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Class 3: Voltage Dividers

Activity 3 – Voltage Dividers

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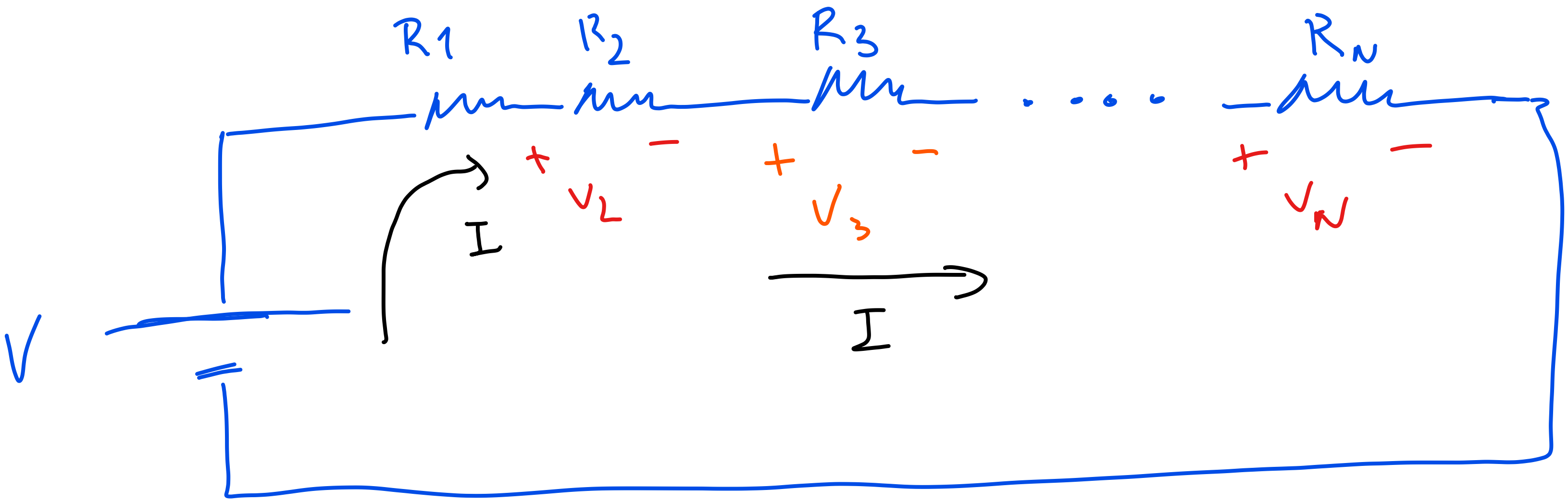
Intro to ECSE

Derivation of Voltage Divider Equation



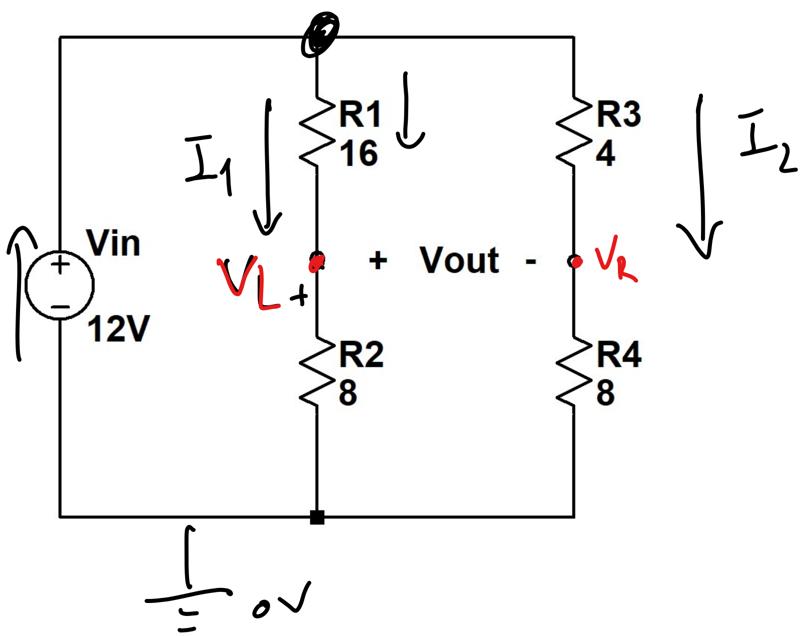
$$V = R\,I$$

$$I = \frac{V}{R} = \frac{V}{\sum_{k=1}^{N} R_k}$$

$$V_k = R_k \times I = V \times \frac{R_k}{\sum_{k=1}^{N} R_k}$$

↑ Ohm's law

Example: Find Vout



$V_{OUT} = V_L - V_R$

$V_L = V_{in} \cdot \frac{R_2}{R_1 + R_2} = 12v \frac{8}{16+8} = 4V$

$V_R = V_{R4} = V_{in} \frac{R_4}{R_3 + R_4} = 12v \frac{2}{3} = 8V$

$V_{OUT} = V_L - V_R = 4V - 8V = -4V$

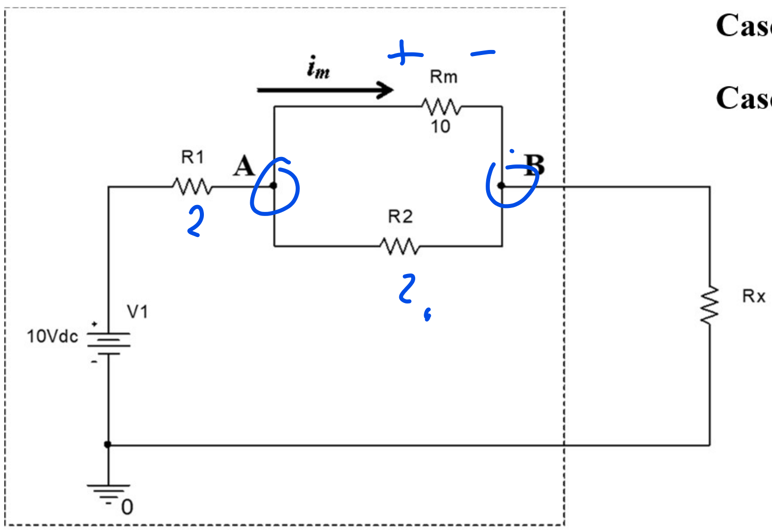
$2/3$

$V_{R2} = V_L - 0 = V_L$

$V_L = V_{in} - V_{R1} = V_{in} - V_{in} \left(R_1 / R_1 + R_2 \right) = 12V - 8V = 4V$

A bit more complicated example

$V_{AB} = V_{R_m} = R_m I_m$



Case 1: Given that when Rx = 0 Ω, the current through resistor Rm is 2 mA, i.e. i_m = 2 mA.

Case 2: Given that when Rx = 2000 Ω, the current through resistor Rm is 1 mA, i.e. i_m = 1 mA.

Find voltage between points A and B for <u>each of the cases</u> described above

case 1 : $V_{AB} = R_m i_m = 20$ mV

case 2 : $V_{AB} = R_m i_m = 10$ mV

What is the equivalent resistance between points A and B, R_{AB}? (Express in terms of R2)

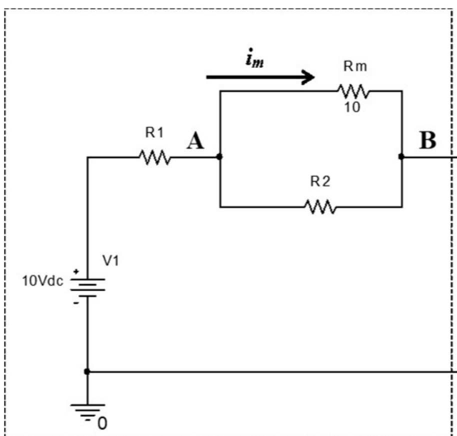
$V_{AB} = V_{R_2} = R_2 I_2$

$$R_{AB} = R_m \parallel R_2 = \frac{R_m R_2}{R_m + R_2}$$

Rm and R2 are in parallel

$$R_{AB} = \frac{10 R_2}{10 + R_2}$$

A bit more complicated example (contd.)

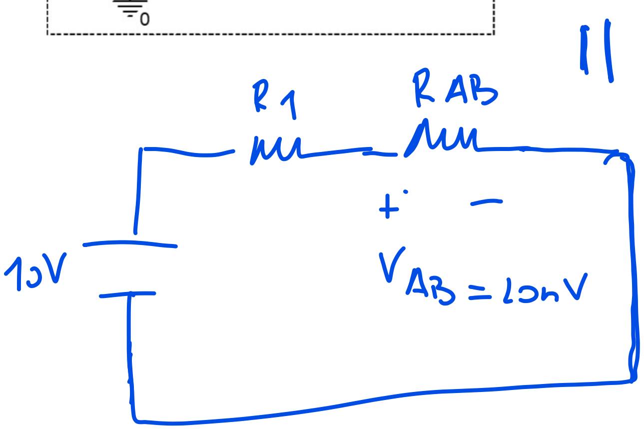


Using voltage divider and your previous findings, develop a relationship between R1 and R2 for case 1

$$V_{AB} = 10V \cdot \frac{R_{AB}}{R_1 + R_{AB}}$$

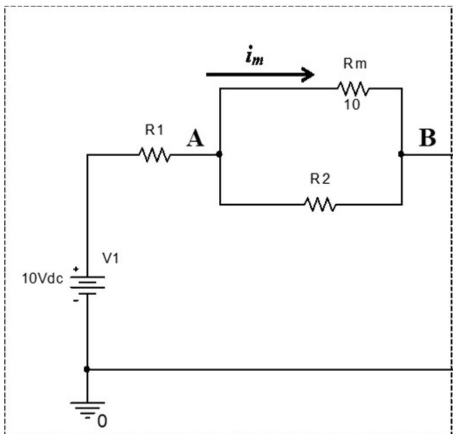
$$20mV = 10V \cdot \frac{\frac{10R_2}{10+R_2}}{R_1 + \frac{10R_2}{10+R_2}}$$

$$\Rightarrow \boxed{10R_1 - 4990R_2 + R_1R_2 = 0}$$



$$R_{AB} = \frac{10R_2}{10 + R_2}$$

A bit more complicated example (contd.)

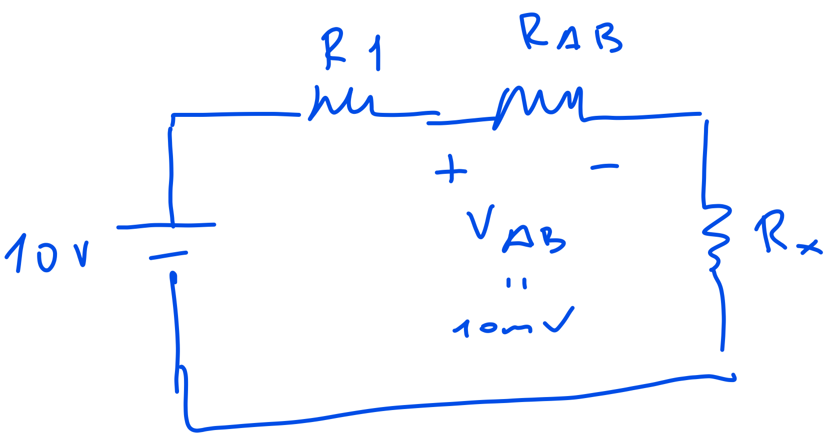


$R_x = 2\,K\Omega$

Using voltage divider and your answer to parts a and b, develop a relationship between R1 and R2 for case 2

$$V_{AB} = 10V \cdot \frac{R_{AB}}{R_1 + R_{AB} + R_x}$$

$$\Rightarrow \boxed{10R_1 - 7990R_2 + R_1R_2 = -20\,000}$$



$$R_{AB} = \frac{R_2\, 10}{R_2 + 10}$$

A bit more complicated example (contd.)

- Solve the linear relationships derived previously, to determine the values of resistors R1 and R2 such that both case 1 and 2 are satisfied

Case 1: $10R_1 - 4990R_2 + R_1R_2 = 0$

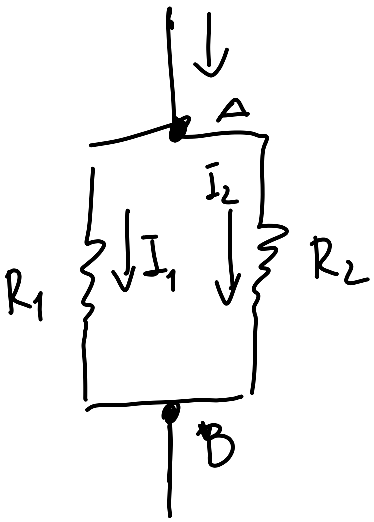
Case 2: $10R_1 - 7990R_2 + R_1R_2 = -20000$

$10R_1 - 4990R_2 + R_1R_2 - (10R_1 - 7990R_2 + R_1R_2) = 0 - (-20000)$

$3000R_2 = 20000 \Rightarrow R_2 = 6.667\,\Omega$

$\Rightarrow R_1 = 1996\,\Omega$

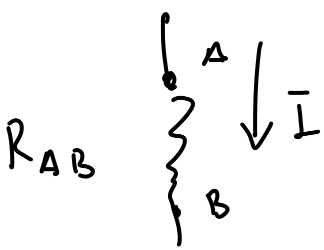
What about Current Division?



$$I = I_1 + I_2$$

$$I_1 = \frac{V_{AB}}{R_1}, \quad I_2 = \frac{V_{AB}}{R_2}$$

$$R_{AB} = R_2 \| R_1 = \frac{R_2 R_1}{R_1 + R_2}$$



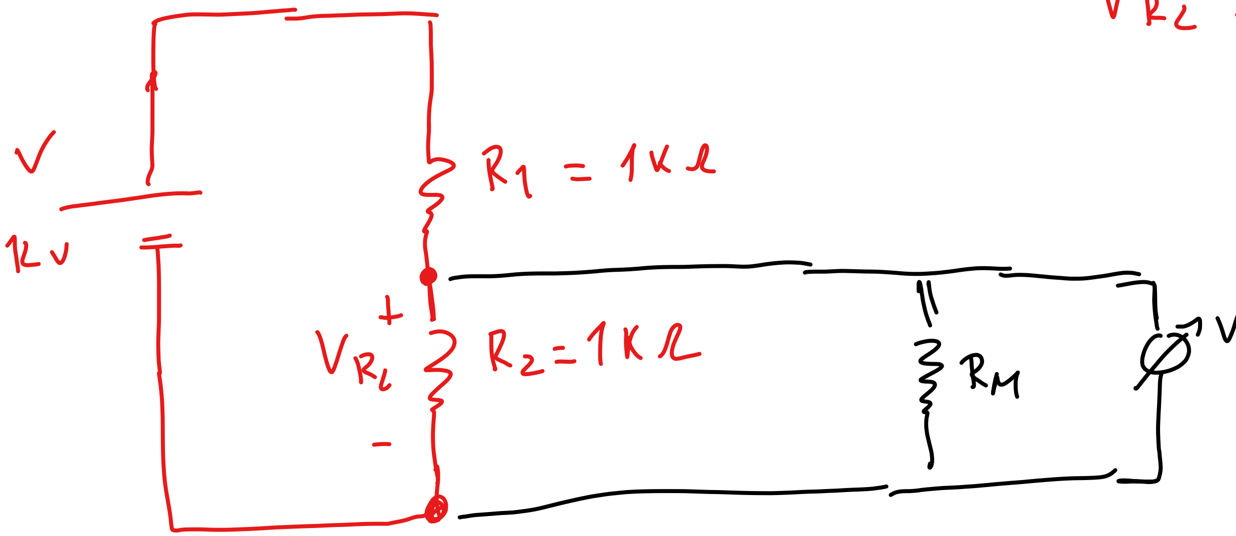
$$\boxed{V_{AB} = R_{AB}\, I}$$

$$I_1 = \frac{R_{AB}}{R_1} I = \frac{R_2 \cancel{R_1}}{R_1 + R_2} \frac{1}{\cancel{R_1}} I = \frac{R_2}{R_1 + R_2} I$$

$$I_2 = R_1 / (R_1 + R_2)\, I$$

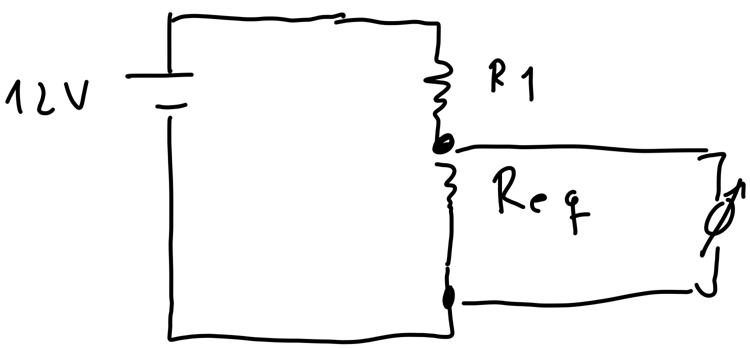
Input Impedance of Voltmeter

$$V_{R_2} = \frac{R_2}{R_1+R_2} V = \frac{V}{2} = 6\,V$$



$$R_M >> R_L$$

$$R_{eq} = R_2 \| R_M = \frac{R_2 R_M}{R_2+R_M} \approx R_2$$



$$V = \frac{R_{eq}}{R_1+R_{eq}} 12V$$

Activity 3: Voltage Divider

- Go to the class website
- Look under class 3
- Find activity 3
- Do the activity
  - Individual submission for activity 3
  - Encouraged to discuss with others in the class on WebEx Teams
- Answer the activity using template (attached class 3)
- When complete – upload to Gradescope
  - Due Thursday, January 27th at 11:59 pm
  - Use guides to learn how to upload documents