Revision Lecture 1: Nodal Analysis

Exam

Exam Format

Question 1 (40%): eight short parts covering the whole syllabus.

Questions 2 and 3: single topic questions (answer both)

Syllabus

Does include: Everything in the notes.

Does not include: Two-port parameters (2008:1j), Gaussian elimination (2007:2c), Application areas (2008:3d), Nullators and Norators (2008:4c), Small-signal component models (2008:4e), Gain-bandwidth product (2006:4c), Zener Diodes (2008/9 syllabus), Non-ideal models of L, C and transformer (2011/12 syllabus), Transmission lines VSWR and crank diagram (2011/12 syllabus).

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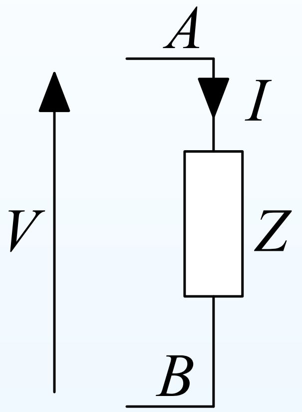
- Components are in series if the same current is forced to flow through each one.
- KCL (Kirchoff's Current Law): The total current going out of a node (or any collection of nodes) sums to zero.

Ohm's Law

Ohm's law relates the voltage drop across a resistor to the current flowing in it:

$$V = IZ$$



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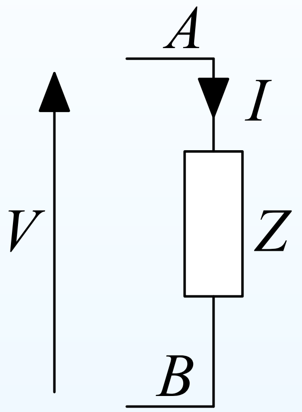

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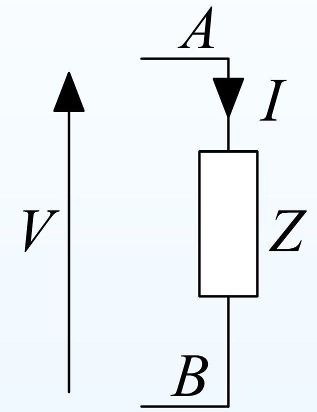

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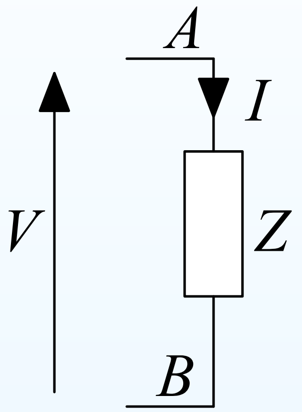

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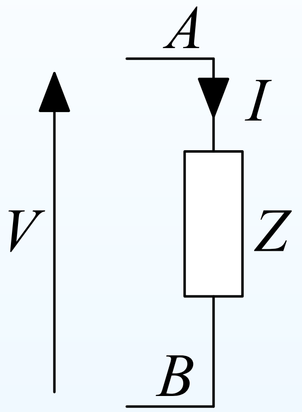

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Ohm's law still true if all currents and all voltages are RMS values: $\widetilde{V} = \tilde{I}Z$ where $\widetilde{V} = \frac{V}{\sqrt{2}}$ for a voltage phasor V.

Nodal Analysis

(1) Pick any node as the voltage reference. Label its voltage as $0\ \mathrm{V}$. Label any dependent sources with $V_S,\ I_S,\ \ldots$.

(2) If any voltage sources are connected to a labelled node, label their other ends by adding the value of the source onto the voltage of the labelled end.

(3) Pick an unlabelled node and label it with $X,\ Y,\ \ldots$, then loop back to step (2) until all nodes are labelled.

(4) For each **dependent source**, write down an equation that expresses its value in terms of other node voltages.

(5) Write down a KCL equation for each "normal" node (i.e. one that is not connected to a floating voltage source).

(6) Write down a KCL equation for each "super-node". A super-node consists of a set of nodes that are joined by floating voltage sources and includes any other components linking these nodes.

(7) Solve the set of simultaneous equations that you have written down.

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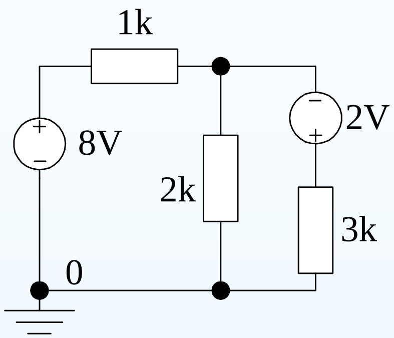

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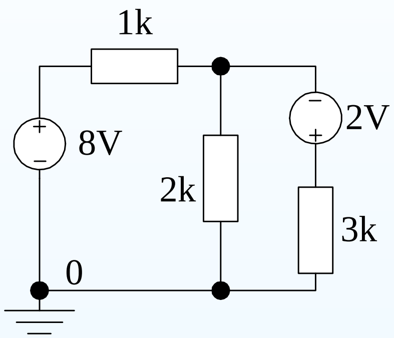
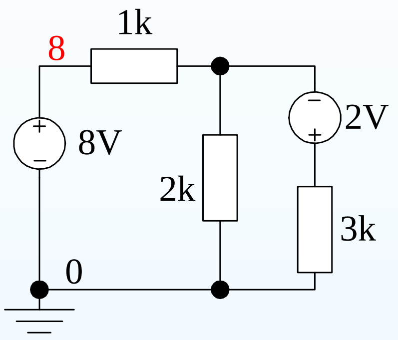


Nodal Analysis Example

(1) Pick reference node.

(2) Label nodes: 8



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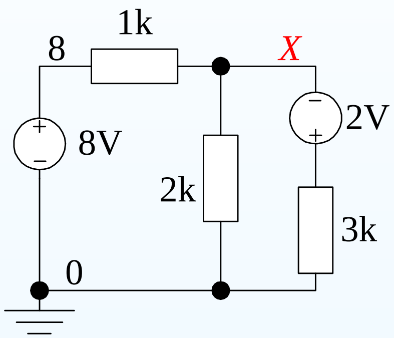

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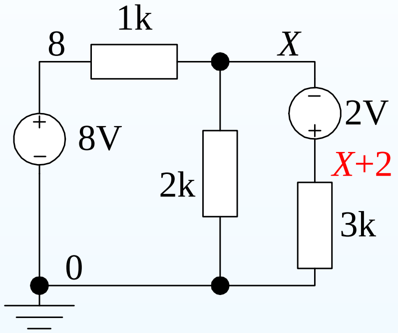
(1) Pick reference node.

(2) Label nodes: 8, X and $X + 2$ since it is joined to X via a voltage source.



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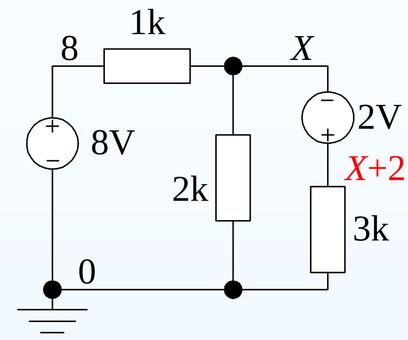
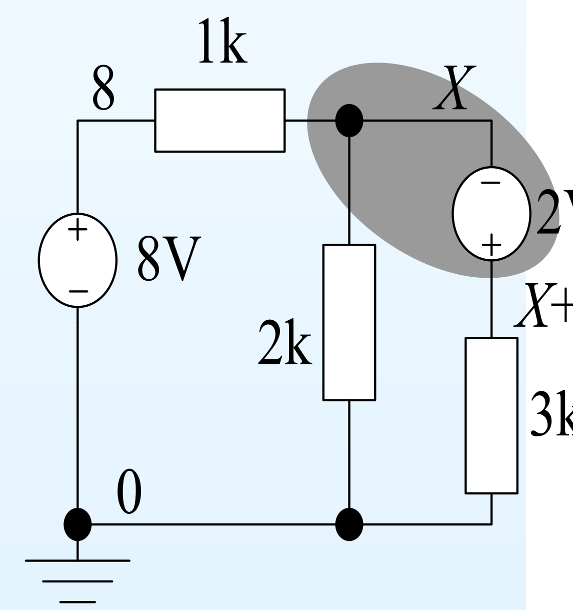
$$\frac{X-8}{1} + \frac{X}{2} + \frac{(X+2)-0}{3} = 0$$





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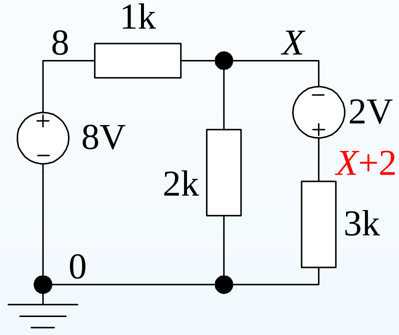

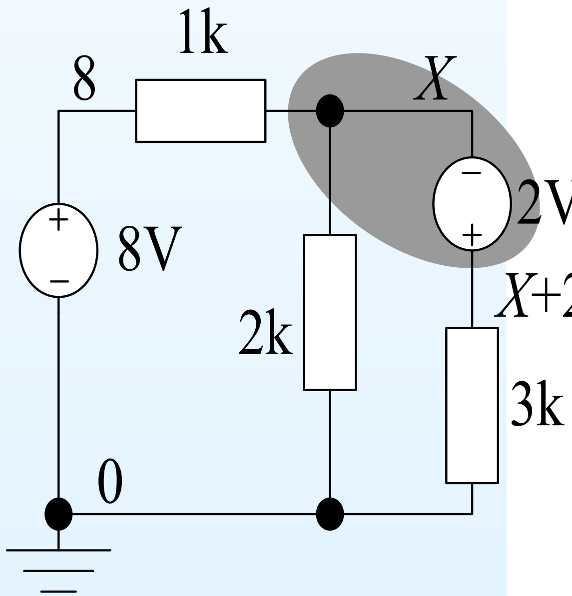

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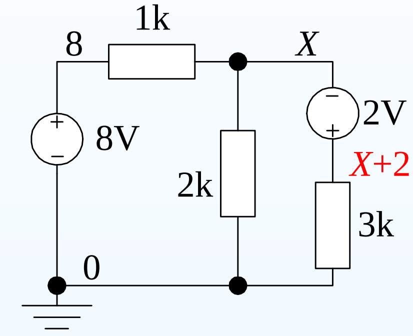

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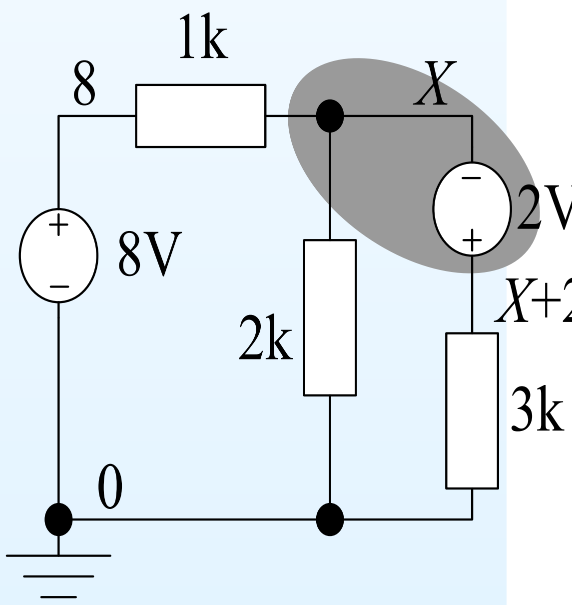
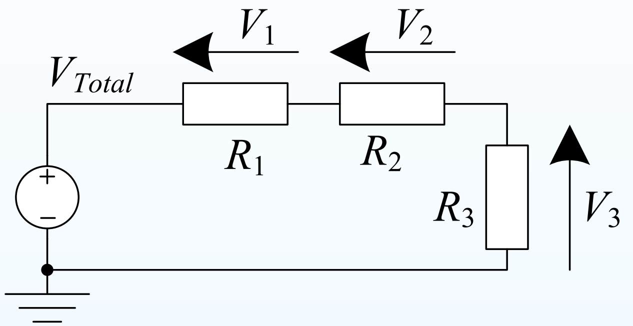


(4) Solve the equations: $X=4$

Voltage and Current Dividers

Components in series form a voltage divider: Voltages $\propto R$.

$$\frac{V_k}{V_{Total}} = \frac{R_k}{R_{Total}}$$



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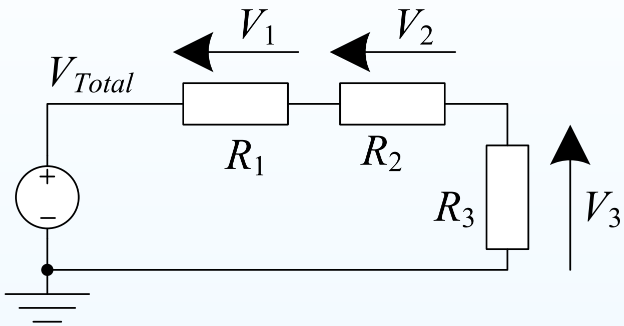

Components in parallel form a current divider: Currents $\propto G$.

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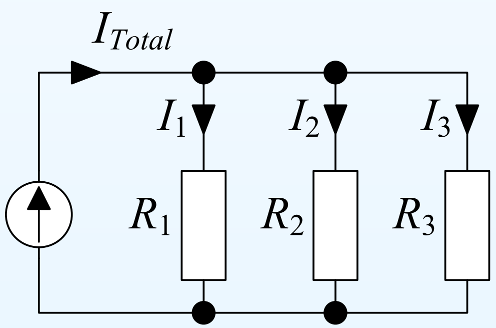

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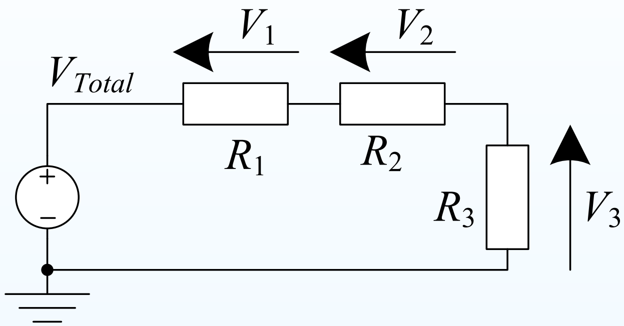

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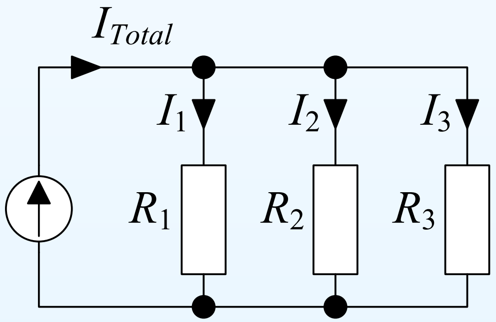

Summing Junction: X is a weighted average with weights $\propto G$.

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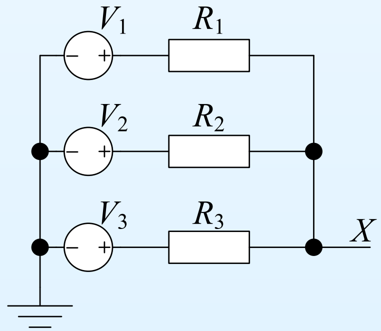

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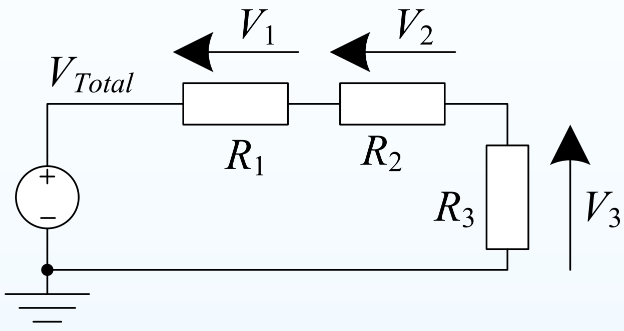

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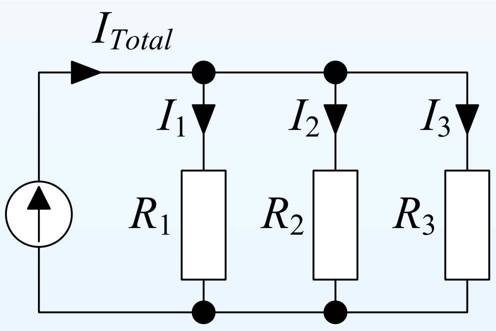

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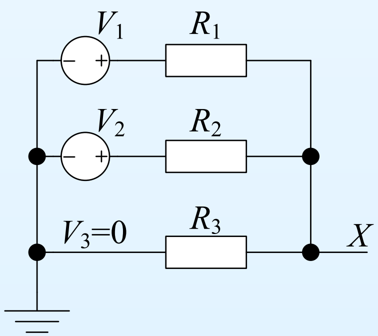
Also works if V_k is zero (less obvious).



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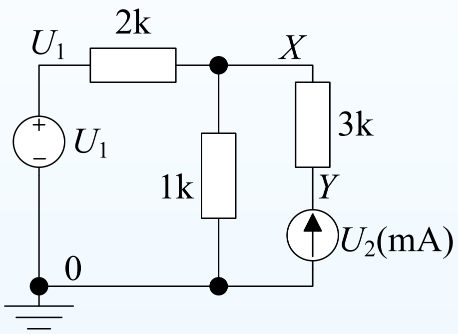
- Repeat for each of the sources and add up the results to get a formula for the voltage at each node.
- Express all dependent source values in terms of node voltages and eliminate them from the formulae. A source is dependent if its value is determined by the voltages/currents elsewhere in the circuit.

Superposition Example

Problem: Find X in terms of U_1 and U_2.



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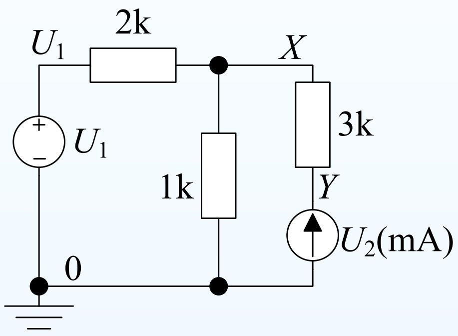

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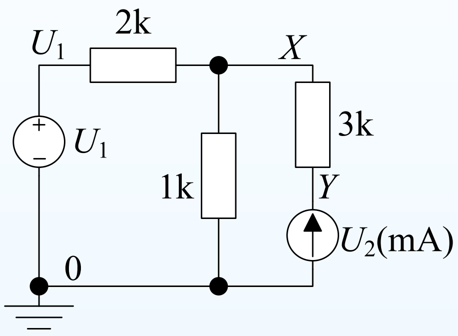

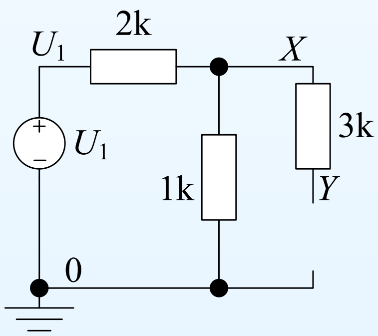

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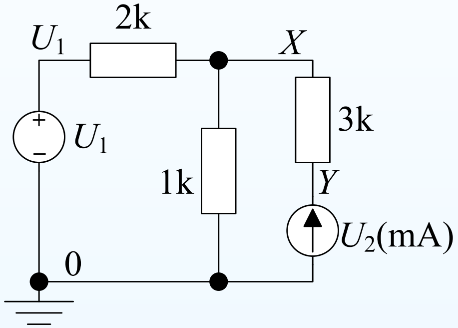

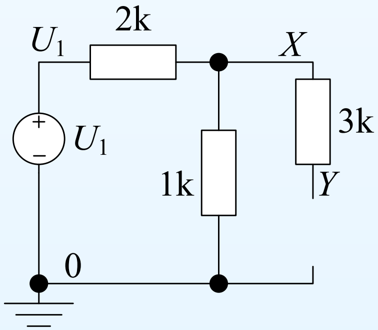

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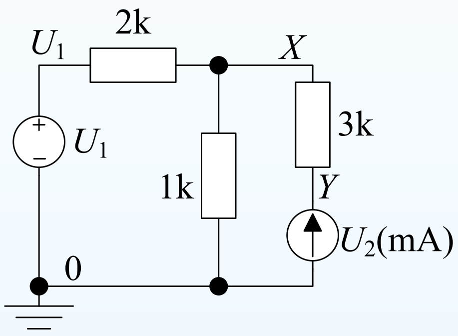

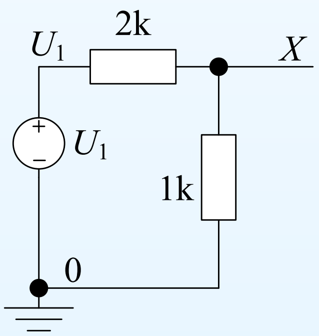

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Problem: Find X in terms of U_1 and U_2.

- If we set $U_2 = 0$ then the current source becomes an *open circuit* and now the 3 k plays no part in the circuit.

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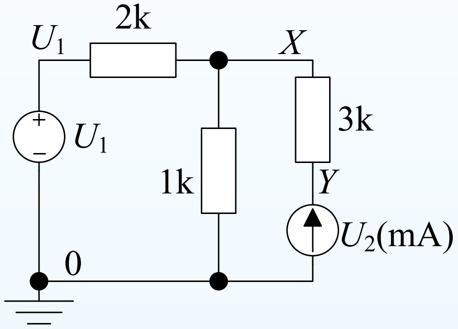

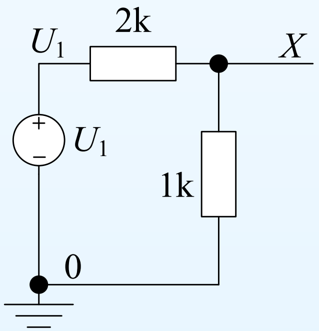

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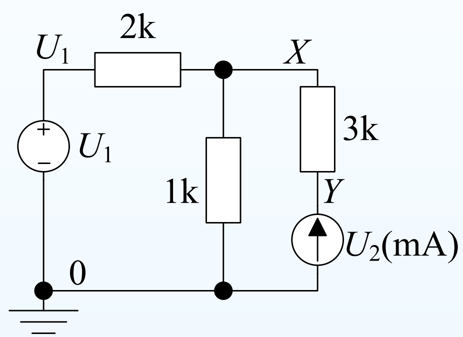

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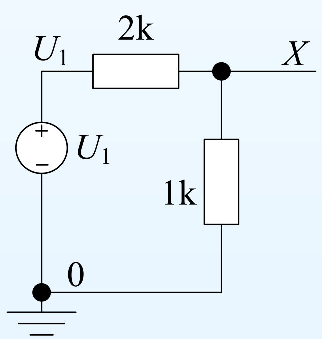

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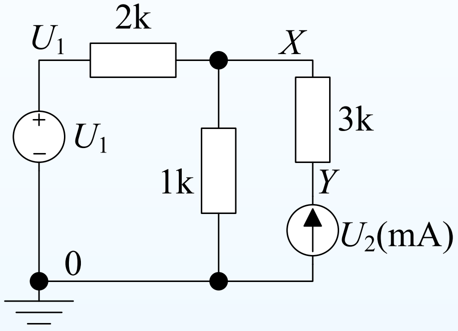

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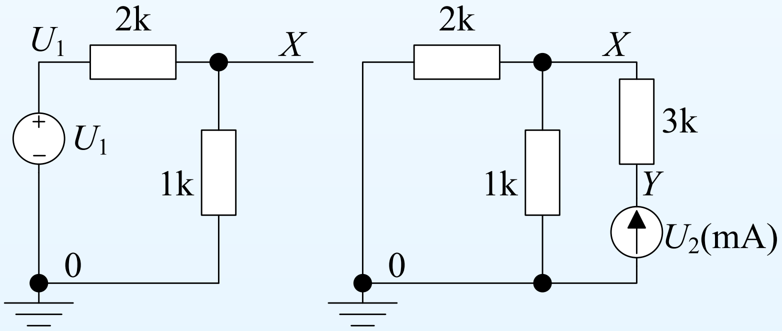

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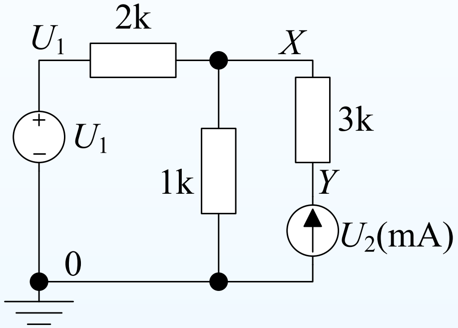

- If we set $U_1 = 0$ then the voltage source becomes a *short circuit* and the $2\ \text{k}$ and $1\ \text{k}$ are in parallel.

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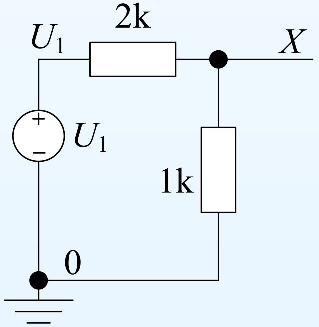

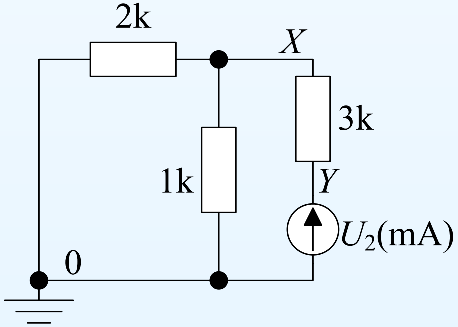

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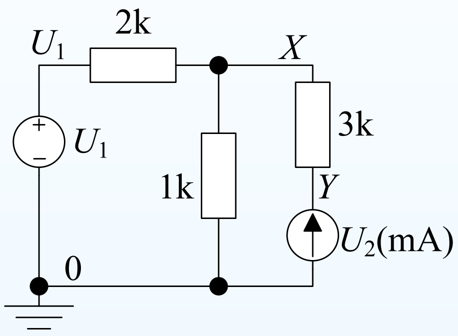

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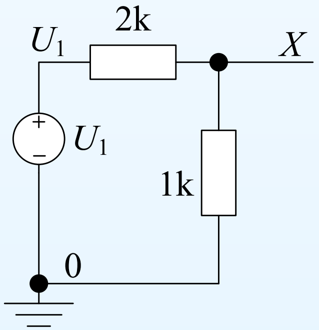

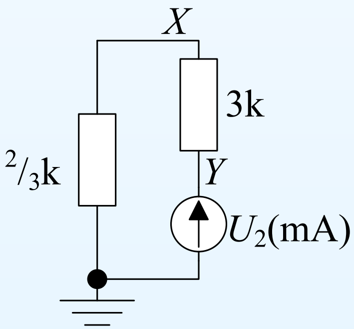

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  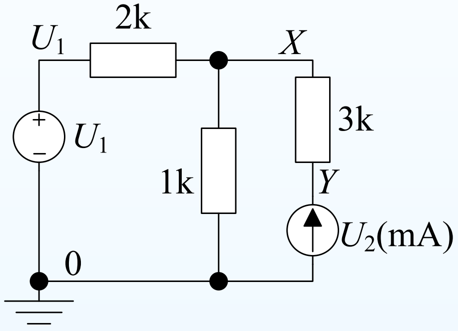

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  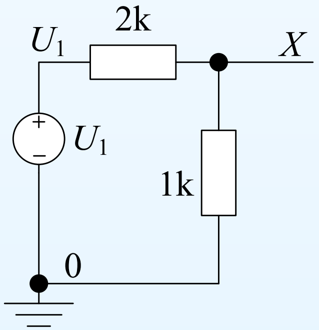

  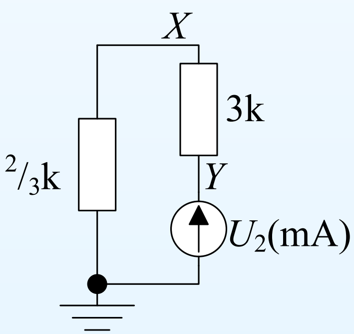

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- Combining these two gives $X = \frac{1}{3}U_1 + \frac{2}{3}U_2$.

Thévenin and Norton

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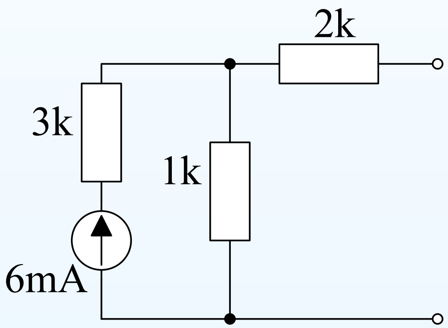

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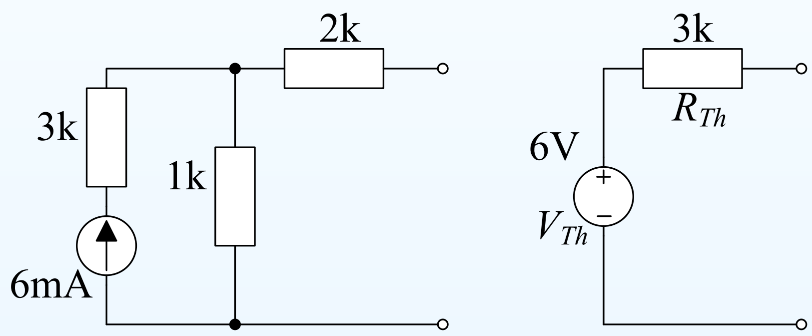

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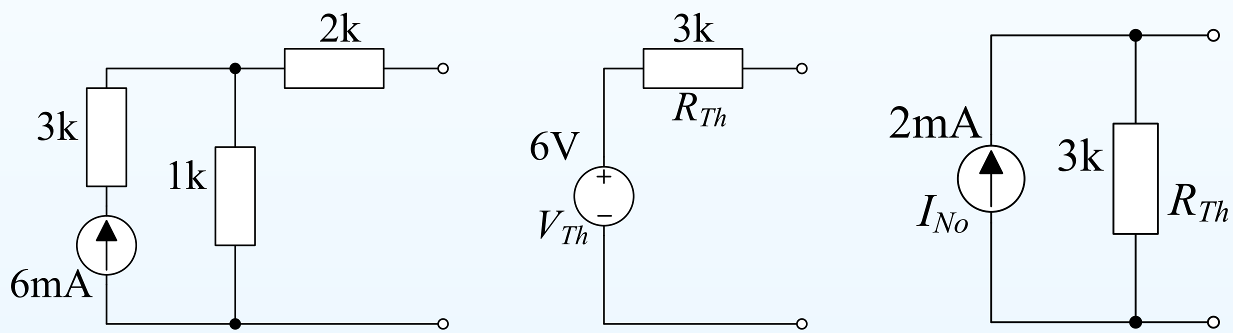

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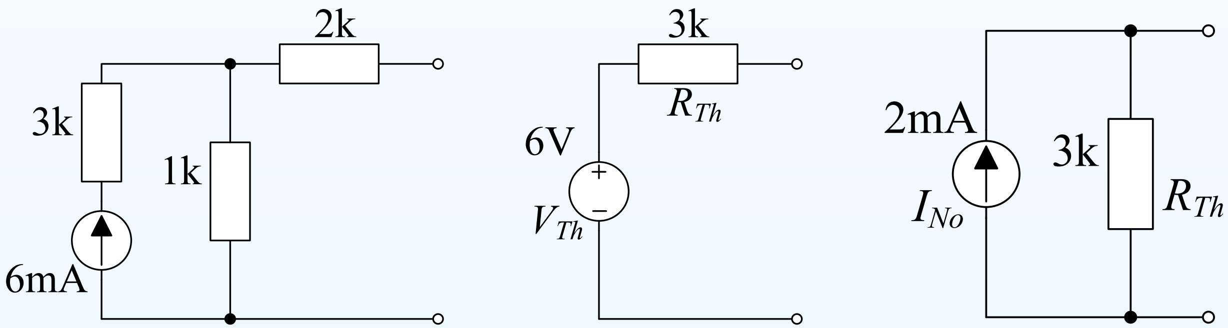

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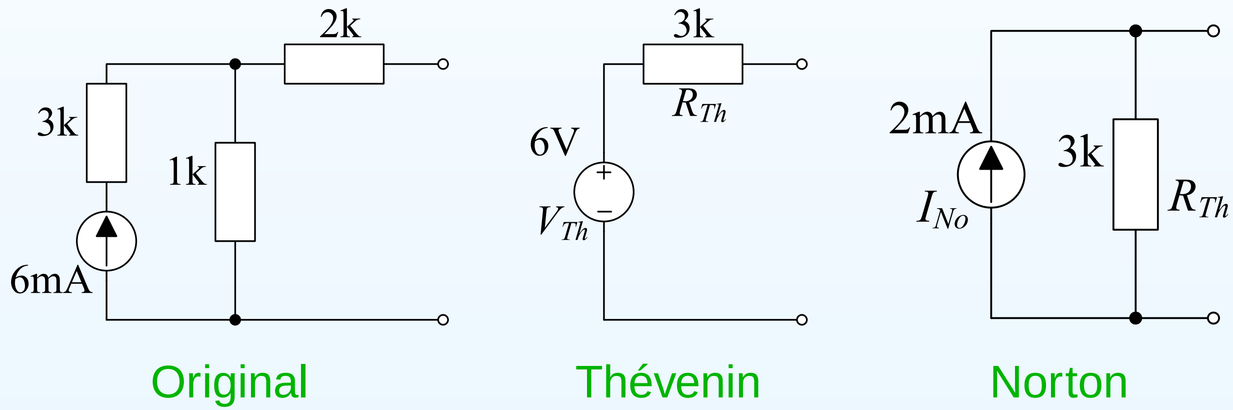

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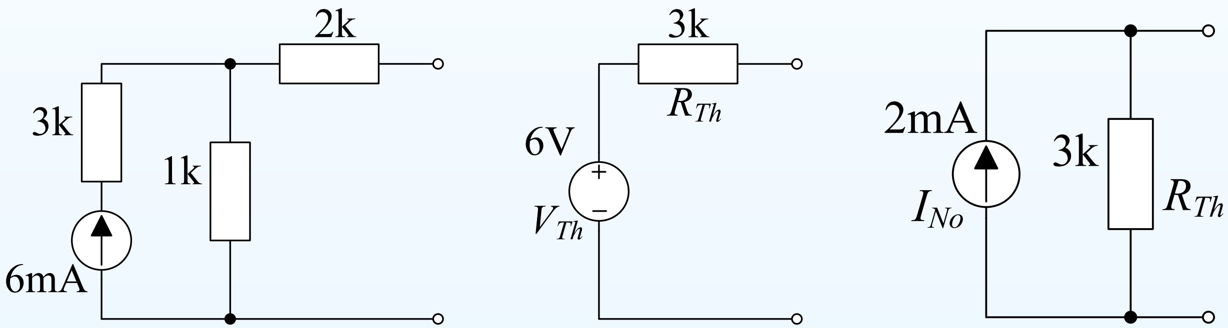

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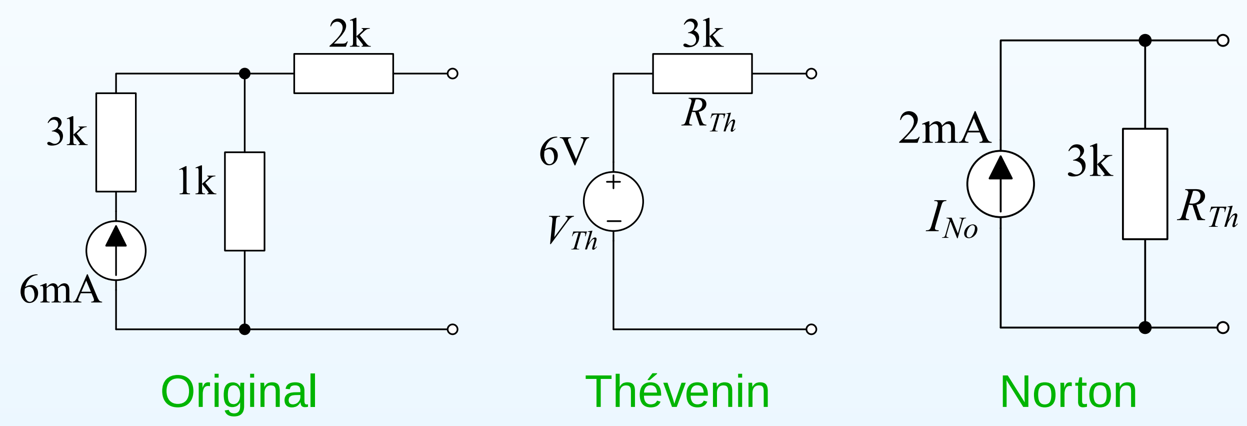

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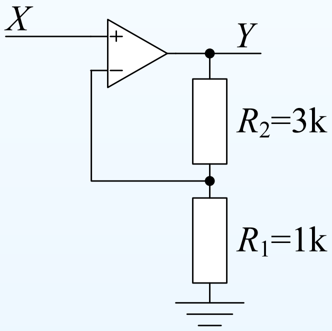
Op Amps

- Ideal Op Amp: (a) Zero input current, (b) Infinite gain
  (b) $\Rightarrow V_+ = V_-$ provided the circuit has negative feedback.
- Negative Feedback: An increase in V_{out} causes$(V_+ - V_-)$ to decrease.



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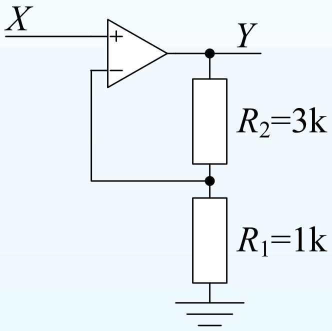
$$Y = \left(1 + \frac{3}{1}\right) X$$



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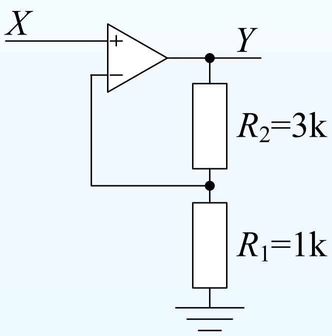
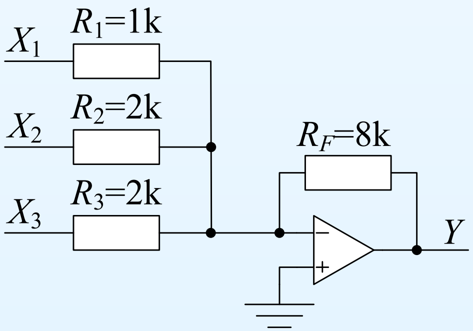


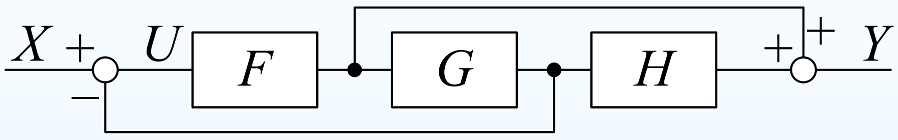
Inverting amplifier

$$Y = \frac{-8}{1} X_1 + \frac{-8}{2} X_2 + \frac{-8}{2} X_3$$



Block Diagrams

Blocks are labelled with their gains and connected using adder/subtractors shown as circles. Adder inputs are marked $+$ for add or $-$ for subtract.



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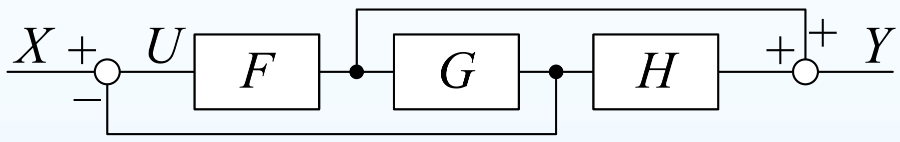

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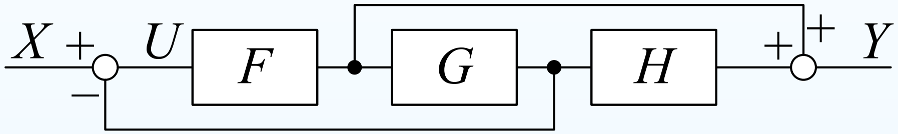

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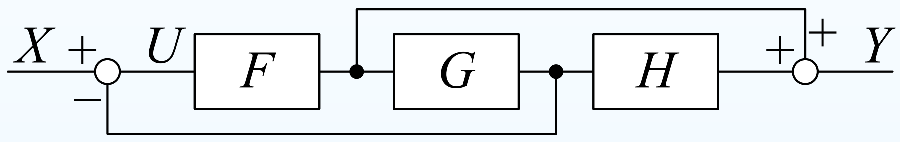

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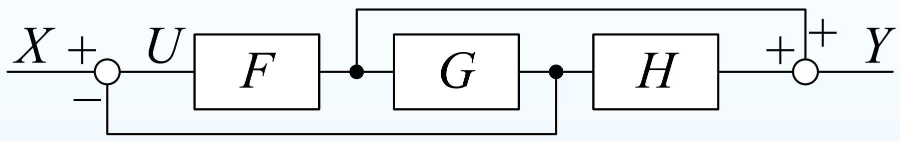

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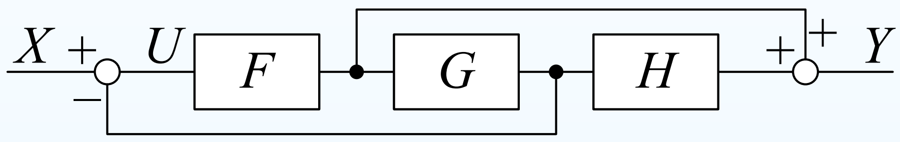

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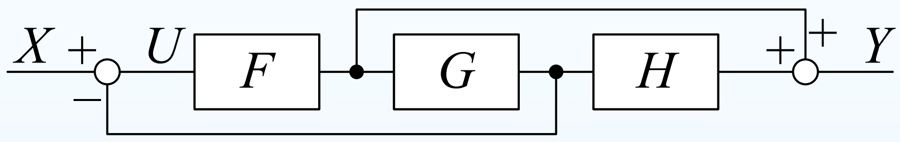

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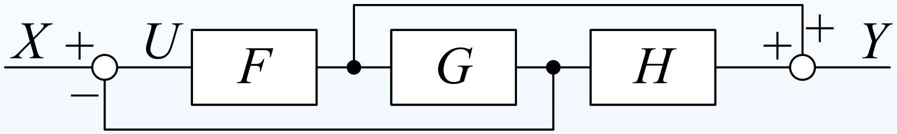

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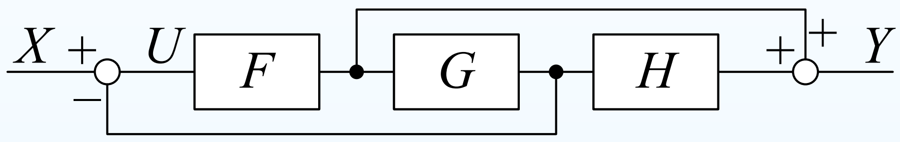

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[Note: "Wires" carry information not current: KCL not valid]

Diodes

Each diode in a circuit is in one of two modes; each has an equality condition and an inequality condition:

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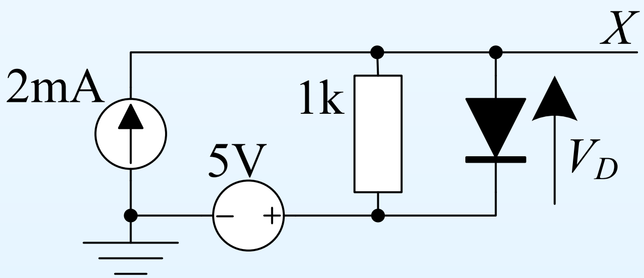
$$X = 5 + 2 = 7$$



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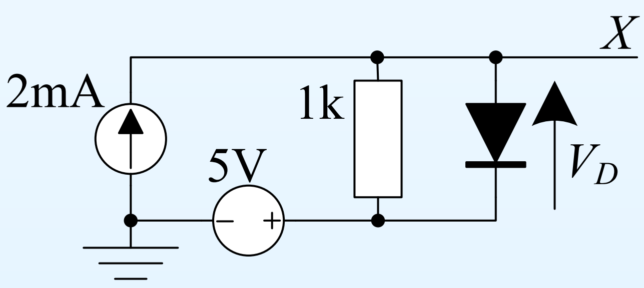

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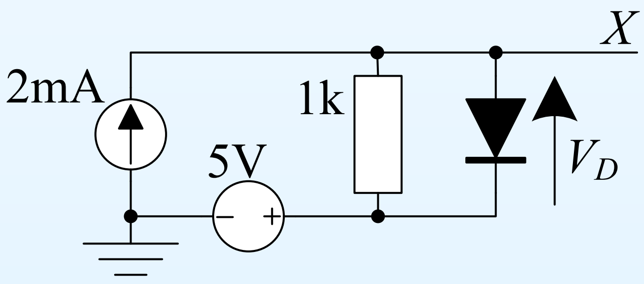

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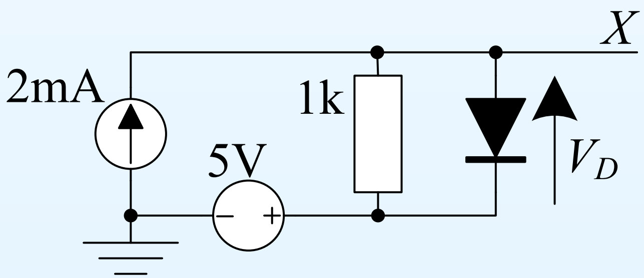
$$X = 5 + 0.7 = 5.7$$



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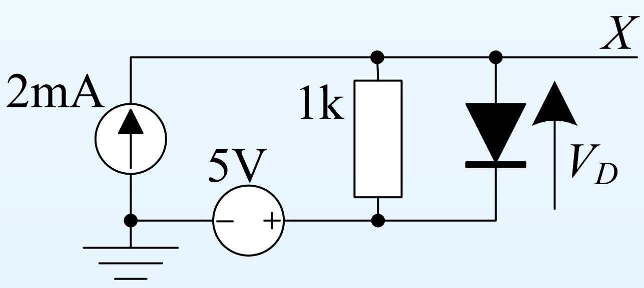
(c) Check the inequality condition. If the inequality condition fails, you made the wrong guess.

- Assume Diode Off

$$X = 5 + 2 = 7$$
$$V_D = 2 \quad \text{Fail: } V_D > 0.7$$

- Assume Diode On

$$X = 5 + 0.7 = 5.7$$
$$I_D + \frac{0.7}{1\,\text{k}} = 2\,\text{mA}$$



Diodes

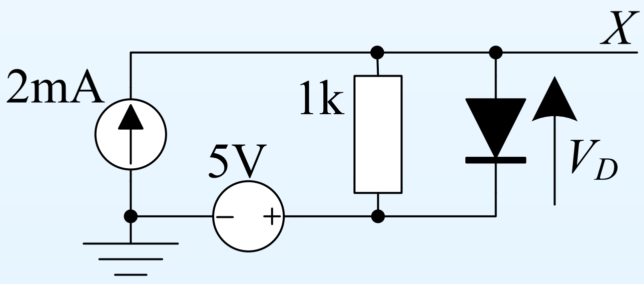
Each diode in a circuit is in one of two modes; each has an equality condition and an inequality condition:

- Off: $I_D = 0$, $V_D < 0.7$
- On: $V_D = 0.7$, $I_D > 0$

(a) Guess the mode
(b) Do nodal analysis assuming the equality condition
(c) Check the inequality condition. If the inequality condition fails, you made the wrong guess.

- Assume Diode Off

$$X = 5 + 2 = 7$$
$V_D = 2$ Fail: $V_D > 0.7$



- Assume Diode On

$$X = 5 + 0.7 = 5.7$$
$I_D + \frac{0.7}{1\,\text{k}} = 2\,\text{mA}$ OK: $I_D > 0$