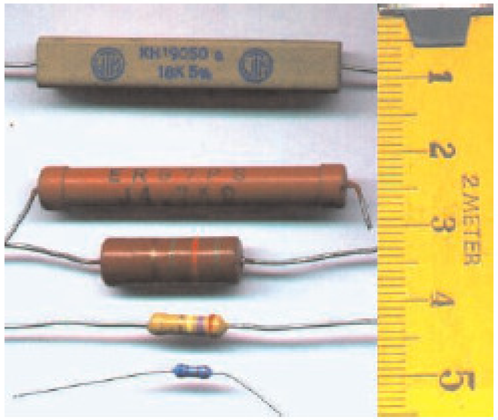
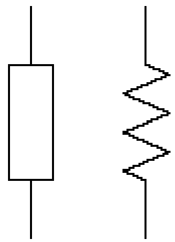
Creative Electronics

Resistance and Resistors

Resistance and Resistors

- Resistance in electrical engineering is a measure of the degree of opposition that current is faced with.
- A resistor is a physical component that “implements” the definition of resistance.
- Weerstand!
- Conductance and conductor





Two symbols for resistors

Relation between Voltage and Current - Ohm's Law

$$R = \frac{V}{I} \tag{3.1}$$

- R is the resistance of the object, measured in Ohms.
- V is the voltage across the object, measured in volts.
- I is the current through the object, measured in amperes.

Relation between Voltage and Current

Ohm's Law

$$R = \frac{V}{I} \qquad (3.1)$$

Resistance is independent of

- the applied voltage
- the resulting current
- the frequency
- the air humidity
- the pressure

Power Behavior

$$P = V \cdot I \qquad (2.1)$$

Quantity	Unity	Symbol
Voltage, potential diff.	Volt (V)	V
Current	Ampere (A)	I
Power	Watt (W)	P

Table 2.1: *Electrical quantities with their respective unities and symbols.*

$$P_{resistor} = V_{resistor} \cdot I_{resistor} \qquad (3.2)$$

The product of the voltage applied to a resistor and the current that flows through it results in a power $P_{resistor}$

- $P_{resistor}$ is dissipated in the resistor.
- The dissipated power is transformed into heat.

Power Behavior

$$P = V \cdot I \qquad (2.1)$$

Ohm's law $$R = \frac{V}{I} \qquad (3.1)$$

$$P = \frac{V^2}{R}$$

$$P = I^2 R$$

Using a Resistor

- Don not overload a resistor! Usually the low-power models can handle a power of 1/4 W or 1/3 W.
- The resistance values are approximations! They have tolerance ranges, for example $\pm 5\%$
- Appendix B provides information on color codes that indicate the resistance value and tolerance.

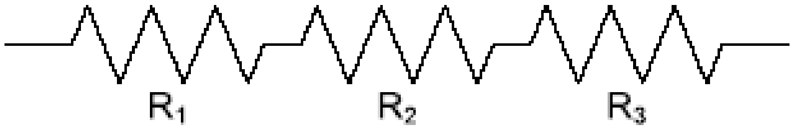
(what if you still cannot decide the resistance by analysing its color? – Measure it!)

- You cannot buy a resistor with arbitrary resistance value. Resistors are produced in E-series.

http://www.st-andrews.ac.uk/~jcgl/Scots_Guide/info/comp/passive/resistor/e12/e12.html

- In order to obtain the desired resistance value, you need to combine several resistors.

Series and Parallel Connections - Series Connection



Example of a series connection

The same current flows through all the resistors.

$$R_{re} = \sum_{i=1}^{N} R_i. \tag{3.3}$$

R_{re} is always higher than the largest (single) resistance value;

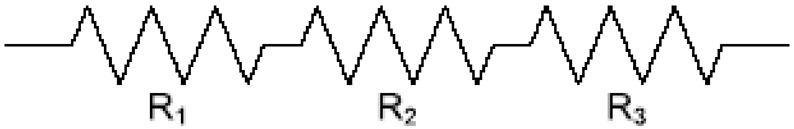
If one of the single resistance values is much higher than the other two, R_{re} is almost equal to that value;

The power dissipated in a single resistor is always lower than the power dissipated in R_{re}.

Series and Parallel Connections
- Series Connection

The power dissipated in a single resistor is always lower than the power dissipated in R_{re}.

$$P = I^2 R$$

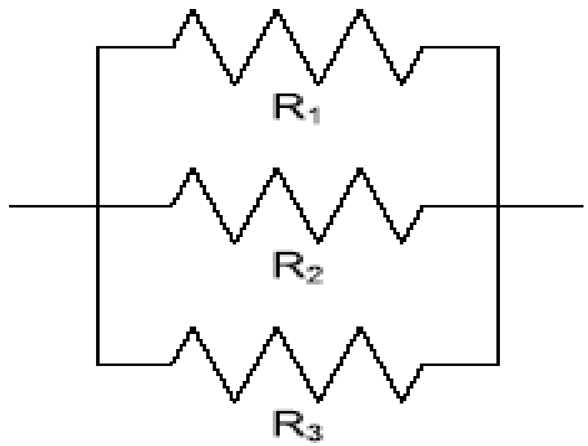


The same current flows through all the resistors.

$$R_{re} = \sum_{i=1}^{N} R_i. \qquad (3.3)$$

P_{re} – the same current on the bigger resister R_{re}.

Parallel Connection



Example of a parallel connection

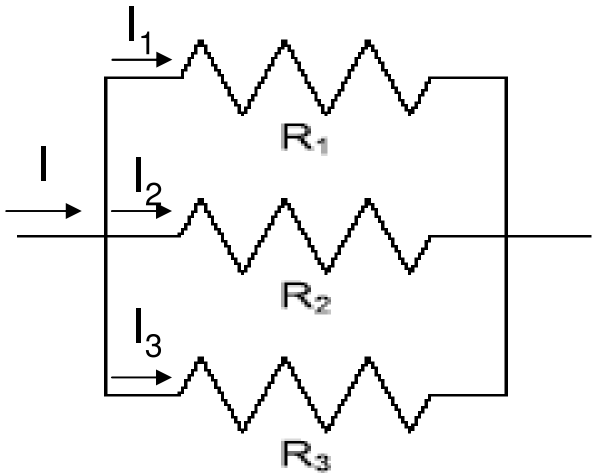
- The voltage over each resistor is equal.
- The current is divided over the resistors.

Parallel Connection

$$R_{re} = \frac{1}{\sum_{i=1}^{N} \frac{1}{R_i}}. \qquad (3.4)$$

$$\frac{1}{R_{re}} = \sum_{i=1}^{N} \frac{1}{R_i}$$

- The voltage over each resistor is equal.
- The current is divided over the resistors.



$$I = \sum_{i=1}^{N} I_i$$

$$\frac{V}{R_{re}} = \sum_{i=1}^{N} \frac{V}{R_i}$$

Parallel Connection

- The voltage over each resistor is equal.
- The current is divided over the resistors.

$$R_{re} = \frac{1}{\sum_{i=1}^{N} \frac{1}{R_i}}. \qquad (3.4)$$

$$\frac{1}{R_{re}} = \sum_{i=1}^{N} \frac{1}{R_i}$$

R_{re} is always lower than the lowest R;

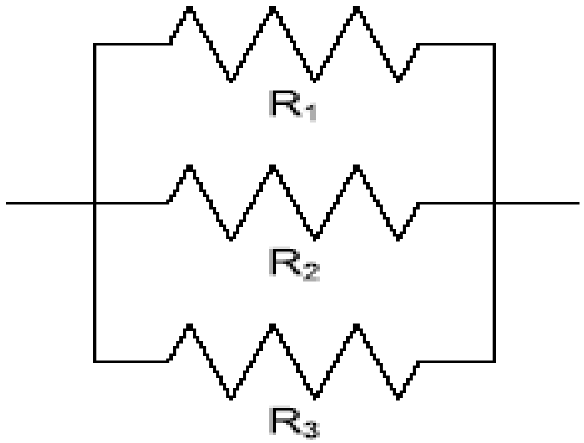
If one of the single resistance values is much lower than the other two, R_{re} is almost equal to that value;

The power dissipated in a single resistor is always lower than the power dissipated in R_{re}.

Series and Parallel Connections - Parallel Connection

The power dissipated in a single resistor is always lower than the power dissipated in R_{re}.

$$P = \frac{V^2}{R}$$



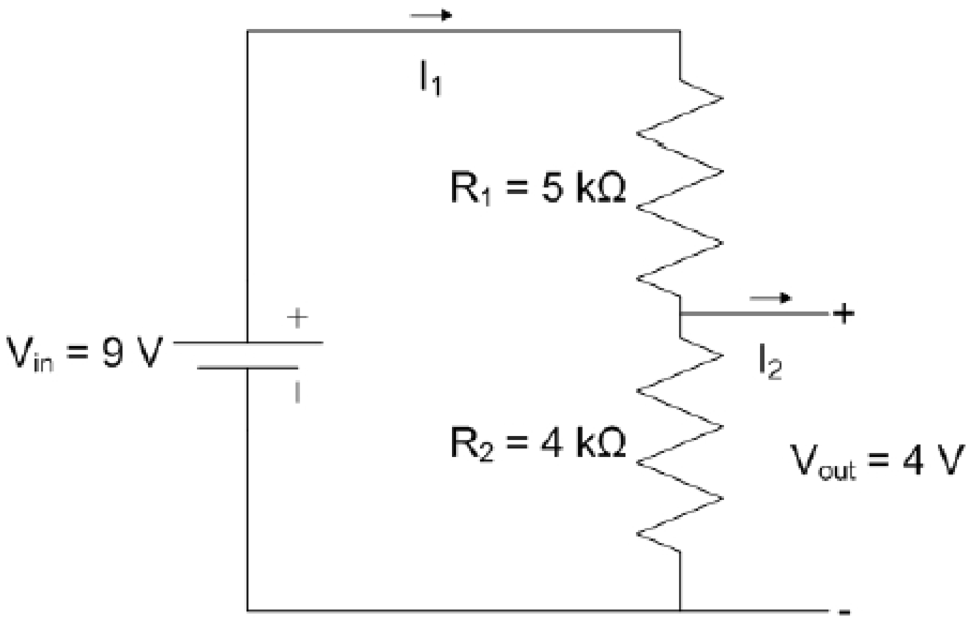
P_{re} – the same voltage on the smaller resister R_{re}.

Applications of Resistors

- Filters
- Switch circuitry
- Integrators
- Amplifiers
- …
- Voltage divider

Voltage Divider

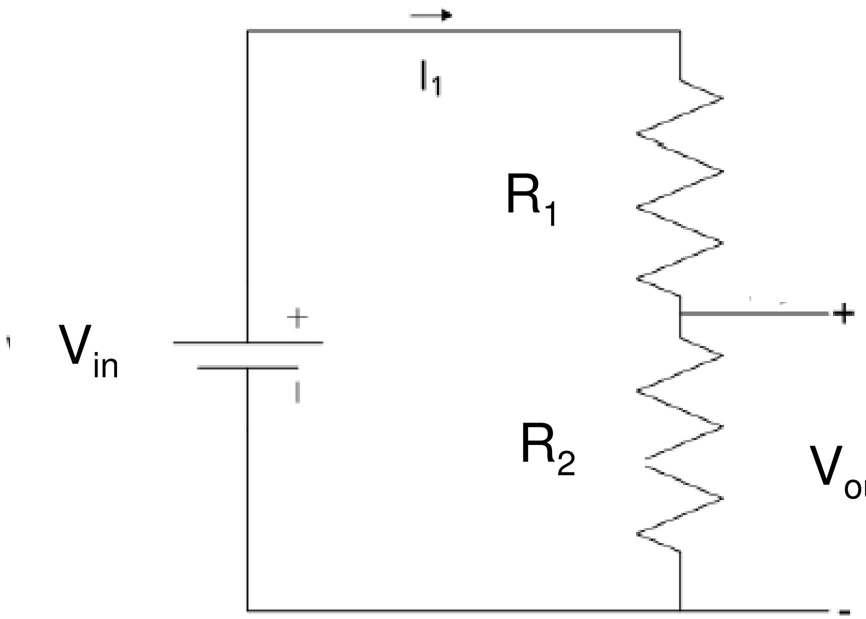
A voltage divider is designed to create an output voltage which is proportional to the input voltage.



Example of a voltage divider

Voltage Divider

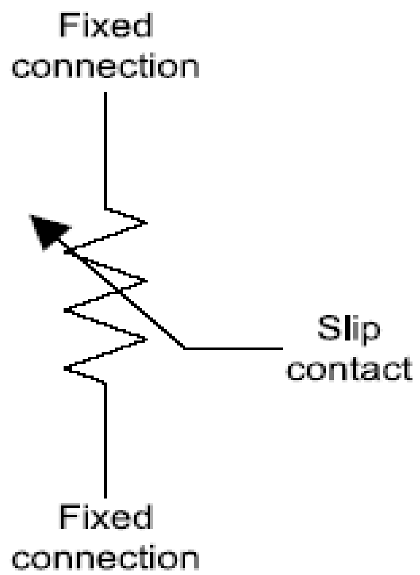
A voltage divider is designed to create an output voltage which is proportional to the input voltage.



$$V_{out} = V_{in} R_2 / (R_1 + R_2)$$

Example of a voltage divider

Potentiometers



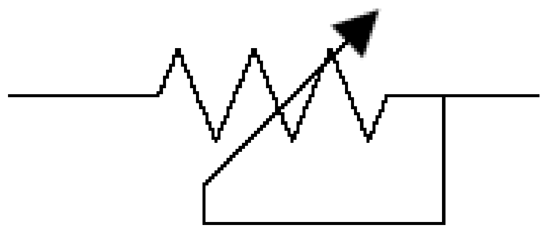
"wiper"

Schematic symbol of a potmeter

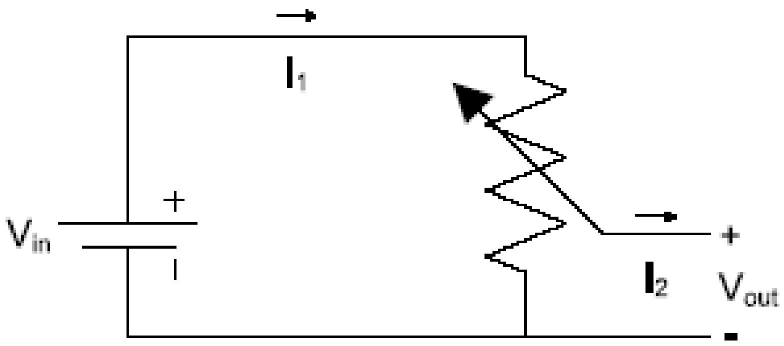
- Adjustable resistors - Potmeters

Applications of Potmeters

- An adjustable resistance value for filtering (next chapter)
- Adjustable voltage divider (e.g. in an audio amplifier)



“Plain” adjustable resistance value



adjustable voltage divider

Types of Potmeters

- Turn potmeters - with a portable rotation axis

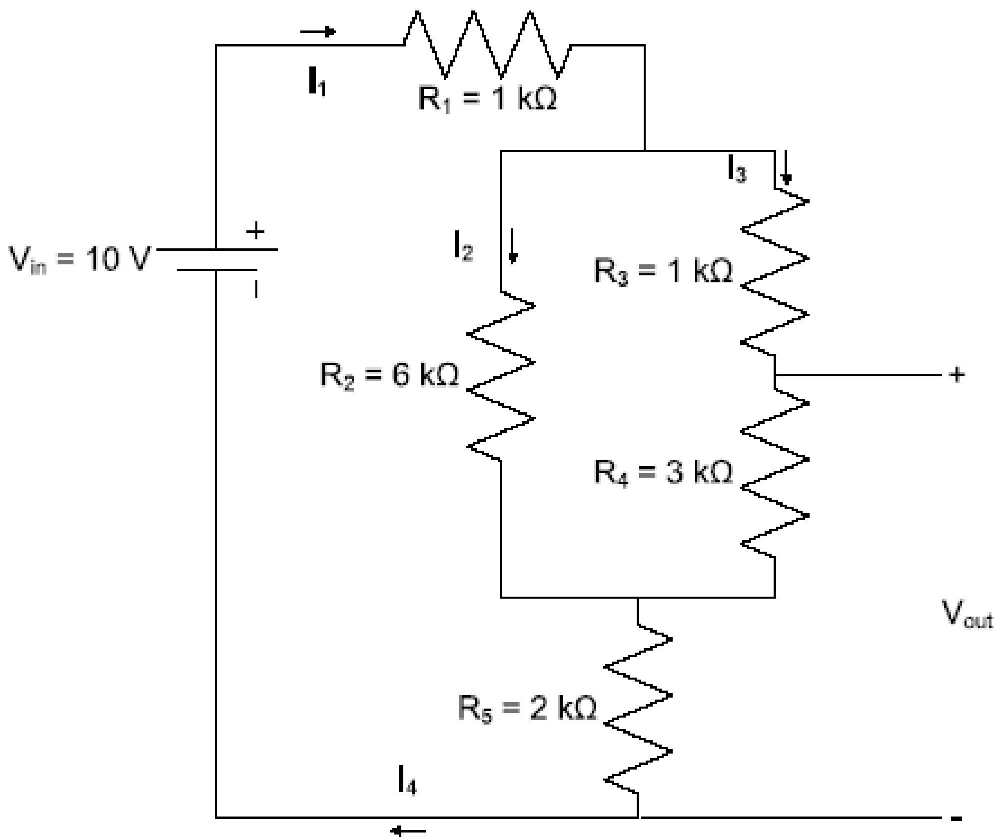
from *wikipedia.org*

- Slide potmeters

from *www.made-in-china.com*

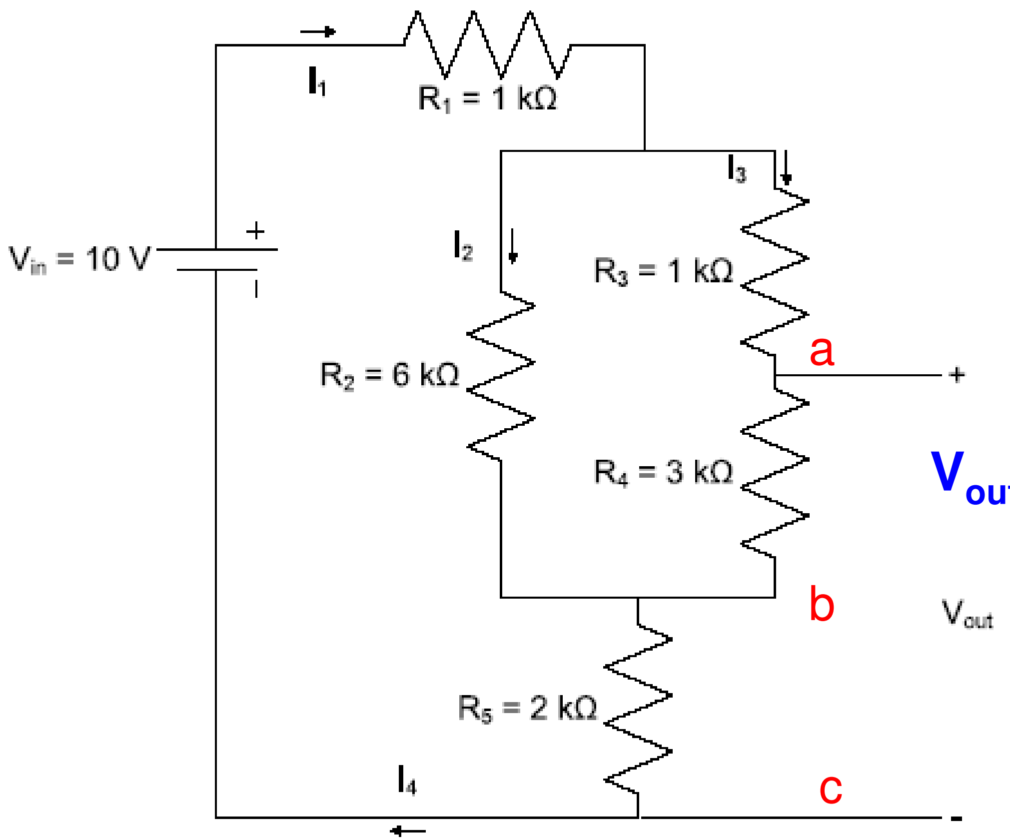
- Linear - the resistance value is proportional to the degree of rotation or slide
- Logarithmic - regulate volume in an audio amplifier

Calculation of Replacement Resistance Value



V_{out} = ?

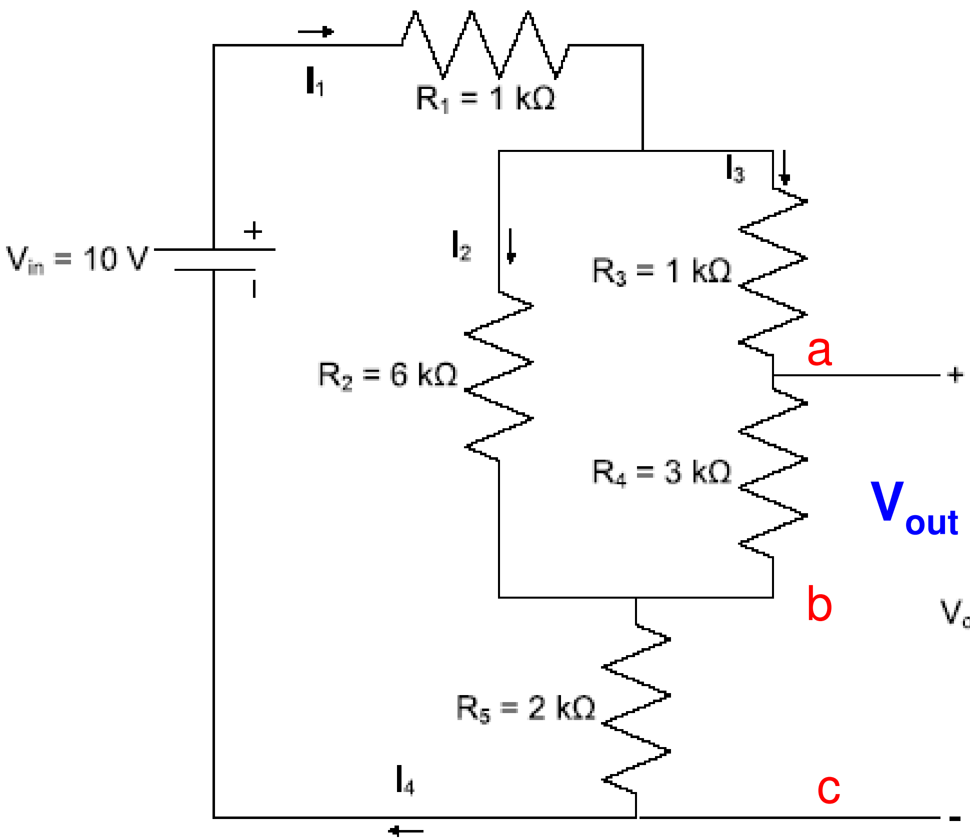
Calculation of Replacement Resistance Value



$V_{out} = V_{ac} = V_{ab} + V_{bc}$

$V_{out} = V_{R4} + V_{R5}$

Calculation of Replacement Resistance Value



Ohm's law

$$V_{out} = I_1 \cdot R_5 + I_3 \cdot R_4$$

$$I_1 = I_4 = I_2 + I_3$$

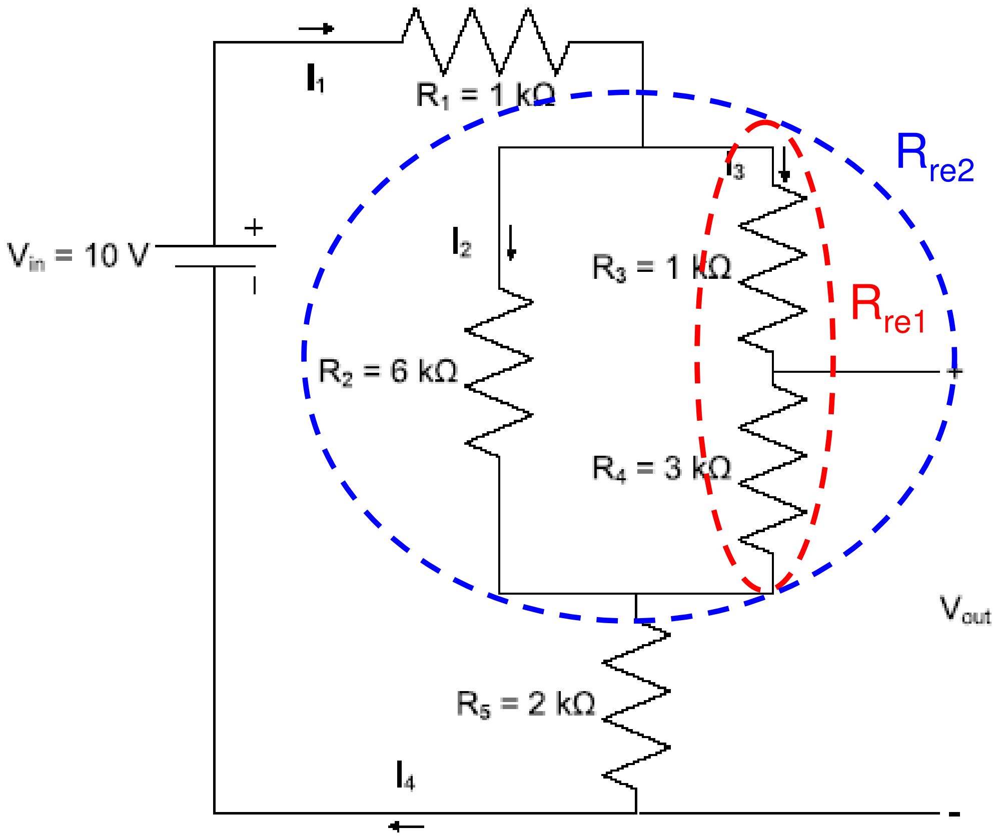
$V_{out} = V_{ac} = V_{ab} + V_{bc}$

$V_{out} = V_{R4} + V_{R5}$

$I_1 = ?$

$I_3 = ?$

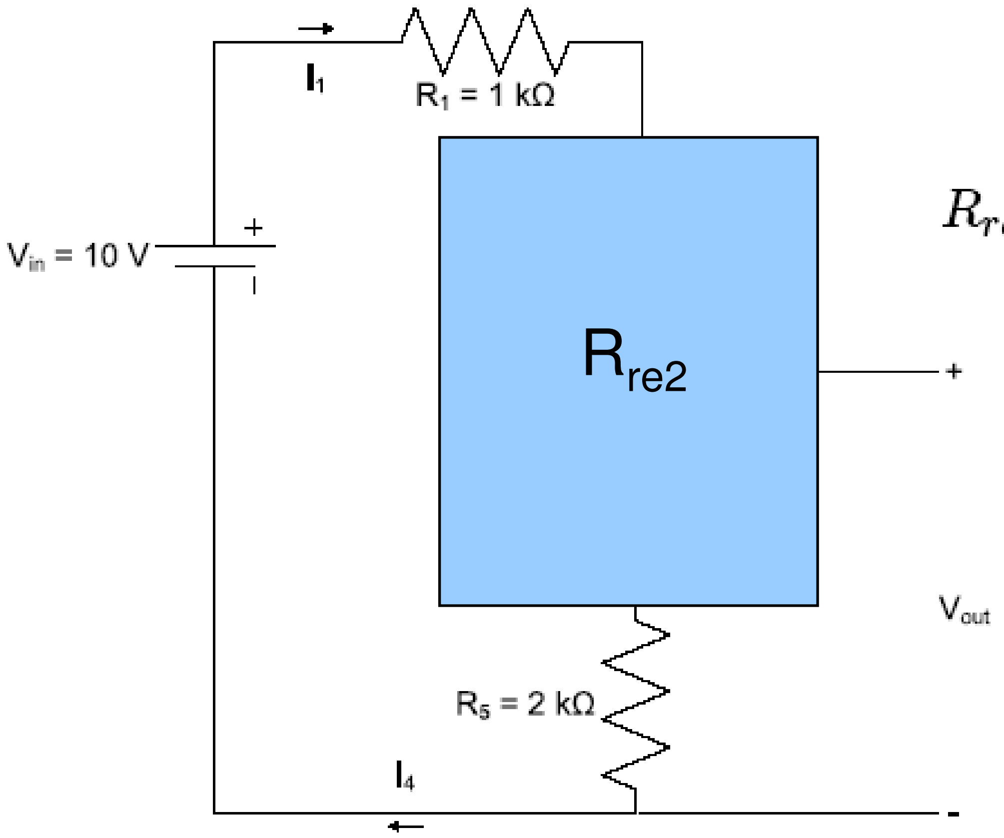
Calculation of Replacement Resistance Value



$$R_{re1} = R_3 + R_4 = 4\ \mathrm{k}\Omega$$

$$R_{re2} = \frac{1}{\frac{1}{R_2} + \frac{1}{R_{r1}}} = 2.4\ \mathrm{k}\Omega$$

Calculation of Replacement Resistance Value

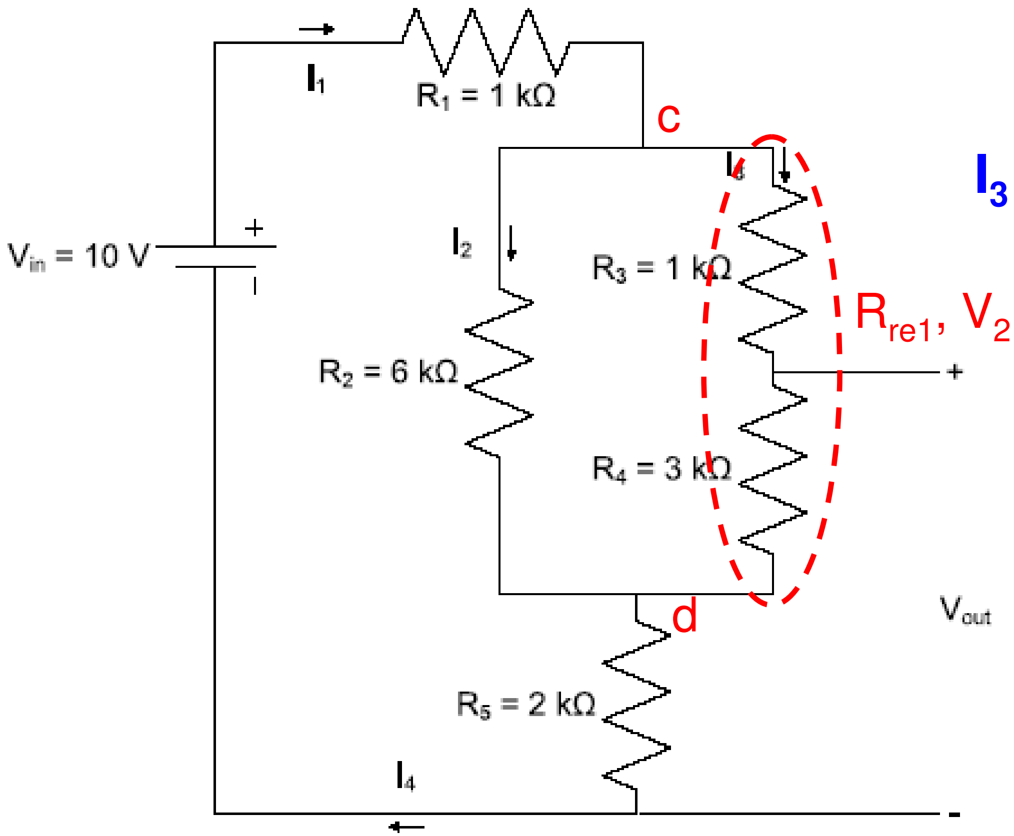


$$R_{retotal} = R_1 + R_{r2} + R_5 = 5.4 \text{ k}\Omega$$

$$I_1 = \frac{V_{in}}{R_{retotal}} = 1.85 \text{ mA}$$

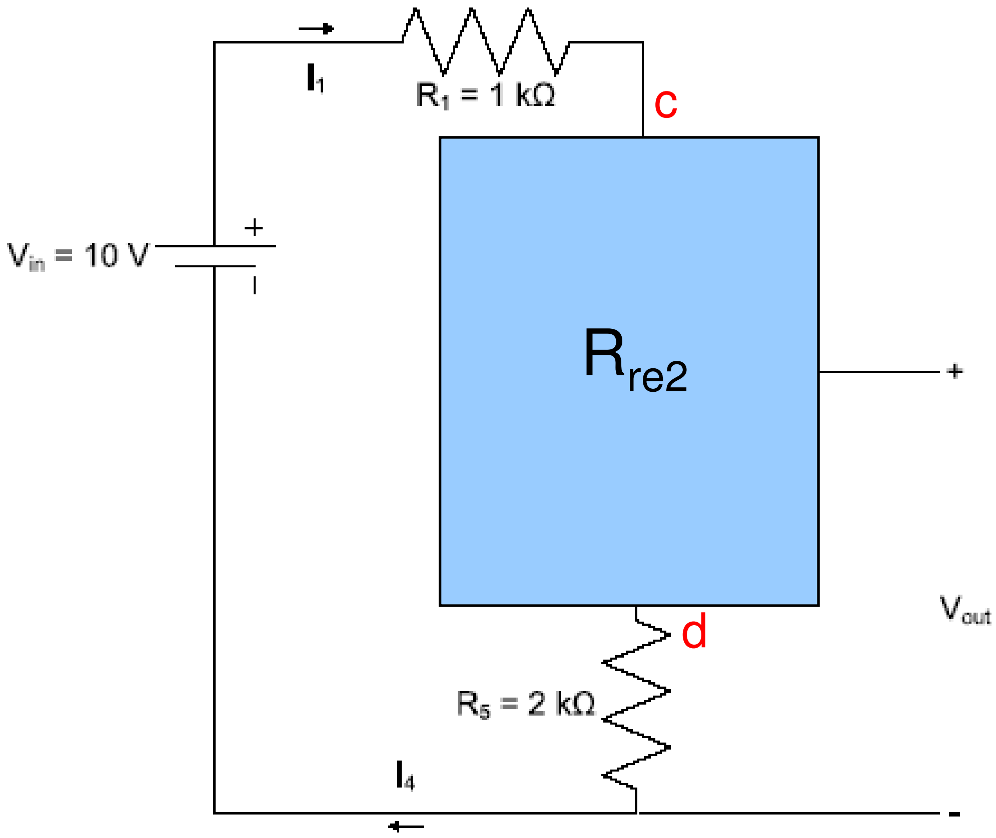
Next, I_3 ?

Calculation of Replacement Resistance Value



$I_3 = V_{cd} / R_{re1} = V_2 / R_{re1}$

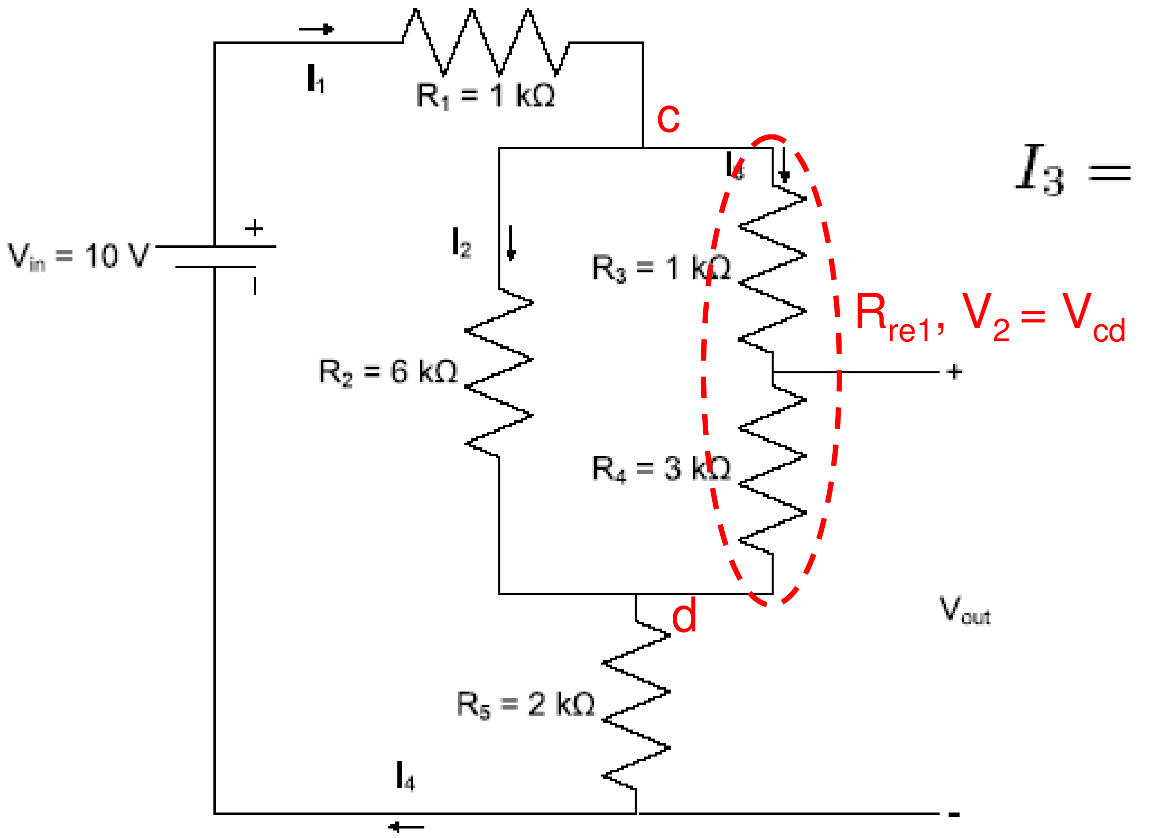
Calculation of Replacement Resistance Value



$$V_2 = V_{cd} = I_1 \bullet R_{re2}$$

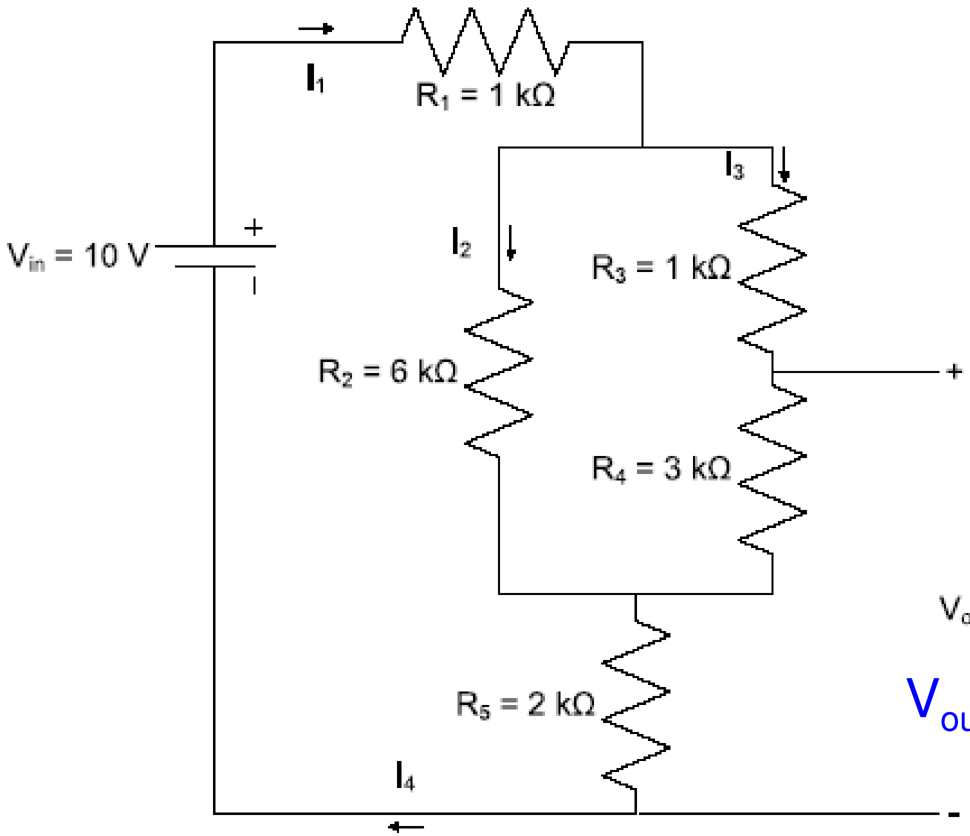
$$V_2 = 1.85 \text{ mA} \cdot 2.4 \text{ k}\Omega = 4.44 \text{ V}$$

Calculation of Replacement Resistance Value



$$I_3 = \frac{V_2}{R_{r1}} = 1.1\ \text{mA}$$

Calculation of Replacement Resistance Value



Ohm's law

$$V_{out} = I_1 \cdot R_5 + I_3 \cdot R_4$$

$$I_1 = \frac{V_{in}}{R_{retotal}} = 1.85 \text{ mA}$$

$$I_3 = \frac{V_2}{R_{r1}} = 1.1 \text{ mA}$$

V_{out}= 1.85 mA • 2 kΩ + 1.1 mA • 3 kΩ
= 7.04 V