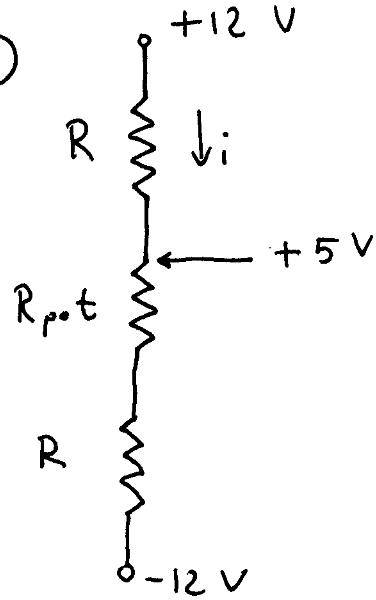
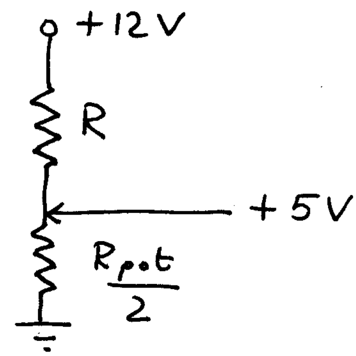
ME333 Introduction to Mechatronics
Assignment 1

(1)



Due to symmetry, this circuit equals



voltage divider:

$$\frac{5}{12} = \frac{\left(\frac{R_{pot}}{2}\right)}{R + \left(\frac{R_{pot}}{2}\right)}$$

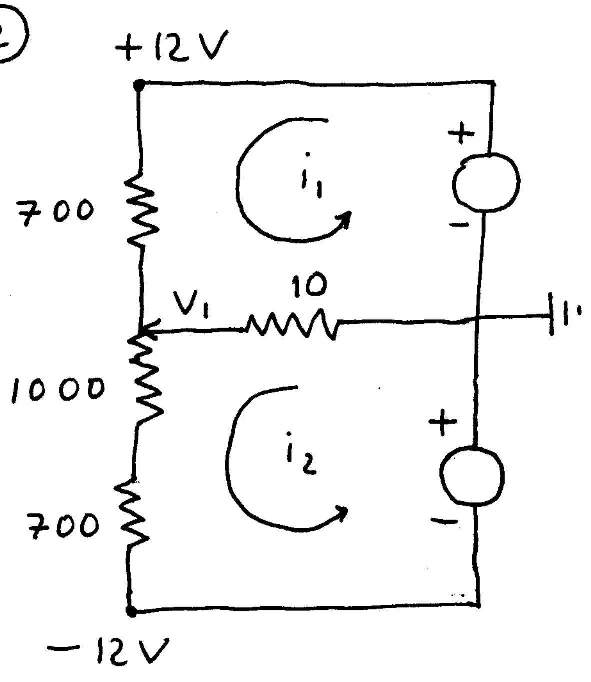
yielding $\boxed{R = 0.7\, R_{pot}}$

Current: $12 = Ri + 5 \Rightarrow i = \frac{7}{R} = \frac{10}{R_{pot}}$

Total resistance: $R_T = 2R + R_{pot} = 2.4\, R_{pot}$

Power dissipated: $\boxed{P = i^2 R_T = \frac{240}{R_{pot}}}$

(2)



Equations:

$$12 = 700 i_1 + V_1$$

$$V_1 = 1700 i_2 - 12$$

$$V_1 = 10 (i_1 - i_2)$$

Arranging terms,

$$V_1 + 700 i_1 = 12$$

$$V_1 - 1700 i_2 = -12$$

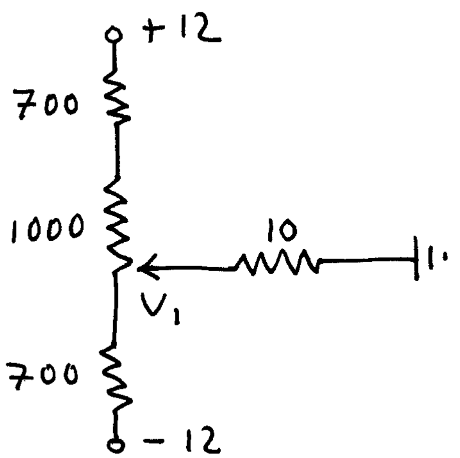
$$V_1 - 10 i_1 + 10 i_2 = 0$$

Solving the system, $\boxed{V_1 = 0.09885 \text{ V}}$

also, $i_1 = 17.0$ mA

$i_2 = 7.11$ mA

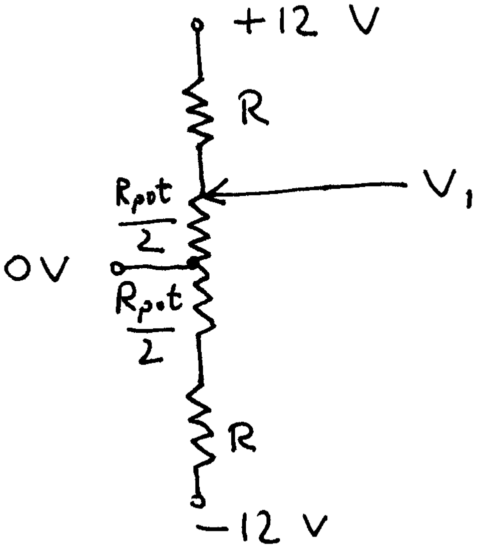
Wiper at bottom:



again using symmetry,

$\boxed{V_1 = -0.09885 \text{ V}}$

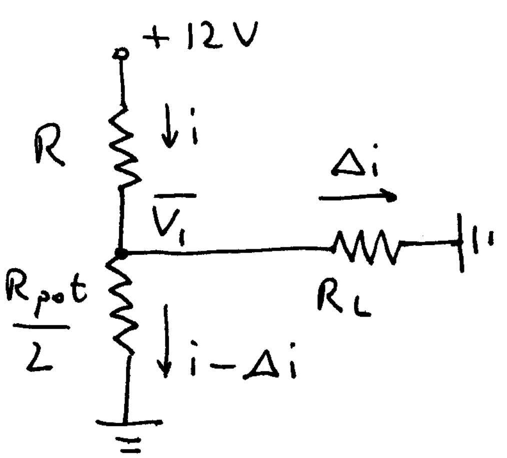
(3) Without load, the circuit is a simple voltage divider. V_1 is our "signal"; when the wiper is at the top, we have



$$V_1 = \frac{\frac{R_{pot}}{2}}{R + \frac{R_{pot}}{2}} (12)$$

$$\boxed{V_1 = 12 \frac{R_{pot}}{2R + R_{pot}}}$$

when we load the circuit with R_L, the above expression for V_1 no longer holds:



let's find $\overline{V_1}$:

$$12 = Ri + \overline{V_1}$$

$$\overline{V_1} = R_L \Delta i$$

$$\overline{V_1} = \frac{R_{pot}}{2} (i - \Delta i)$$

After some manipulation we obtain

$$\boxed{\overline{V_1} = 12 \frac{R_{pot}}{2R + R_{pot} + \frac{R R_{pot}}{R_L}}}$$

the last term in the denominator, $\frac{R R_{pot}}{R_L}$, causes $\overline{V_1}$ to be smaller than the desired value $\overline{V_1}$. The lower the load impedance, R_L, the greater the difference between $\overline{V_1}$ and V_1.

We could reduce the effect of the term $\frac{R R_{pot}}{R_L}$ by reducing R or R_{pot}.

However, the power dissipated by the unloaded circuit is

$$P = \frac{(12 - (-12))^2}{2R + R_{pot}} = \frac{576}{2R + R_{pot}}$$

in consequence, reducing R or R_{pot} will increase power dissipation

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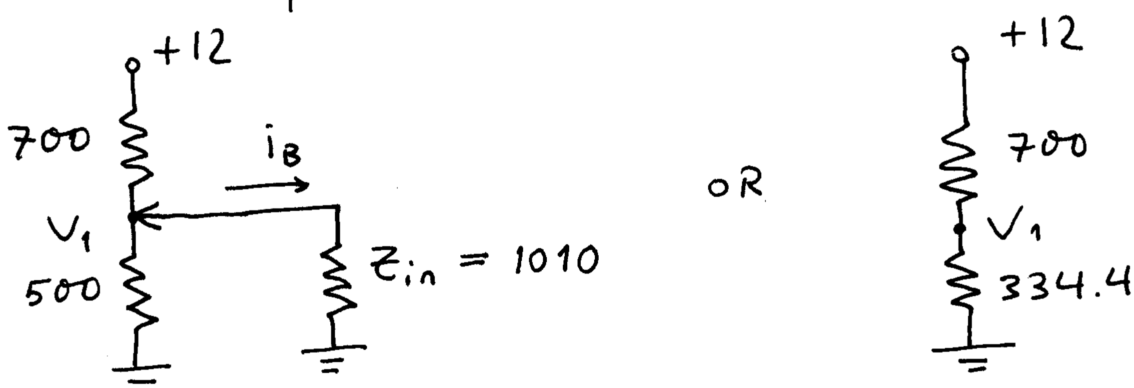
(4) Let's call the 10 Ω resistor R_L;

$h_{FE} \equiv$ transistor current gain $= 100$

The equivalent impedance of the amplifier with load is $\boxed{Z_{in} = (h_{FE} + 1) R_L = 1010\ \Omega}$

∴ an equivalent circuit would be



$$\therefore V_1 = \frac{334.4}{700 + 334.4}(12) = \boxed{3.88\ V}$$

$$i_B = \frac{V_1}{Z_{in}} = \frac{3.88\ V}{1010\ \Omega} = \boxed{3.84\ mA}$$

V_{OUT} : the base-emitter junction typically has a "conducting diode" voltage drop V_{BE} of about 0.6 V

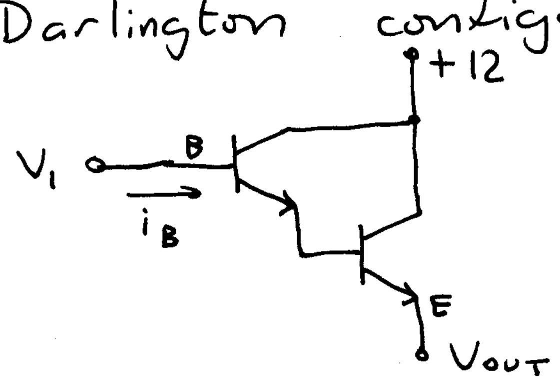
thus $V_{OUT} = V_1 - V_{BE} \simeq 3.28$ V

The amplifier is not ideal because:

a) The input impedance Z_{in} is not large enough; it still loads the control circuit considerably, causing V_1 to be 3.88 V instead of the desired 5V.

b) The base-emitter voltage drop means that the amplifier will turn off whenever $V_1 < V_{BE}$.

The amplifier could be improved by increasing the current gain (hence increasing Z_{in}). This could be achieved by cascading two transistors (Darlington configuration):



now $Z_{in} = (h_{FE}+1)^2 R_L$
however at the cost of increasing deadband
($V_{BE} \simeq 1.2$ V)

Wiper at bottom-most position: (current flows right to left: