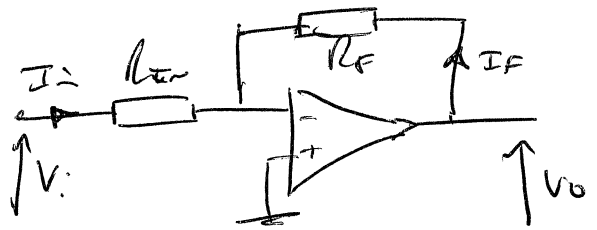
$$\frac{V_i - V^-}{R_{in}} = \frac{V^- - V_o}{R_F}$$

$$V^- = V^+ = 0$$

$$\frac{V_i}{R_{in}} = -\frac{V_o}{R_F}$$

$$-\frac{V_o}{V_i} = \frac{R_F}{R_{in}}$$

$$\therefore \frac{V_o}{V_i} = -\frac{R_F}{R_{in}}$$



$$I_F + I_{in} = 0$$

$$\frac{V_o - V^-}{R_F} + \frac{V_i - V^-}{R_{in}} = 0$$

SOLVE FOR V^-

$$(V_o - V^-) R_{in} + (V_i - V^-) R_F = 0$$

$$V^- = \frac{V_o R_{in} + V_i R_F}{R_{in} + R_F}$$

USE V^- IN $V_o = A_V(V^+ - V^-)$ AND $V^+ = 0$

$$V_o = A_V\left(0 - \frac{V_o R_{in} + V_i R_F}{R_i + R_F}\right)$$

... DO SOME TRANSPOSITION...

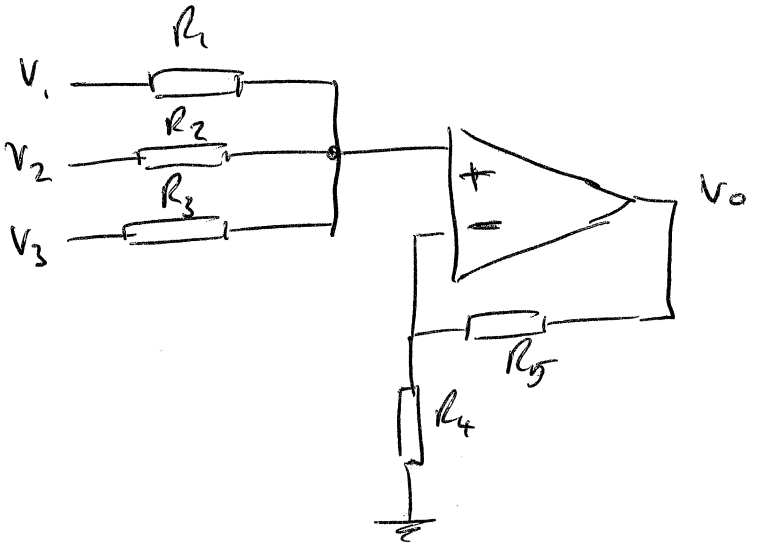
$$\frac{V_o}{V_i} = \frac{-A_V R_F}{R_i + R_F + A_V R_{in}}$$

÷ BY A_V...

$$\frac{V_o}{V_i} = \frac{-R_F}{\frac{1}{A_V}\left[R_{in} + R_F\right] + R_{in}}$$

6(c) SEVERAL POSSIBLE METHODS...

FIRST



$$V_o\big|_{V_1} = V_1 \cdot \frac{R_2 /\!/ R_3}{R_1 + R_2 /\!/ R_3} \cdot \frac{R_5 + R_4}{R_4}$$

$$V_o\big|_{V_2} = V_2 \cdot \frac{R_1 /\!/ R_3}{R_2 + R_1 /\!/ R_3} \cdot \frac{R_5 + R_4}{R_4}$$

$$V_o\big|_{V_3} = V_3 \cdot \frac{R_1 /\!/ R_2}{R_3 + R_1 /\!/ R_2} \cdot \frac{R_5 + R_4}{R_4}$$

$$V_o = \left(V_1 \cdot \frac{R_2 /\!/ R_3}{R_1 + R_2 /\!/ R_3} + V_2 \frac{R_1 /\!/ R_3}{R_2 + R_1 /\!/ R_3} + V_3 \frac{R_2 /\!/ R_1}{R_3 + R_2 /\!/ R_1} \right) \left(\frac{R_5 + R_4}{R_4} \right)$$

ii) THIS IS A KIND OF SUMMING AMPLIFIER. MORE SPECIFICALLY IF $R_1 = R_2 = R_3$ V_o/V_i IS THE AVERAGE OF THE THREE INPUTS MULTIPLIED BY A GAIN OF $\frac{R_5 + R_4}{R_4}$.

6bi) SECOND METHOD

$$\frac{V_1 - V^+}{R_1} + \frac{V_2 - V^+}{R_2} + \frac{V_3 - V^+}{R_3} = 0$$

$$V_o = V^+ \cdot \frac{R_4 + R_5}{R_4}$$

$$(V_1 - V^+) R_2 R_3 + (V_2 - V^+) R_1 R_3 + (V_3 - V^+) R_1 R_2 = 0$$

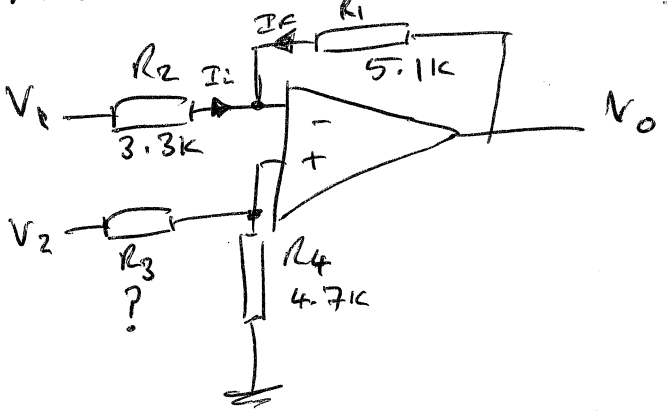
$$V_1 R_2 R_3 - V^+ R_2 R_3 + V_2 R_1 R_3 - V^+ R_1 R_3 + V_3 R_1 R_2 - V^+ R_1 R_2 = 0$$

$$-V^+ (R_2 R_3 + R_1 R_3 + R_1 R_2) + V_1 R_2 R_3 + V_2 R_1 R_3 + V_3 R_1 R_2 = 0$$

$$V^+ = \frac{V_1 R_2 R_3 + V_2 R_1 R_3 + V_3 R_1 R_2}{R_2 R_3 + R_1 R_3 + R_1 R_2}$$

$$V_o = \left(\frac{V_1 R_2 R_3 + V_2 R_1 R_3 + V_3 R_1 R_2}{R_2 R_3 + R_1 R_3 + R_1 R_2} \right) \left(\frac{R_4 + R_5}{R_4} \right)$$

6ci) ALSO SAVERAL METHODS... FIRST.



$$I_{IN} = I_F$$

$$\frac{V_1 - V^-}{R_2} + \frac{V_o - V^-}{R_1} = 0 \quad (1)$$

$$V^+ = V^- \quad (2)$$

$$V^+ = \frac{V_2 R_4}{R_3 + R_4} \quad (3)$$

$((3) \to (2)) \to (1)$

$$\frac{V_1 - \frac{V_2 R_4}{R_3 + R_4}}{R_2} + \frac{V_o - \frac{V_2 R_4}{R_3 + R_4}}{R_1} = 0$$

$$V_o = -\frac{\left(V_1 - \frac{V_2 R_4}{R_3 + R_4}\right) R_1}{R_2} + \frac{V_2 R_4}{R_3 + R_4} \quad (4)$$

SOLVE (4) FOR R_3 TO GET...

$$R_3 = \frac{-R_4 (-R_1 - R_2) V_2}{R_1 V_1 + R_2 V_o} - R_4$$

$$= \frac{-4.7 (-5.1 - 3.3) \cdot -8}{5.1 \cdot (-6) + 3.3 \cdot 0} = \underline{5.621 \text{ k}\Omega}$$

SECOND METHOD

$$V_o|_{V_1} = V_1 \cdot -R_1/R_2 \qquad V_o|_{V_2} = V_2 \cdot \frac{R_4}{R_3 + R_4} \cdot \frac{R_1 + R_2}{R_2}$$

$$V_o = V_1 - R_1/R_2 + V_2 \frac{R_4}{R_3 + R_4} \cdot \frac{R_1 + R_2}{R_2} \quad (V^+ = V^- \ldots)$$

SUB $V_o = 0$ ...

$$\therefore \quad V_1 - R_1/R_2 = -\frac{V_2 R_4}{R_3 + R_4} \cdot \frac{R_1 + R_2}{R_2}$$

SOLVE FOR R_3 --

$$R_3 = \frac{V_2(R_4R_1 + R_4R_2)R_2 - V_1R_1R_4R_2}{V_1R_1R_2}$$

SUBSTITUTE VALUES.

$$R_3 = \frac{-8(4.7 \cdot 5.1 + 4.7 \cdot 3.3)3.3 - (-6)5.1 \cdot 4.7 \cdot 3.3}{(-6)5.1 \cdot 3.3}$$

$$= \underline{5.621\,k\Omega}$$

THIRD METHOD

$$\frac{V_1 - V^-}{R_2} + \frac{V_o - V^-}{R_1} = 0$$

$$V_1R_1 - V^-R_1 + V_oR_2 - V^-R_2 = 0$$

$$-V^-(R_1 + R_2) = -V_1R_1 - V_oR_2$$

$$V^- = \frac{V_1R_1 + V_oR_2}{R_1 + R_2} \quad (1)$$

$$\frac{V_2 - V^+}{R_3} = V^+/R_4 \quad (2) \rightarrow (V_2 - V^+)R_4 = V^+R_3$$

$$V^+ = V^- \quad (3)$$

$(1 \text{ \& } 2) \rightarrow 3$

$$\left(V_2 - \frac{V_1R_1 + V_oR_2}{R_1 + R_2}\right)R_4 = \frac{V_1R_1 + V_oR_2}{R_1 + R_2} \cdot R_3$$

$$R_4 V_2 (R_1 + R_2) - V_1 R_1 R_4 + V_o R_2 R_4 = V_1 R_1 R_3 + V_o R_2 R_3$$

$$V_o (R_2 R_4 - R_2 R_3) = V_1 R_1 R_3 - V_2 (R_1 + R_2) R_4 + V_1 R_1 R_4$$

$$V_o = \frac{V_1 R_1 R_3 - R_4 V_2 (R_1 + R_2) + V_1 R_1 R_4}{R_2 R_4 - R_2 R_3}$$

$$V_o = \frac{V_1 (R_1 R_3 + R_1 R_4) - V_2 (R_1 + R_2) R_4}{R_2 (R_4 - R_3)}$$

$$= -\frac{6(5.1(5.621 + 4.7)) - (-8)(5.1 + 3.3)4.7}{3.3(4.7 - 5.621)}$$

$$= \sim \underline{0.0174 V}$$

So 5.621 kΩ IS CORRECT (MORE OR LESS...)