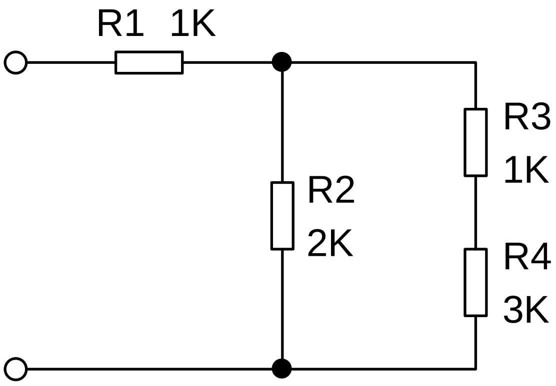
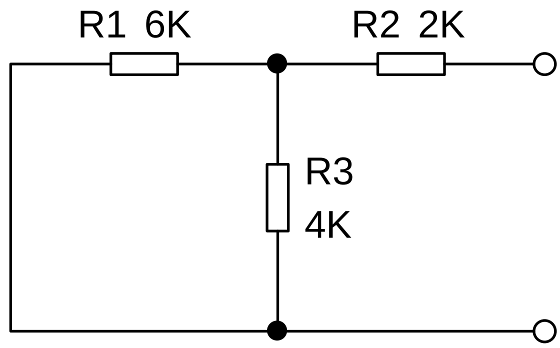
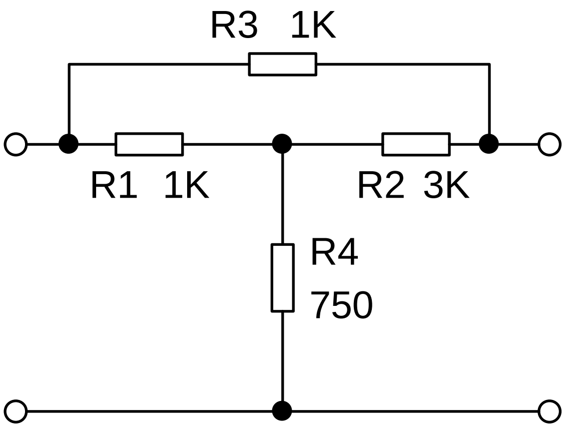
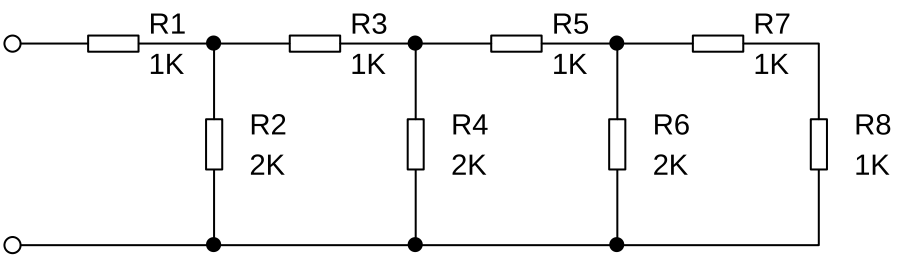
Combining resistors

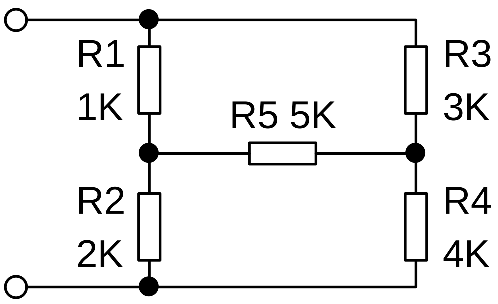
By combining the resistors in figures find equivalent resistivity between terminals:







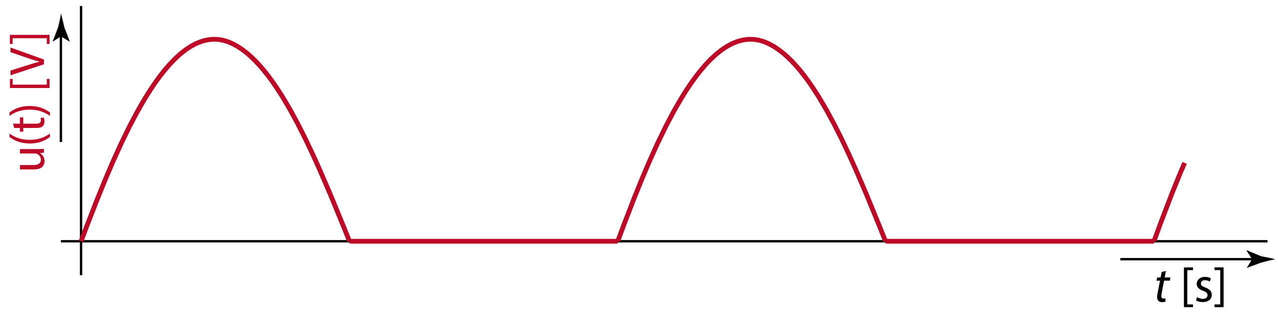




Special values of circuit variables (average and rms values)

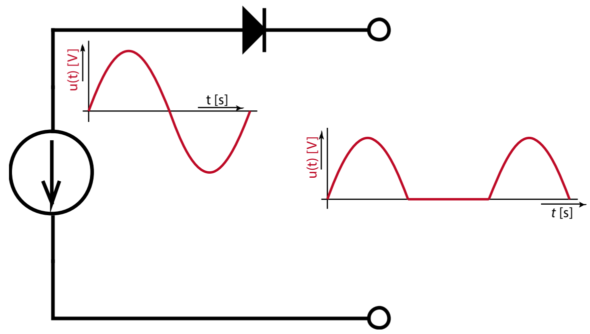
1) Pulse-width modulation (PWM) controlling circuit generates rectangular waveform with variable pulse ratio. The minimum and maximum voltage is 0 V and 12 V. Find average and rms values of this waveform, if the pulse ratio is 1:3, or 3:1.

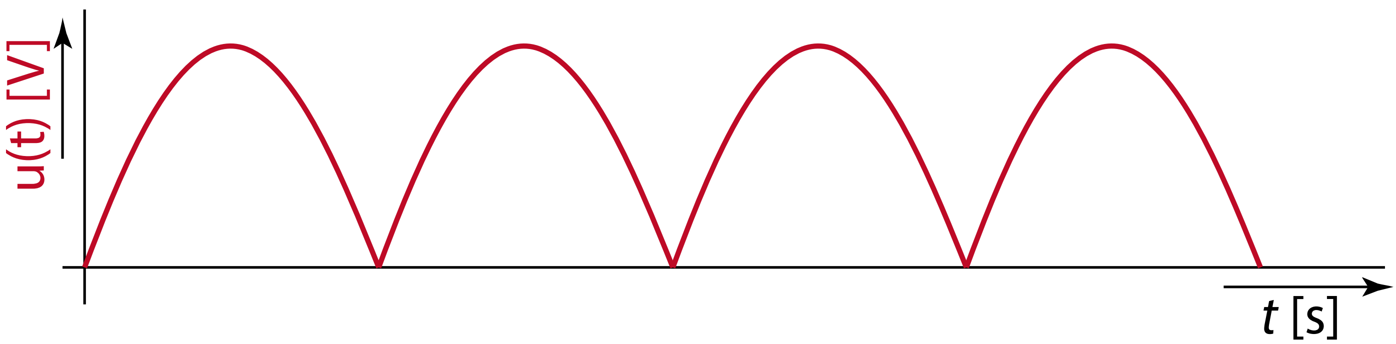
2) In the wall outlet is sinusoidal voltage with RMS value 230 V. Find its maximum value.
   a) Find average value of the voltage.
   b) Find average and RMS values of half way and full way rectified voltage.



Half way rectified voltage

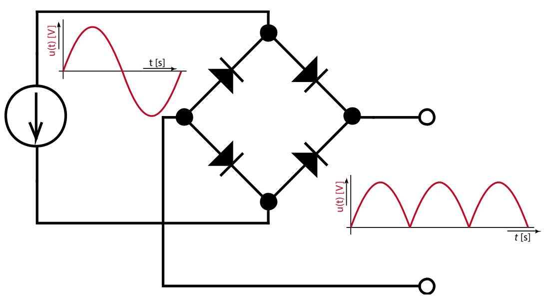
Note: Half way rectified waveform is output of device that converts AC to DC. Due to less power efficiency is used largely as detectors of radio signals.



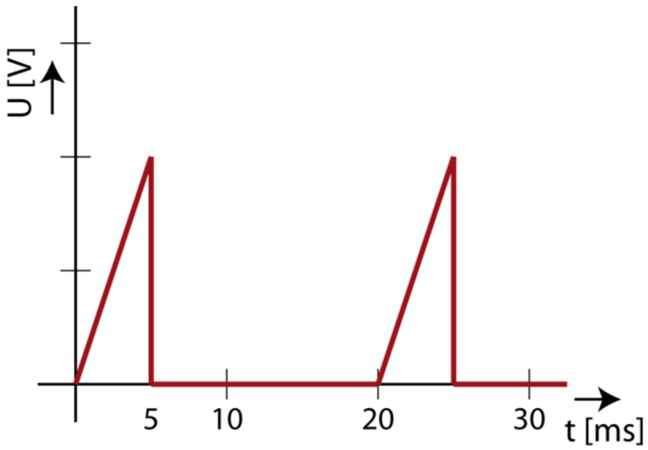


Full rectified voltage

Note: full wave rectification is used in power supplies for AC to DC conversion.



3) Magneto-electric (moving-coil) voltmeter measures average value of rectified voltage. But the meter is calibrated to indicate in RMS units (when the voltage is sinusoidal). Indicated value of voltage is 100 V. Using oscilloscope we learned, the voltage has waveform according to the figure Find its true RMS value.



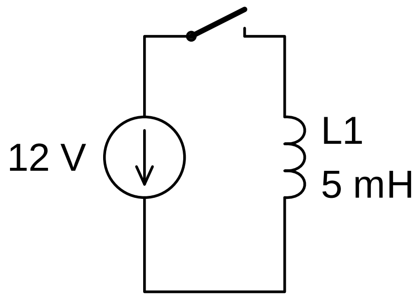
Fundamental passive and active circuit elements

1. Find capacitance of capacitor, which stores energy 400 J when voltage across its terminals is 10 V.
    a. Find the volume of such capacitor, if energy density (energy in J stored per cm^{-3}) is 0.25 $J \cdot cm^{-3}$ (typical electrolytic capacitor).
    b. How long does it take to charge the capacitor from constant current source 5 A?
    c. What kind of source would be used? (*voltage or current – which kind*)

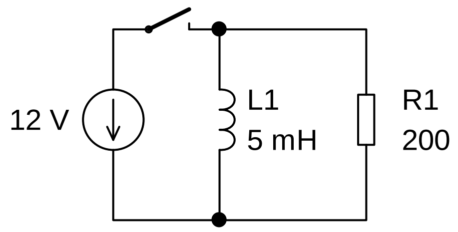
2. Find voltage across capacitor with capacitance 45 μF, if it stores energy 400 J.
    a. Determine volume of general high voltage capacitor with energy density 0.02 $J \cdot cm^{-3}$, and special defibrillator capacitor with energy density 1.06 $J \cdot cm^{-3}$.
    b. Why capacitors with low energy density are mass-produced when special defibrillator capacitor has much less volume and mass?

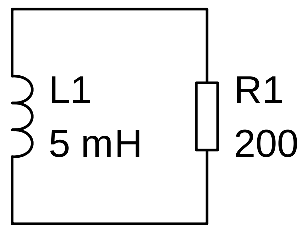
3. DC current 1 mA flow in the capacitor with capacitance 100 nF.
    a. Compute the charge stored in the capacitor at t = 1 ms?
    b. Compute the voltage across capacitor's terminals.
    c. Determine the energy stored in the capacitor.
    d. Draw waveforms of charge, voltage and stored energy for DC current source, as well as other waveforms of source current (triangular, sinusoidal …).

4. An ideal inductor with inductance L_1 = 5 mH is connected (at t = 0) in parallel to ideal voltage source U = 12 V. No current flows through the inductor before the voltage source was connected. Compute current flowing through the inductor at t = 1 ms?

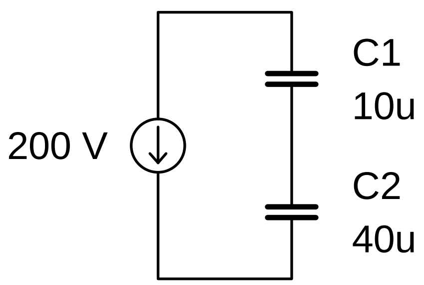


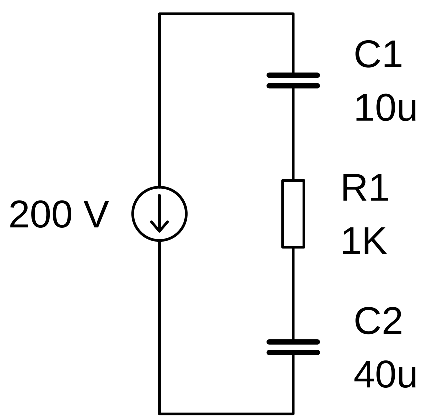
5. An ideal inductor (same as in previous problem) with inductance L_1 = 5 mH is connected at t = 0 in parallel with an ideal voltage source U = 12 V. No current flows through the inductor before the voltage source was connected. In addition, in parallel is connected resistor with resistivity $R_1 = 200\,\Omega$. The switcher is switched off at t = 1 ms and disconnect voltage source. Determine the voltage across inductor at the moment when the source is disconnected?





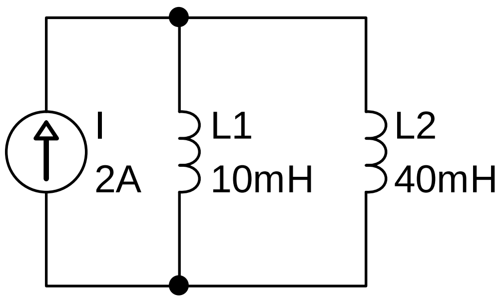
6. Given two capacitors, $C_1 = 10\,\mu\mathrm{F}$ and $C_2 = 40\,\mu\mathrm{F}$. Capacitors are without charge. Capacitors are connected in series and supplied from the DC voltage source $U = 200\,\mathrm{V}$.
   a. Determine total capacitance of series connection of capacitors.
   b. Compute voltage across both capacitors.
   c. Consider general case of *n* capacitors connected in series. Calculate voltage across three capacitors connected in series with capacitances 3, 2 and 1 μF.





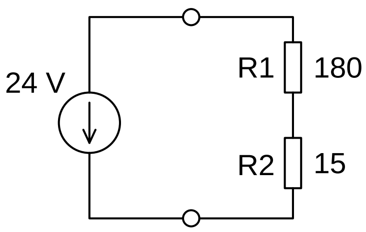
   d. Between both capacitors connect resistor $R = 1\,\mathrm{k}\Omega$. How the voltage across capacitors changes? Suppose the capacitors were without charge before they had been connected to the source.
   e. Evaluate charge stored in both capacitors. Evaluate charge delivered by the voltage source.
   f. Now suppose before we connected the source the first capacitor has been charged with charge $q_1(0) = 400\,\mu\mathrm{C}$ and the second with charge $q_2(0) = 200\,\mu\mathrm{C}$. Calculate voltages across capacitors.

7. The two ideal inductors with inductances L_1 = 10 mH and L_2 = 40 mH were connected in parallel. They were connected to DC current source I = 2 A. No current passed through the inductors before they were connected to the current source.
   a. Determine the equivalent inductance.
   b. Compute currents flowing through both inductors.



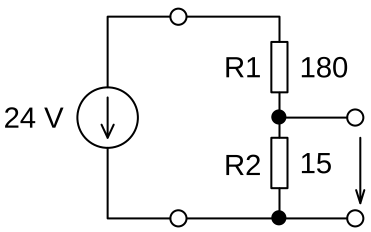
Basic laws and theorems, simple circuits excited by one and several independent sources

1. Given the circuit according to the figure below (voltage divider), resistors have values $R_1 = 180\,\Omega$, $R_2 = 15\,\Omega$. The circuit is supplied from ideal DC voltage source U = 24 V.



   a. Compute current which flows in the circuit.
   b. Determine voltage across both resistors.
   c. Compute powers absorbed by both resistors and power, delivered to the circuit by voltage source. Using on-line catalog of some distributor of electronic components (e.g. www.gme.cz, http://www.ges.cz/index/homepage.html, or other) pick resistors applicable to practical circuit implementation.

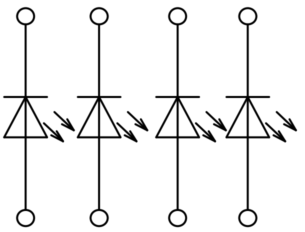
2. Now we use voltage divider from previous problem as voltage source. *Why use voltage divider as voltage source? The reason could be the need of less voltage than is value of voltage source.*



   a. Compute voltage across output terminals, if we deliver to the connected load circuit current $I_z = 50\,\mathrm{mA}$. *Use both Kirchhoff's laws.*
   b. Determine maximum possible current, we may load from output terminals – at which voltage?

c. Draw load characteristic of voltage divider.
d. Replace the circuit with Thévenin's equivalent circuit. Internal resistivity determine both using rules for removing of sources and basic definition equation $R_i = \frac{U_p}{I_k}$.
e. Suppose maximum allowable voltage drop across output terminals is 5%. Compute maximum possible current we may load from voltage divider. Determine efficiency of the source (consider the source is whole circuit including voltage divider).

3. We decided to use for illumination "white" power LED lighting device L-ACULED VHL 5555. It consists of 4 separate LED chips. We have 12 V DC voltage source. It is not possible to connect LED diode directly to voltage source, as it would be destroyed by high current and resulting heat. Let's design a circuit that limits maximum flowing current.



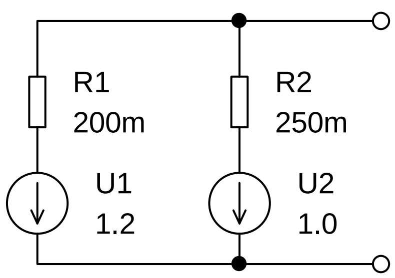
Parameters of LED lighting device are:

- LED junction voltage at operating conditions (fully shining): $U_f = 3.5\ \mathrm{V}$
- Flowing current: $I = 700\ \mathrm{mA}$ / each chip

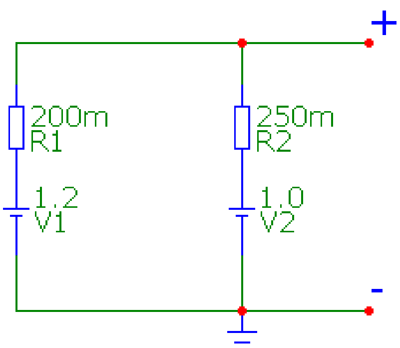
a) Determine resistivity of additional resistor (or resistors)
b) Determine power delivered by the source, power dissipated on resistors and power dissipated by LED chips (light and heat).

Note: Total luminous flux is 360 lm. An equivalent incandescent lamp would have about 30 W (since its efficiency decreases with power), but, comparing with 100 W incandescent lamp with efficiency about 20 lm per Watt, the LED has the luminous flux equivalent to 18 W dissipated in incandescent bulb… ☺

4. Two NiMH accumulators were connected in parallel. The first, fully charged had voltage 1.2 V and internal resistivity 200 mΩ, the second, weak, had voltage 1.0 V and internal resistivity 250 mΩ .



An equivalent circuit diagram in Microcap:

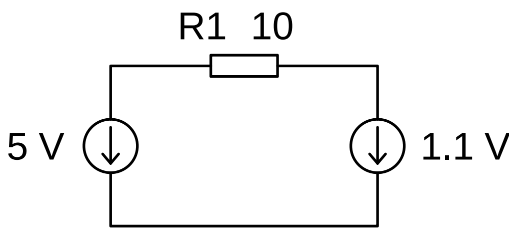


a. Compute voltage across the terminals just after we connect accumulators in parallel.
b. Will be the same voltage across the terminals after few hours?
c. Determine maximum possible current we may load from accumulators, if they are alone, and after we connect them in parallel.
d. Evaluate parameters of Thévenin's equivalent circuit.
e. Compute maximum current we may load from parallel connected accumulators, if the voltage across their terminals should not drop under 1 V?

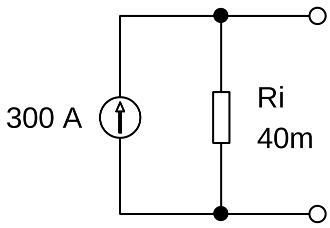
5. Given 3 cell LiPol accumulator, fully charged, with voltage 4.2 V / cell and internal resistivity 20 mΩ / cell. To the accumulator is connected regulator, which maintain constant current drain I = 30 A. It also ensures the power consumer is disconnected when the voltage across terminals of accumulator drops at 7.95 V (shut down voltage). Internal voltage of one accumulator cell should not drop under 3.2 V, or the accumulator may be damaged.
   a. Is the value of shut down voltage correct?

6. To the regulator from previous problem will be connected accumulator with internal resistivity 5 mΩ / cell, the current demand decrease at I = 15 A and the shut down voltage remains the same.
   a. Is the value of shut down voltage correct?
   b. Determine minimum safe shut down voltage (when internal voltage doesn't drop under 3.2 V).
   c. Compute current demand when the shut down voltage 7.95 V is suitable.

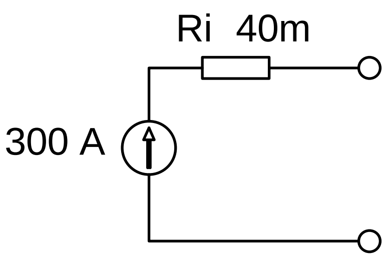
7. In the circuit in the figure below are connected two voltage sources, $U_1 = 5\,\mathrm{V}$ and $U_2 = 1.1\,\mathrm{V}$ and resistor with resistivity$R = 10\,\Omega$.
   a. Compute current, flowing in the circuit.
   b. Compute powers delivered by both sources and power dissipated on resistir. Explain the signs of results. Can you find any practical meaning of such circuit (in its basic principle)?



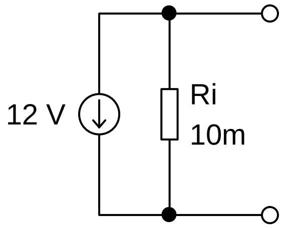
8. In parallel with ideal current source $I_i = 300\,\mathrm{A}$ is connected resistor with resistivity $R_i = 0.04\,\Omega$. From the point of view of output terminals, is possible to replace this circuit with equivalent circuit, where voltage source and resistor would be connected? Determine parameters of such circuit.
   a. Draw I-V characteristic of both circuits.



9. In series with ideal current source $I_i = 300\,\mathrm{A}$ is connected resistor with resistivity $R_i = 0.04\,\Omega$. From the point of view of output terminals, is possible to replace this circuit with equivalent circuit, where voltage source and resistor would be connected? Determine parameters of such circuit.

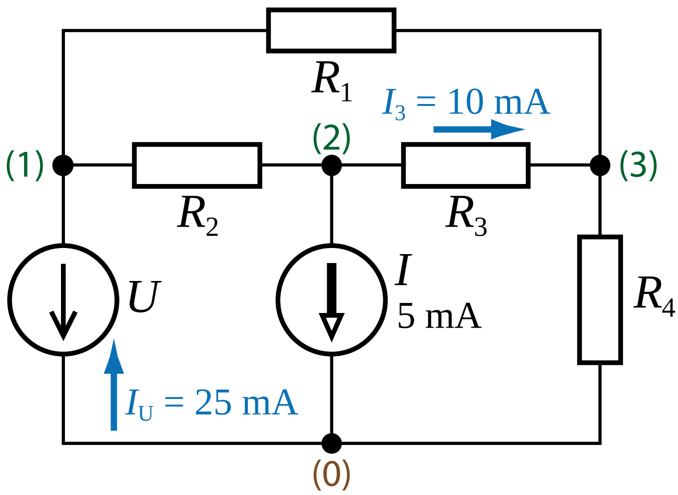


10. In parallel with ideal voltage source $U_i = 12\,\mathrm{V}$ is connected resistor with resistivity $R_i = 0.01\,\Omega$. From the point of view of output terminals, is possible to replace this circuit with equivalent circuit, where current source and resistor would be connected? Determine parameters of such circuit.

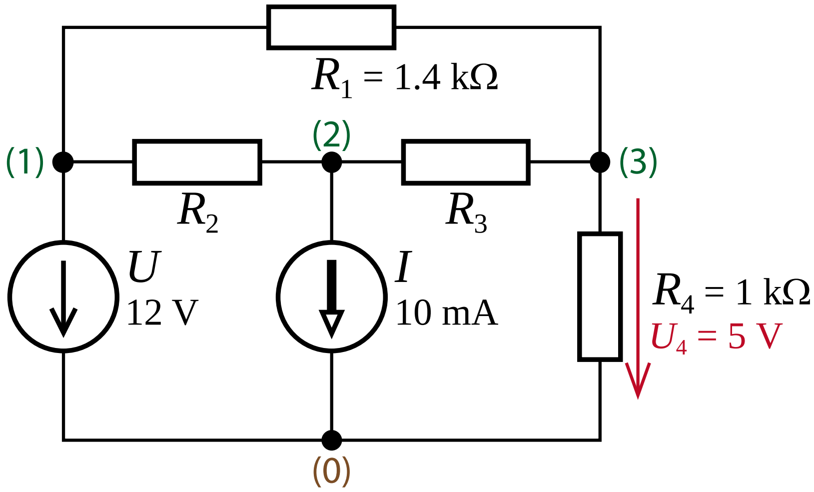


Kirchhoff's laws

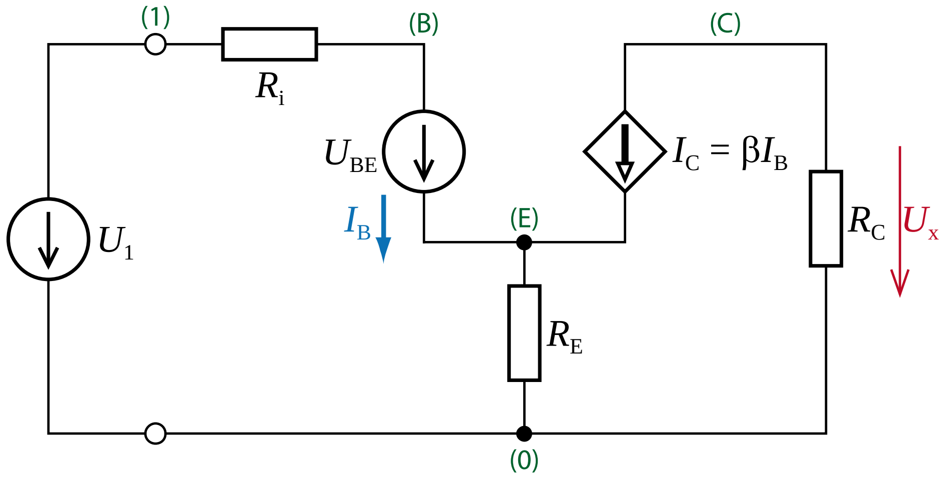
1. In circuit in the figure below were measured currents I_3 and I_U.
   a. Compute currents I_1, I_2 and I_4, which flows through resistors R_1, R_2 and R_4.
   b. Voltage source has value $U = 12$ V, $R_3 = 300\ \Omega$. The voltage across resistor R_4 was measured as $U_4 = 3$ V. Compute resistivity of other resistors in the circuit and voltage at node (2).
   c. Determine powers, delivered to the circuit by both sources.



2. In circuit in the figure below we know value of the voltage source $U = 12$ V, current of the current source $I = 10$ mA, resistivity of resistors $R_1 = 1.4\ \mathrm{k}\Omega$, $R_4 = 1\ \mathrm{k}\Omega$ and voltage across resistor R_4.
   a. Determine currents I_1, I_2, I_3 and I_4, which flows through resistors R_1, R_2, R_3 a R_4.
   b. Compute voltage at node (2) and resistivity of resistor R_2.

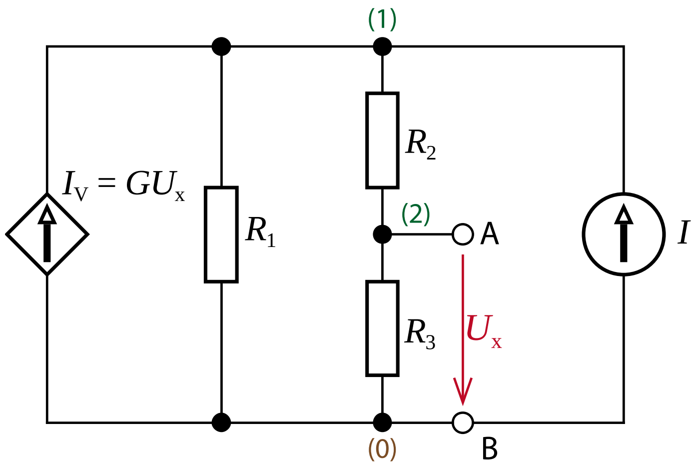


3. To determine operating point, common-emitter amplifier circuit with bipolar junction transistor was replaced by its model for DC conditions according to the figure below. The values of circuit elements are: R_E = 1.5 kΩ, R_C = 6.8 kΩ, Ri = 75 kΩ, U_{BE} = 0.7 V, β = 300, U_1 = 3 V.
   a. Calculate current I_B.
   b. Calculate the voltage U_x.

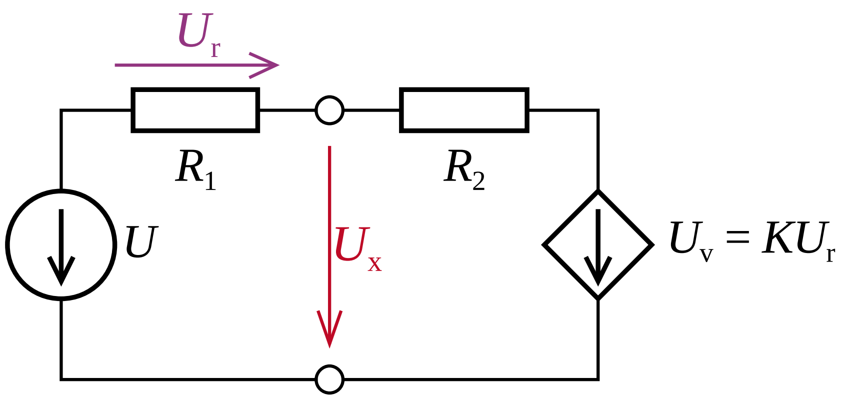


4. In the circuit in figure below:
   a. Calculate the voltage Ux.
   b. Find the Thévenin equivalent circuit of the circuit in figure at terminals AB.

The circuit elements have values: R_1 = 1 kΩ, R_2 = 2 kΩ, R_3 = 3 kΩ, G = 0.001, I = 9 mA.

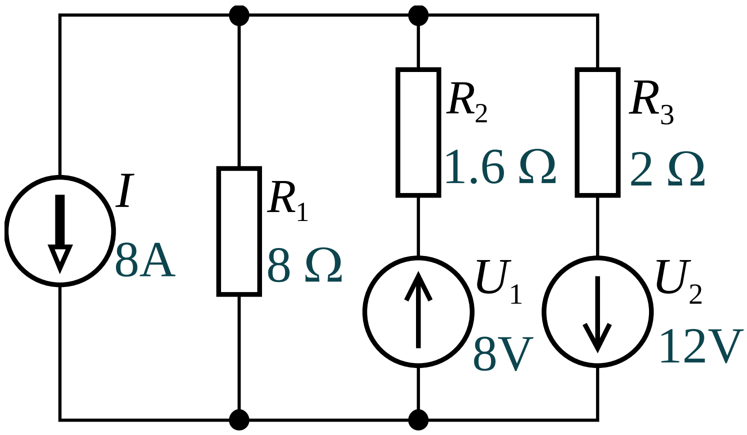


5. In the circuit in the figure below compute the voltage U_x. Circuit elements have values: $R_1 = 10\ \mathrm{k\Omega}$, $R_2 = 2\ \mathrm{k\Omega}$, $K = 10$, $U = 12\ \mathrm{V}$.

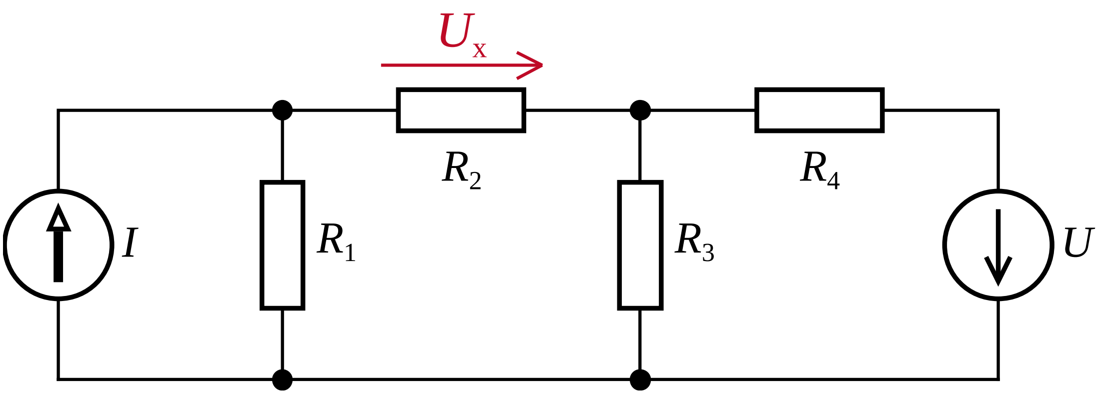


Source transformation

1. Use source transformations to reduce the circuit to a single voltage source in series with a single resistor.

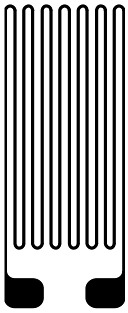


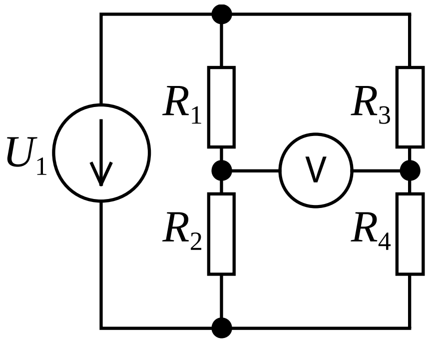
2. Use source transformation to find the voltage U_x.
   $R_1 = 500\ \Omega$, $R_2 = 1\ \mathrm{k\Omega}$, $R_3 = 6\ \mathrm{k\Omega}$, $R_4 = 4\ \mathrm{k\Omega}$, $I = 20\ \mathrm{mA}$, $U = 30\ \mathrm{V}$
   Compare this method with superposition.



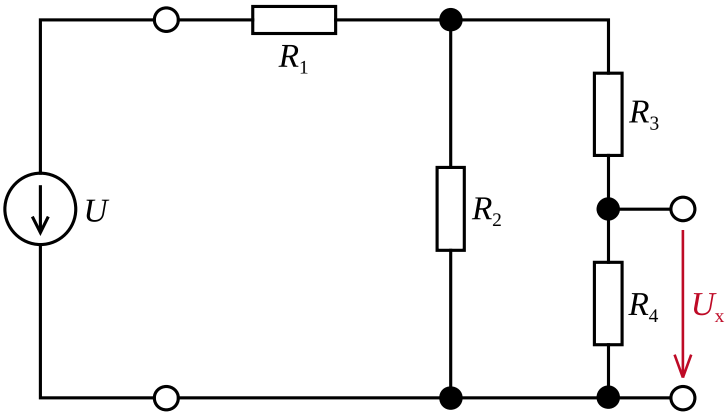
Circuit Theorems and Basic Laws

1. A Wheatstone bridge is an accurate device for measuring resistance. An example of its application is a system used to determine a weight of a truck as shown in a figure below. Strain gauge is a device which changes its resistivity depending on mechanical stress. Its nominal resistivity is 350 Ω.
   a. Find voltage on Wheatstone bridge diagonal, where four strain gauges are connected and their resistances were: $R_1 = 349\ \Omega$, $R_2 = 351\ \Omega$, $R_3 = 351\ \Omega$, $R_4 = 349\ \Omega$. A Wheatstone bridge is supplied by voltage source $U = 10$ V.
   b. Now consider we connect electronic probe which satisfy maximum power transfer theorem condition. Has it any meaning? Evaluate value of voltage on bridge's diagonal.

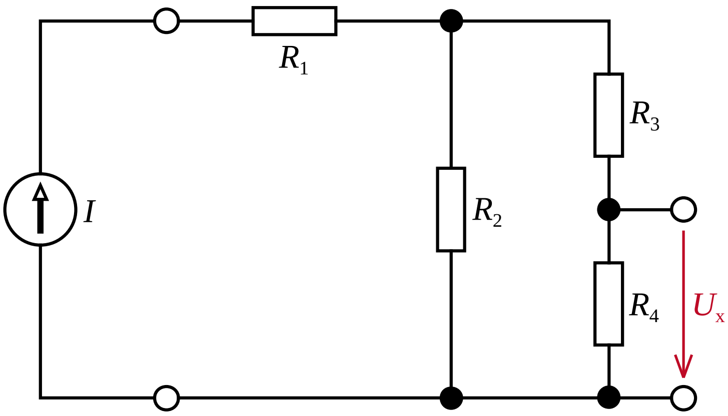




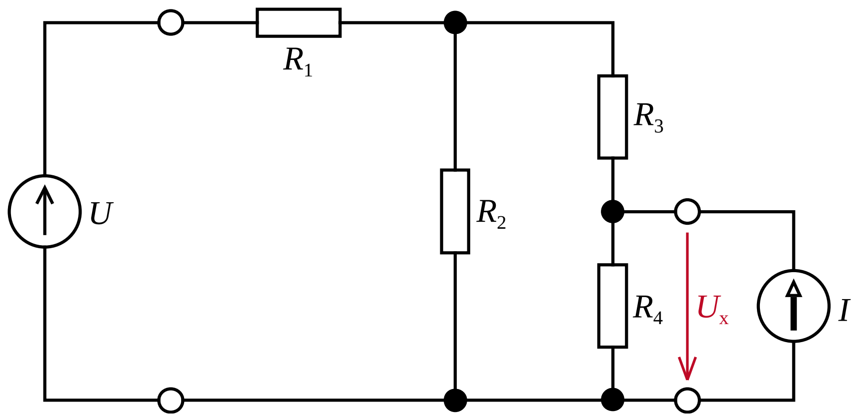
2. Compute the voltage U_x in the figure below. Values of circuit elements are:
   $R_1 = 1200\ \Omega$, $R_2 = 1\ \text{k}\Omega$, $R_3 = 1\ \text{k}\Omega$, $R_4 = 3\ \text{k}\Omega$, $U = 20$ V.



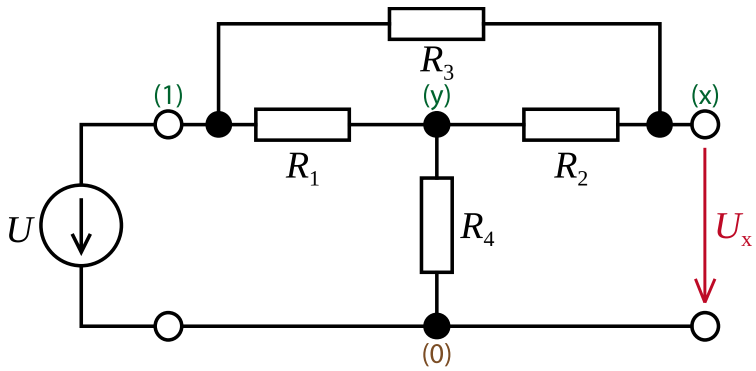
3. Compute the voltage U_x in the figure below. Values of circuit elements are:
   $R_1 = 1200\ \Omega$, $R_2 = 1\ \text{k}\Omega$, $R_3 = 1\ \text{k}\Omega$, $R_4 = 3\ \text{k}\Omega$, $I = 30$ mA.



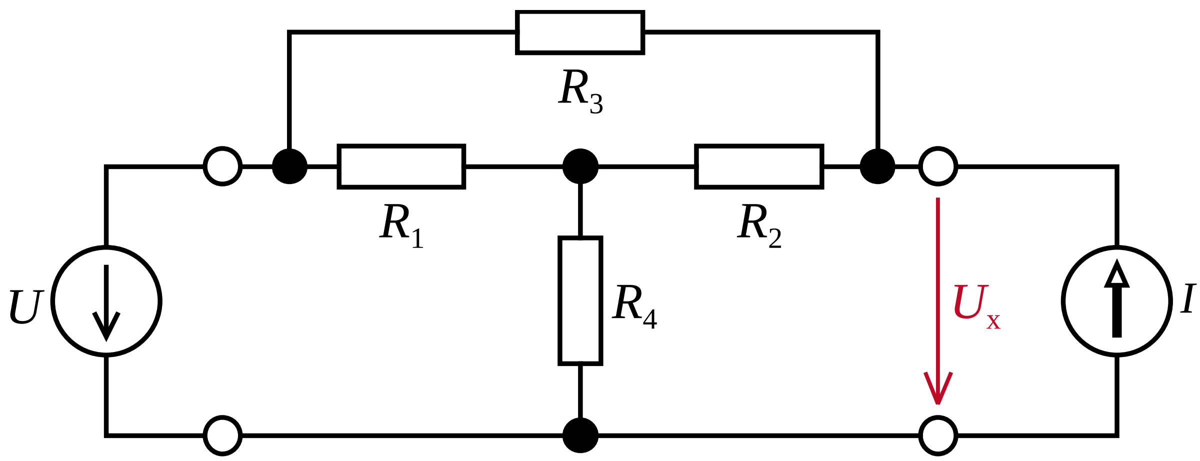
4. Compute the voltage U_x in the figure below. Values of circuit elements are:
$R_1 = 1200\ \Omega$, $R_2 = 1\ k\Omega$, $R_3 = 1\ k\Omega$, $R_4 = 3\ k\Omega$, $U = 20$ V, $I = 30$ mA.



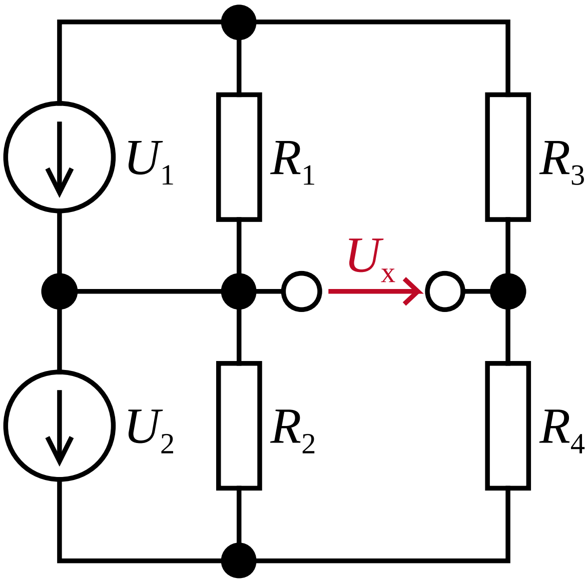
5. Compute the voltage U_x in the figure below. Values of circuit elements are:
$R_1 = 1\ k\Omega$, $R_2 = 3\ k\Omega$, $R_3 = 1\ k\Omega$, $R_4 = 750\ \Omega$, $U = 70$ V.



6. Compute the voltage U_x in the figure below. Values of circuit elements are:
$R_1 = 1\ k\Omega$, $R_2 = 3\ k\Omega$, $R_3 = 1\ k\Omega$, $R_4 = 750\ \Omega$, $U = 70$ V, $I = 10$ mA.



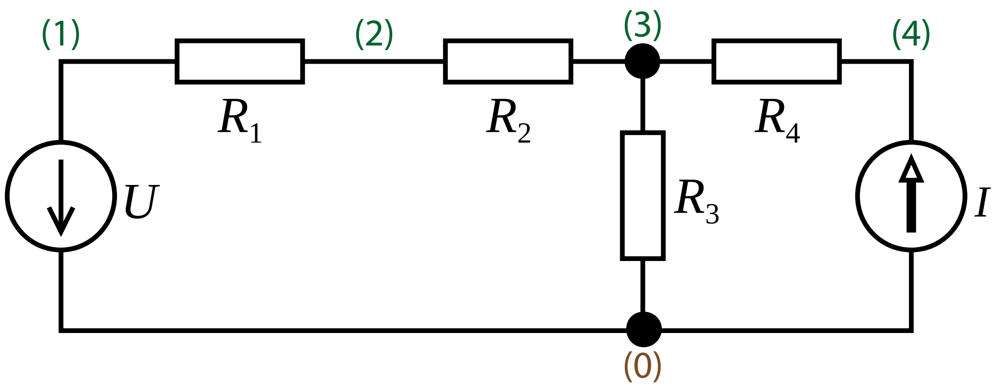
7. For the circuit in the figure below calculate currents which flows through both voltage sources and voltage U_x at terminals. Values of circuit elements are:
   R_1 = 1 kΩ, R_2 = 2 kΩ, R_3 = 2 kΩ, R_4 = 3 kΩ, U_1 = 20 V, U_2 = 30 V.



8. In the circuit below calculate:
   a. Voltage across all resistors – i.e. between nodes (1) and (2), (2) and (3), (3) and (4), (3) and (0).
   b. Power, delivered to the circuit by both sources and power, absorbed by all resistors.

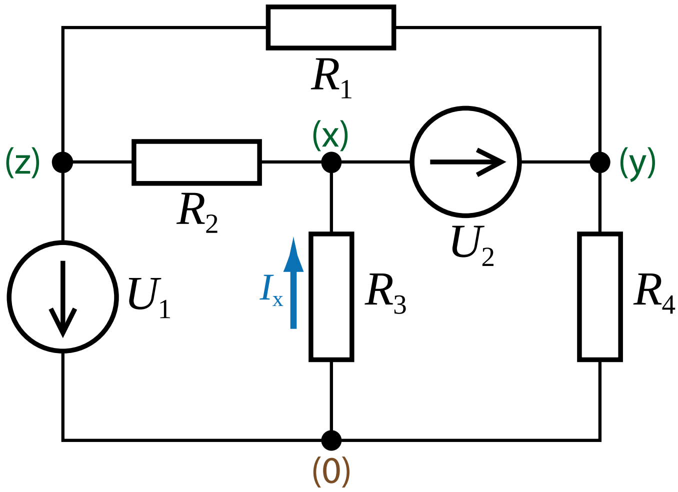
   Values of circuit elements are:

   R_1 = 200 Ω, R_2 = 200 Ω, R_3 = 100 Ω, R_4 = 400 Ω, U = 20 V, I = 200 mA

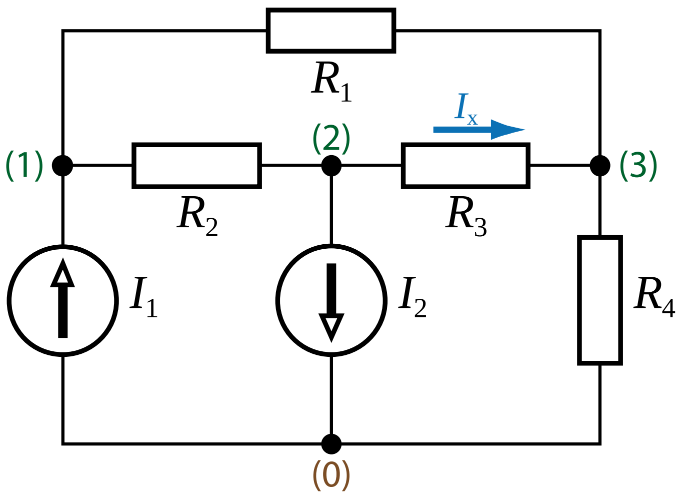


Circuit equations

1. In the circuit in the figure below calculate current I_x. Use nodal voltages.
   Values of circuit elements are:
   $R_1 = 1\ \text{k}\Omega$, $R_2 = 2\ \text{k}\Omega$, $R_3 = 1\ \text{k}\Omega$, $R_4 = 5\ \text{k}\Omega$, $U_1 = 20\ \text{V}$, $U_2 = 30\ \text{V}$



2. In the circuit in the figure below calculate current I_x. Use mesh analysis.
   Values of circuit elements are:
   $R_1 = 2\ \text{k}\Omega$, $R_2 = 1\ \text{k}\Omega$, $R_3 = 1\ \text{k}\Omega$, $R_4 = 2\ \text{k}\Omega$, $I_1 = 20\ \text{mA}$, $I_2 = 10\ \text{mA}$



3. In the circuit in the figure below calculate voltage U_x. Use mesh analysis.
   Values of circuit elements are:
   $R_1 = 4\ \text{k}\Omega$, $R_2 = 500\ \Omega$, $R_3 = 1.5\ \text{k}\Omega$, $\beta = 150$, $U = 12\ \text{V}$