Circuit animations

Resources and methods for learning about these subjects (list a few here, in preparation for your research):

Question 1

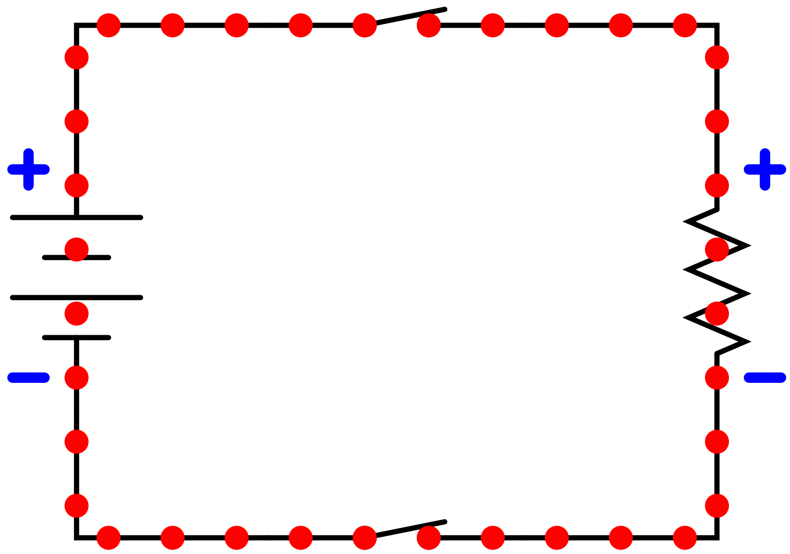
Animation: simple circuit with switch

This question consists of a series of images (one per page) that form an animation. Flip the pages with your fingers to view this animation (or click on the "next" button on your viewer) frame-by-frame.

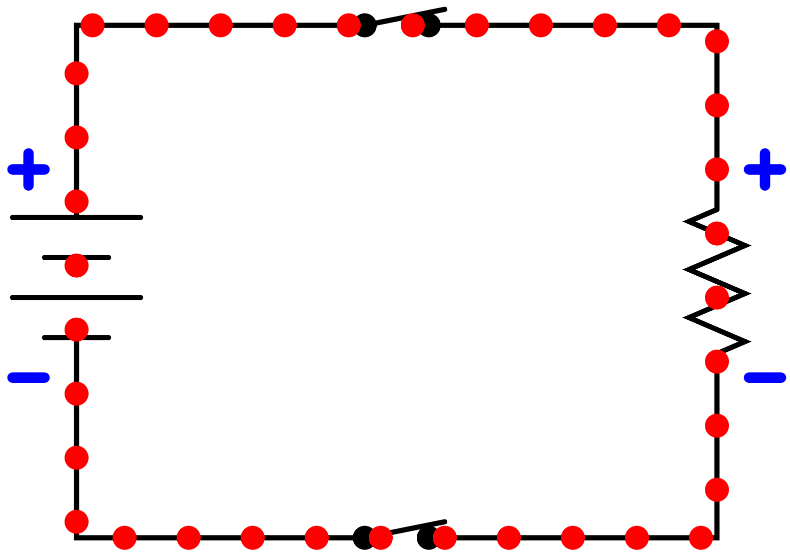
The following animation shows a simple circuit with one battery, two switches, and a resistor. Watch what happens when both switches are closed, and when either switch opens. Here are some things to look for:

- How do we define what an "open" switch is?
- What is opposite of "open" for an electric switch? Hint: it isn't "shut"
- Where does a voltage "drop" appear?
- Which direction do the electrons move?
- Compare the effects of the two switches: does one switch have any more effect on the circuit's current than the other? If so, which one?

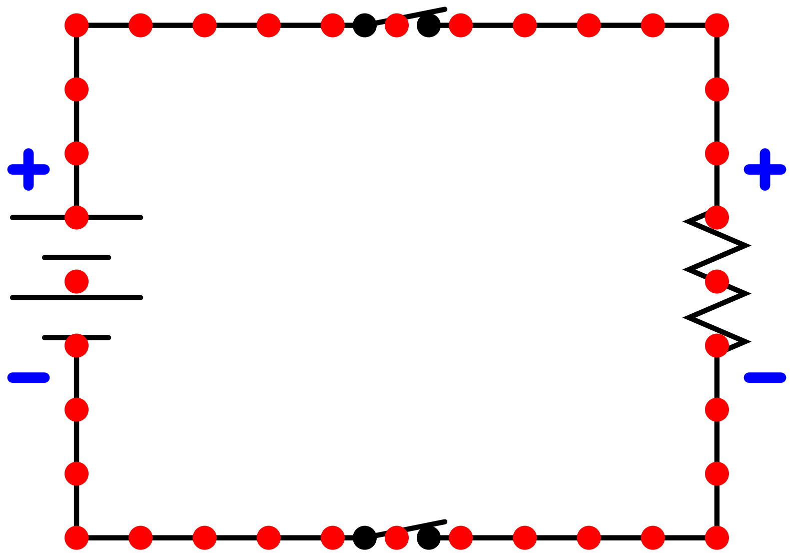
Direction of electron motion



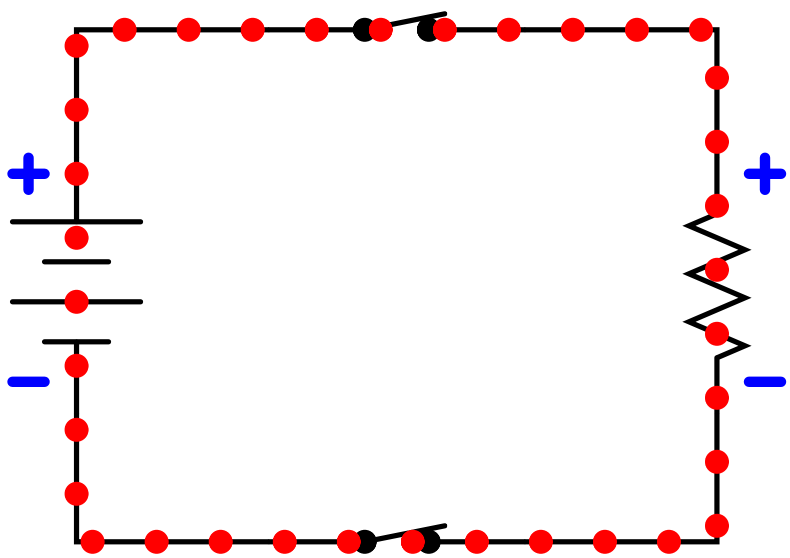
Direction of electron motion



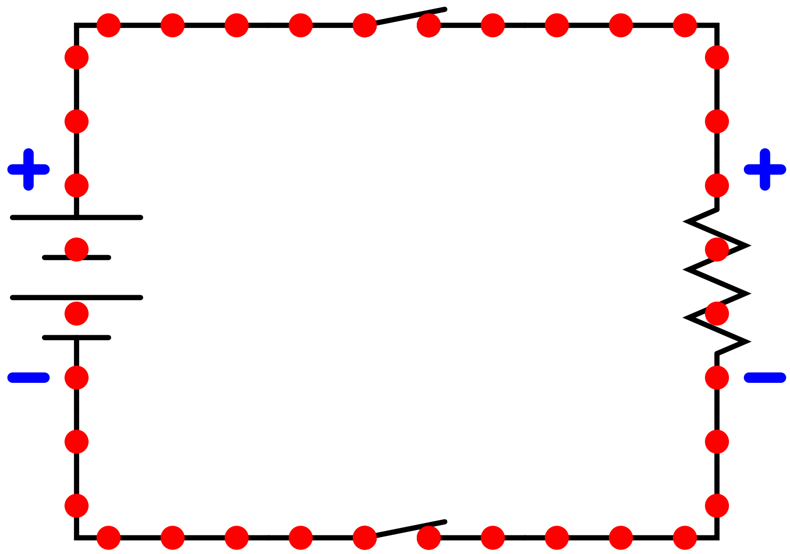
Direction of electron motion



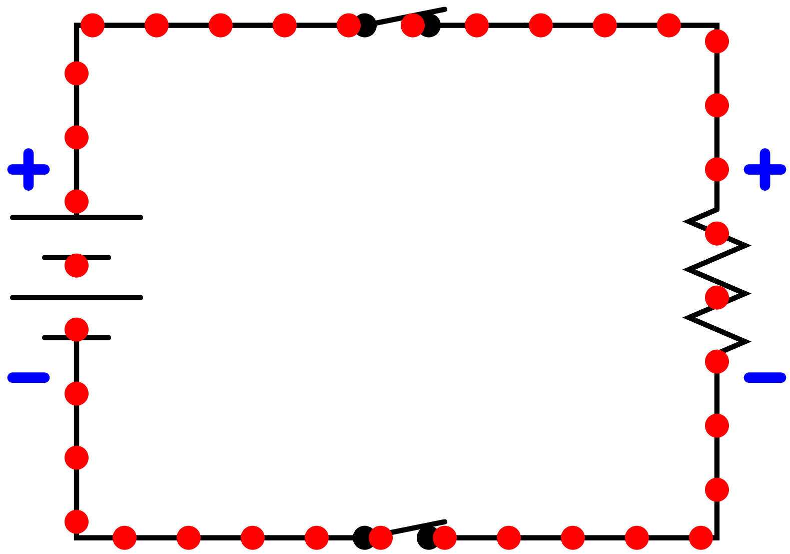
Direction of electron motion



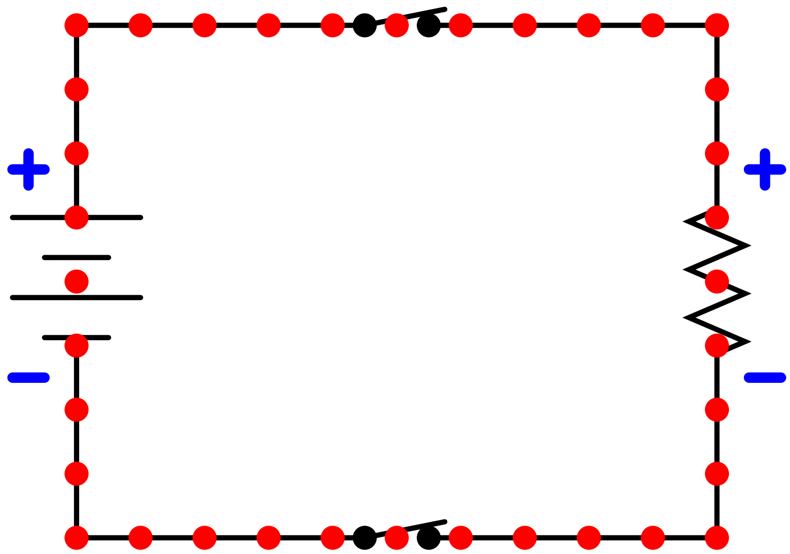
Direction of electron motion



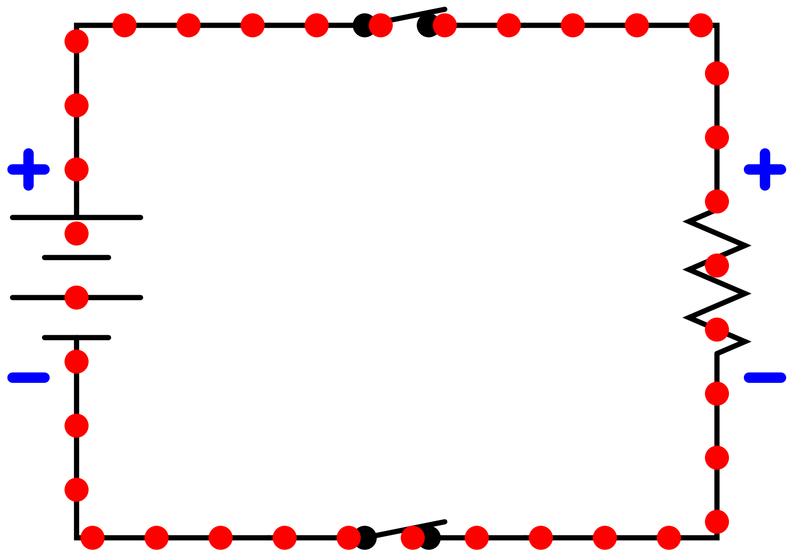
Direction of electron motion



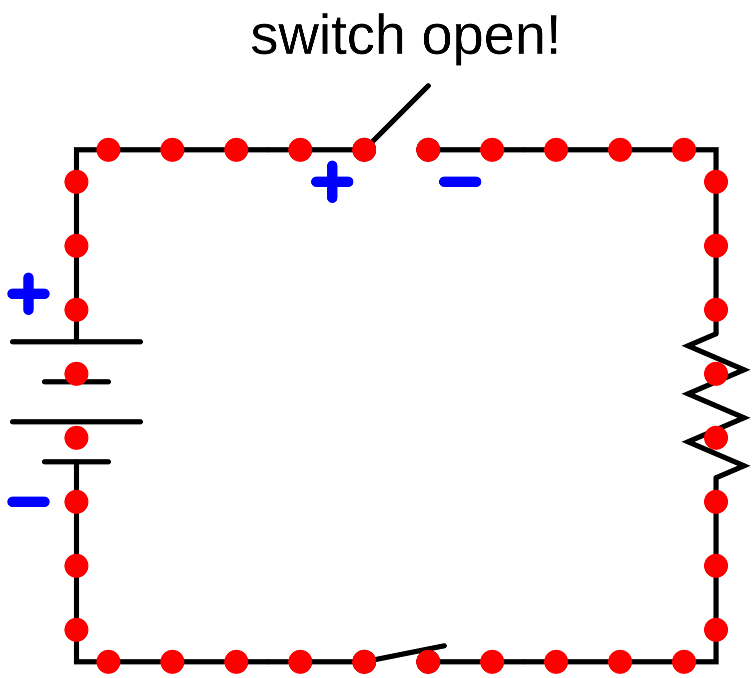
Direction of electron motion



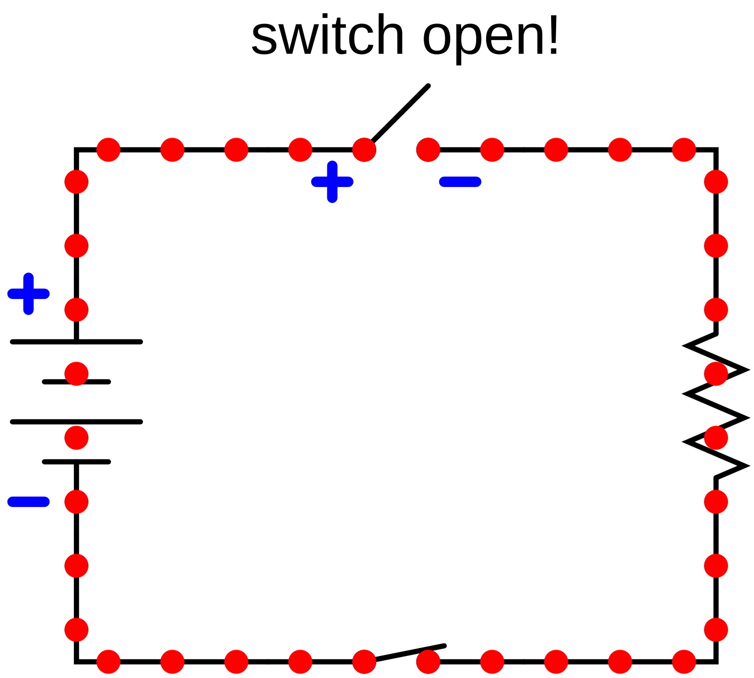
Direction of electron motion



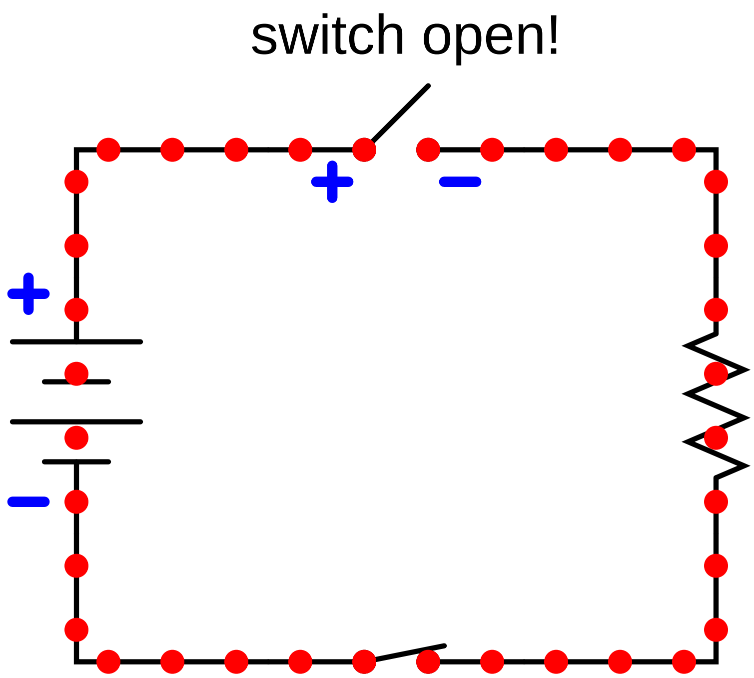
Direction of electron motion



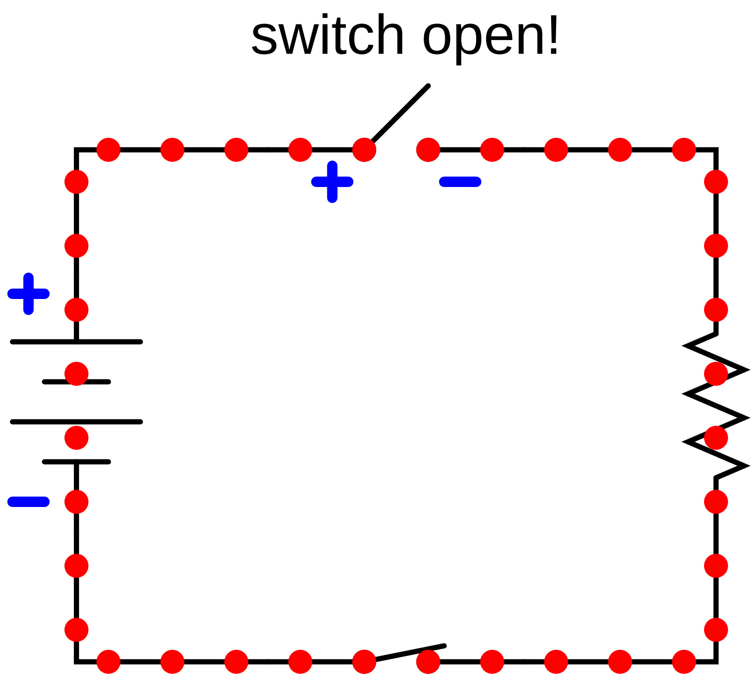
Direction of electron motion



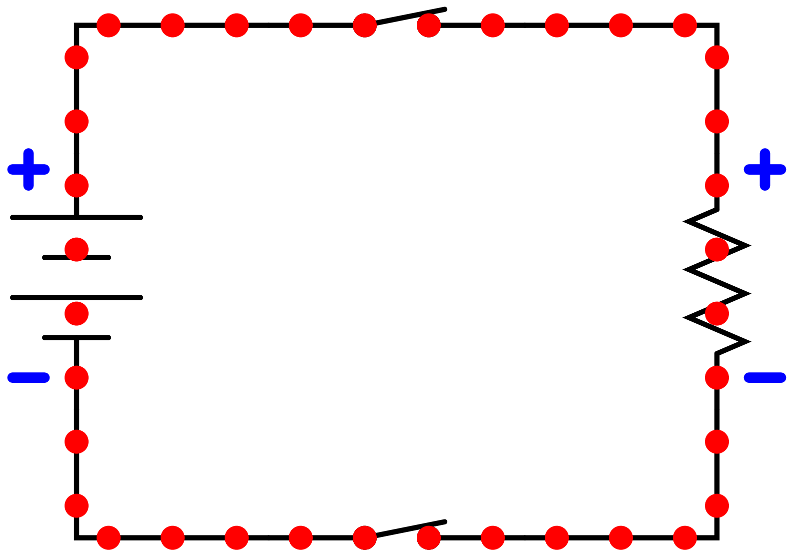
Direction of electron motion



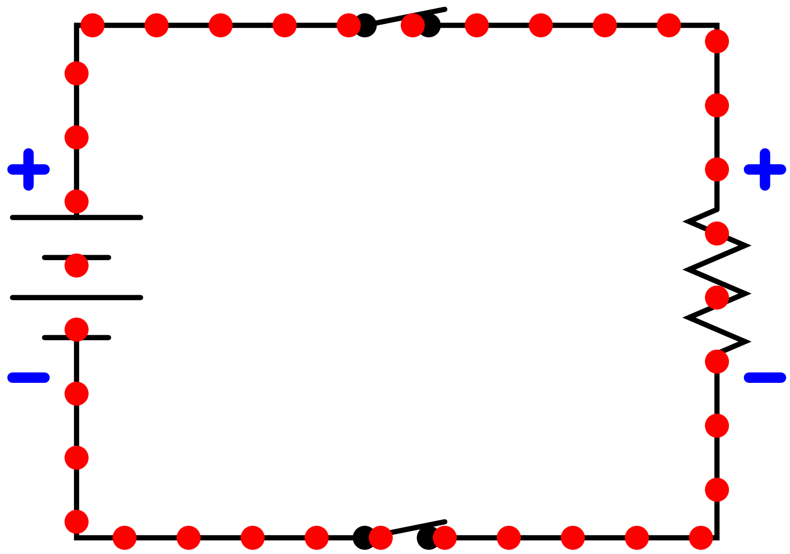
Direction of electron motion



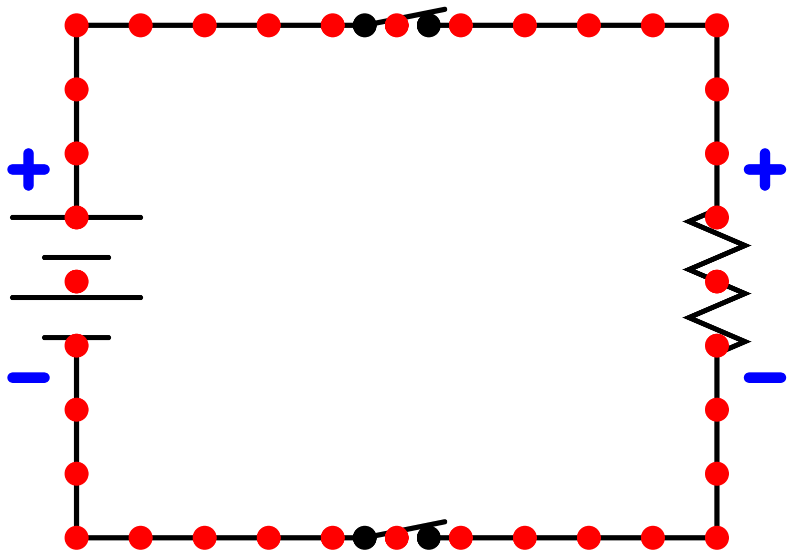
Direction of electron motion



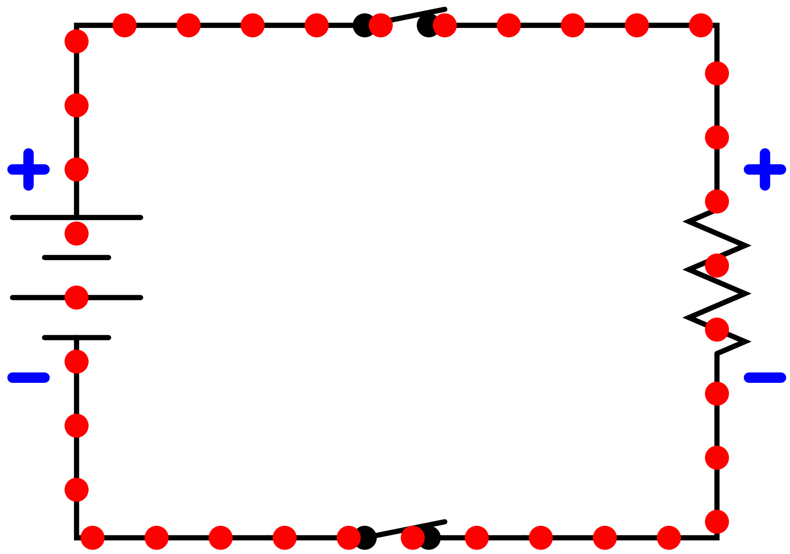
Direction of electron motion



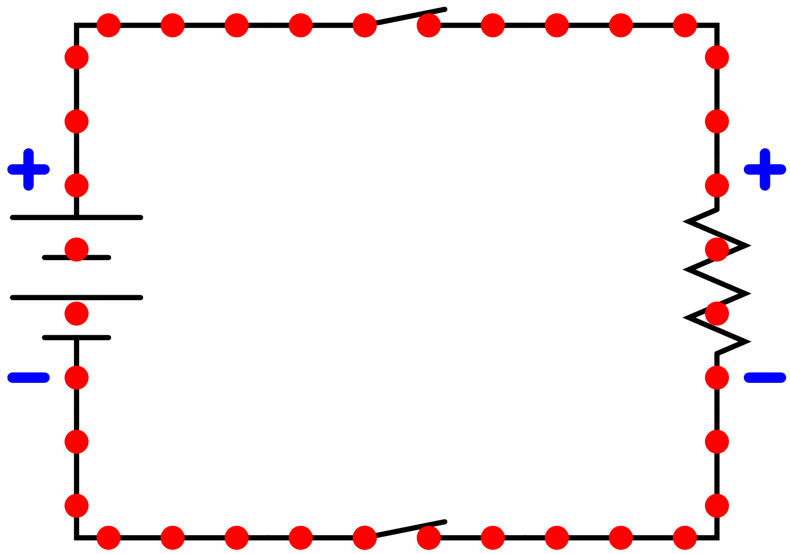
Direction of electron motion



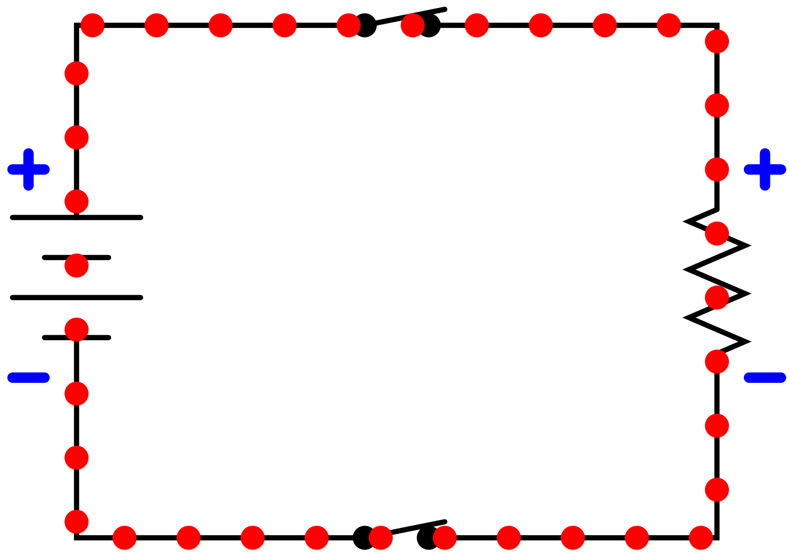
Direction of electron motion



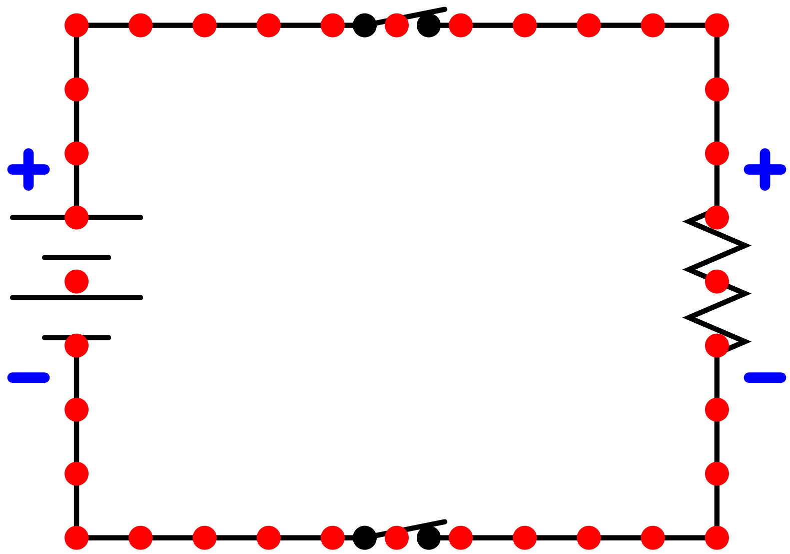
Direction of electron motion



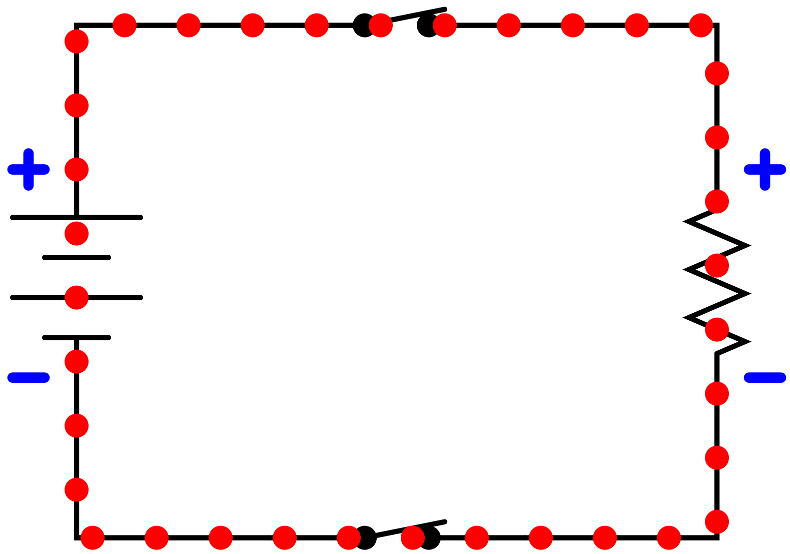
Direction of electron motion



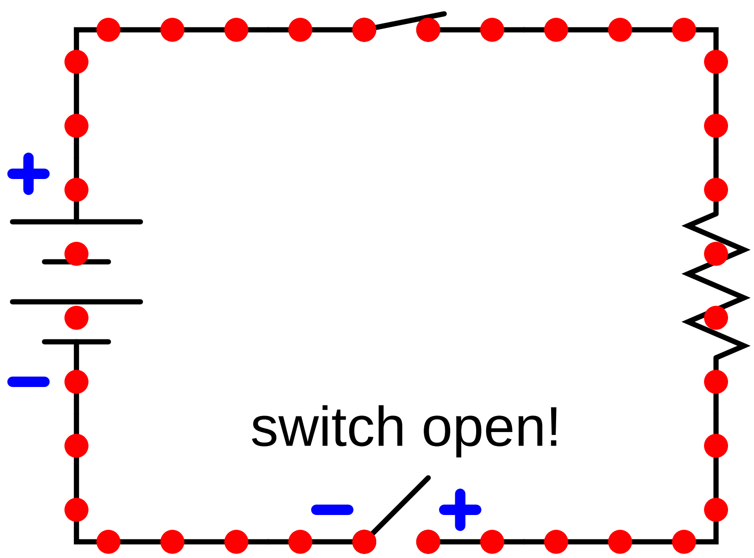
Direction of electron motion



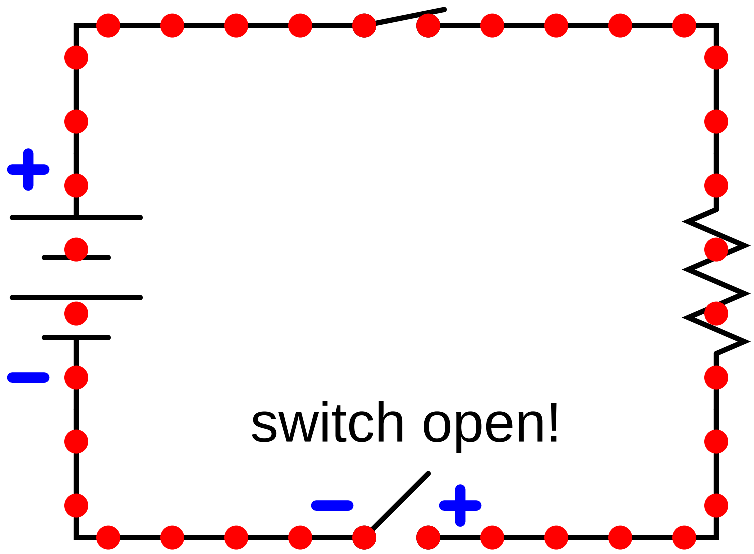
Direction of electron motion



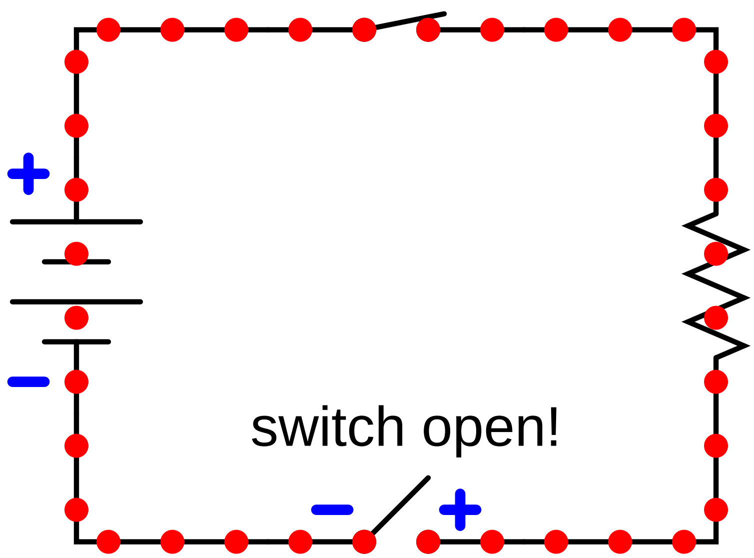
Direction of electron motion



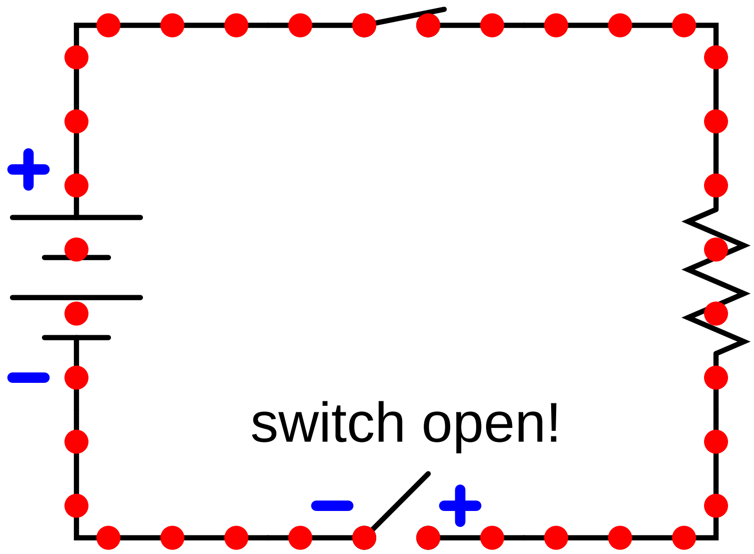
Direction of electron motion



Direction of electron motion



Direction of electron motion



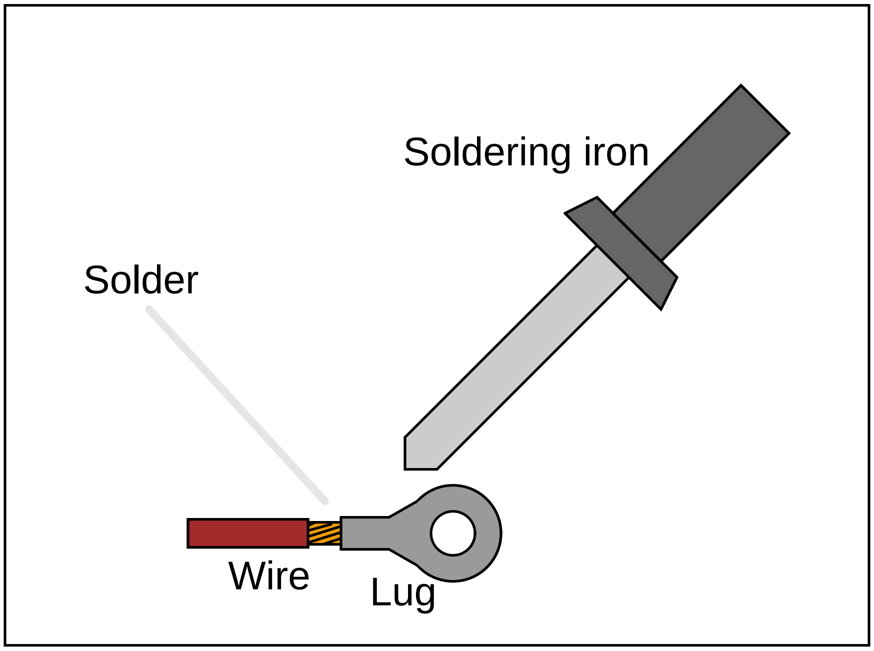
file 03231

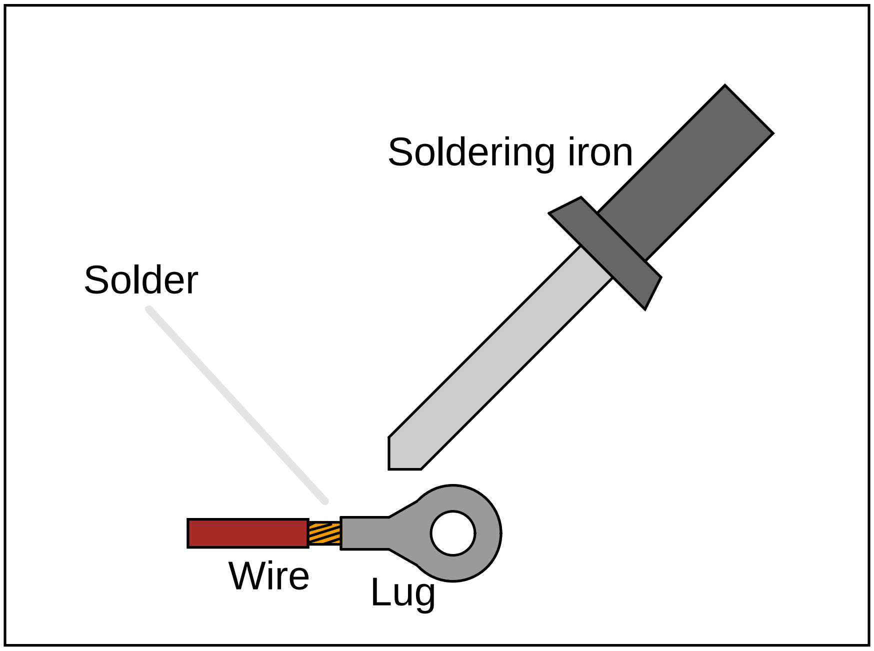
Question 2

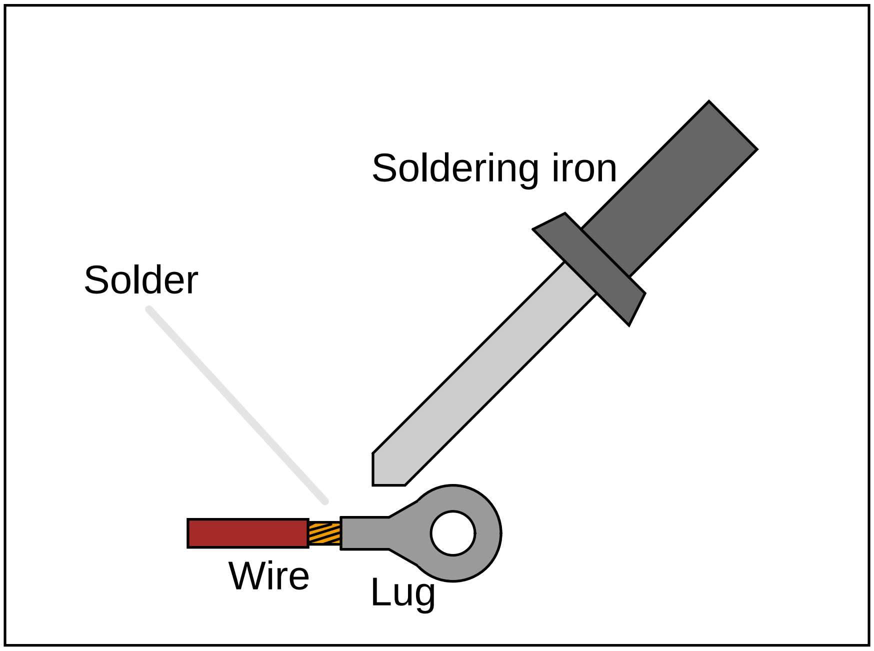
Animation: Soldering a wire to a lug

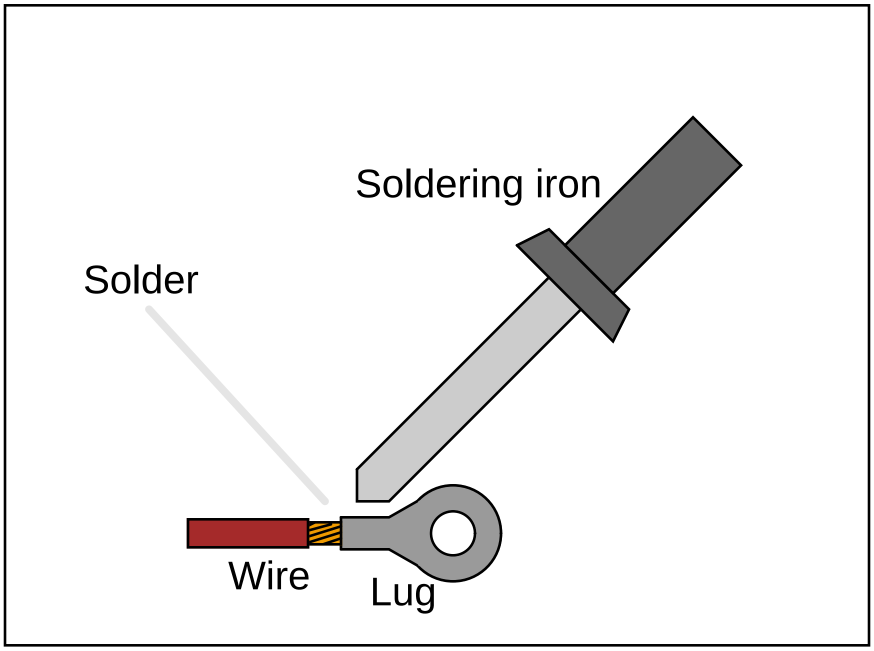
This question consists of a series of images (one per page) that form an animation. Flip the pages with your fingers to view this animation (or click on the "next" button on your viewer) frame-by-frame.

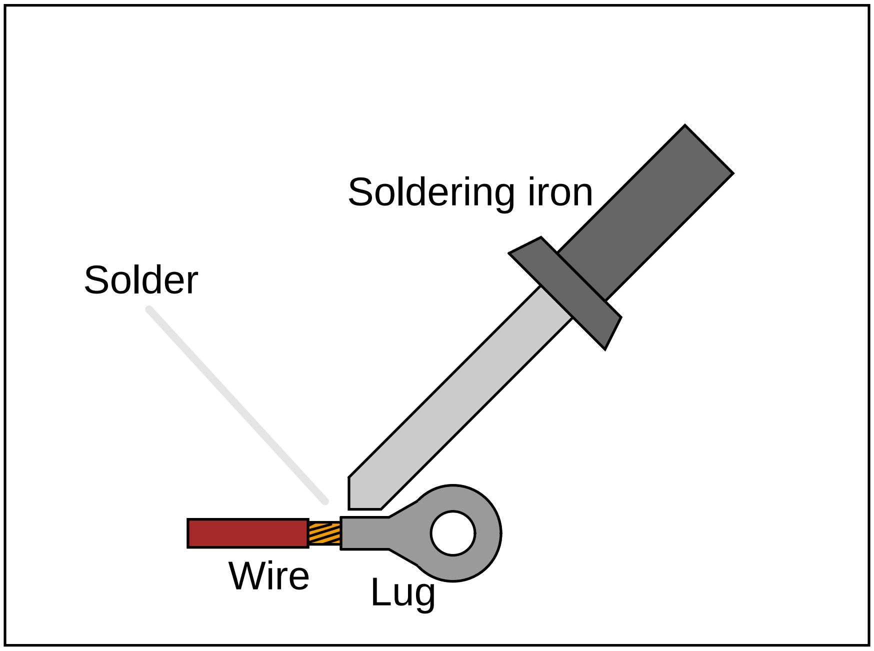
The following animation shows the procedure for properly soldering a wire to a lug.

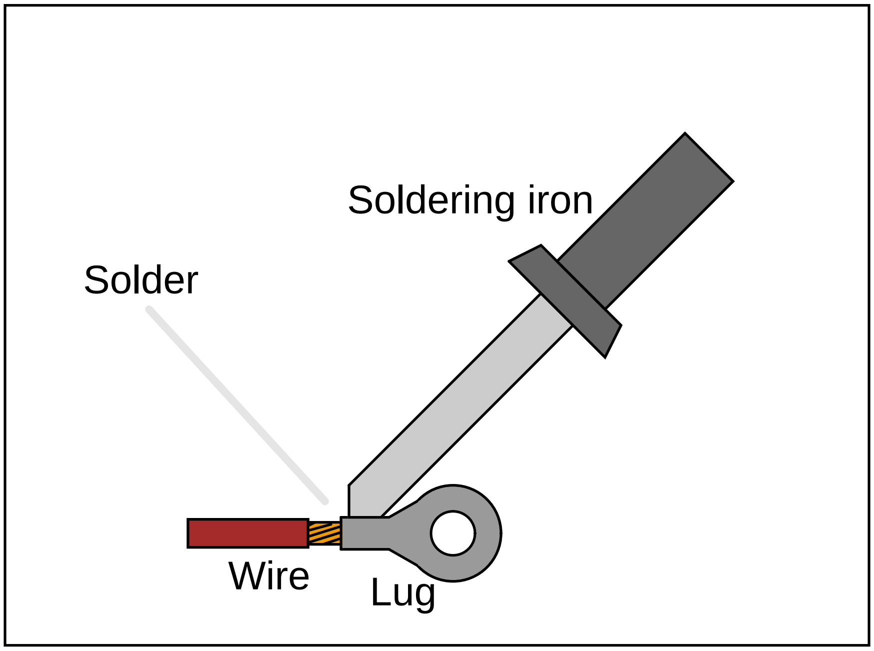

Soldering iron
Solder
Wire
Lug

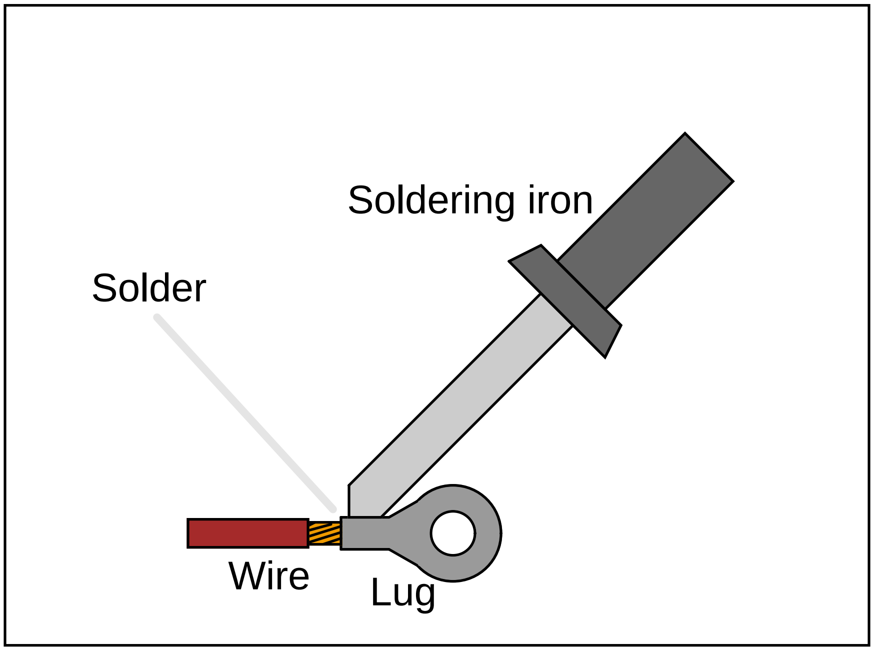

Soldering iron
Solder
Wire
Lug

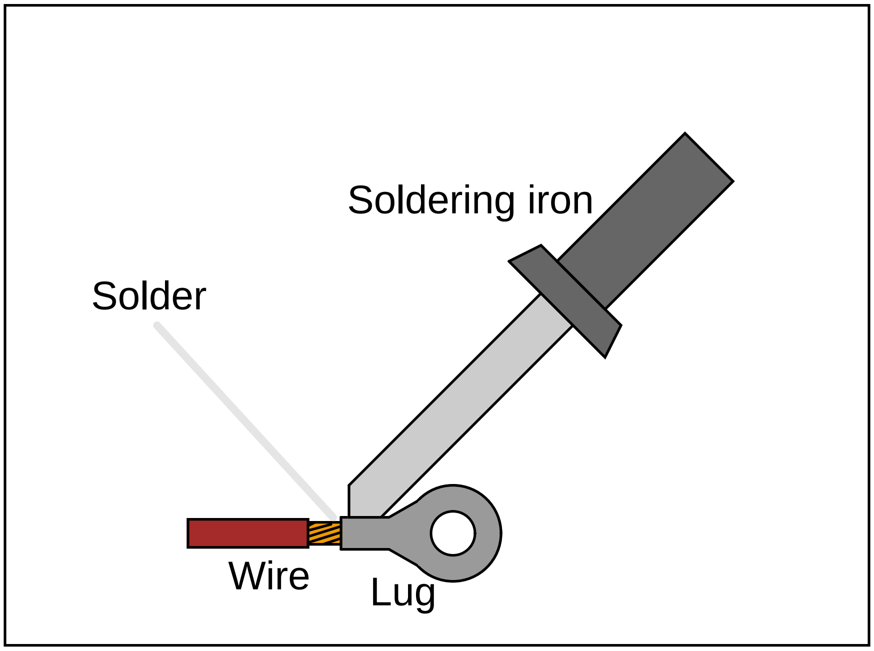

Soldering iron
Solder
Wire
Lug

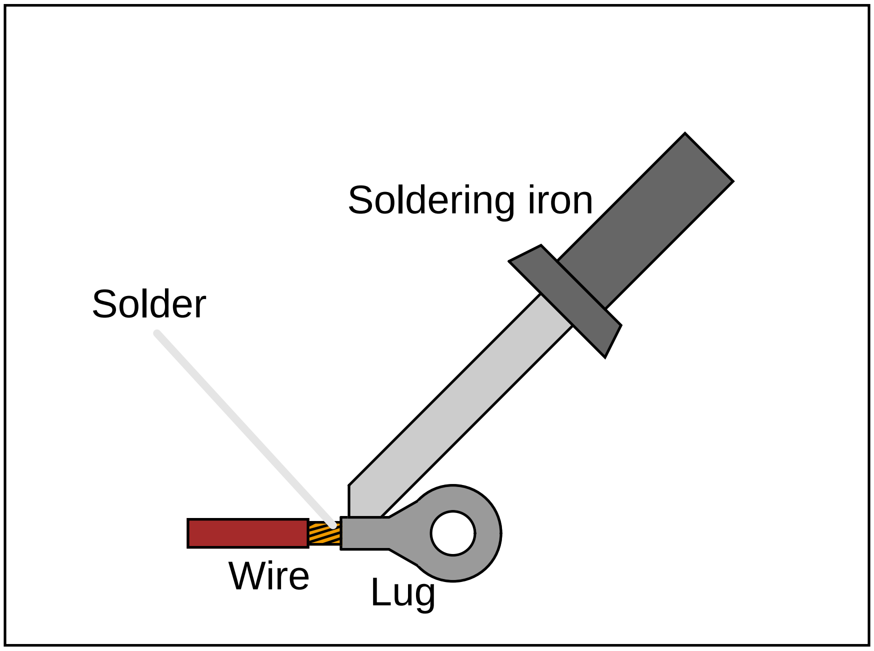

Soldering iron
Solder
Wire
Lug

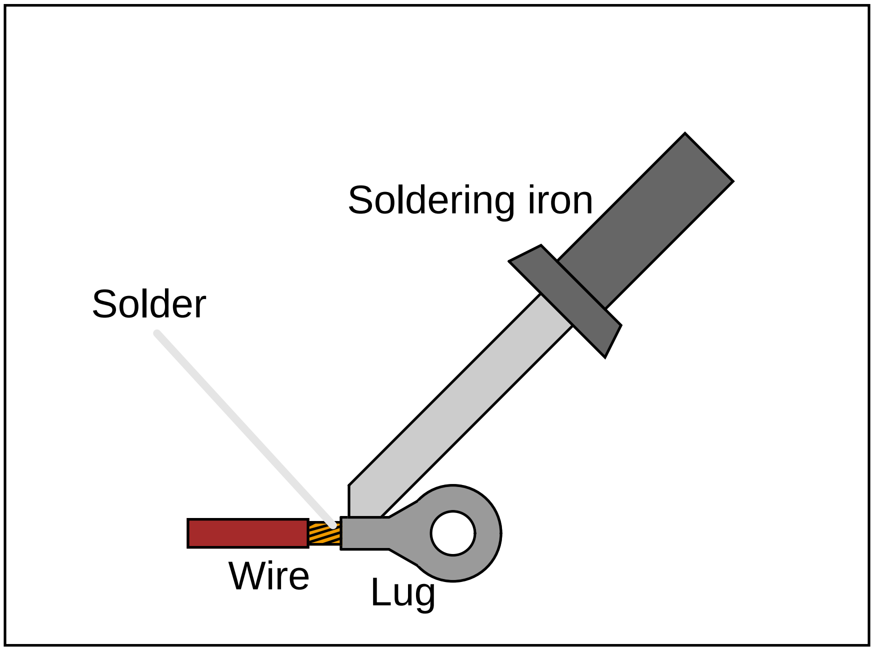

Soldering iron
Solder
Wire
Lug

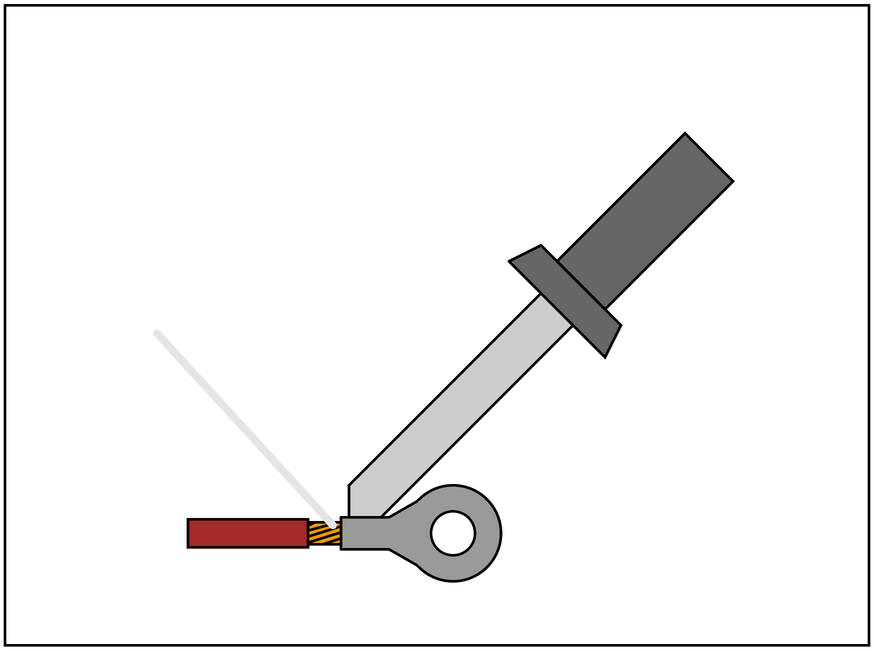

Soldering iron
Solder
Wire
Lug

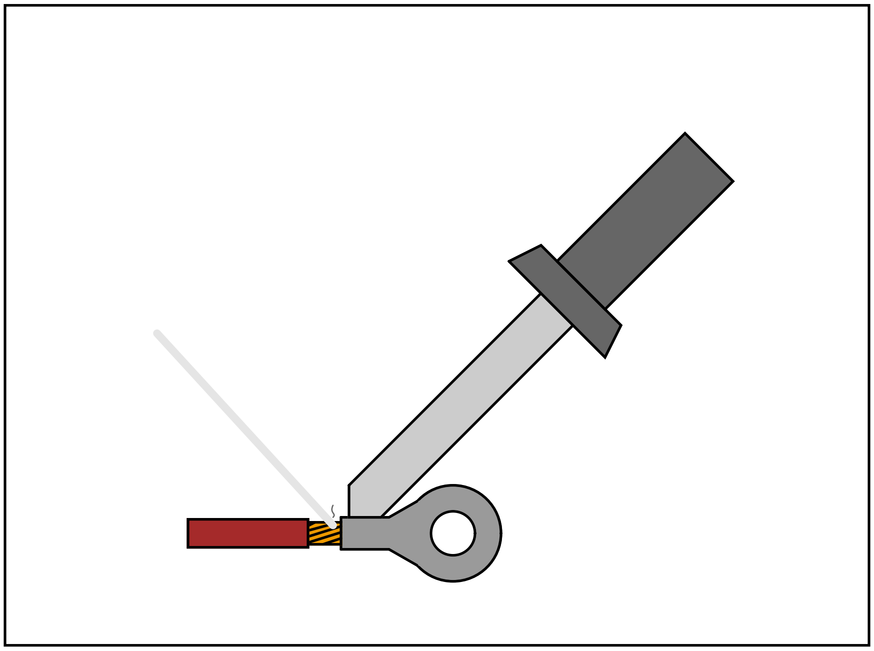

Soldering iron
Solder
Wire
Lug

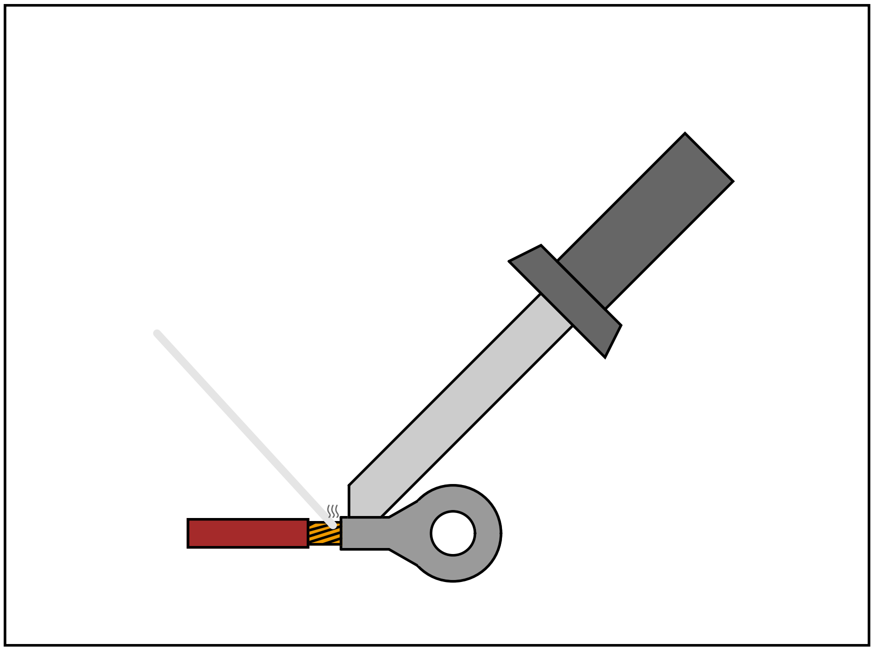

Soldering iron
Solder
Wire
Lug

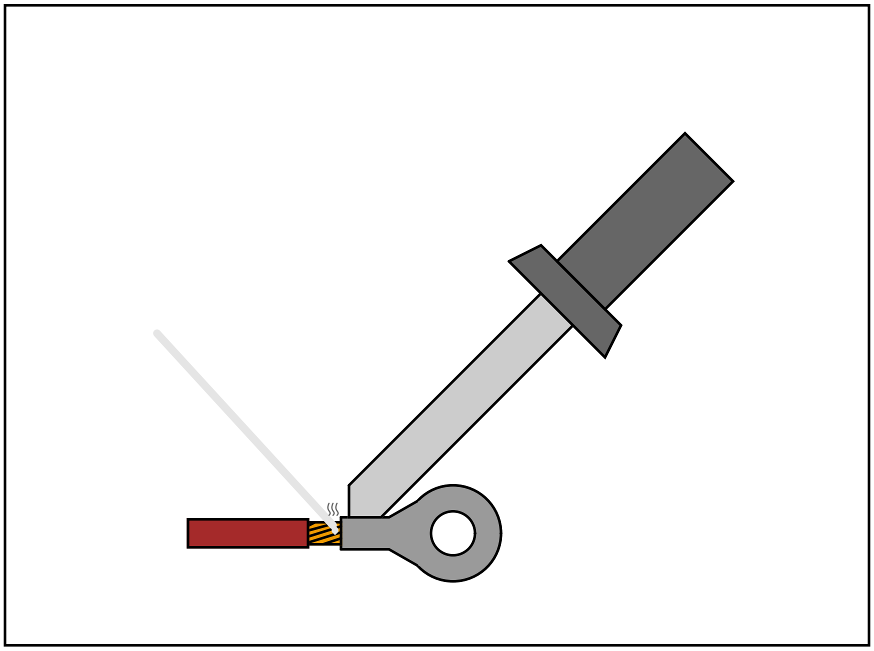

Soldering iron
Solder
Wire
Lug

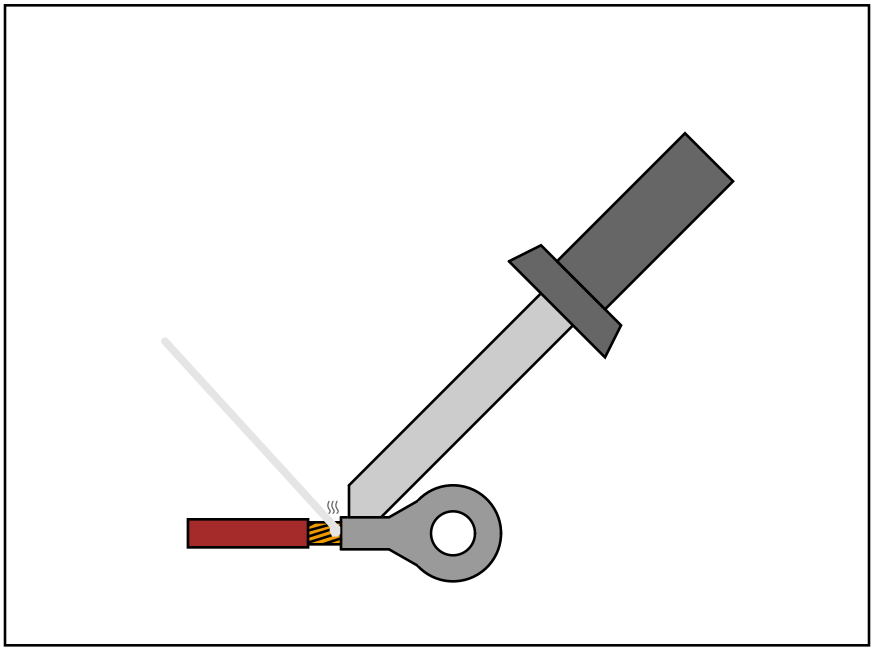

Soldering iron
Solder
Wire
Lug

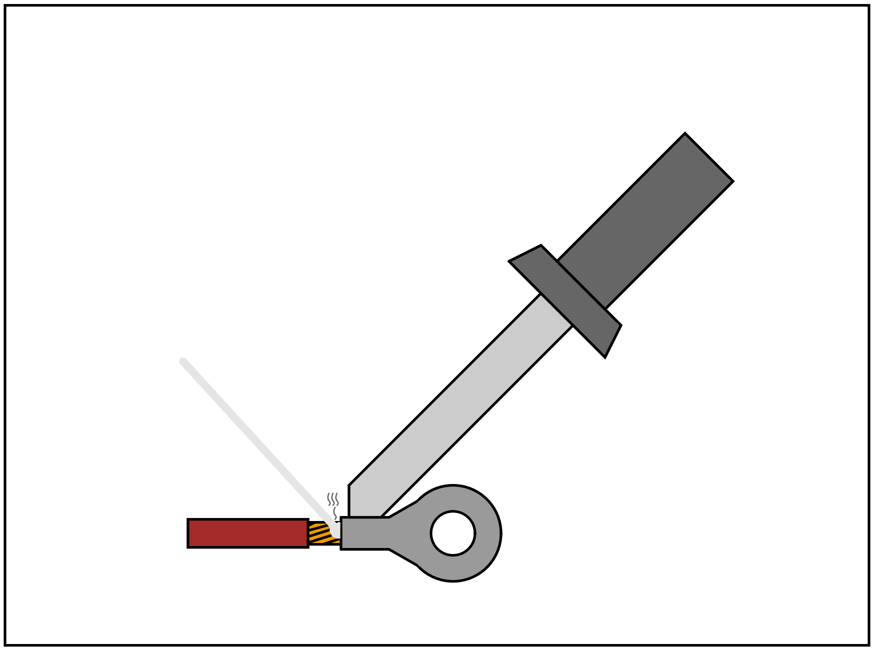


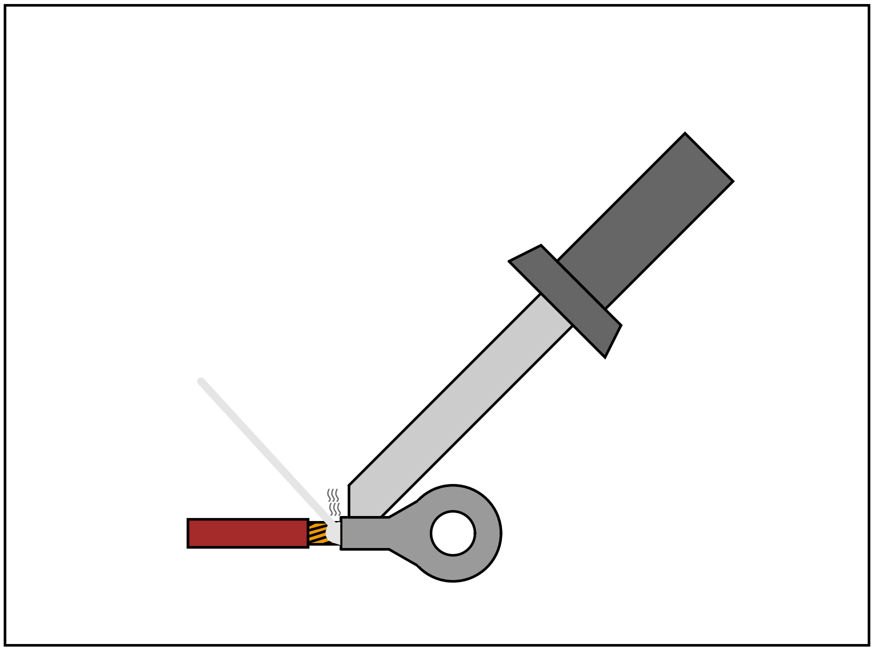


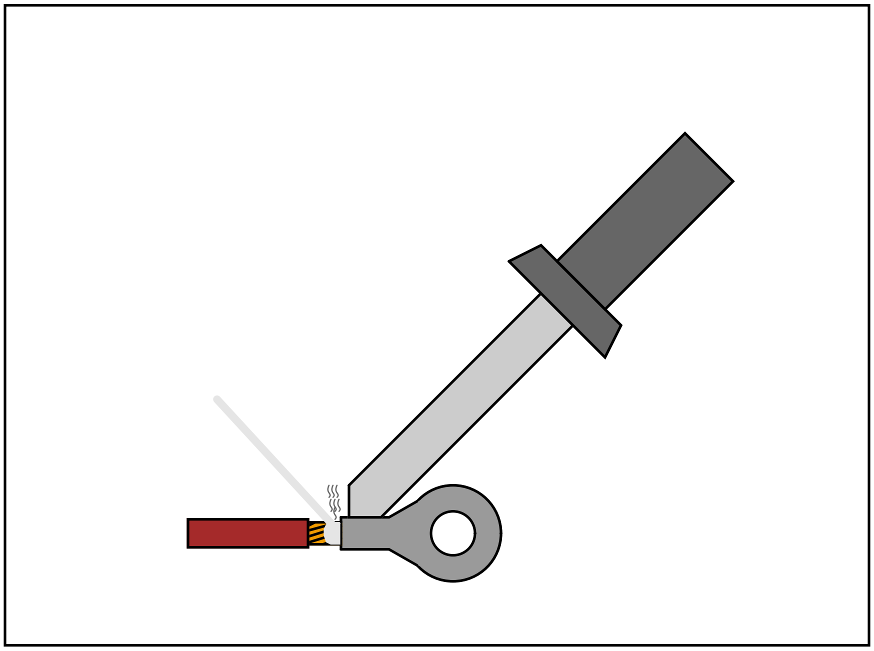


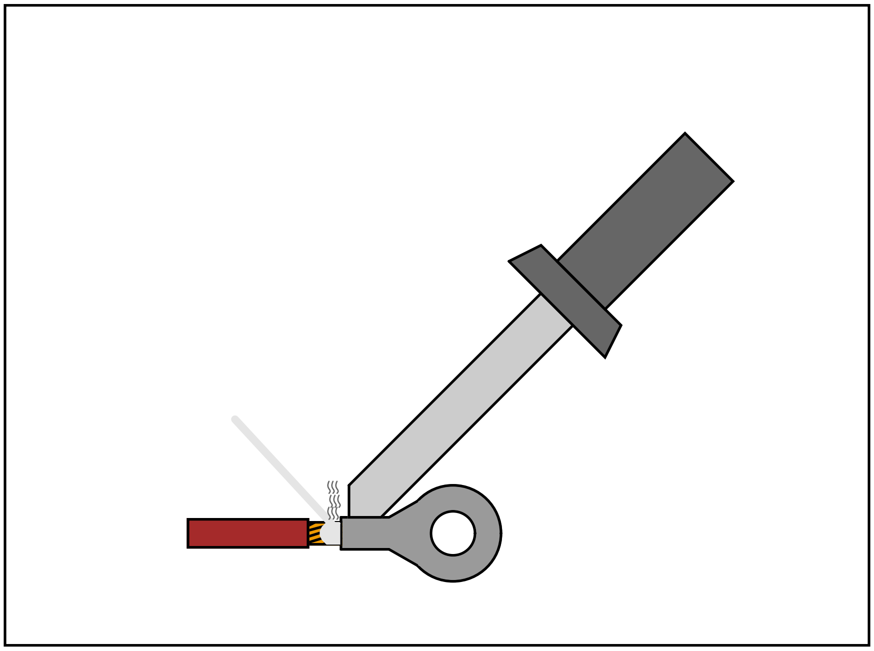


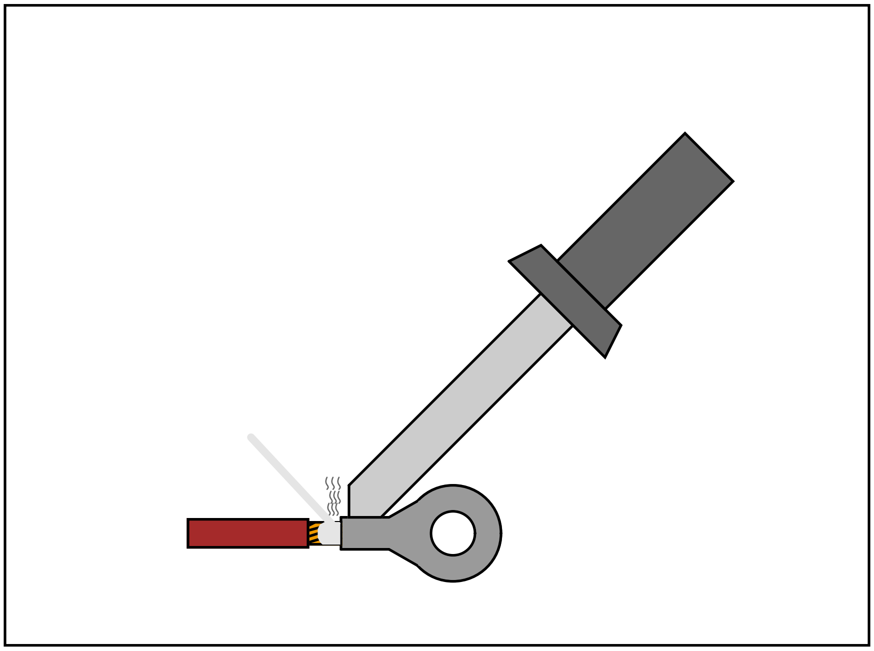


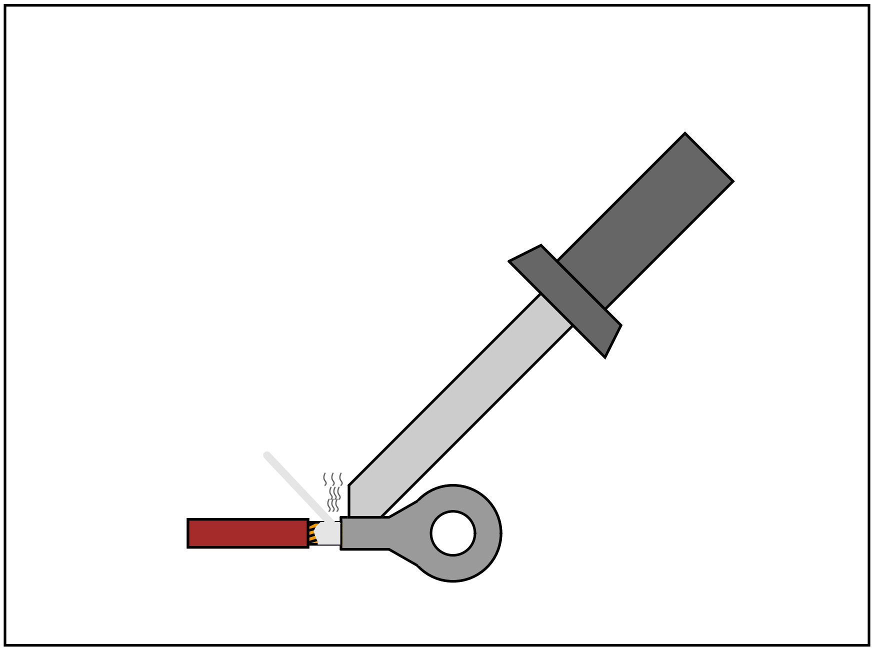


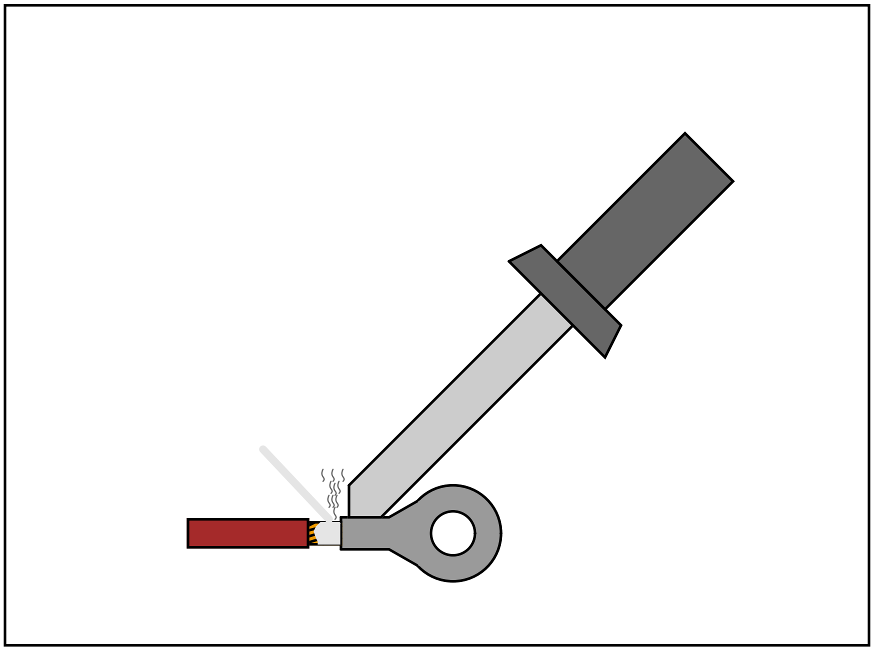


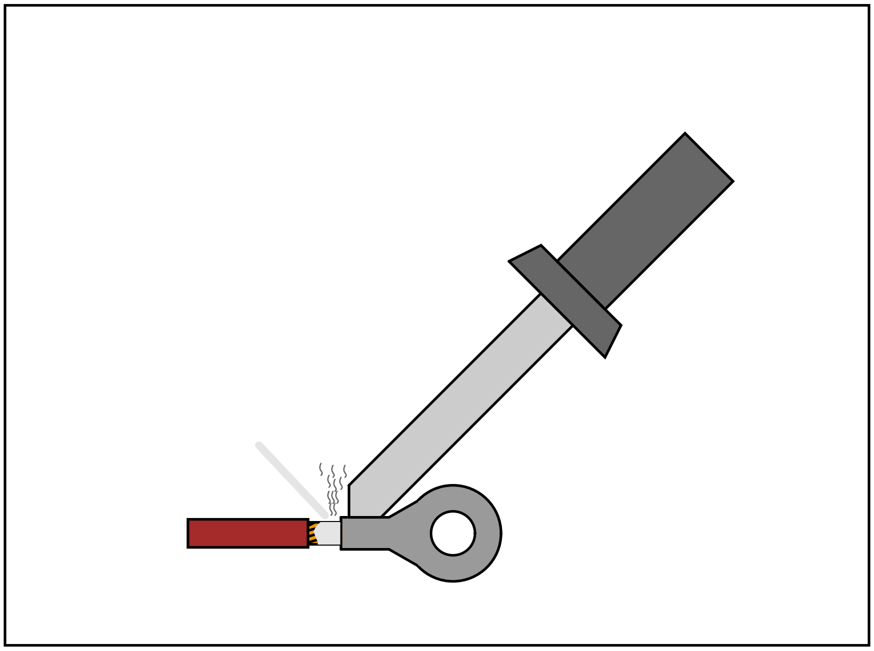


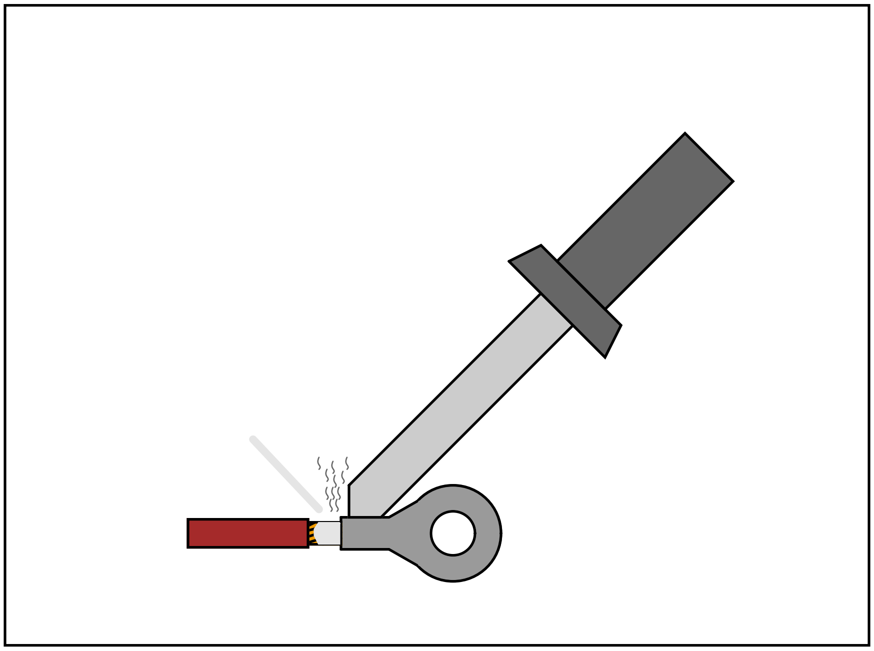


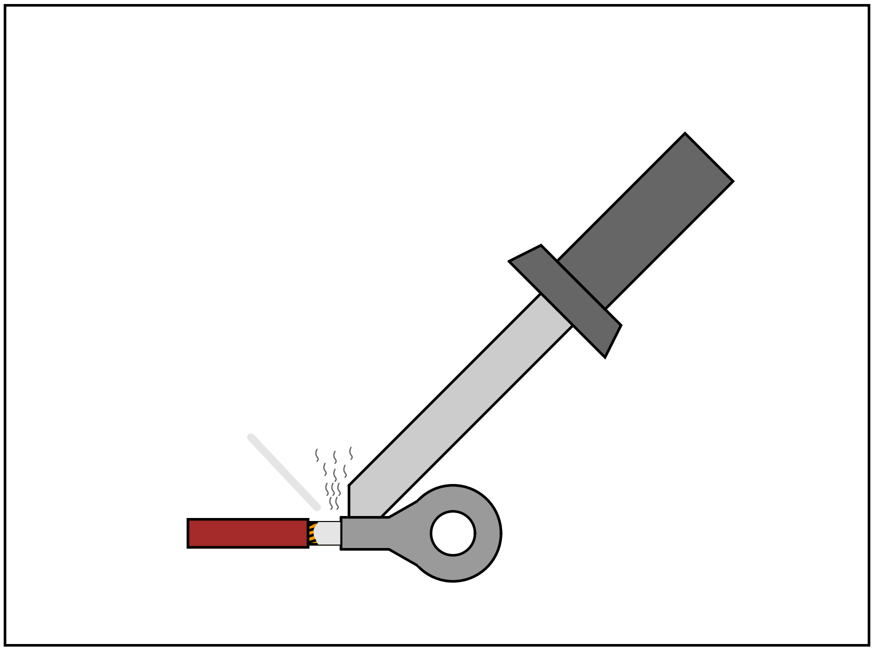


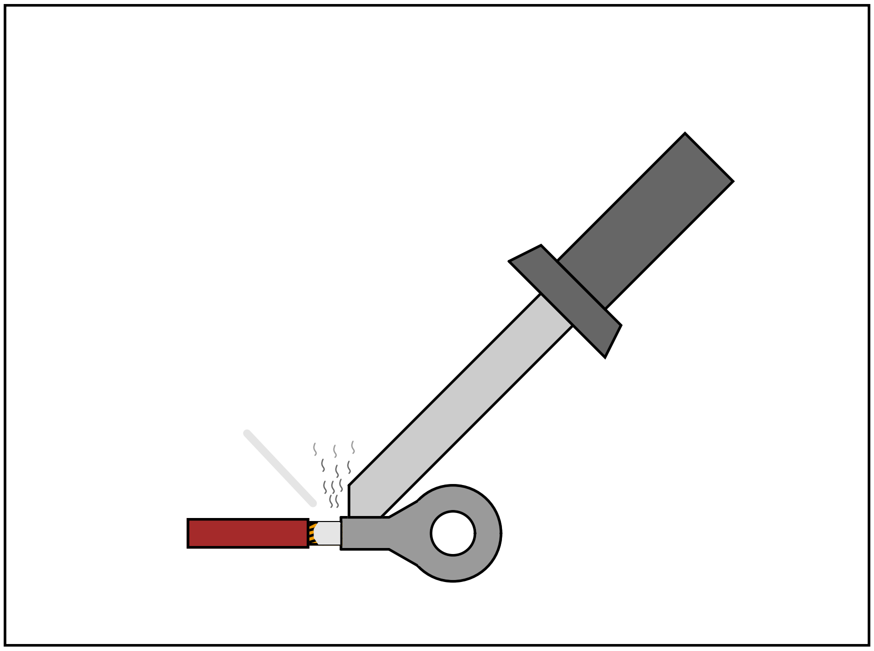


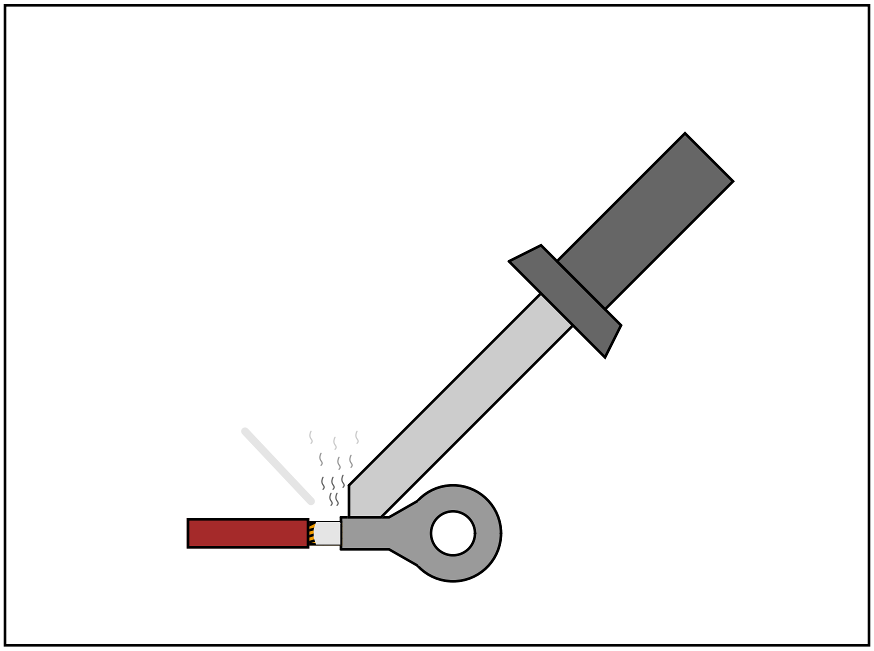


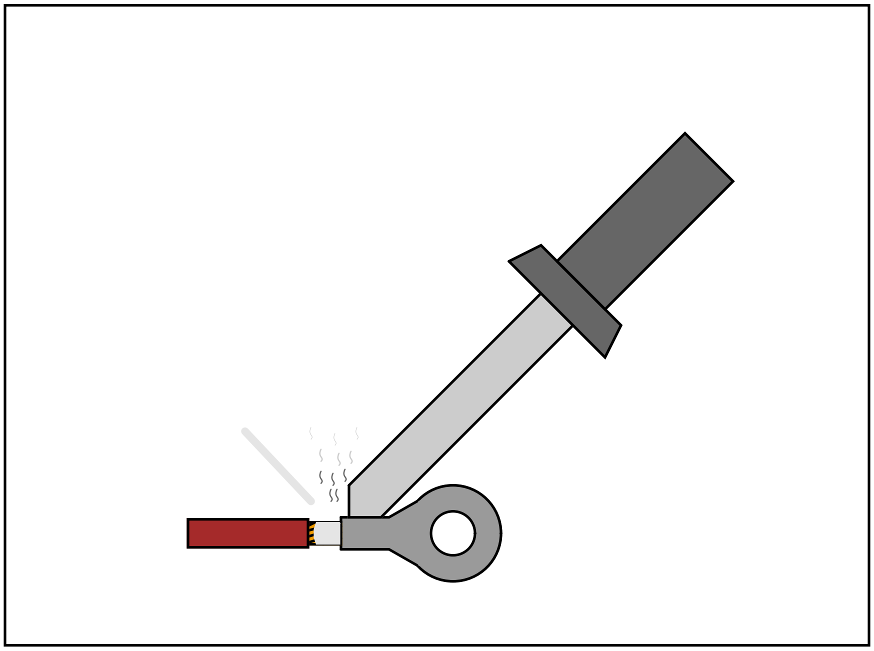


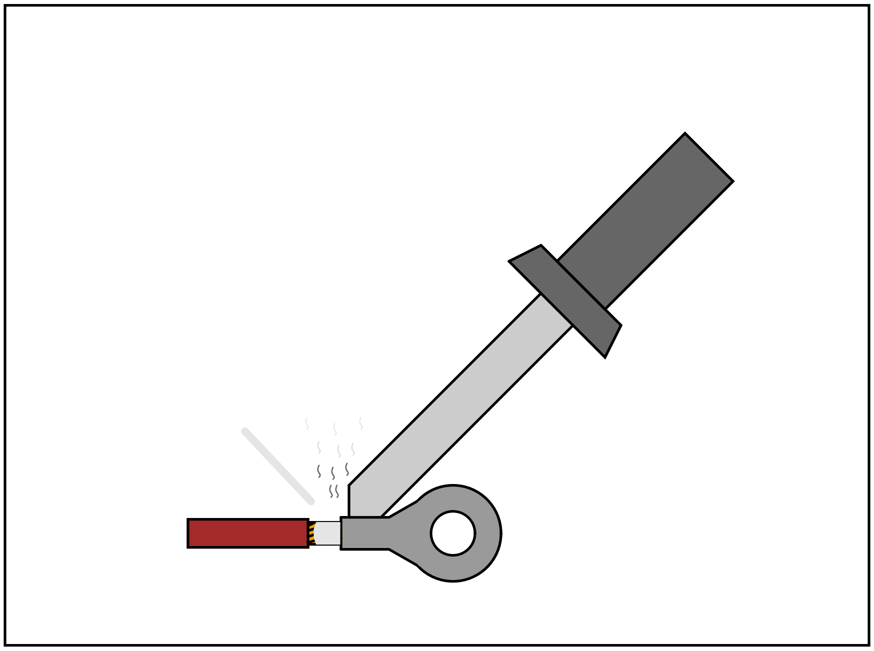


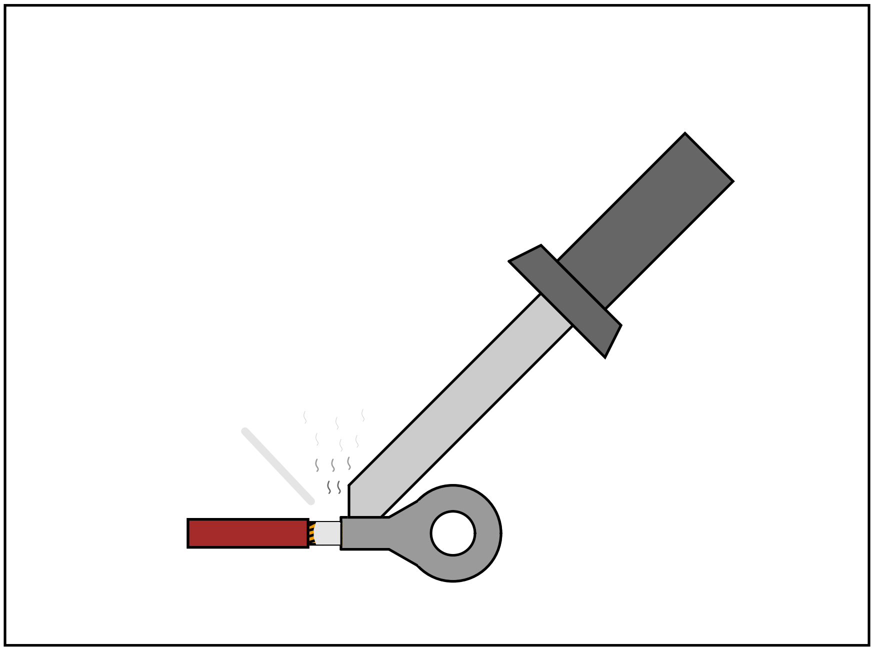


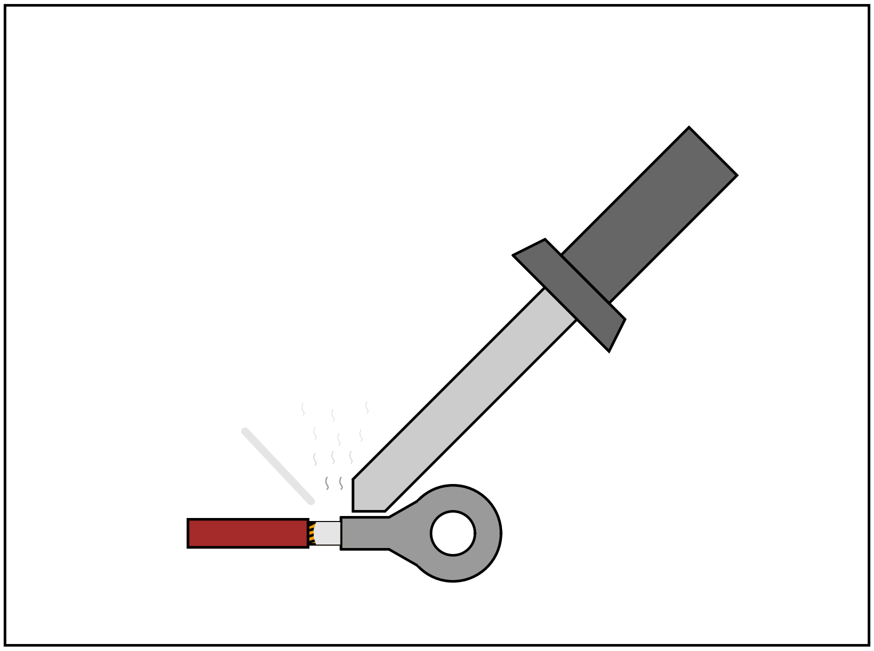


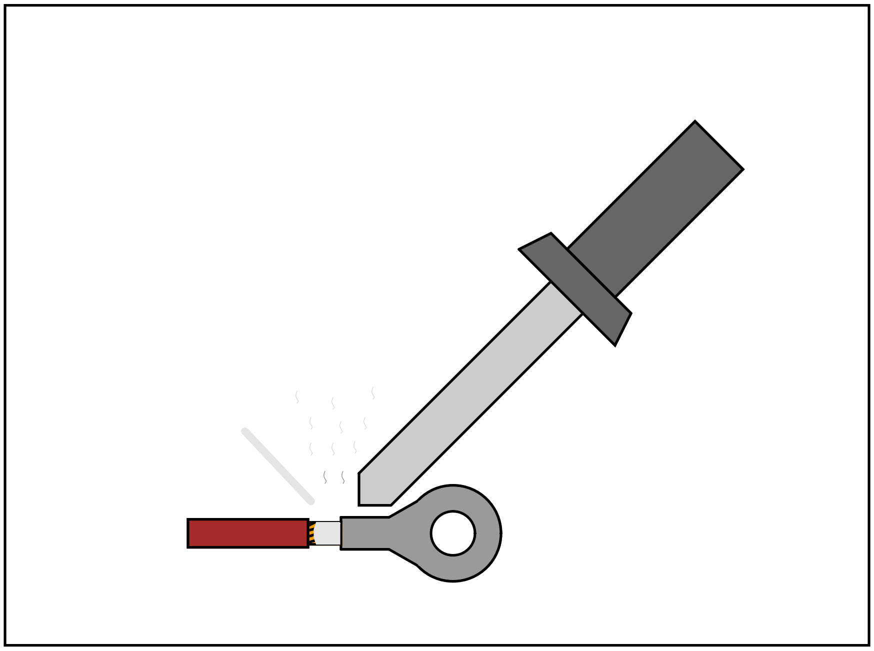


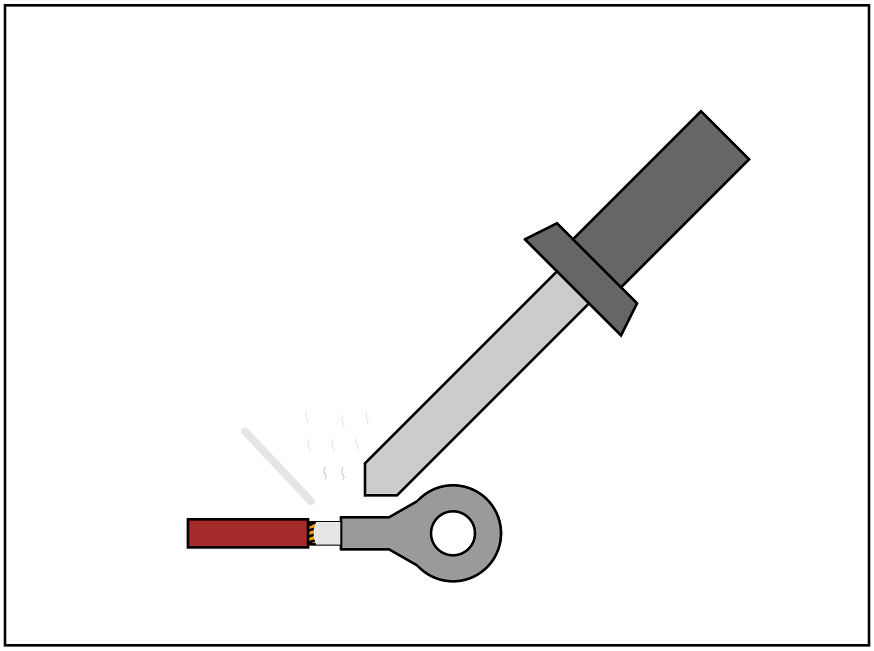


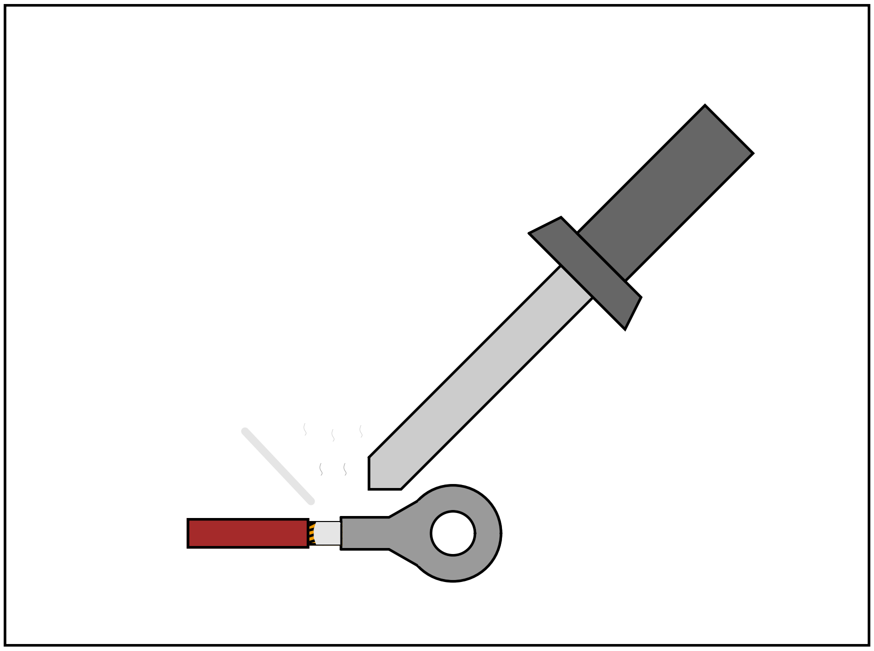


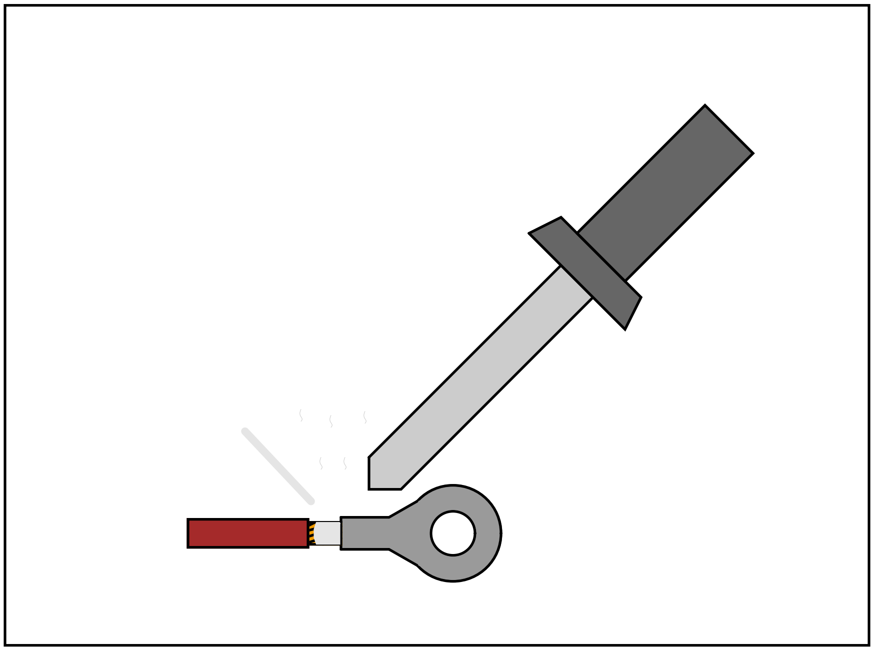


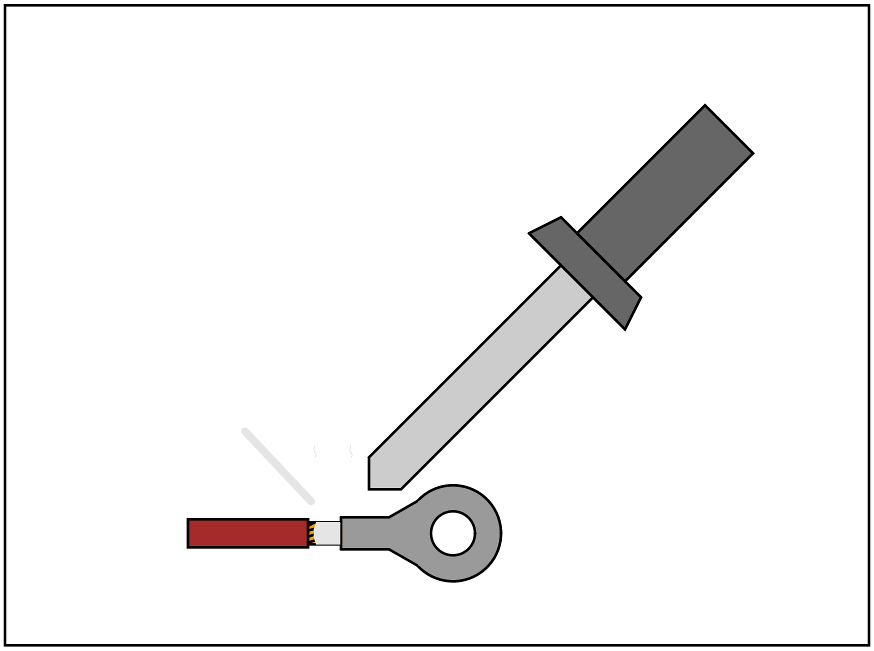


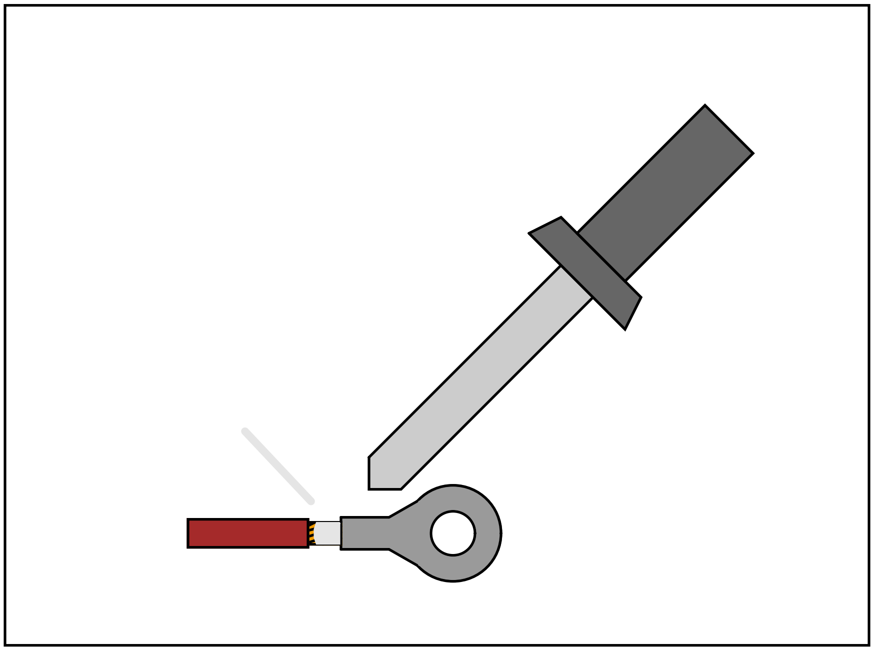


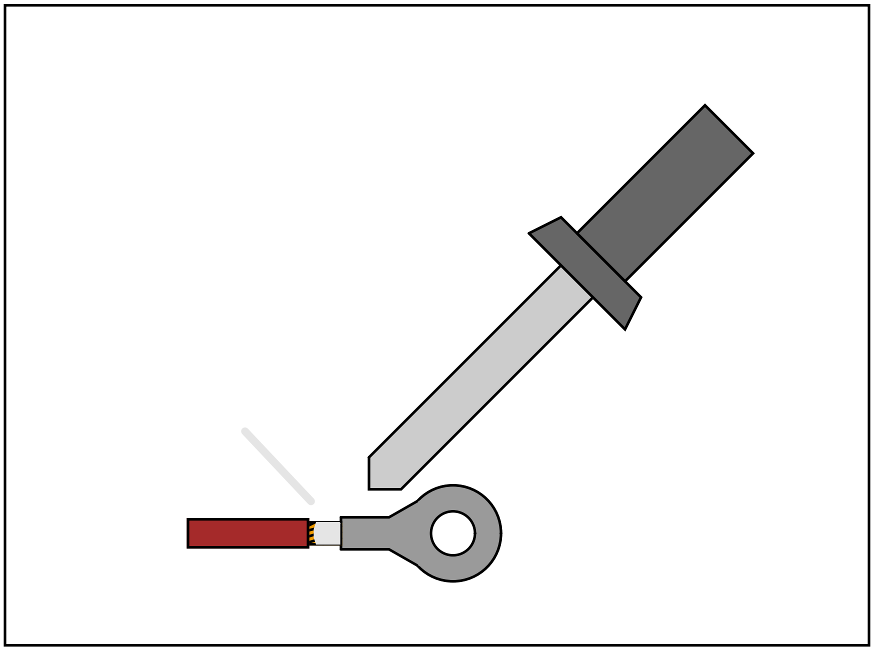


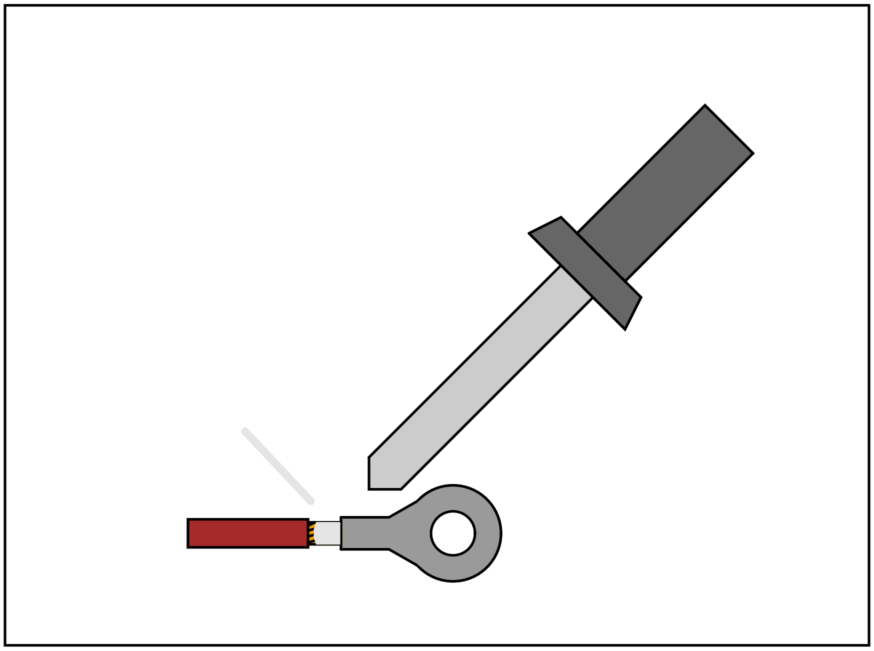


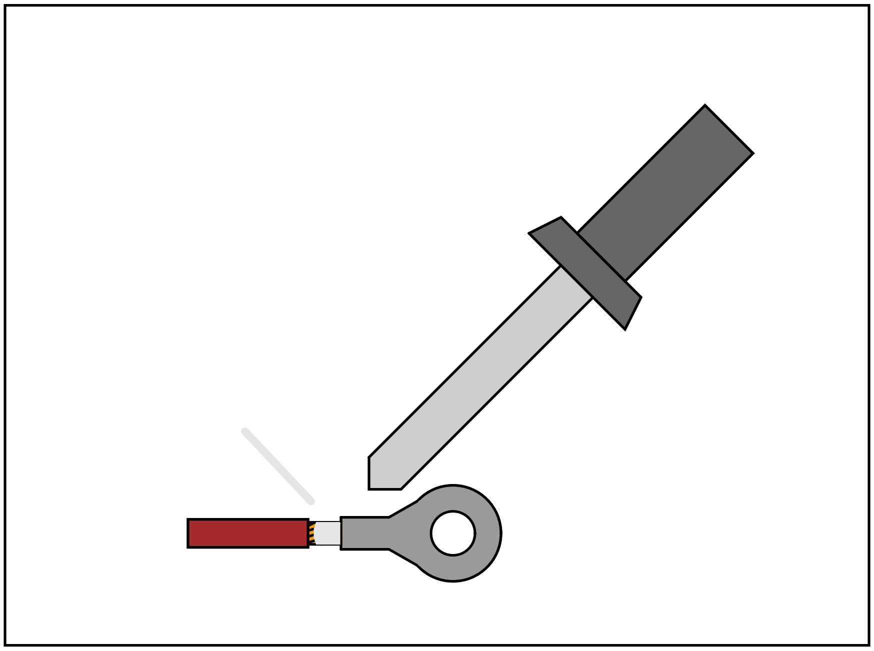












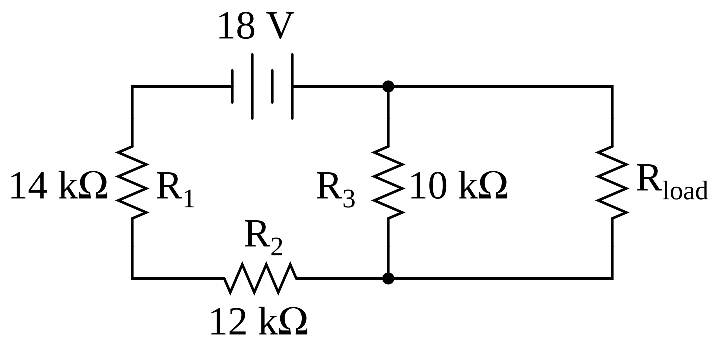
file 03450

Question 3

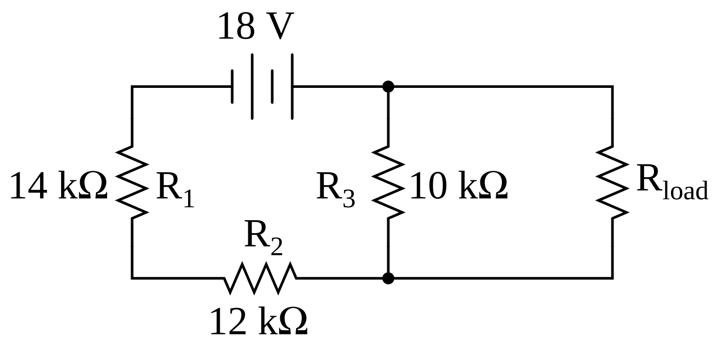
Animation: Applying Thévenin's theorem

This question consists of a series of images (one per page) that form an animation. Flip the pages with your fingers to view this animation (or click on the "next" button on your viewer) frame-by-frame.

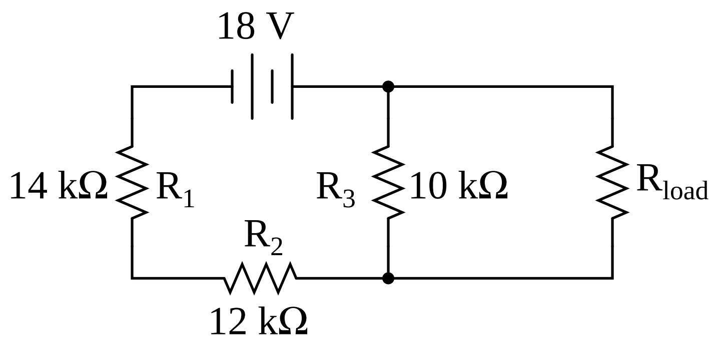
The following animation shows the steps involved in "Thévenizing" a circuit.


18 V
14 kΩ
R1
R3
10 kΩ
Rload
R2
12 kΩ

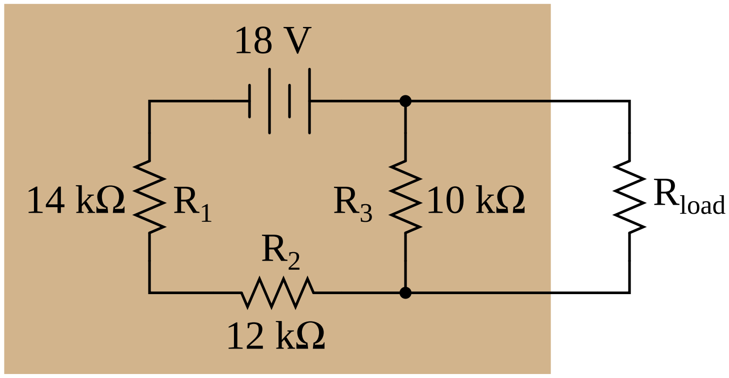
This is our original circuit:

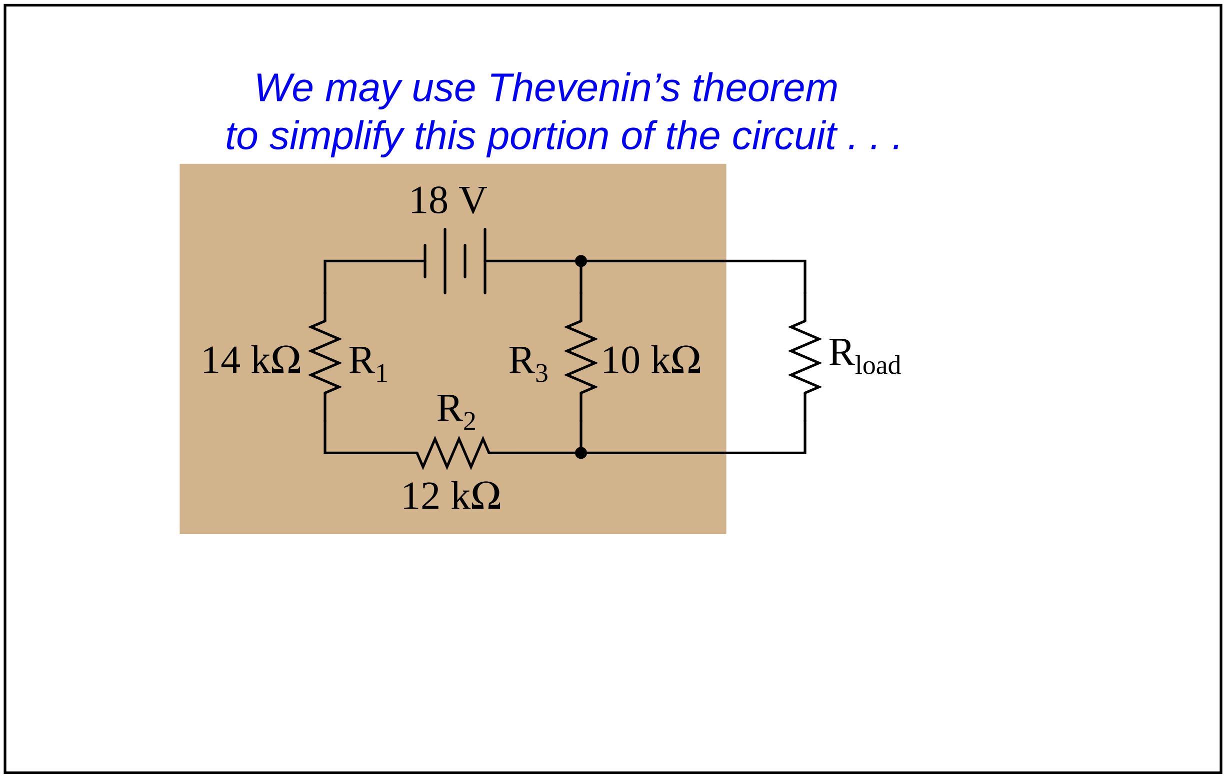


We may use Thevenin's theorem to simplify this portion of the circuit . . .

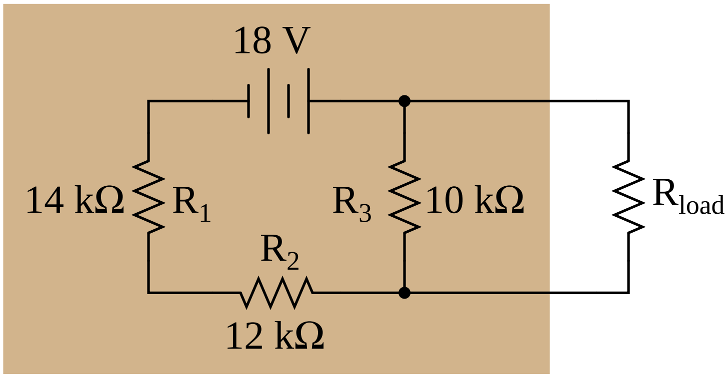


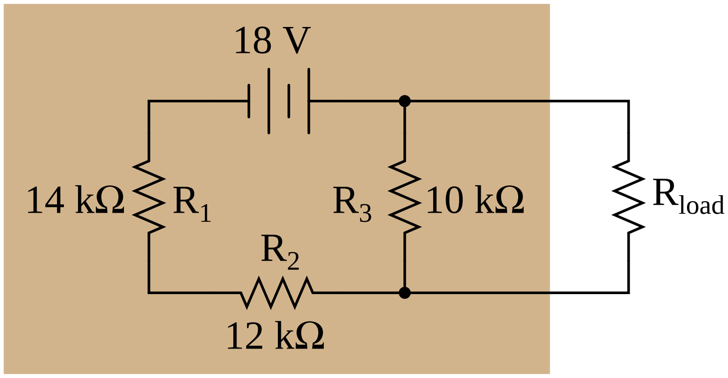
We may use Thevenin's theorem to simplify this portion of the circuit . . .

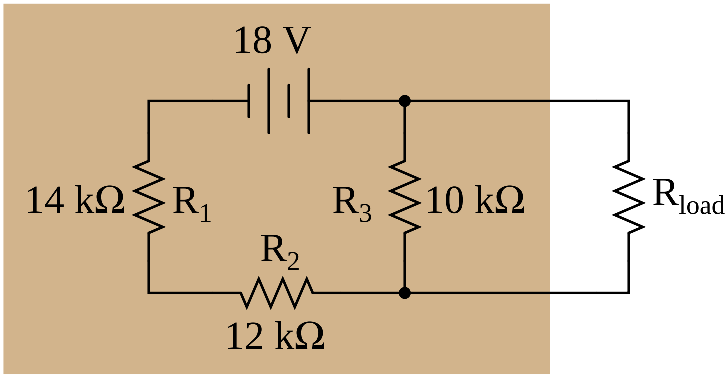



We may use Thevenin's theorem
to simplify this portion of the circuit . . .
18 V
14 kΩ
R1
R3
10 kΩ
Rload
R2
12 kΩ

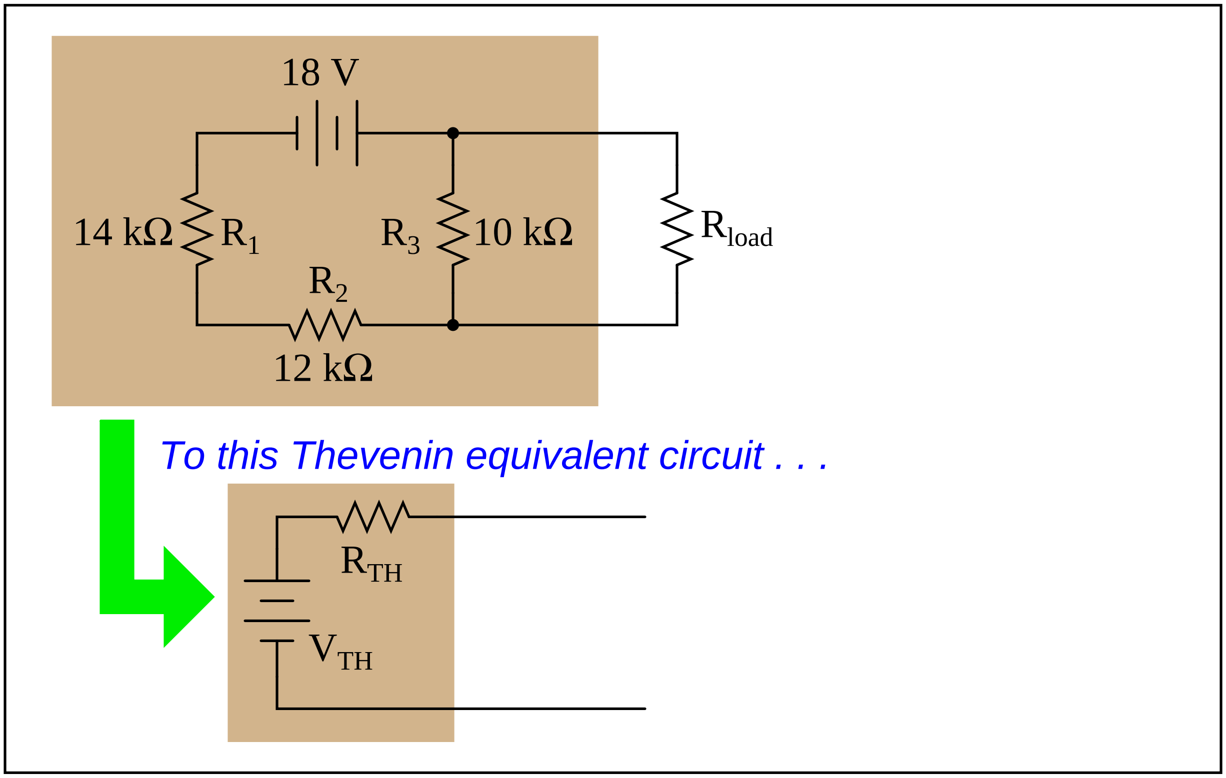
We may use Thevenin's theorem
to simplify this portion of the circuit . . .

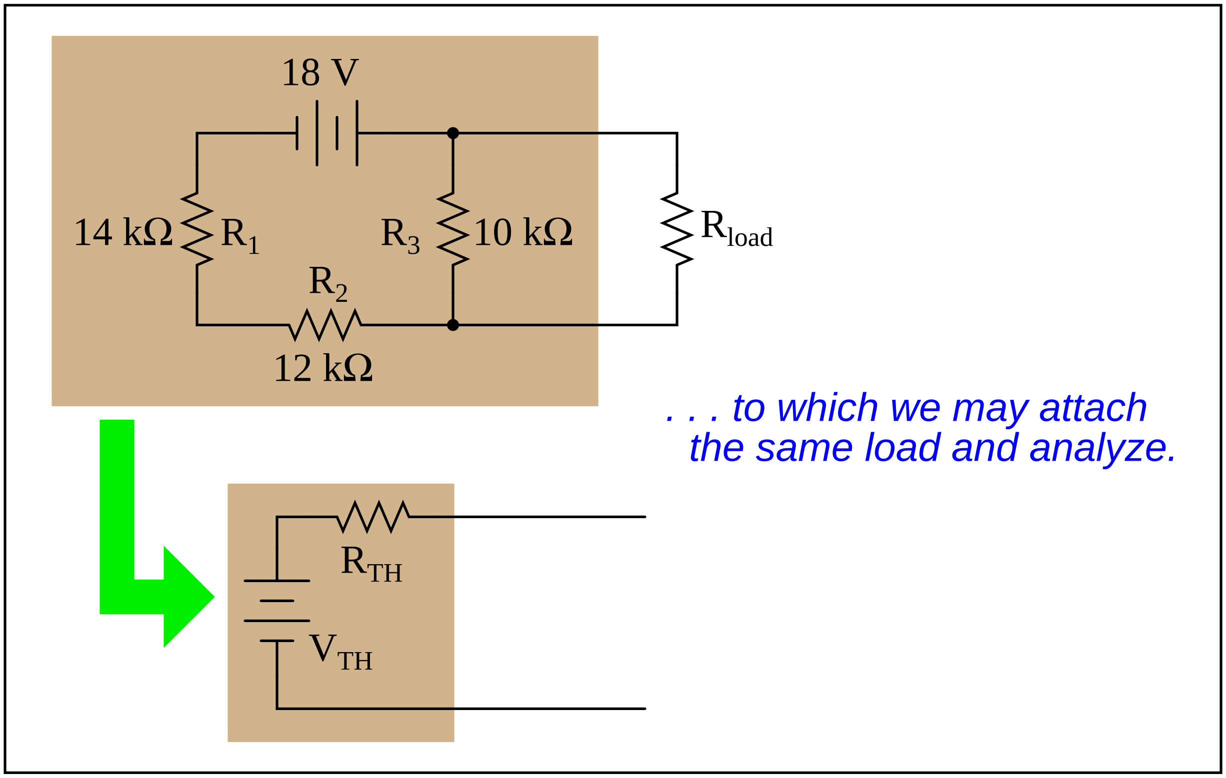


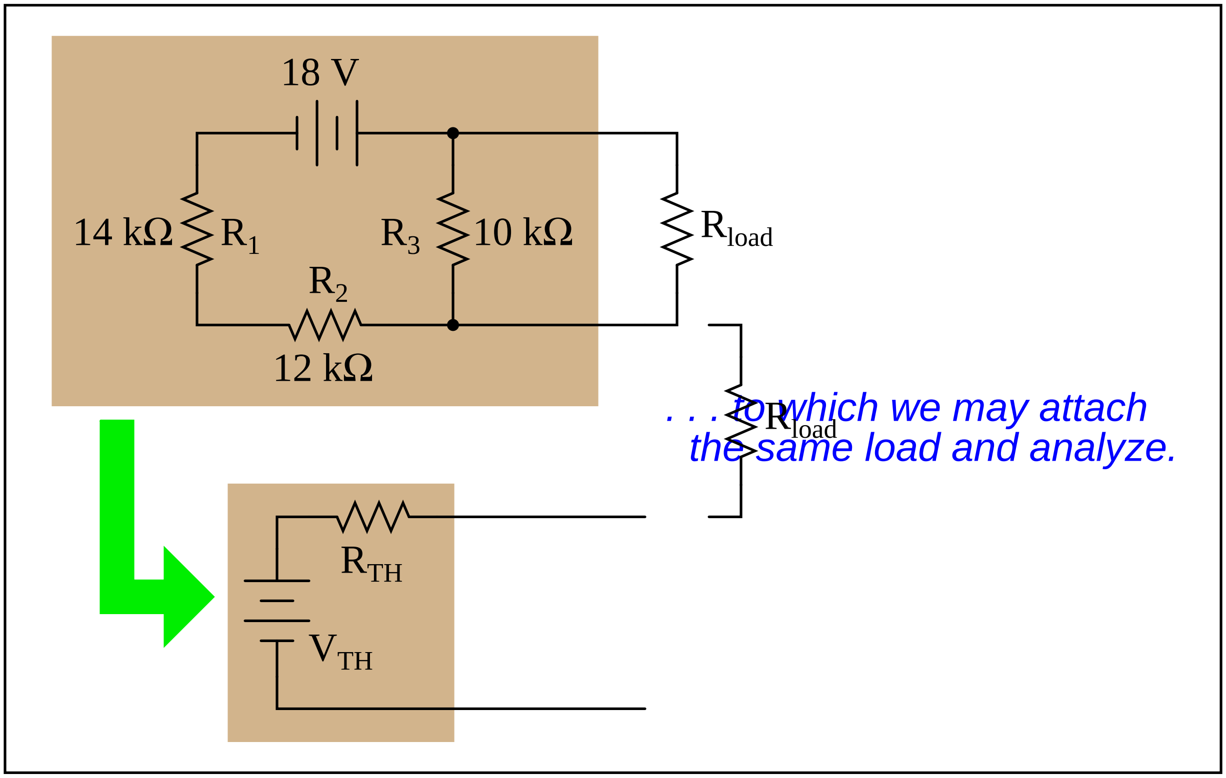

18 V
14 kΩ
R1
R3
10 kΩ
Rload
R2
12 kΩ

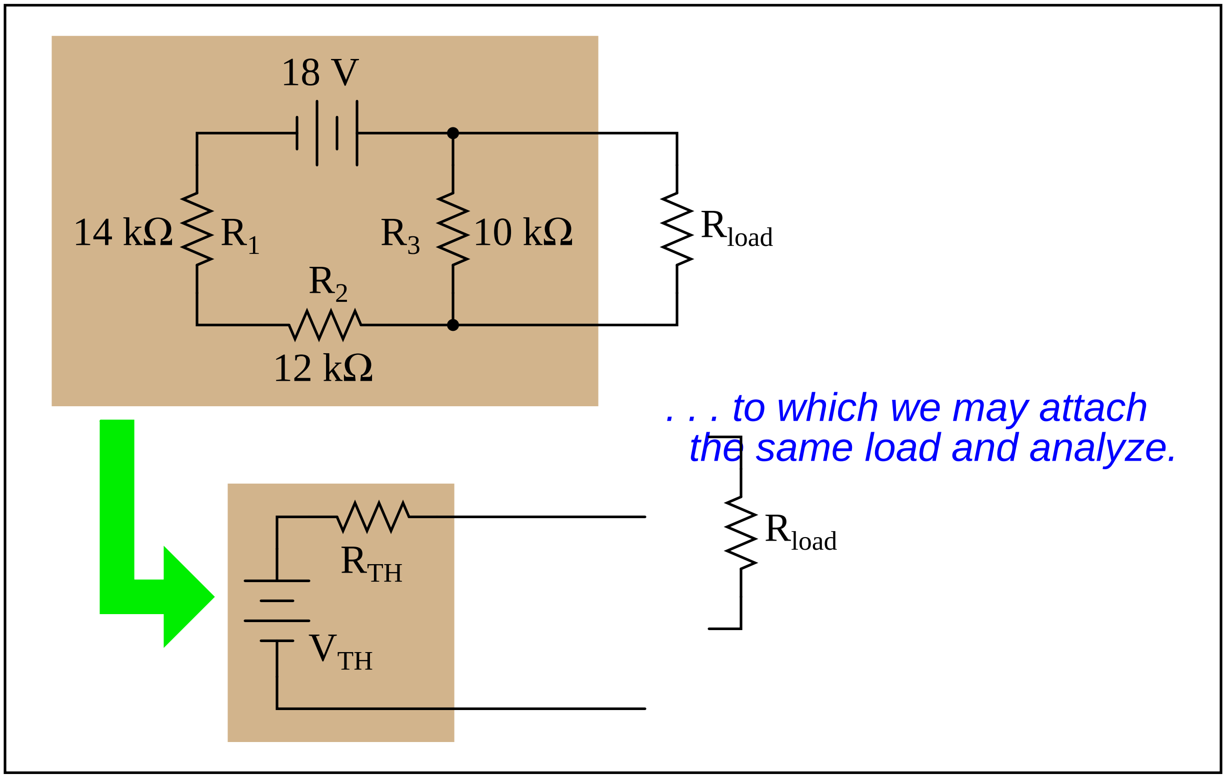


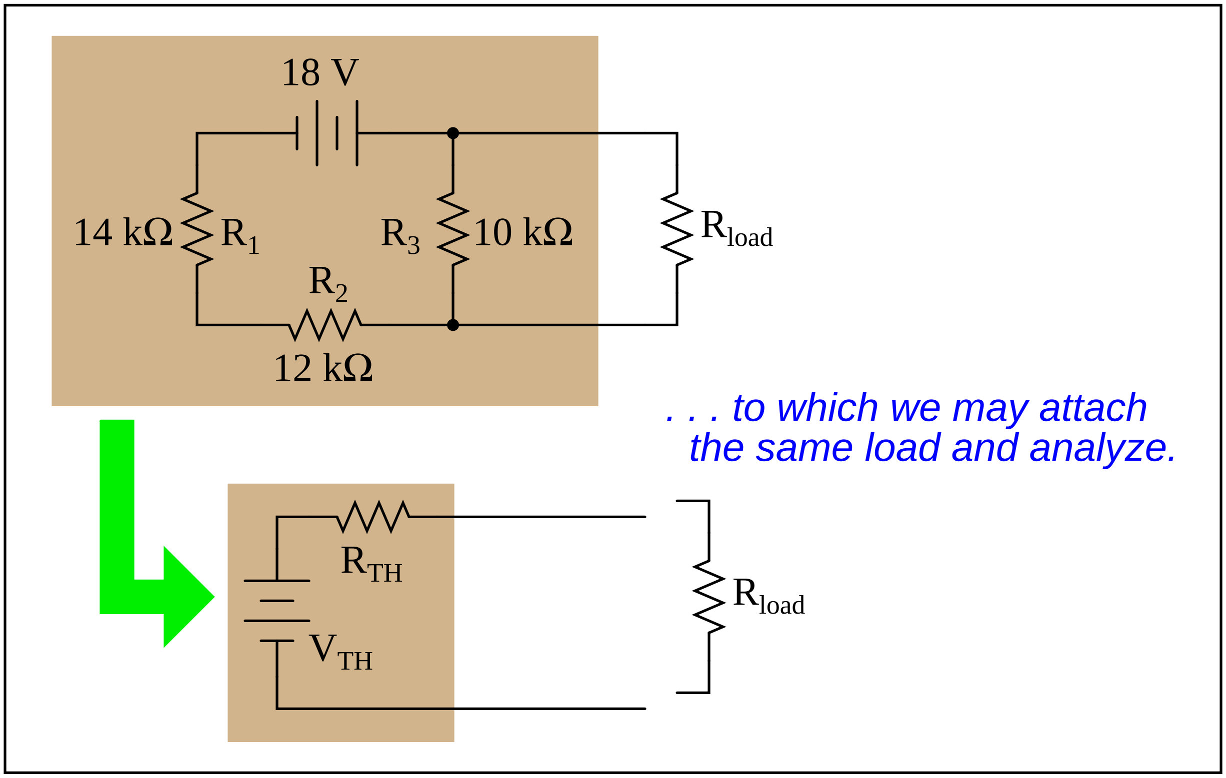
To this Thevenin equivalent circuit . . .

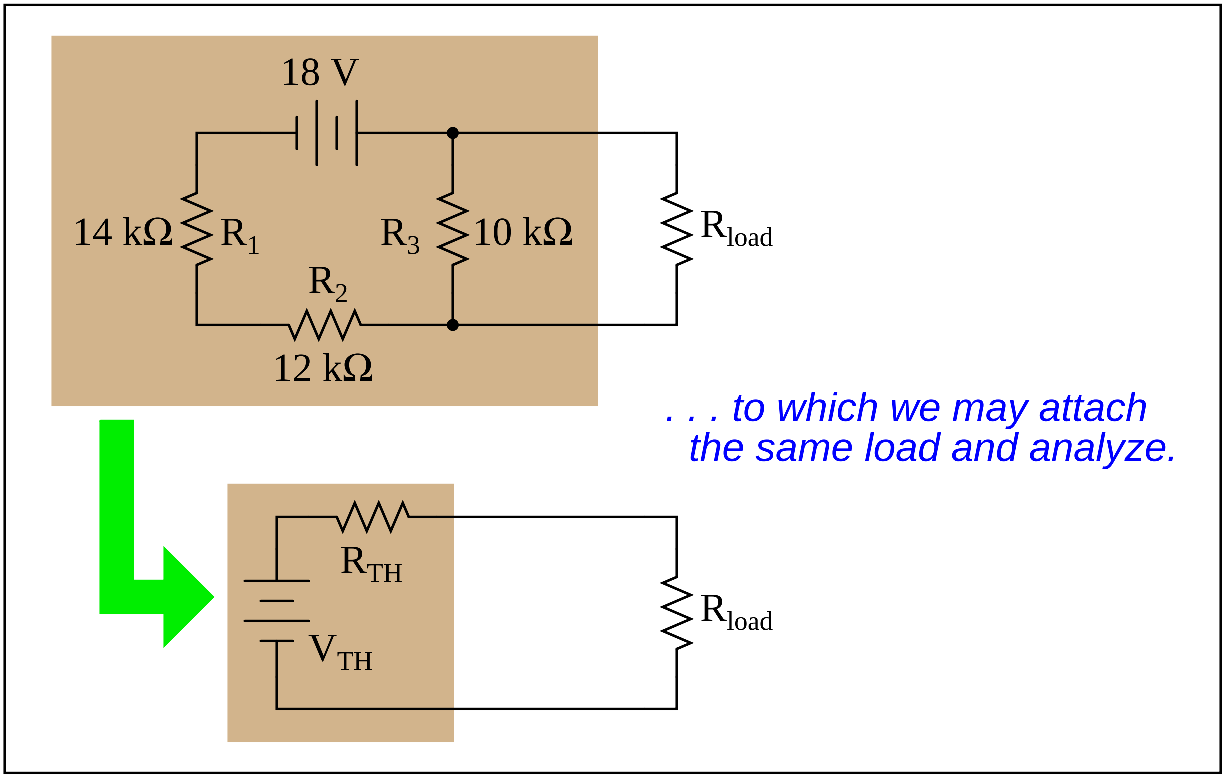

18 V
14 kΩ
R1
R3
10 kΩ
Rload
R2
12 kΩ
To this Thevenin equivalent circuit . . .
RTH
VTH

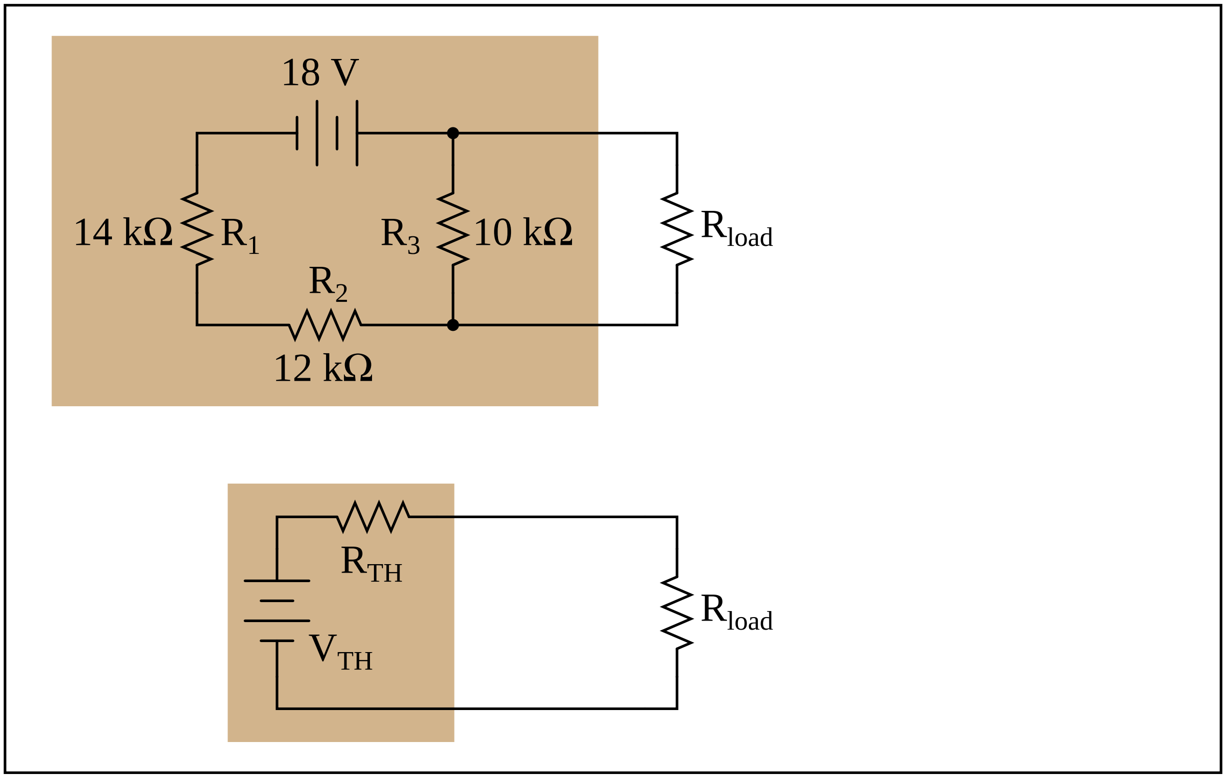

18 V
14 kΩ
R1
R3
10 kΩ
Rload
R2
12 kΩ
. . . to which we may attach
the same load and analyze.
RTH
VTH

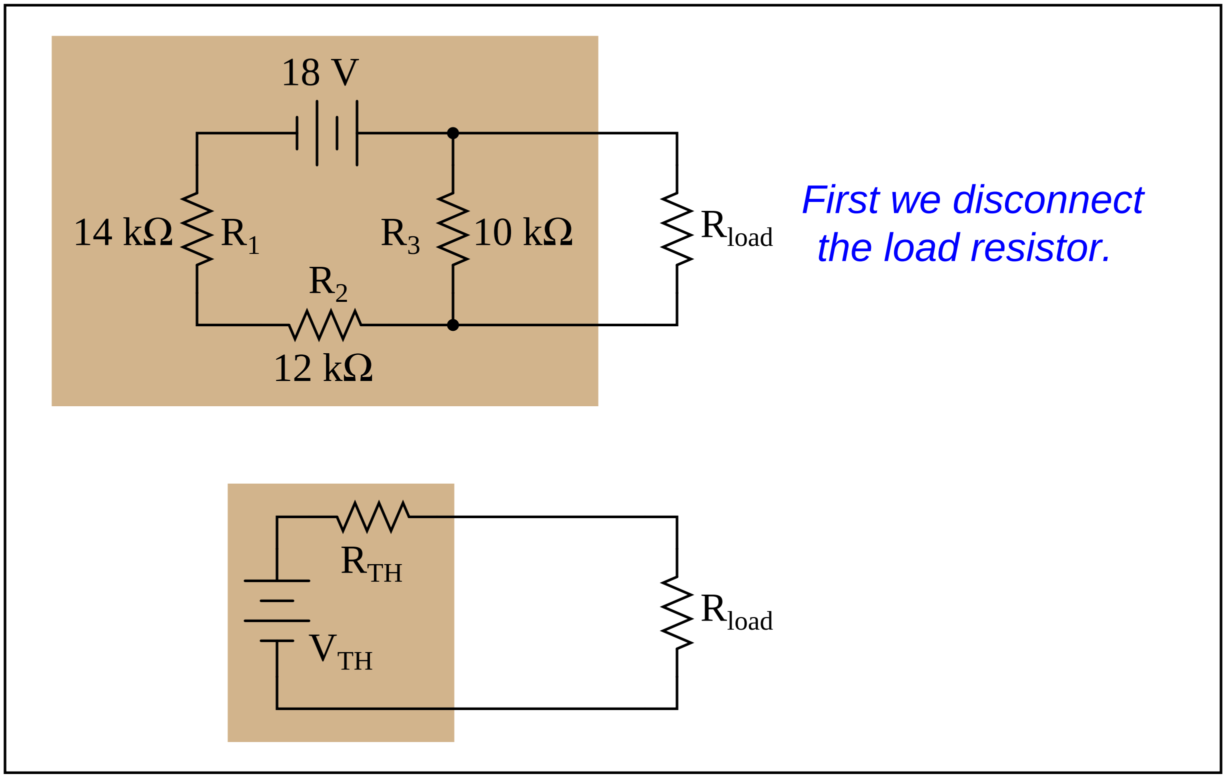

18 V
14 kΩ
R_1
R_3
10 kΩ
R_2
12 kΩ
R_{load}
. . . to which we may attach
the same load and analyze.
R_{load}
R_{TH}
V_{TH}

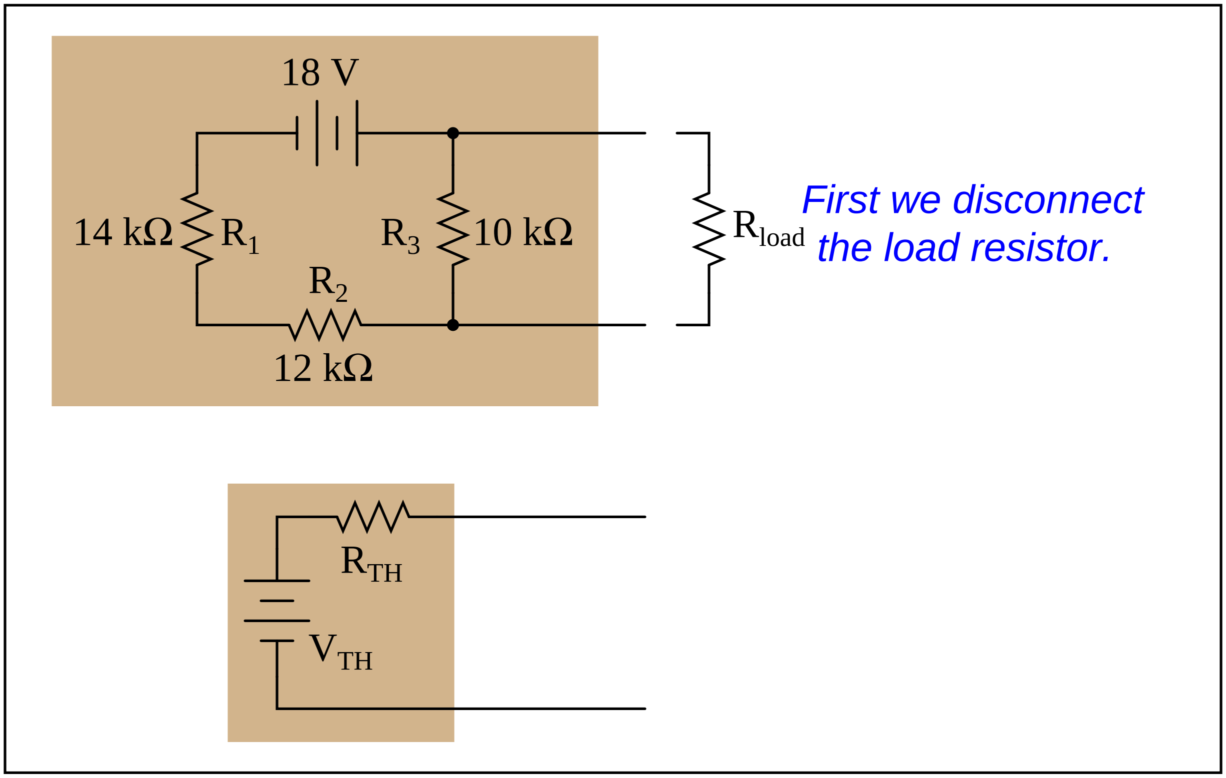

18 V
14 kΩ
R1
R3
10 kΩ
Rload
R2
12 kΩ
. . . to which we may attach
the same load and analyze.
RTH
Rload
VTH

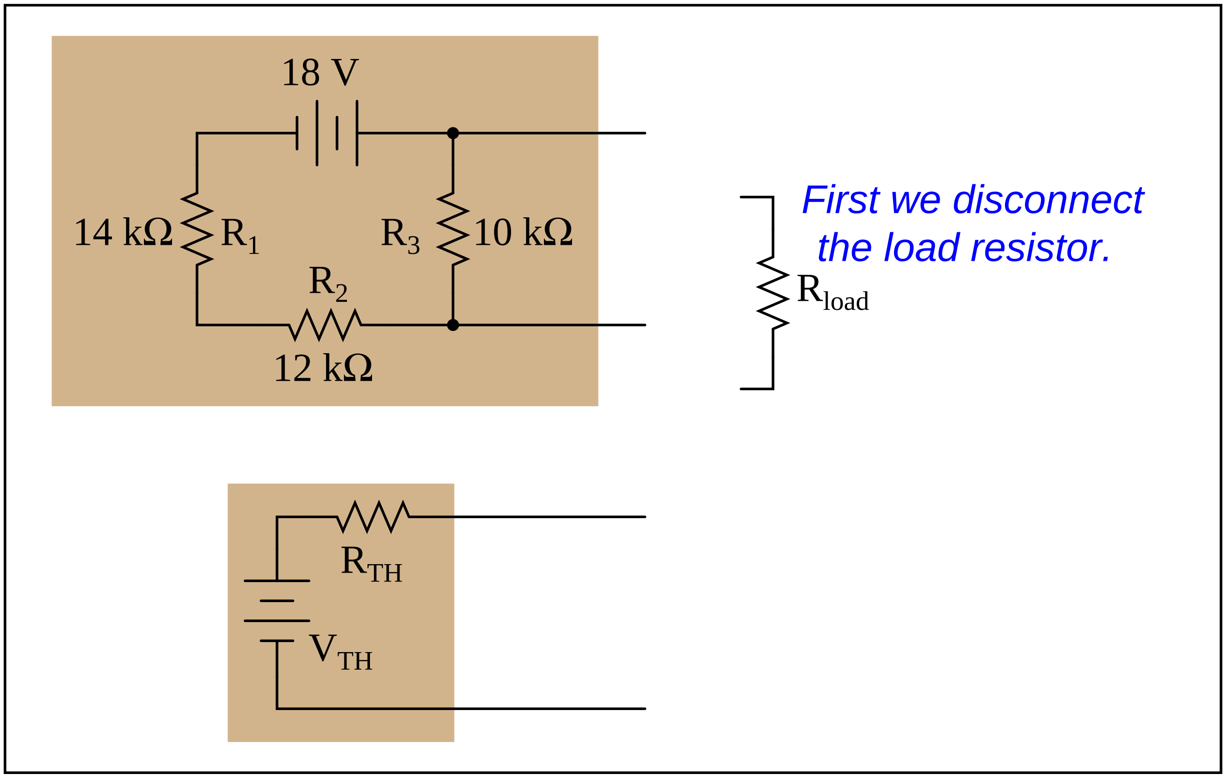

18 V
14 kΩ
R1
R3
10 kΩ
Rload
R2
12 kΩ
. . . to which we may attach the same load and analyze.
RTH
VTH
Rload

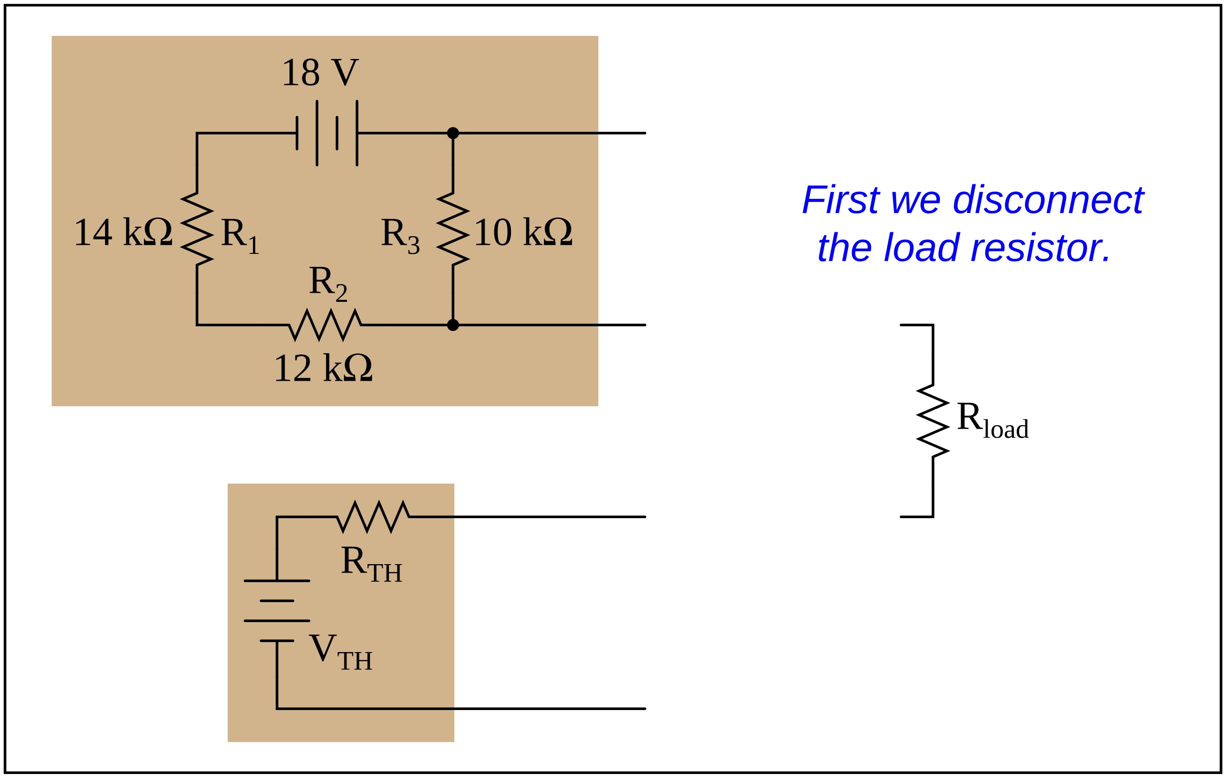

18 V
14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
Rload
. . . to which we may attach
the same load and analyze.
RTH
VTH
Rload

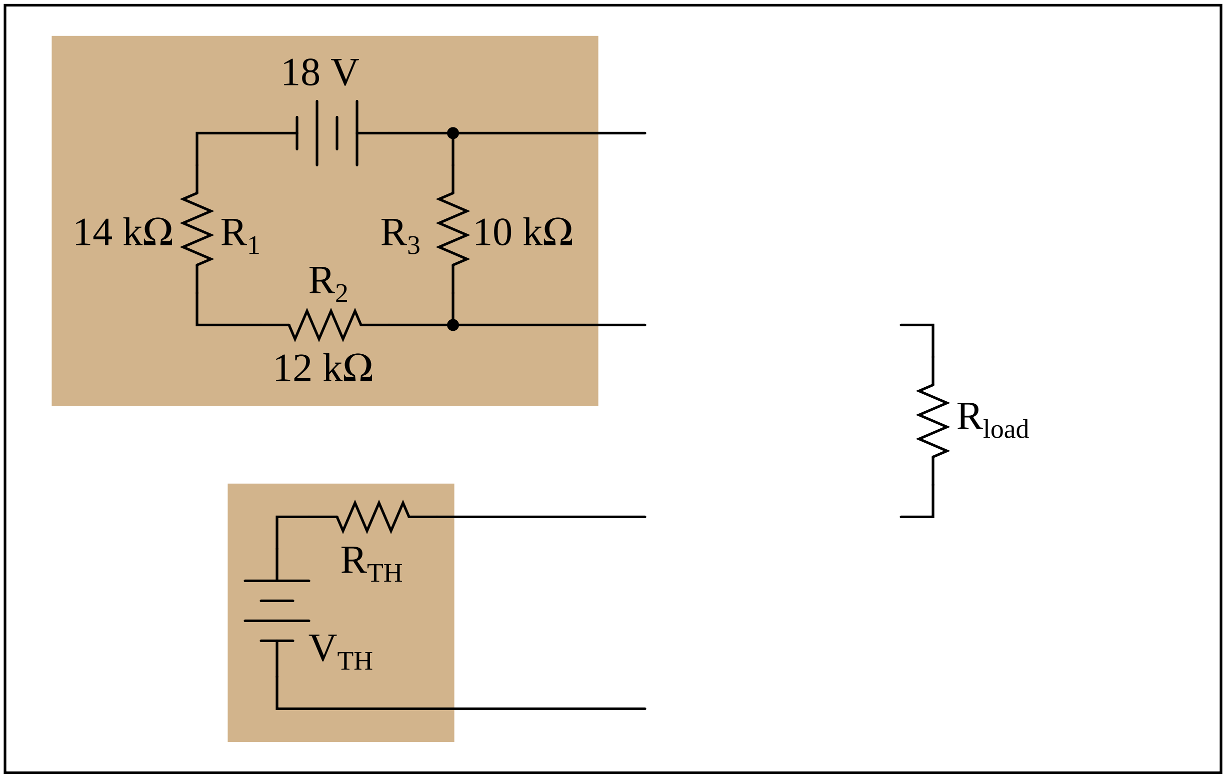

18 V
14 kΩ
R_1
R_3
10 kΩ
R_{load}
R_2
12 kΩ
R_{TH}
R_{load}
V_{TH}


18 V
14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
Rload
First we disconnect the load resistor.
RTH
VTH
Rload

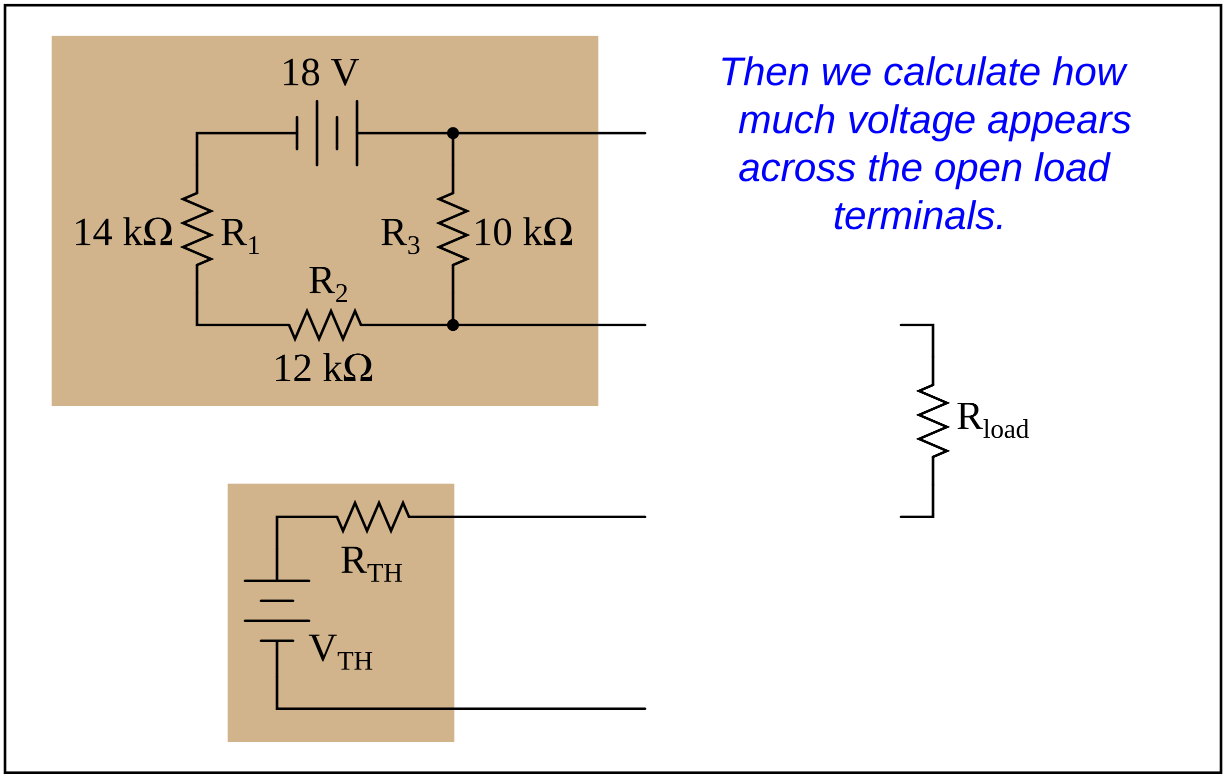

18 V
14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
Rload
First we disconnect the load resistor.
RTH
VTH


18 V
14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
Rload
First we disconnect the load resistor.
RTH
VTH

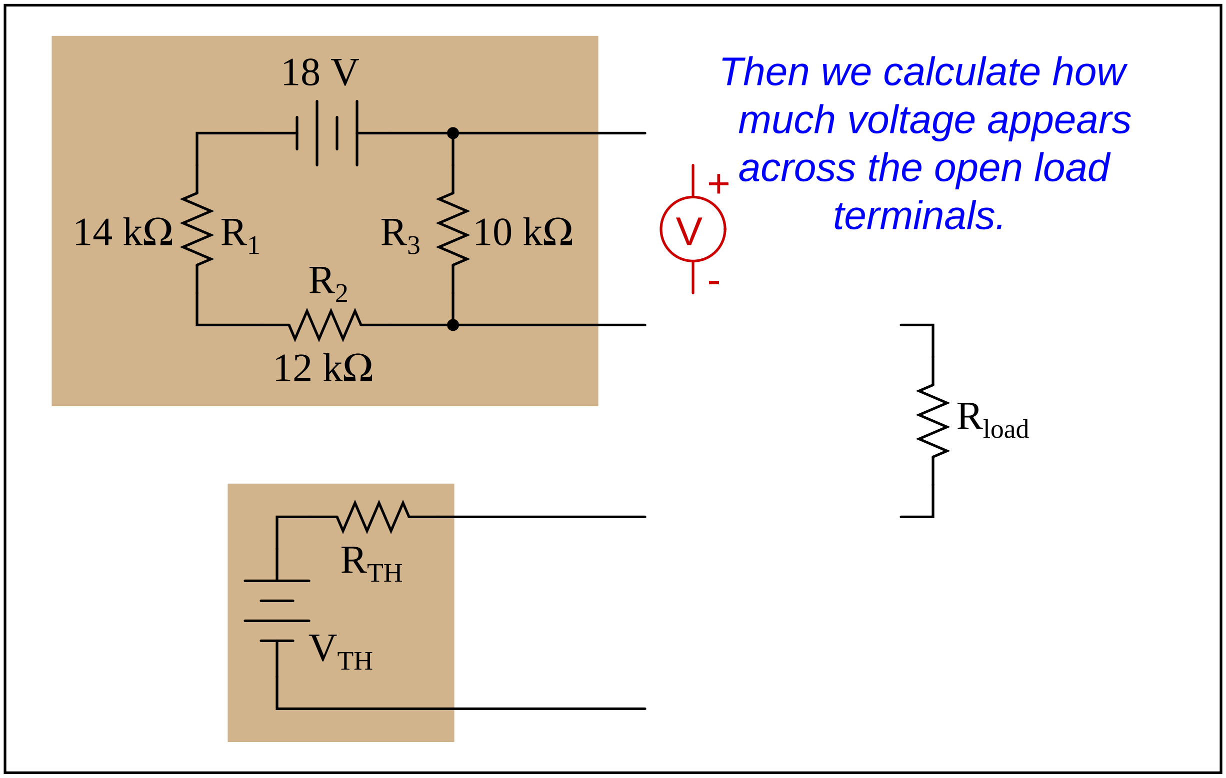

18 V
14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
First we disconnect the load resistor.
Rload
RTH
VTH



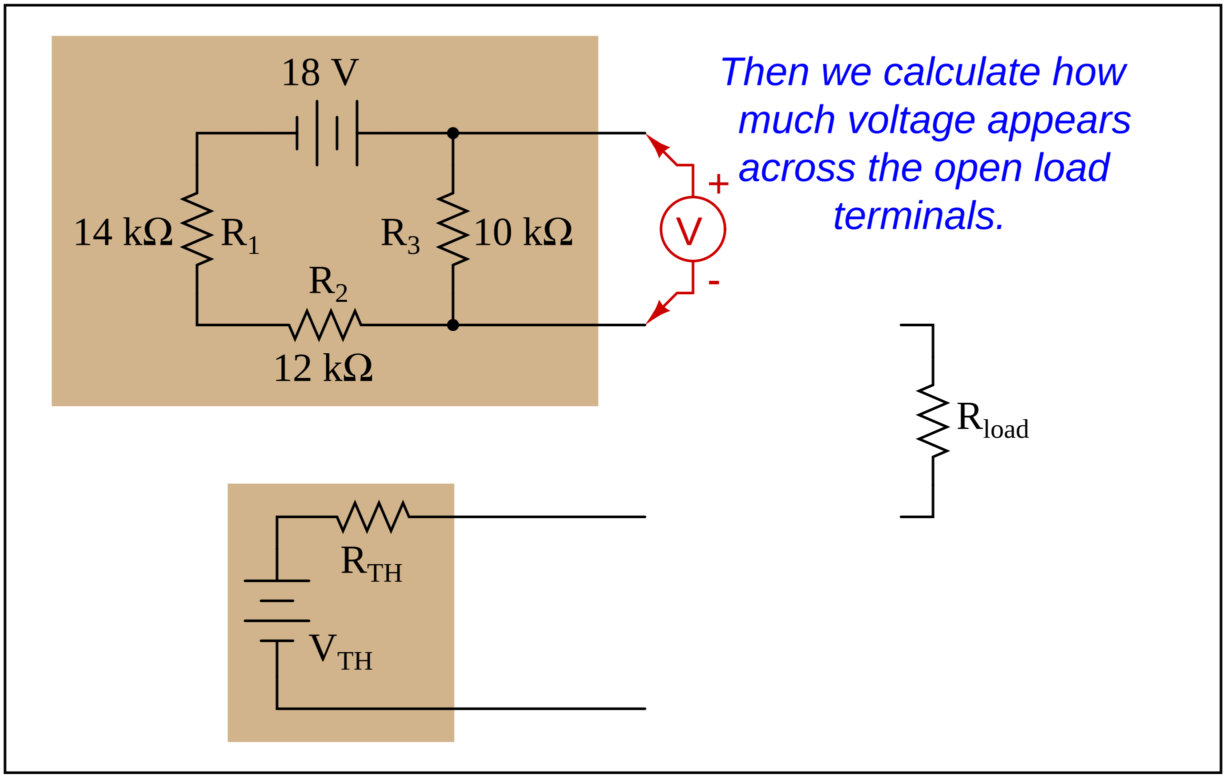
18 V
14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
Rload
RTH
VTH

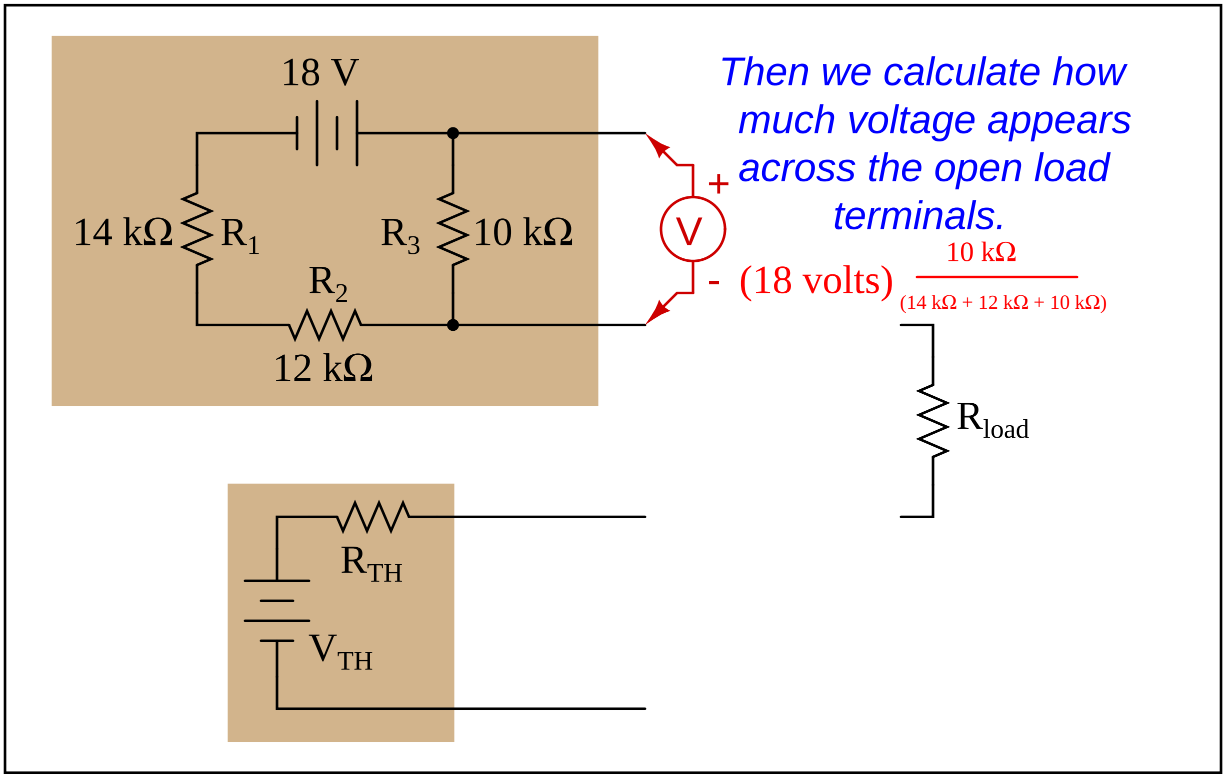


18 V
14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
Then we calculate how much voltage appears across the open load terminals.
Rload
RTH
VTH

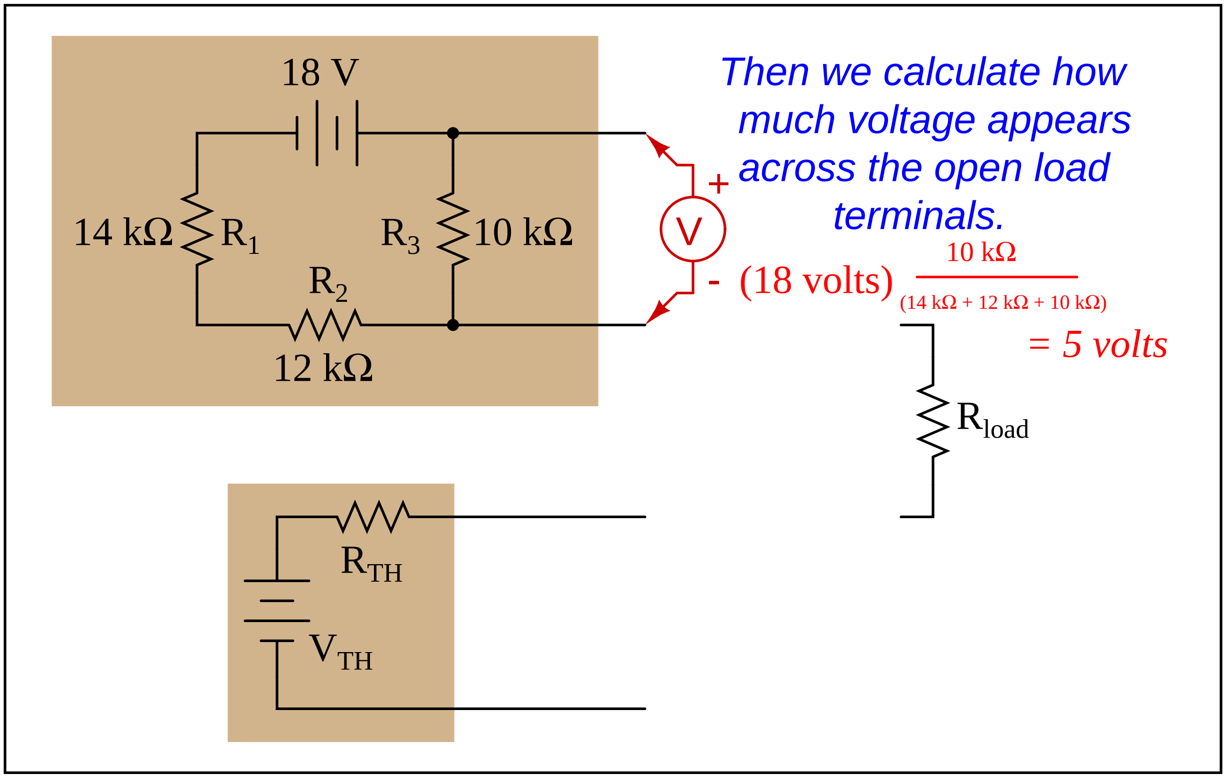


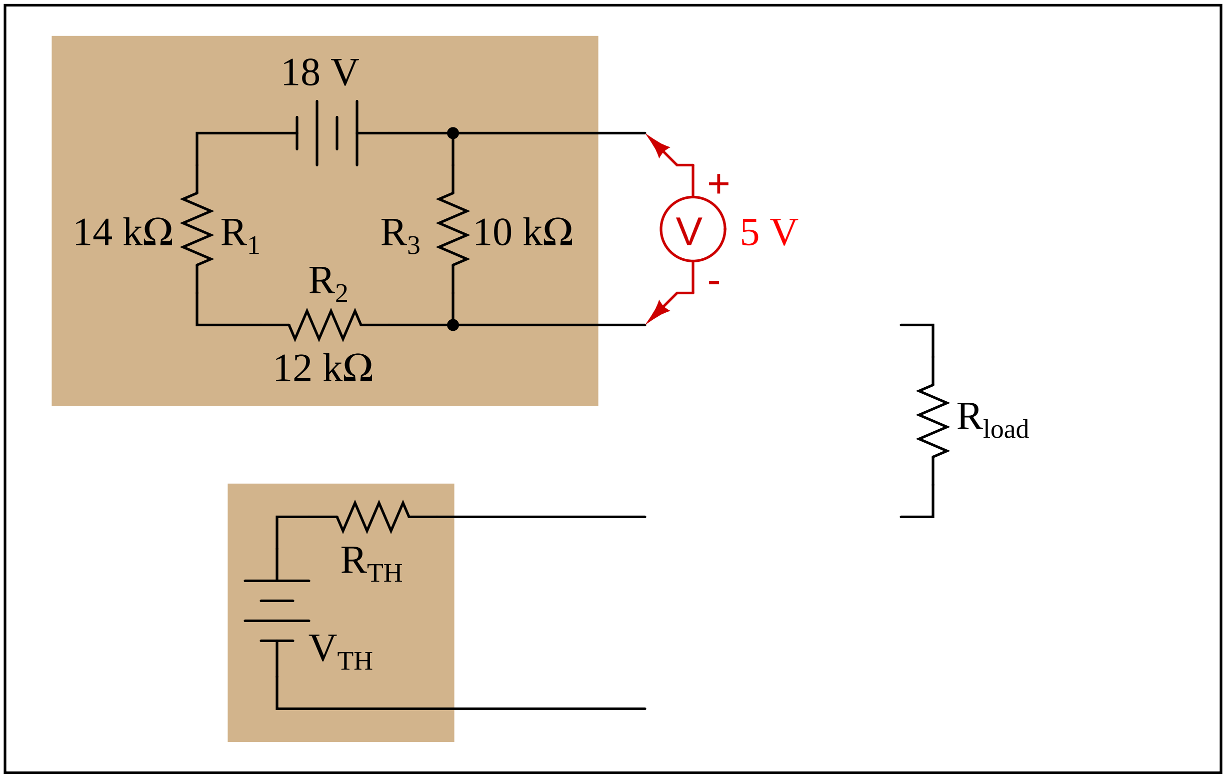
18 V
14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
V
+
-
Then we calculate how much voltage appears across the open load terminals.
Rload
RTH
VTH

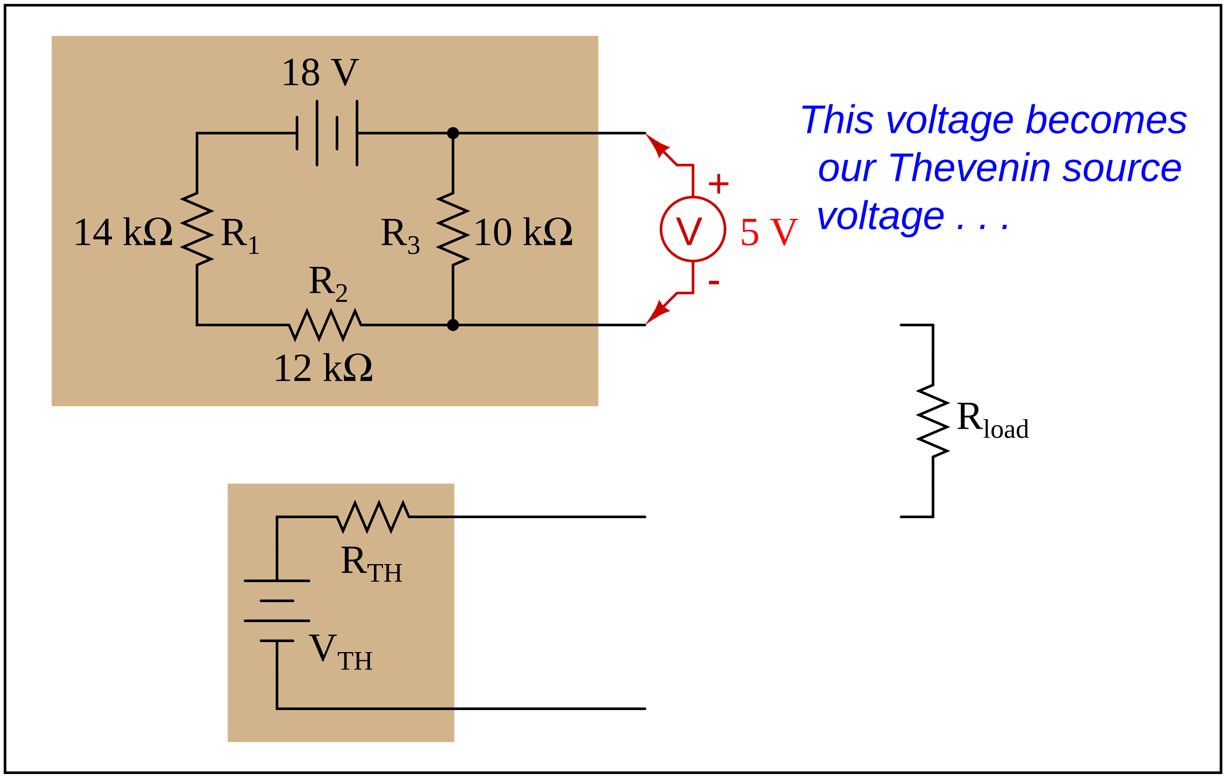

18 V
14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
V
+
-
Then we calculate how much voltage appears across the open load terminals.
Rload
RTH
VTH

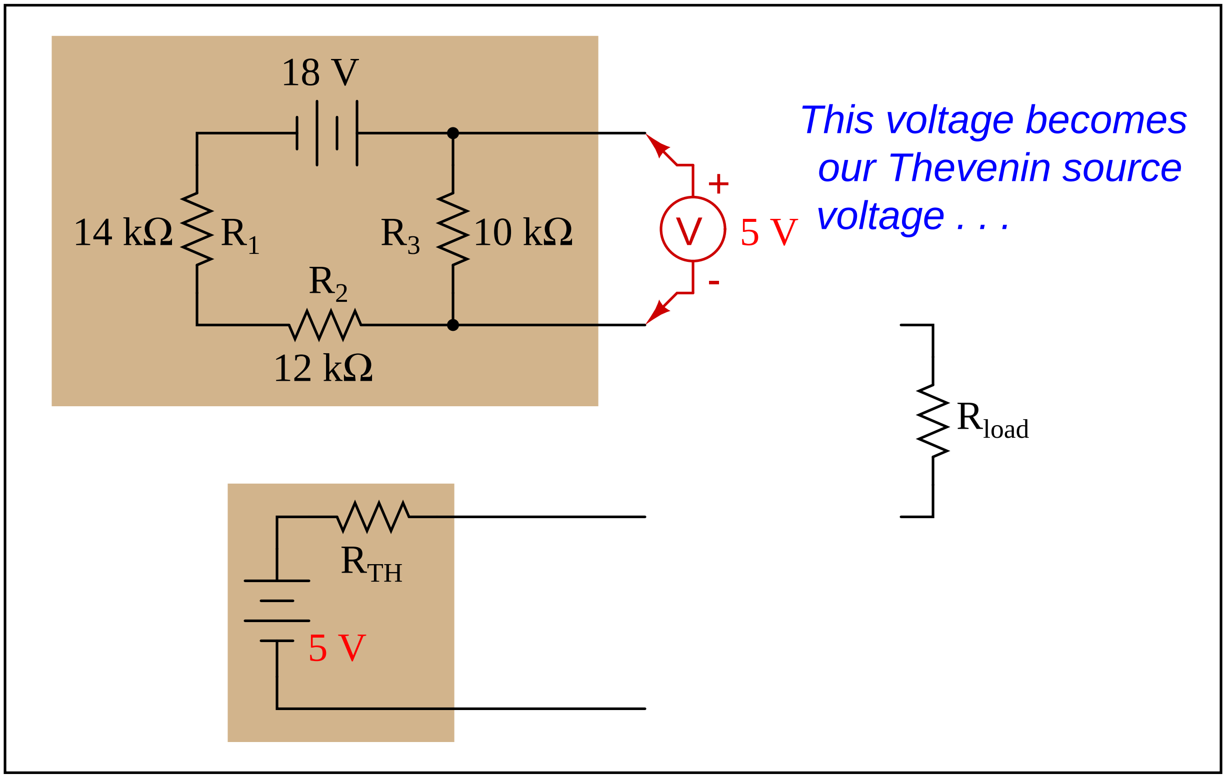


18 V
14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
V
+
-
Then we calculate how much voltage appears across the open load terminals.
(18 volts) 10 kΩ / (14 kΩ + 12 kΩ + 10 kΩ)
Rload
RTH
VTH

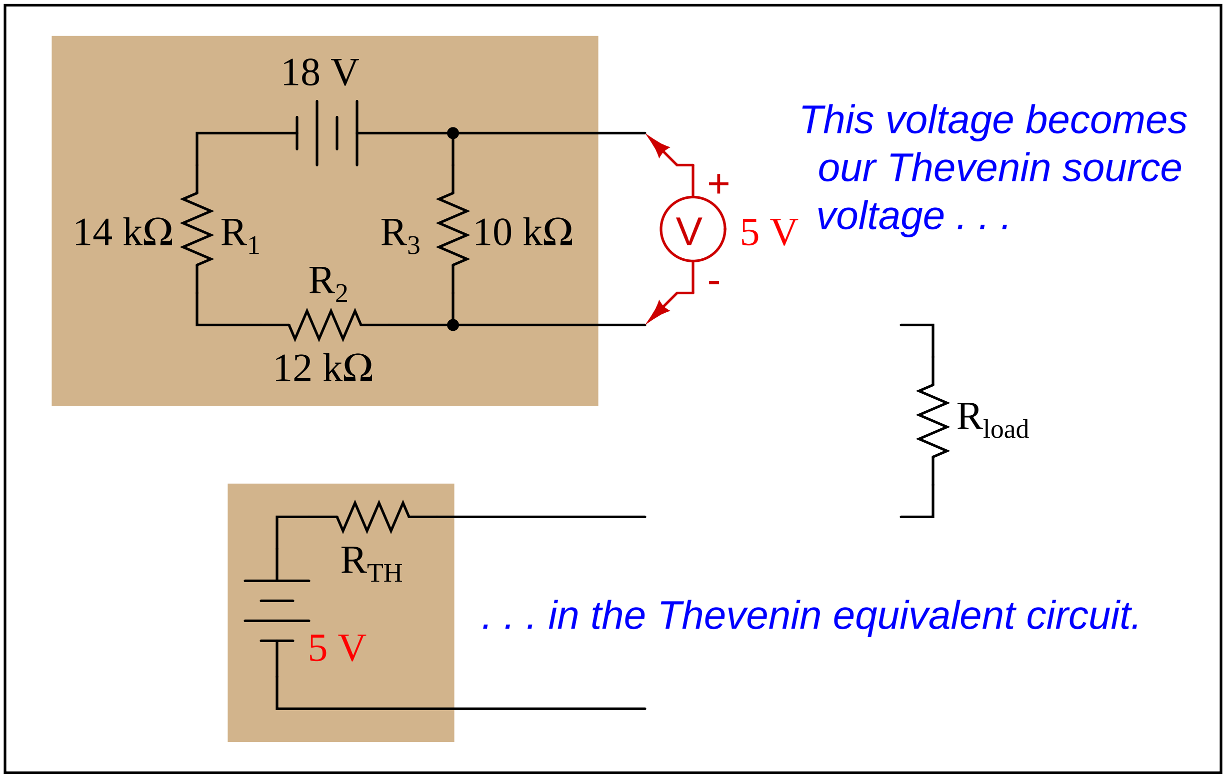

18 V
14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
V
+
-
Then we calculate how much voltage appears across the open load terminals.
(18 volts) 10 kΩ / (14 kΩ + 12 kΩ + 10 kΩ)
= 5 volts
Rload
RTH
VTH

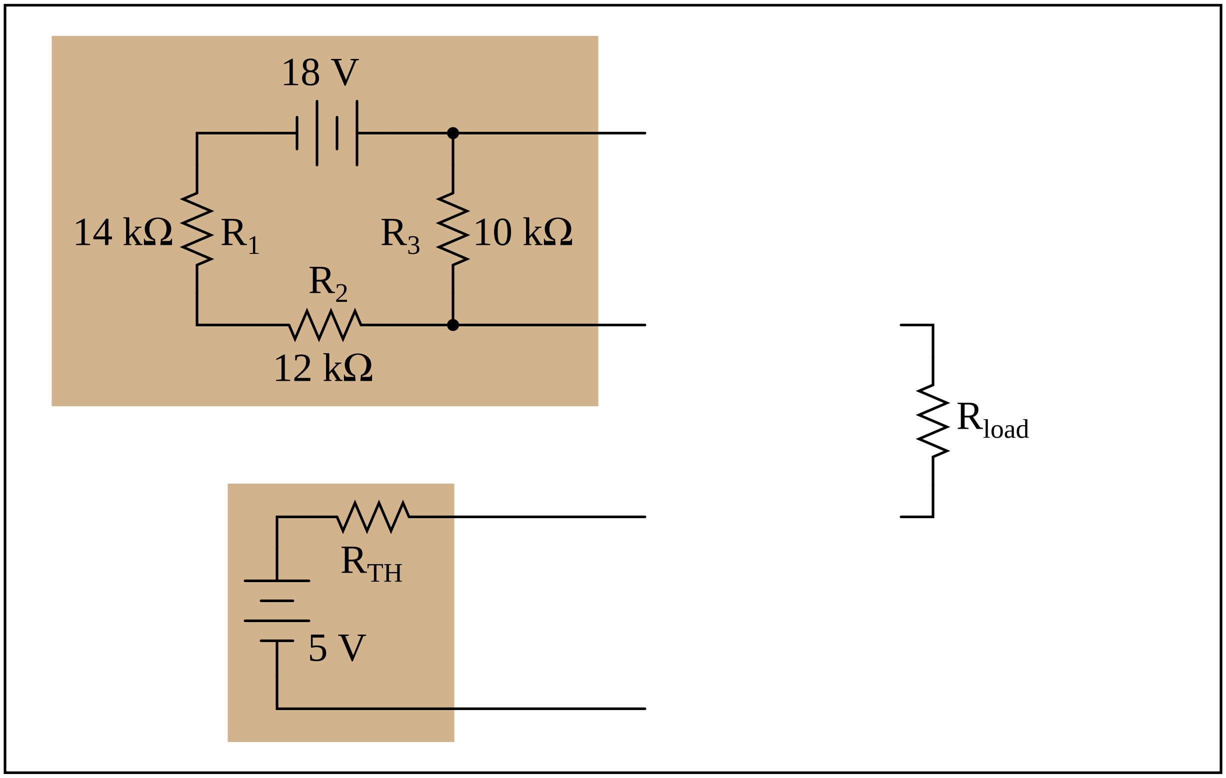

18 V
14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
V
+
-
5 V
Rload
RTH
VTH

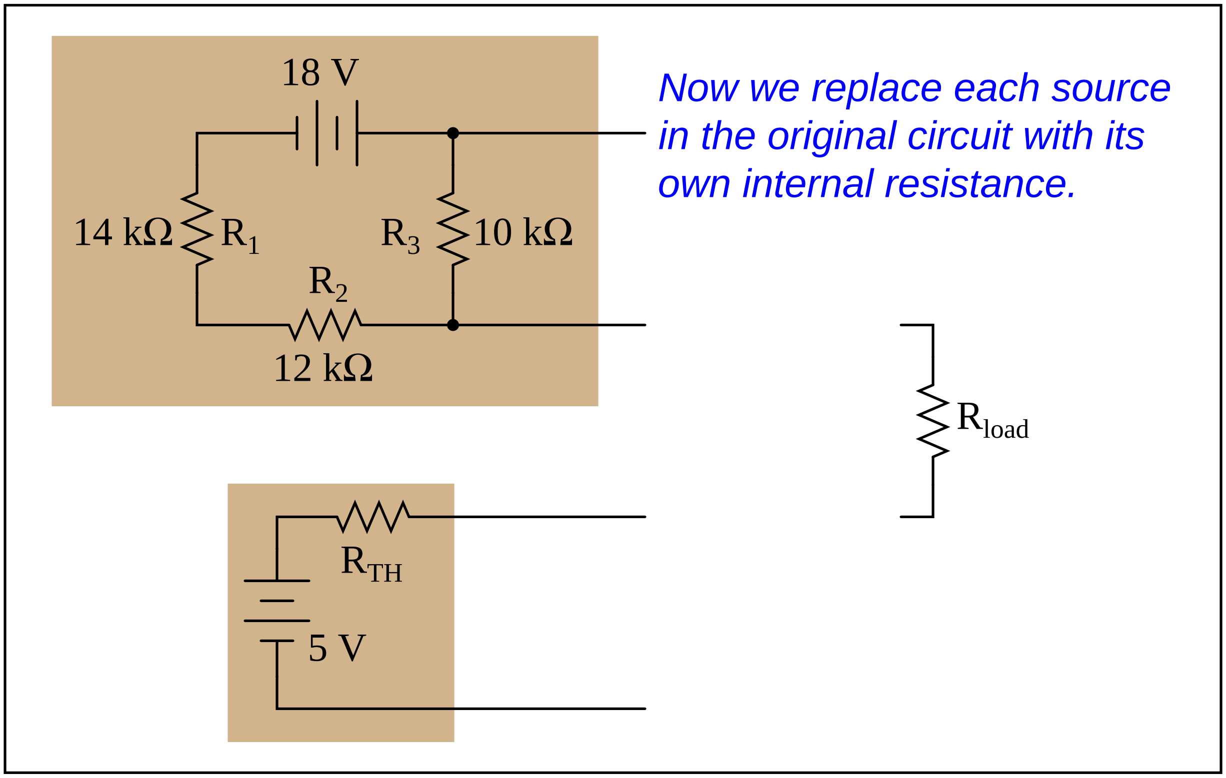

18 V
14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
V
+
-
5 V
This voltage becomes our Thevenin source voltage . . .
Rload
RTH
VTH

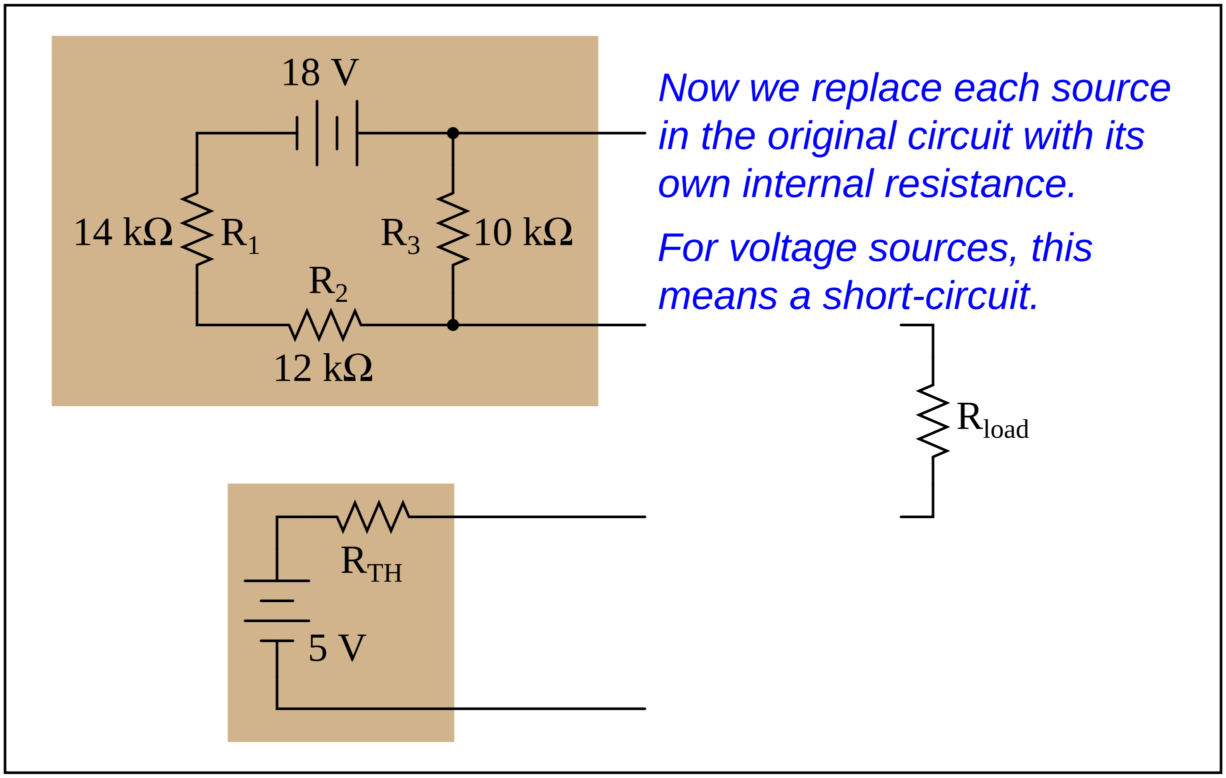


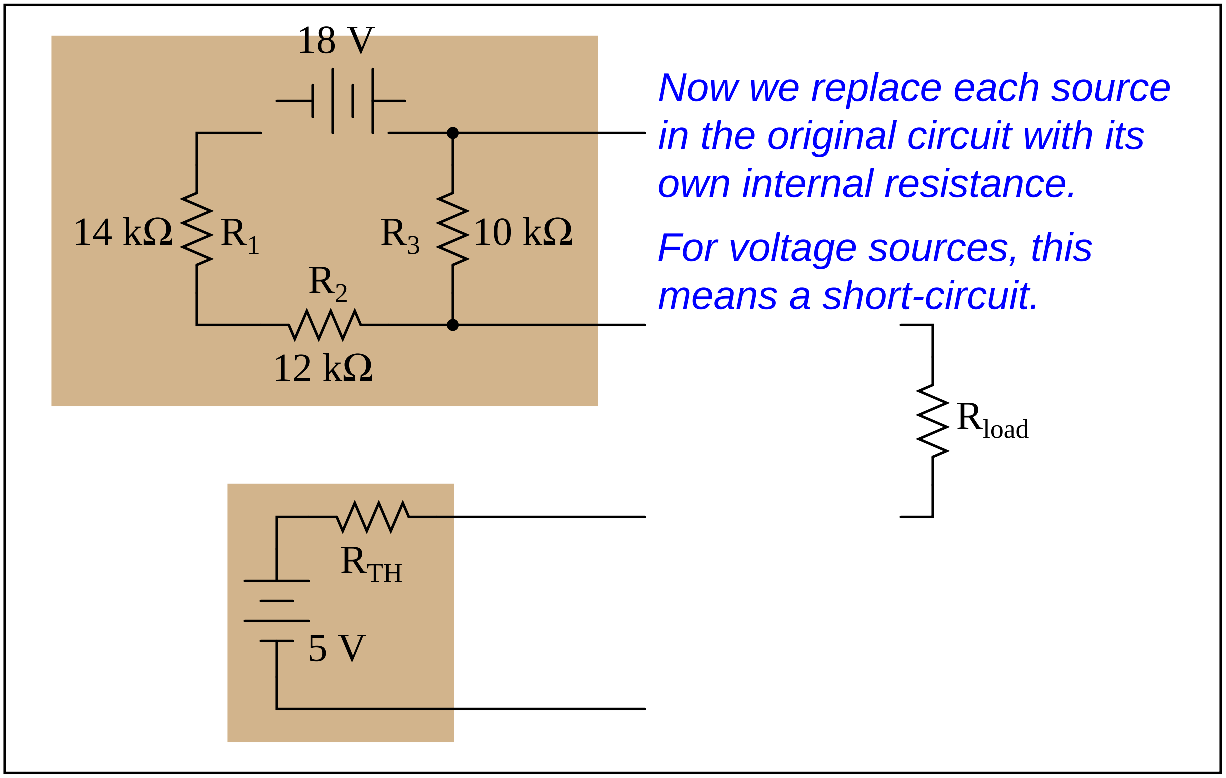
18 V
14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
V
+
-
5 V
This voltage becomes
our Thevenin source
voltage . . .
Rload
RTH
5 V

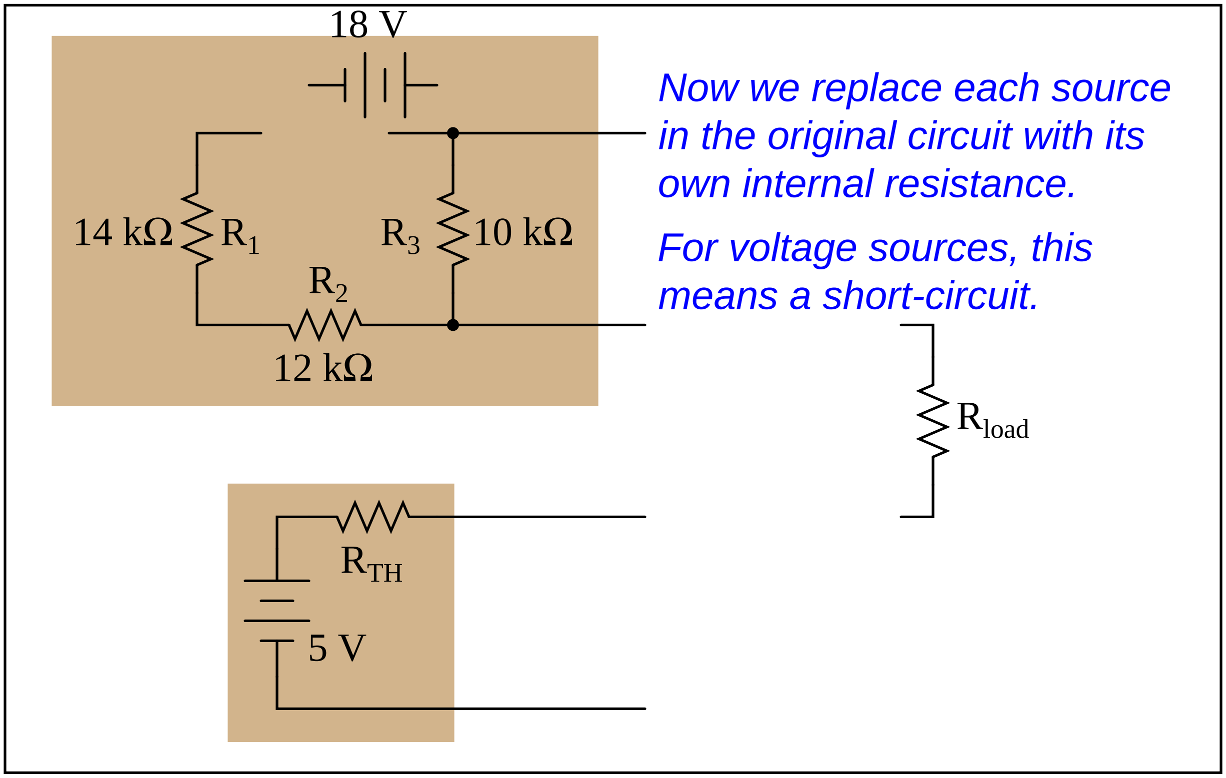

18 V
14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
+
V
5 V
-
This voltage becomes our Thevenin source voltage . . .
Rload
RTH
5 V
. . . in the Thevenin equivalent circuit.

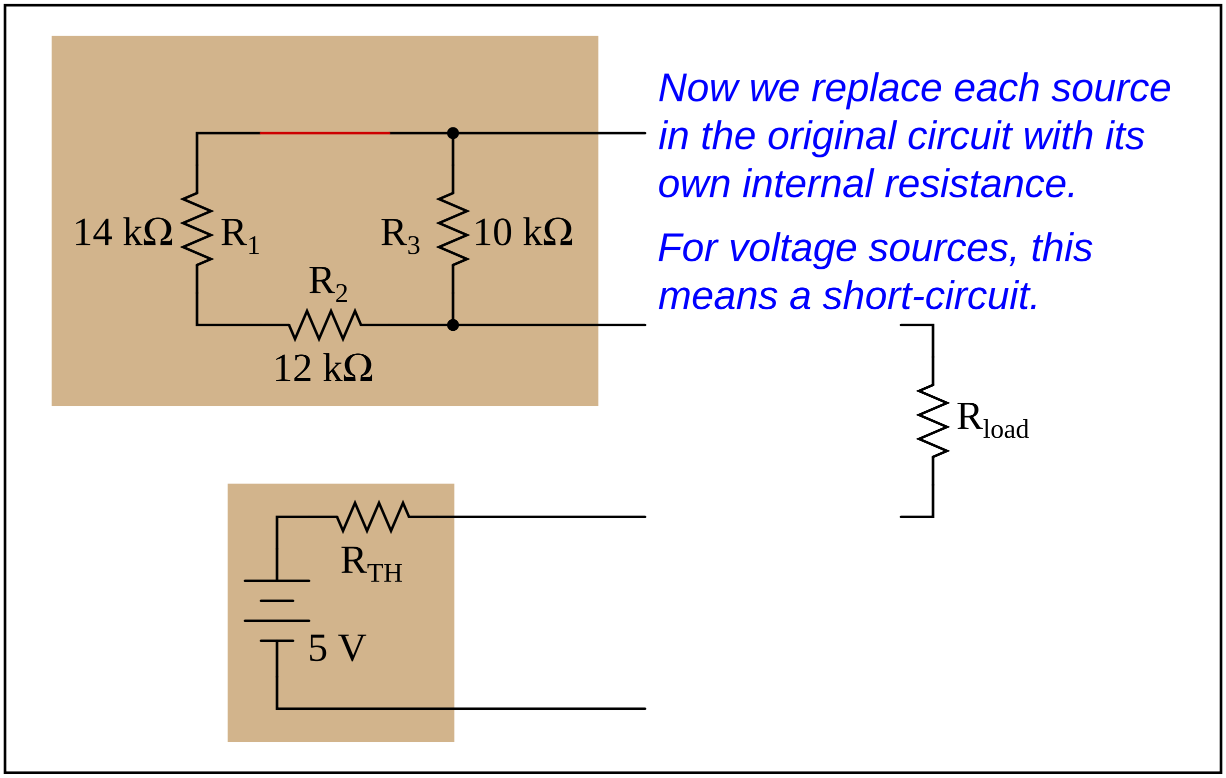

18 V
14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
Rload
RTH
5 V

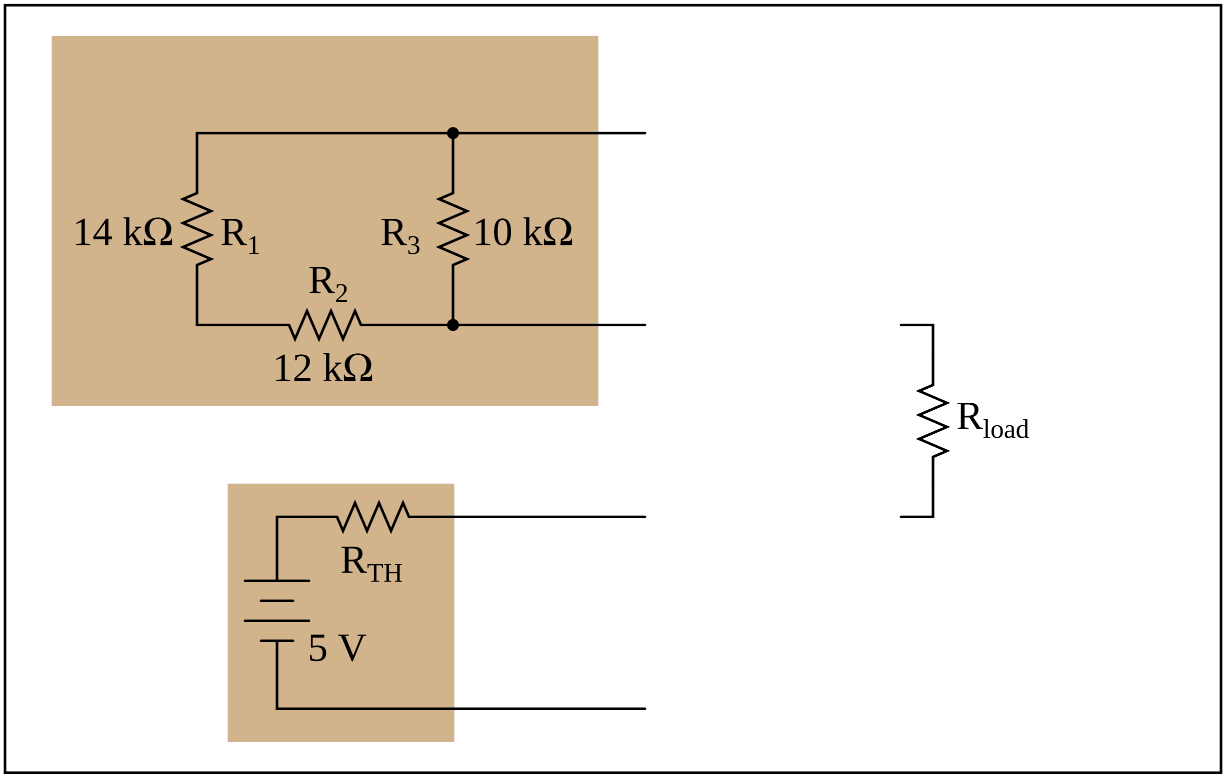

18 V
14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
Now we replace each source in the original circuit with its own internal resistance.
Rload
RTH
5 V

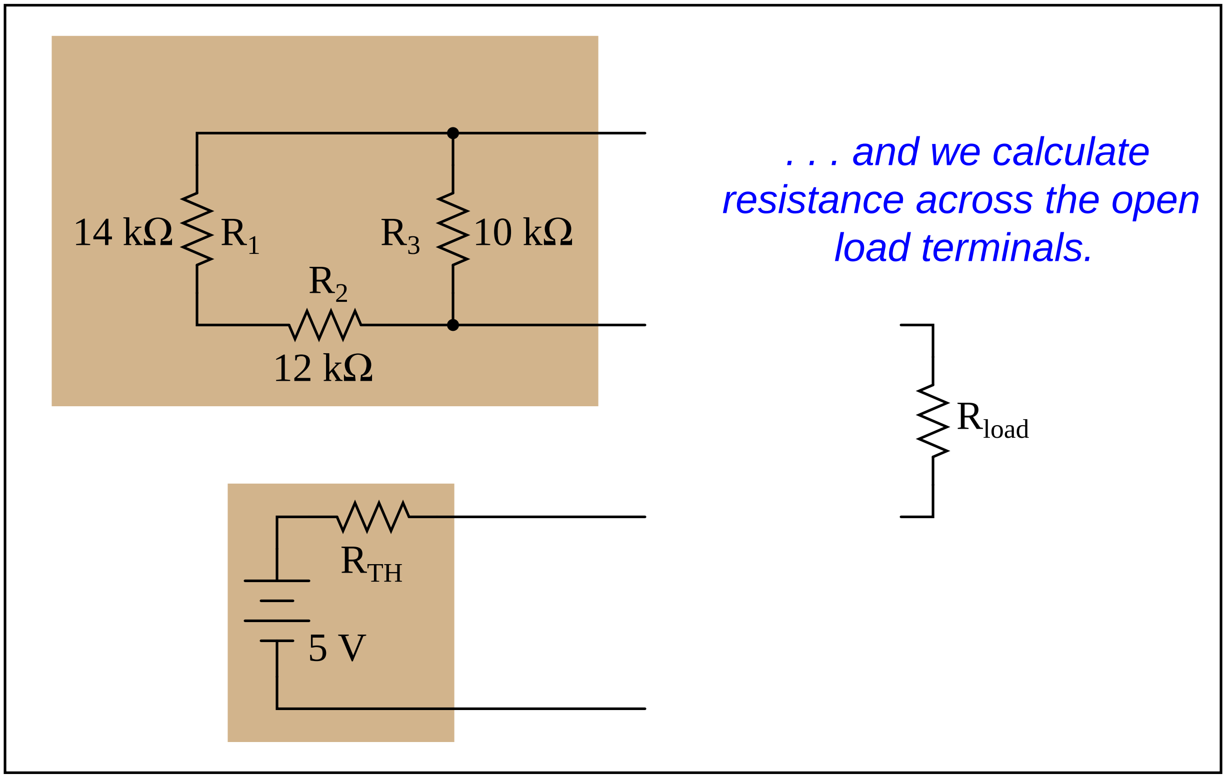

18 V
14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
Now we replace each source in the original circuit with its own internal resistance.
For voltage sources, this means a short-circuit.
Rload
RTH
5 V

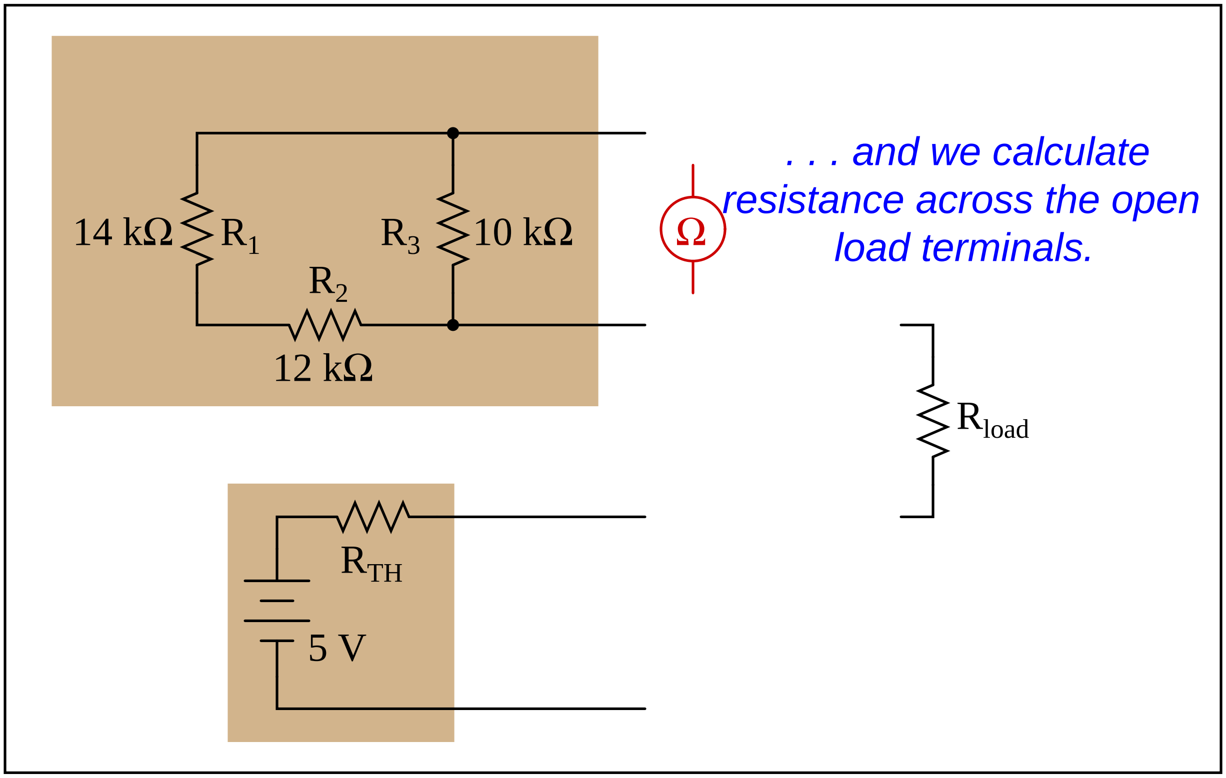

18 V
14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
Now we replace each source in the original circuit with its own internal resistance.
For voltage sources, this means a short-circuit.
Rload
RTH
5 V

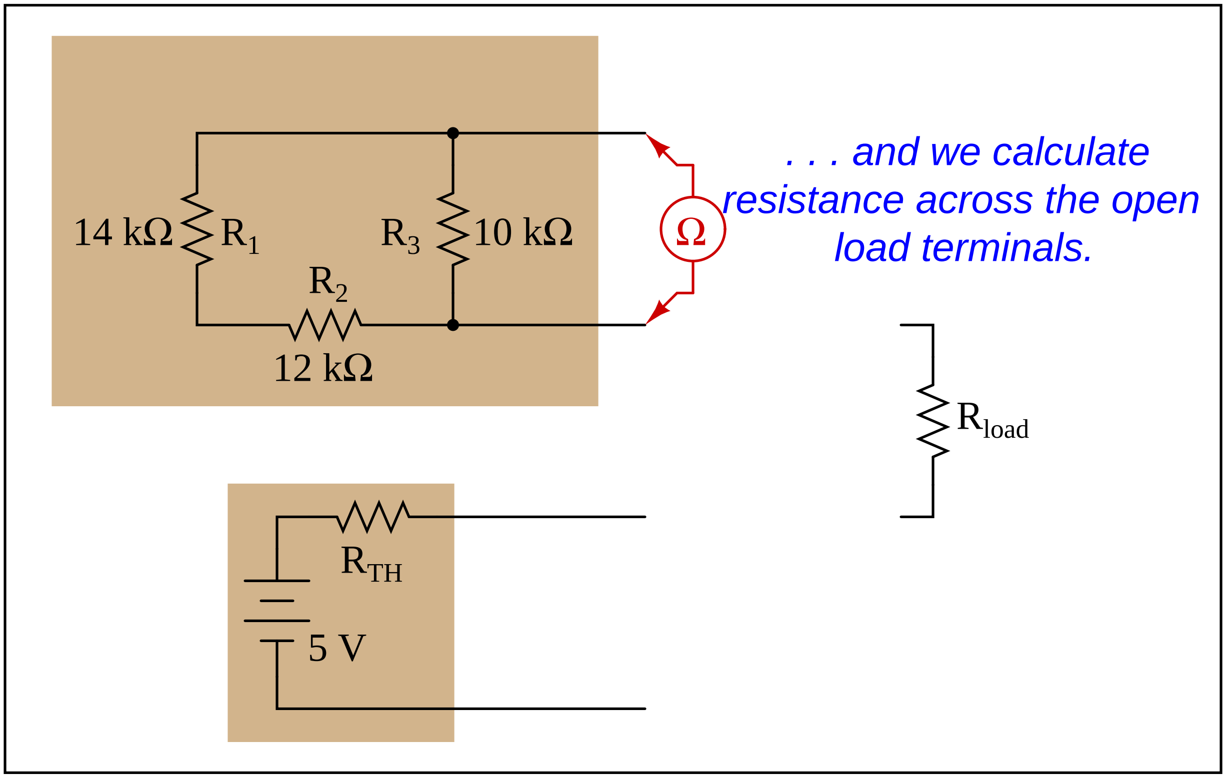

18 V
14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
Now we replace each source in the original circuit with its own internal resistance.
For voltage sources, this means a short-circuit.
Rload
RTH
5 V


Now we replace each source in the original circuit with its own internal resistance.
For voltage sources, this means a short-circuit.
14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
Rload
RTH
5 V

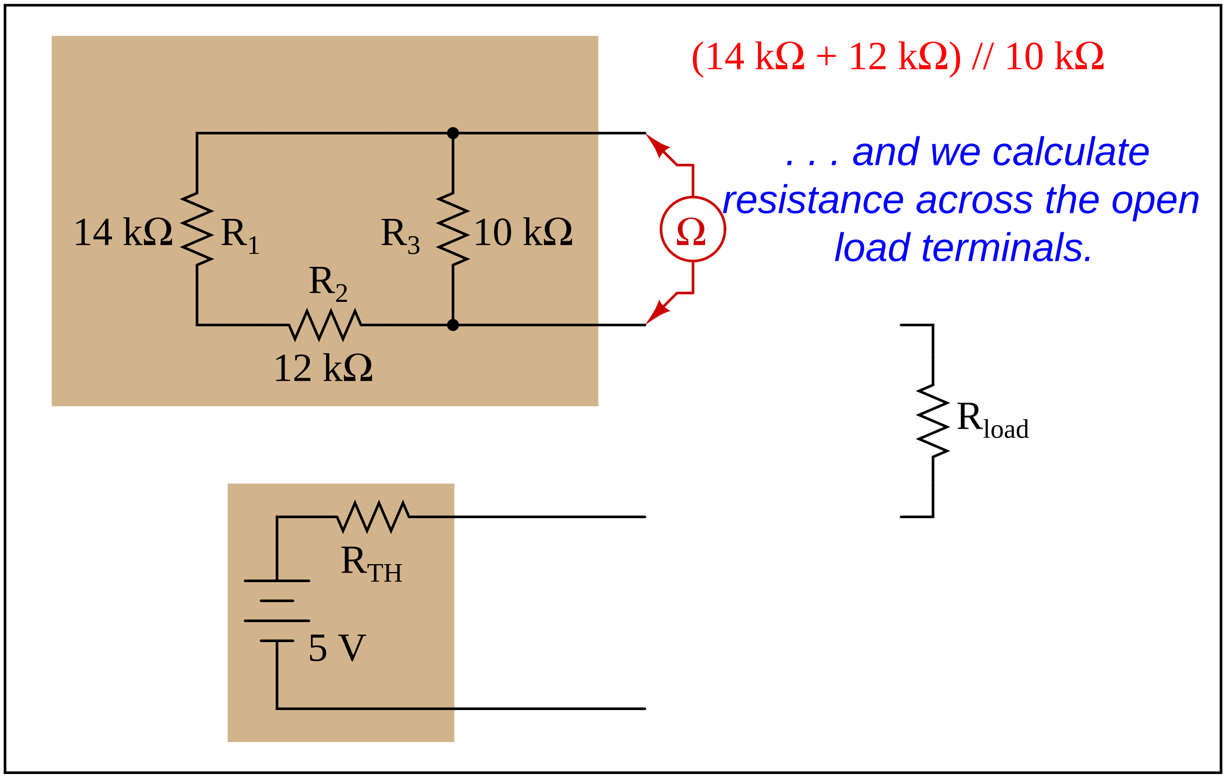

14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
Rload
RTH
5 V

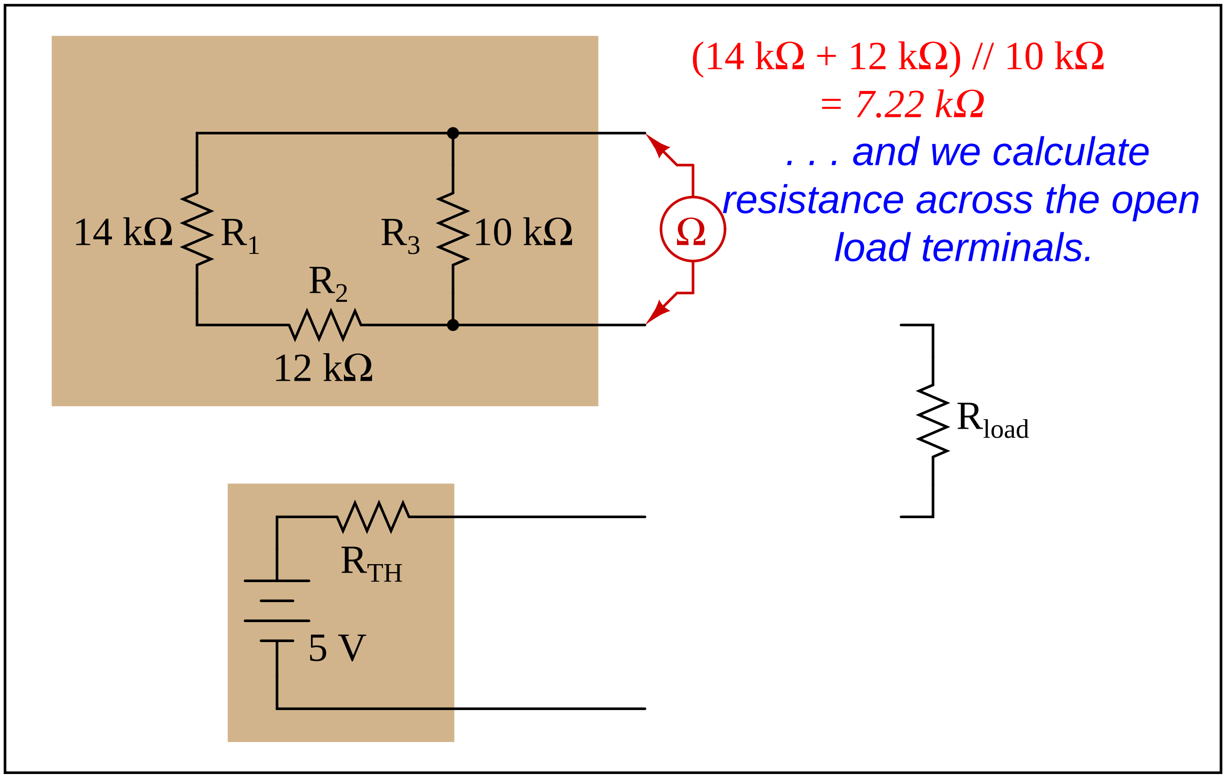

14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
. . . and we calculate resistance across the open load terminals.
Rload
RTH
5 V

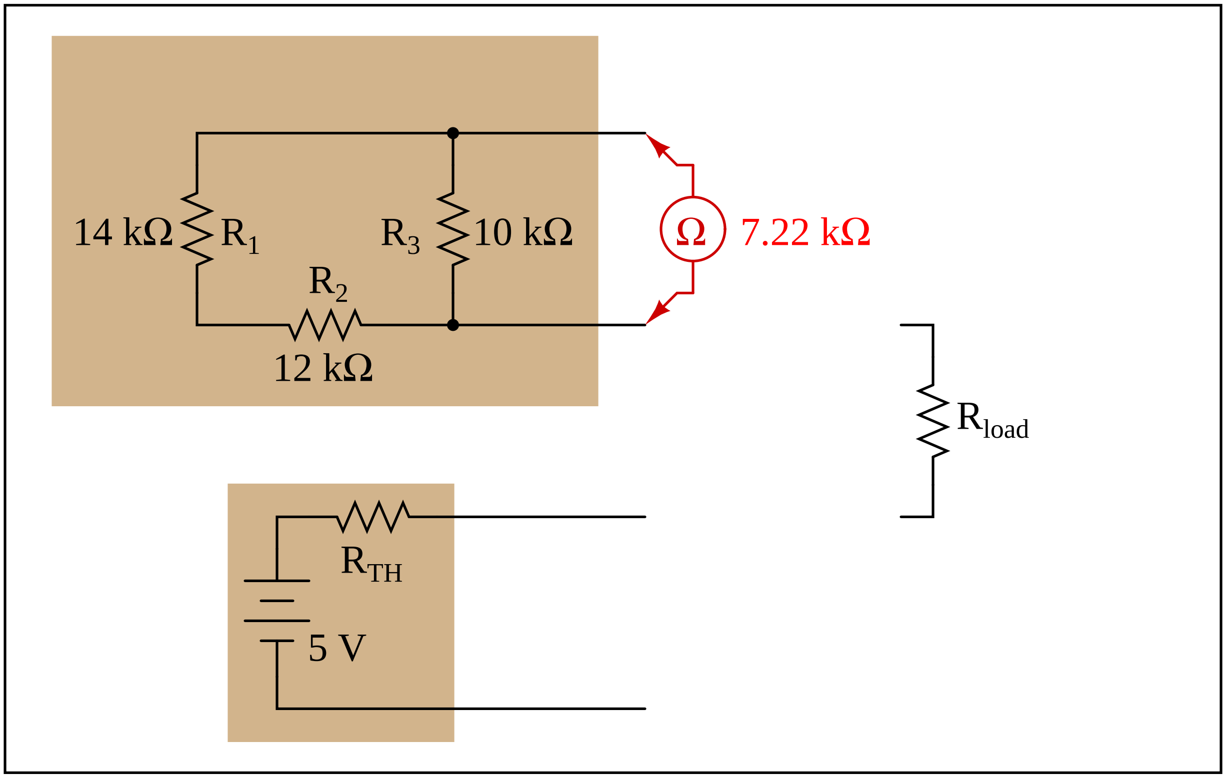

14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
Ω
. . . and we calculate resistance across the open load terminals.
Rload
RTH
5 V

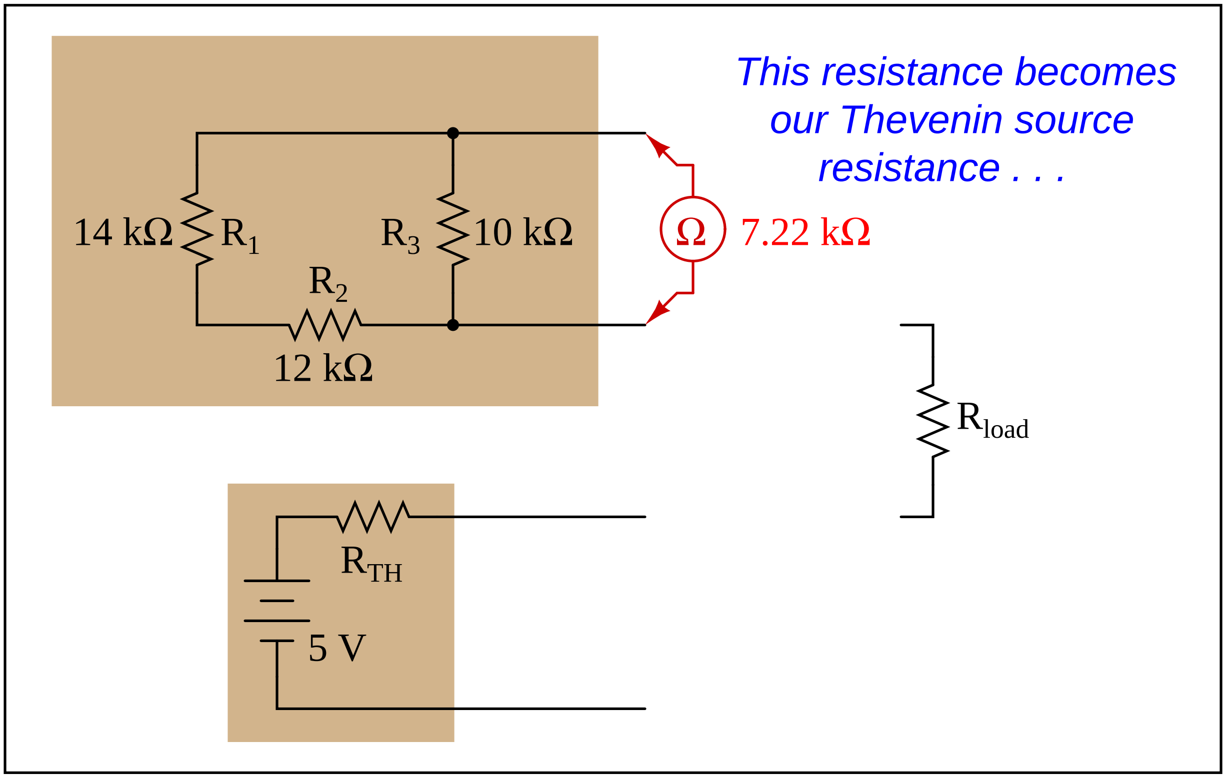


14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
Ω
. . . and we calculate resistance across the open load terminals.
Rload
RTH
5 V

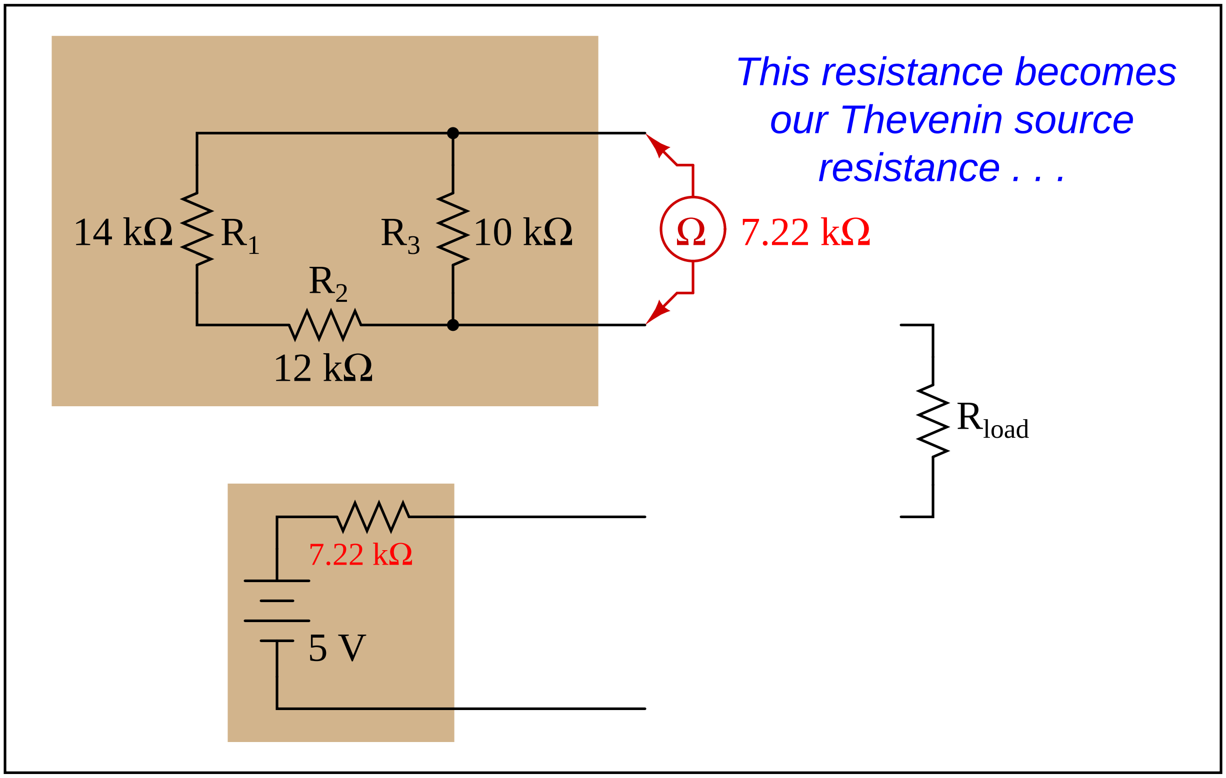

(14 kΩ + 12 kΩ) // 10 kΩ
. . . and we calculate resistance across the open load terminals.
14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
Ω
Rload
RTH
5 V

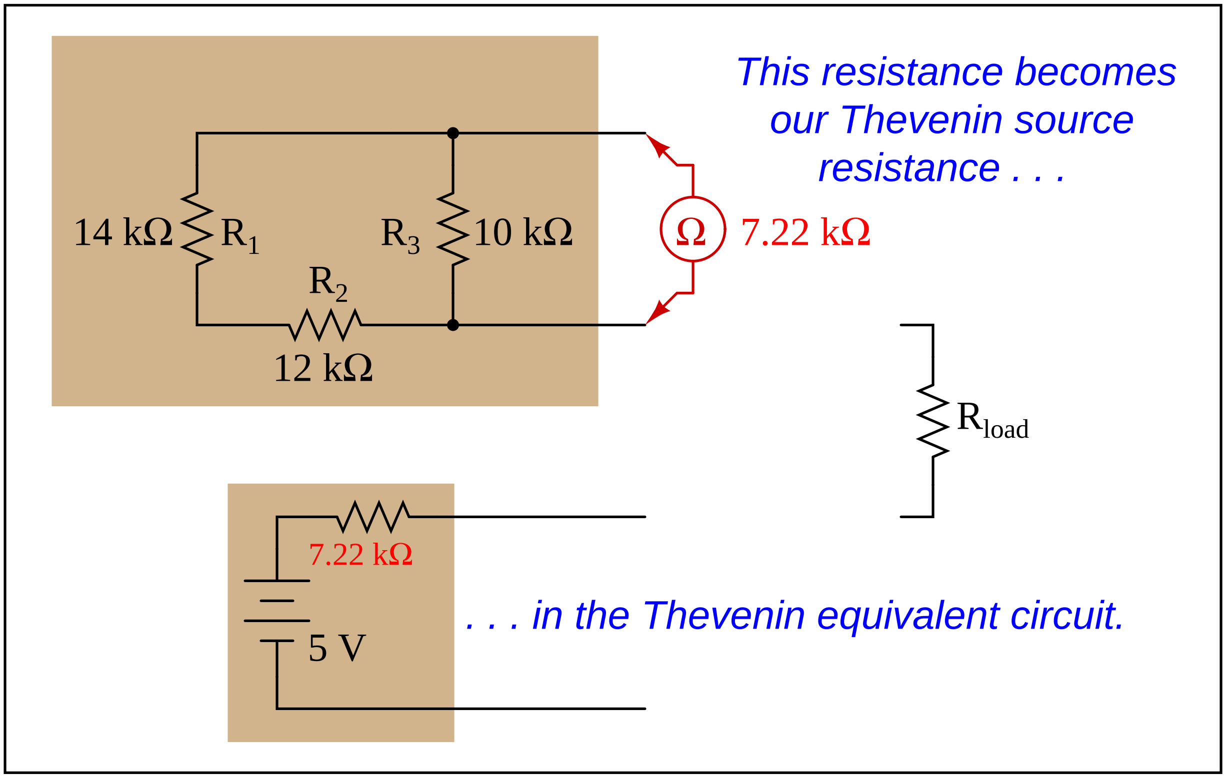

(14 kΩ + 12 kΩ) // 10 kΩ
= 7.22 kΩ
. . . and we calculate resistance across the open load terminals.
14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
Ω
Rload
RTH
5 V

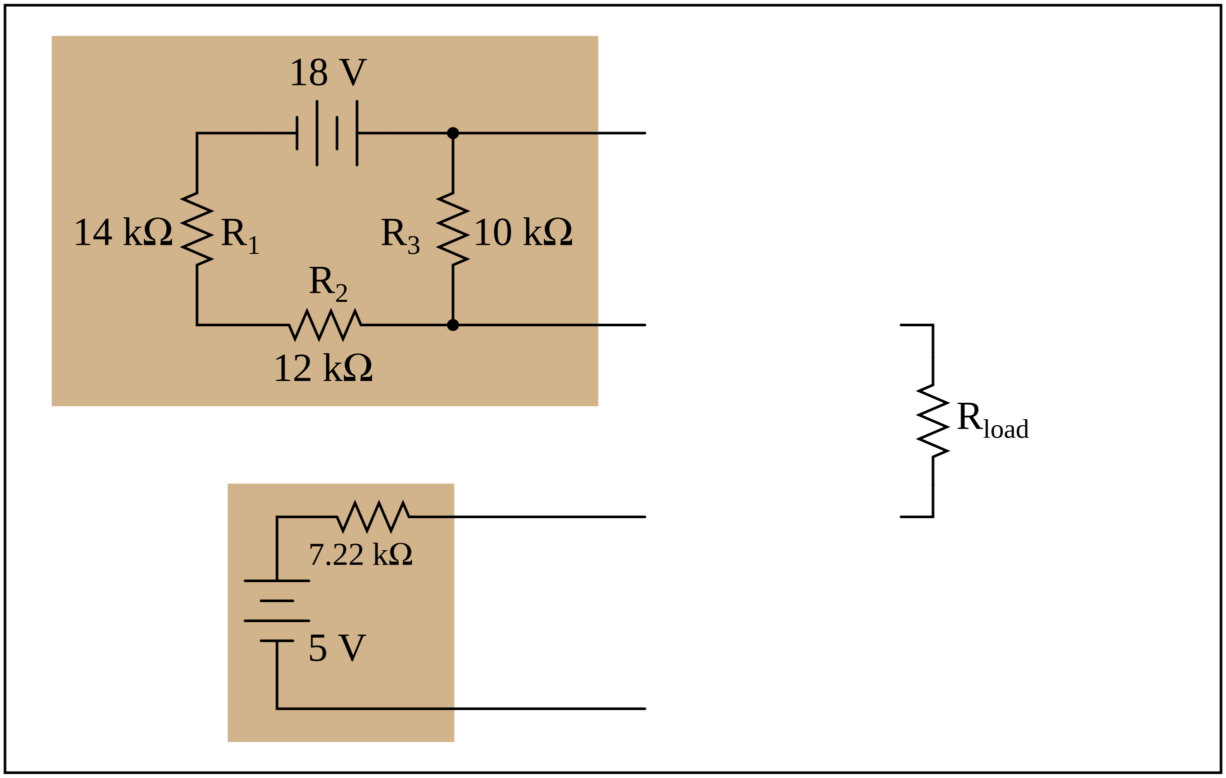

14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
Ω
7.22 kΩ
Rload
RTH
5 V

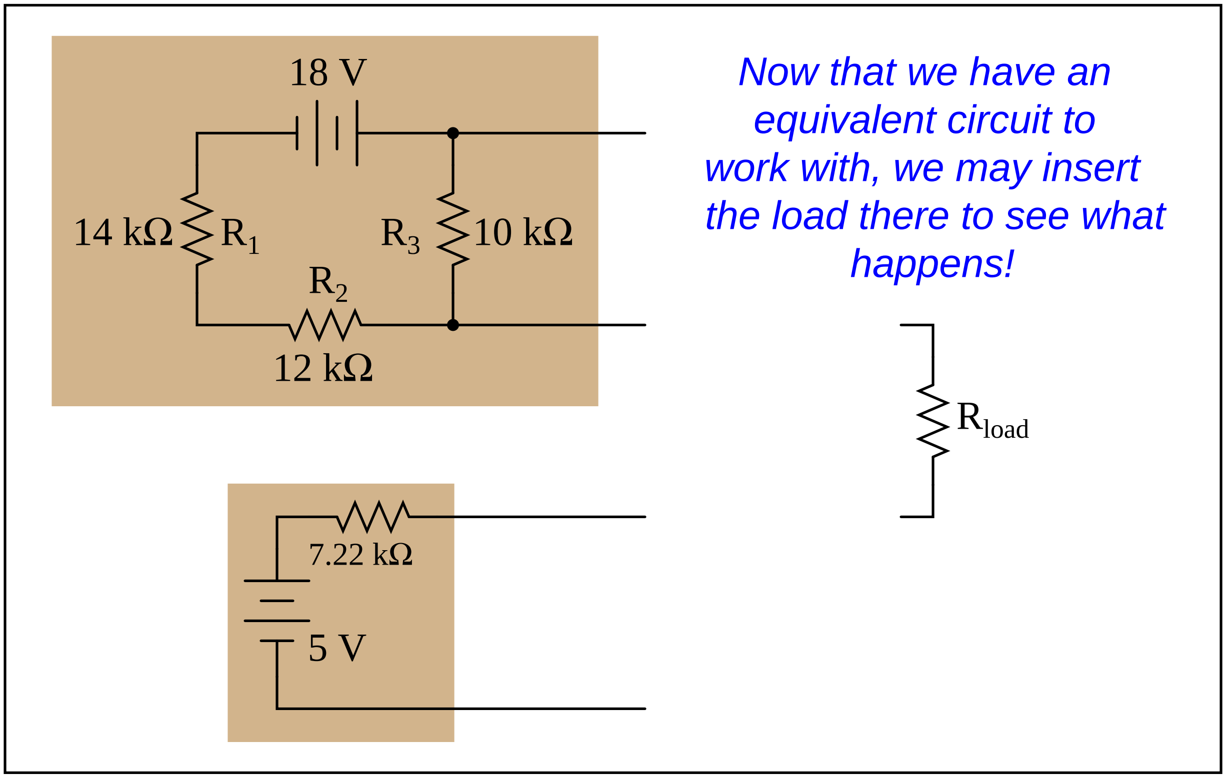


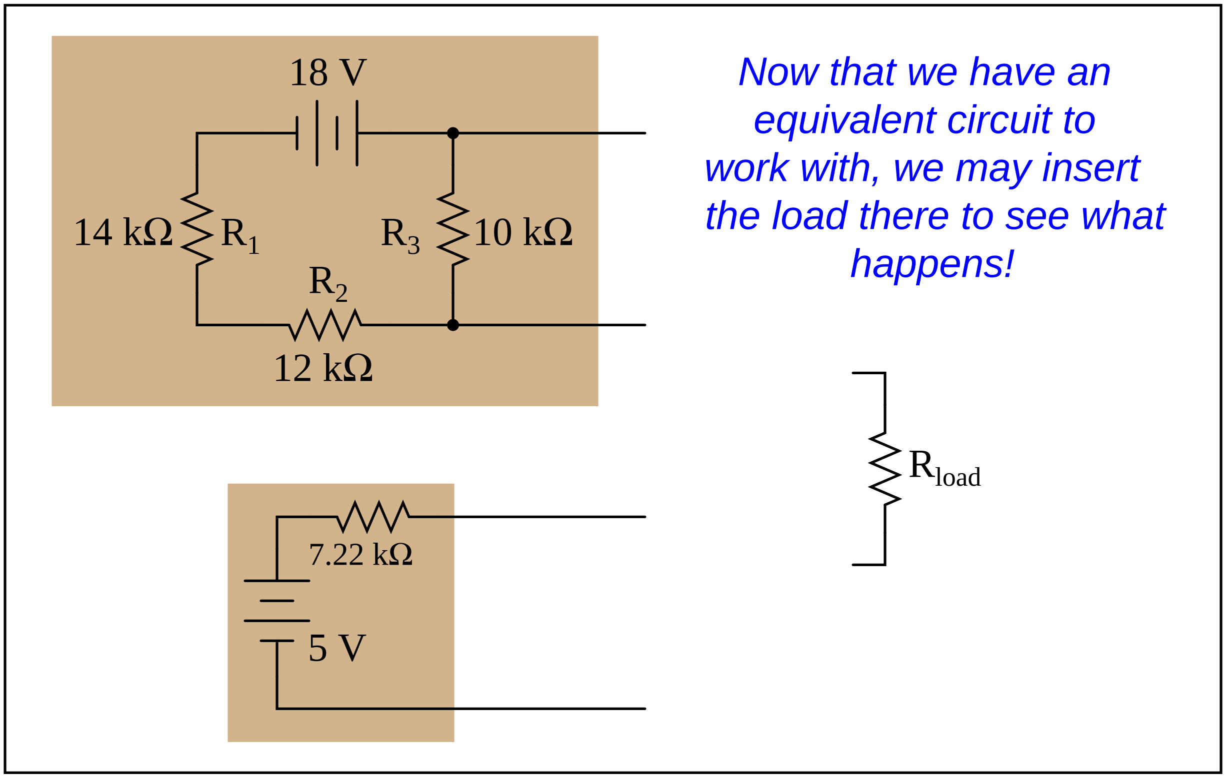
This resistance becomes our Thevenin source resistance . . .
14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
Ω
7.22 kΩ
Rload
RTH
5 V

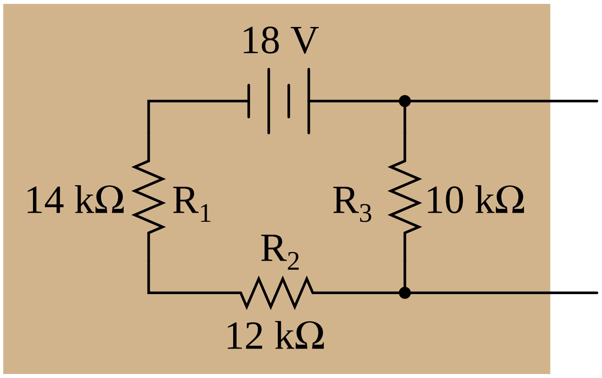

This resistance becomes our Thevenin source resistance . . .
14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
7.22 kΩ
Rload
7.22 kΩ
5 V


This resistance becomes our Thevenin source resistance . . .
14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
Ω
7.22 kΩ
Rload
7.22 kΩ
5 V
. . . in the Thevenin equivalent circuit.

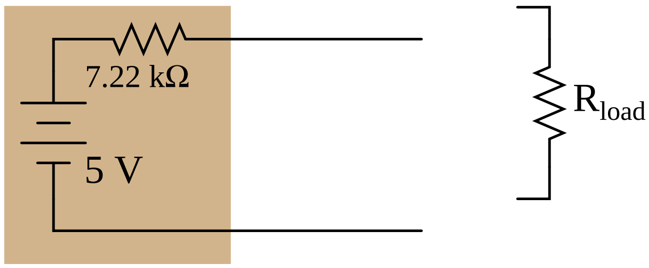

18 V
14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
Rload
7.22 kΩ
5 V

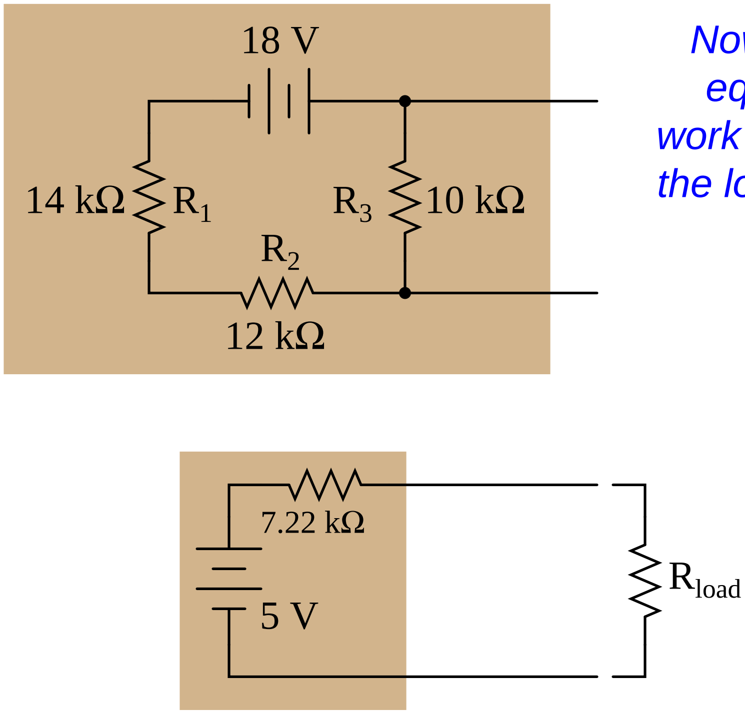

18 V
14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
Now that we have an equivalent circuit to work with, we may insert the load there to see what happens!
Rload
7.22 kΩ
5 V


18 V
14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
7.22 kΩ
5 V
Now that we have an equivalent circuit to work with, we may insert the load there to see what happens!
Rload

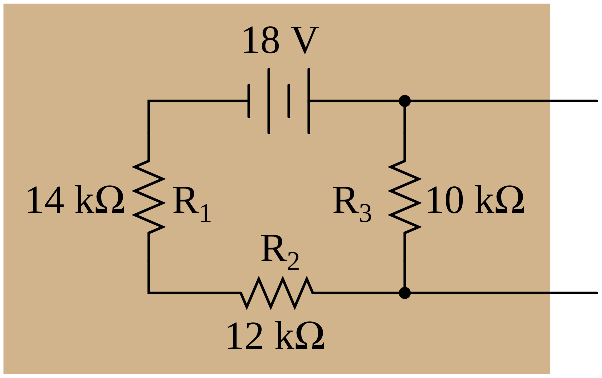


Now that we have an equivalent circuit to work with, we may insert the load there to see what happens!

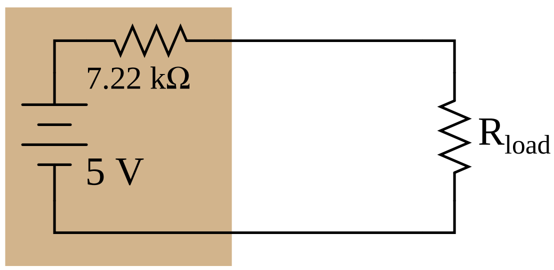


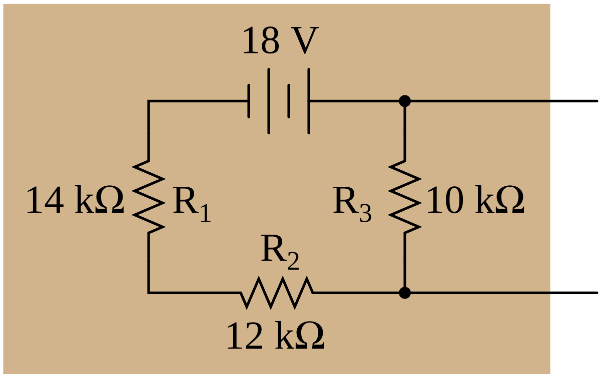


Now that we have an equivalent circuit to work with, we may insert the load there to see what happens!

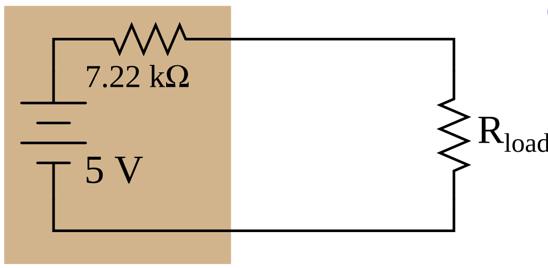


Now that we have an equivalent circuit to work with, we may insert the load there to see what happens!

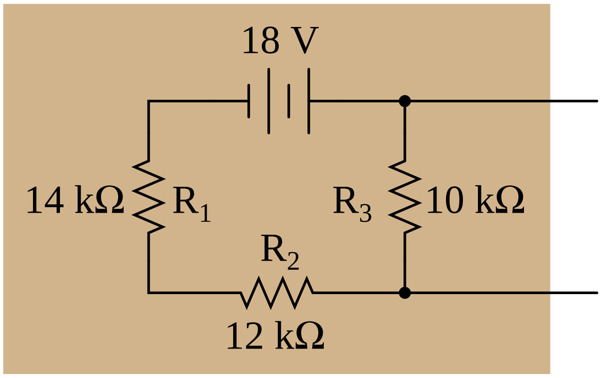




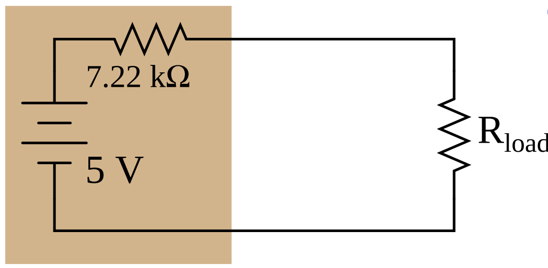
Now that we have an equivalent circuit to work with, we may insert the load there to see what happens!



Calculate:

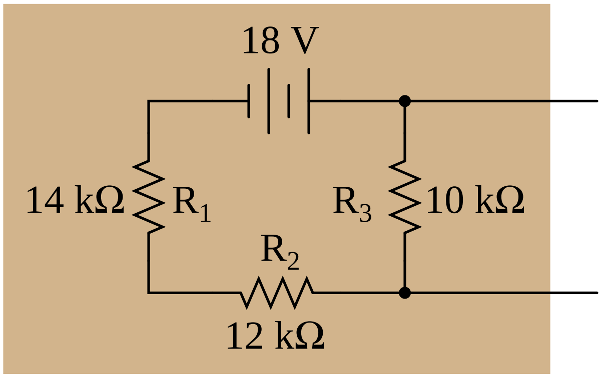


Now that we have an equivalent circuit to work with, we may insert the load there to see what happens!

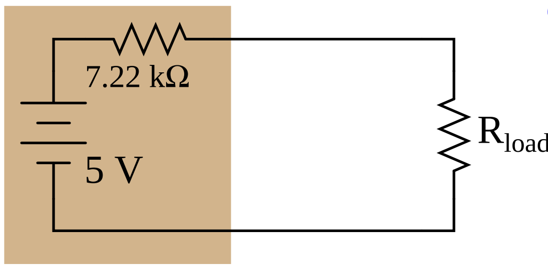


Calculate:

V_{load}



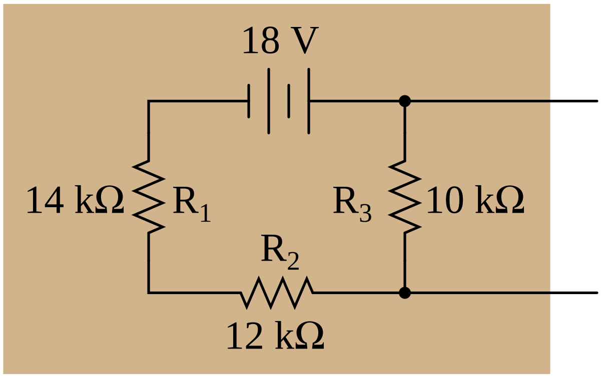
Now that we have an equivalent circuit to work with, we may insert the load there to see what happens!



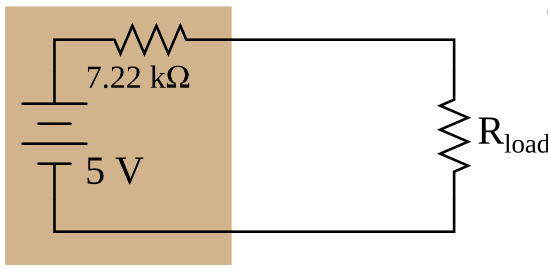
Calculate:

V_{load}

I_{load}



Now that we have an equivalent circuit to work with, we may insert the load there to see what happens!

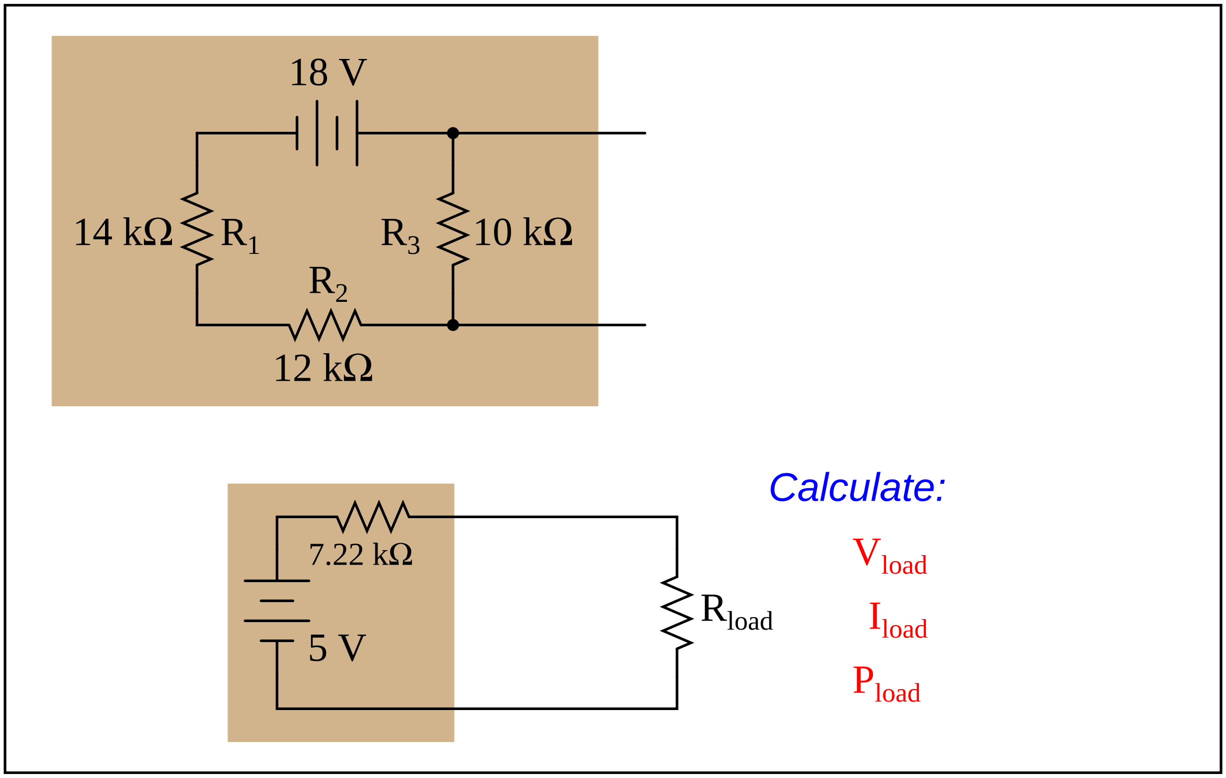


Calculate:

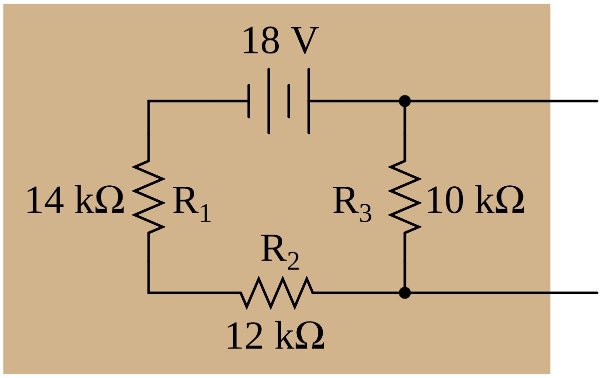
V_{load}

I_{load}

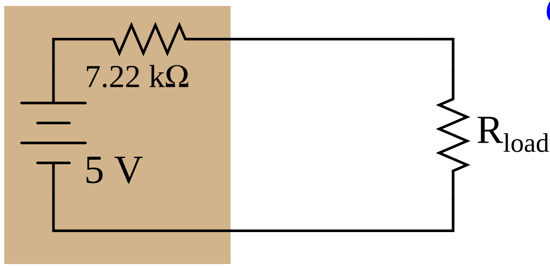
P_{load}



18 V
14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
7.22 kΩ
5 V
Rload
Calculate:
Vload
Iload
Pload



These load calculations will reflect what happens in the original circuit!

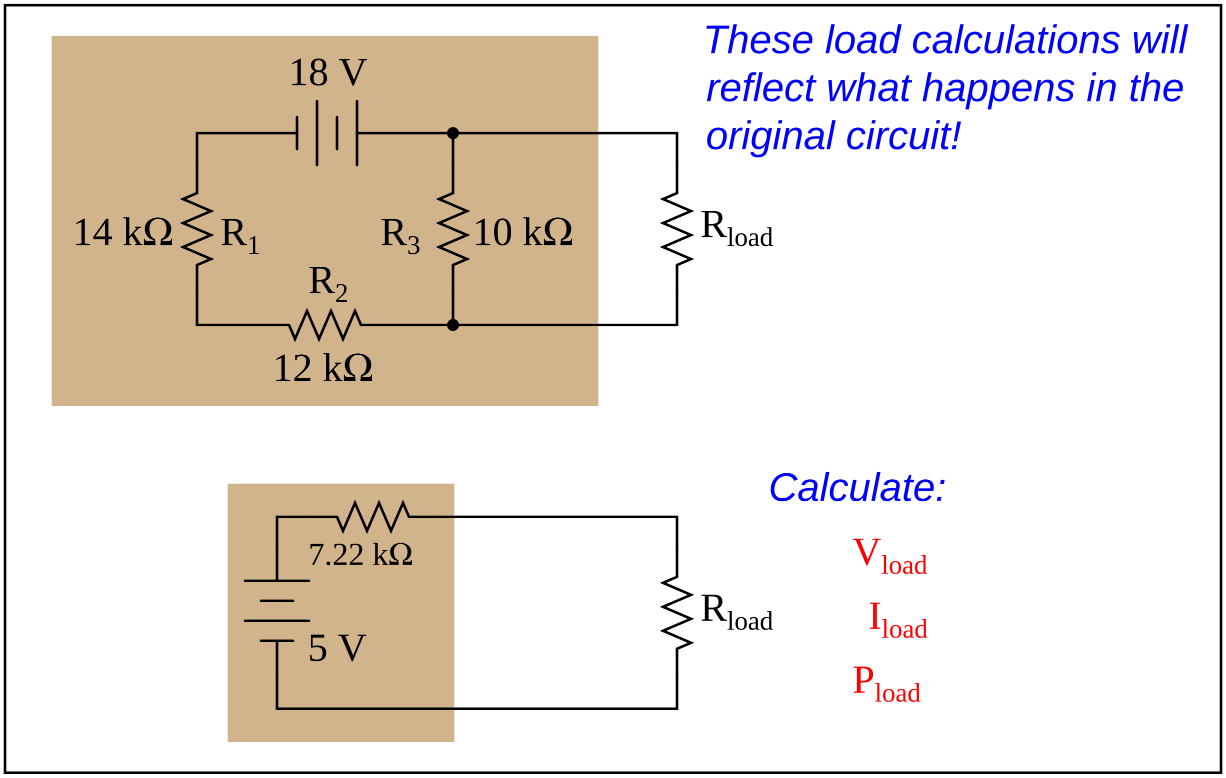


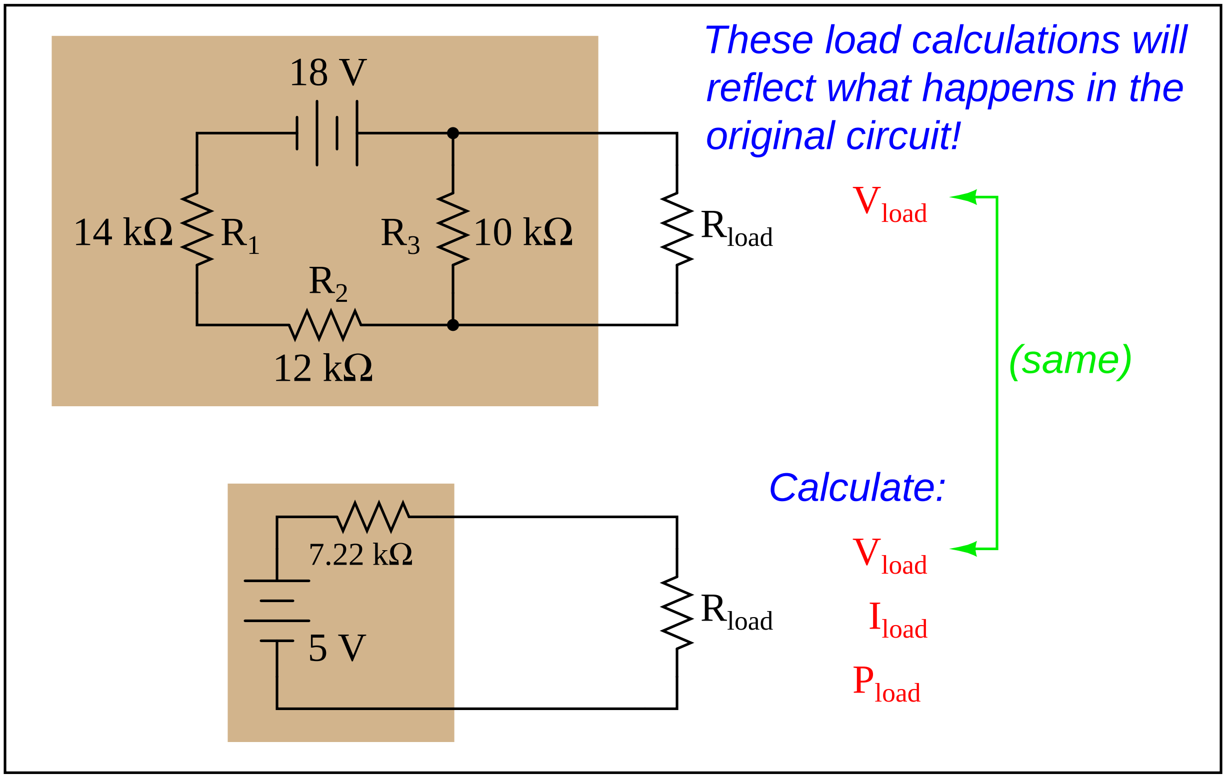
Calculate:

V_{load}

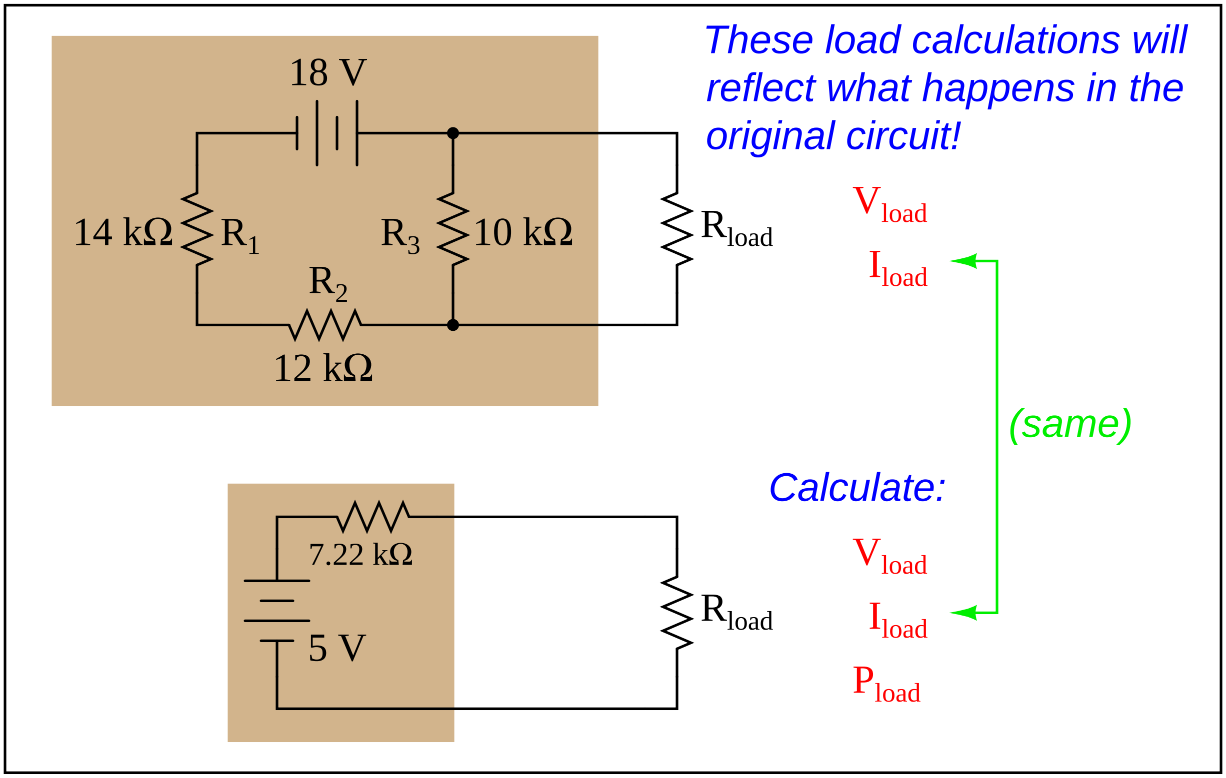
I_{load}

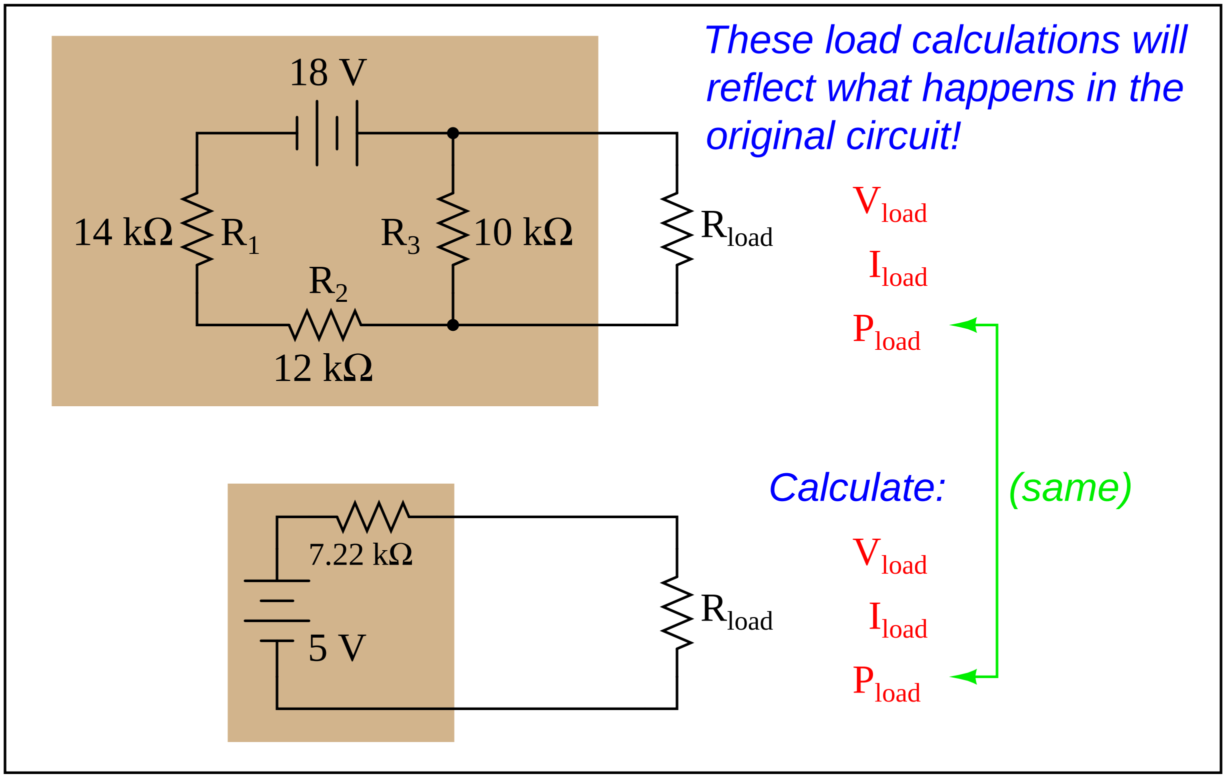
P_{load}


These load calculations will reflect what happens in the original circuit!
18 V
14 kΩ
R1
R3
10 kΩ
Rload
R2
12 kΩ
Calculate:
7.22 kΩ
Vload
5 V
Rload
Iload
Pload

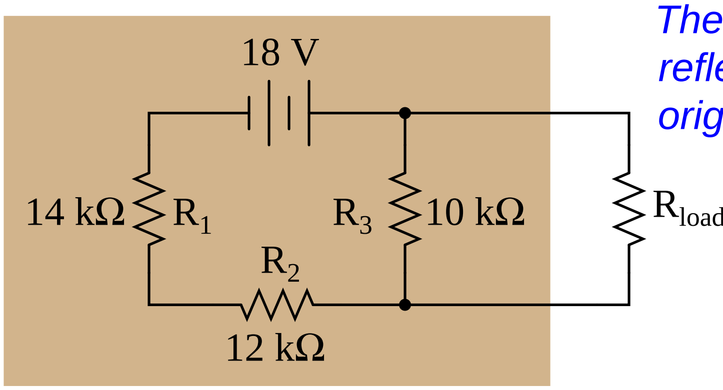


18 V
14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
Rload
These load calculations will reflect what happens in the original circuit!
Vload
(same)
Calculate:
7.22 kΩ
5 V
Rload
Vload
Iload
Pload


These load calculations will reflect what happens in the original circuit!
18 V
14 kΩ
R1
R2
R3
10 kΩ
12 kΩ
Rload
Vload
Iload
(same)
Calculate:
7.22 kΩ
5 V
Rload
Vload
Iload
Pload



18 V
14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
Rload
These load calculations will reflect what happens in the original circuit!
Vload
Iload
Pload
Calculate:
(same)
7.22 kΩ
5 V
Rload
Vload
Iload
Pload

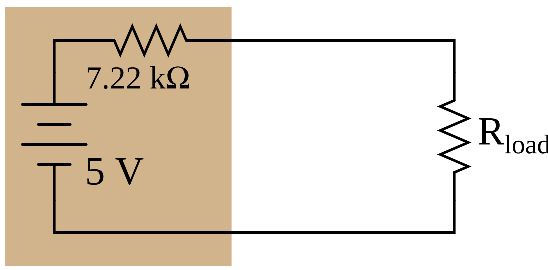


These load calculations will reflect what happens in the original circuit!

V_{load}

I_{load}

P_{load}

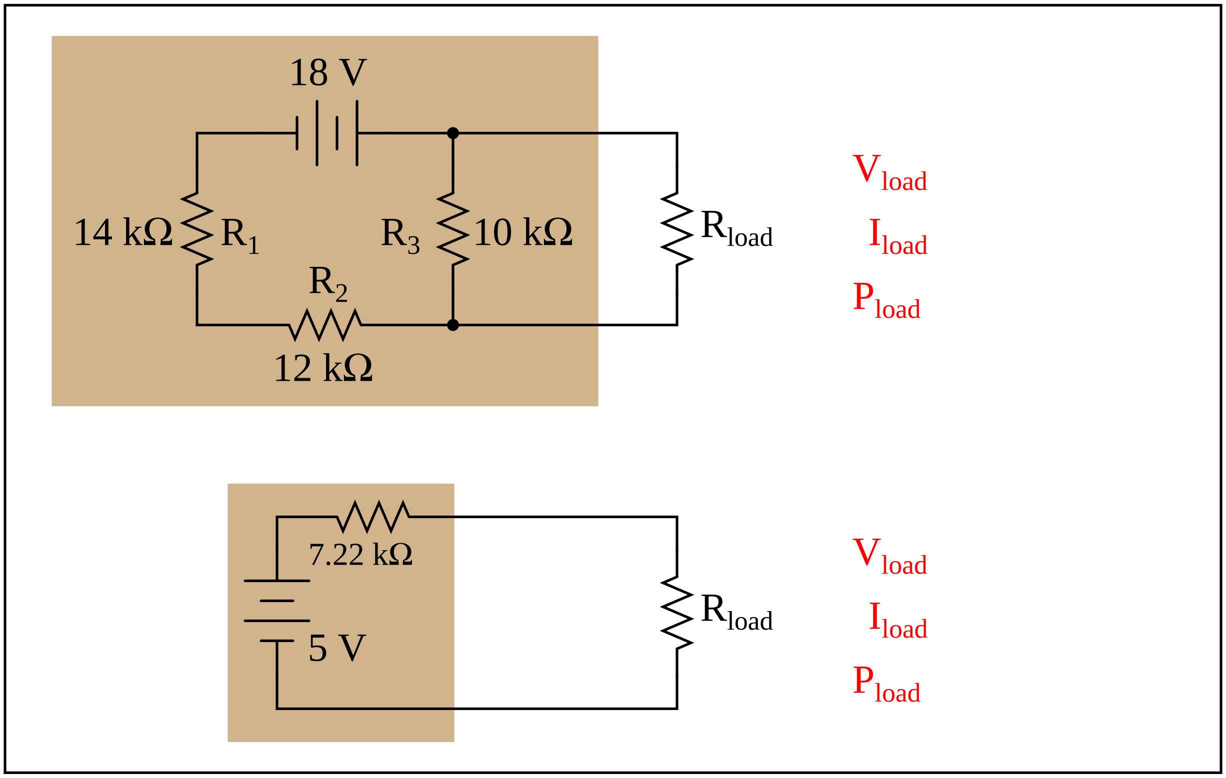


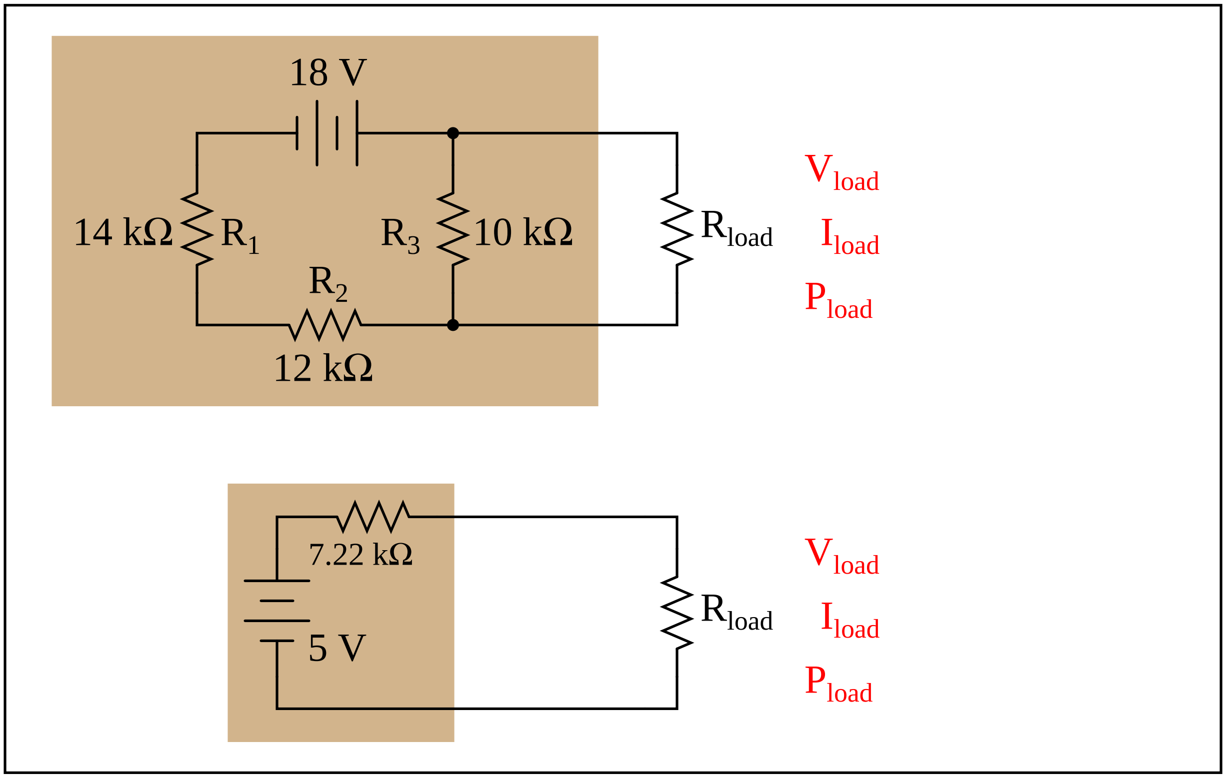
Calculate:

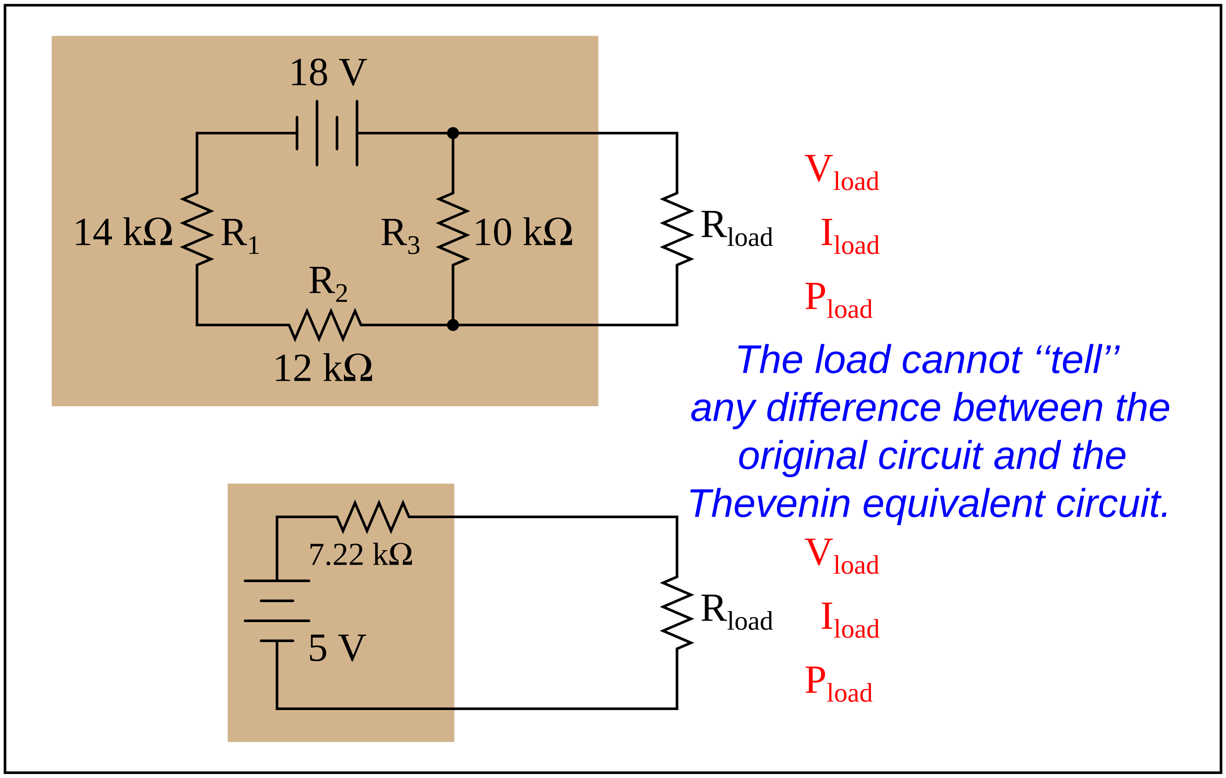
V_{load}

I_{load}

P_{load}


18 V
14 kΩ
R1
R3
10 kΩ
Rload
R2
12 kΩ
Vload
Iload
Pload
7.22 kΩ
5 V
Rload
Vload
Iload
Pload


18 V
14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
Rload
Vload
Iload
Pload
7.22 kΩ
5 V
Rload
Vload
Iload
Pload



18 V
14 kΩ
R1
R3
10 kΩ
R2
12 kΩ
Rload
Vload
Iload
Pload
The load cannot "tell"
any difference between the
original circuit and the
Thevenin equivalent circuit.
7.22 kΩ
5 V
Rload
Vload
Iload
Pload

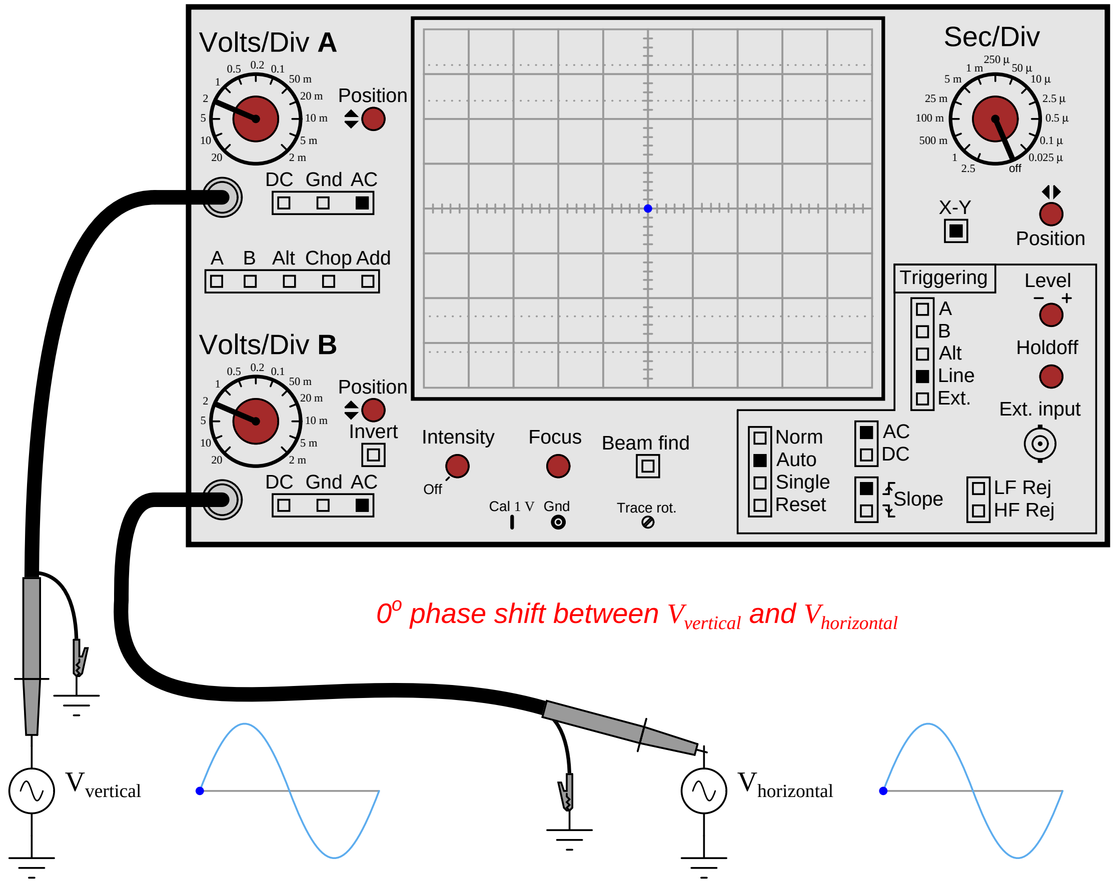
file 03261

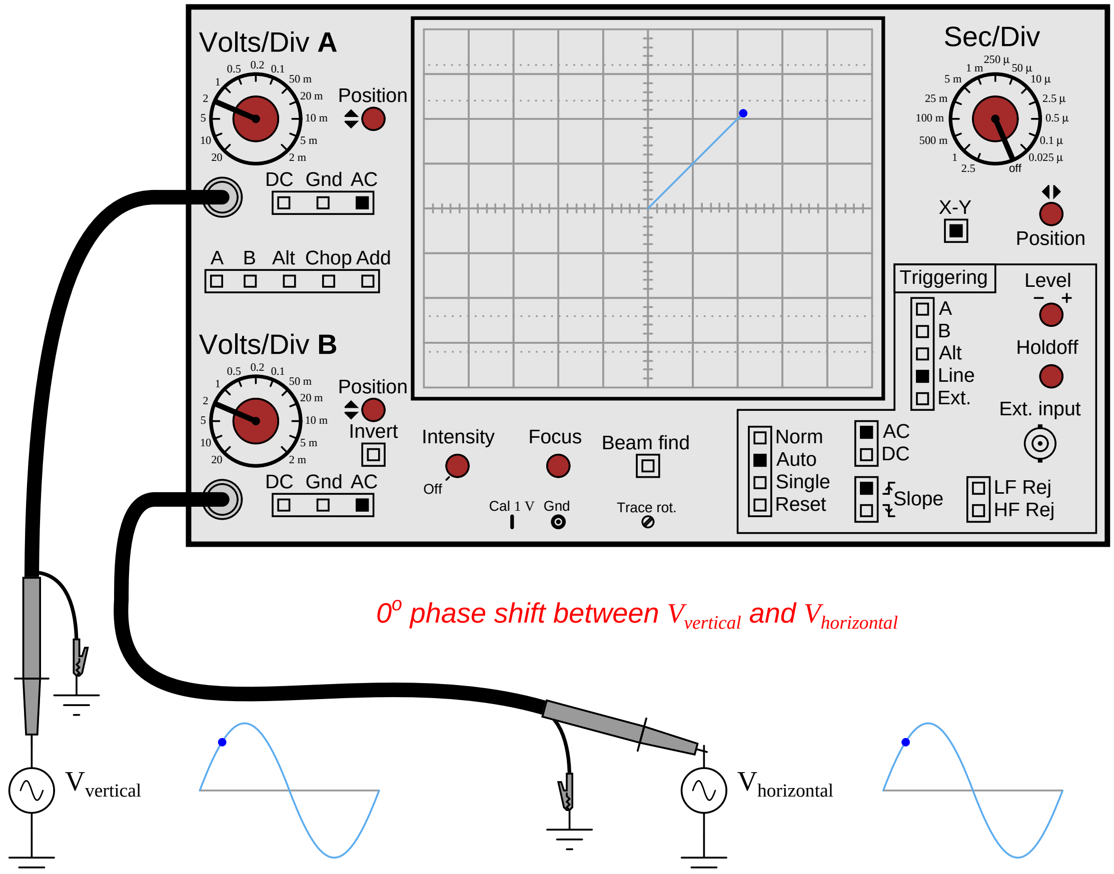
Question 4

Animation: Lissajous figures on an oscilloscope with 0 degrees phase shift

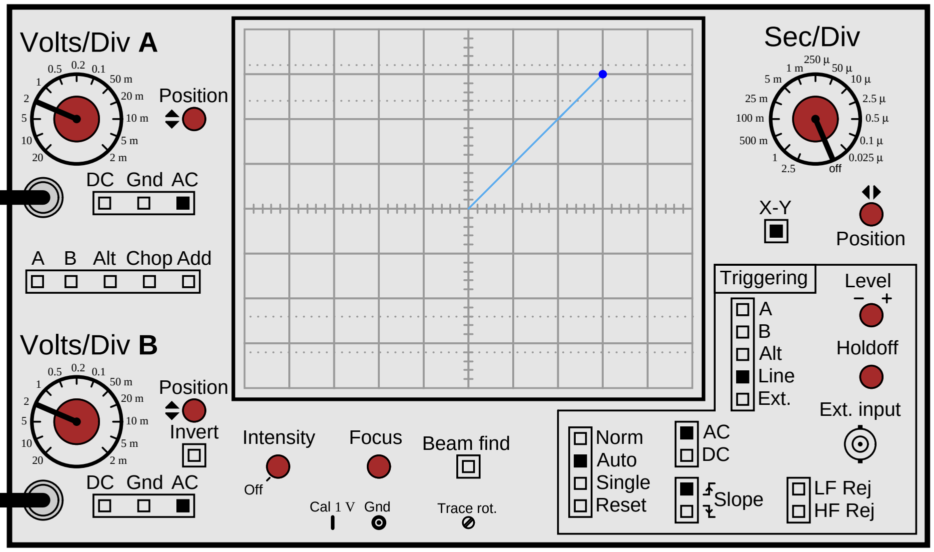
This question consists of a series of images (one per page) that form an animation. Flip the pages with your fingers to view this animation (or click on the "next" button on your viewer) frame-by-frame.

The following animation shows how two sinusoidal voltages with 0 degrees phase shift between them can draw a Lissajous figure on the screen of an oscilloscope.

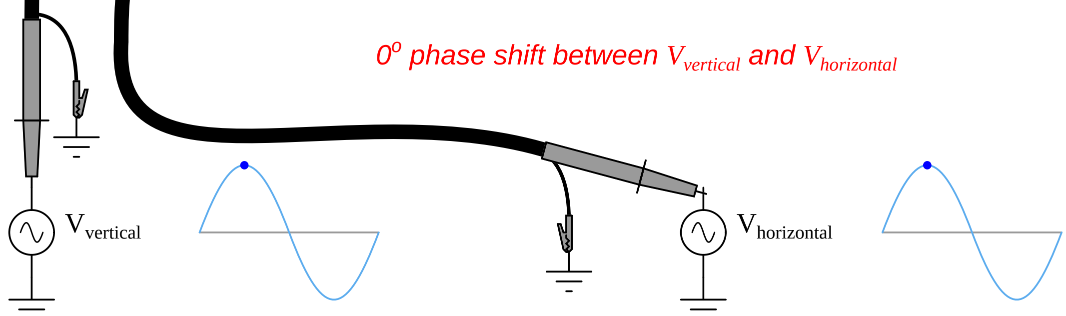

Volts/Div A
Position
DC Gnd AC
A B Alt Chop Add
Volts/Div B
Position
Invert
DC Gnd AC
Intensity
Off
Focus
Beam find
Cal 1 V Gnd
Trace rot.
Sec/Div
X-Y
Position
Triggering
A
B
Alt
Line
Ext.
Level
Holdoff
Ext. input
Norm
Auto
Single
Reset
AC
DC
Slope
LF Rej
HF Rej
0° phase shift between $V_{vertical}$ and $V_{horizontal}$
$V_{vertical}$
$V_{horizontal}$

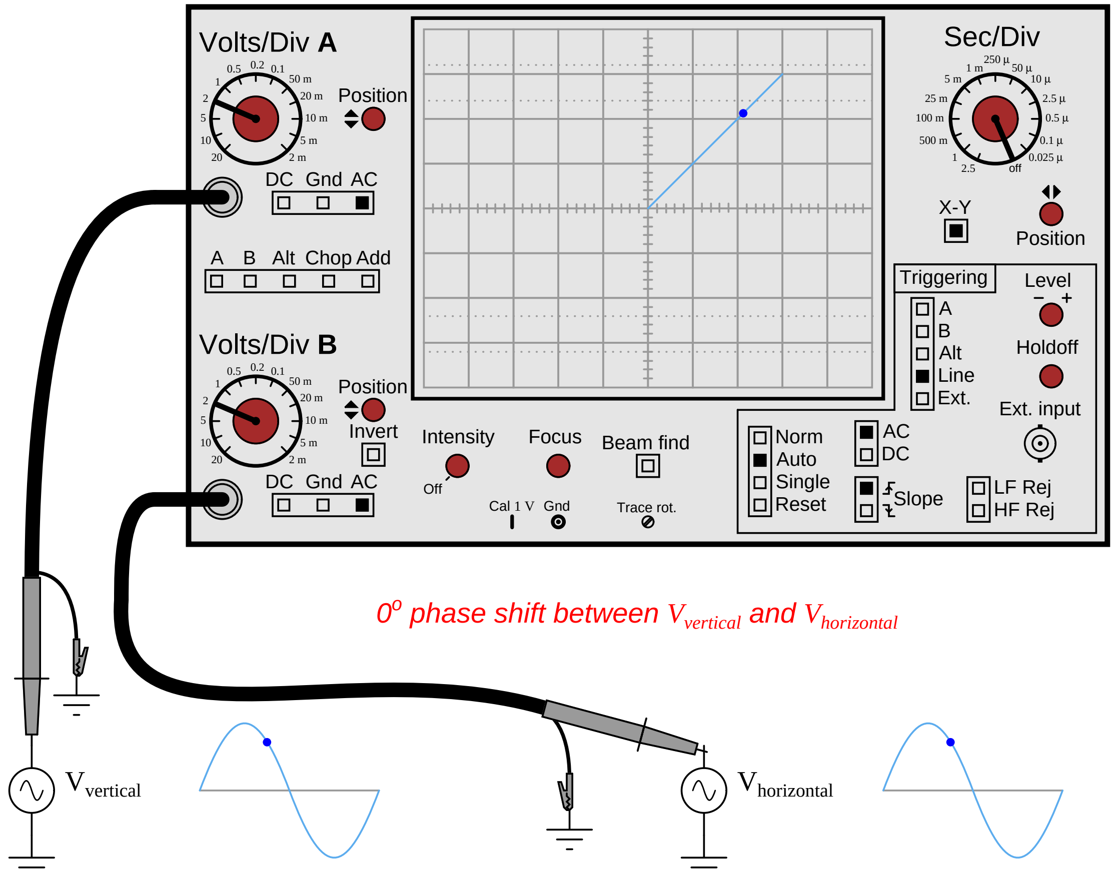


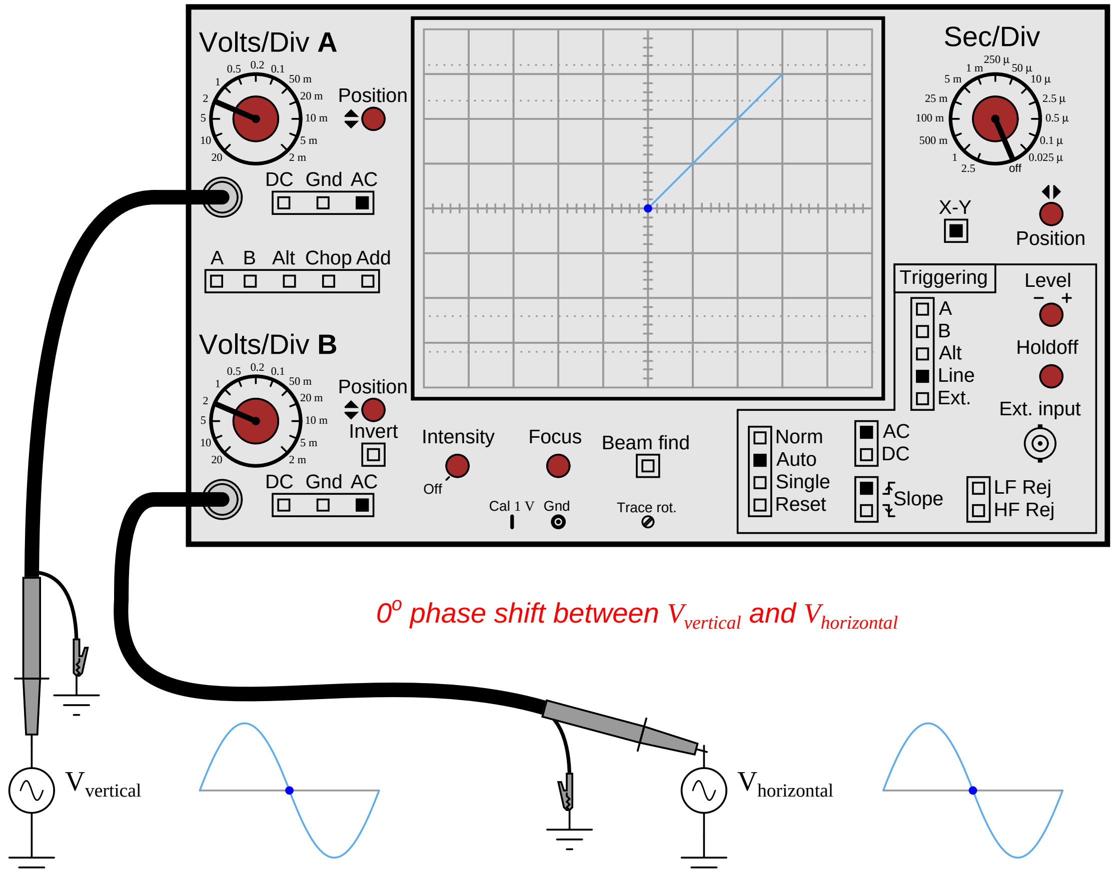
Volts/Div A
Position
DC Gnd AC
A B Alt Chop Add
Volts/Div B
Position
Invert
DC Gnd AC
Intensity
Off
Focus
Beam find
Cal 1 V
Gnd
Trace rot.
Sec/Div
X-Y
Position
Triggering
A
B
Alt
Line
Ext.
Level
Holdoff
Ext. input
Norm
Auto
Single
Reset
AC
DC
Slope
LF Rej
HF Rej
0° phase shift between $V_{vertical}$ and $V_{horizontal}$
$V_{vertical}$
$V_{horizontal}$

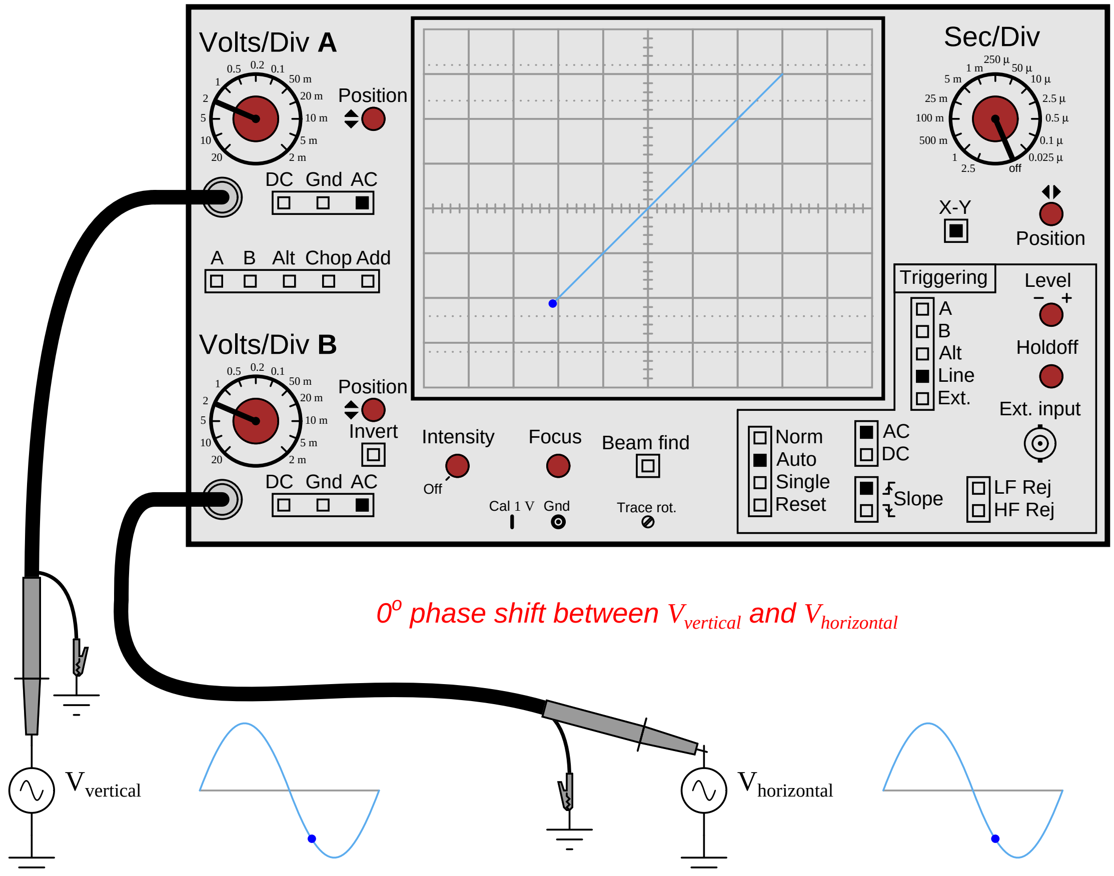


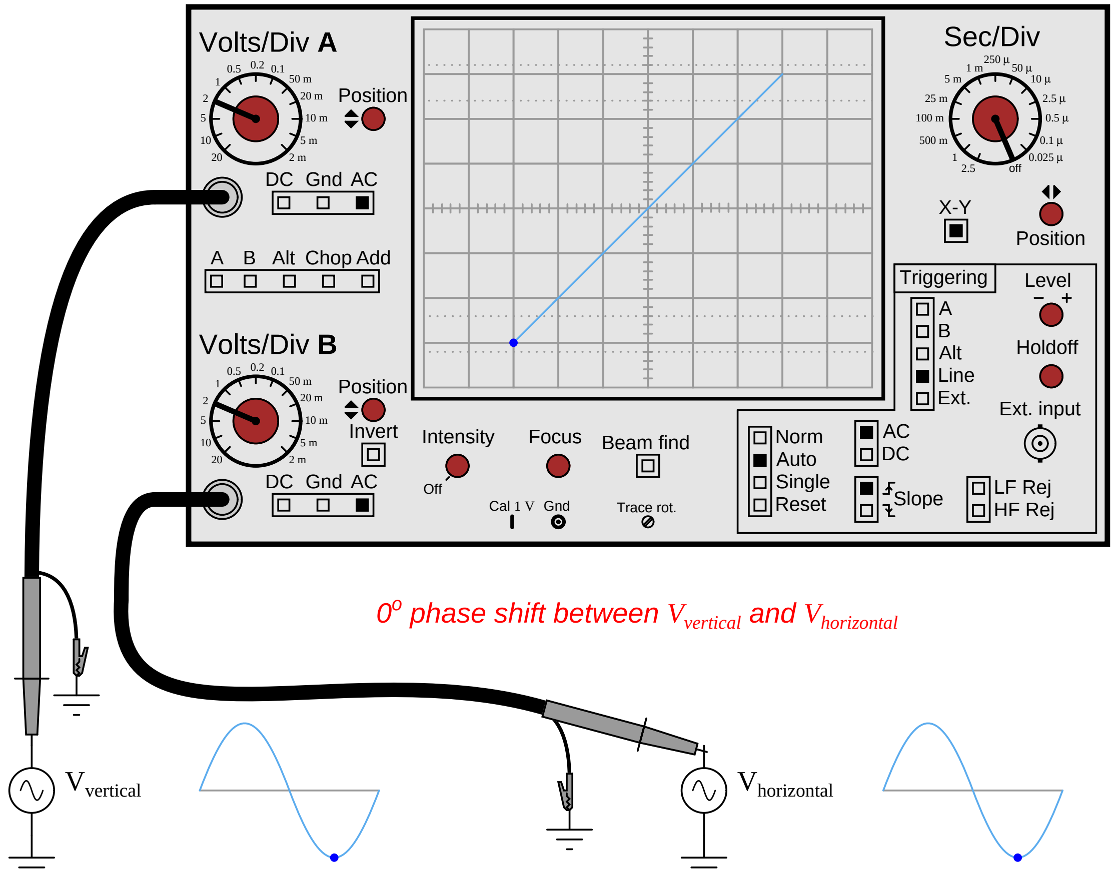
0^o phase shift between $V_{vertical}$ and $V_{horizontal}$



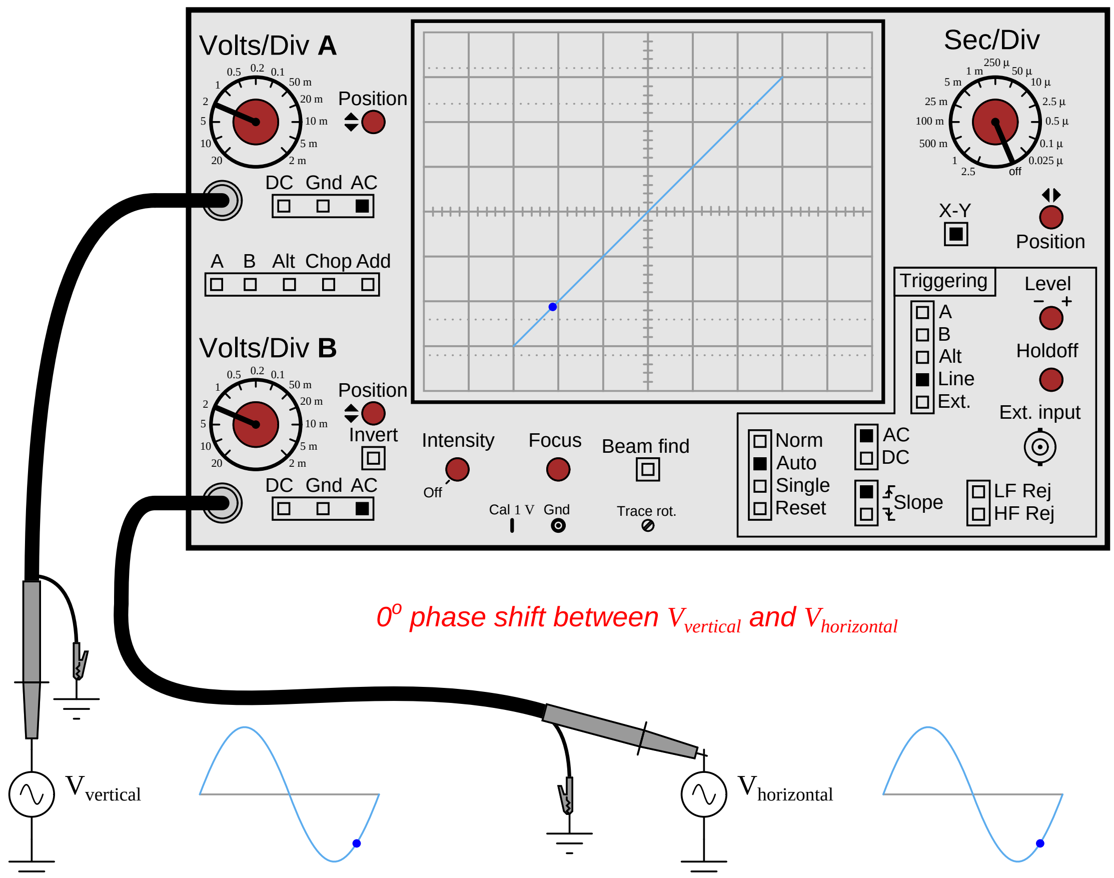

Volts/Div A
Position
DC Gnd AC
A B Alt Chop Add
Volts/Div B
Position
Invert
DC Gnd AC
Intensity
Off
Focus
Beam find
Cal 1 V
Gnd
Trace rot.
Sec/Div
X-Y
Position
Triggering
A
B
Alt
Line
Ext.
Level
Holdoff
Ext. input
Norm
Auto
Single
Reset
AC
DC
Slope
LF Rej
HF Rej
0° phase shift between $V_{vertical}$ and $V_{horizontal}$
$V_{vertical}$
$V_{horizontal}$

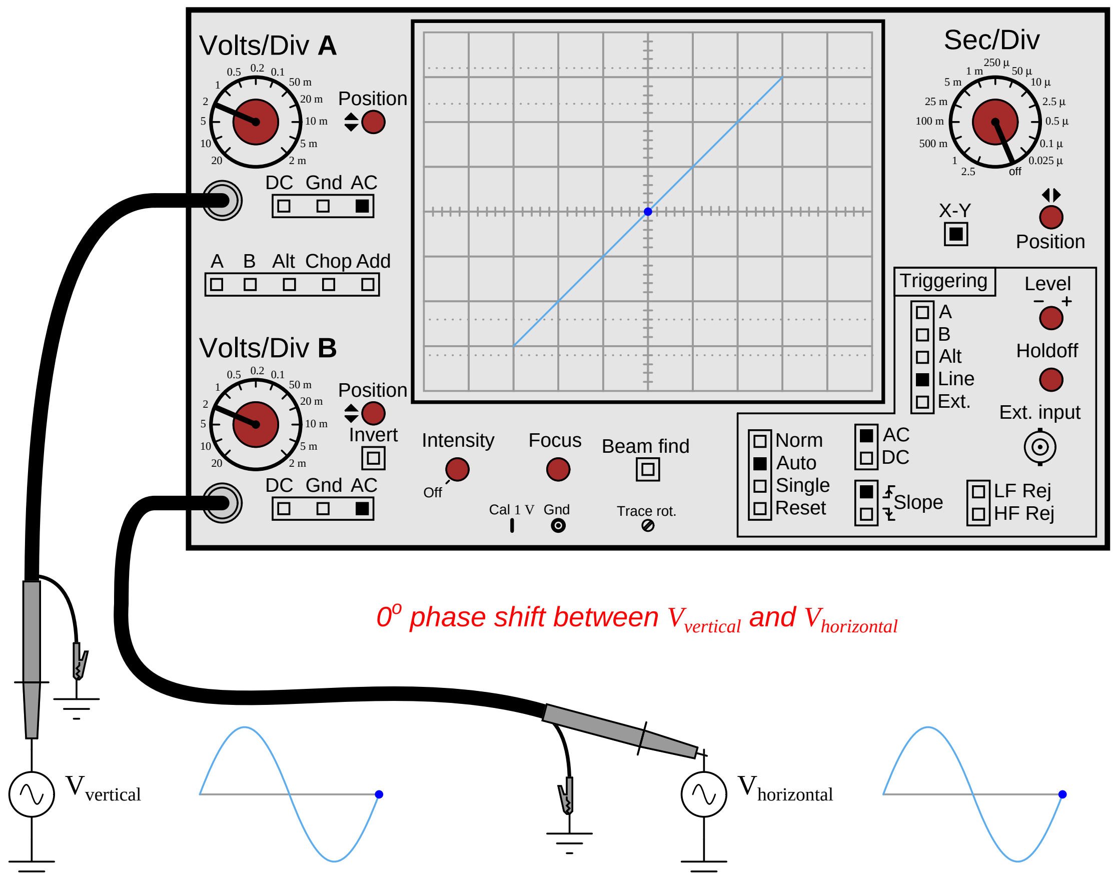

Volts/Div A
Position
DC Gnd AC
A B Alt Chop Add
Volts/Div B
Position
Invert
DC Gnd AC
Intensity
Off
Focus
Beam find
Cal 1 V Gnd
Trace rot.
Sec/Div
X-Y
Position
Triggering
A
B
Alt
Line
Ext.
Level
Holdoff
Ext. input
Norm
Auto
Single
Reset
AC
DC
Slope
LF Rej
HF Rej
0° phase shift between $V_{vertical}$ and $V_{horizontal}$
$V_{vertical}$
$V_{horizontal}$


Volts/Div A
Position
DC Gnd AC
A B Alt Chop Add
Volts/Div B
Position
Invert
DC Gnd AC
Intensity
Off
Focus
Beam find
Cal 1 V Gnd
Trace rot.
Sec/Div
X-Y
Position
Triggering
A
B
Alt
Line
Ext.
Level
Holdoff
Ext. input
Norm
Auto
Single
Reset
AC
DC
Slope
LF Rej
HF Rej
0° phase shift between $V_{vertical}$ and $V_{horizontal}$
$V_{vertical}$
$V_{horizontal}$



0^o phase shift between $V_{vertical}$ and $V_{horizontal}$


Volts/Div A
Position
DC Gnd AC
A B Alt Chop Add
Volts/Div B
Position
Invert
DC Gnd AC
Intensity
Off
Focus
Beam find
Cal 1 V
Gnd
Trace rot.
Sec/Div
X-Y
Position
Triggering
A
B
Alt
Line
Ext.
Level
Holdoff
Ext. input
Norm
Auto
Single
Reset
AC
DC
Slope
LF Rej
HF Rej
0^o phase shift between $V_{vertical}$ and $V_{horizontal}$
$V_{vertical}$
$V_{horizontal}$



Volts/Div A
Position
DC Gnd AC
A B Alt Chop Add
Volts/Div B
Position
Invert
DC Gnd AC
Intensity
Off
Focus
Beam find
Cal 1 V Gnd
Trace rot.
Sec/Div
X-Y
Position
Triggering
A
B
Alt
Line
Ext.
Level
Holdoff
Ext. input
Norm
Auto
Single
Reset
AC
DC
Slope
LF Rej
HF Rej
0° phase shift between V vertical and V horizontal
V vertical
V horizontal

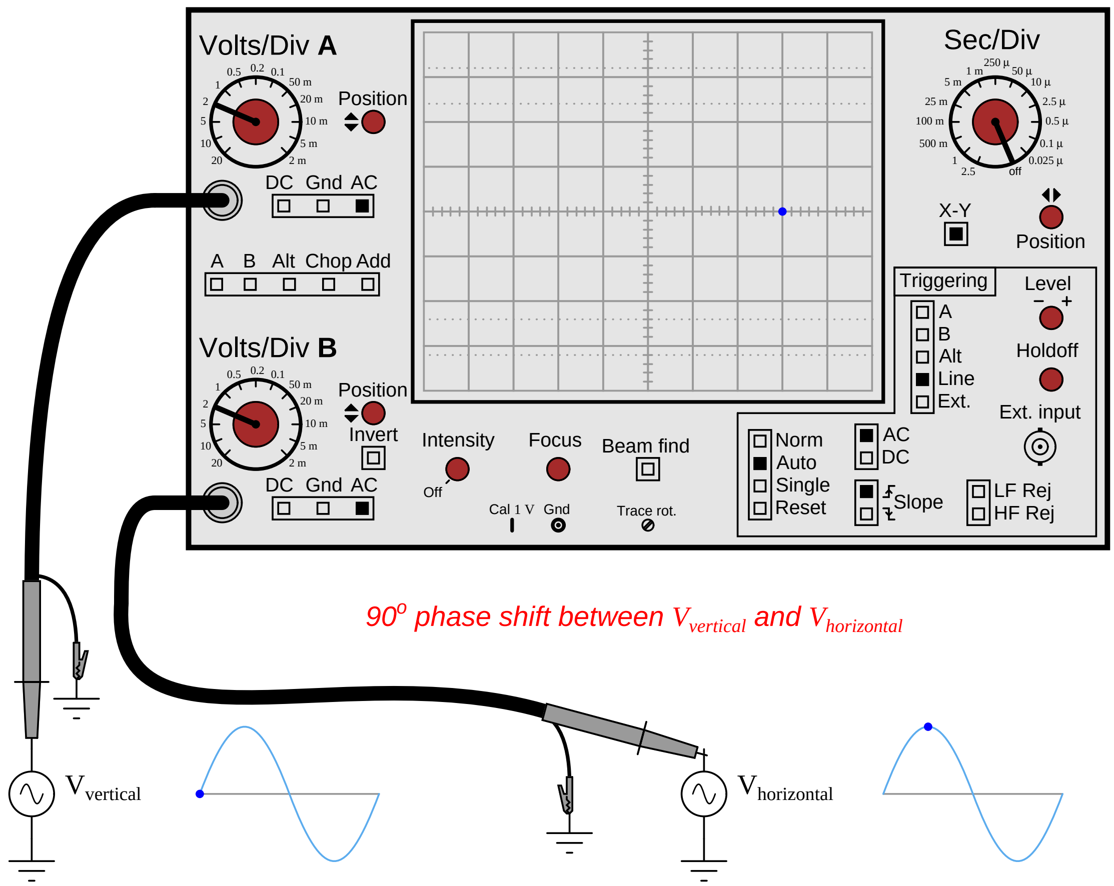
file 03263

Question 5

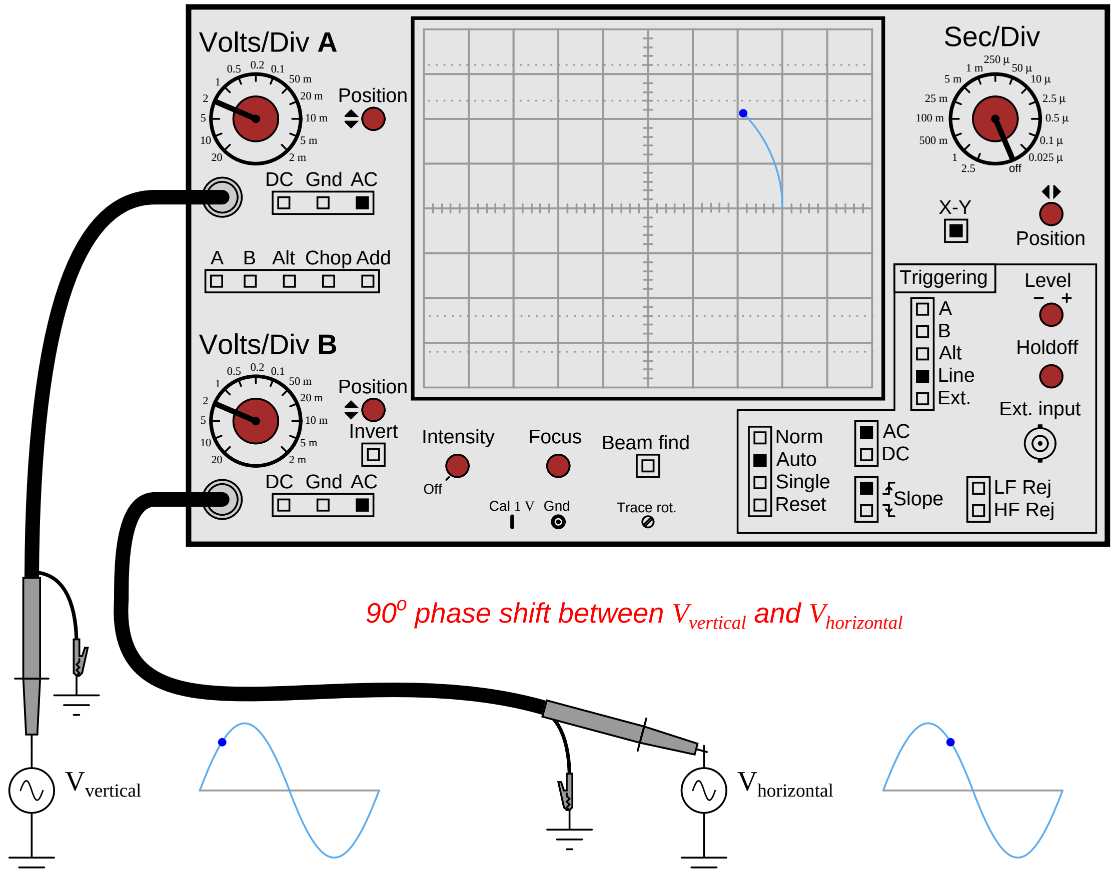
Animation: Lissajous figures on an oscilloscope with 90 degrees phase shift

This question consists of a series of images (one per page) that form an animation. Flip the pages with your fingers to view this animation (or click on the "next" button on your viewer) frame-by-frame.

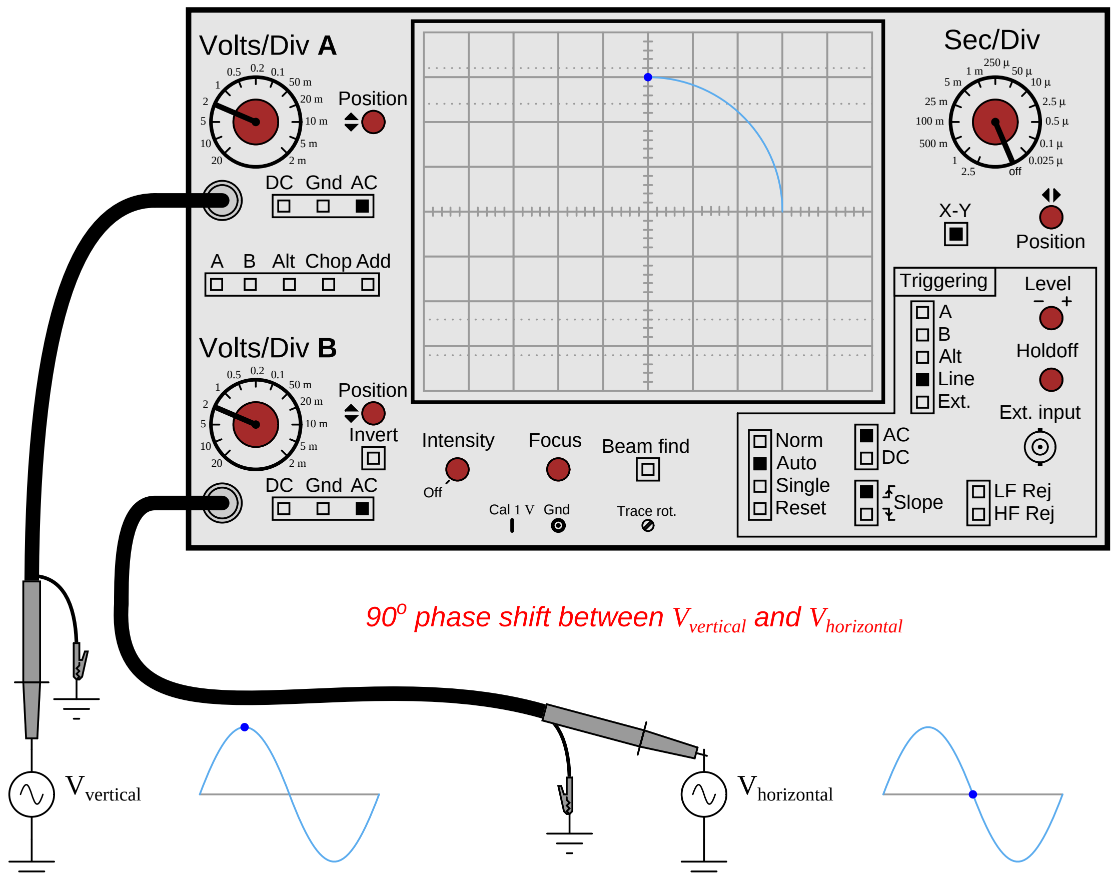
The following animation shows how two sinusoidal voltages with 90 degrees phase shift between them can draw a Lissajous figure on the screen of an oscilloscope.



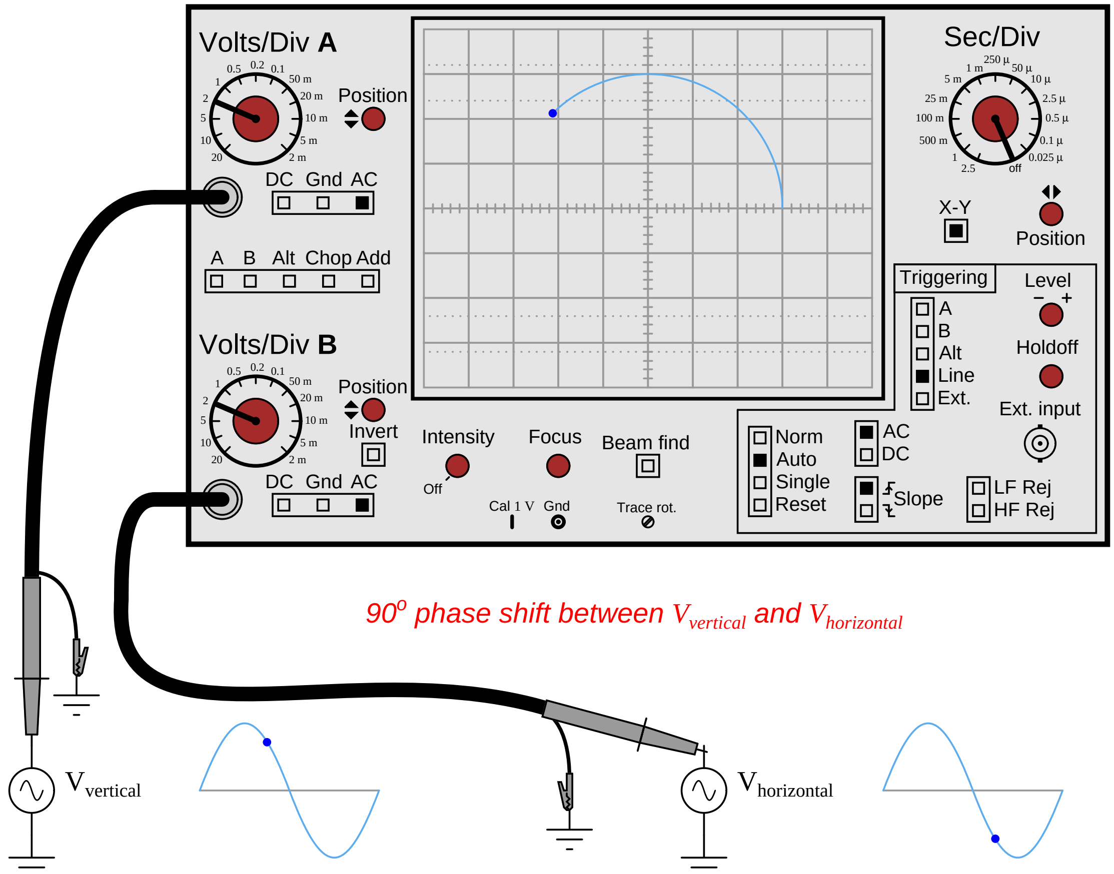
Volts/Div A
Position
DC Gnd AC
A B Alt Chop Add
Volts/Div B
Position
Invert
DC Gnd AC
Intensity
Off
Focus
Beam find
Cal 1 V
Gnd
Trace rot.
Sec/Div
X-Y
Position
Triggering
A
B
Alt
Line
Ext.
Level
Holdoff
Ext. input
Norm
Auto
Single
Reset
AC
DC
Slope
LF Rej
HF Rej
90^o phase shift between $V_{vertical}$ and $V_{horizontal}$
$V_{vertical}$
$V_{horizontal}$



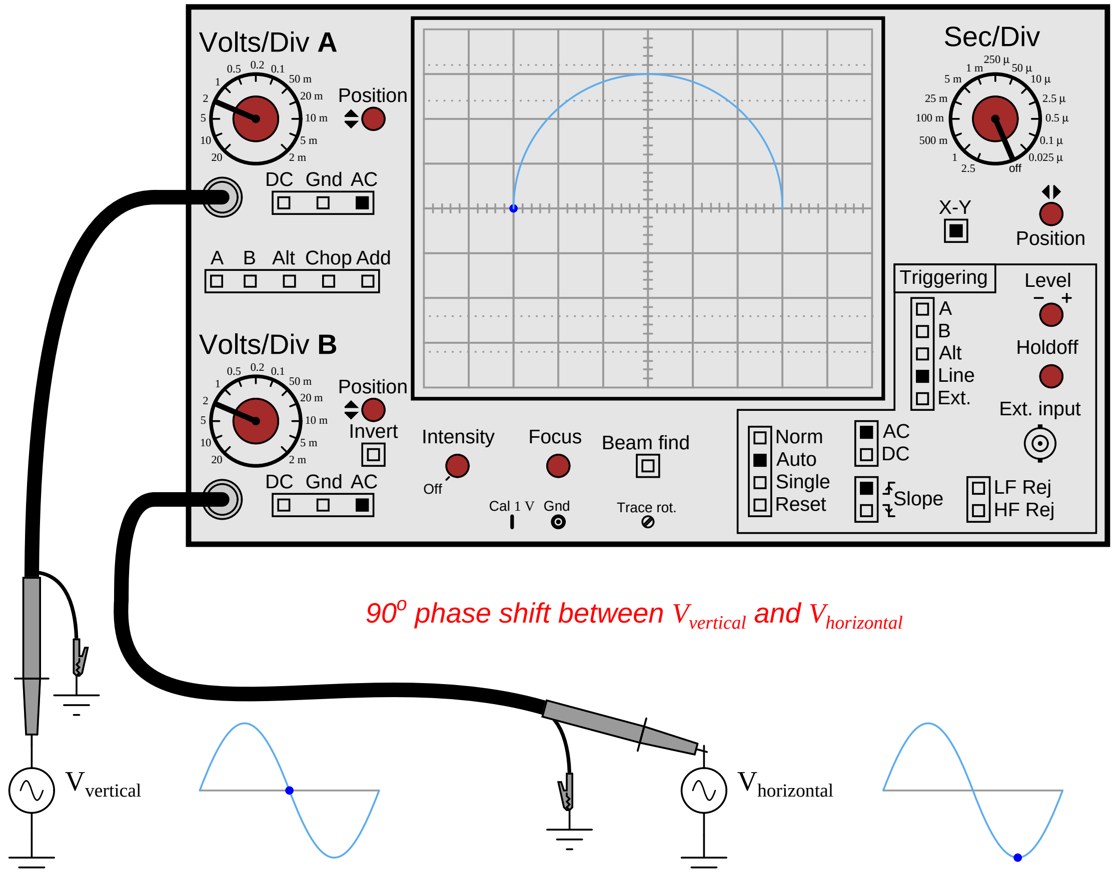
Volts/Div A
Position
DC Gnd AC
A B Alt Chop Add
Volts/Div B
Position
Invert
DC Gnd AC
Intensity
Off
Focus
Beam find
Cal 1 V
Gnd
Trace rot.
Sec/Div
X-Y
Position
Triggering
A
B
Alt
Line
Ext.
Level
Holdoff
Ext. input
Norm
Auto
Single
Reset
AC
DC
Slope
LF Rej
HF Rej
90° phase shift between $V_{vertical}$ and $V_{horizontal}$
$V_{vertical}$
$V_{horizontal}$



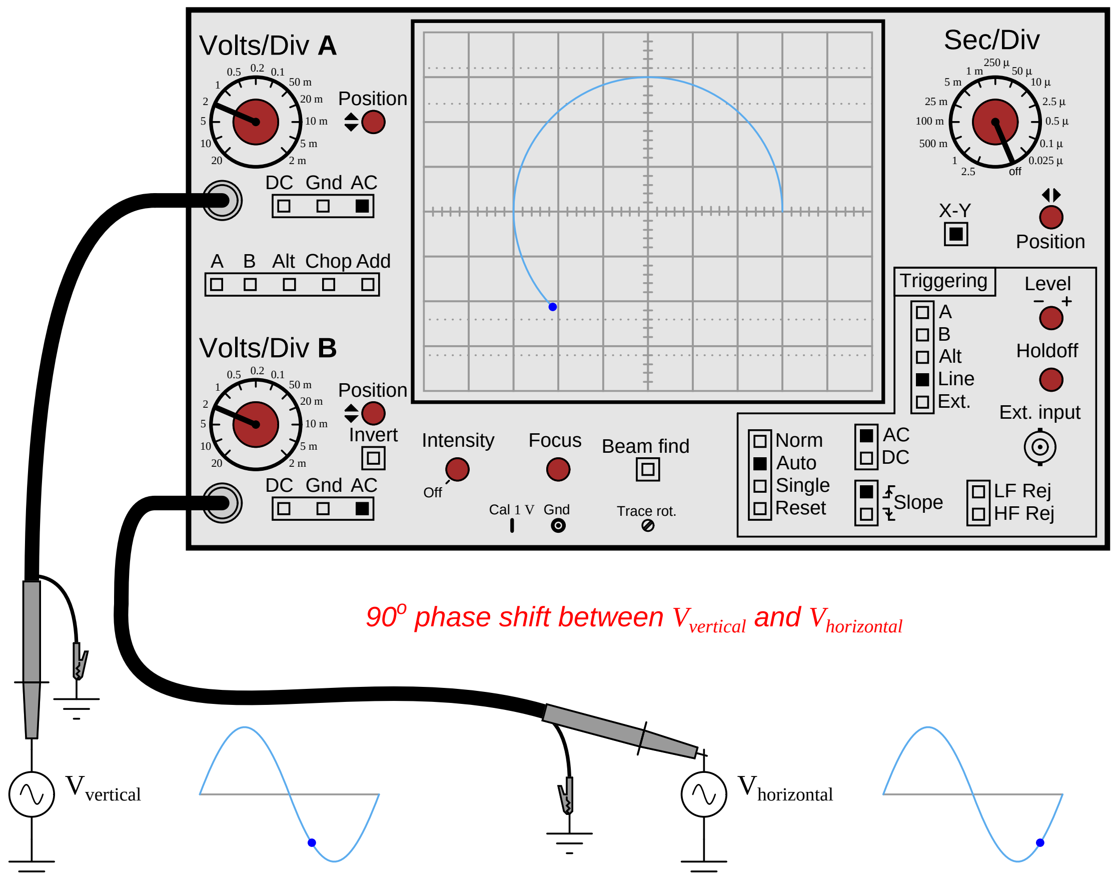
Volts/Div A
Position
DC Gnd AC
A B Alt Chop Add
Volts/Div B
Position
Invert
DC Gnd AC
Intensity
Off
Focus
Beam find
Cal 1 V Gnd
Trace rot.
Sec/Div
X-Y
Position
Triggering
A
B
Alt
Line
Ext.
Level
Holdoff
Ext. input
Norm
Auto
Single
Reset
AC
DC
Slope
LF Rej
HF Rej
90° phase shift between V_vertical and V_horizontal
V_vertical
V_horizontal

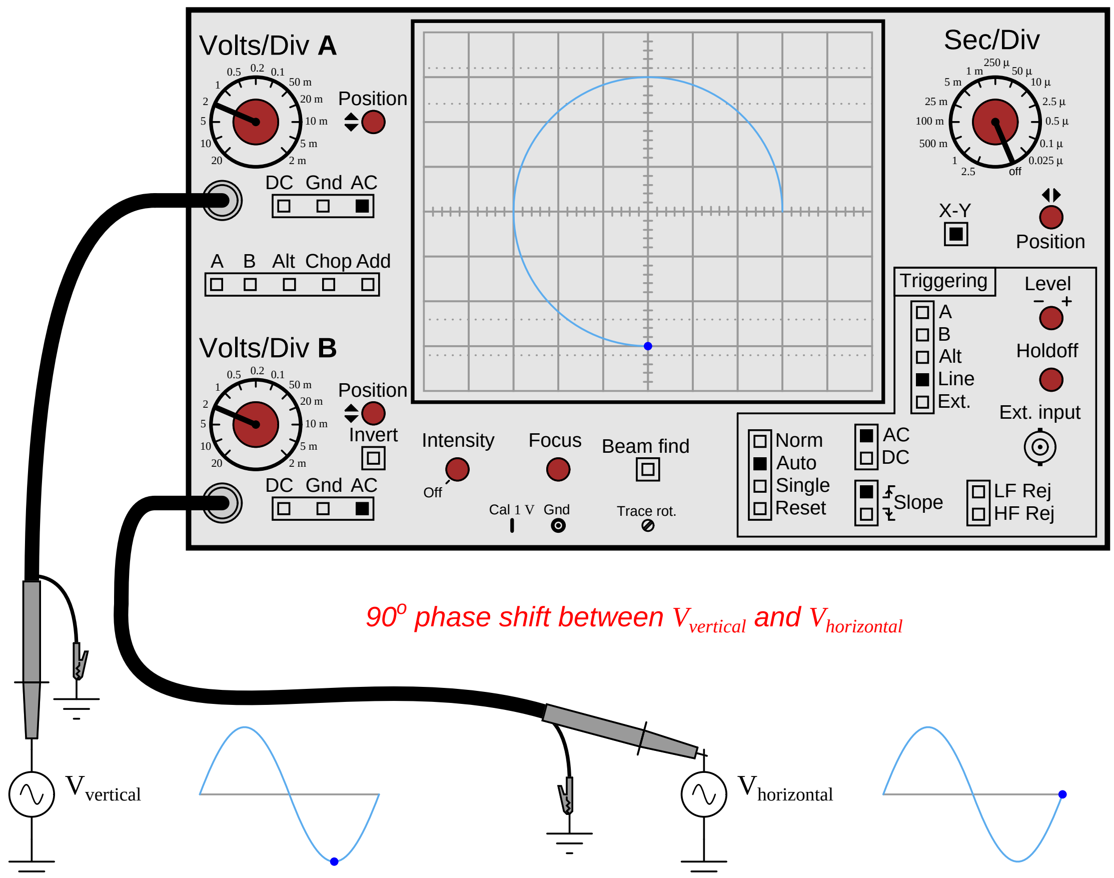


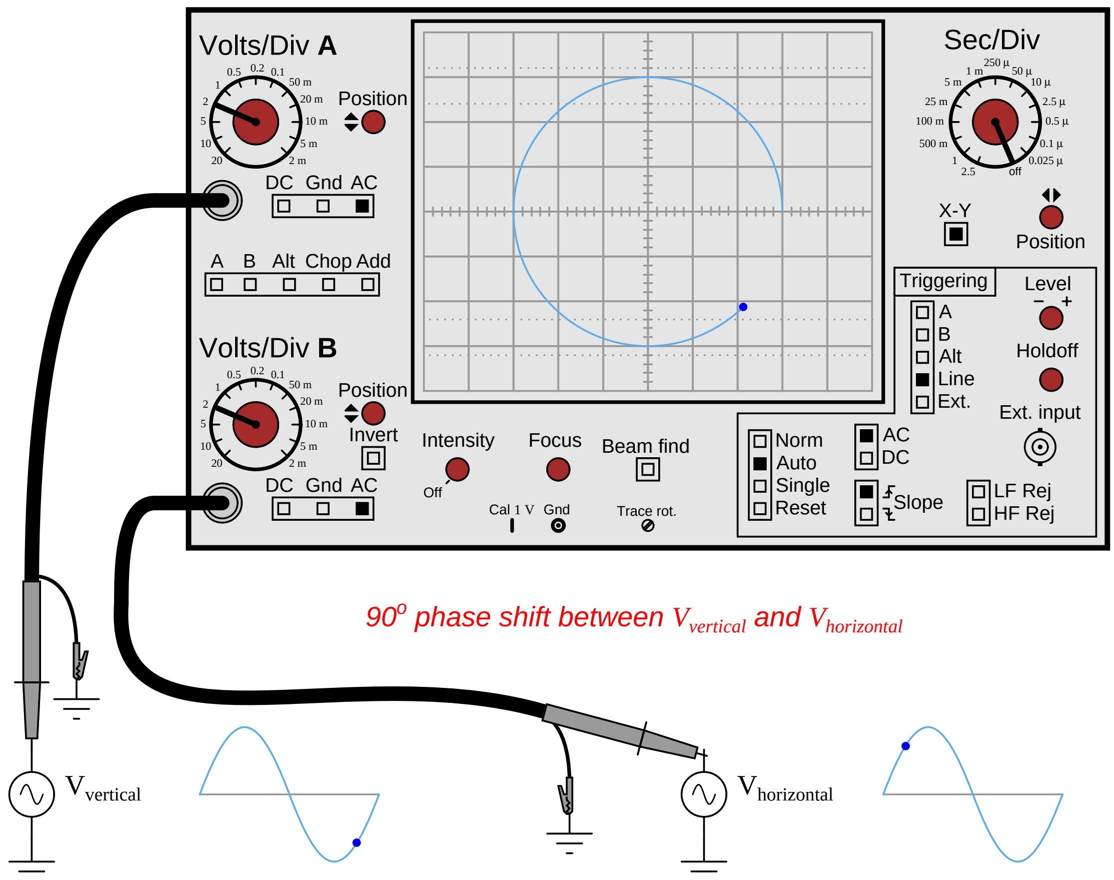
Volts/Div A
Position
DC Gnd AC
A B Alt Chop Add
Volts/Div B
Position
Invert
DC Gnd AC
Intensity
Off
Focus
Beam find
Cal 1 V
Gnd
Trace rot.
Sec/Div
X-Y
Position
Triggering
A
B
Alt
Line
Ext.
Level
Holdoff
Ext. input
Norm
Auto
Single
Reset
AC
DC
Slope
LF Rej
HF Rej
90° phase shift between $V_{vertical}$ and $V_{horizontal}$
$V_{vertical}$
$V_{horizontal}$

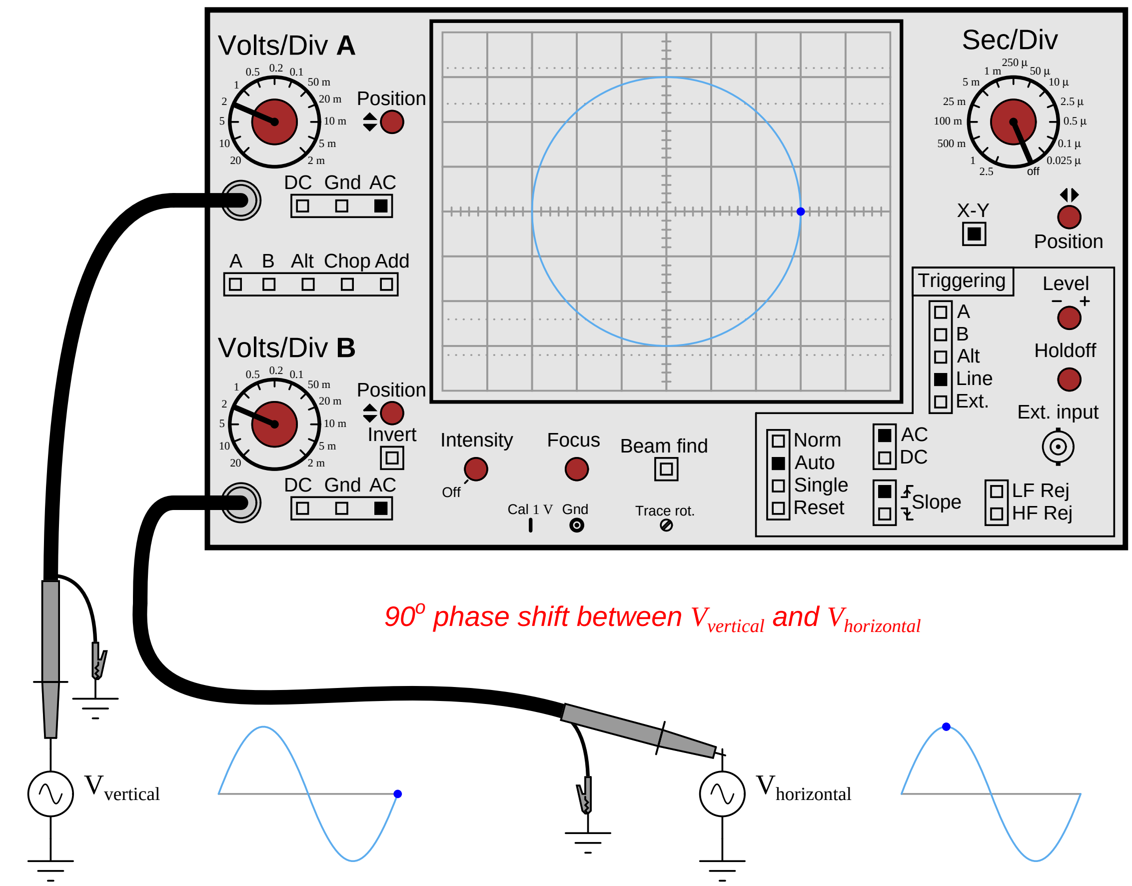


Volts/Div A
Position
DC Gnd AC
A B Alt Chop Add
Volts/Div B
Position
Invert
DC Gnd AC
Intensity
Off
Focus
Beam find
Cal 1 V
Gnd
Trace rot.
Sec/Div
X-Y
Position
Triggering
A
B
Alt
Line
Ext.
Level
Holdoff
Ext. input
Norm
Auto
Single
Reset
AC
DC
Slope
LF Rej
HF Rej
90° phase shift between V vertical and V horizontal
V vertical
V horizontal


Volts/Div A
Position
DC Gnd AC
A B Alt Chop Add
Volts/Div B
Position
Invert
DC Gnd AC
Intensity
Off
Focus
Beam find
Cal 1 V
Gnd
Trace rot.
Sec/Div
X-Y
Position
Triggering
A
B
Alt
Line
Ext.
Level
Holdoff
Ext. input
Norm
Auto
Single
Reset
AC
DC
Slope
LF Rej
HF Rej
90° phase shift between V vertical and V horizontal
V vertical
V horizontal


Volts/Div A
Position
DC Gnd AC
A B Alt Chop Add
Volts/Div B
Position
Invert
DC Gnd AC
Intensity
Focus
Beam find
Off
Cal 1 V
Gnd
Trace rot.
Sec/Div
X-Y
Position
Triggering
A
B
Alt
Line
Ext.
Level
Holdoff
Ext. input
Norm
Auto
Single
Reset
AC
DC
Slope
LF Rej
HF Rej
90° phase shift between $V_{vertical}$ and $V_{horizontal}$
$V_{vertical}$
$V_{horizontal}$


Volts/Div A
Position
DC Gnd AC
A B Alt Chop Add
Volts/Div B
Position
Invert
DC Gnd AC
Intensity
Off
Focus
Beam find
Cal 1 V
Gnd
Trace rot.
Sec/Div
X-Y
Position
Triggering
A
B
Alt
Line
Ext.
Level
Holdoff
Ext. input
Norm
Auto
Single
Reset
AC
DC
Slope
LF Rej
HF Rej
90° phase shift between $V_{vertical}$ and $V_{horizontal}$
$V_{vertical}$
$V_{horizontal}$



Volts/Div A
Position
DC Gnd AC
A B Alt Chop Add
Volts/Div B
Position
Invert
DC Gnd AC
Intensity
Off
Focus
Beam find
Cal 1 V
Gnd
Trace rot.
Sec/Div
X-Y
Position
Triggering
A
B
Alt
Line
Ext.
Level
Holdoff
Ext. input
Norm
Auto
Single
Reset
AC
DC
Slope
LF Rej
HF Rej
90° phase shift between V vertical and V horizontal
V vertical
V horizontal

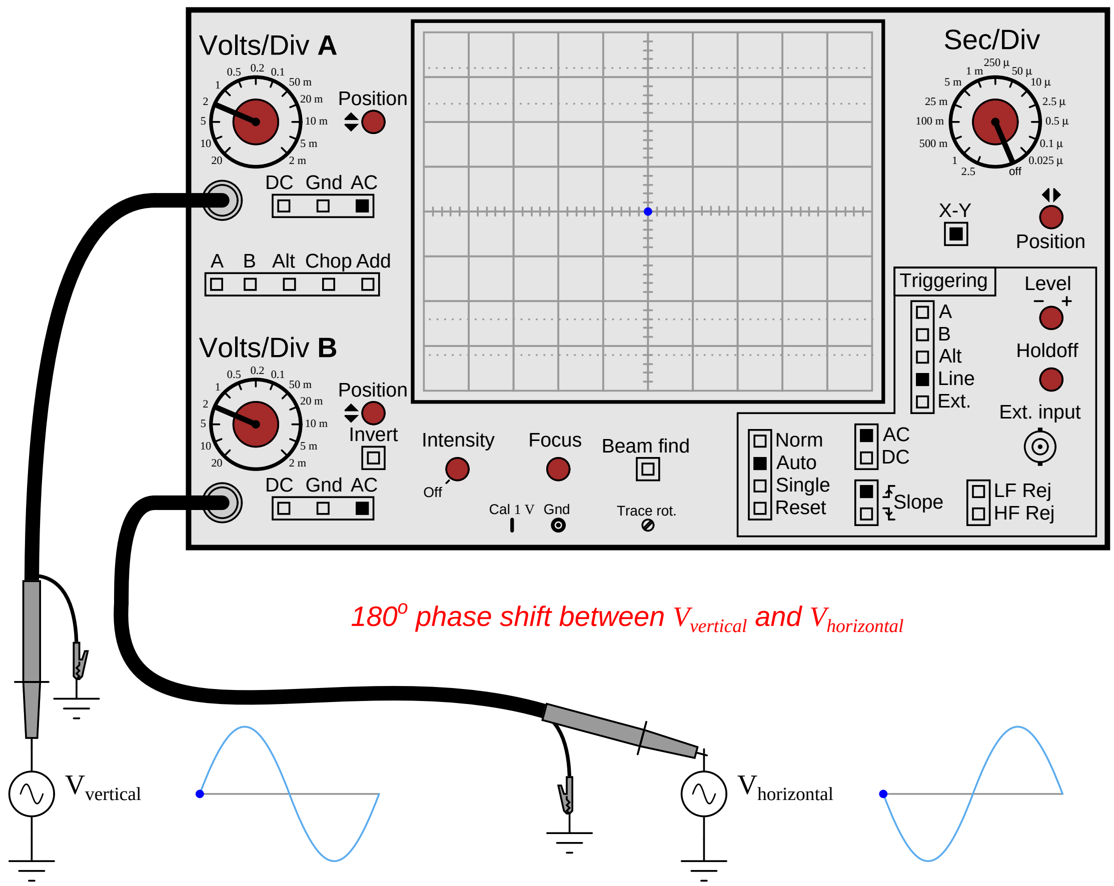
file 03264

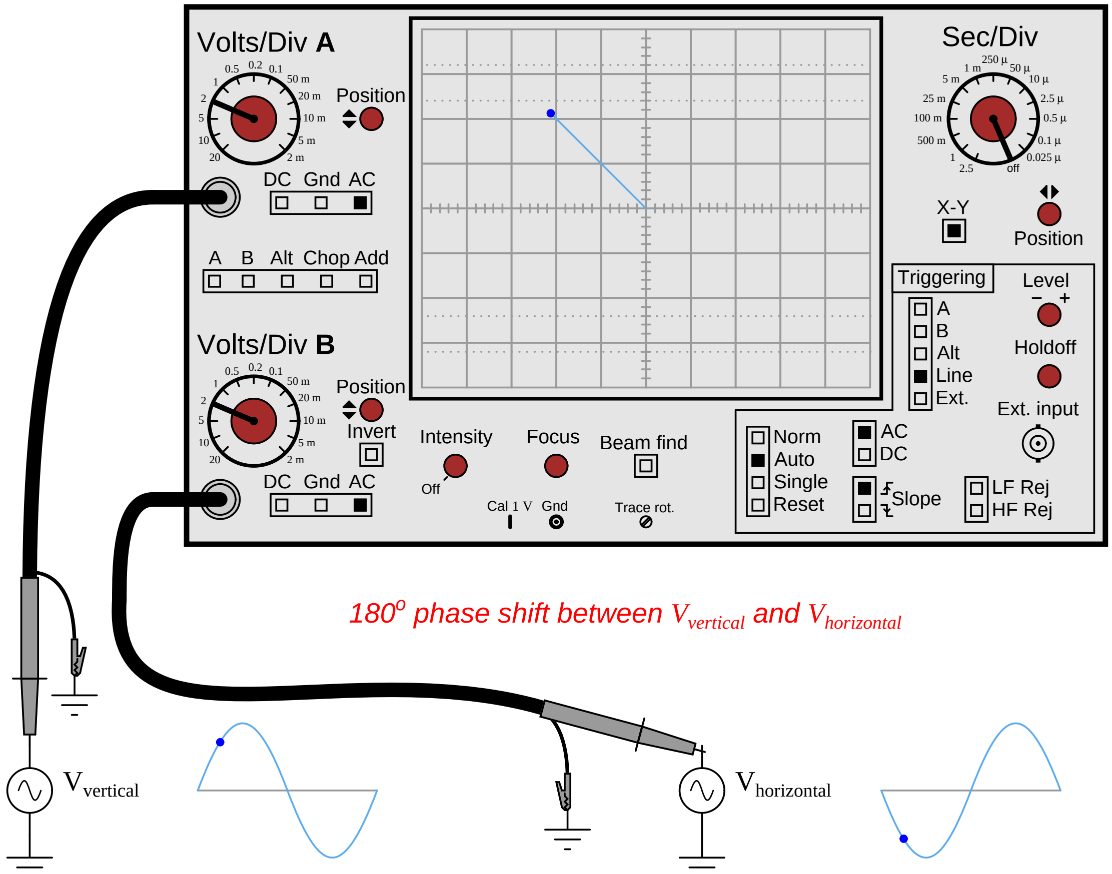
Question 6

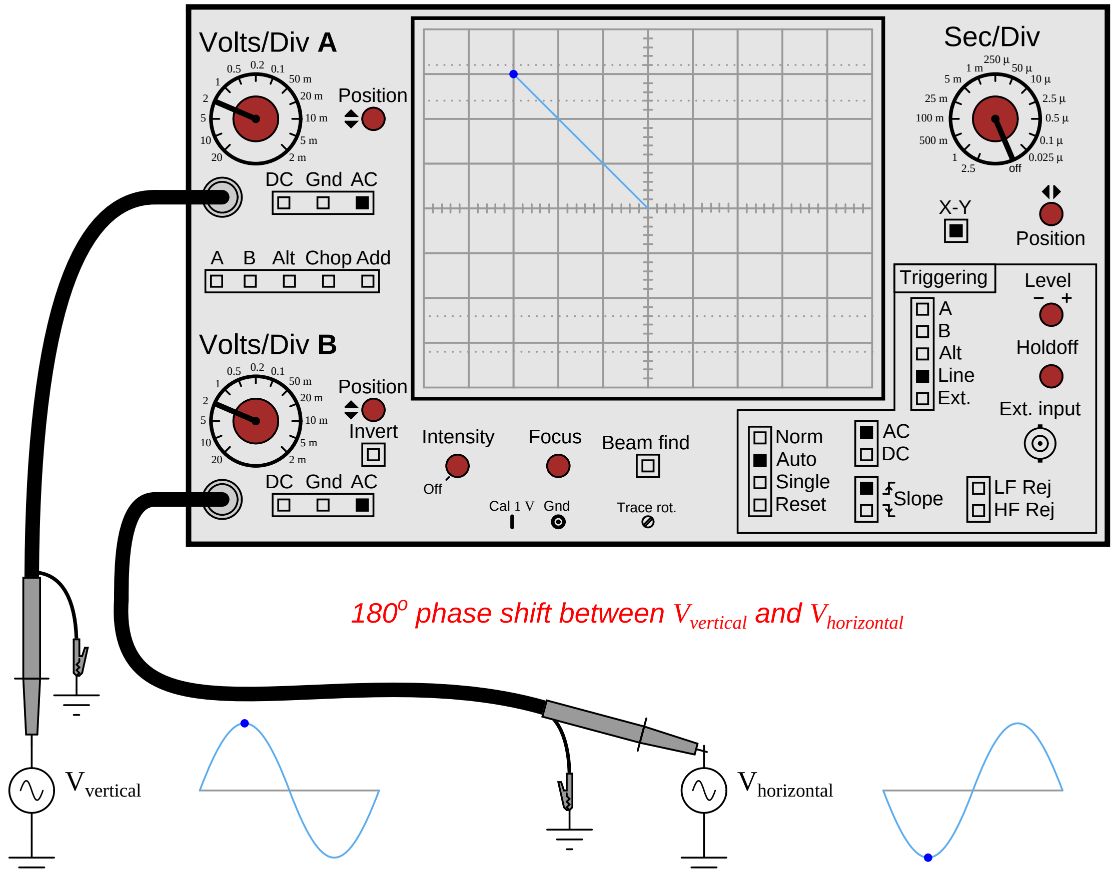
Animation: Lissajous figures on an oscilloscope with 180 degrees phase shift

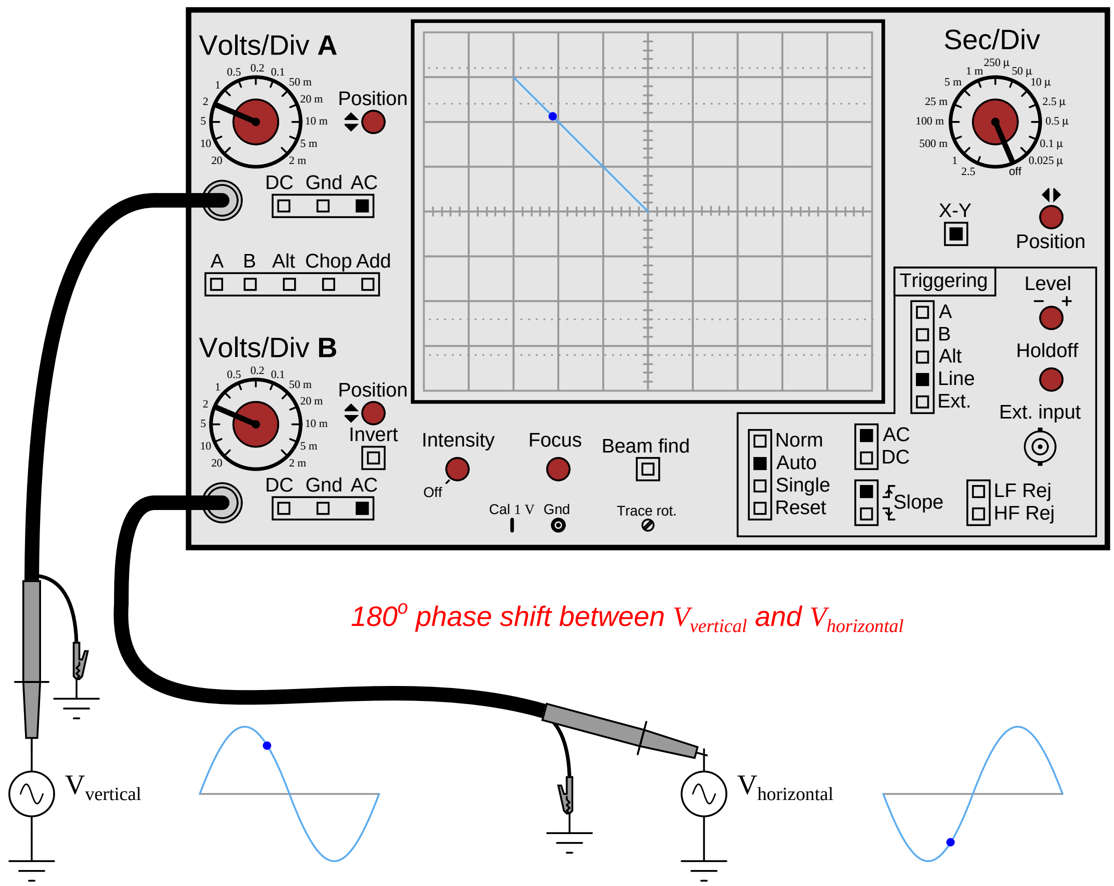
This question consists of a series of images (one per page) that form an animation. Flip the pages with your fingers to view this animation (or click on the "next" button on your viewer) frame-by-frame.

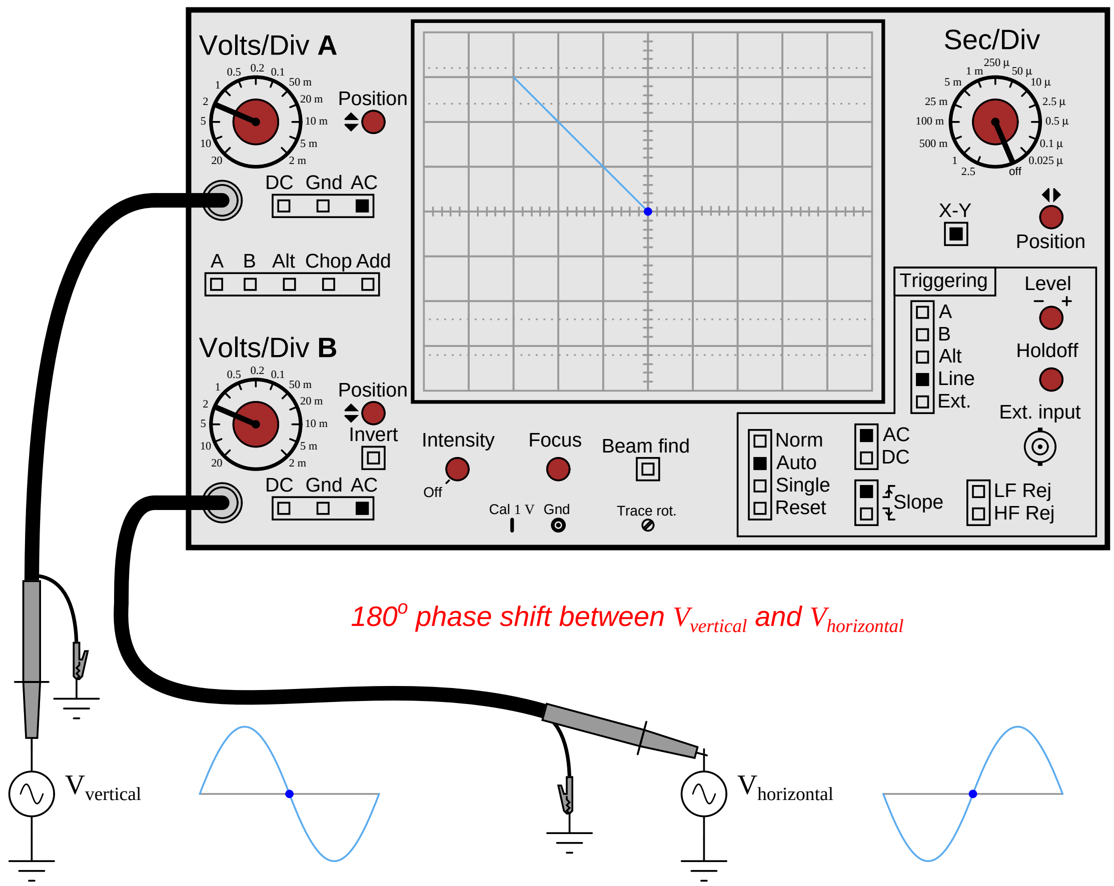
The following animation shows how two sinusoidal voltages with 180 degrees phase shift between them can draw a Lissajous figure on the screen of an oscilloscope.


Volts/Div A
Position
DC Gnd AC
A B Alt Chop Add
Volts/Div B
Position
Invert
DC Gnd AC
Intensity
Focus
Beam find
Off
Cal 1 V
Gnd
Trace rot.
Sec/Div
X-Y
Position
Triggering
A
B
Alt
Line
Ext.
Level
Holdoff
Ext. input
Norm
Auto
Single
Reset
AC
DC
Slope
LF Rej
HF Rej
180° phase shift between V vertical and V horizontal
V vertical
V horizontal

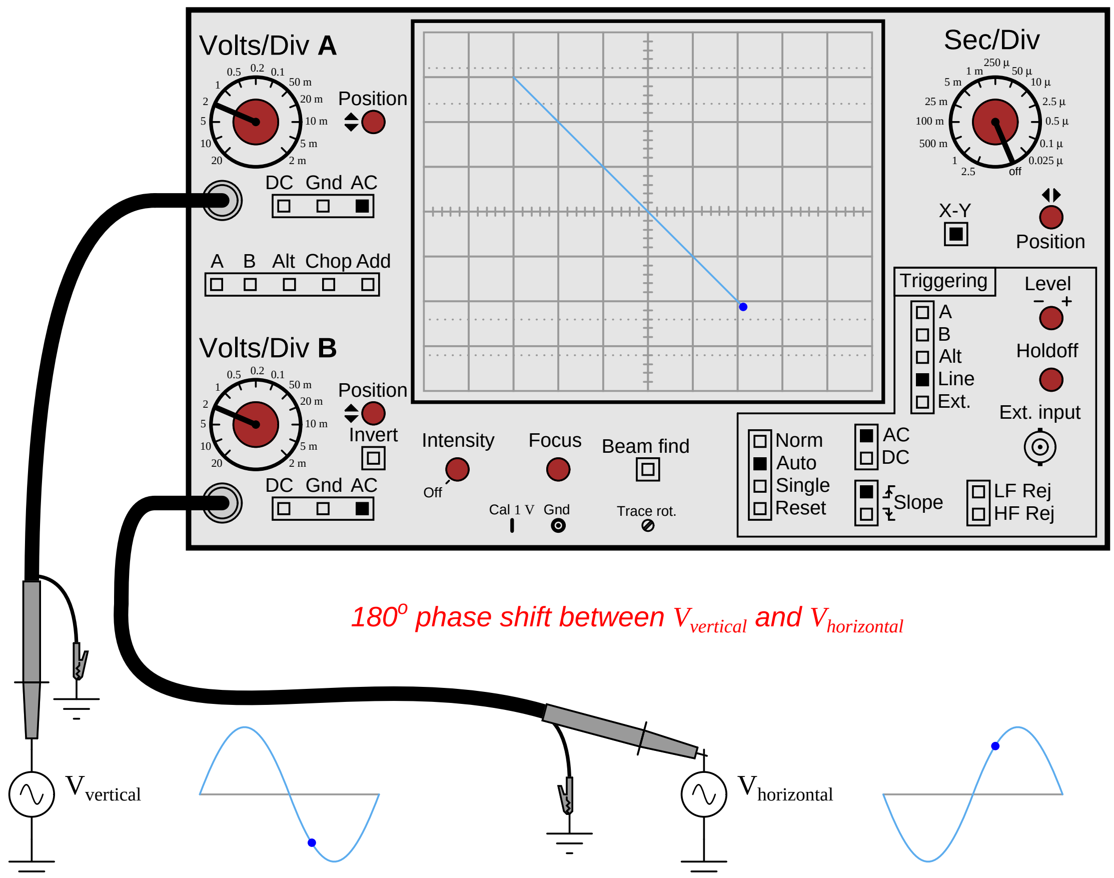

Volts/Div A
Position
DC Gnd AC
A B Alt Chop Add
Volts/Div B
Position
Invert
DC Gnd AC
Intensity
Off
Focus
Beam find
Cal 1 V
Gnd
Trace rot.
Sec/Div
X-Y
Position
Triggering
A
B
Alt
Line
Ext.
Level
Holdoff
Ext. input
Norm
Auto
Single
Reset
AC
DC
Slope
LF Rej
HF Rej
180° phase shift between V vertical and V horizontal
V vertical
V horizontal

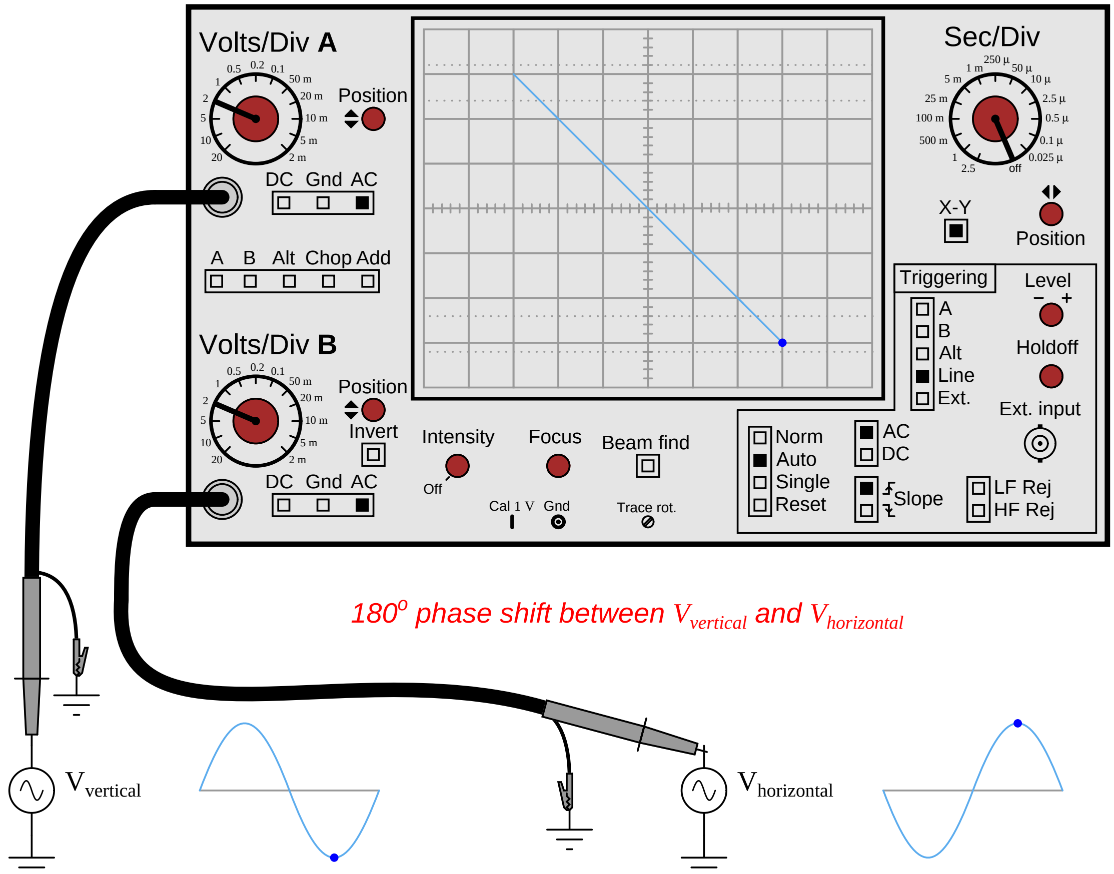

Volts/Div A
Position
DC Gnd AC
A B Alt Chop Add
Volts/Div B
Position
Invert
DC Gnd AC
Intensity
Off
Focus
Beam find
Cal 1 V Gnd
Trace rot.
Sec/Div
X-Y
Position
Triggering
A
B
Alt
Line
Ext.
Level
Holdoff
Ext. input
Norm
Auto
Single
Reset
AC
DC
Slope
LF Rej
HF Rej
180° phase shift between V_vertical and V_horizontal
V_vertical
V_horizontal

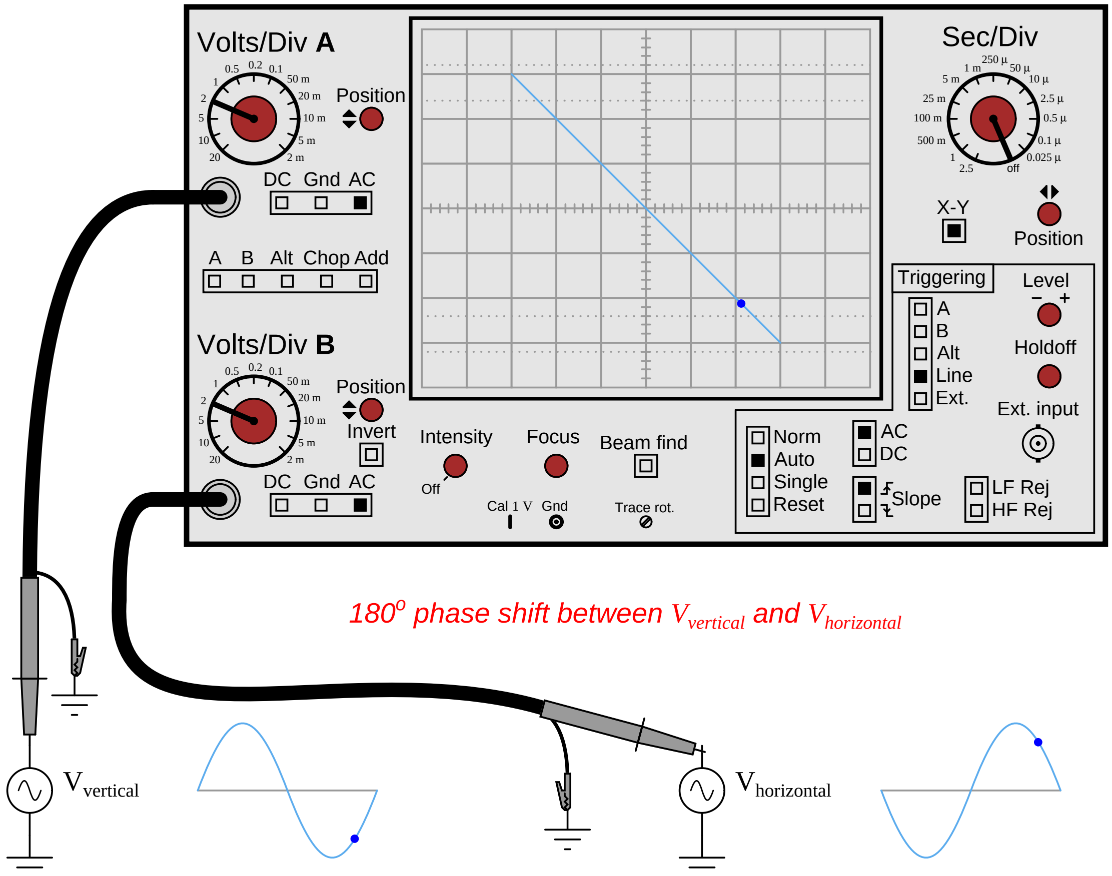

Volts/Div A
Position
DC Gnd AC
A B Alt Chop Add
Volts/Div B
Position
Invert
DC Gnd AC
Intensity
Off
Focus
Beam find
Cal 1 V
Gnd
Trace rot.
Sec/Div
X-Y
Position
Triggering
A
B
Alt
Line
Ext.
Level
Holdoff
Ext. input
Norm
Auto
Single
Reset
AC
DC
Slope
LF Rej
HF Rej
180° phase shift between $V_{vertical}$ and $V_{horizontal}$
$V_{vertical}$
$V_{horizontal}$



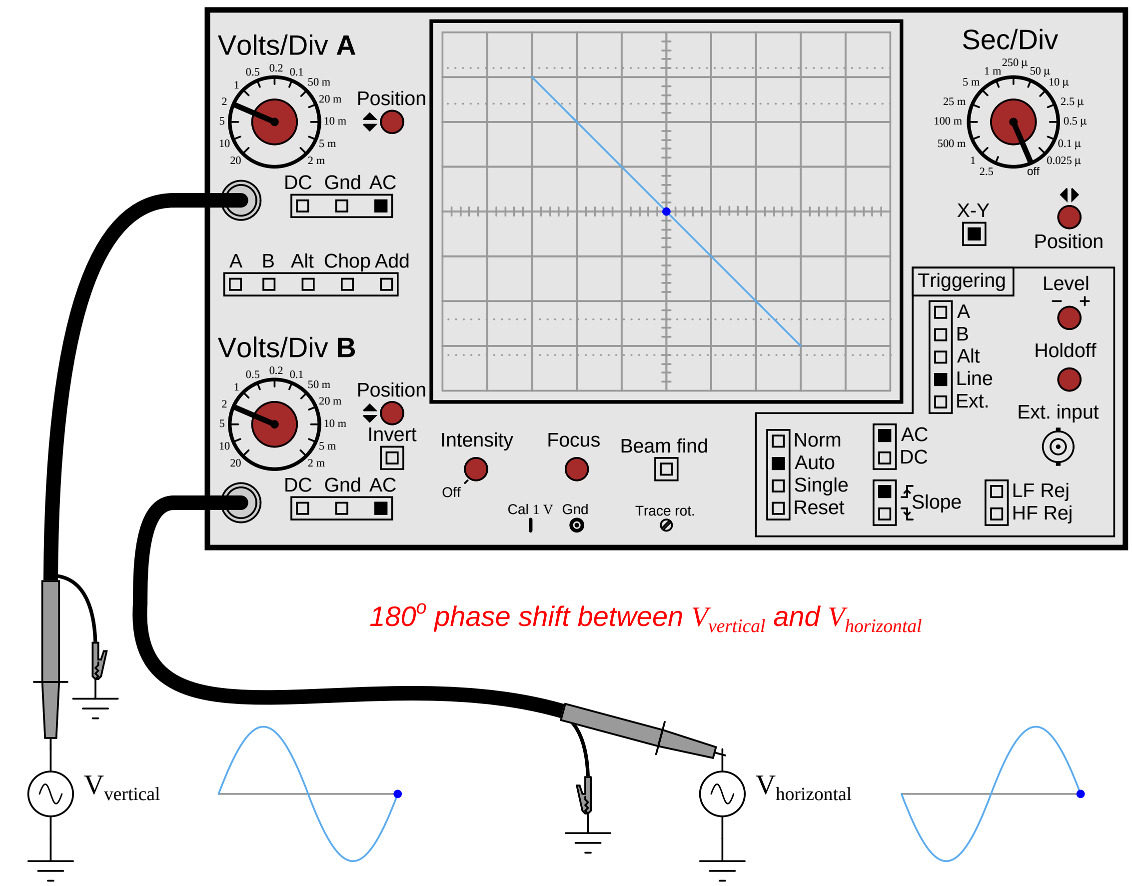
Volts/Div A
0.5
0.2
0.1
50 m
20 m
10 m
5 m
2 m
1
2
5
10
20
Position
DC Gnd AC
A B Alt Chop Add
Volts/Div B
Position
Invert
Intensity
Off
Focus
Beam find
Cal 1 V
Gnd
Trace rot.
Sec/Div
250 µ
1 m
50 µ
5 m
10 µ
25 m
2.5 µ
100 m
0.5 µ
500 m
0.1 µ
1
0.025 µ
2.5
off
X-Y
Position
Triggering
A
B
Alt
Line
Ext.
Level
Holdoff
Ext. input
Norm
Auto
Single
Reset
AC
DC
Slope
LF Rej
HF Rej
180° phase shift between $V_{vertical}$ and $V_{horizontal}$
$V_{vertical}$
$V_{horizontal}$


Volts/Div A
Position
DC Gnd AC
A B Alt Chop Add
Volts/Div B
Position
Invert
DC Gnd AC
Intensity
Off
Focus
Beam find
Cal 1 V Gnd
Trace rot.
Sec/Div
X-Y
Position
Triggering
A
B
Alt
Line
Ext.
Level
Holdoff
Ext. input
Norm
Auto
Single
Reset
AC
DC
Slope
LF Rej
HF Rej
180° phase shift between V vertical and V horizontal
V vertical
V horizontal


Volts/Div A
Position
DC Gnd AC
A B Alt Chop Add
Volts/Div B
Position
Invert
DC Gnd AC
Intensity
Off
Focus
Beam find
Cal 1 V
Gnd
Trace rot.
Sec/Div
X-Y
Position
Triggering
A
B
Alt
Line
Ext.
Level
Holdoff
Ext. input
Norm
Auto
Single
Reset
AC
DC
Slope
LF Rej
HF Rej
180° phase shift between V_vertical and V_horizontal
V_vertical
V_horizontal



Volts/Div A
Position
DC Gnd AC
A B Alt Chop Add
Volts/Div B
Position
Invert
DC Gnd AC
Intensity
Off
Focus
Beam find
Cal 1 V
Gnd
Trace rot.
Sec/Div
X-Y
Position
Triggering
A
B
Alt
Line
Ext.
Level
Holdoff
Ext. input
Norm
Auto
Single
Reset
AC
DC
Slope
LF Rej
HF Rej
180° phase shift between $V_{vertical}$ and $V_{horizontal}$
$V_{vertical}$
$V_{horizontal}$


Volts/Div A
Position
DC Gnd AC
A B Alt Chop Add
Volts/Div B
Position
Invert
DC Gnd AC
Intensity
Off
Focus
Beam find
Cal 1 V
Gnd
Trace rot.
Sec/Div
X-Y
Position
Triggering
A
B
Alt
Line
Ext.
Level
Holdoff
Ext. input
Norm
Auto
Single
Reset
AC
DC
Slope
LF Rej
HF Rej
180^o phase shift between $V_{vertical}$ and $V_{horizontal}$
$V_{vertical}$
$V_{horizontal}$

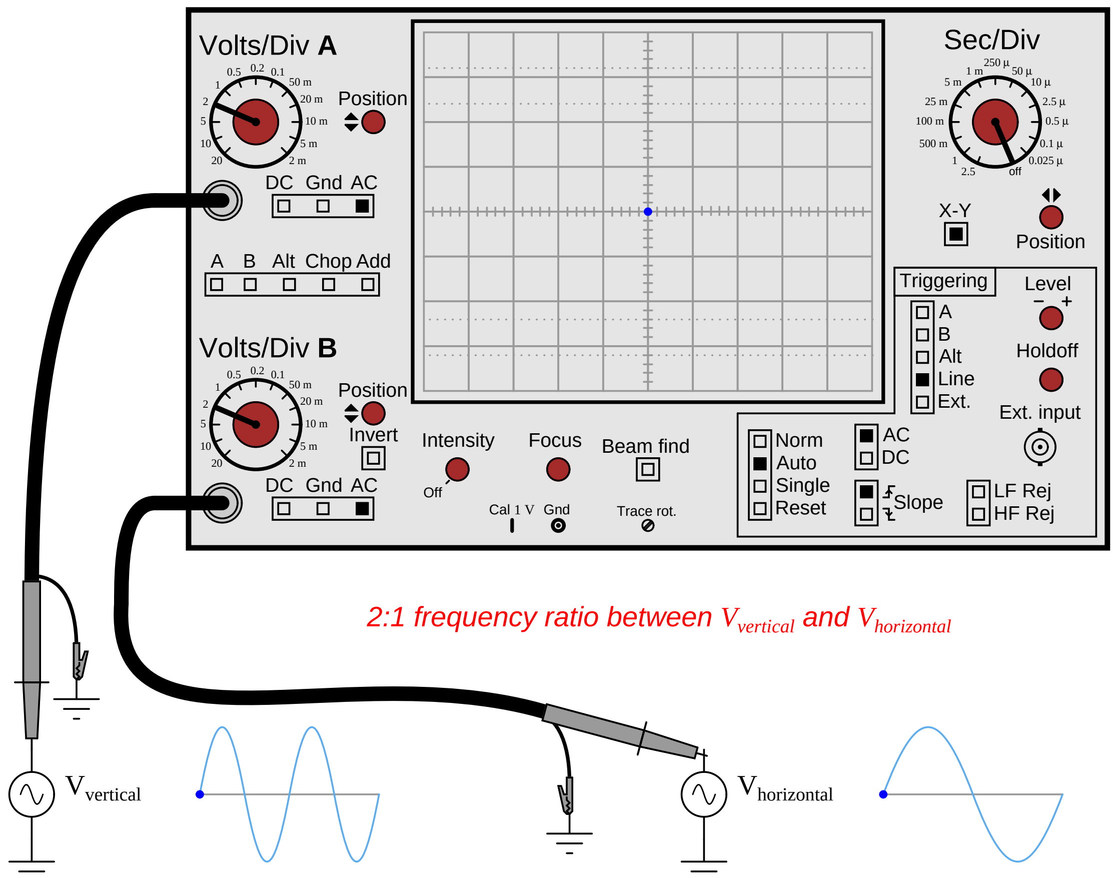
file 03265

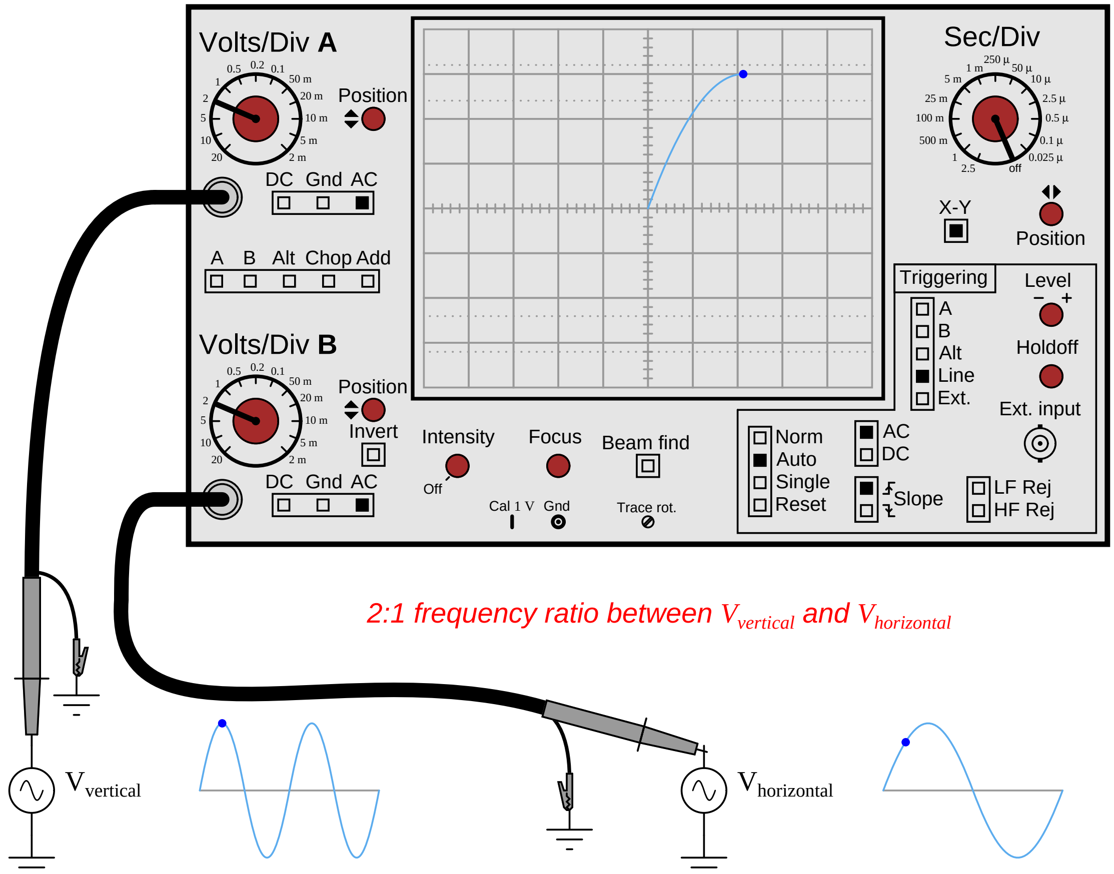
Question 7

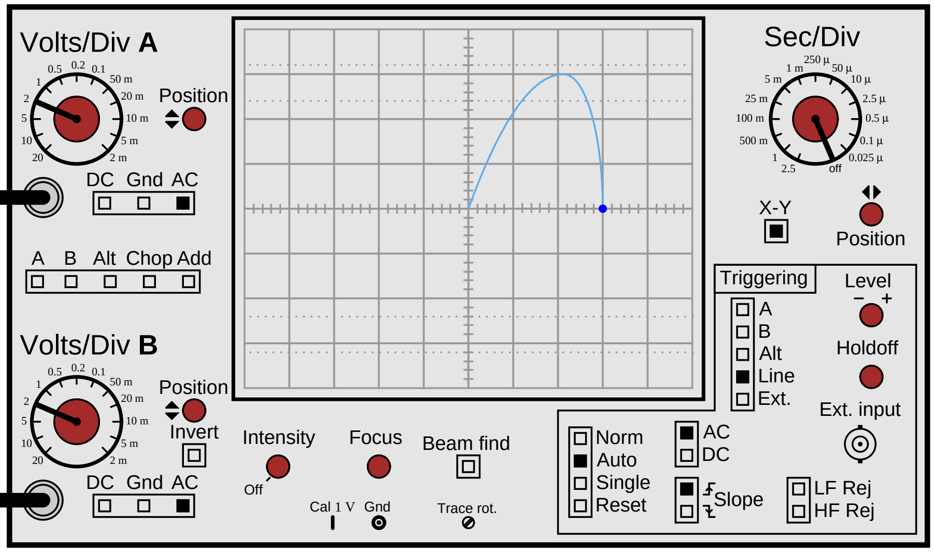
Animation: Lissajous figures on an oscilloscope with 2:1 frequency ratio

This question consists of a series of images (one per page) that form an animation. Flip the pages with your fingers to view this animation (or click on the "next" button on your viewer) frame-by-frame.

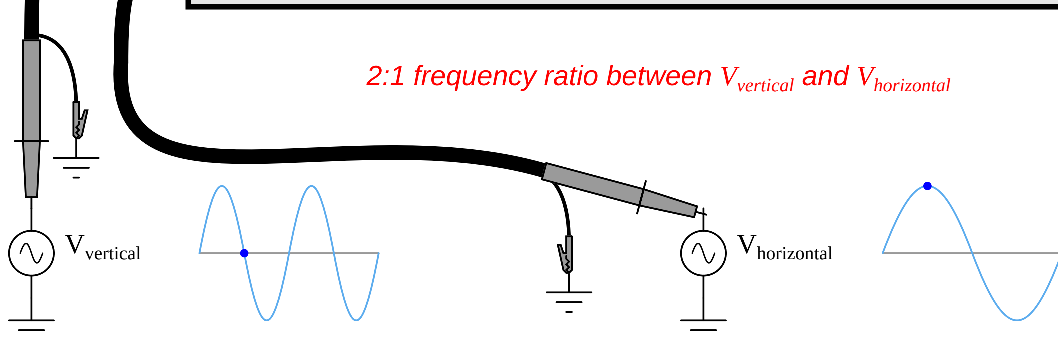
The following animation shows how two sinusoidal voltages with a frequency ratio of 2:1 draw a Lissajous figure on the screen of an oscilloscope.

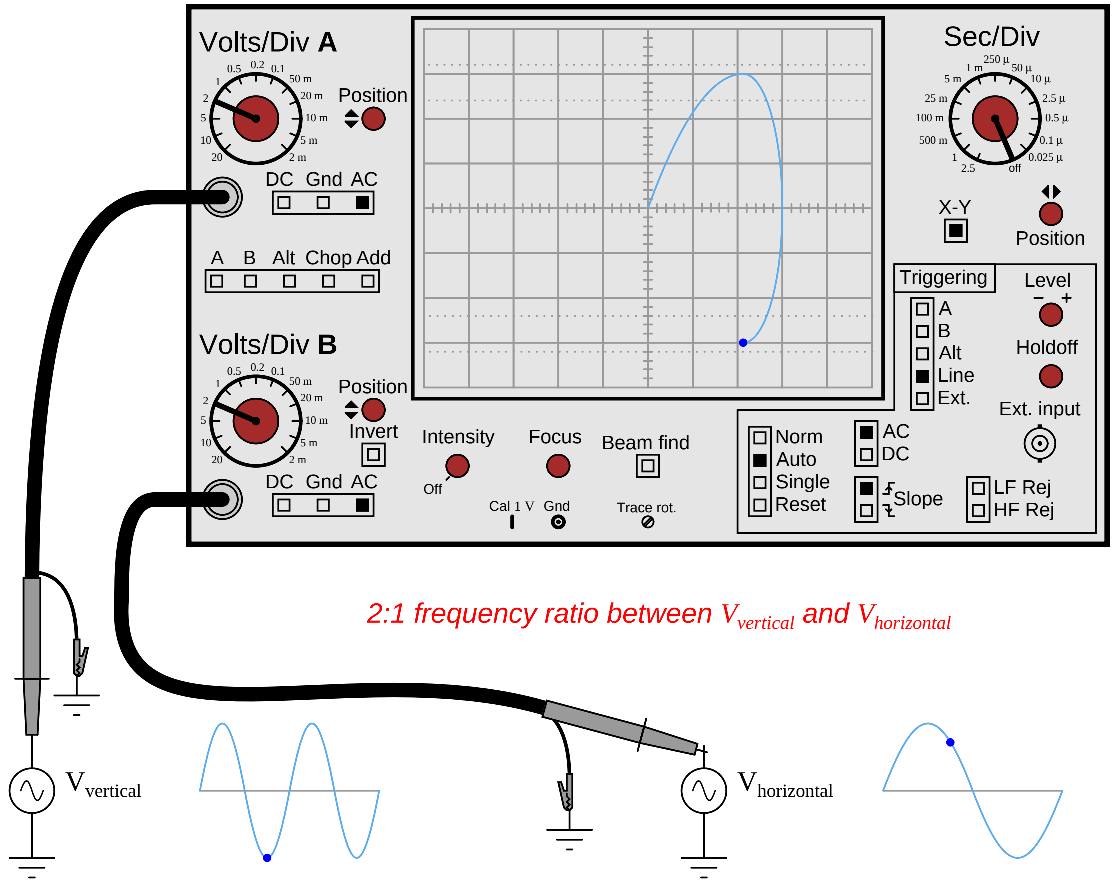

Volts/Div A
0.5
0.2
0.1
1
50 m
2
20 m
5
10 m
10
5 m
20
2 m
Position
DC Gnd AC
A B Alt Chop Add
Volts/Div B
Position
Invert
DC Gnd AC
Intensity
Off
Focus
Beam find
Cal 1 V Gnd
Trace rot.
Sec/Div
250 µ
1 m
50 µ
5 m
10 µ
25 m
2.5 µ
100 m
0.5 µ
500 m
0.1 µ
1
0.025 µ
2.5
off
X-Y
Position
Triggering
A
B
Alt
Line
Ext.
Level
Holdoff
Ext. input
Norm
Auto
Single
Reset
AC
DC
Slope
LF Rej
HF Rej
2:1 frequency ratio between $V_{vertical}$ and $V_{horizontal}$
$V_{vertical}$
$V_{horizontal}$


Volts/Div A
Position
DC Gnd AC
A B Alt Chop Add
Volts/Div B
Position
Invert
DC Gnd AC
Intensity
Off
Focus
Beam find
Cal 1 V
Gnd
Trace rot.
Sec/Div
X-Y
Position
Triggering
A
B
Alt
Line
Ext.
Level
Holdoff
Ext. input
Norm
Auto
Single
Reset
AC
DC
Slope
LF Rej
HF Rej
2:1 frequency ratio between $V_{vertical}$ and $V_{horizontal}$
$V_{vertical}$
$V_{horizontal}$

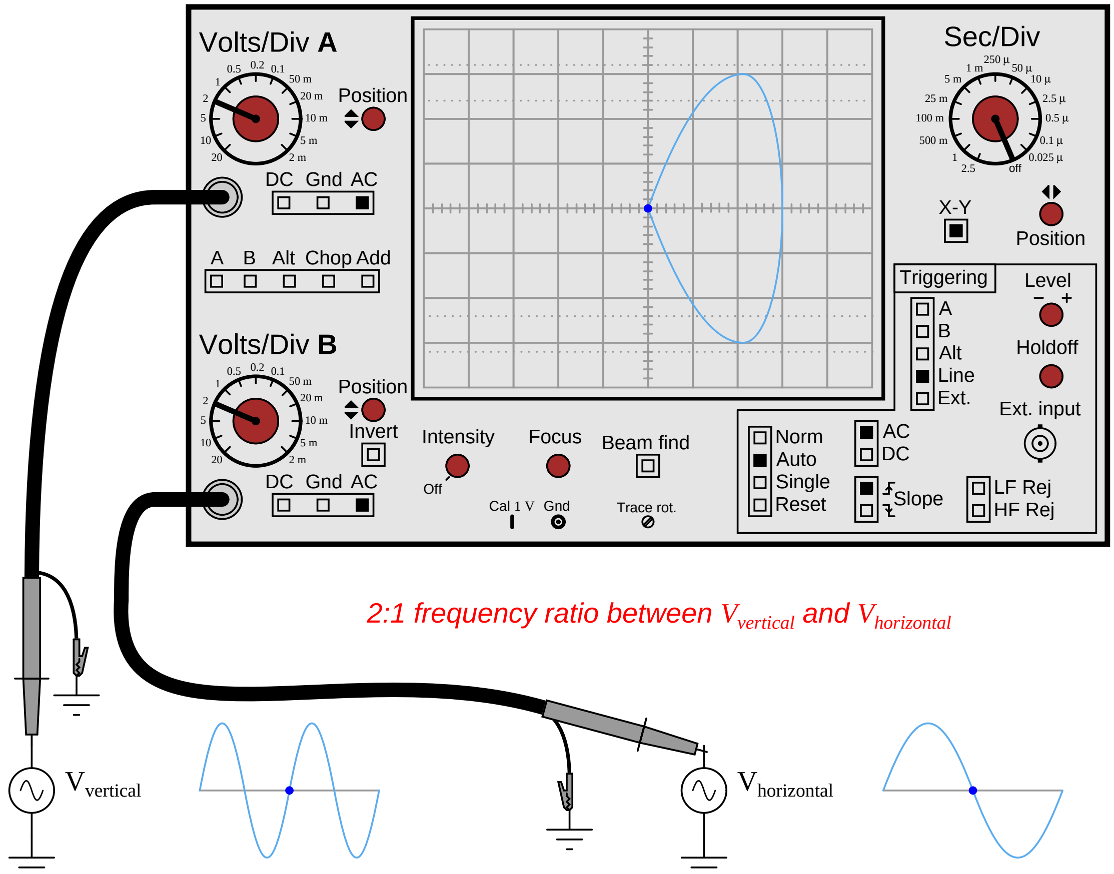


2:1 frequency ratio between $V_{vertical}$ and $V_{horizontal}$

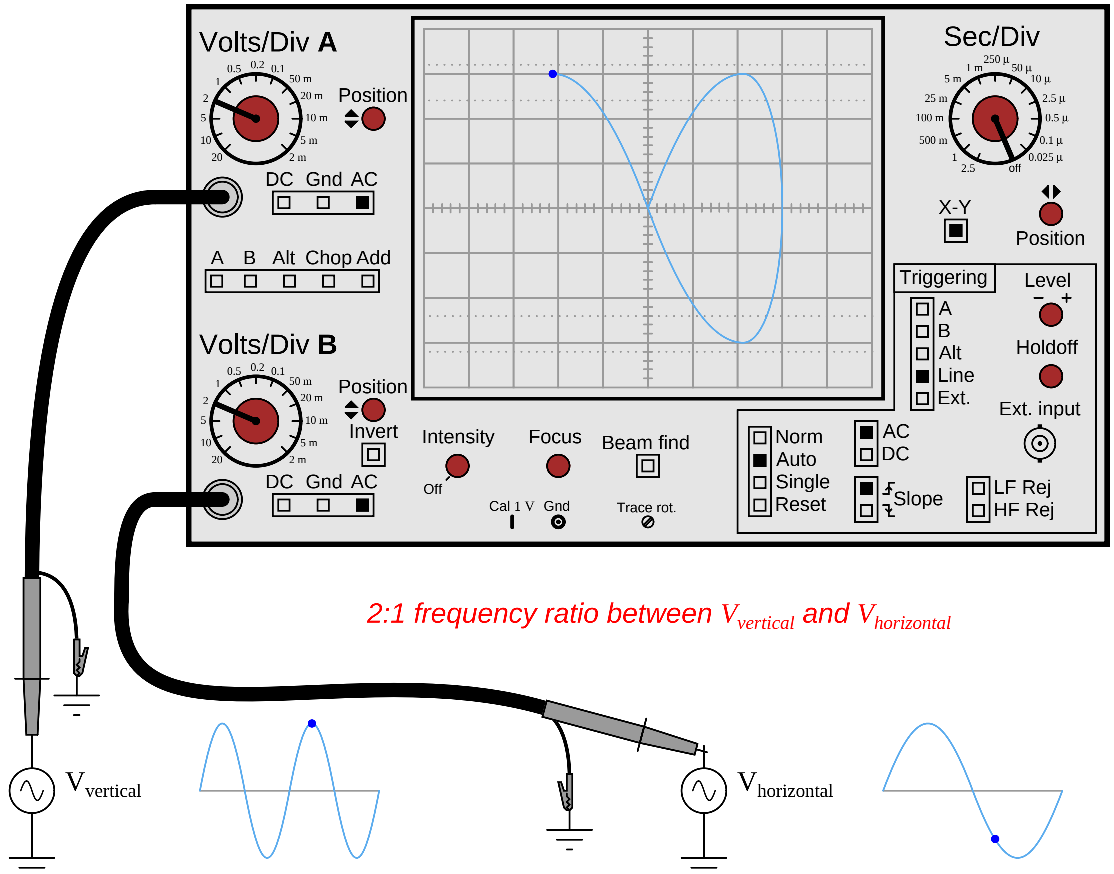




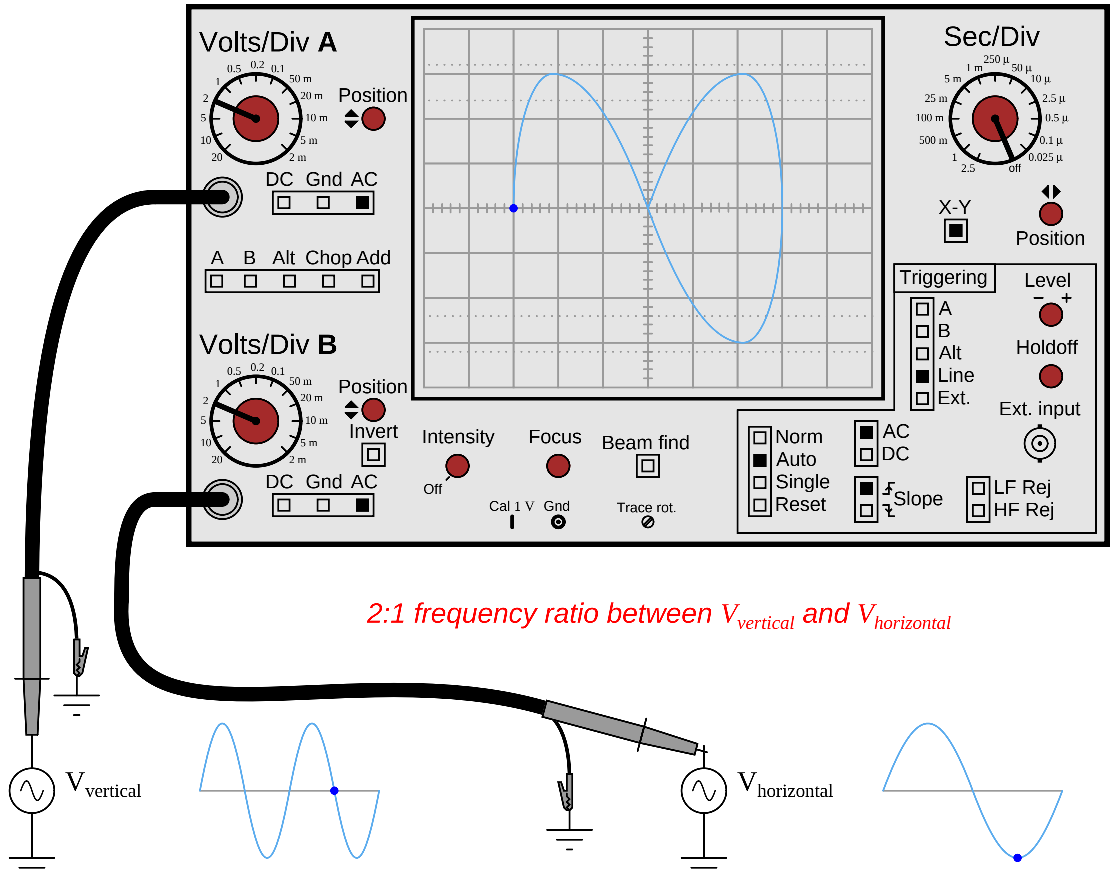
2:1 frequency ratio between $V_{vertical}$ and $V_{horizontal}$

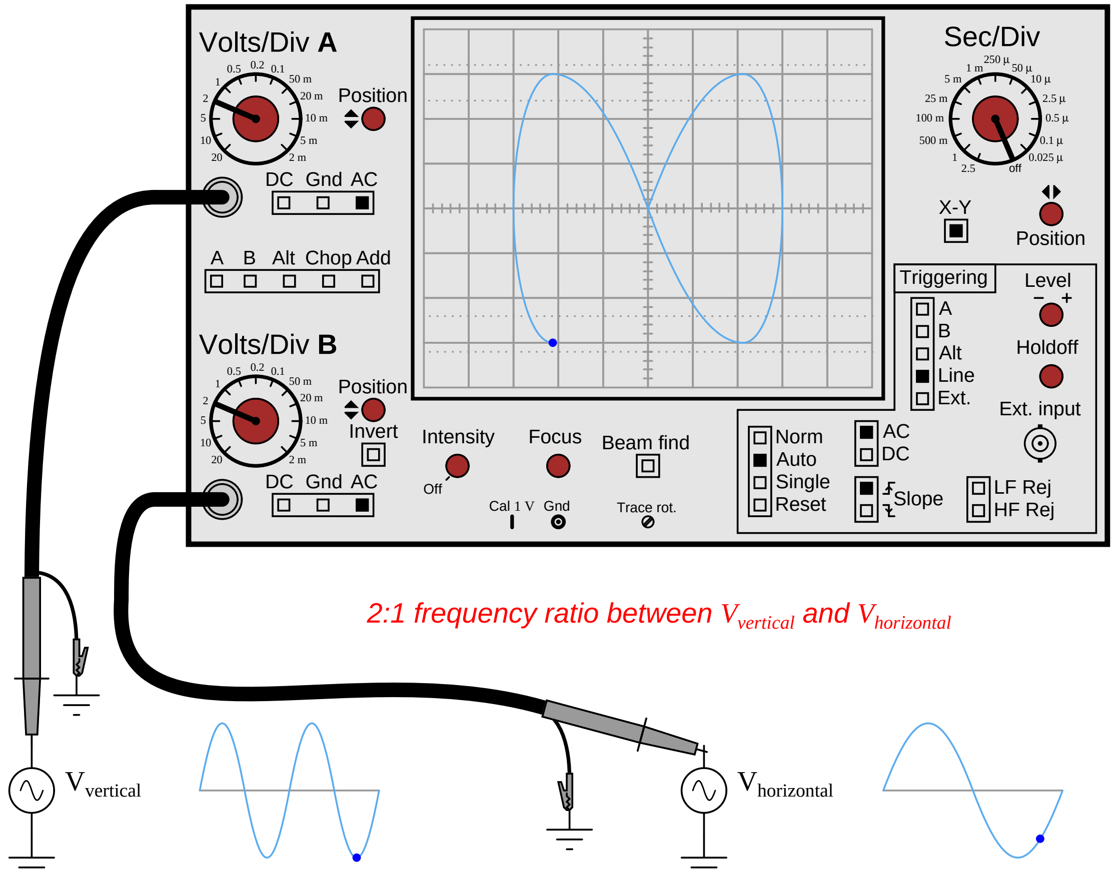


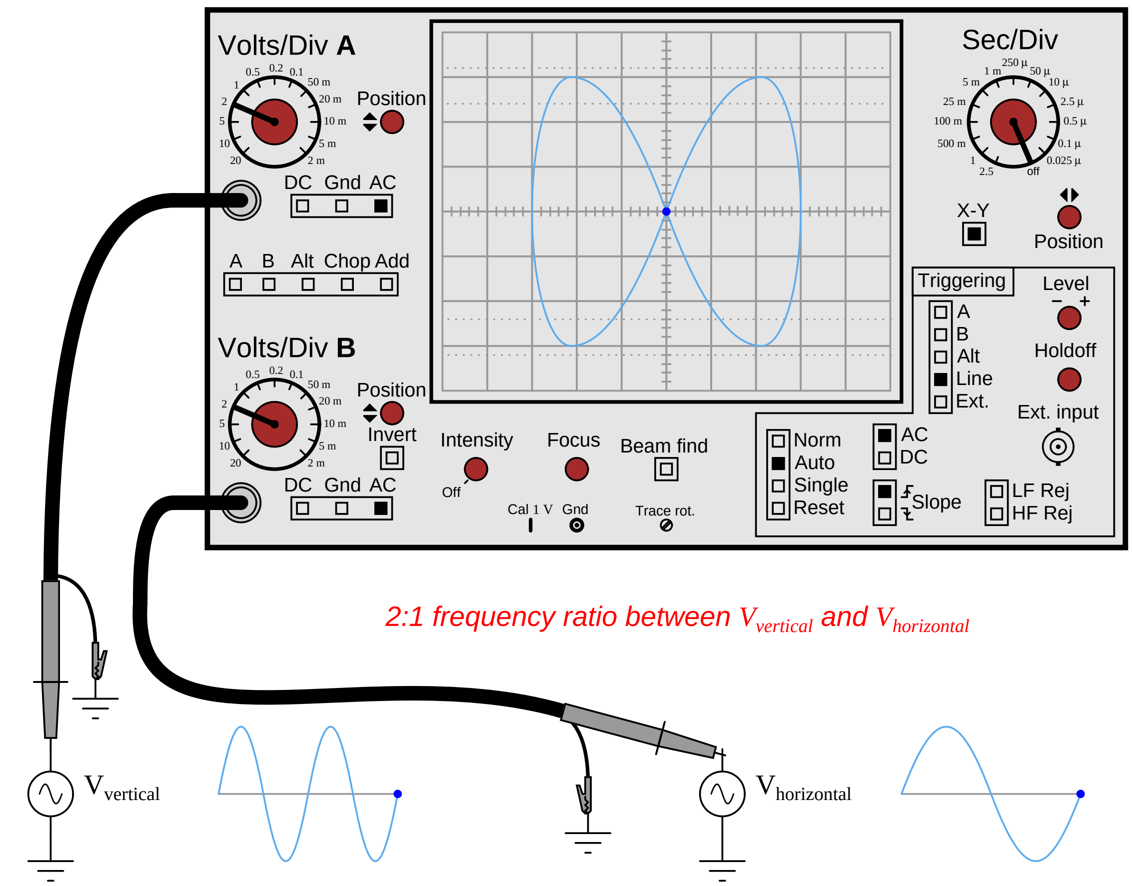
2:1 frequency ratio between $V_{vertical}$ and $V_{horizontal}$



2:1 frequency ratio between $V_{vertical}$ and $V_{horizontal}$


Volts/Div A
Position
DC Gnd AC
A B Alt Chop Add
Volts/Div B
Position
Invert
DC Gnd AC
Intensity
Off
Focus
Beam find
Cal 1 V
Gnd
Trace rot.
Sec/Div
X-Y
Position
Triggering
A
B
Alt
Line
Ext.
Level
Holdoff
Ext. input
Norm
Auto
Single
Reset
AC
DC
Slope
LF Rej
HF Rej
2:1 frequency ratio between $V_{vertical}$ and $V_{horizontal}$
$V_{vertical}$
$V_{horizontal}$


Volts/Div A
Position
DC Gnd AC
A B Alt Chop Add
Volts/Div B
Position
Invert
DC Gnd AC
Intensity
Off
Focus
Beam find
Cal 1 V Gnd
Trace rot.
Sec/Div
X-Y
Position
Triggering
A
B
Alt
Line
Ext.
Level
Holdoff
Ext. input
Norm
Auto
Single
Reset
AC
DC
Slope
LF Rej
HF Rej
2:1 frequency ratio between $V_{vertical}$ and $V_{horizontal}$
$V_{vertical}$
$V_{horizontal}$


Volts/Div A
Position
DC Gnd AC
A B Alt Chop Add
Volts/Div B
Position
Invert
DC Gnd AC
Intensity
Off
Focus
Beam find
Cal 1 V
Gnd
Trace rot.
Sec/Div
X-Y
Position
Triggering
A
B
Alt
Line
Ext.
Level
Holdoff
Ext. input
Norm
Auto
Single
Reset
AC
DC
Slope
LF Rej
HF Rej
2:1 frequency ratio between $V_{vertical}$ and $V_{horizontal}$
$V_{vertical}$
$V_{horizontal}$

file 03266

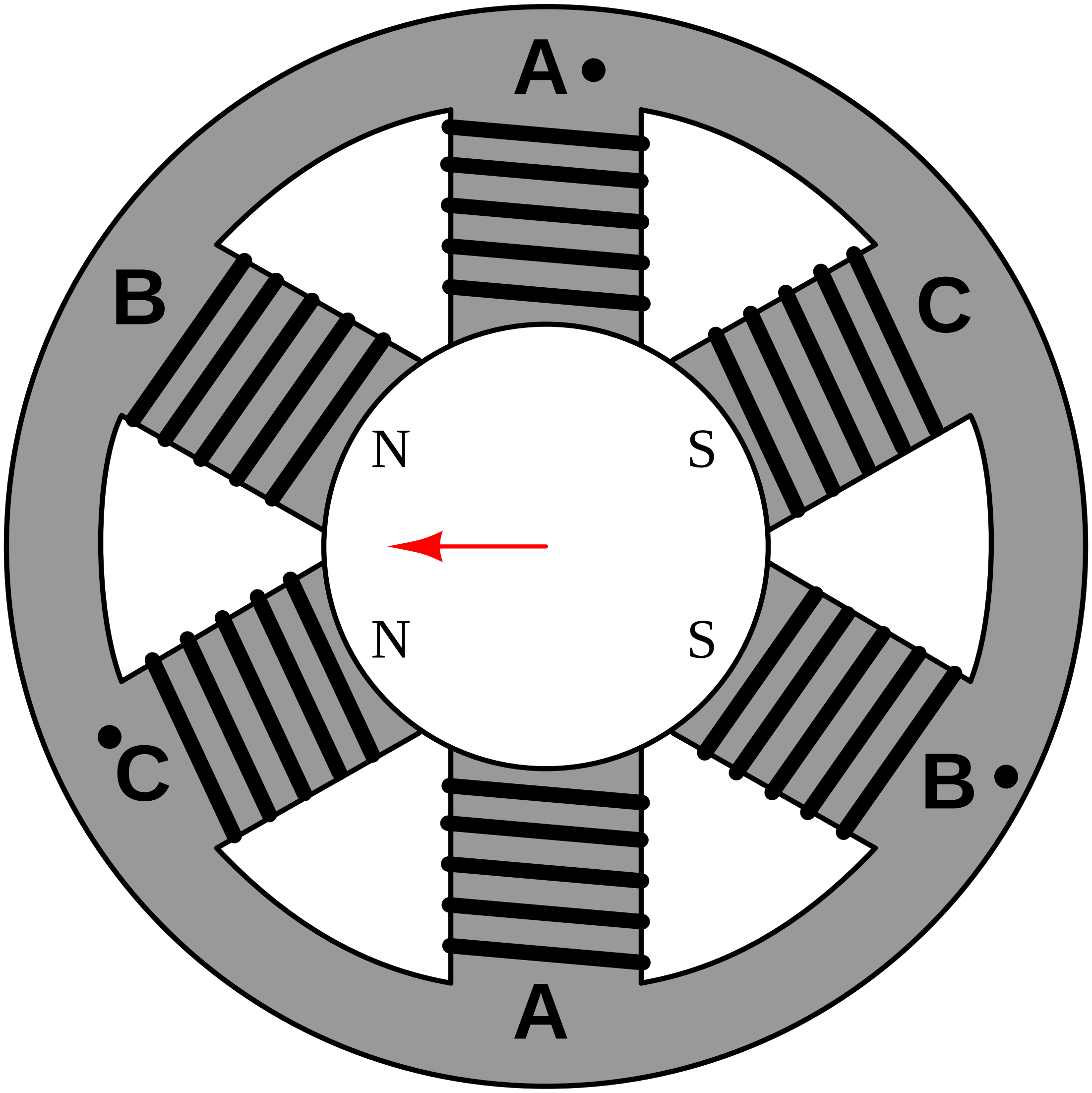
Question 8

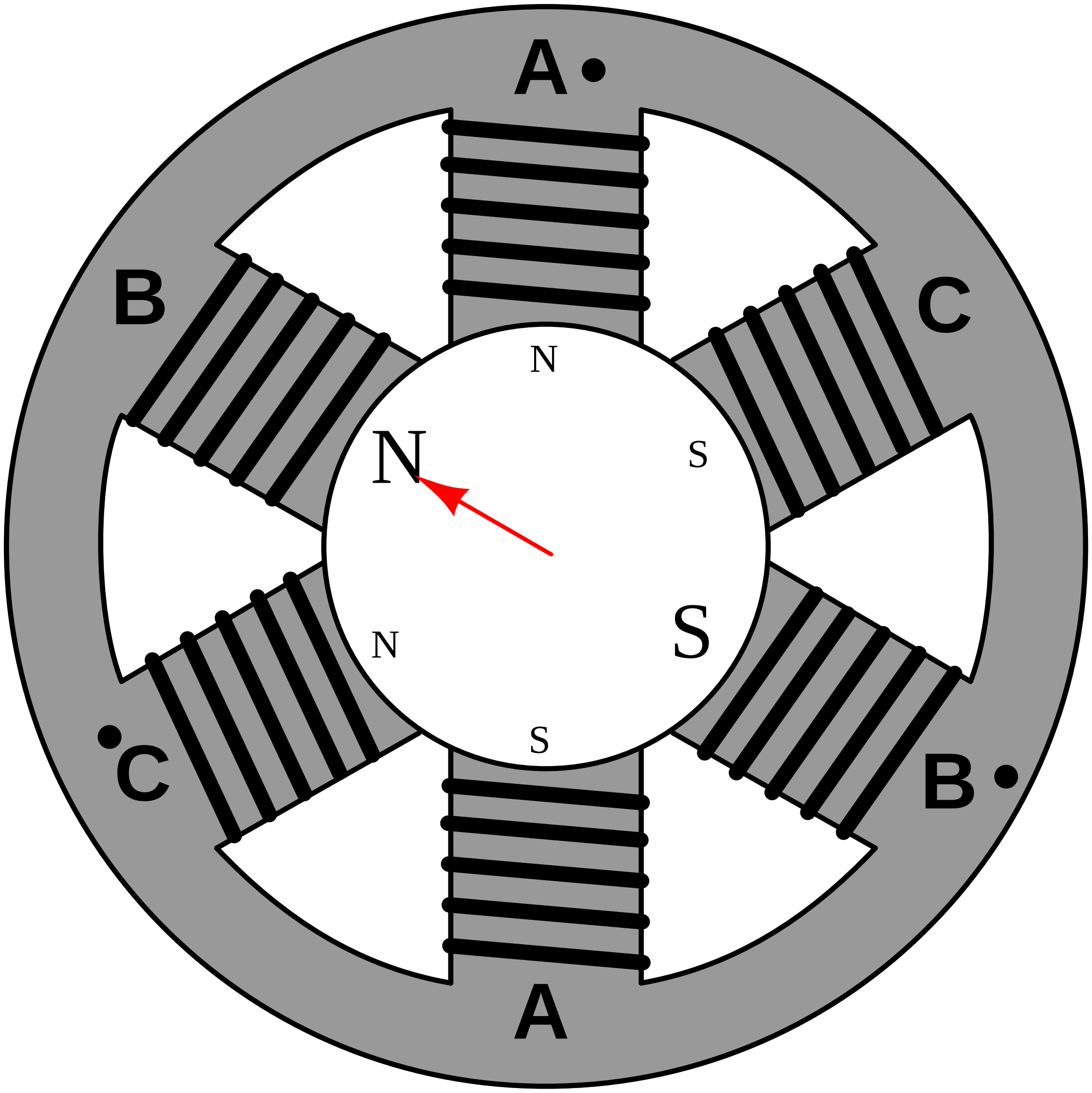
Animation: three-phase electric motor

This question consists of a series of images (one per page) that form an animation. Flip the pages with your fingers to view this animation (or click on the "next" button on your viewer) frame-by-frame.

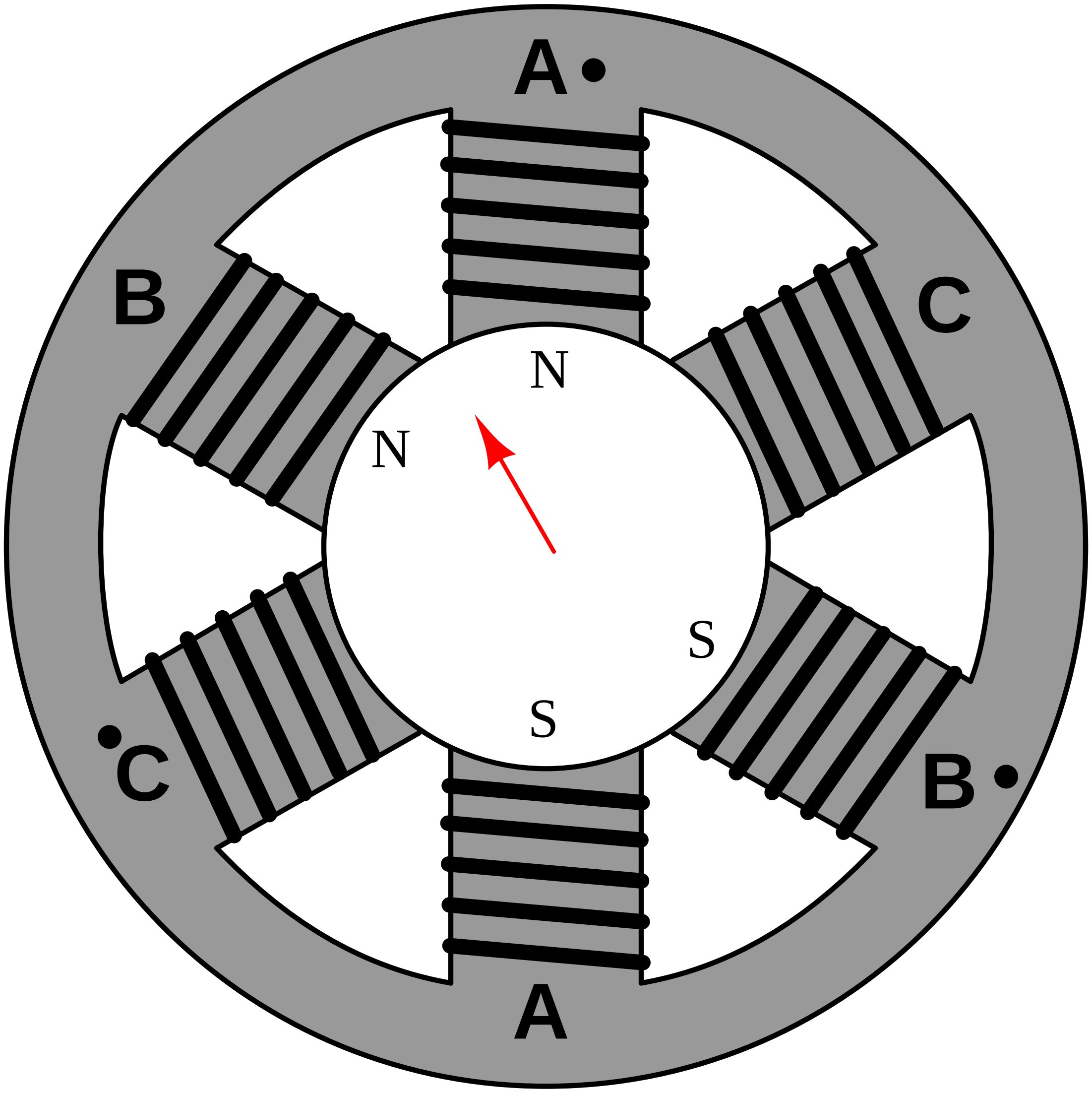
The following animation shows how three sets of electromagnet poles create a rotating magnetic field when energized by three-phase AC power. Relative strengths of the magnetic fields produced by each pair of poles are indicated by the size of the "N" (North) and "S" (South) letters. Here are some things to look for in this animation:

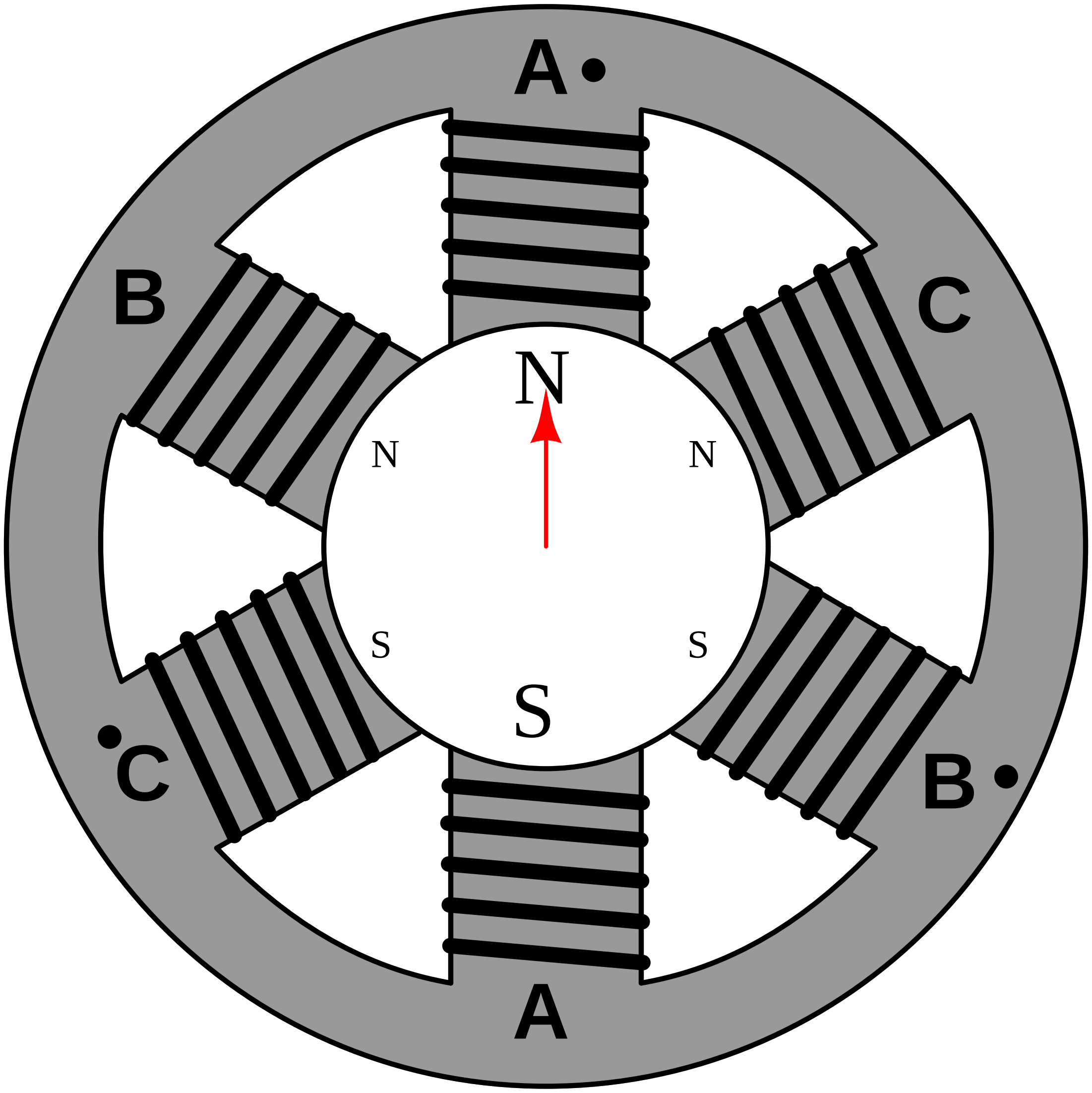
- What determines the direction of the vector arrow?
- Note when each pole pair (A and A', etc.) reaches its peak magnetic field strength.
- Is there any time where more than one pair of electromagnet poles is at its maximum field strength?

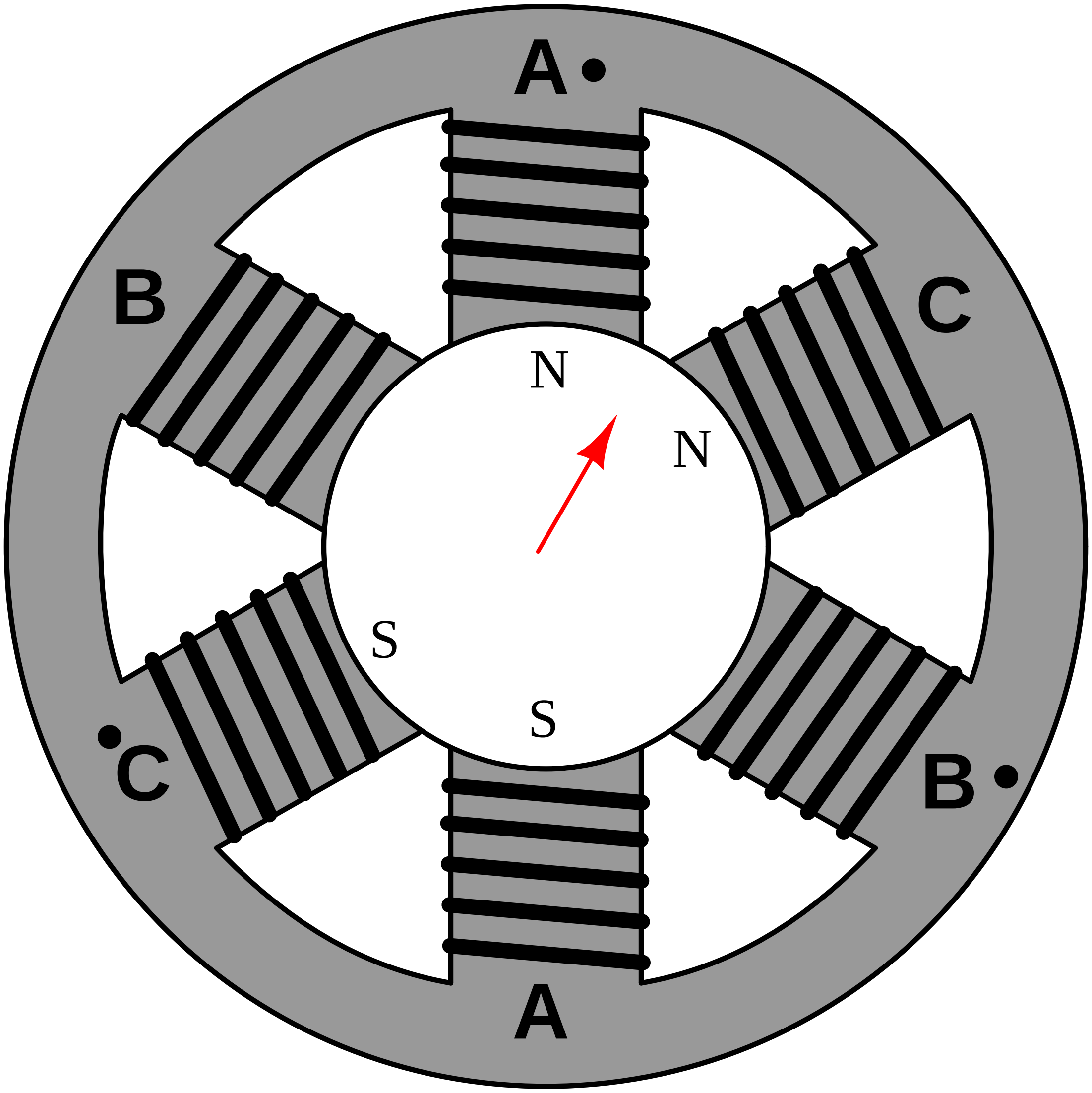

A
B
C
N
S
N
S
C
B
A

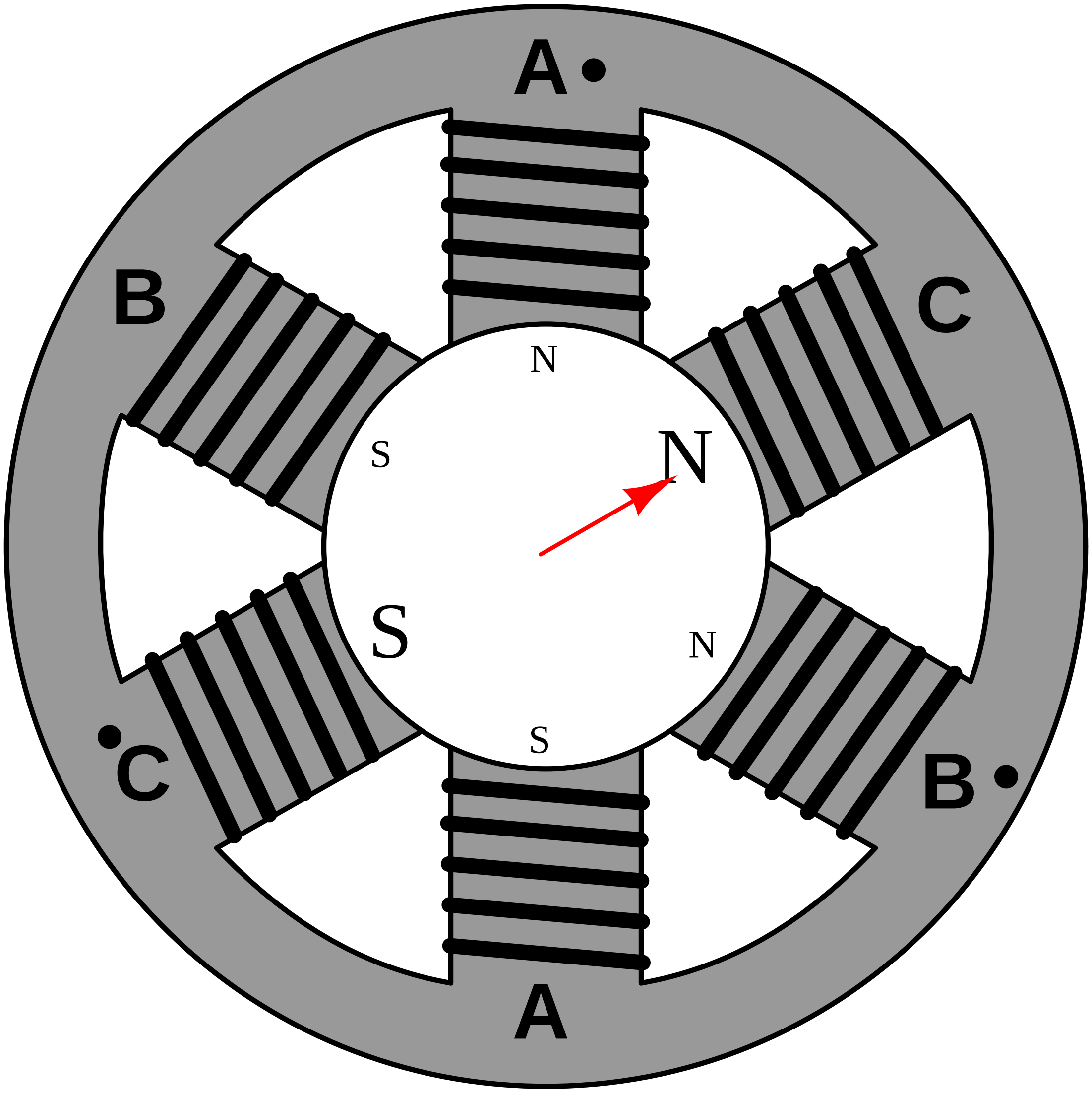


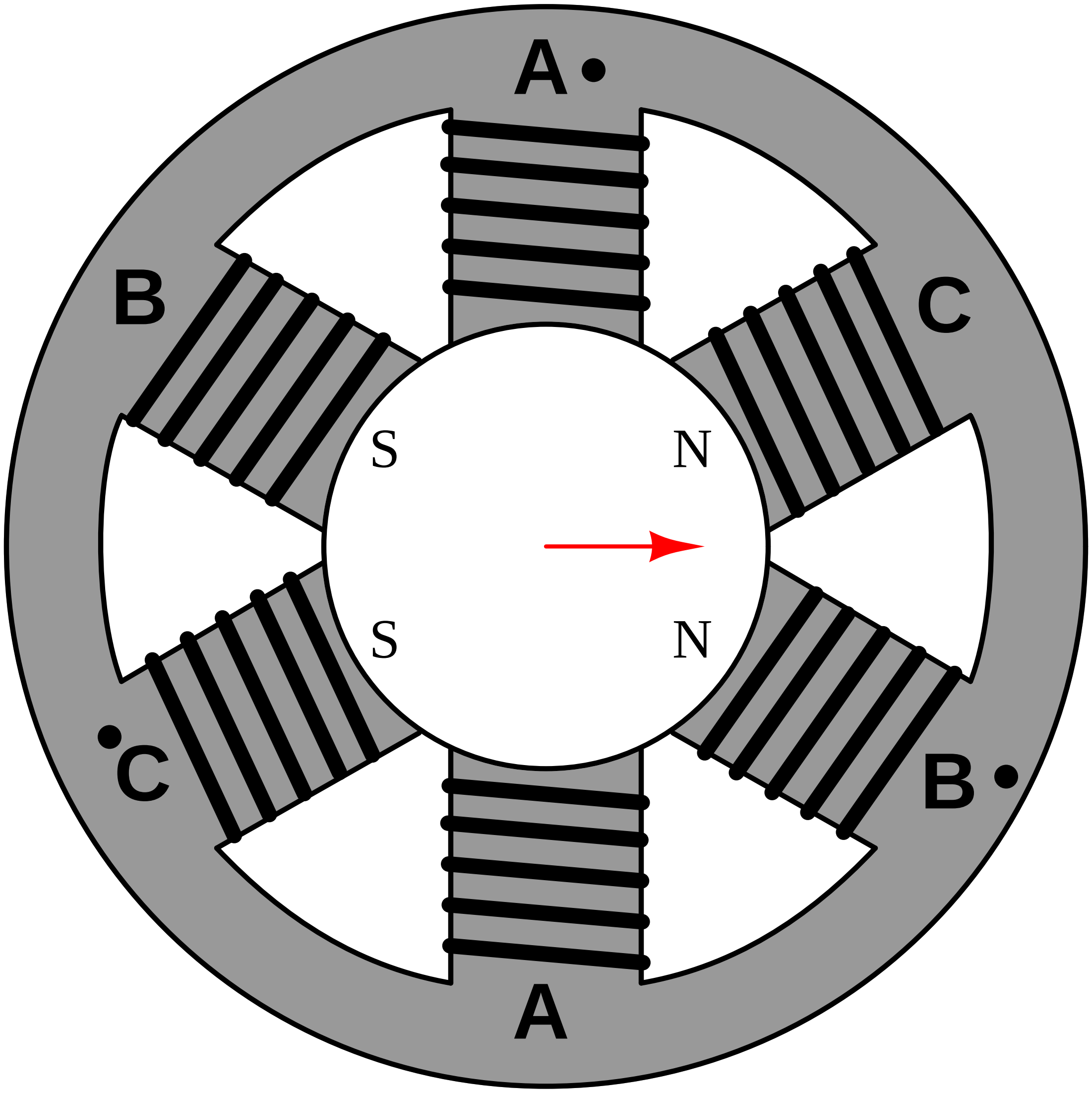
A
B
C
N
N
S
N
S
S
C
B
A

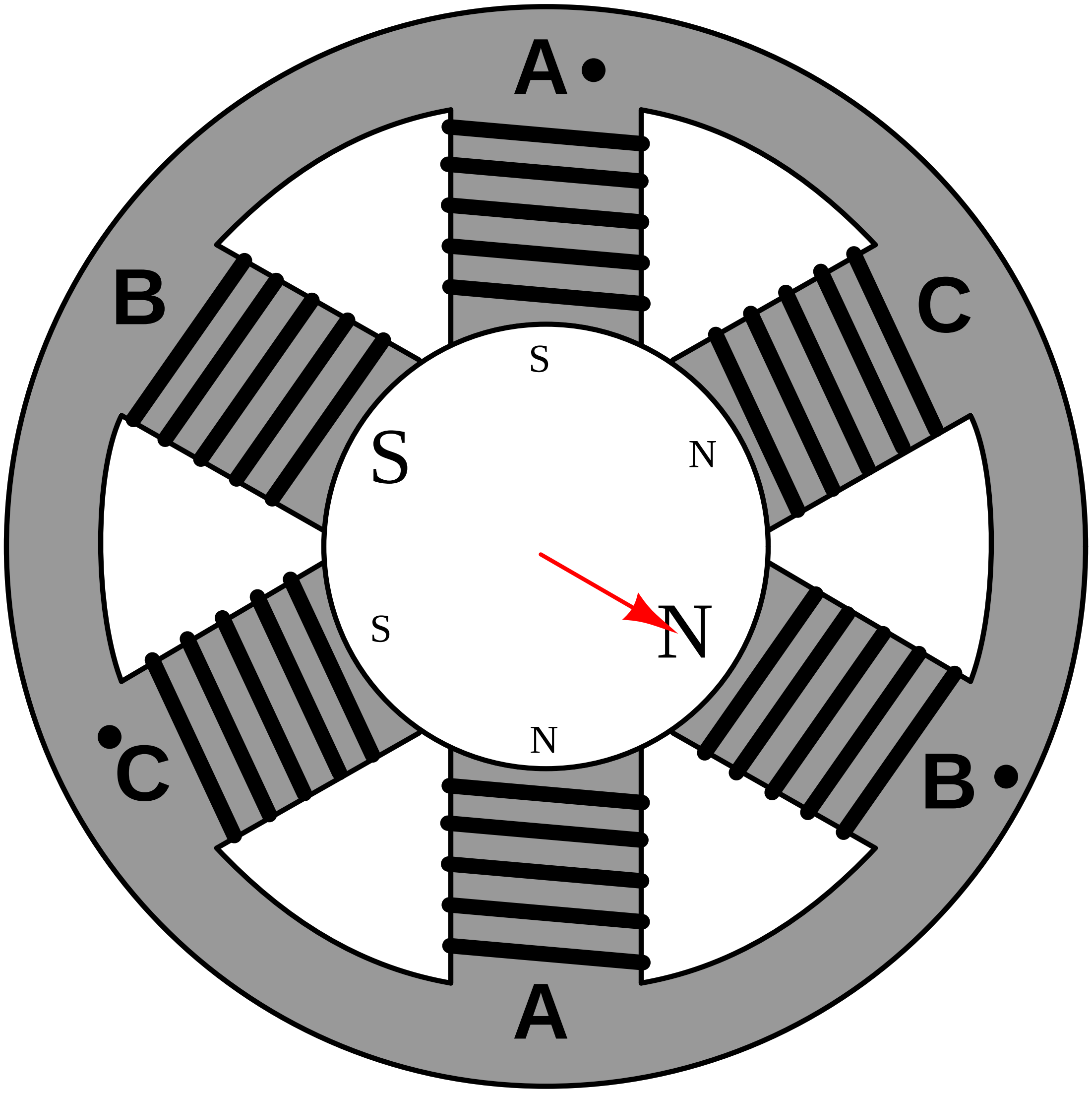

A
B
C
N
N
S
S
C
B
A

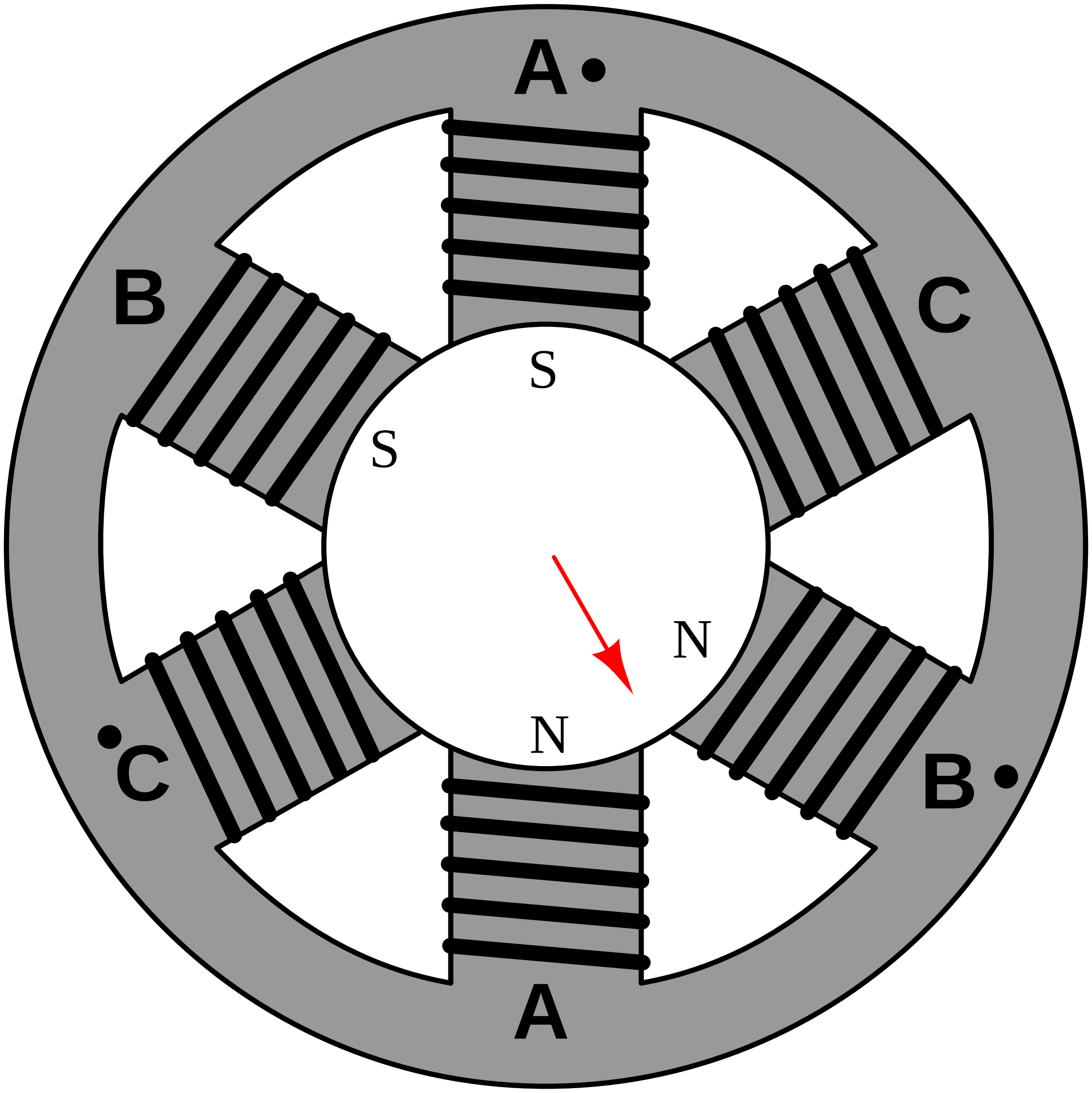

A
B
C
N
N
N
S
S
S
C
B
A

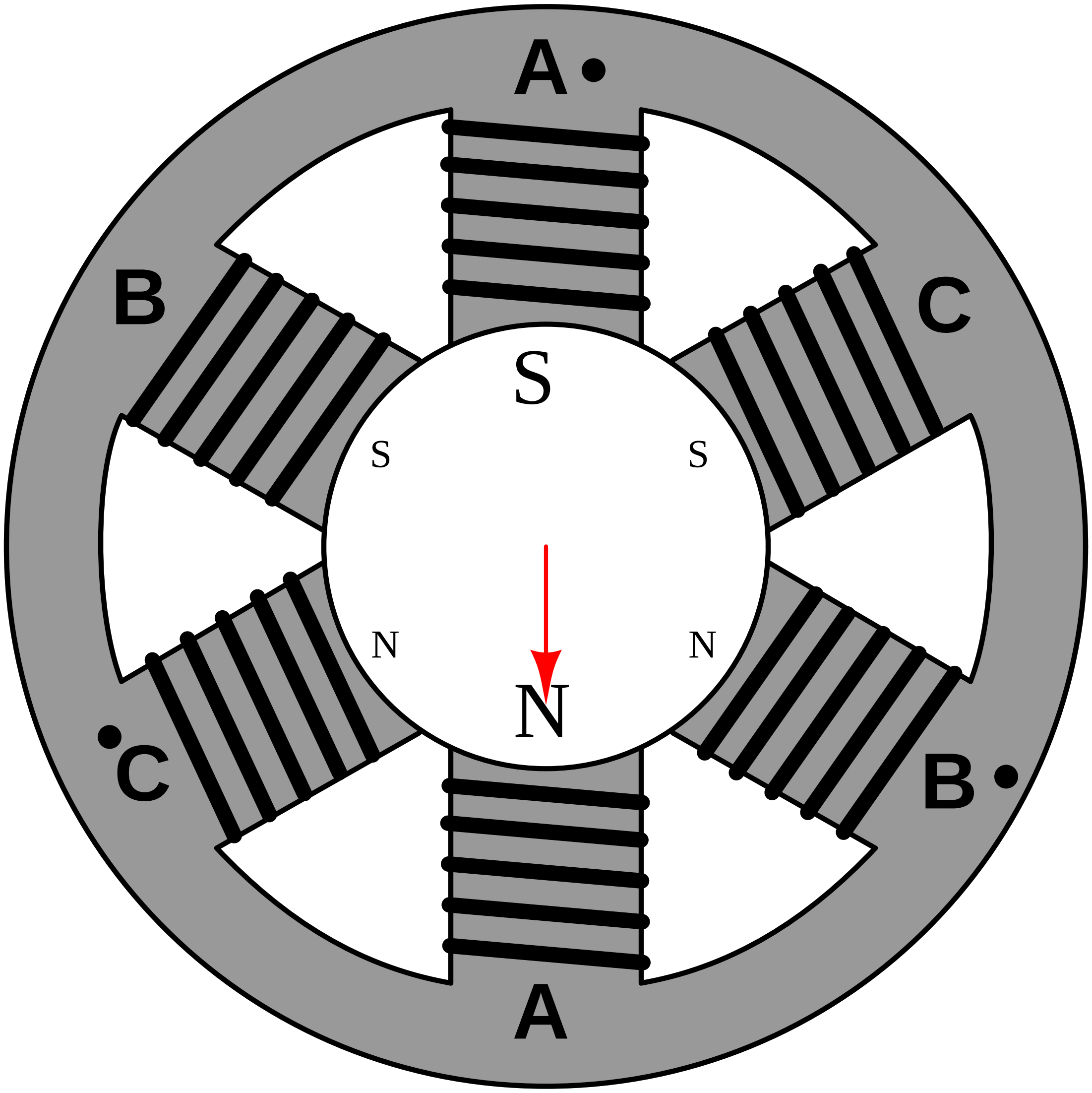

A
B
C
N
N
S
S
C
B
A

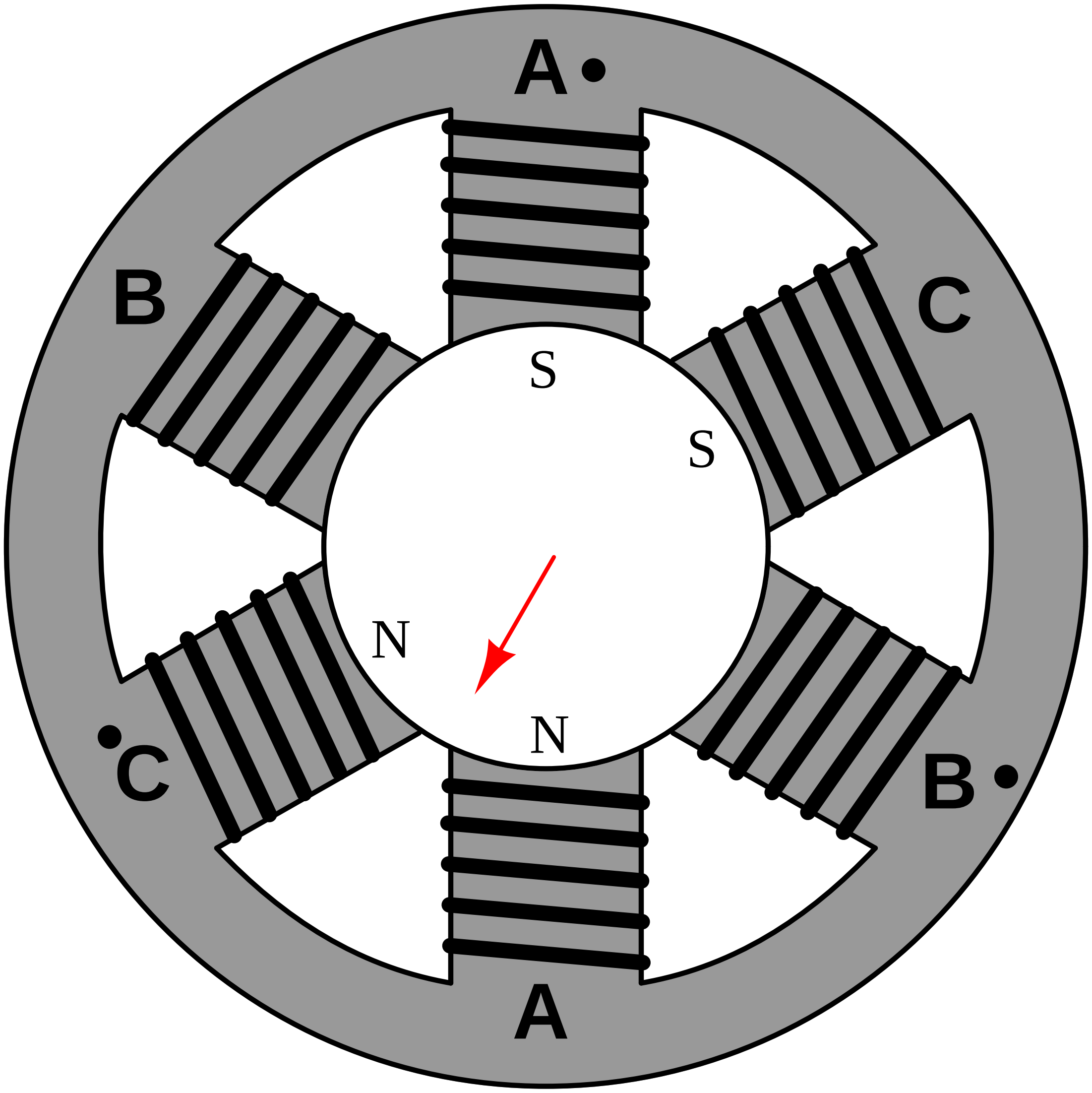

A
B
C
N
S
N
S
N
S
C
B
A

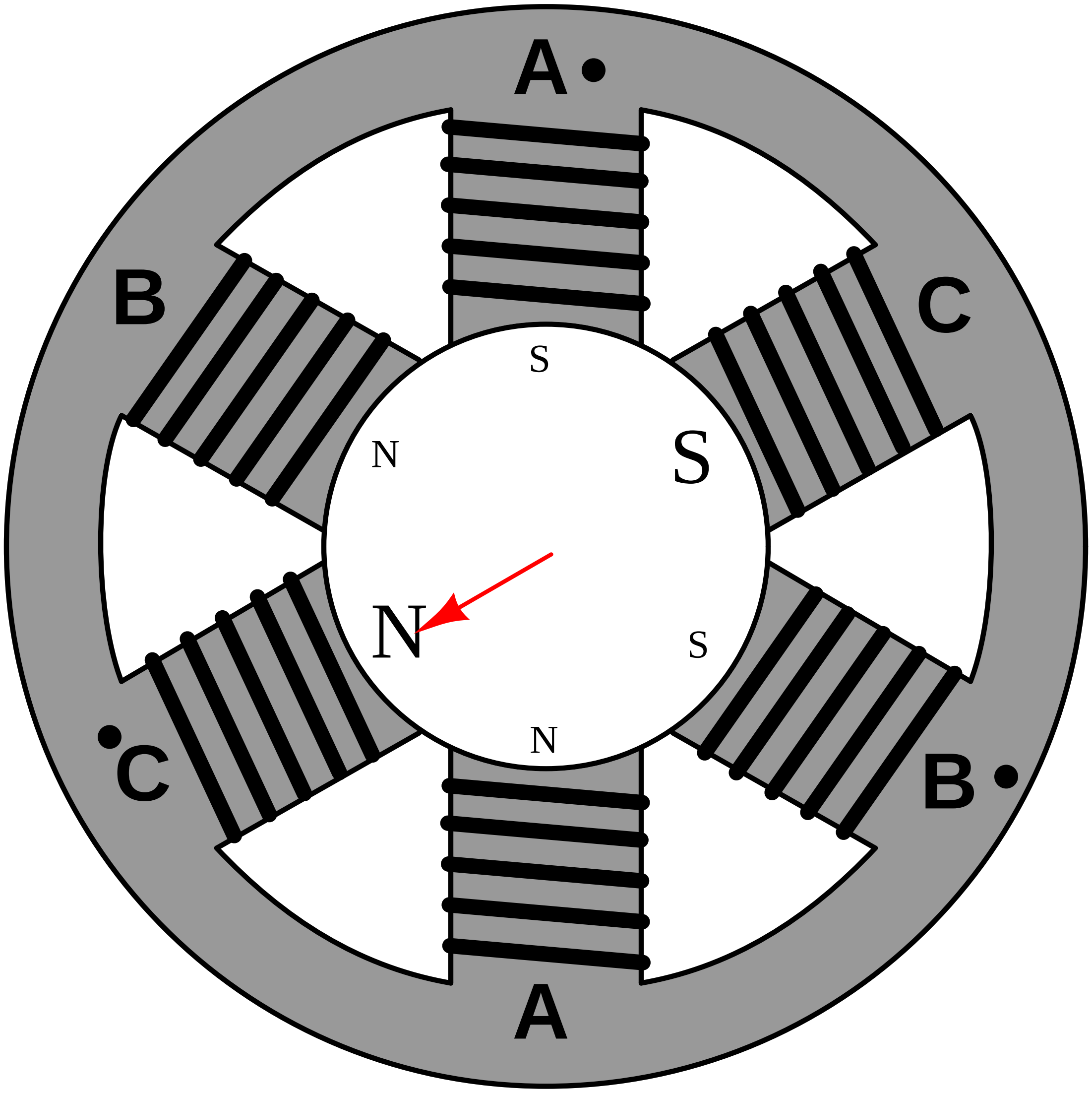

A
B
C
S
N
S
N
C
B
A


A
B
C
S
S
N
S
N
N
C
B
A


A
B
C
S
S
N
N
C
B
A


A
B
C
S
S
S
N
N
N
C
B
A


A
B
C
S
S
N
N
C
B
A



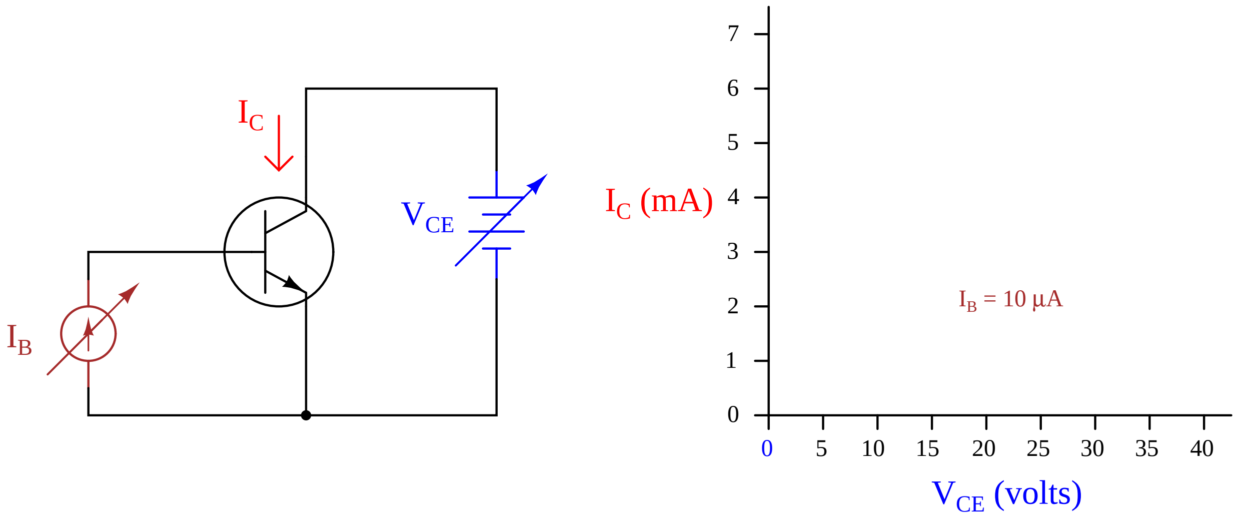
file 03232

Question 9

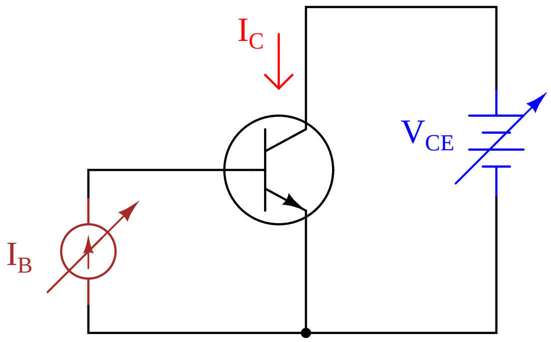
Animation: sketching characteristic curves for a transistor

This question consists of a series of images (one per page) that form an animation. Flip the pages with your fingers to view this animation (or click on the "next" button on your viewer) frame-by-frame.

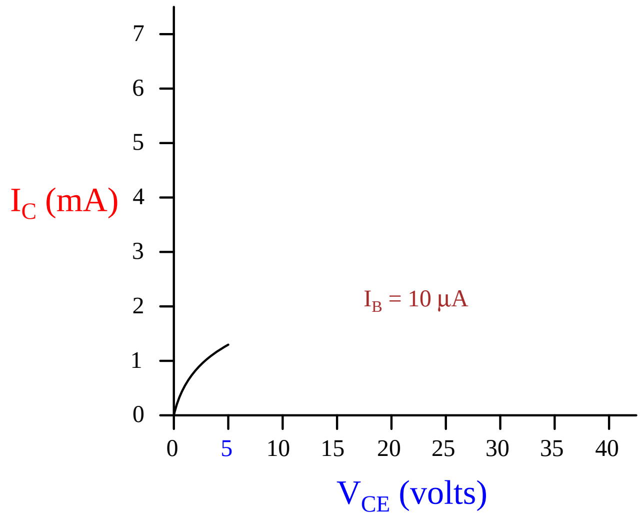
The following animation shows how a family of characteristic curves are sketched for a bipolar junction transistor. Pay close attention to what parameters are varied as each curve is sketched.



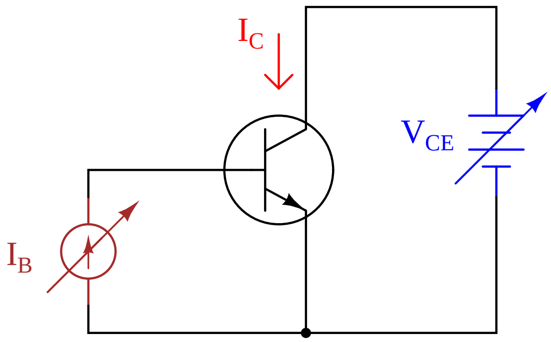
I_C
V_CE
I_B
I_C (mA)
7
6
5
4
3
2
1
0
I_B = 10 µA
0
5
10
15
20
25
30
35
40
V_CE (volts)

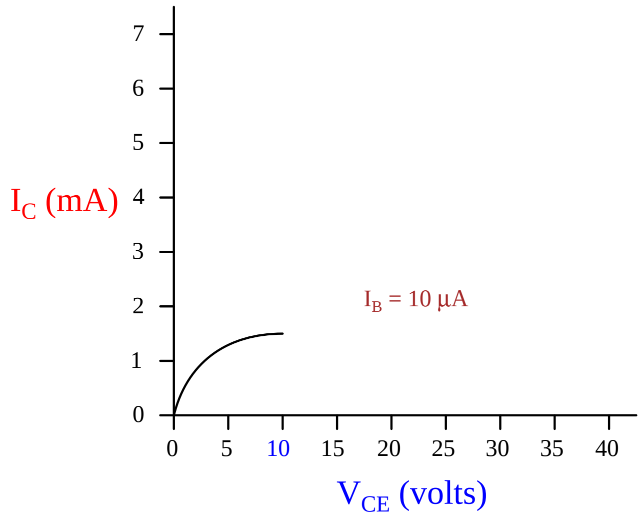


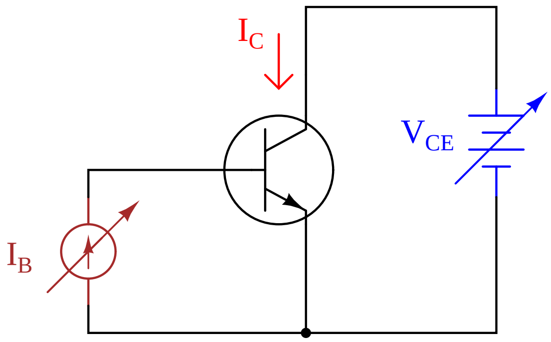
I_C
V_{CE}
I_B



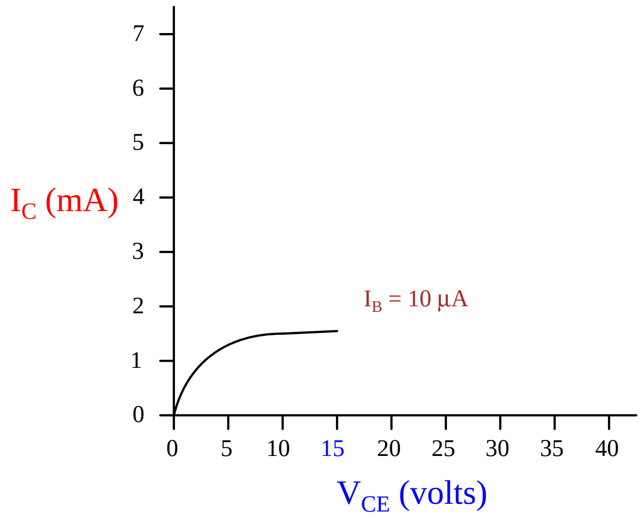
I_C (mA)
0
1
2
3
4
5
6
7
0
5
10
15
20
25
30
35
40
V_{CE} (volts)
I_B = 10 µA


I_C
V_CE
I_B

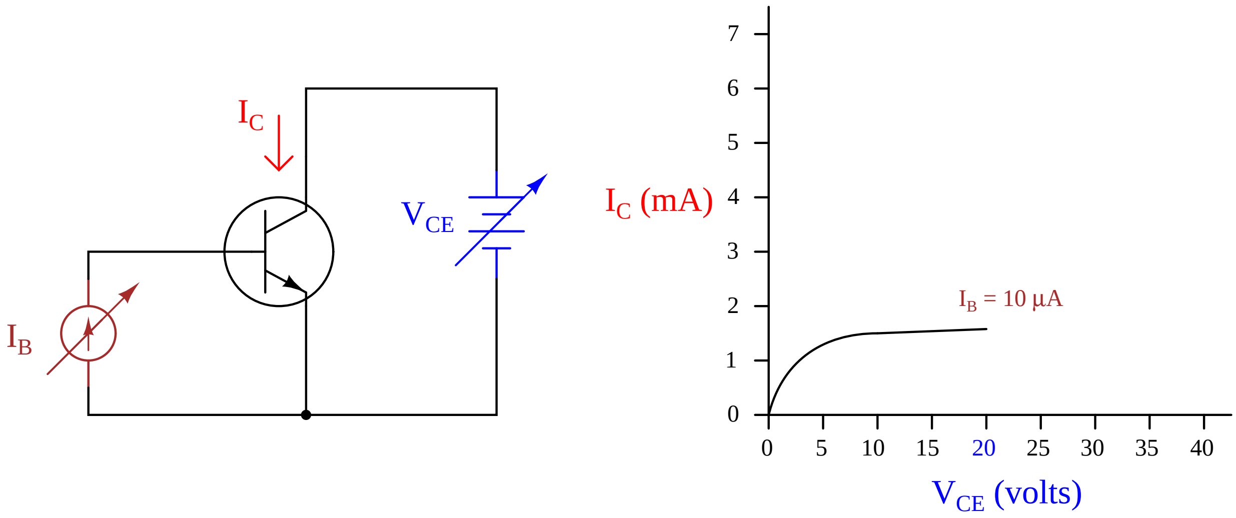

I_C (mA)
7
6
5
4
3
2
1
0
I_B = 10 µA
0
5
10
15
20
25
30
35
40
V_CE (volts)



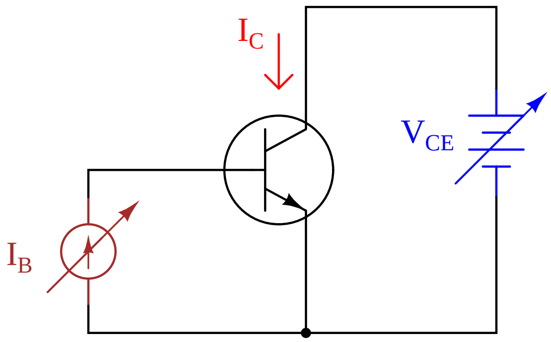
I_C
V_{CE}
I_B



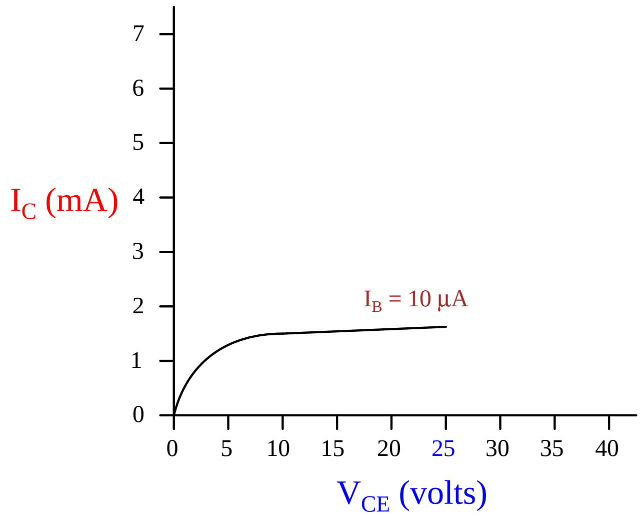
I_C (mA)
7
6
5
4
3
2
1
0
I_B = 10 µA
0
5
10
15
20
25
30
35
40
V_{CE} (volts)



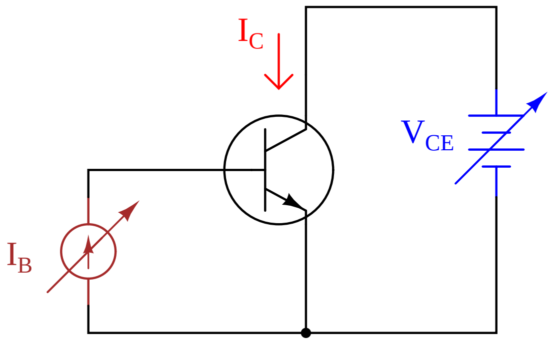
IC
VCE
IB
IC (mA)
7
6
5
4
3
2
1
0
IB = 10 µA
0
5
10
15
20
25
30
35
40
VCE (volts)



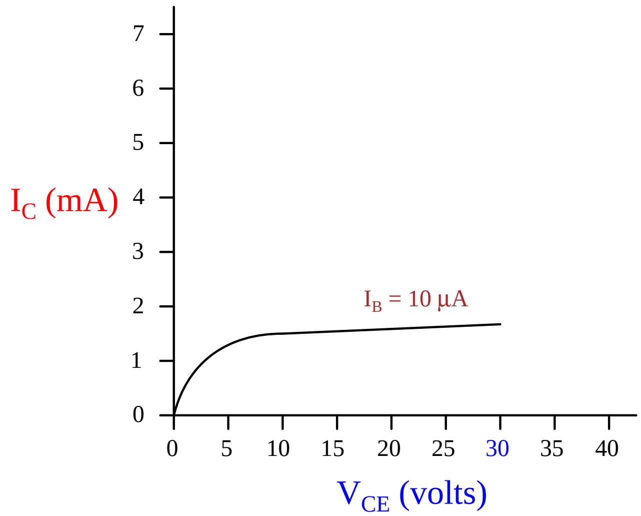
I_C
V_CE
I_B



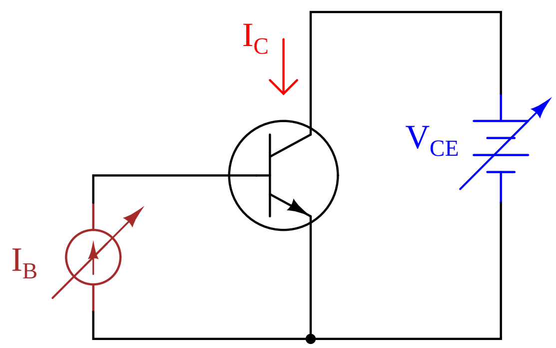
I_C (mA)
7
6
5
4
3
2
1
0
I_B = 10 µA
0
5
10
15
20
25
30
35
40
V_CE (volts)

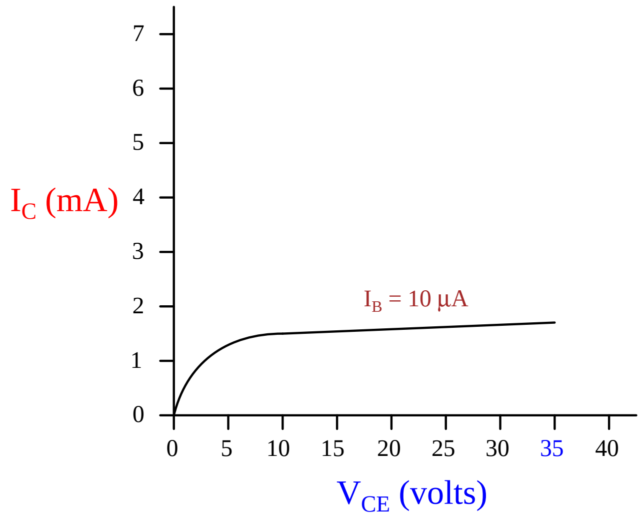


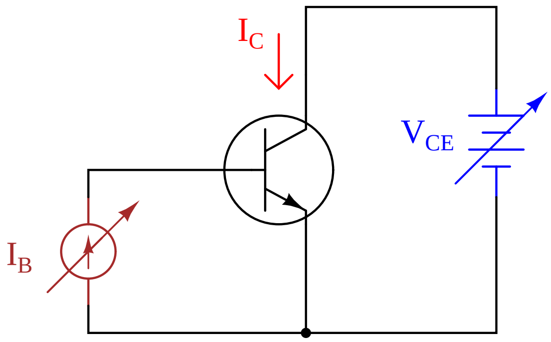
IC
VCE
IB



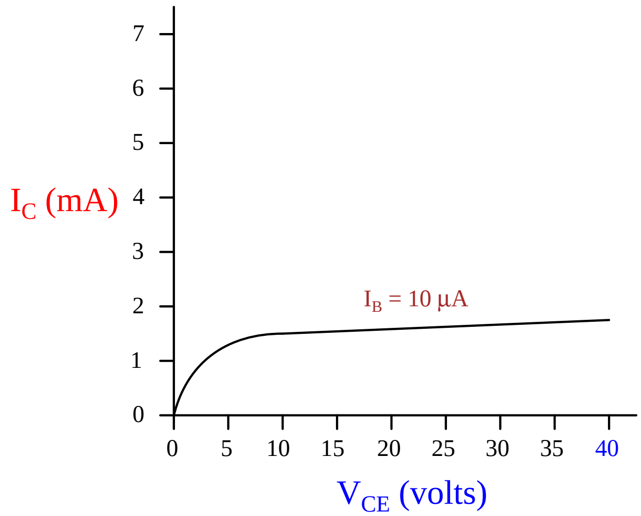
7
6
5
4
3
2
1
0
IC (mA)
IB = 10 µA
0
5
10
15
20
25
30
35
40
VCE (volts)


I_C
V_CE
I_B

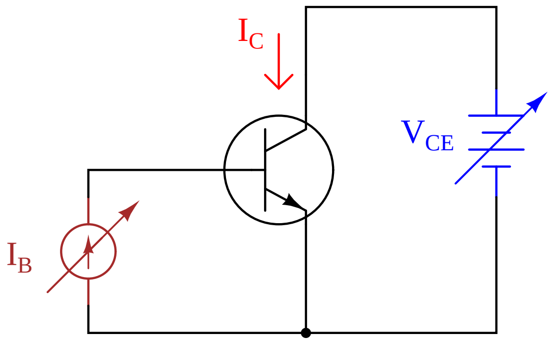

I_C (mA)
7
6
5
4
3
2
1
0
I_B = 10 μA
0
5
10
15
20
25
30
35
40
V_CE (volts)

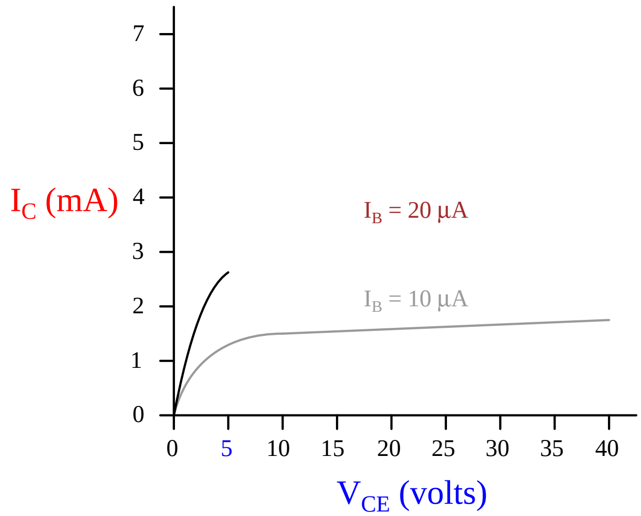


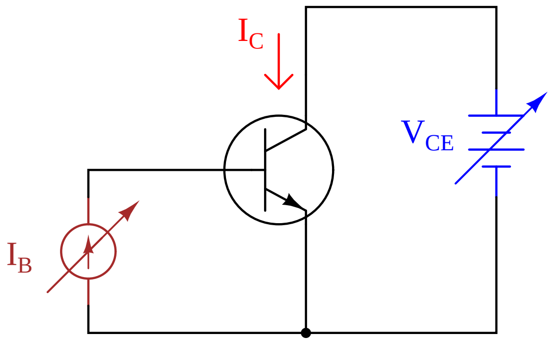
I_C
V_CE
I_B



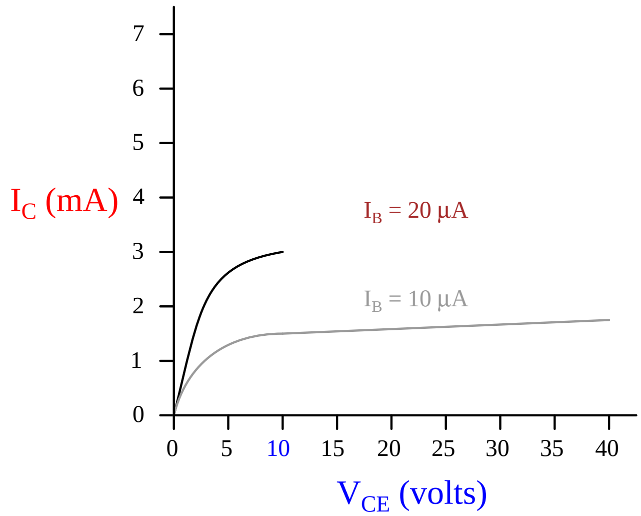
I_C (mA)
7
6
5
4
3
2
1
0
I_B = 10 μA
0
5
10
15
20
25
30
35
40
V_CE (volts)


I_C
V_{CE}
I_B

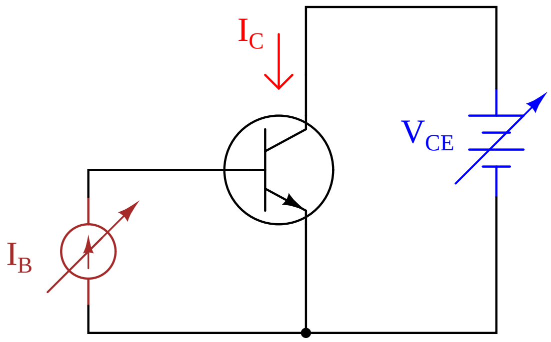

I_C (mA)
I_B = 20 µA
I_B = 10 µA
0 1 2 3 4 5 6 7
0 5 10 15 20 25 30 35 40
V_CE (volts)

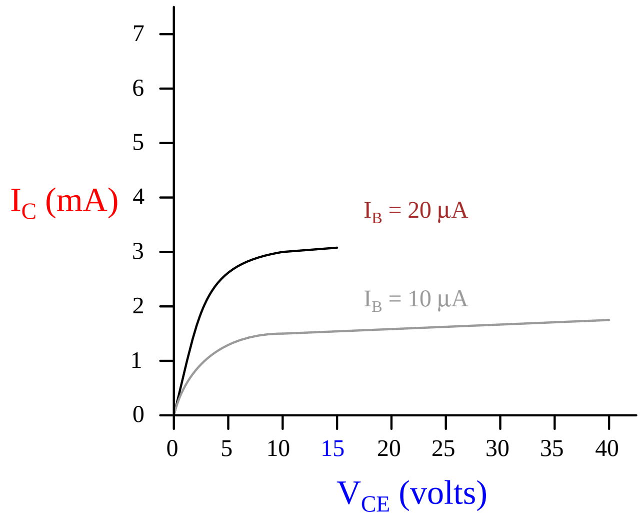


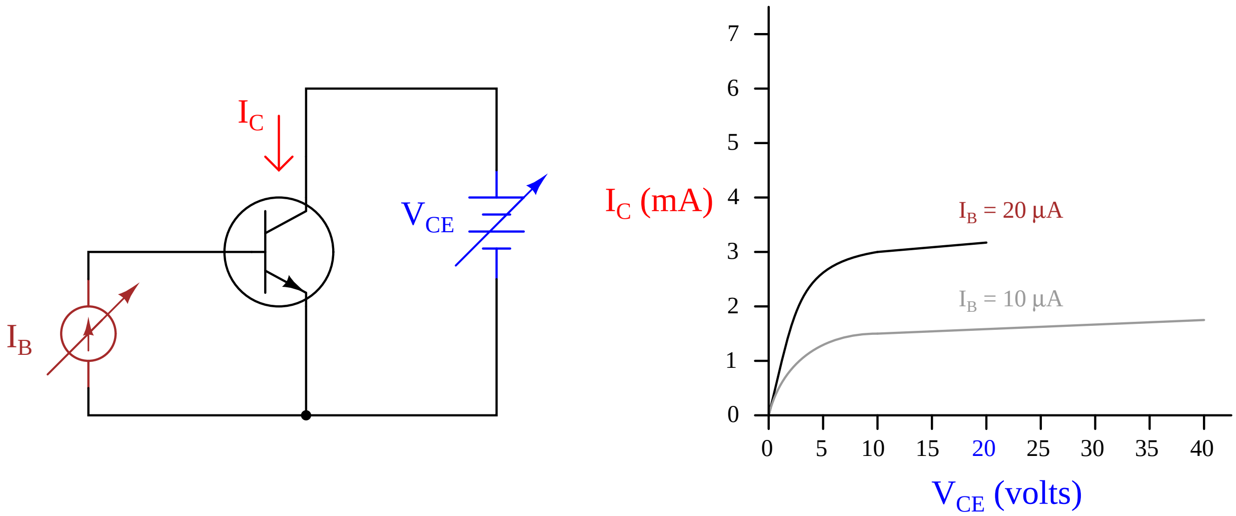
I_C
V_{CE}
I_B



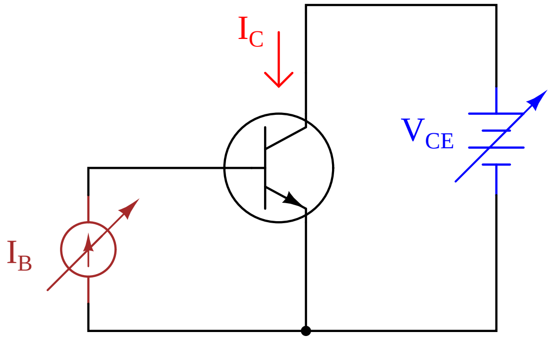
I_C (mA)
7
6
5
4
3
2
1
0
I_B = 20 µA
I_B = 10 µA
0 5 10 15 20 25 30 35 40
V_{CE} (volts)


I_C
V_CE
I_B

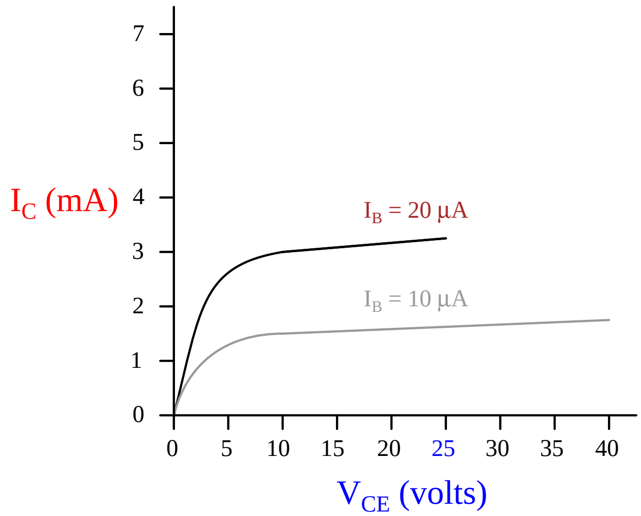

I_C (mA)
7
6
5
4
3
2
1
0
I_B = 20 µA
I_B = 10 µA
0
5
10
15
20
25
30
35
40
V_CE (volts)



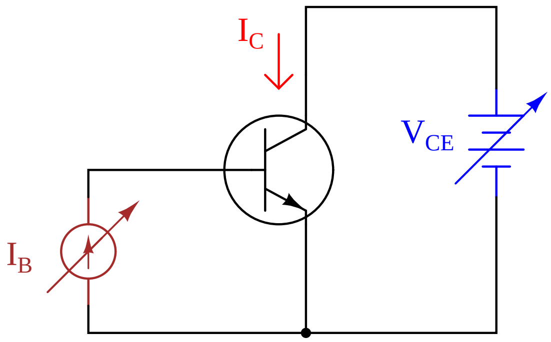
IC
VCE
IB
IC (mA)
IB = 20 µA
IB = 10 µA
0 1 2 3 4 5 6 7
0 5 10 15 20 25 30 35 40
VCE (volts)



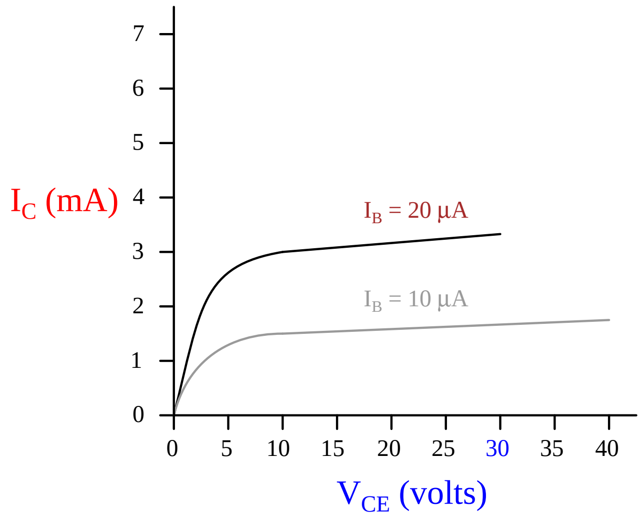
I_C
V_CE
I_B



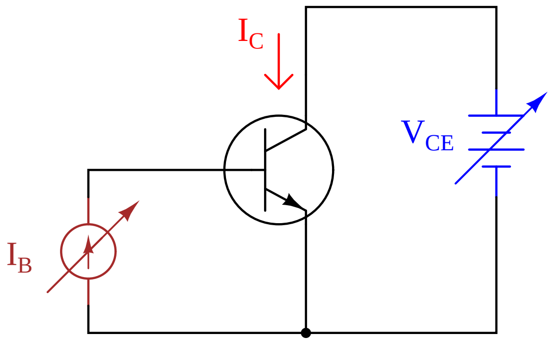
I_C (mA)
7
6
5
4
3
2
1
0
I_B = 20 µA
I_B = 10 µA
0
5
10
15
20
25
30
35
40
V_CE (volts)



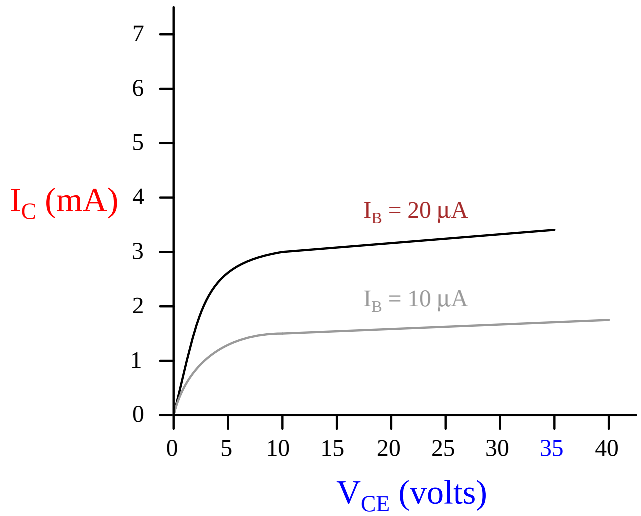
I_C
V_{CE}
I_B



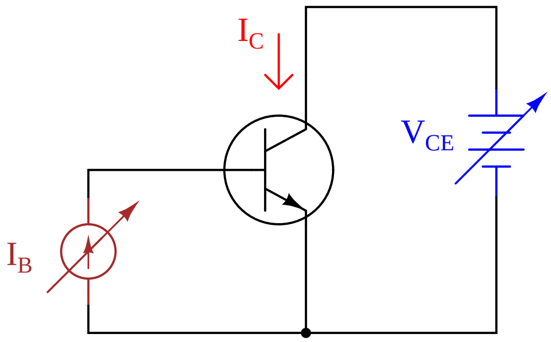
I_C (mA)
7
6
5
4
3
2
1
0
I_B = 20 µA
I_B = 10 µA
0
5
10
15
20
25
30
35
40
V_{CE} (volts)



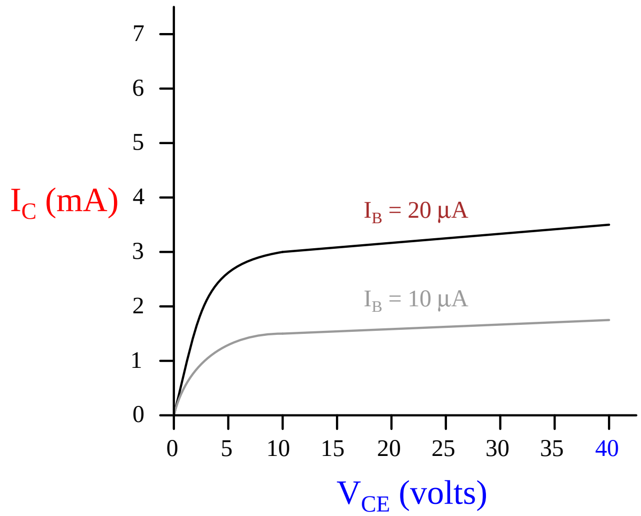
I_C
V_{CE}
I_B



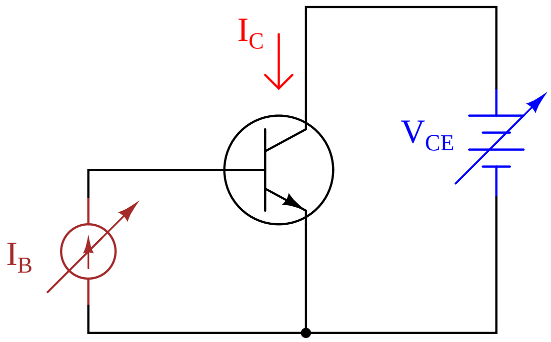
I_C (mA)
I_B = 20 µA
I_B = 10 µA
V_{CE} (volts)
0
1
2
3
4
5
6
7
0
5
10
15
20
25
30
35
40



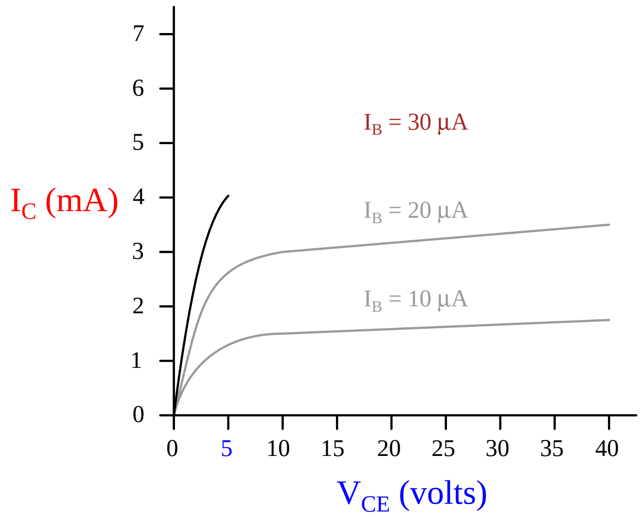
I_C
V_CE
I_B



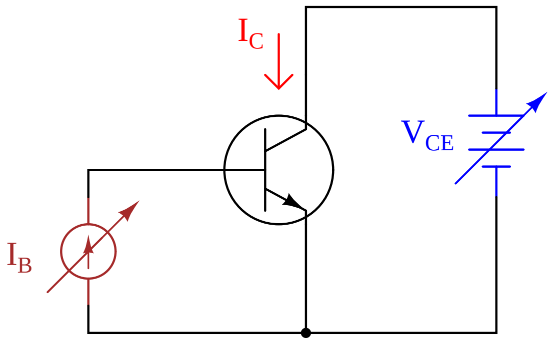
I_C (mA)
I_B = 20 µA
I_B = 10 µA
V_CE (volts)
0 1 2 3 4 5 6 7
0 5 10 15 20 25 30 35 40

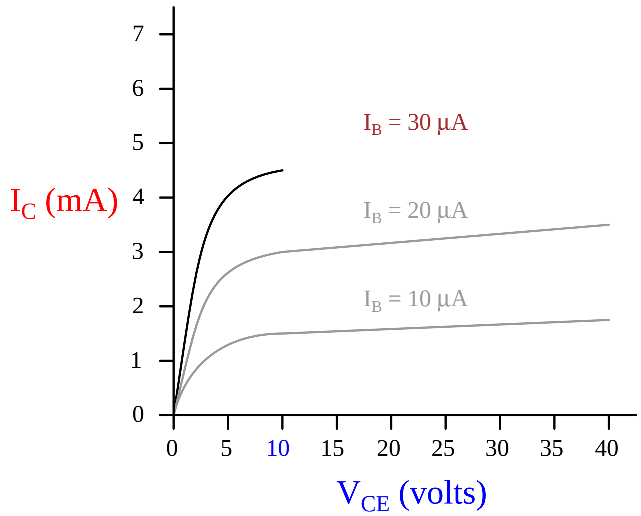


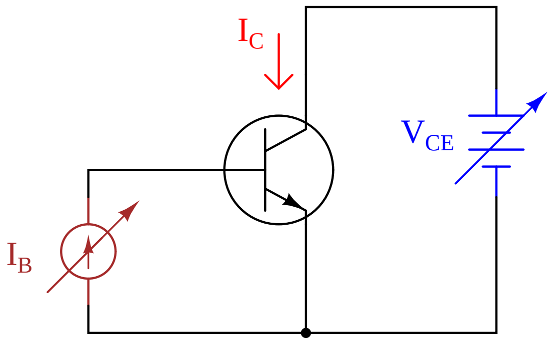
IC
VCE
IB

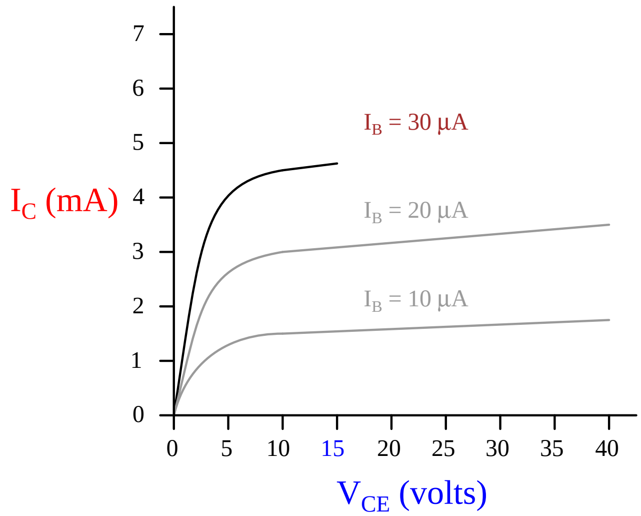


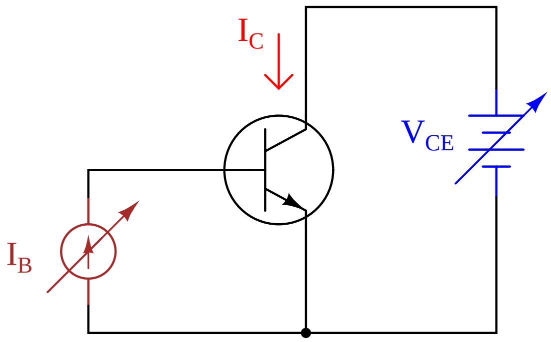
IC (mA)
7
6
5
4
3
2
1
0
IB = 30 µA
IB = 20 µA
IB = 10 µA
0
5
10
15
20
25
30
35
40
VCE (volts)

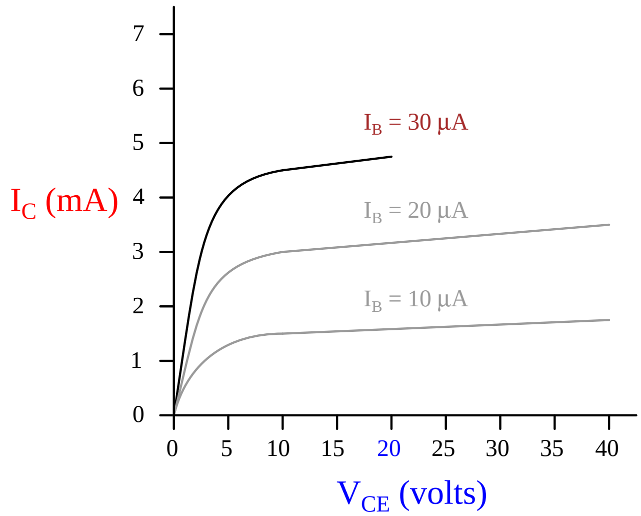

I_C
V_CE
I_B

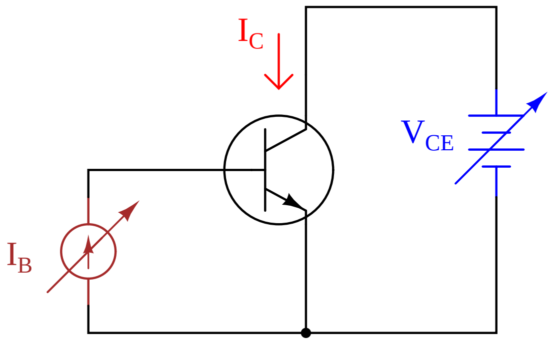

I_C (mA)
V_CE (volts)
I_B = 30 µA
I_B = 20 µA
I_B = 10 µA
0
1
2
3
4
5
6
7
0
5
10
15
20
25
30
35
40


I_C
V_CE
I_B

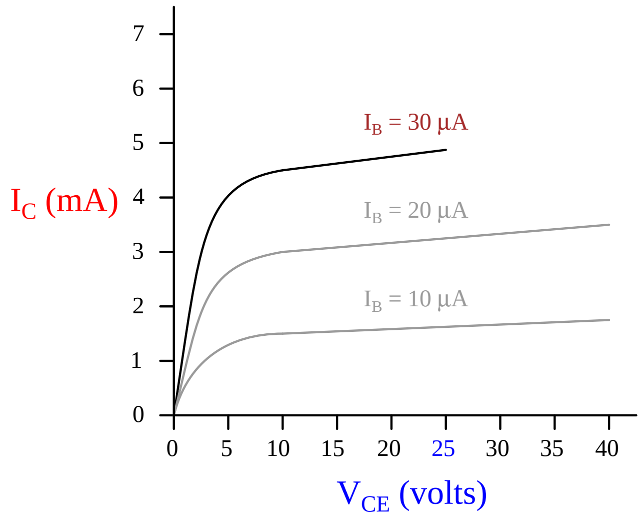

I_C (mA)
V_CE (volts)
I_B = 30 µA
I_B = 20 µA
I_B = 10 µA
0
1
2
3
4
5
6
7
0
5
10
15
20
25
30
35
40


I_C
V_CE
I_B

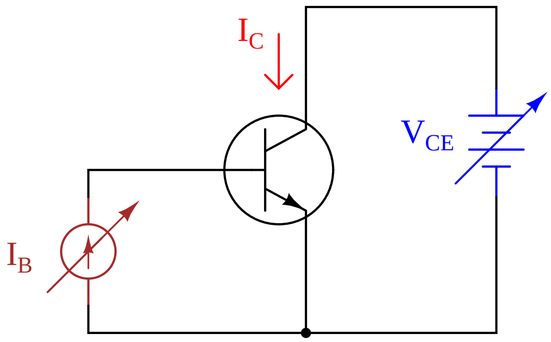

I_C (mA)
7
6
5
4
3
2
1
0
0 5 10 15 20 25 30 35 40
V_CE (volts)
I_B = 30 µA
I_B = 20 µA
I_B = 10 µA



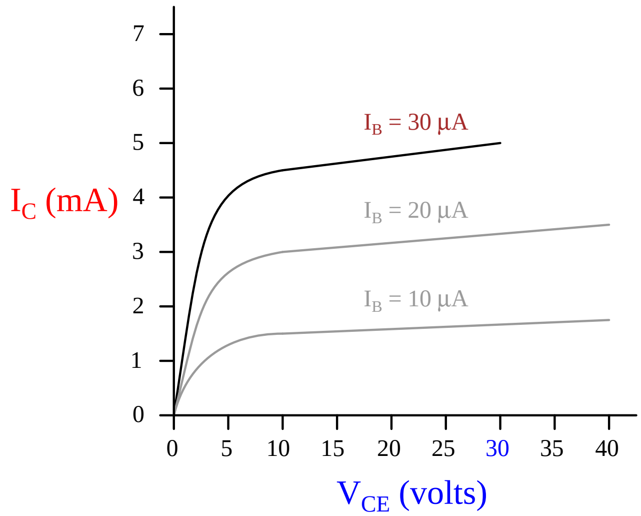
I_C
V_{CE}
I_B



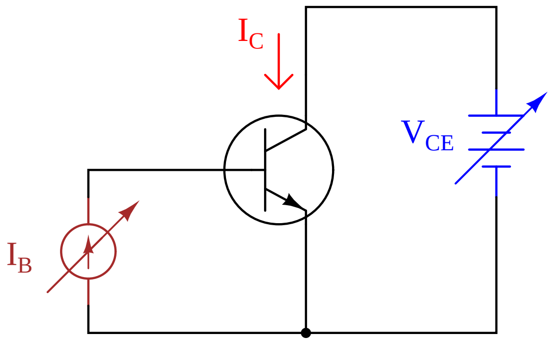
I_B = 30 µA
I_B = 20 µA
I_B = 10 µA
I_C (mA)
V_{CE} (volts)
0
1
2
3
4
5
6
7
0
5
10
15
20
25
30
35
40

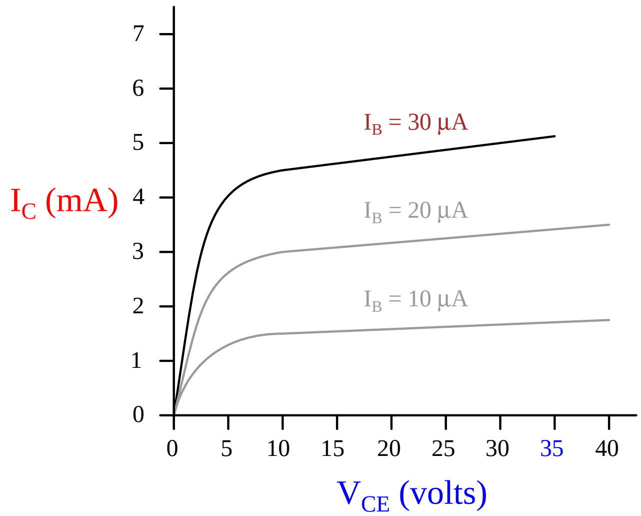


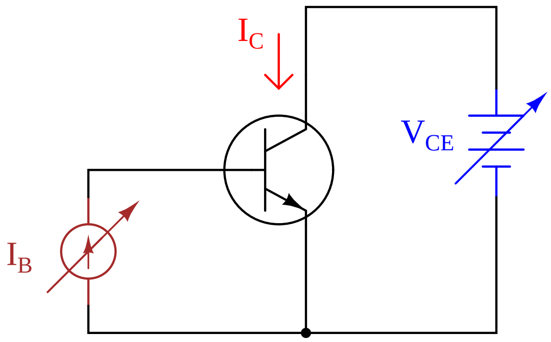
I_C
V_CE
I_B

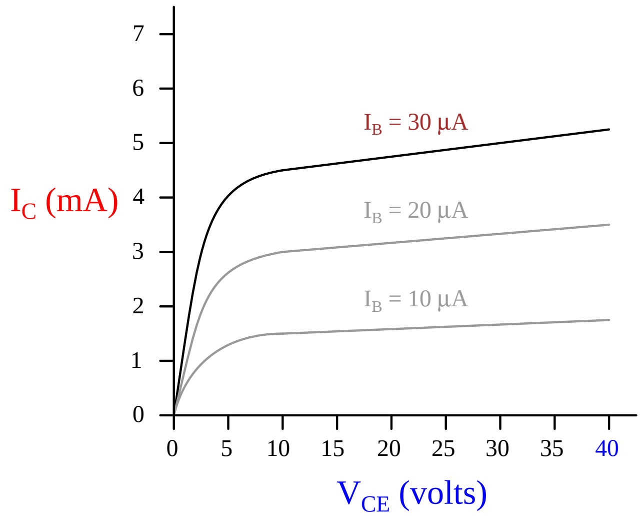


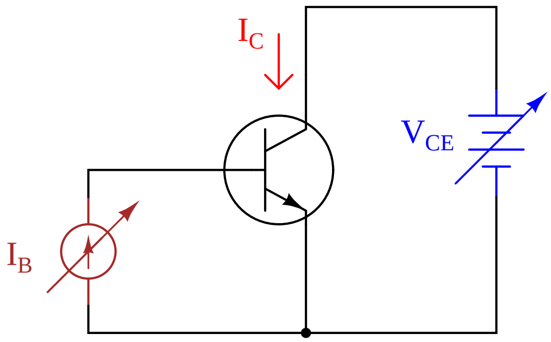
I_C (mA)
7
6
5
4
3
2
1
0
I_B = 30 µA
I_B = 20 µA
I_B = 10 µA
0 5 10 15 20 25 30 35 40
V_CE (volts)


I_C
V_CE
I_B

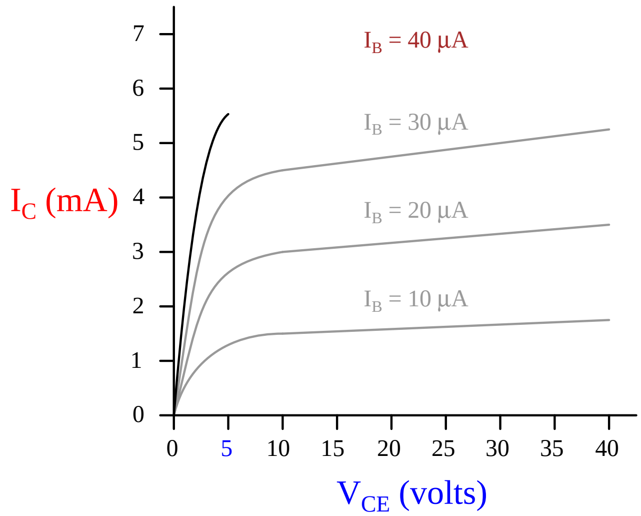

I_C (mA)
7
6
5
4
3
2
1
0
I_B = 30 µA
I_B = 20 µA
I_B = 10 µA
0
5
10
15
20
25
30
35
40
V_CE (volts)


I_C
V_CE
I_B

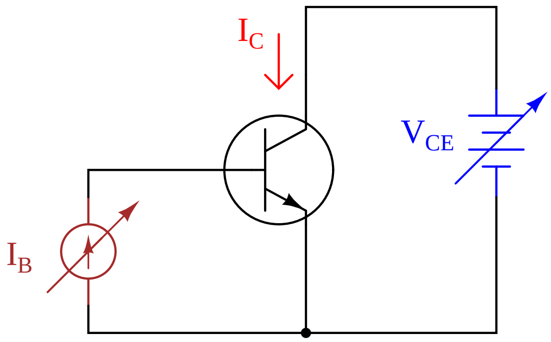

I_C (mA)
0
1
2
3
4
5
6
7
I_B = 30 µA
I_B = 20 µA
I_B = 10 µA
0
5
10
15
20
25
30
35
40
V_CE (volts)

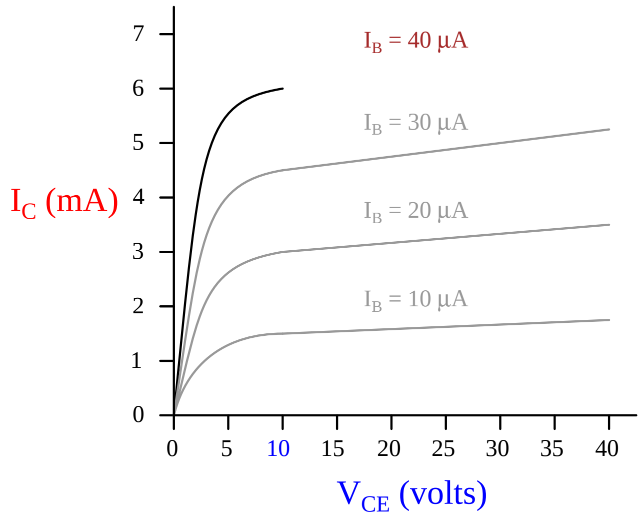


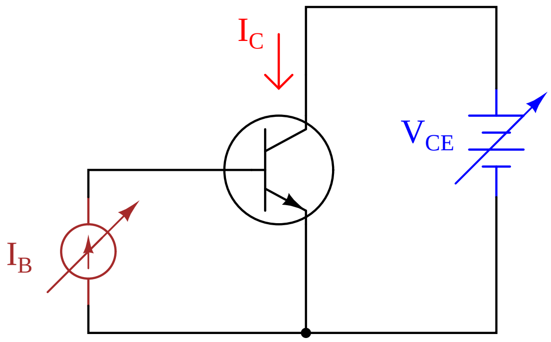
IC
VCE
IB



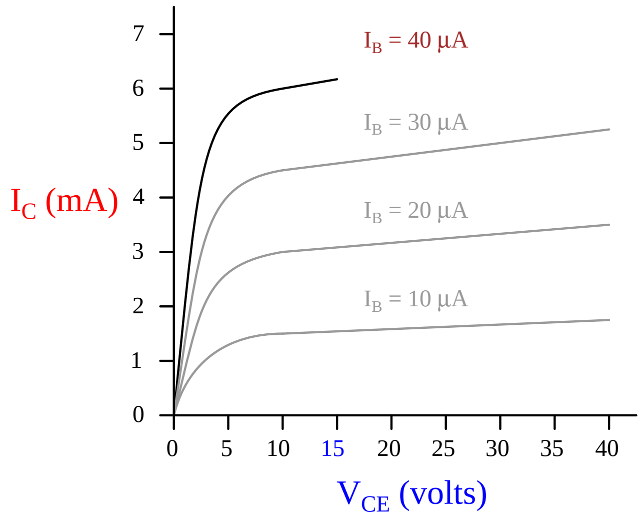
IB = 40 µA
IB = 30 µA
IB = 20 µA
IB = 10 µA
IC (mA)
VCE (volts)
0
1
2
3
4
5
6
7
0
5
10
15
20
25
30
35
40


IC
VCE
IB

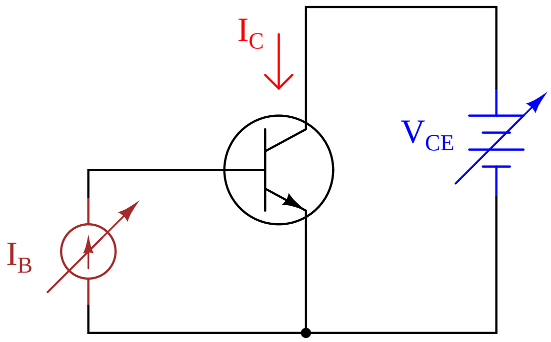

IB = 40 µA
IB = 30 µA
IB = 20 µA
IB = 10 µA
IC (mA)
VCE (volts)
0
1
2
3
4
5
6
7
0
5
10
15
20
25
30
35
40

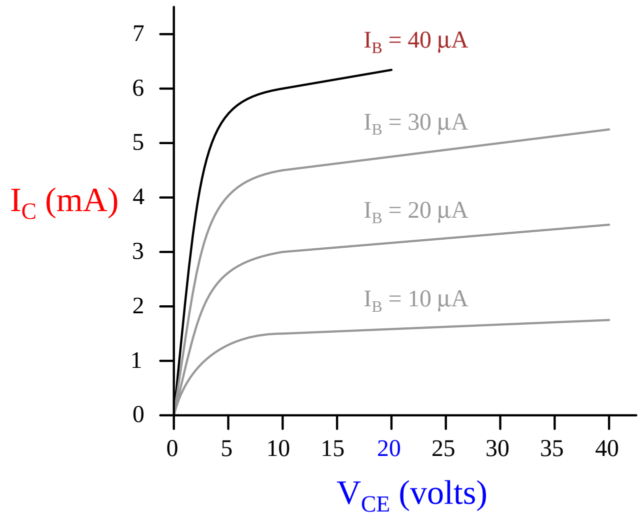


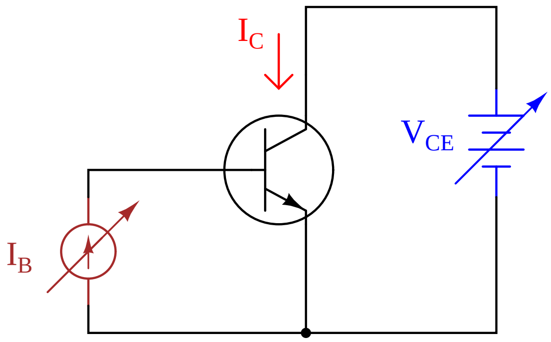
I_C
V_{CE}
I_B

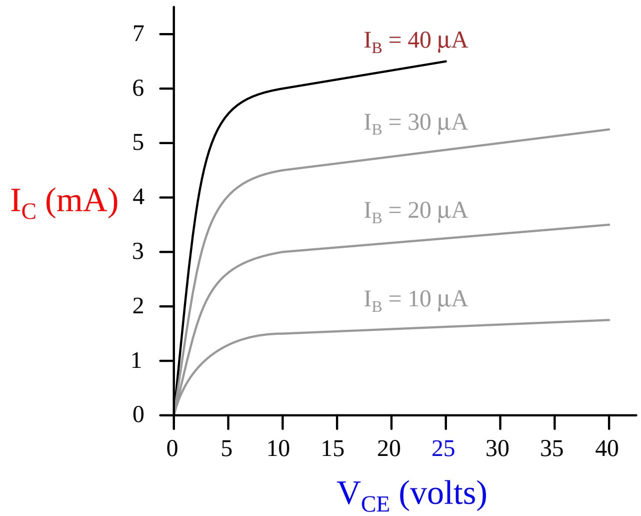


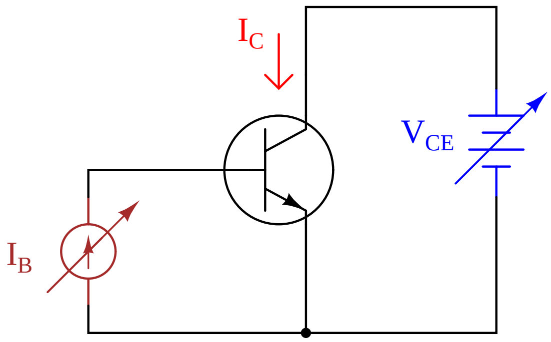
I_B = 40 µA
I_B = 30 µA
I_B = 20 µA
I_B = 10 µA
I_C (mA)
V_{CE} (volts)
0
1
2
3
4
5
6
7
0 5 10 15 20 25 30 35 40

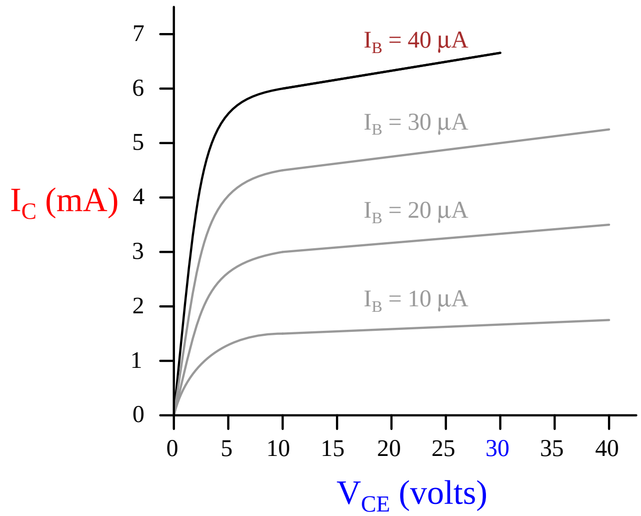

I_C
V_CE
I_B

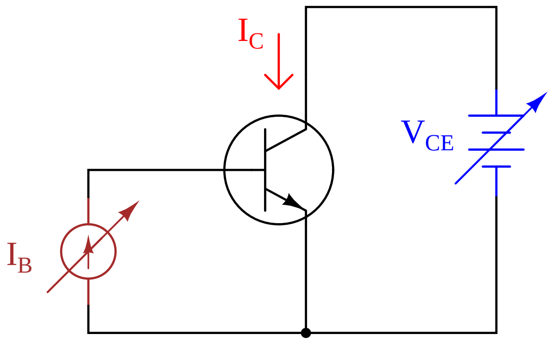

I_B = 40 µA
I_B = 30 µA
I_B = 20 µA
I_B = 10 µA
I_C (mA)
V_CE (volts)
0
1
2
3
4
5
6
7
0
5
10
15
20
25
30
35
40

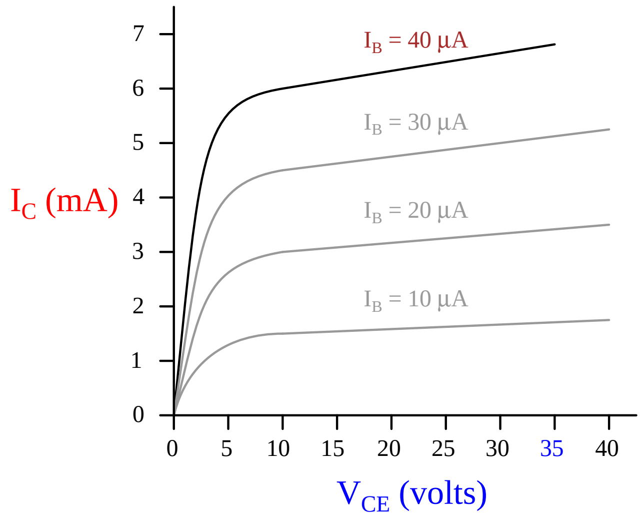

I_C
V_CE
I_B

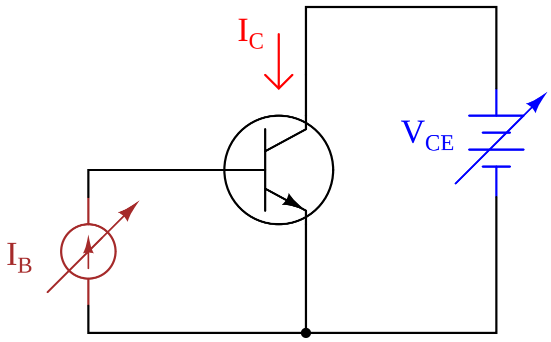

I_B = 40 µA
I_B = 30 µA
I_B = 20 µA
I_B = 10 µA
I_C (mA)
V_CE (volts)
0 1 2 3 4 5 6 7
0 5 10 15 20 25 30 35 40


I_C
V_CE
I_B

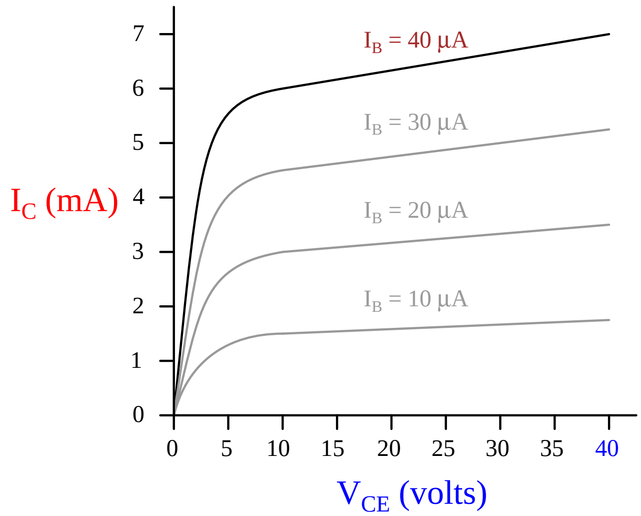

I_B = 40 µA
I_B = 30 µA
I_B = 20 µA
I_B = 10 µA
I_C (mA)
V_CE (volts)
0
1
2
3
4
5
6
7
0
5
10
15
20
25
30
35
40


I_C
V_CE
I_B

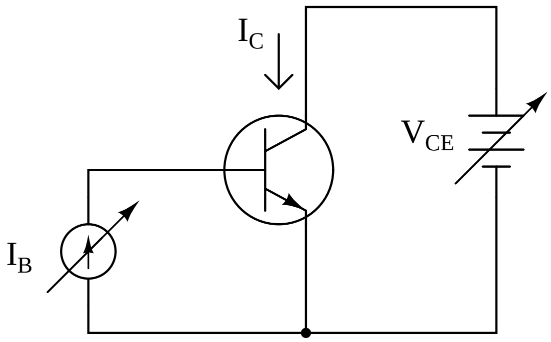

I_B = 40 µA
I_B = 30 µA
I_B = 20 µA
I_B = 10 µA
I_C (mA)
V_CE (volts)
0
1
2
3
4
5
6
7
0
5
10
15
20
25
30
35
40



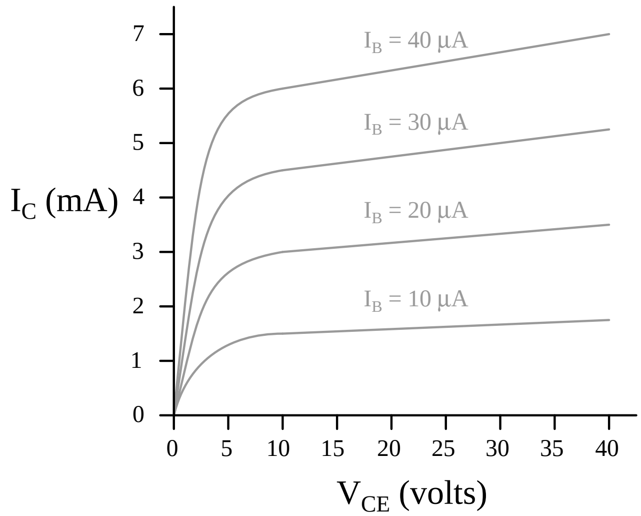
IC
VCE
IB



IB = 40 μA
IB = 30 μA
IB = 20 μA
IB = 10 μA
IC (mA)
7
6
5
4
3
2
1
0
0 5 10 15 20 25 30 35 40
VCE (volts)



I_C
V_{CE}
I_B



I_B = 40 µA
I_B = 30 µA
I_B = 20 µA
I_B = 10 µA
I_C (mA)
V_{CE} (volts)
0
1
2
3
4
5
6
7
0
5
10
15
20
25
30
35
40

file 03237

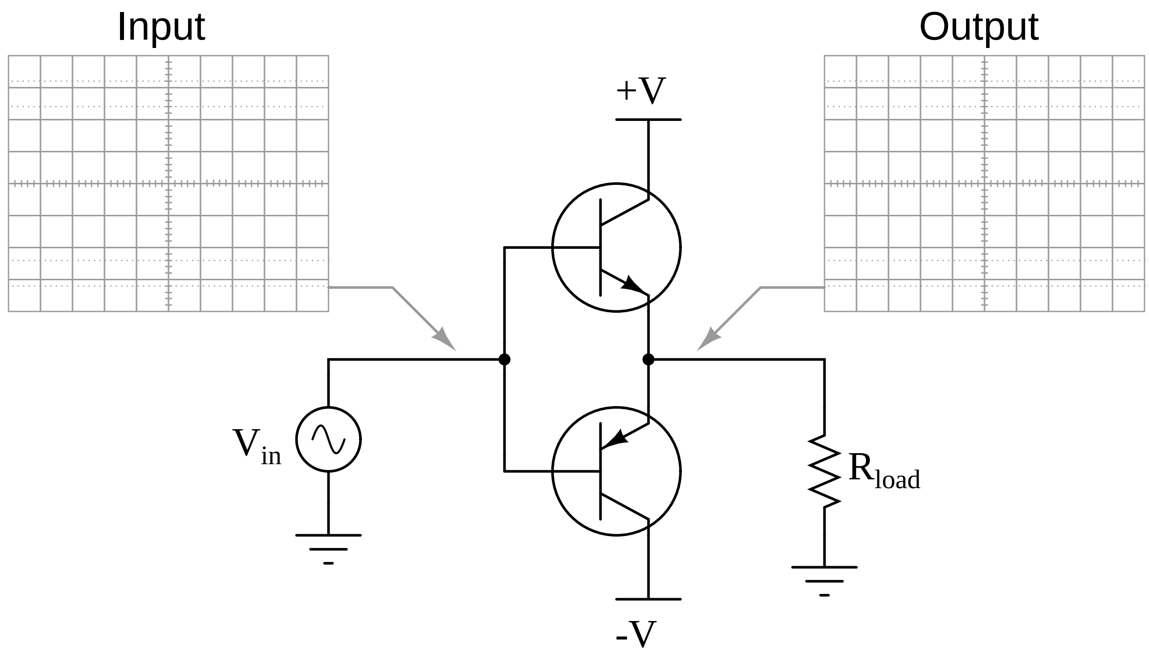
Question 10

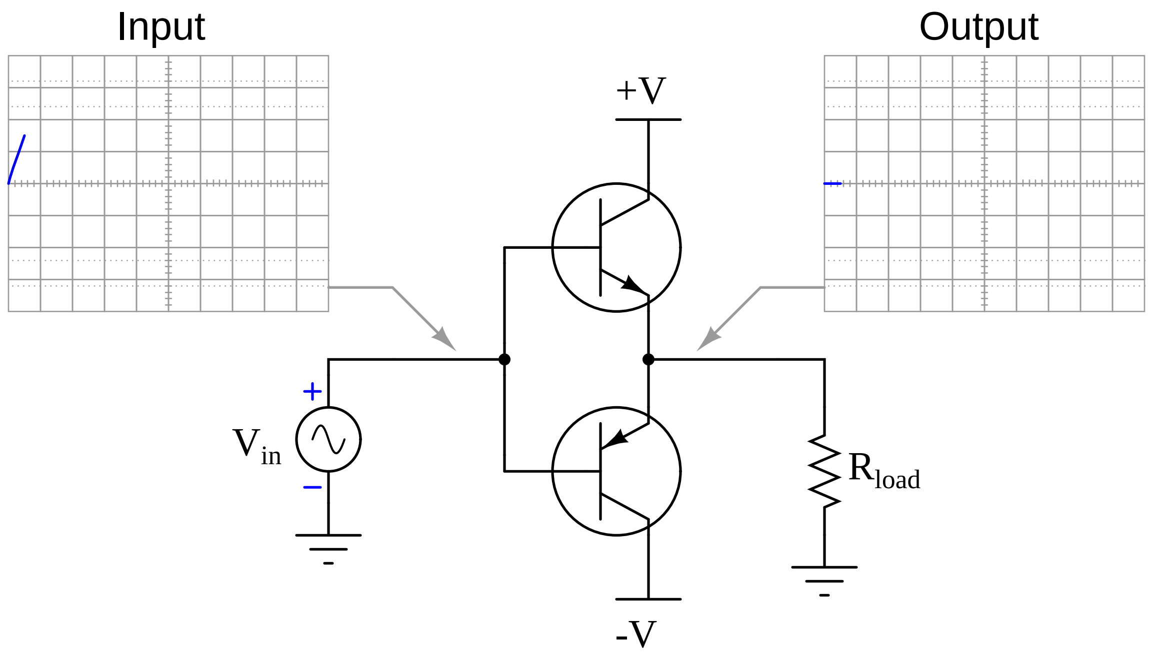
Animation: crossover distortion in a push-pull transistor amplifier

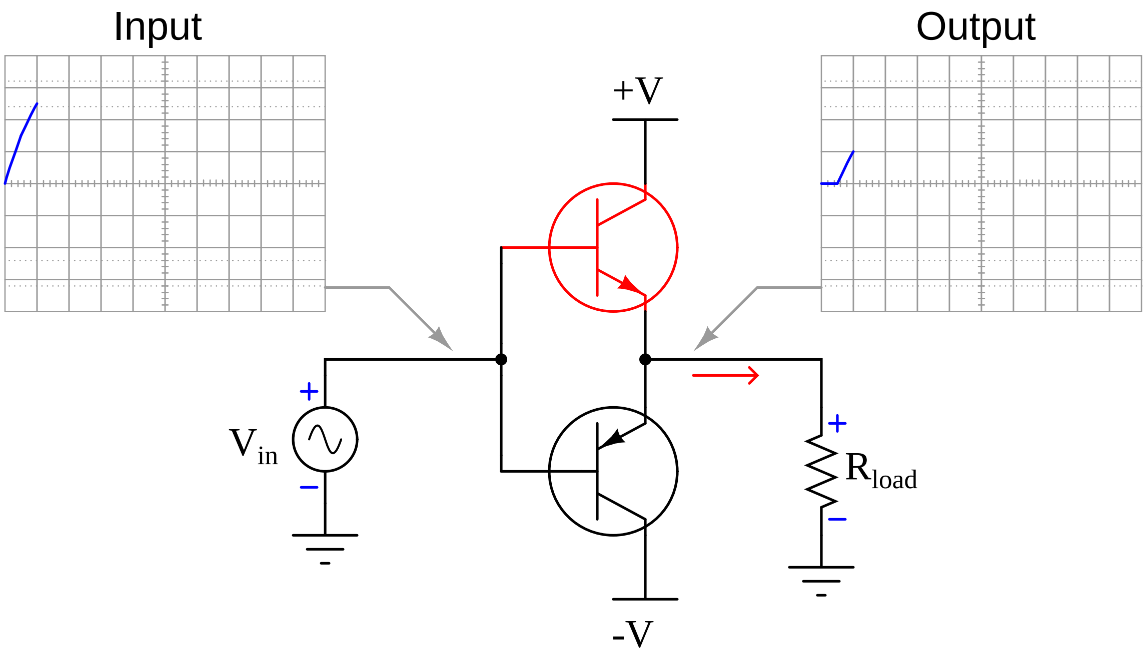
This question consists of a series of images (one per page) that form an animation. Flip the pages with your fingers to view this animation (or click on the "next" button on your viewer) frame-by-frame.

The following animation shows a simple push-pull, emitter-follower amplifier circuit exhibiting crossover distortion. Watch what happens as the input voltage goes through a whole cycle, noting when each transistor begins to conduct, and when each transistor ceases conduction. Here are some things to look for:

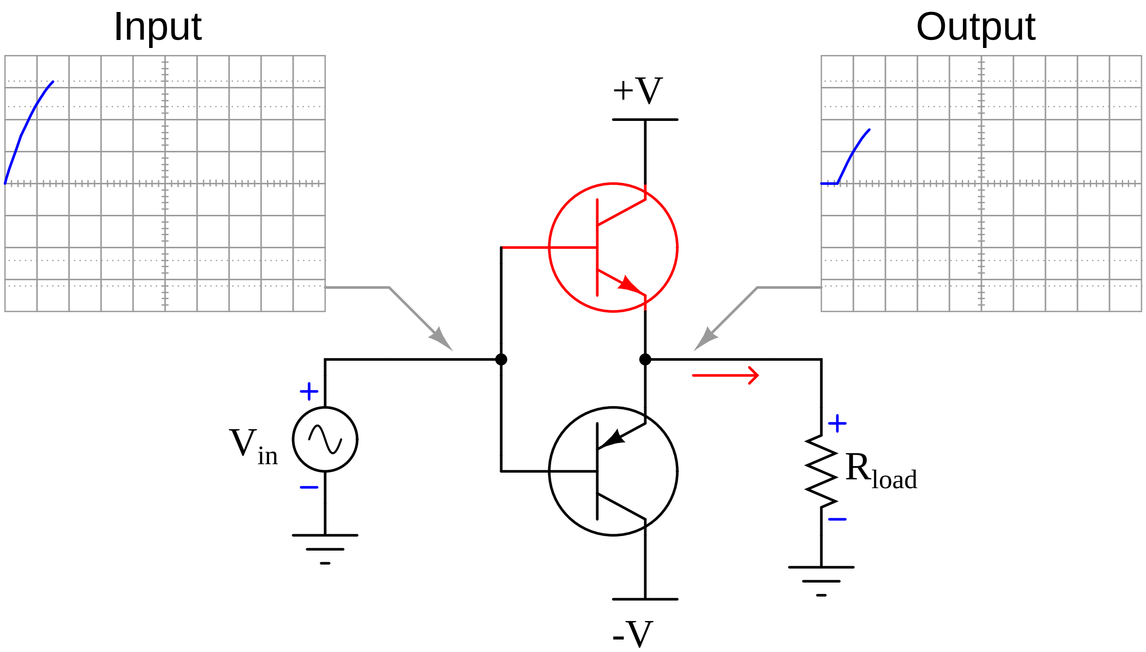
- Which transistor handles which portion of the input waveform (positive versus negative)?
- Why is there a "flat" spot in the output waveform?
- What would have to be done to this circuit to allow it to reproduce the waveform in full?


Input
Output
+V
-V
Vin
Rload

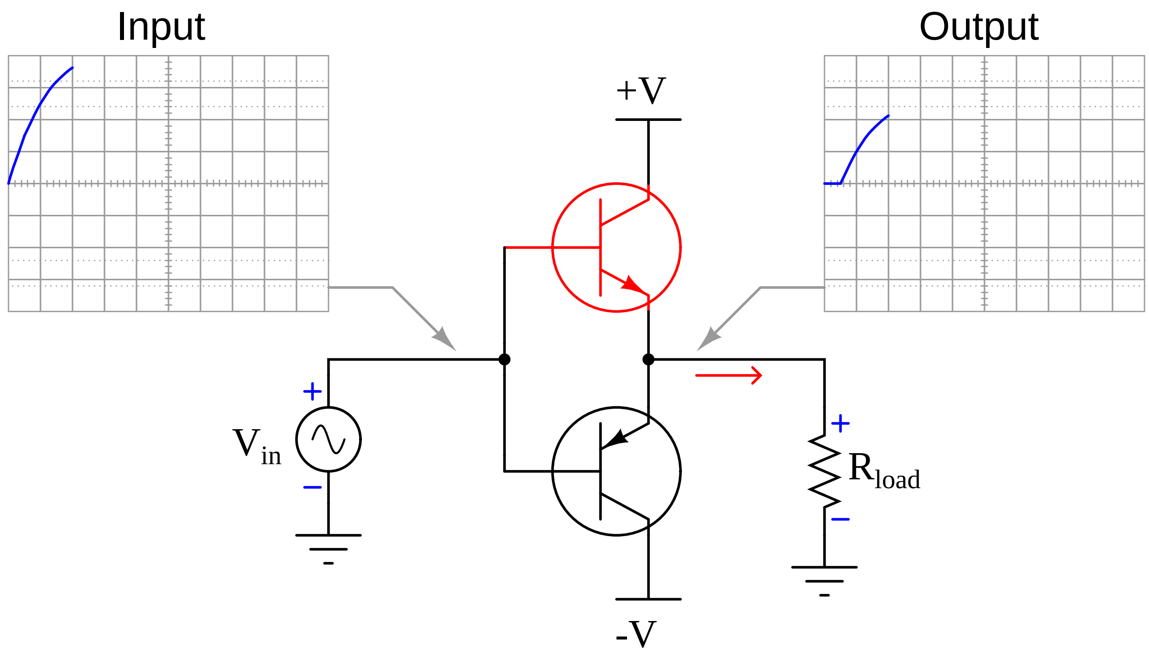

Input
Output
+V
-V
+
−
V_{in}
R_{load}

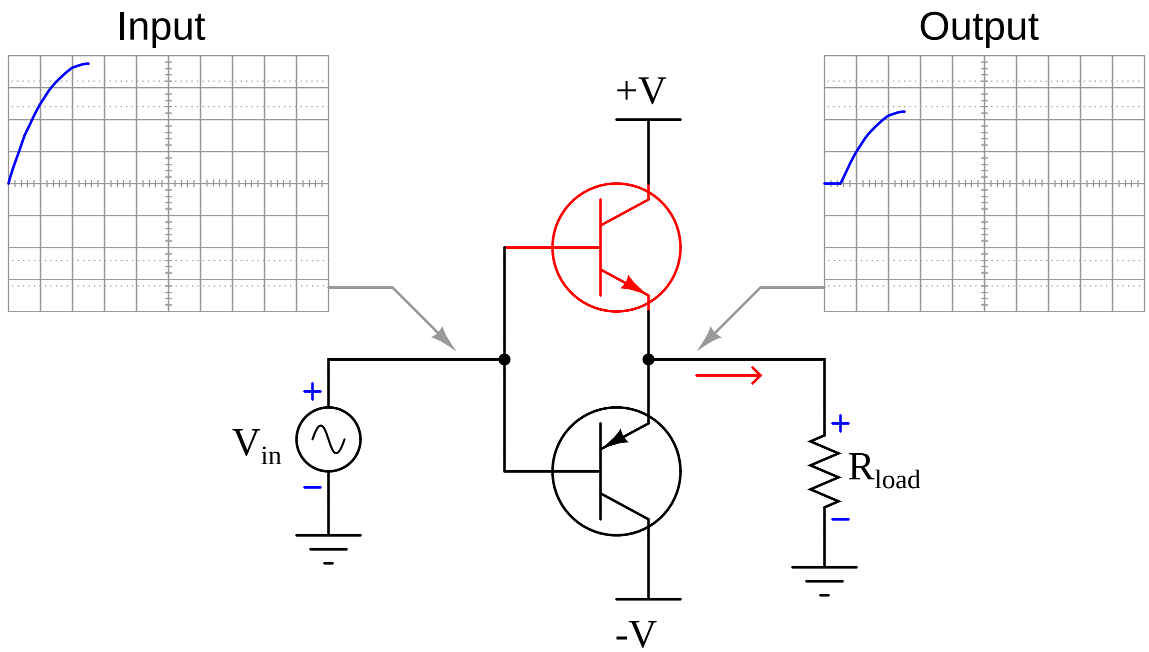


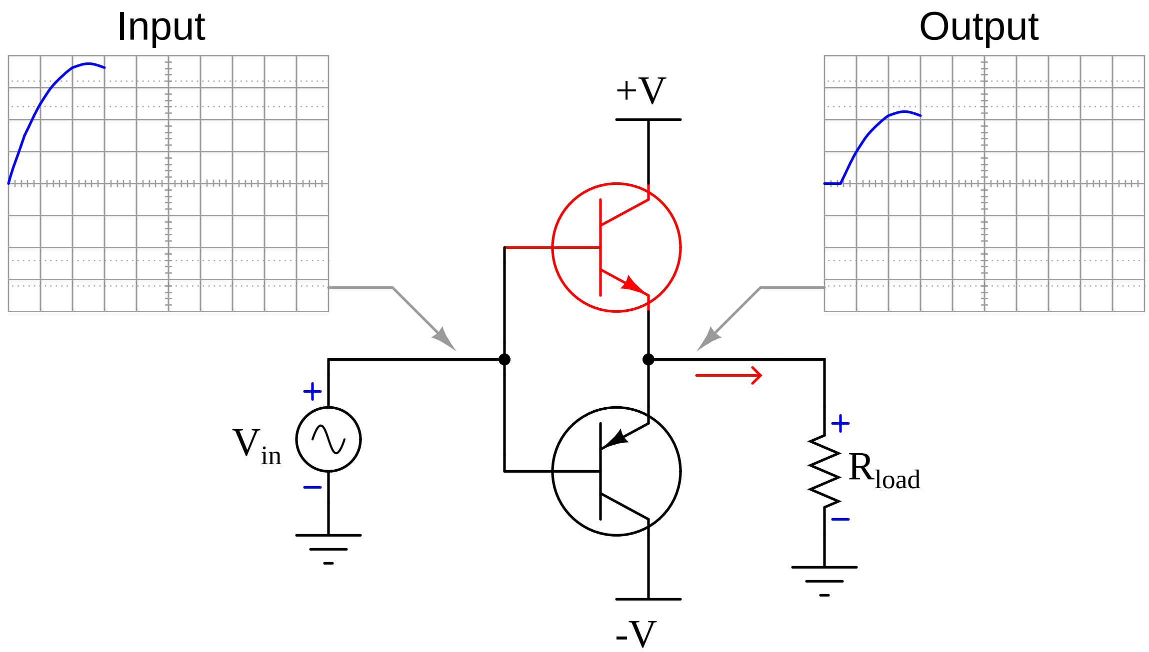
Input
Output
+V
-V
Vin
Rload
+
−
+
−

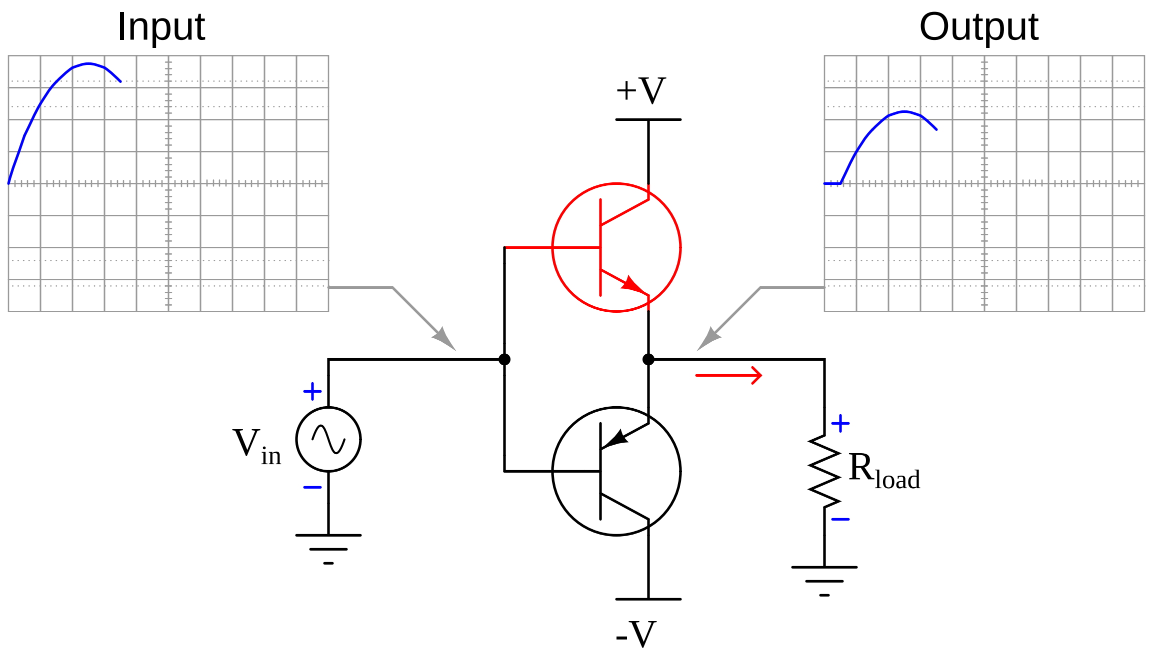


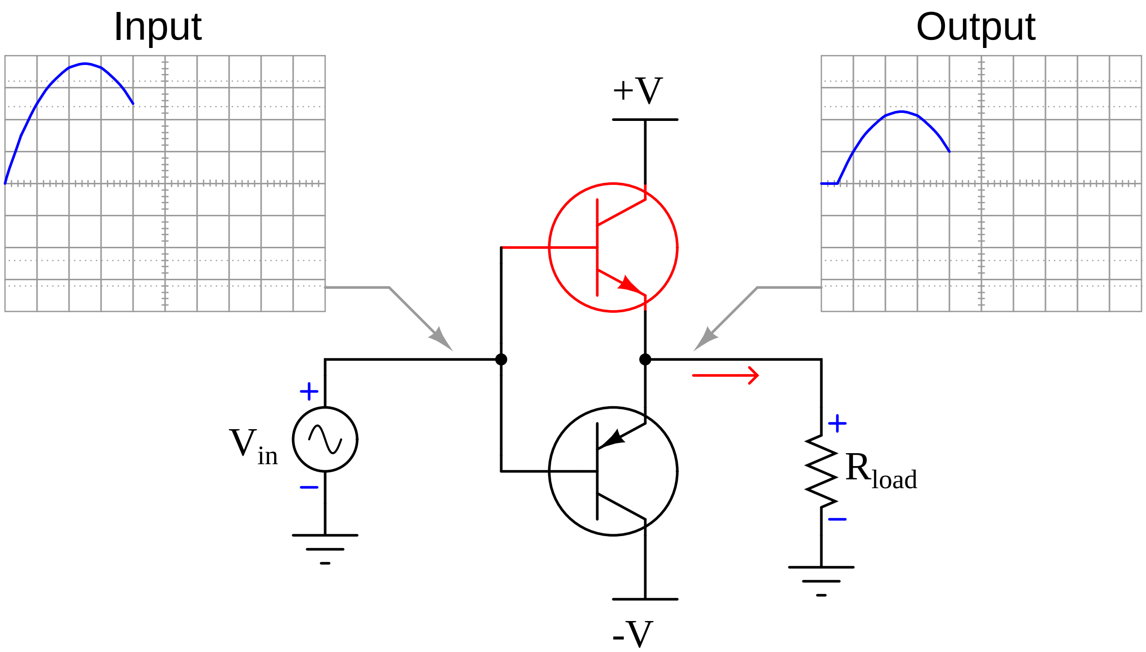
Input
Output
+V
-V
+
−
V_in
+
−
R_load

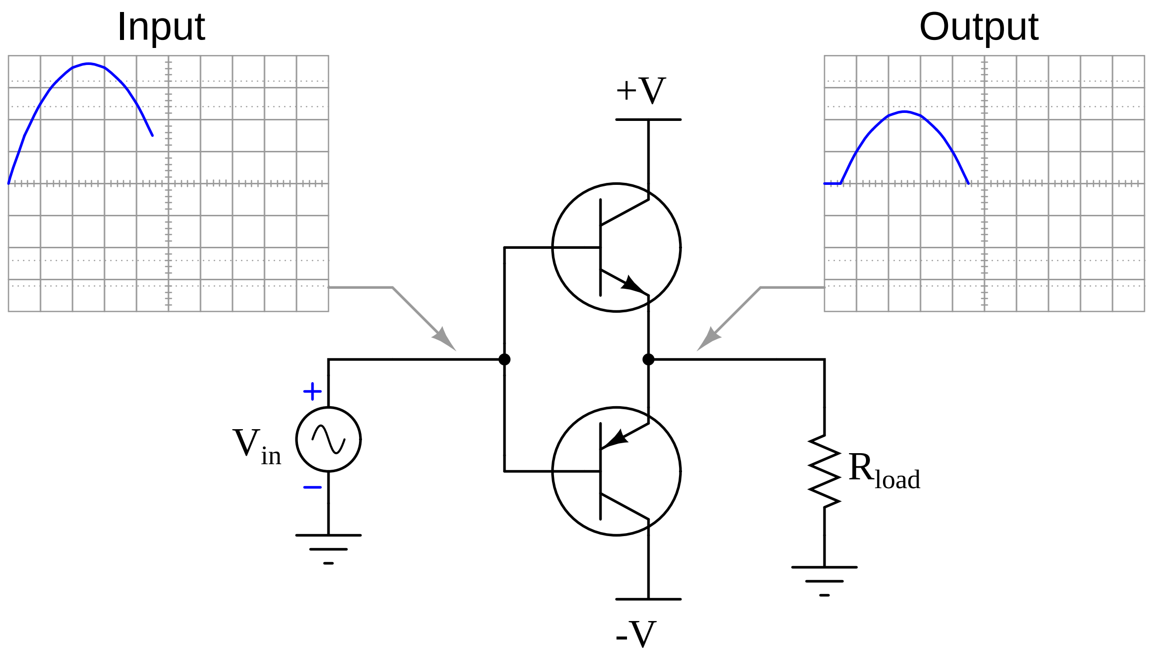

Input
Output
+V
-V
Vin
Rload
+
−
+
−

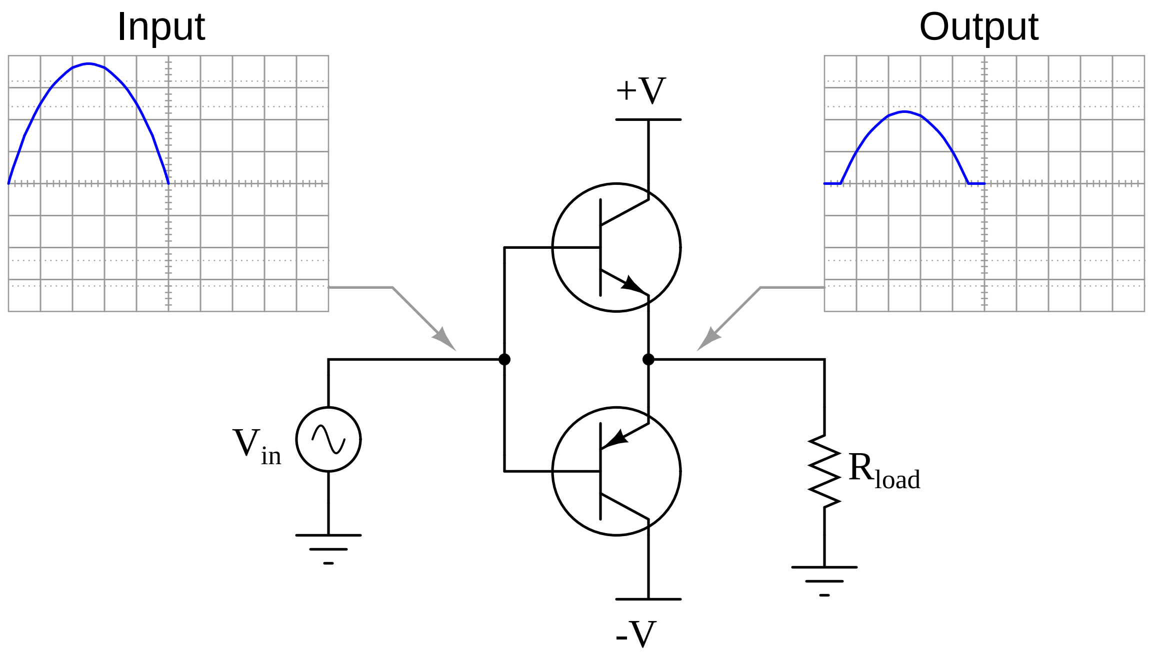

Input
Output
+V
-V
V_{in}
R_{load}
+
−
+
−

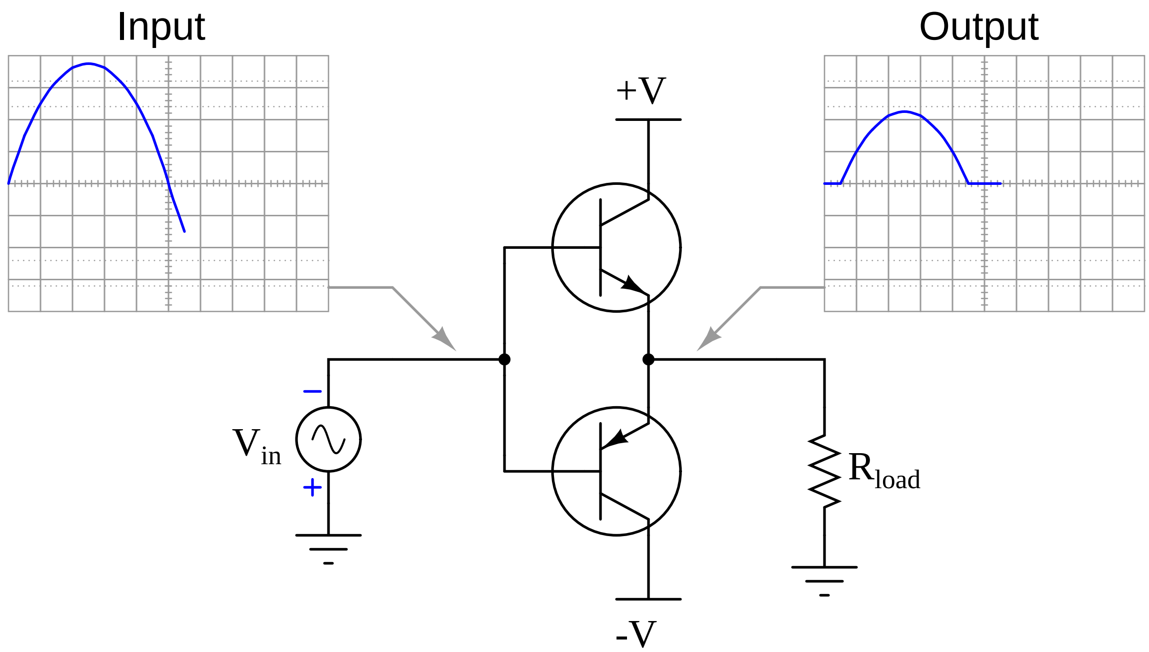

Input
Output
+V
-V
+
−
V_{in}
+
−
R_{load}


Input
Output
+V
-V
+
−
Vin
+
−
Rload

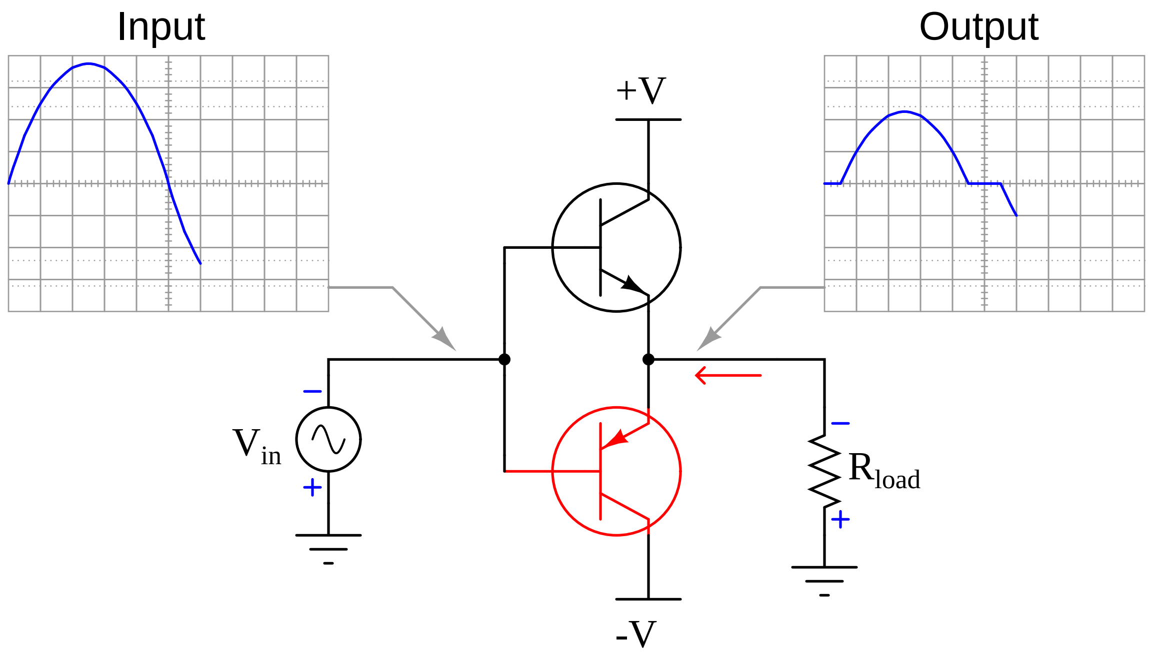

Input
Output
+V
-V
V_{in}
R_{load}
+
−
+
−


Input
Output
+V
-V
+
−
Vin
Rload

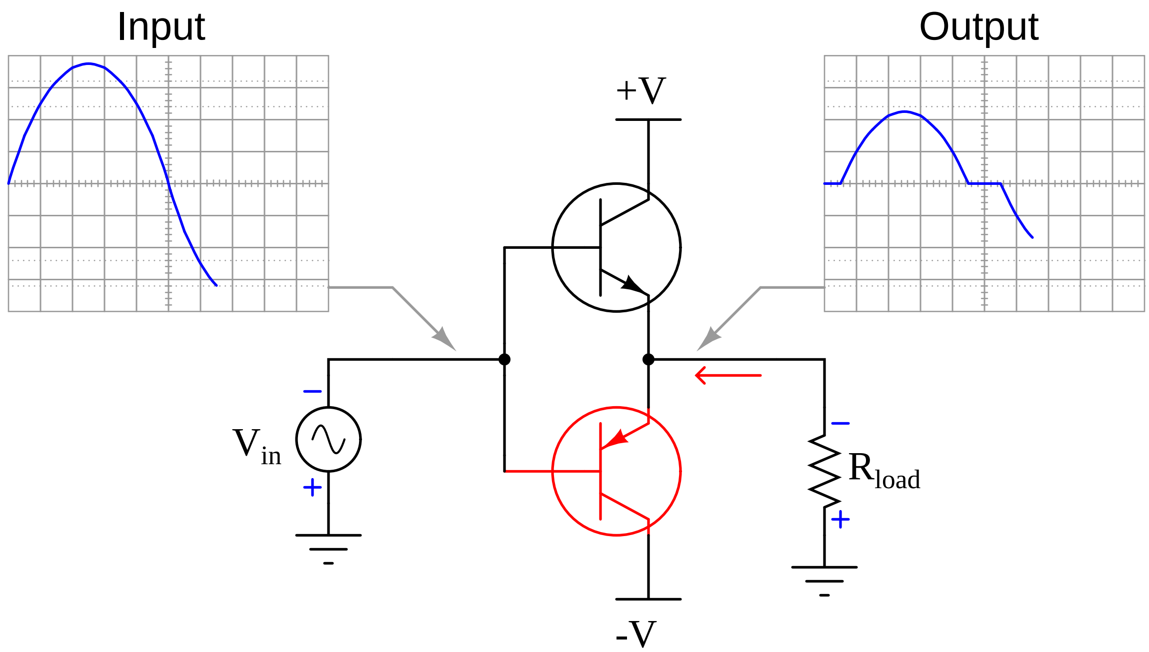

Input
Output
+V
-V
Vin
Rload

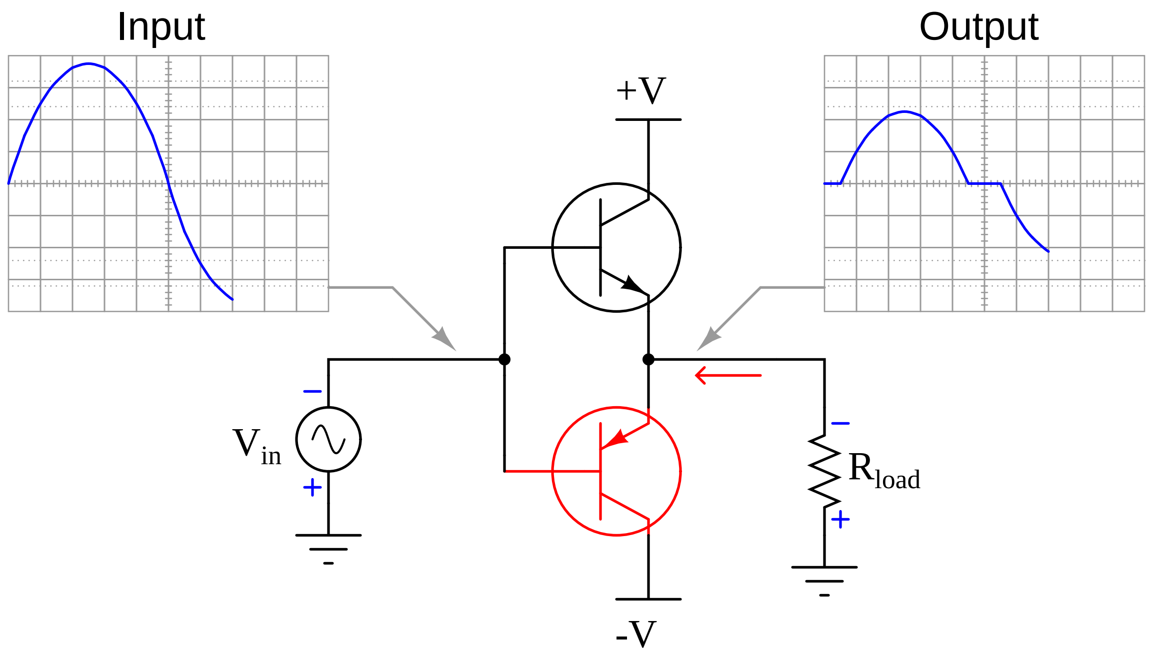


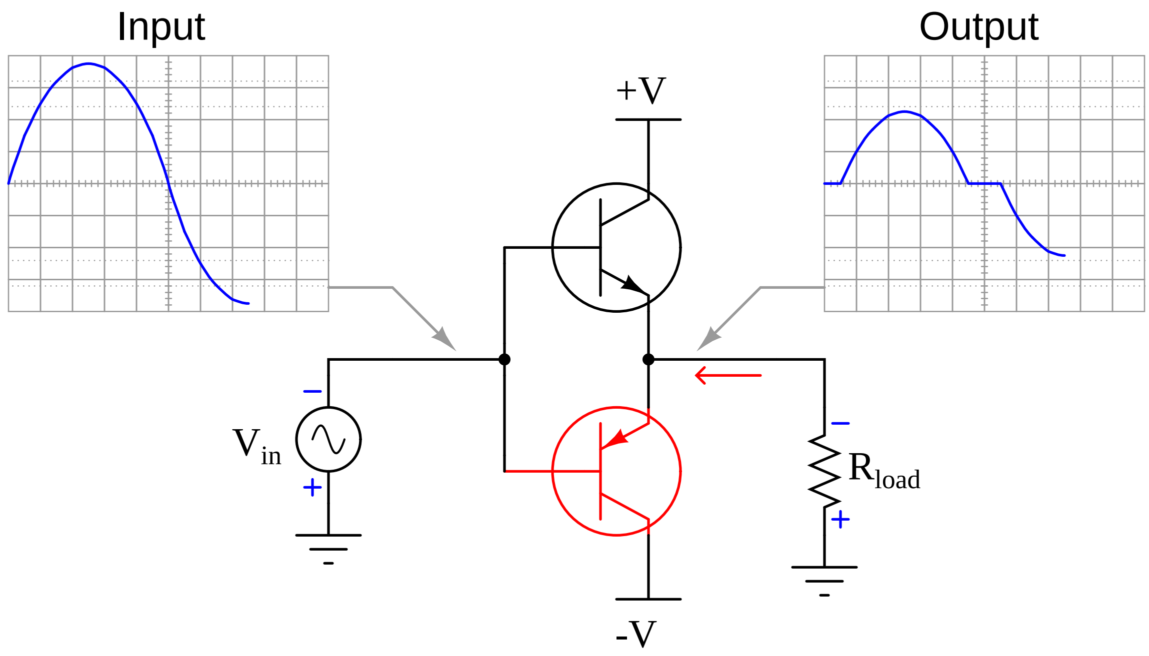
Input
Output
+V
-V
V_{in}
R_{load}



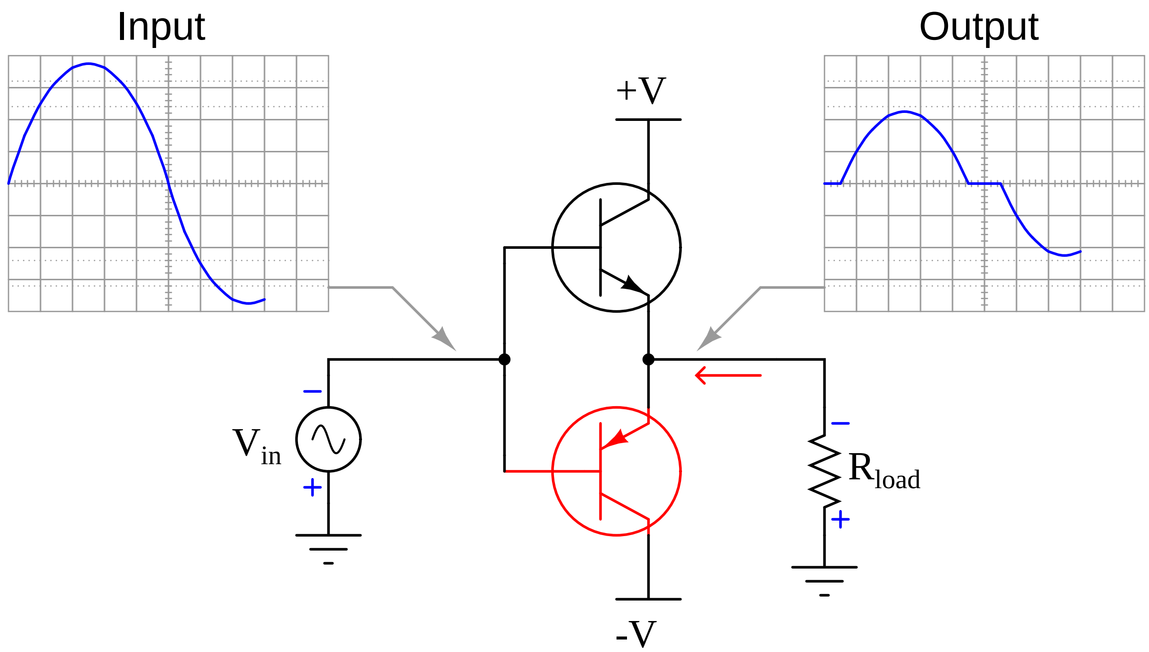
Input
Output
+V
-V
V_{in}
R_{load}

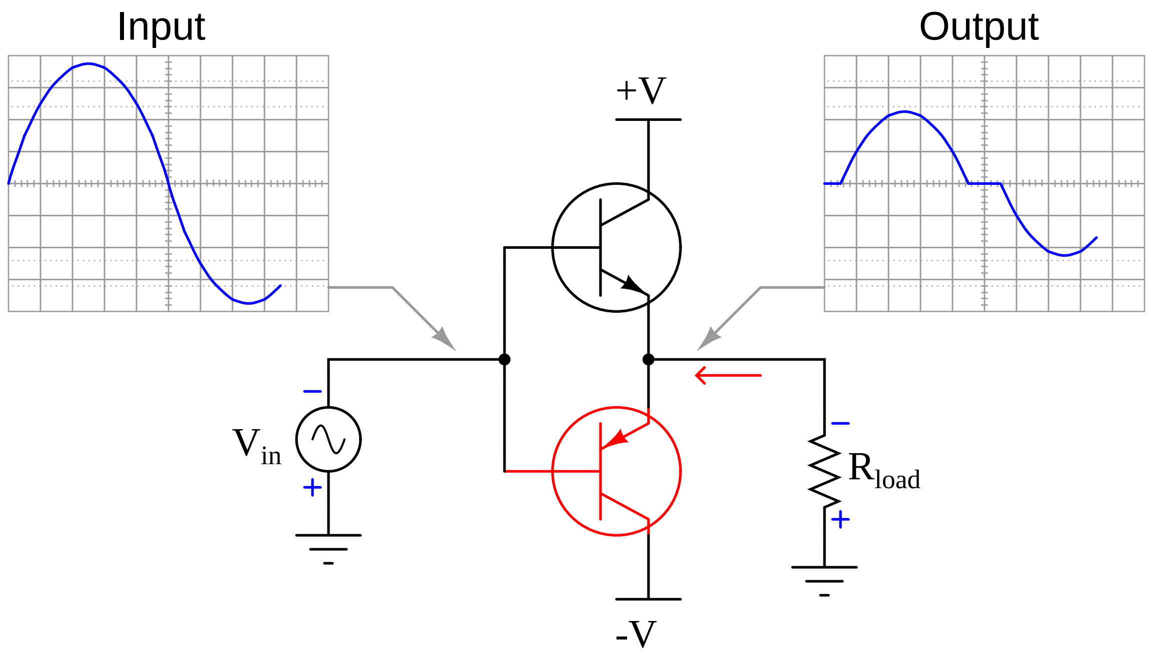

Input
Output
+V
-V
Vin
Rload

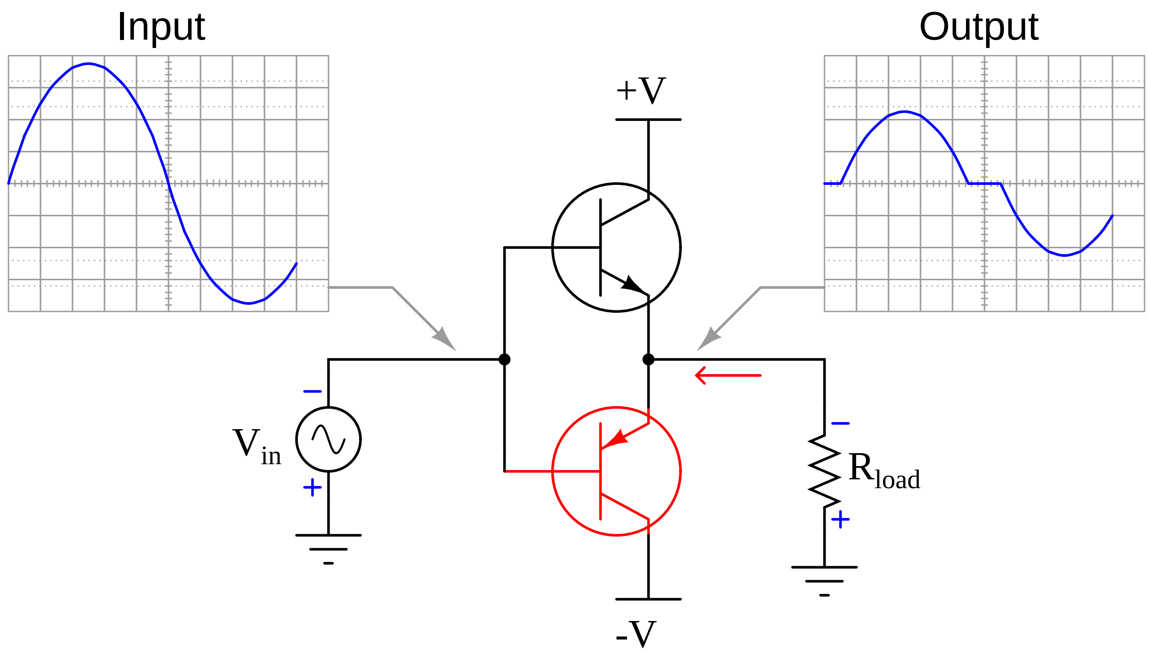

Input
Output
+V
-V
Vin
Rload
−
+
−
+

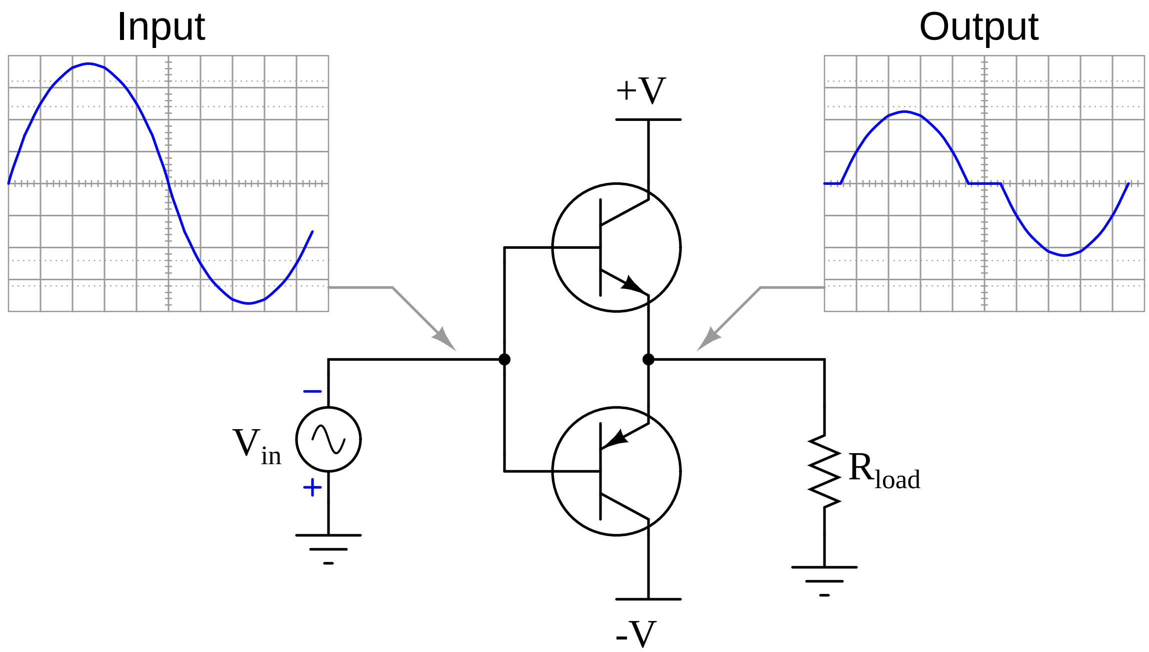


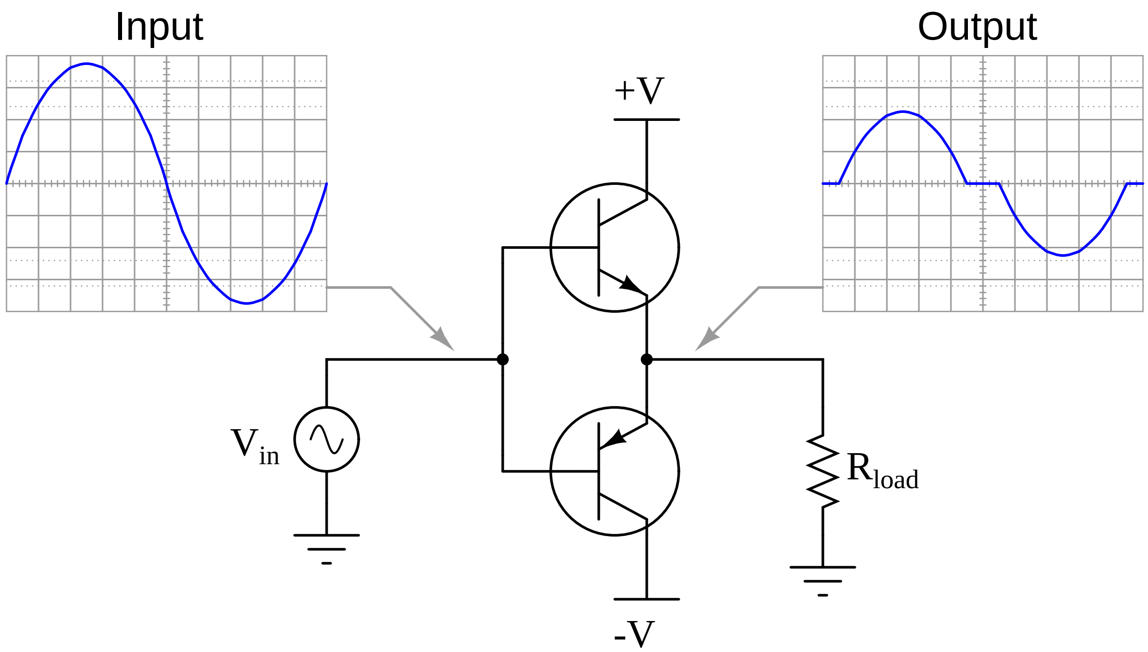
Input
Output
+V
-V
V_{in}
R_{load}


Input
Output
+V
-V
V_in
R_load


Input
Output
+V
-V
Vin
Rload


Input
Output
+V
-V
Vin
Rload


Input
Output
+V
-V
Vin
Rload
−
+



file 03233

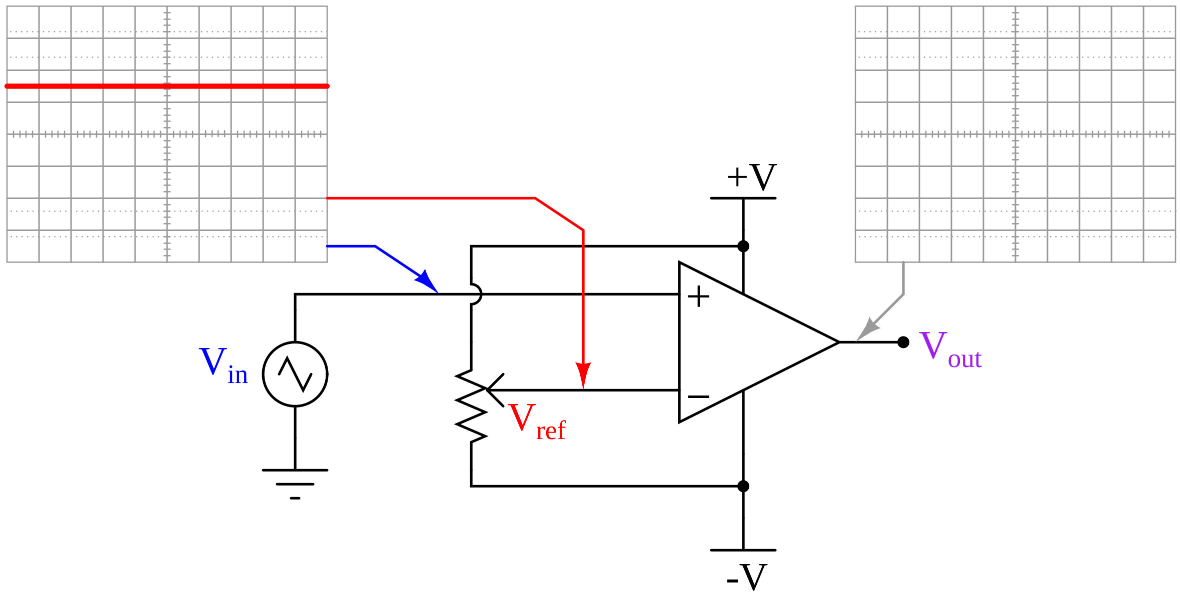
Question 11

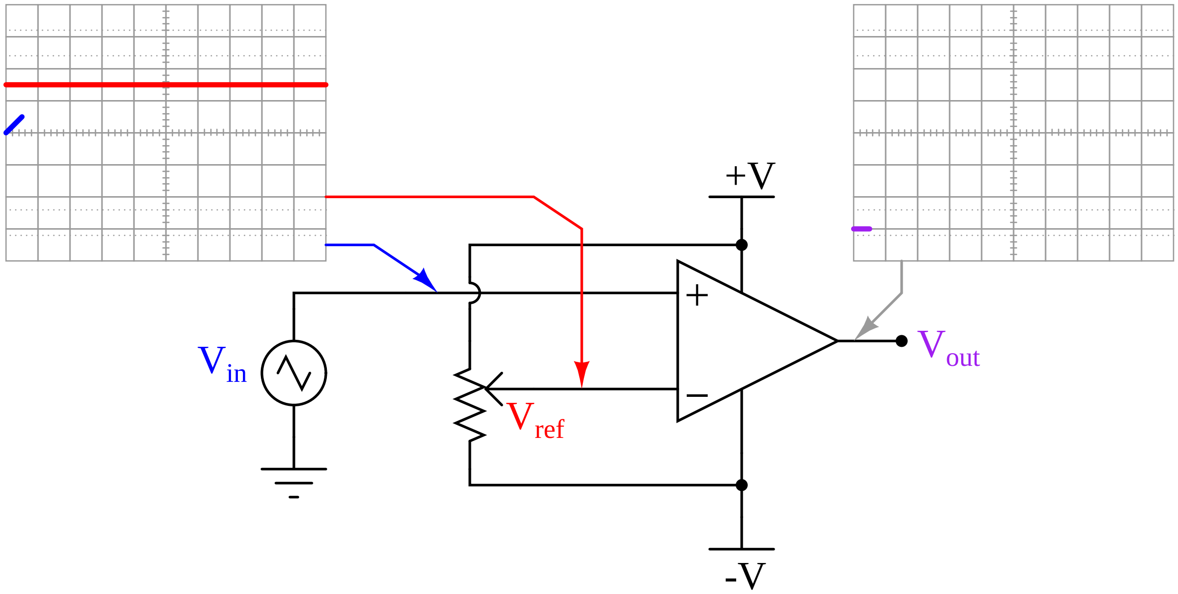
Animation: PWM comparator circuit

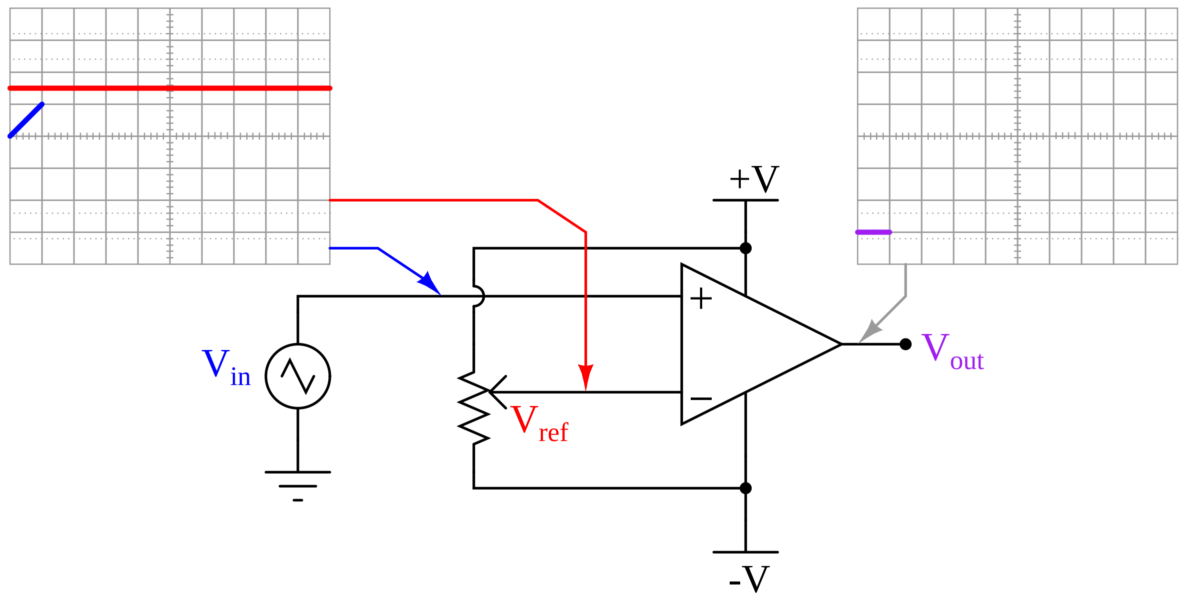
This question consists of a series of images (one per page) that form an animation. Flip the pages with your fingers to view this animation (or click on the "next" button on your viewer) frame-by-frame.

The following animation shows a comparator used to generate a PWM pulse signal from a triangle wave and a DC reference voltage. Watch what happens as the input voltage goes through a whole cycle, noting when the comparator switches output states. Here are some things to look for:

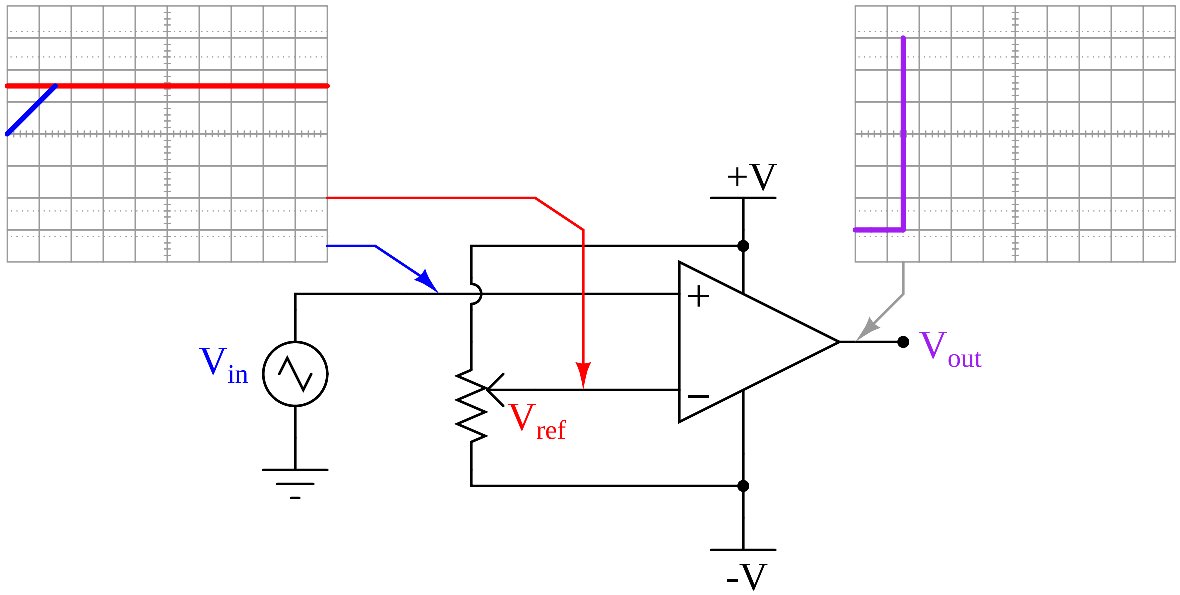
- What input conditions are necessary for the comparator to output a "high" (+V) state?
- What input conditions are necessary for the comparator to output a "low" (-V) state?
- Which direction would you move the potentiometer wiper to increase the duty cycle of the PWM output?

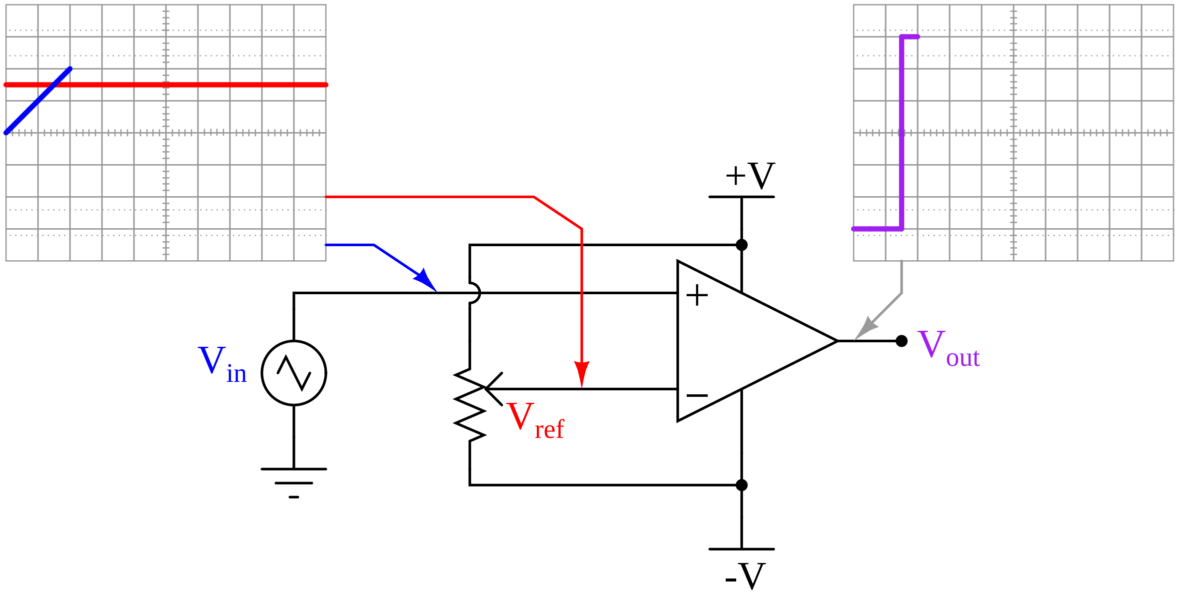

+V
Vin
Vref
Vout
-V


+V
V_in
V_ref
V_out
-V

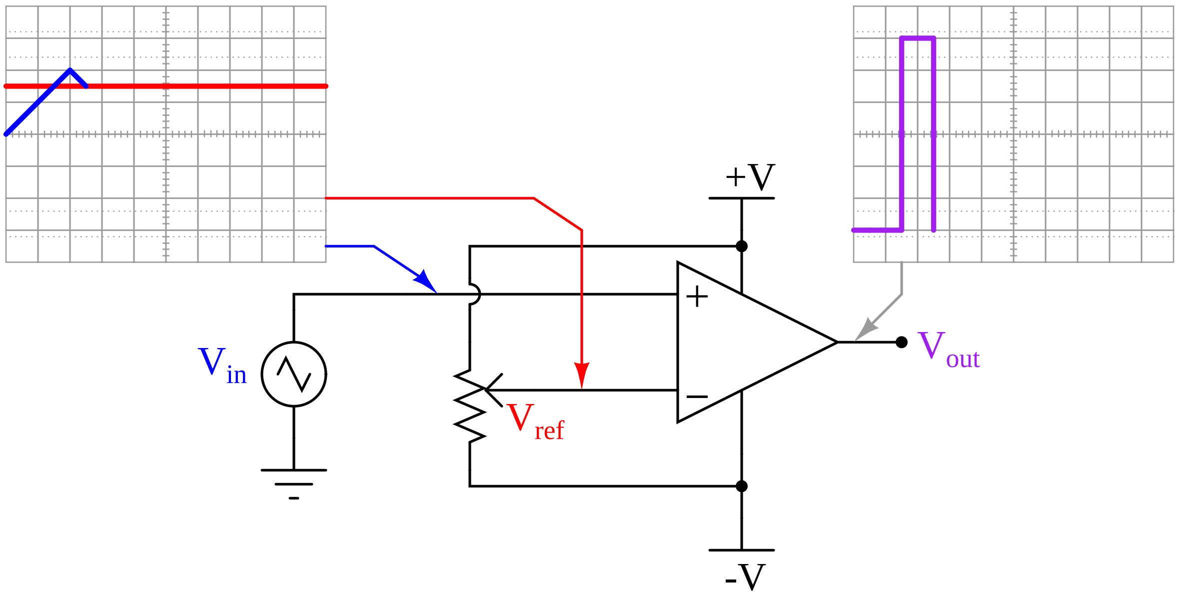


+V
V_{in}
V_{ref}
V_{out}
-V

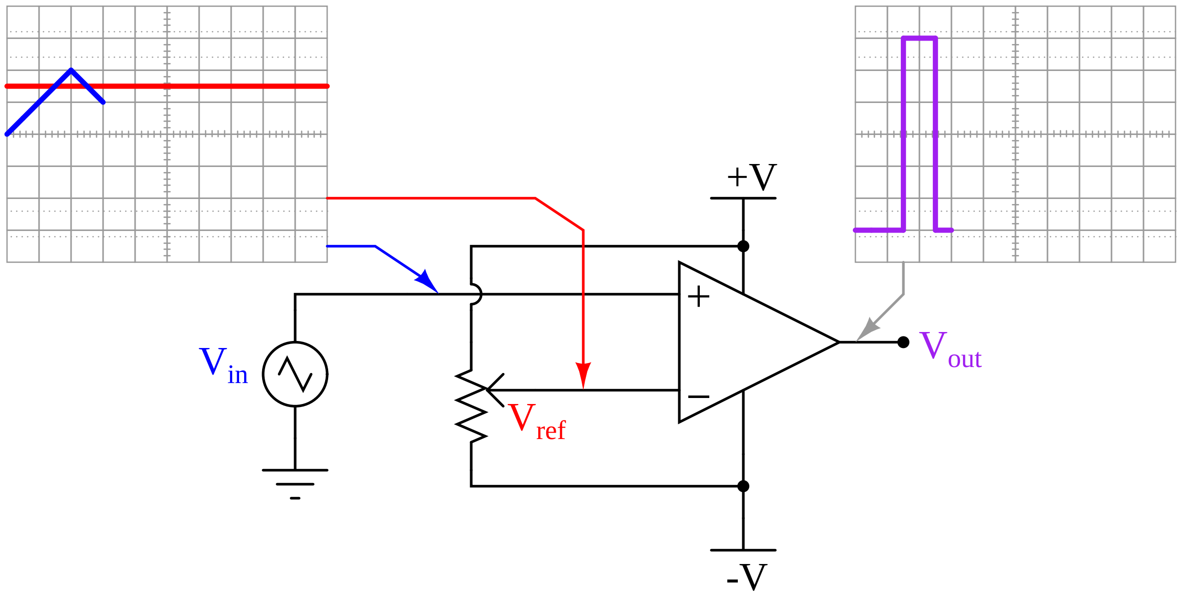

+V
V_in
V_ref
V_out
-V

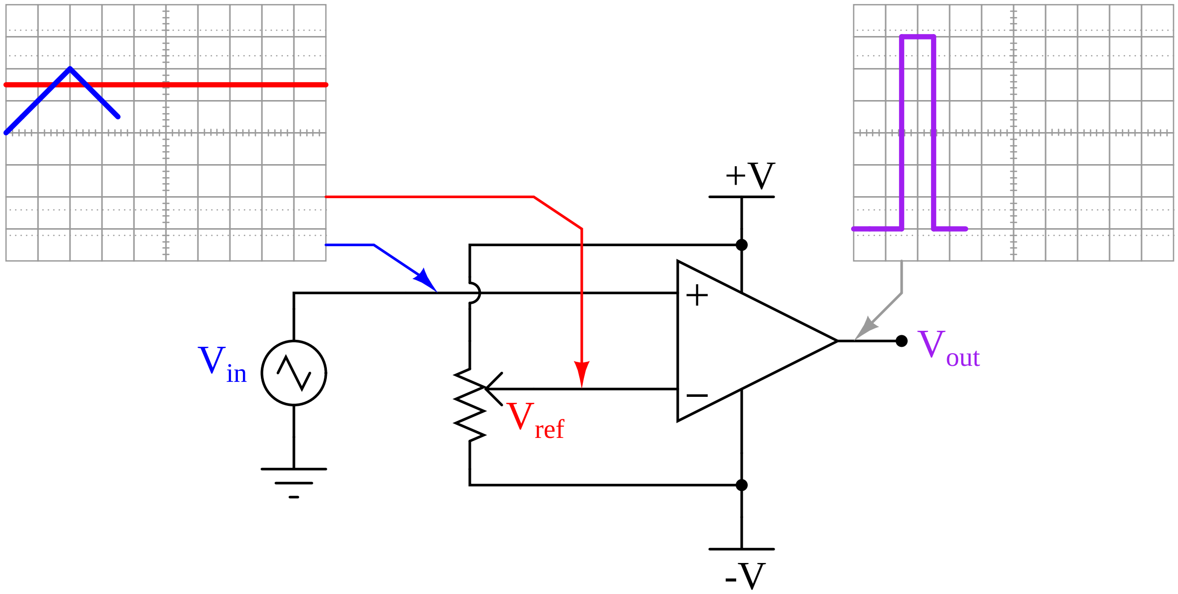


+V
V_{in}
V_{ref}
V_{out}
-V

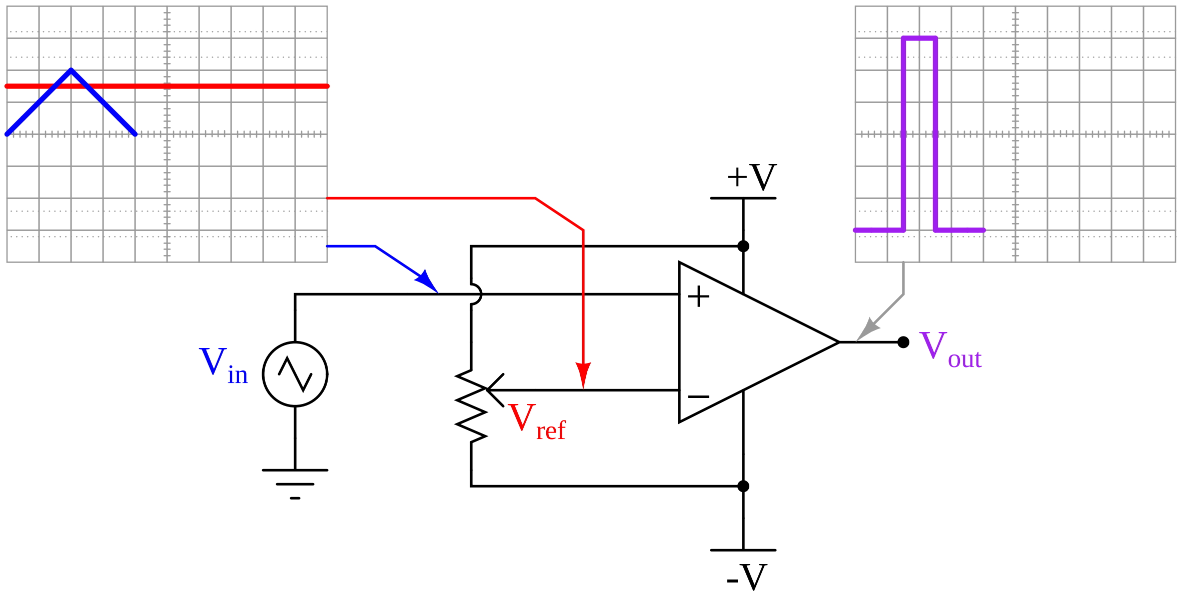


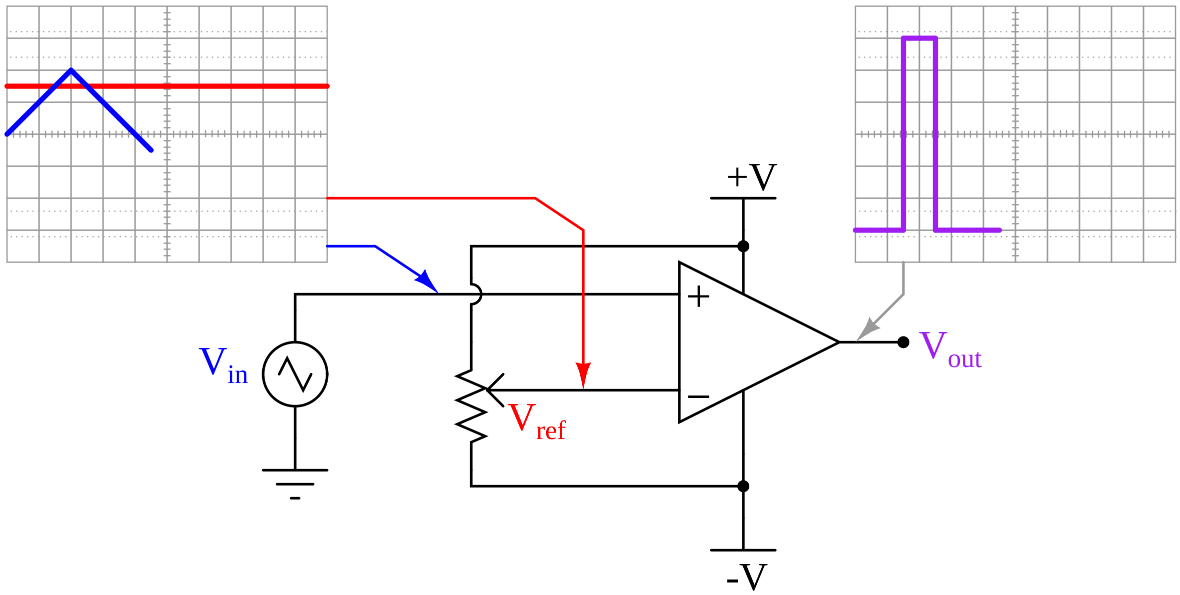
+V
Vin
Vref
Vout
-V


+V
-V
V_{in}
V_{ref}
V_{out}

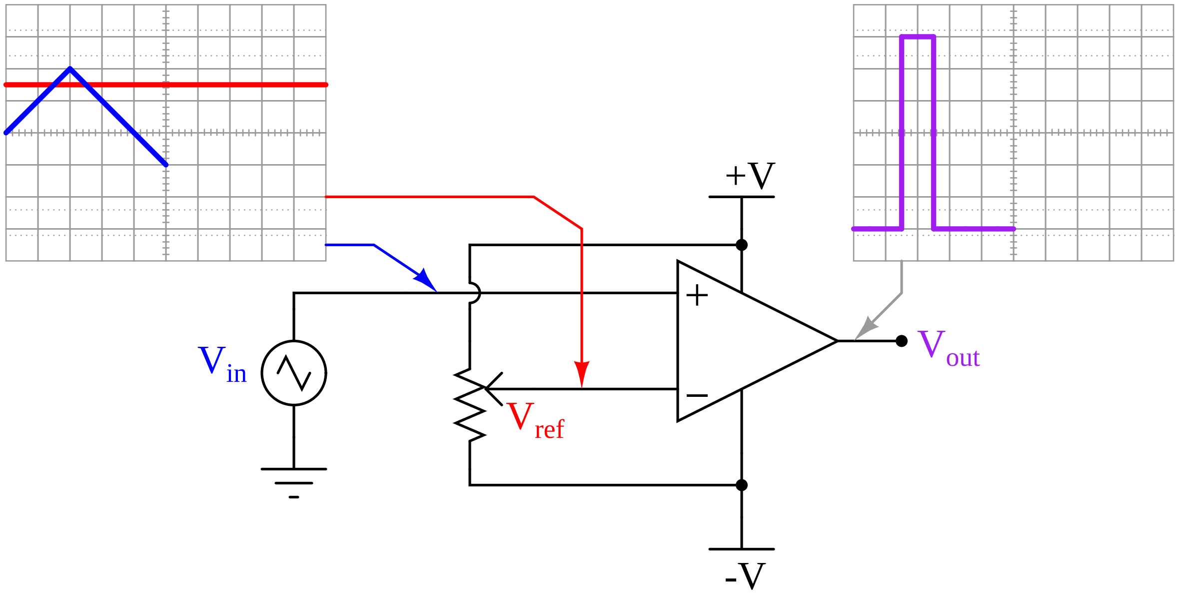


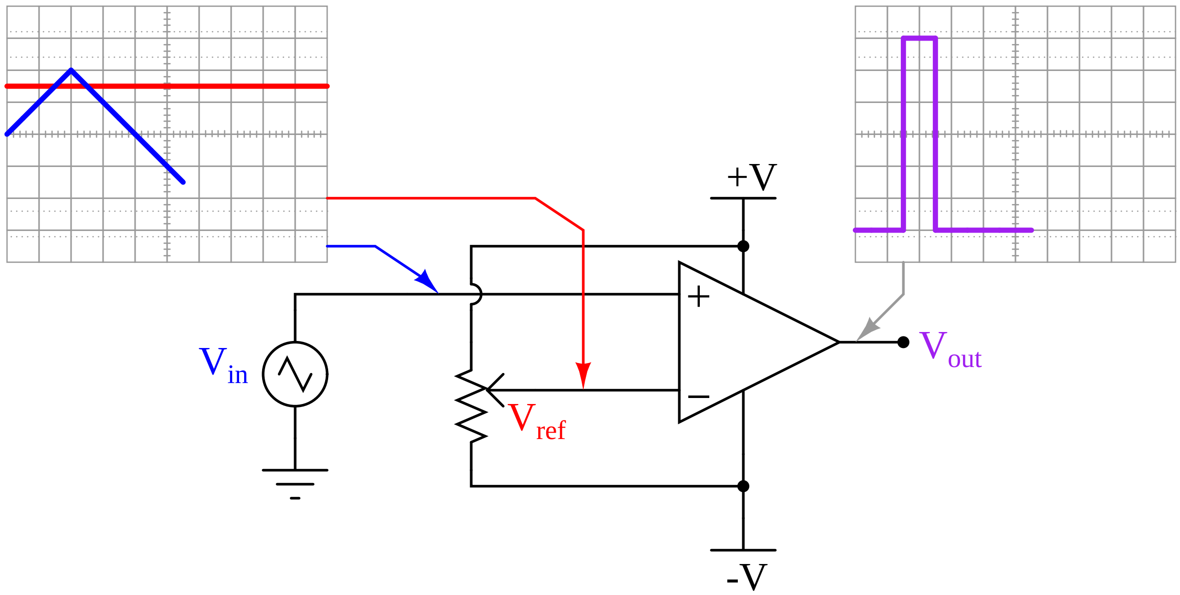
+V
V_in
V_ref
V_out
-V

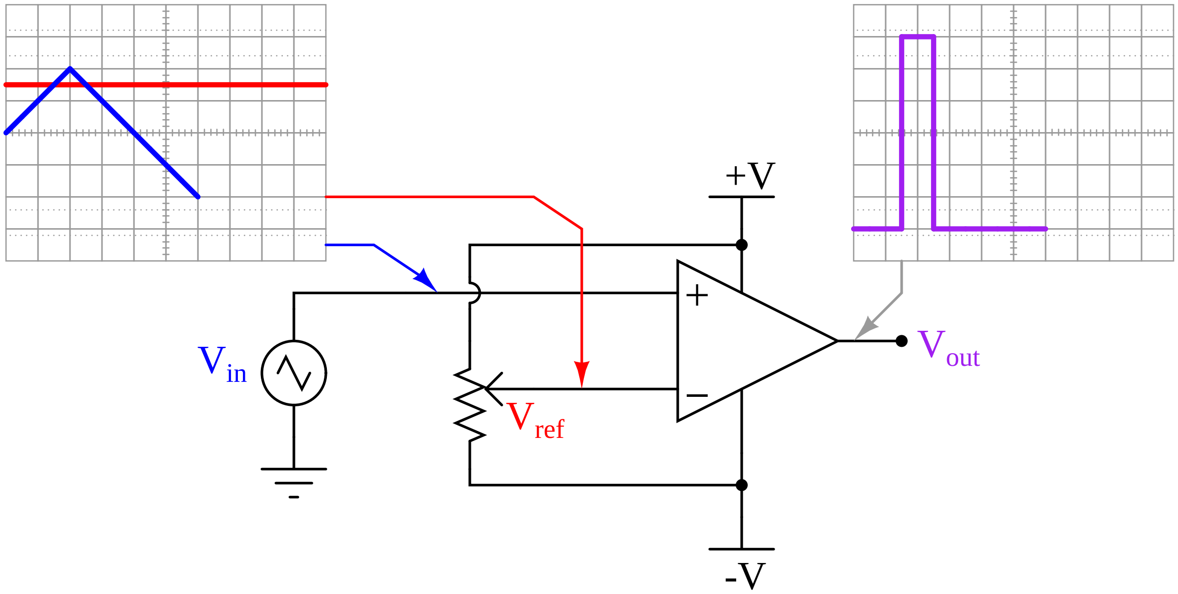

+V
V_in
V_ref
V_out
-V

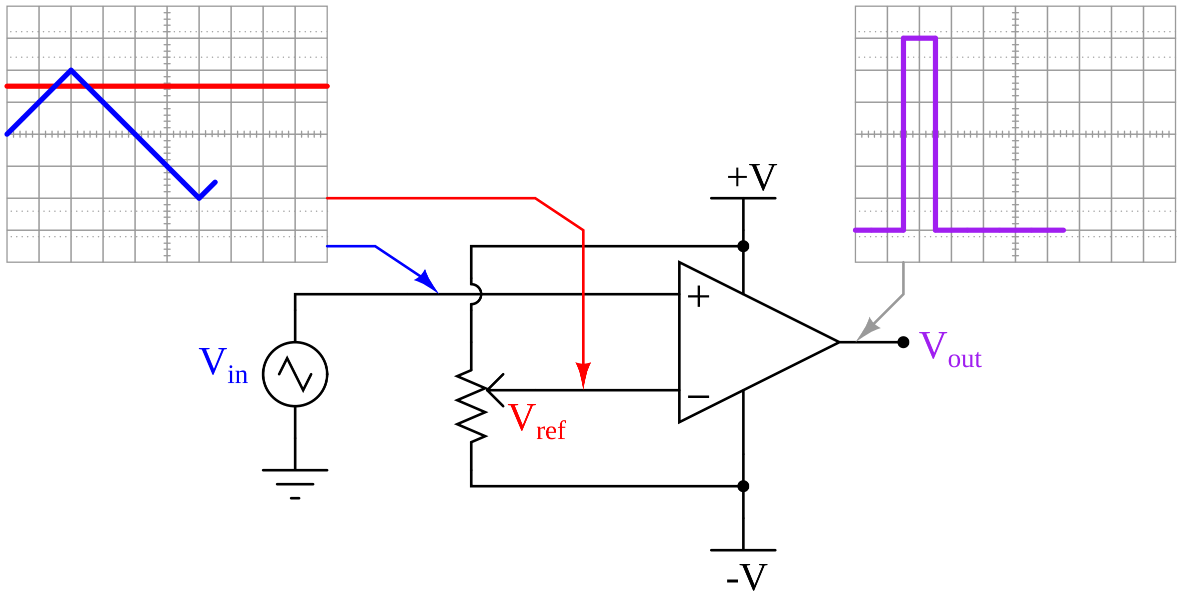


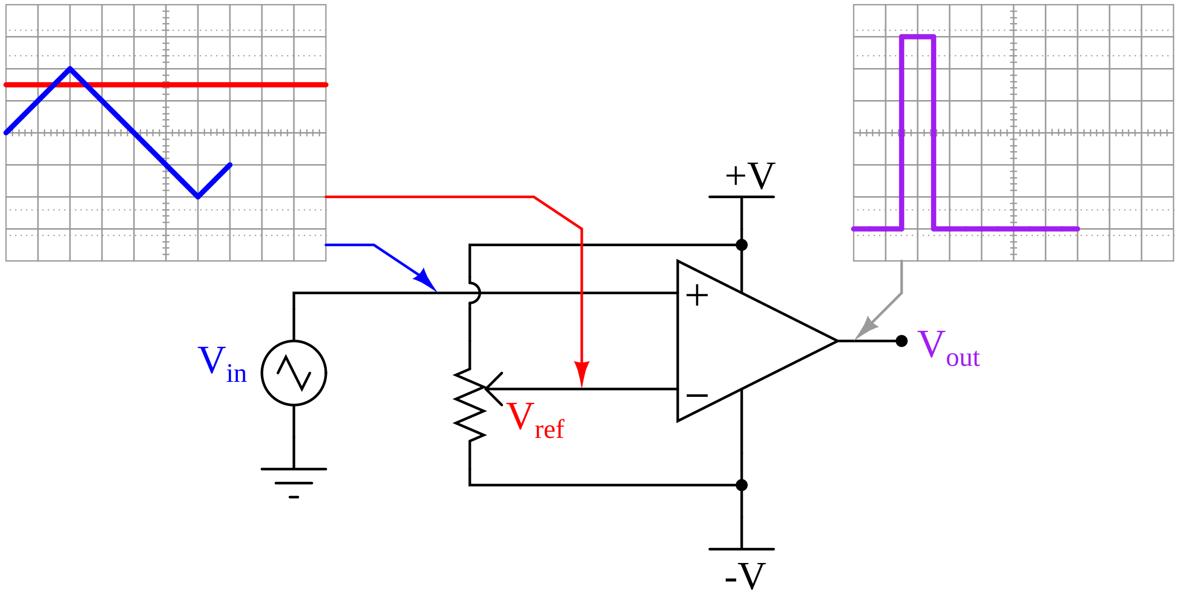
+V
-V
V_{in}
V_{ref}
V_{out}

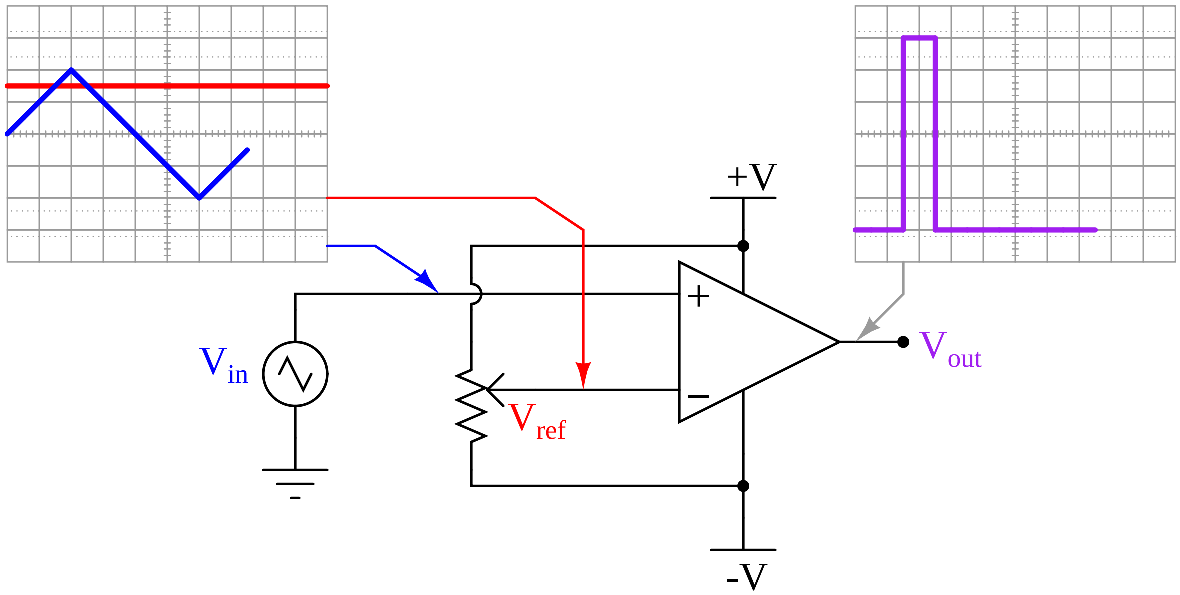

+V
V_in
V_ref
V_out
-V

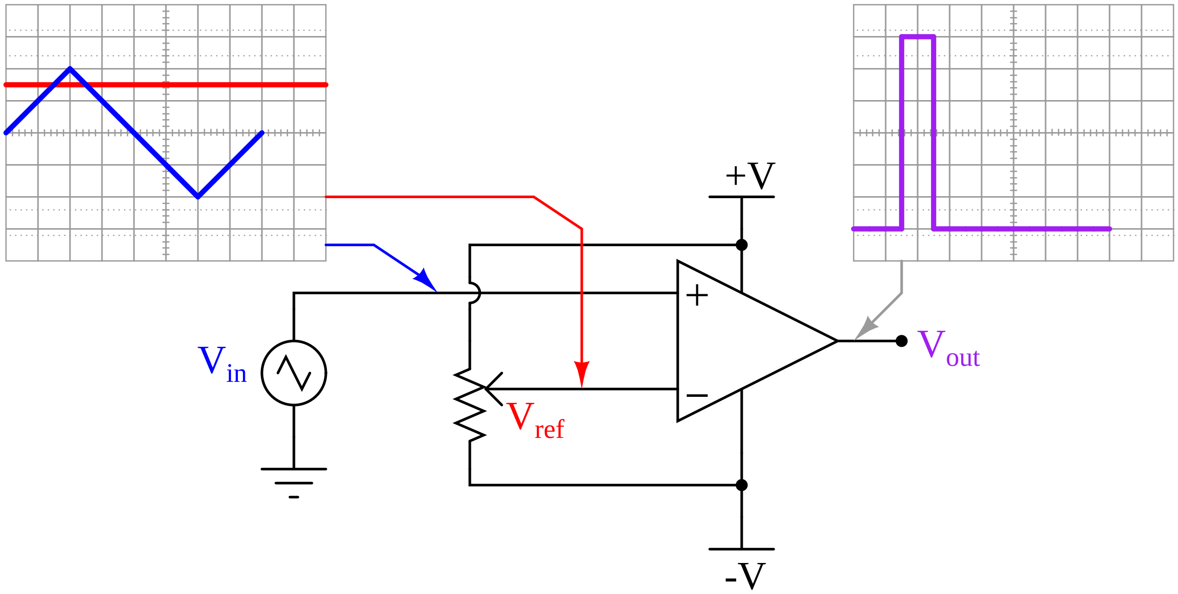

+V
V
in
V
ref
V
out
-V

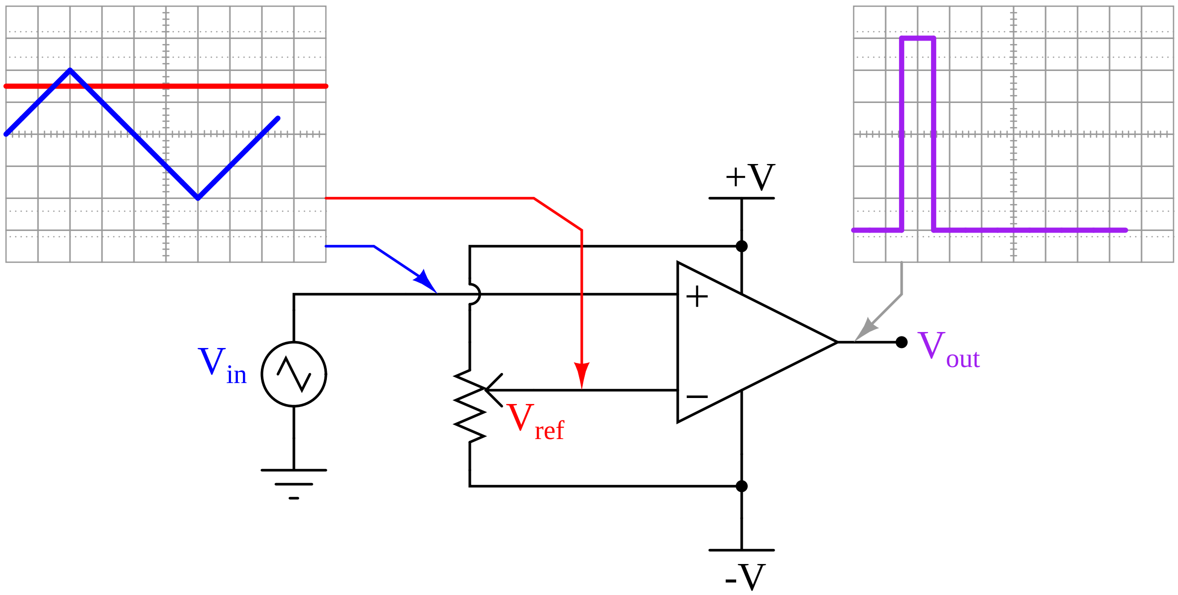

+V
-V
Vin
Vref
Vout
+
−

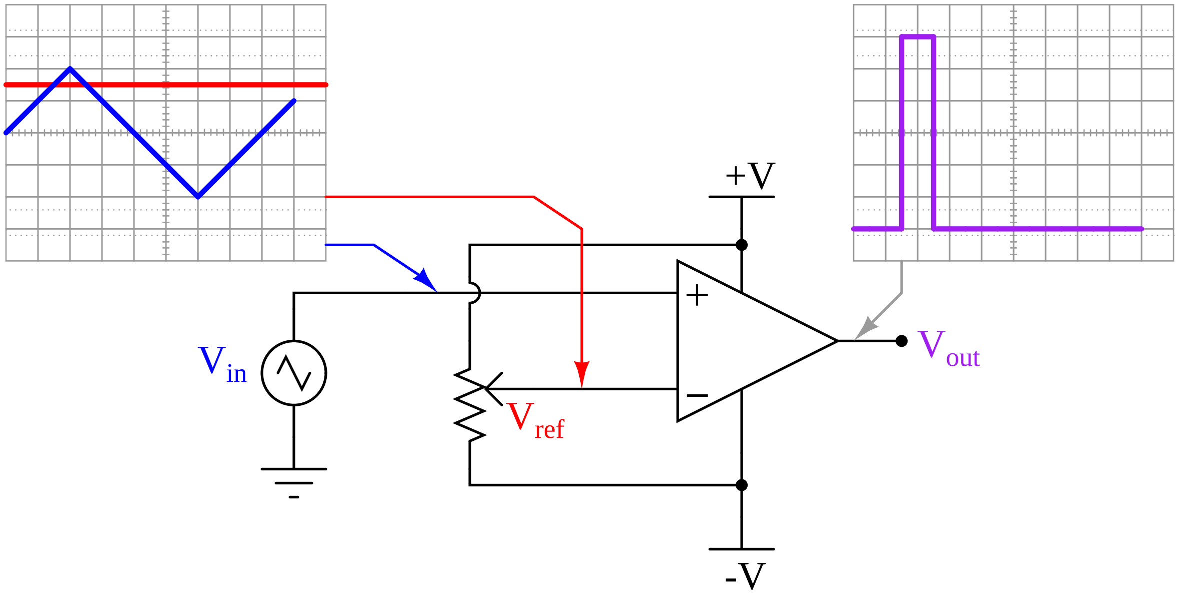

+V
V_in
V_ref
V_out
-V


+V
+
−
V_in
V_ref
V_out
-V

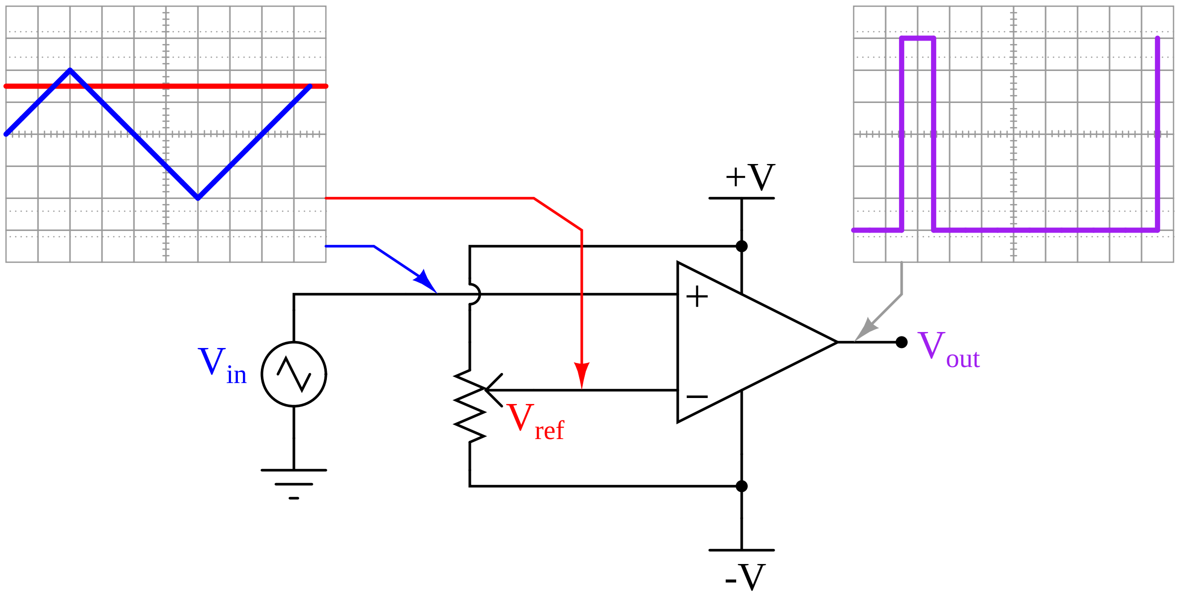

+V
Vin
Vref
Vout
-V

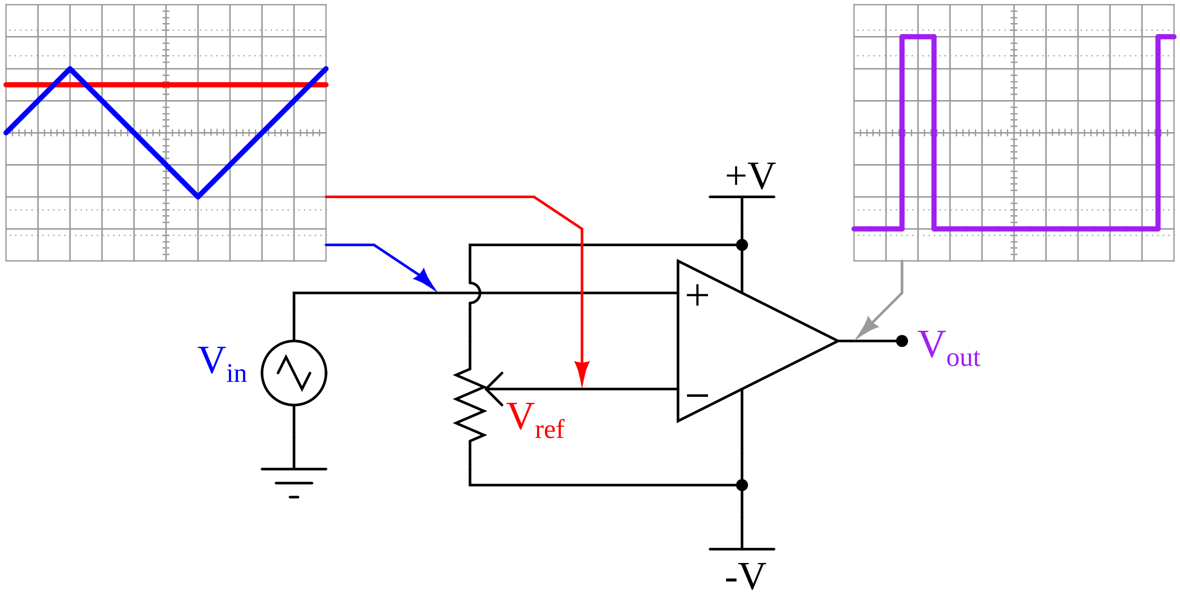

+V
V_{in}
V_{ref}
V_{out}
-V


+V
V$_{in}$
V$_{ref}$
+
−
V$_{out}$
-V

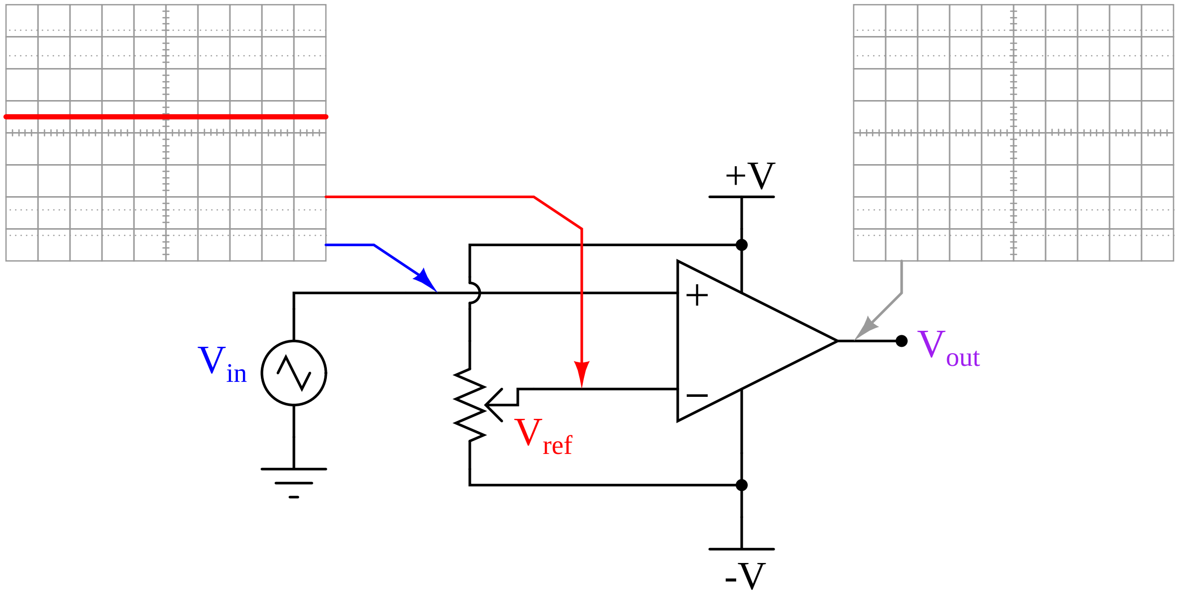


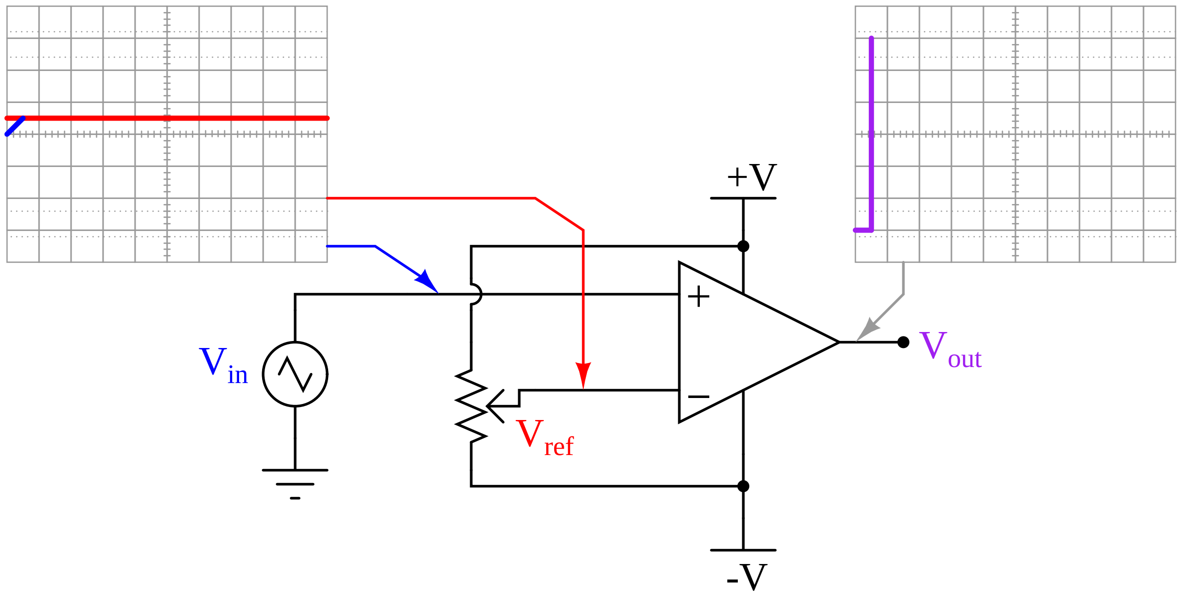
+V
V_{in}
V_{ref}
V_{out}
-V

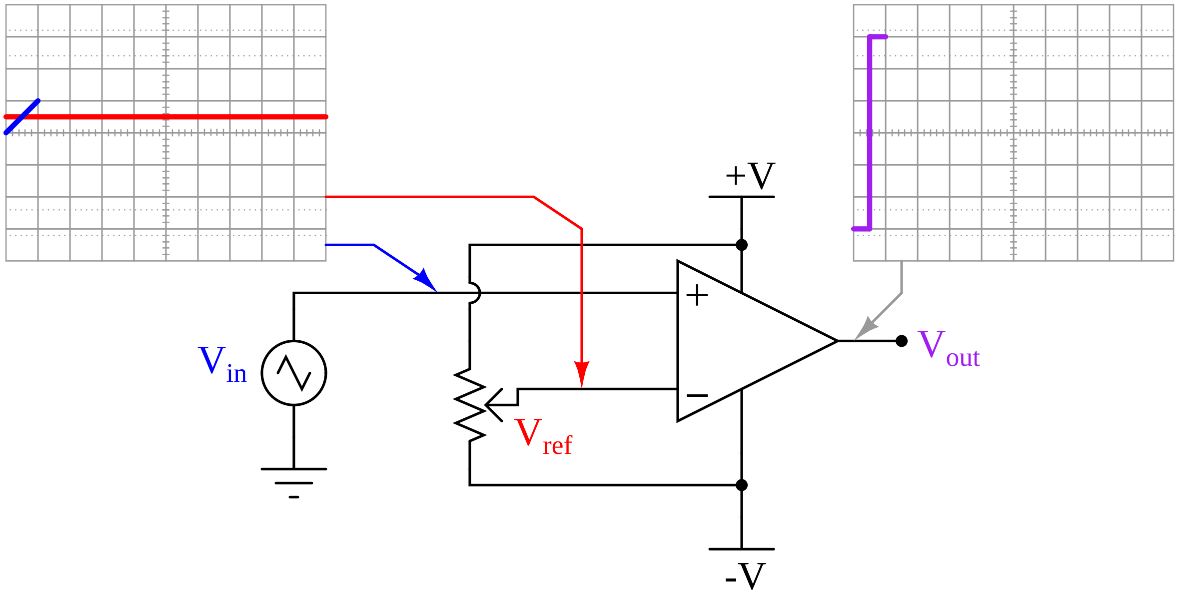

+V
-V
V
in
V
ref
V
out

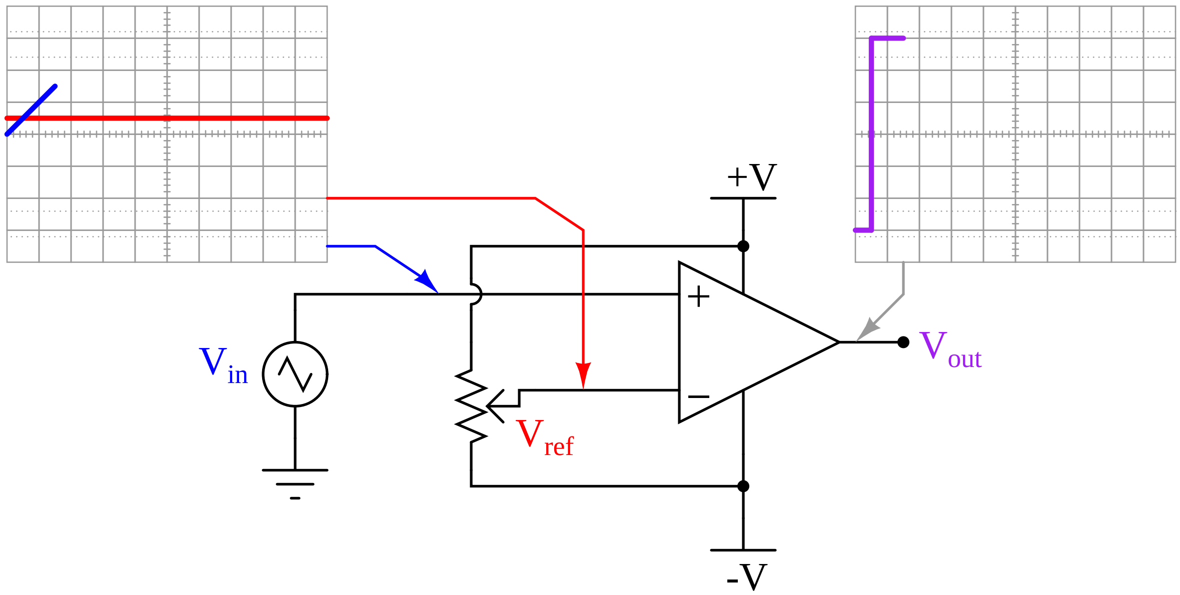


+V
V_{in}
V_{ref}
V_{out}
-V

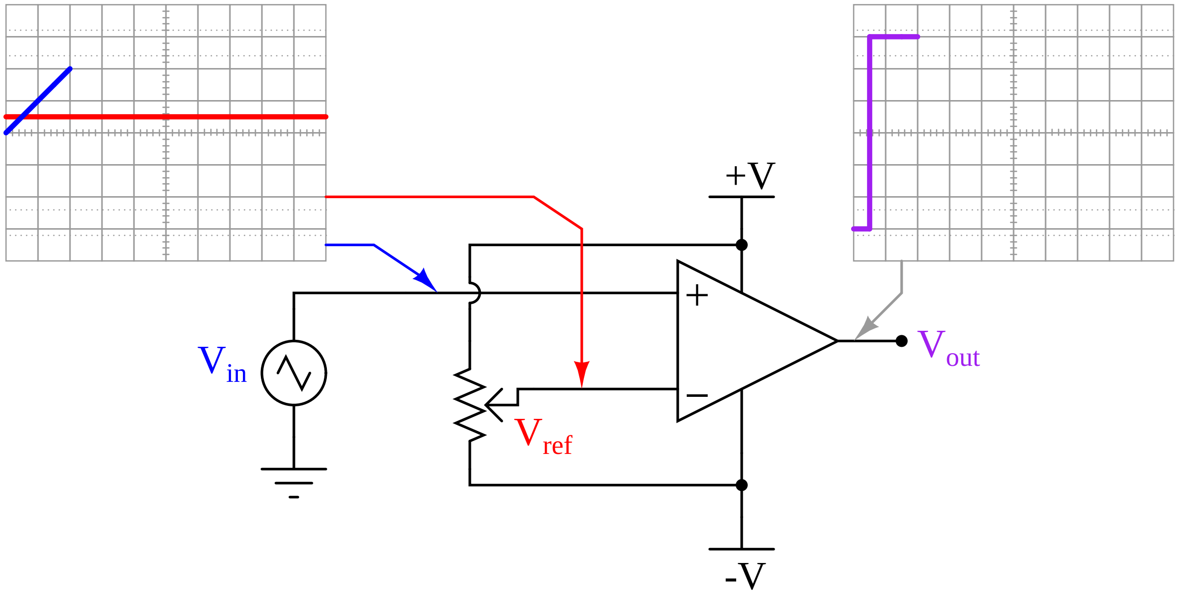

+V
+
−
V_{in}
V_{ref}
V_{out}
-V

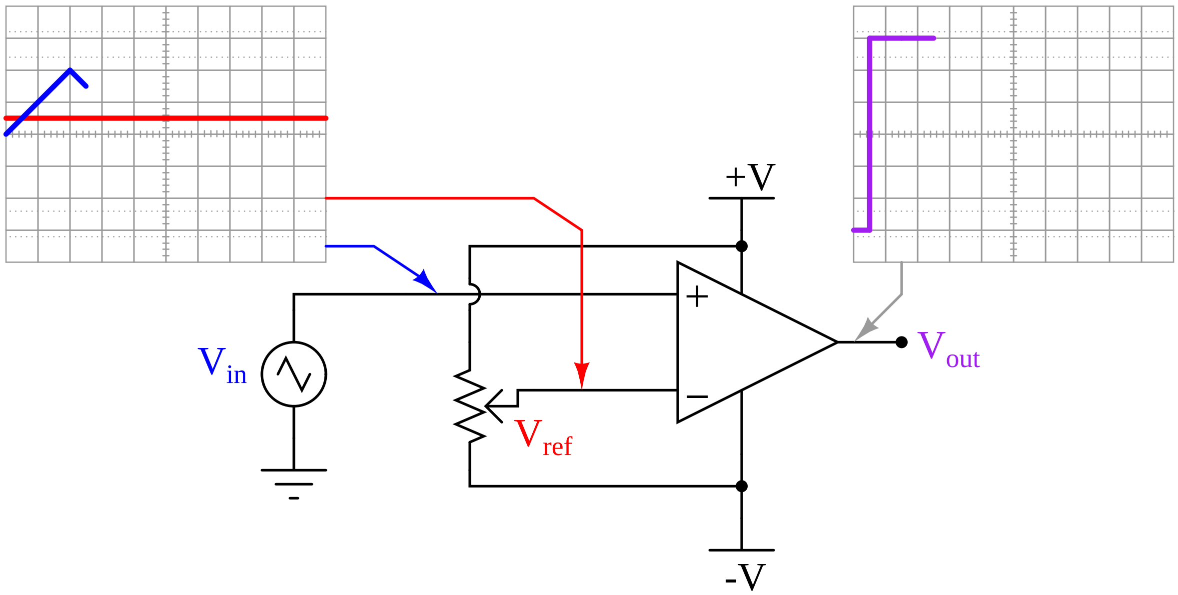

+V
Vin
Vref
Vout
-V

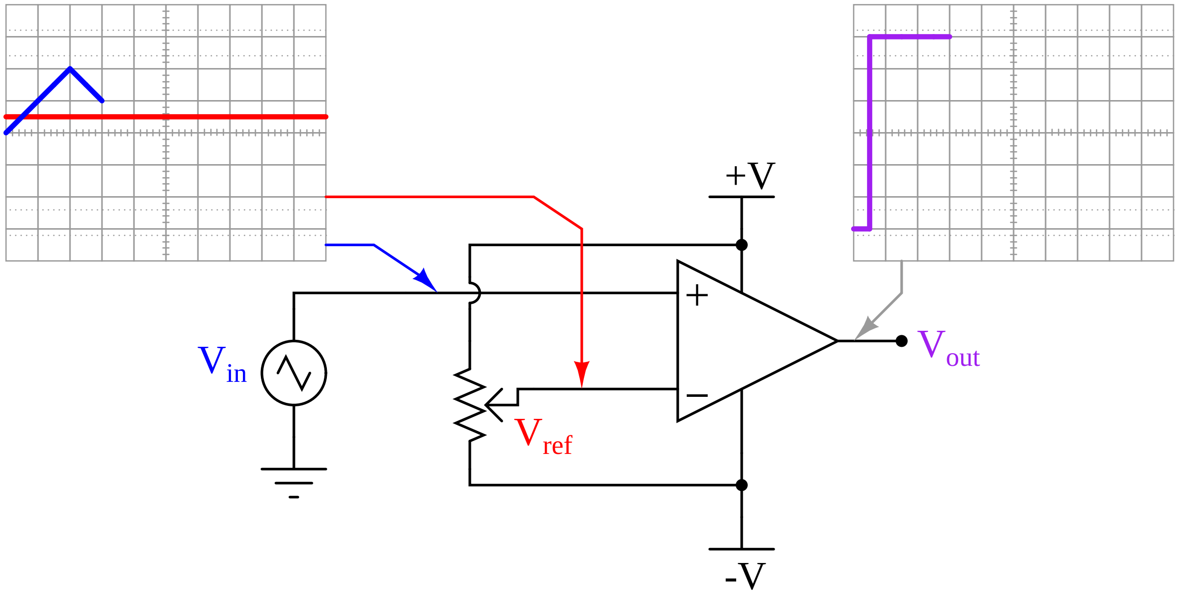

+V
V_in
V_ref
V_out
-V

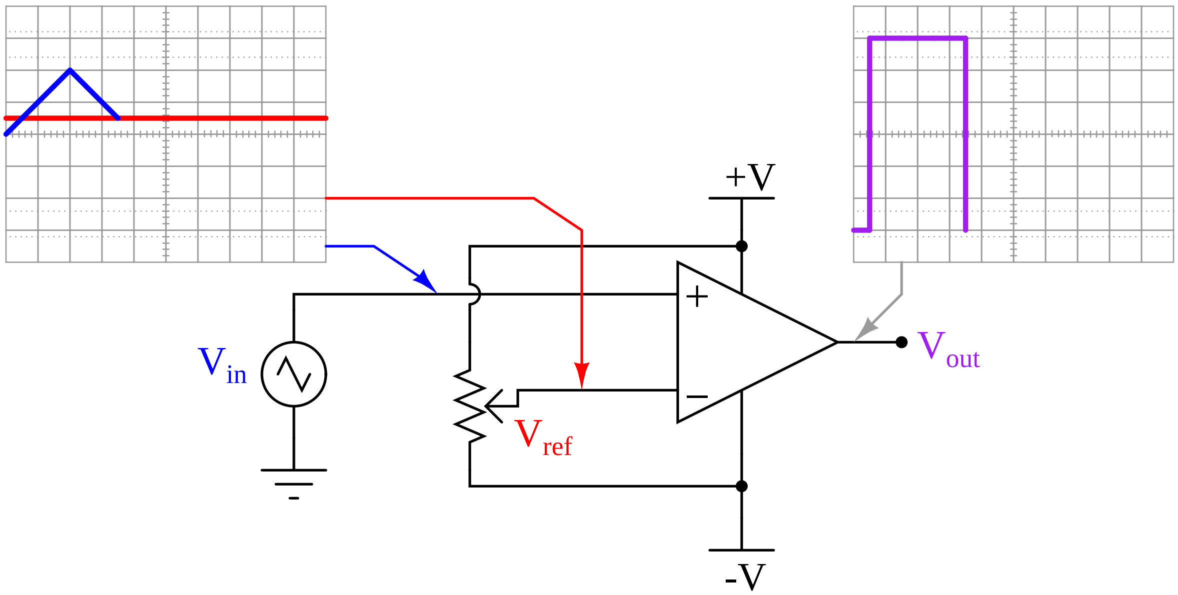


+V
-V
V_{in}
V_{ref}
V_{out}

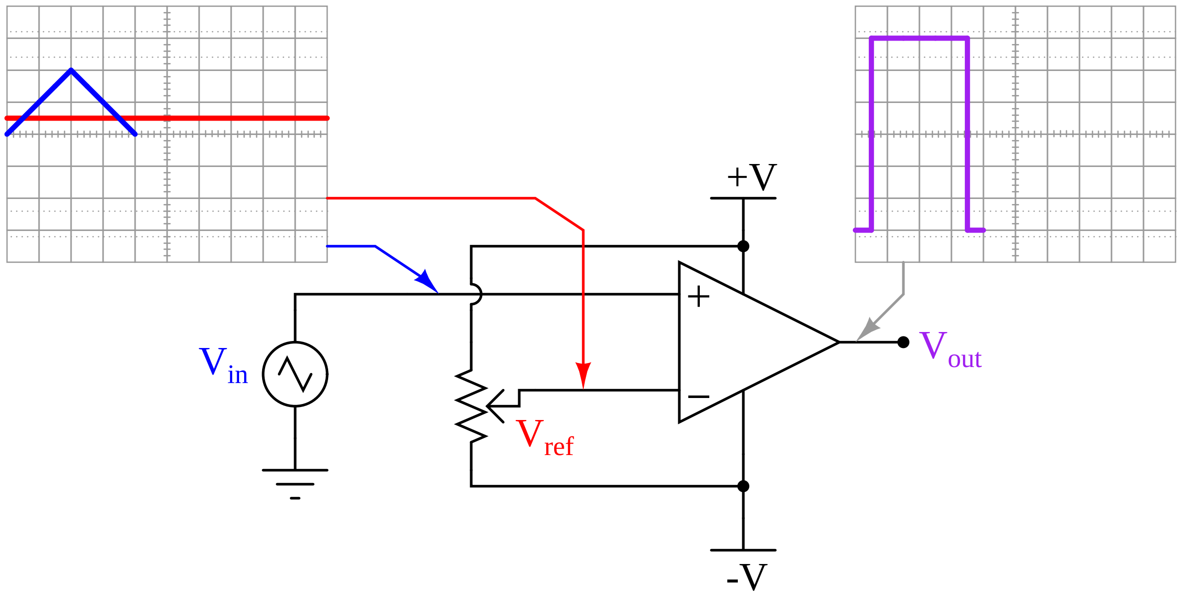

+V
Vin
Vref
Vout
-V

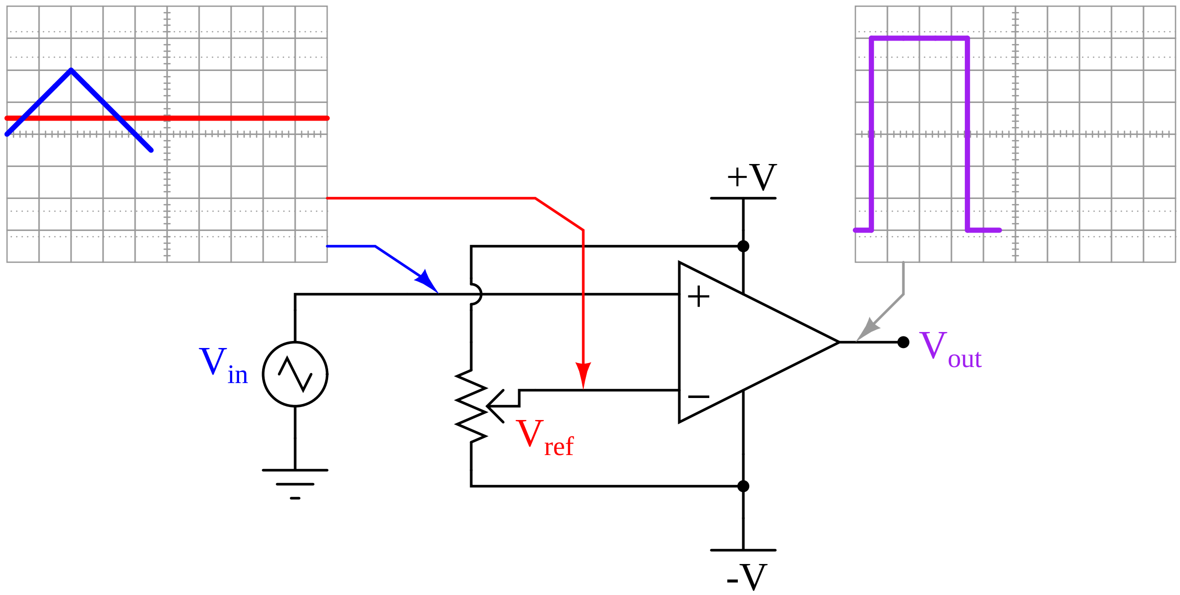

+V
V_in
V_ref
V_out
-V


+V
V_{in}
V_{ref}
V_{out}
-V

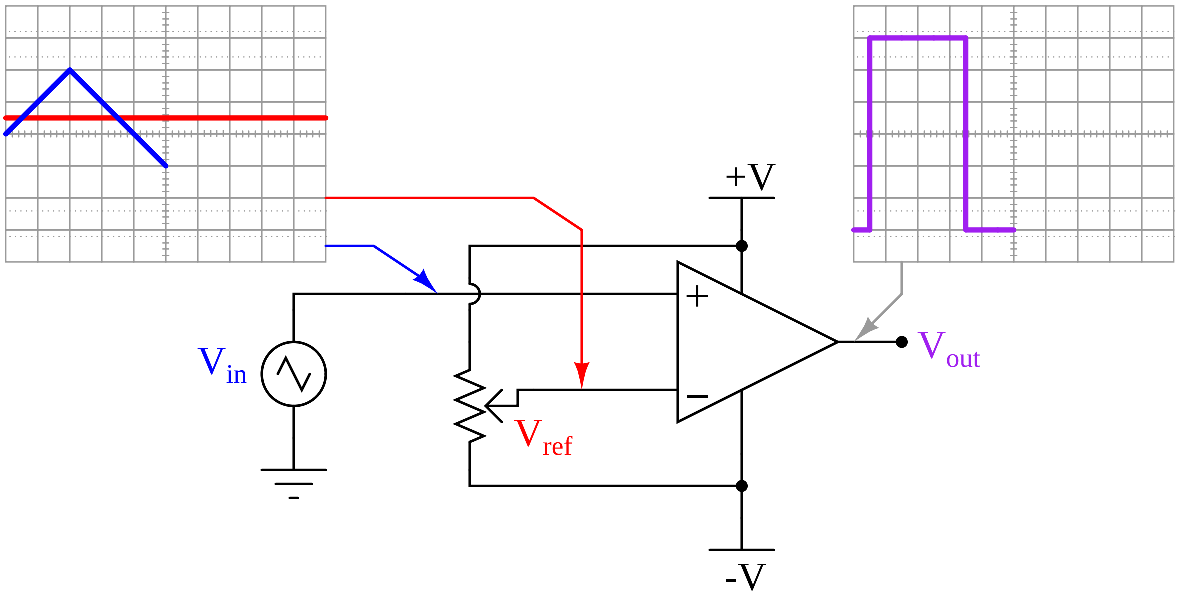


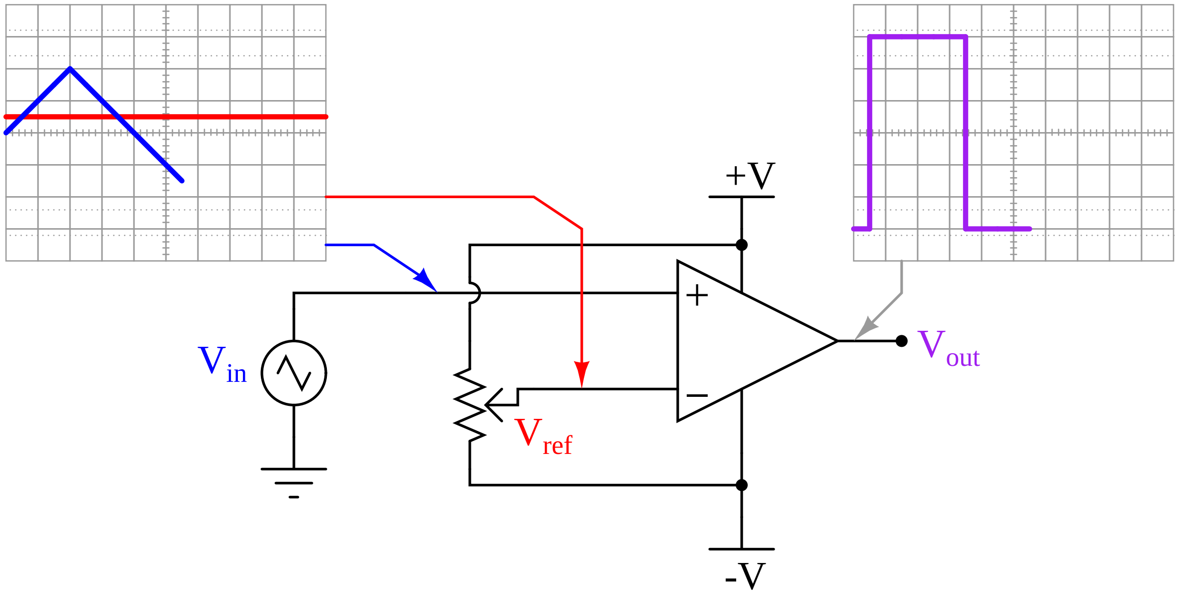
+V
V_in
V_ref
V_out
-V

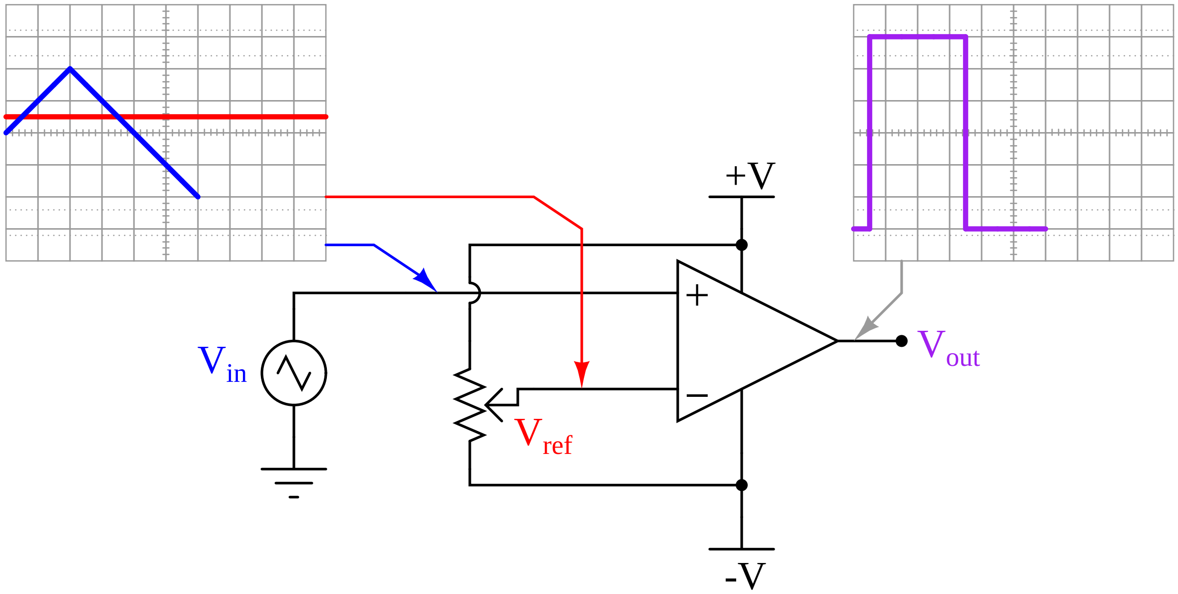

+V
Vin
Vref
Vout
-V



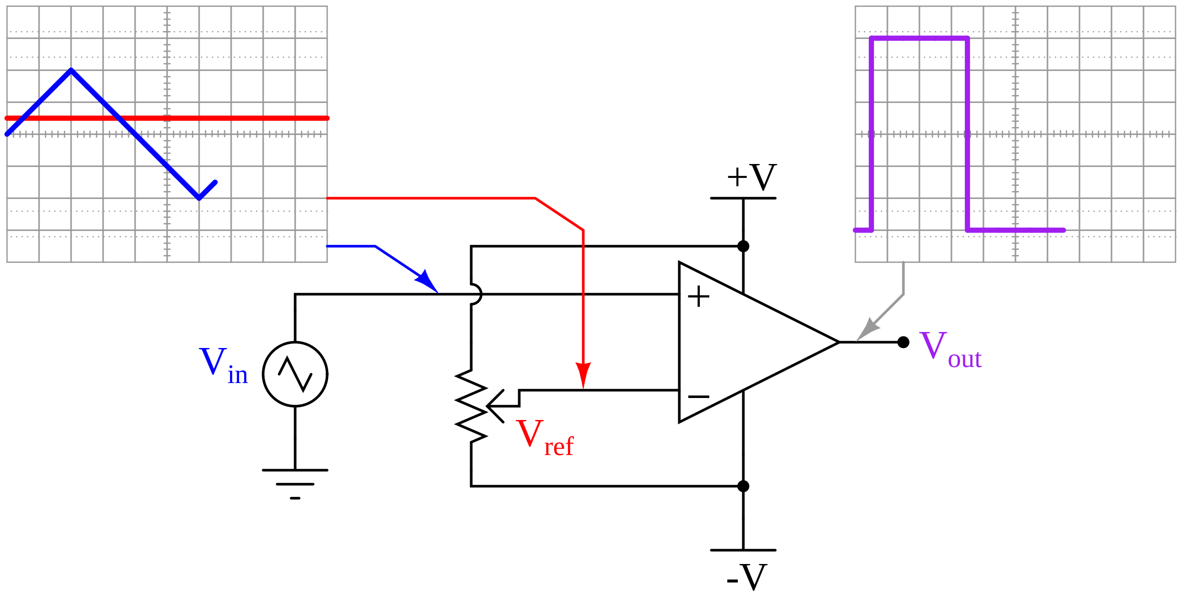
+V
V_in
V_ref
V_out
-V


+V
Vin
Vref
Vout
-V

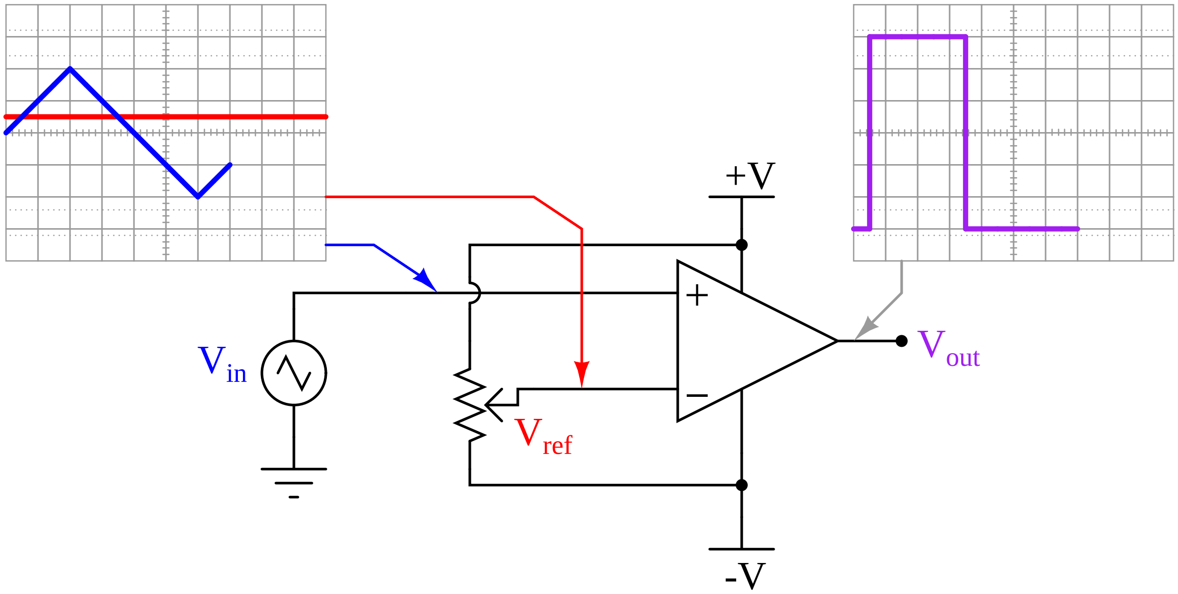

+V
V_{in}
V_{ref}
V_{out}
-V



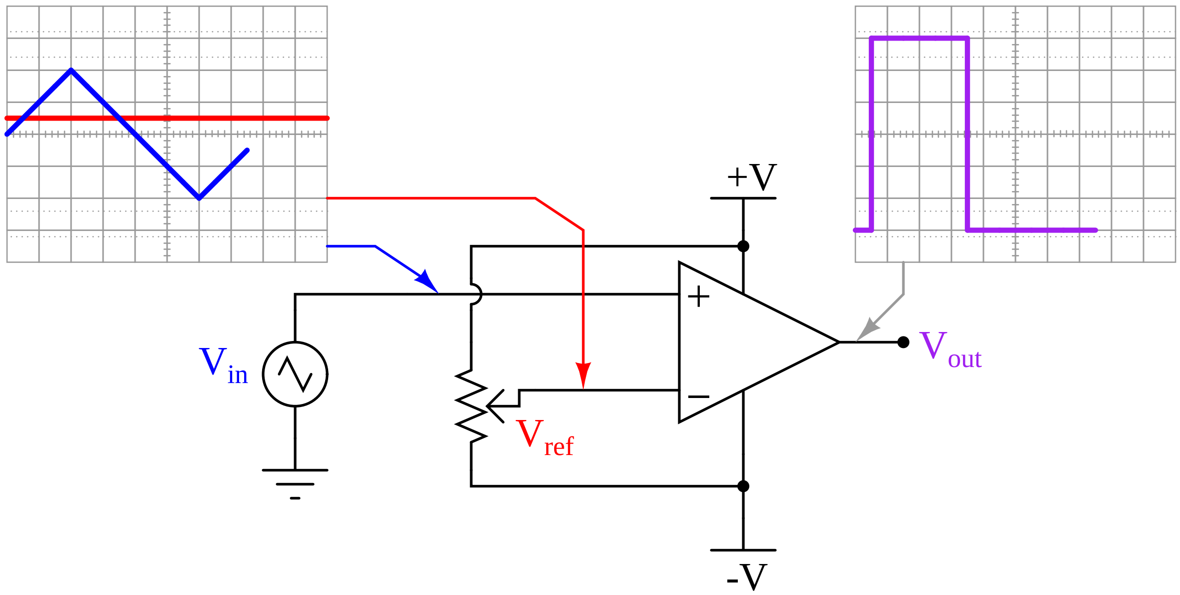
+V
Vin
Vref
Vout
-V

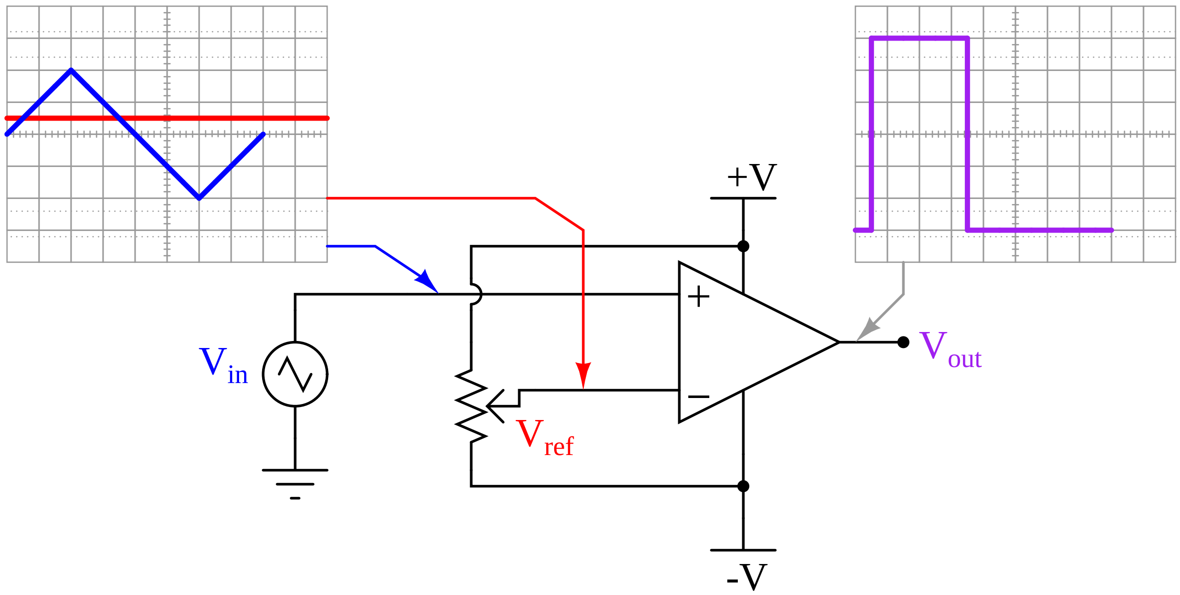


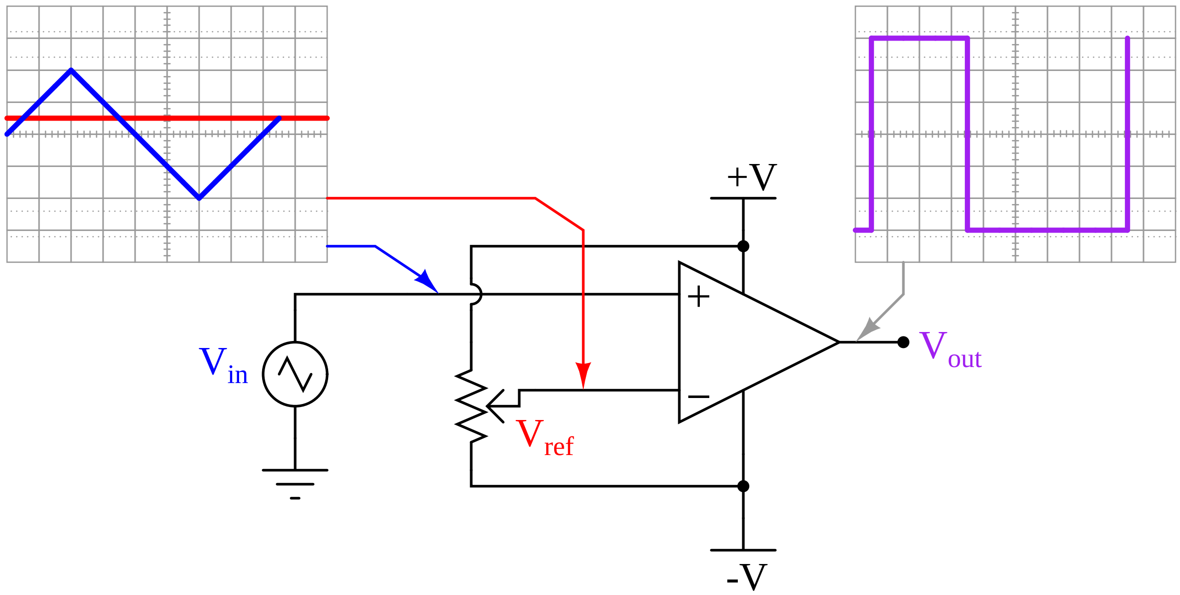
+V
-V
V_{in}
V_{ref}
V_{out}

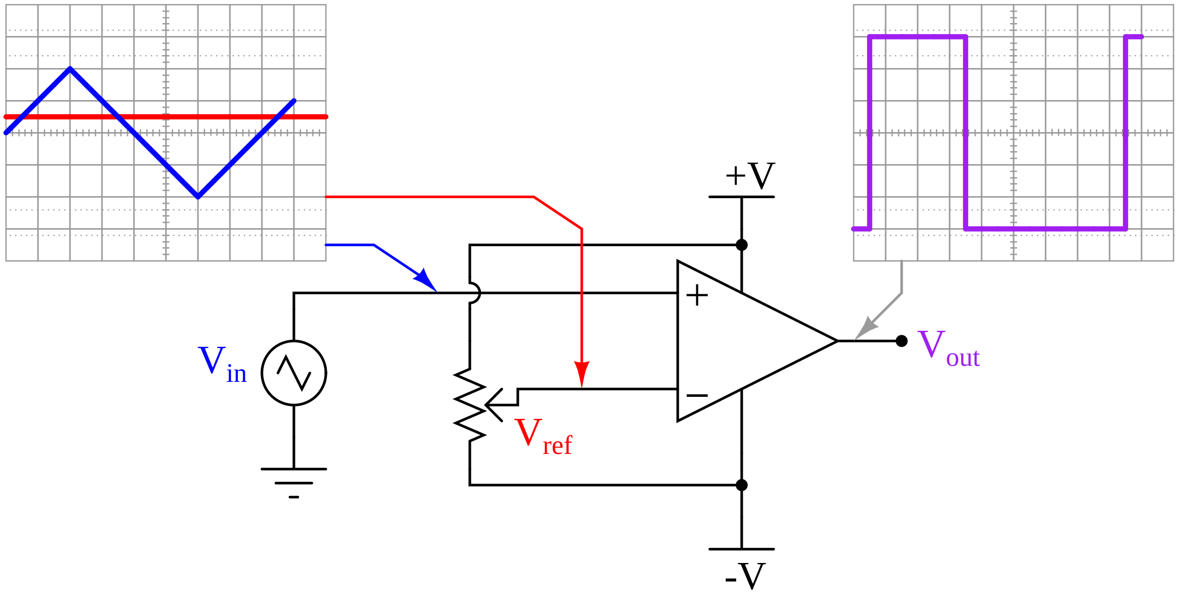


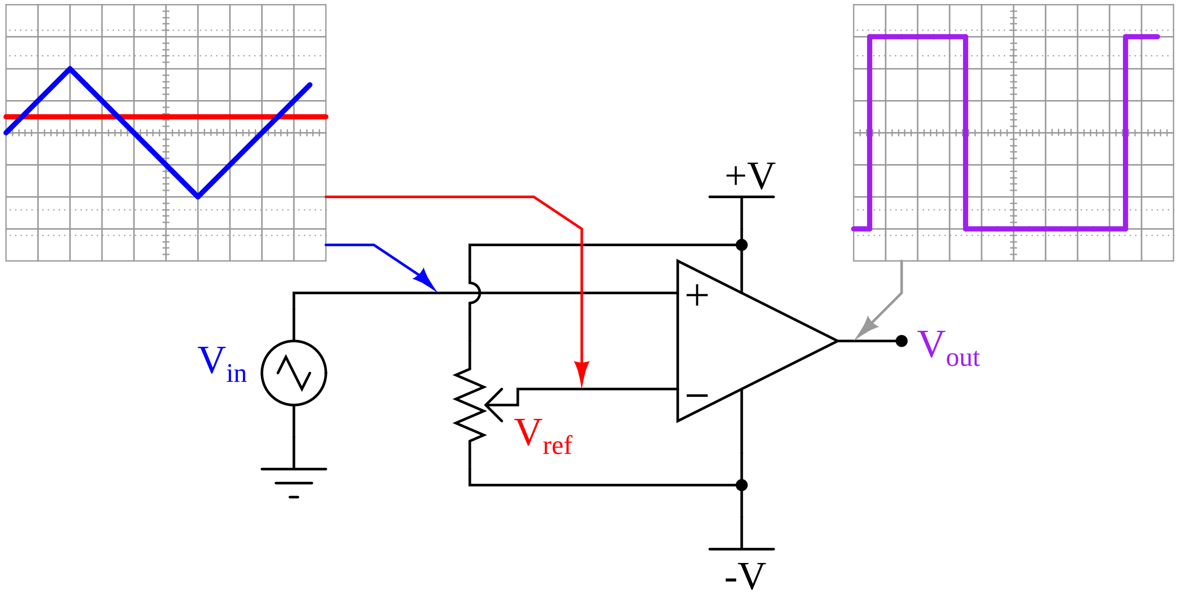
+V
V_{in}
V_{ref}
V_{out}
-V
+
−

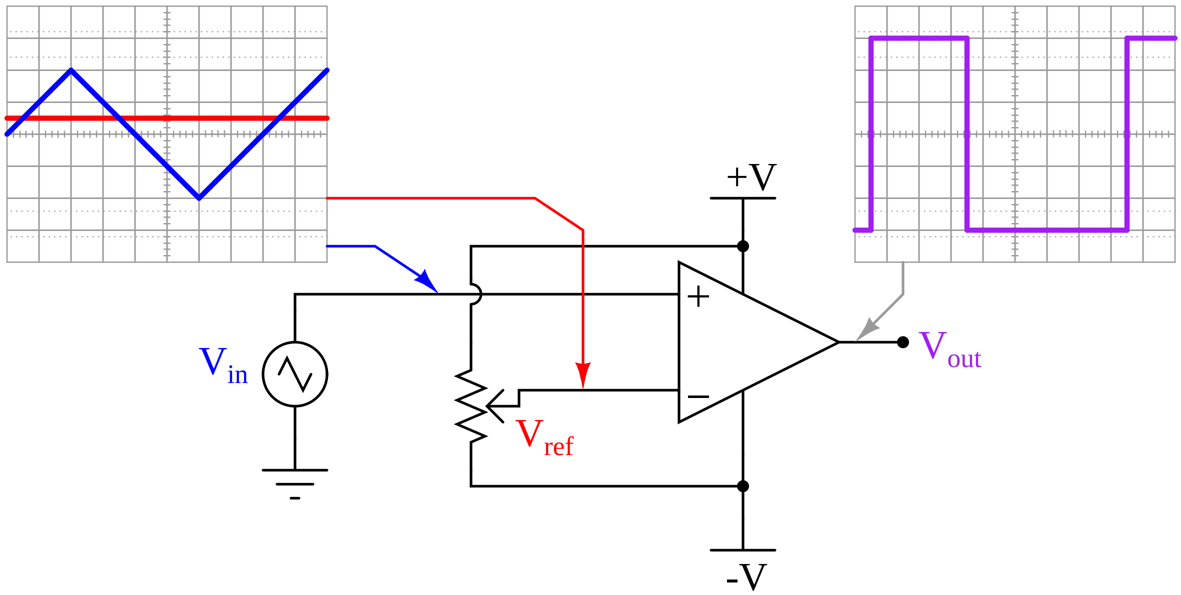

+V
-V
V_{in}
V_{ref}
V_{out}
+
−


+V
V_in
V_ref
V_out
-V


+V
-V
V_{in}
V_{ref}
V_{out}
+
−


+V
-V
V
in
V
ref
V
out
+
−


+V
V_in
V_ref
V_out
-V



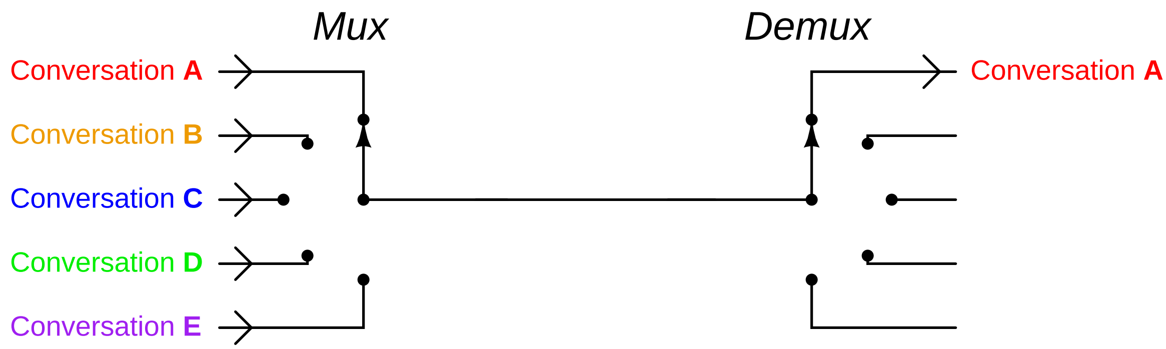
file 03235

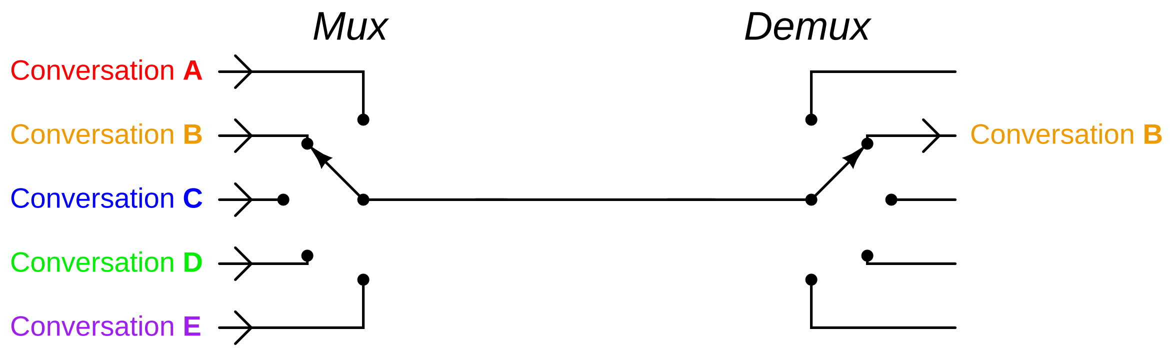
Animation: telephony multiplexer

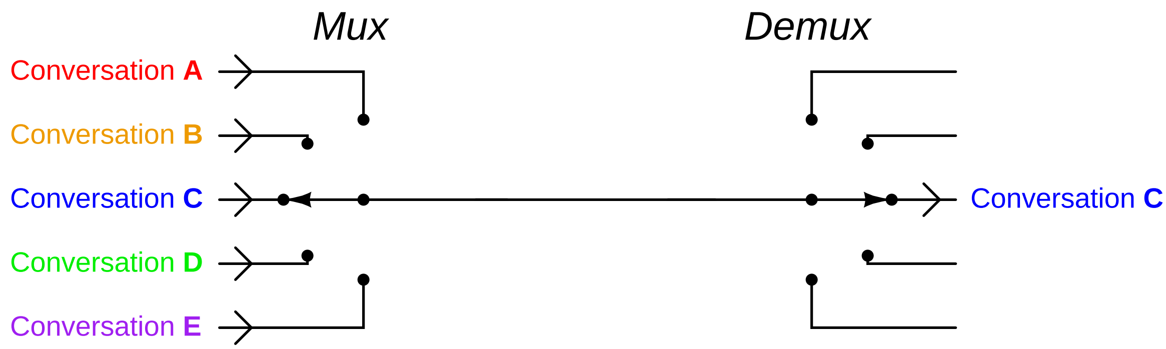
This question consists of a series of images (one per page) that form an animation. Flip the pages with your fingers to view this animation (or click on the "next" button on your viewer) frame-by-frame.

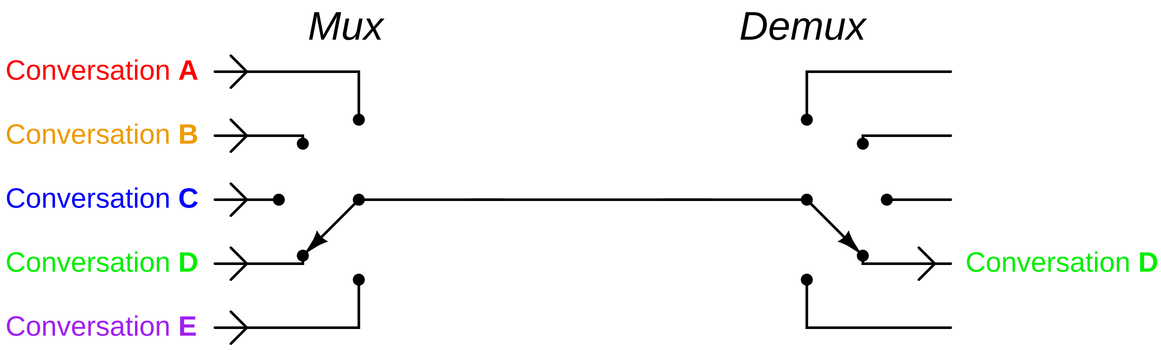
The following animation shows how multiple telephone conversations may be "multiplexed" across a single communication channel. A high switching speed is necessary to make the conversations seamless, which may be simulated by watching the animation at a high frame rate and seeing that the respective conversation outputs appear to be constant. Some questions to ponder:

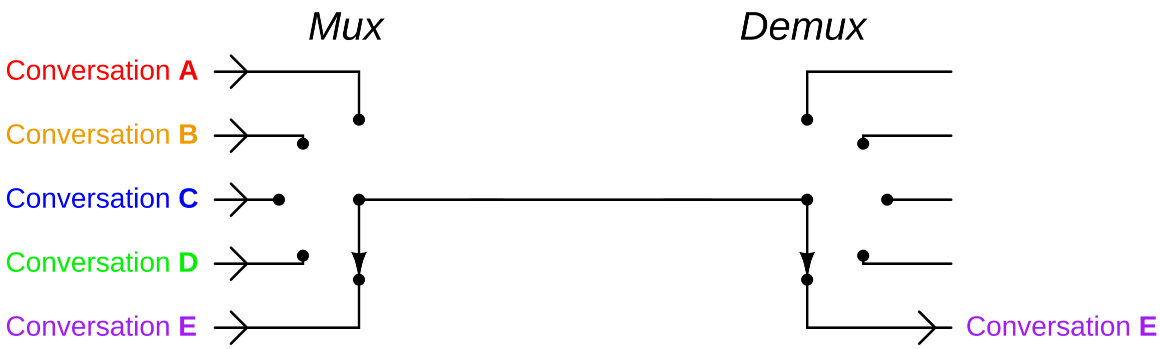
- Why do you suppose anyone would do this? Why not just have five separate lines, one for each conversation?
- How fast do you suppose the mux/demux pair would have to switch in order for the received conversations to appear seamless?


Mux
Demux
Conversation A
Conversation B
Conversation C
Conversation D
Conversation E
Conversation A


Mux
Demux
Conversation A
Conversation B
Conversation C
Conversation D
Conversation E
Conversation B


Mux
Demux
Conversation A
Conversation B
Conversation C
Conversation D
Conversation E
Conversation C


Mux
Demux
Conversation A
Conversation B
Conversation C
Conversation D
Conversation E
Conversation D


Mux
Demux
Conversation A
Conversation B
Conversation C
Conversation D
Conversation E
Conversation E

file 03236

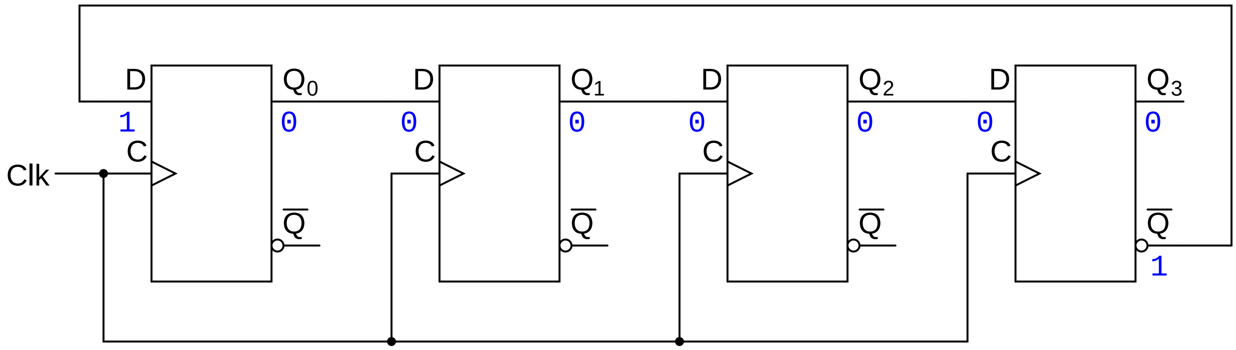
Question 13

Animation: Johnson ring counter

This question consists of a series of images (one per page) that form an animation. Flip the pages with your fingers to view this animation (or click on the "next" button on your viewer) frame-by-frame.

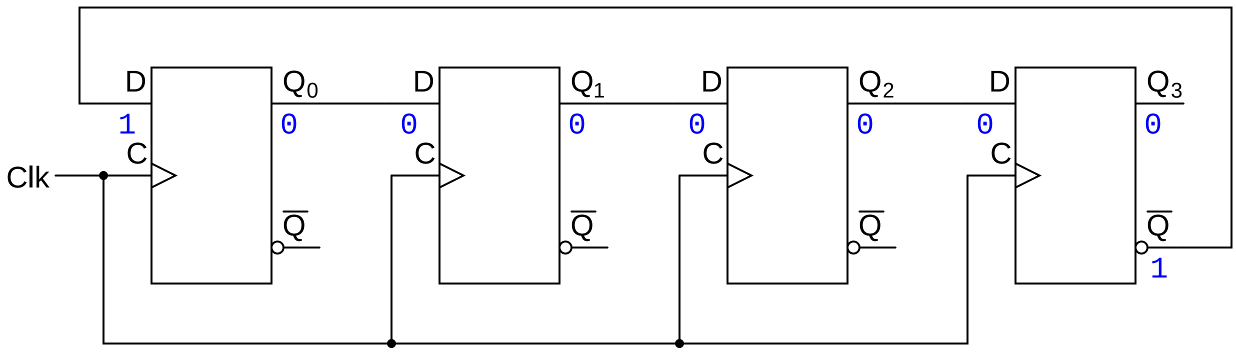
The following animation shows a 4-bit Johnson ring counter circuit. Watch what happens as the clock signal oscillates. Here are some things to look for:

- Note when the logic state at each flip-flop input gets sent to the Q output.
- Why do you think this is called a "ring" counter circuit?

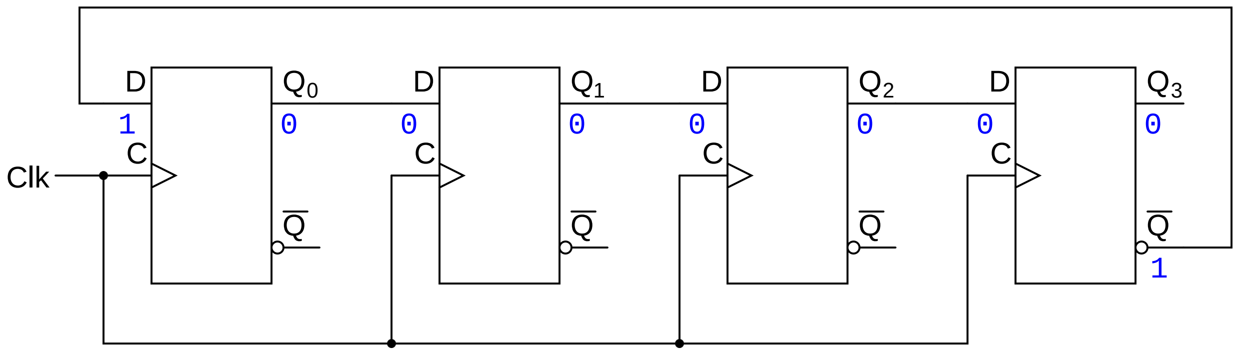


D
Q0
D
Q1
D
Q2
D
Q3
1
0
0
0
0
0
0
0
C
C
C
C
Clk
Q
Q
Q
Q
1

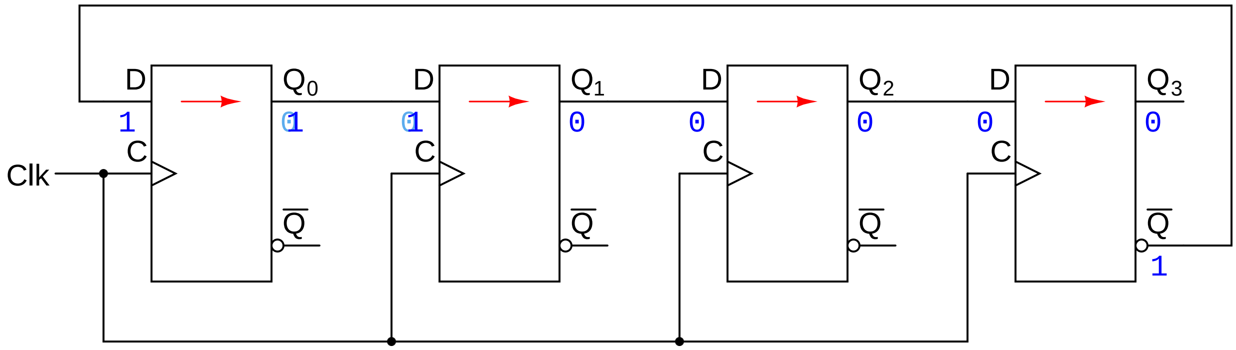
Clock
VDD
Gnd
Q0
VDD
Gnd
Q1
VDD
Gnd
Q2
VDD
Gnd
Q3
VDD
Gnd


D
Q0
D
Q1
D
Q2
D
Q3
1
0
0
0
0
0
0
0
C
C
C
C
Clk
Q
Q
Q
Q
1

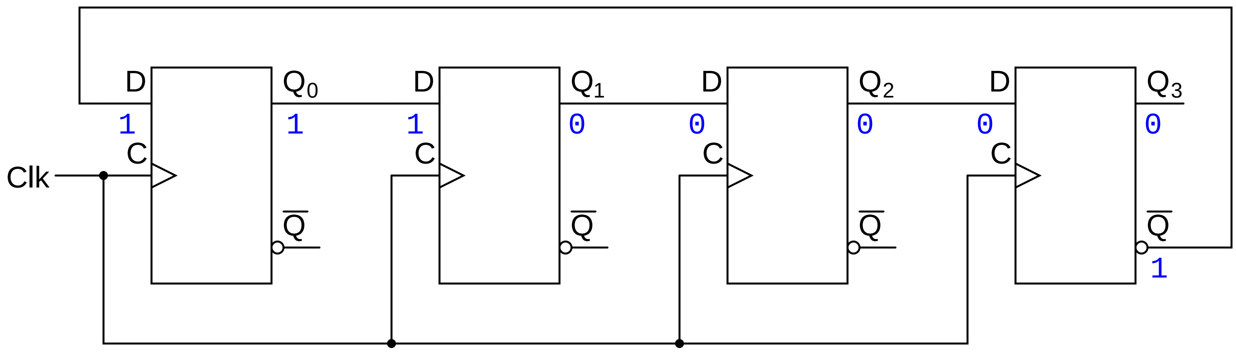

Clock
Q0
Q1
Q2
Q3
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd


D
Q0
D
Q1
D
Q2
D
Q3
1
0
0
0
0
0
0
0
C
C
C
C
Clk
Q
Q
Q
Q
1


Clock
VDD
Gnd
Q0
VDD
Gnd
Q1
VDD
Gnd
Q2
VDD
Gnd
Q3
VDD
Gnd

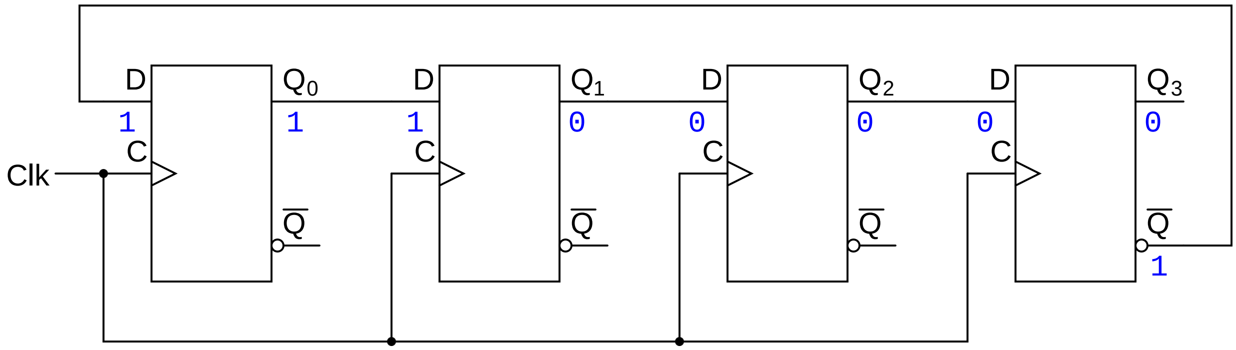

D
Q0
D
Q1
D
Q2
D
Q3
C
C
C
C
Clk
Q
Q
Q
Q
1
1
1
0
0
0
0
0
1


Clock
Q0
Q1
Q2
Q3
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd



D
Q0
D
Q1
D
Q2
D
Q3
C
C
C
C
Clk
Q
Q
Q
Q
1
1
1
0
0
0
0
0
1

Clock
Q0
Q1
Q2
Q3
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd


D
Q0
D
Q1
D
Q2
D
Q3
C
C
C
C
Clk
Q
Q
Q
Q
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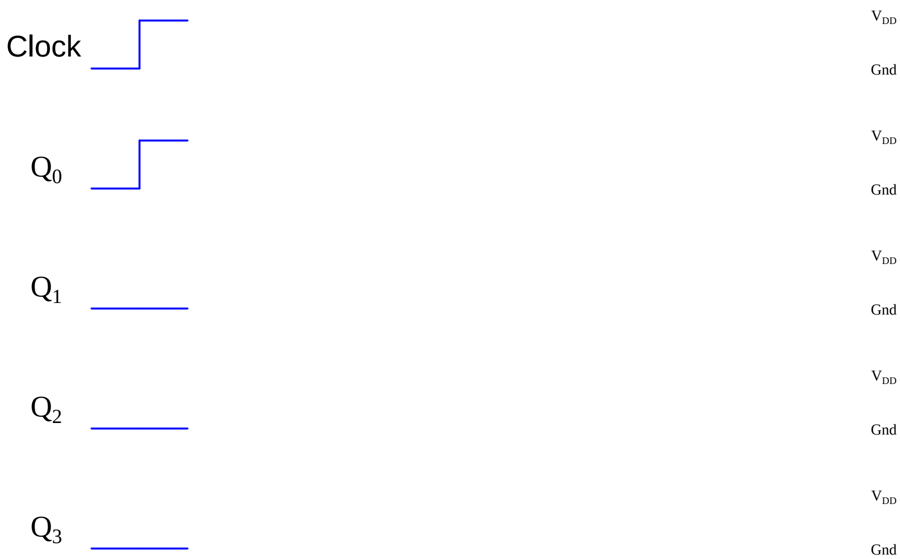
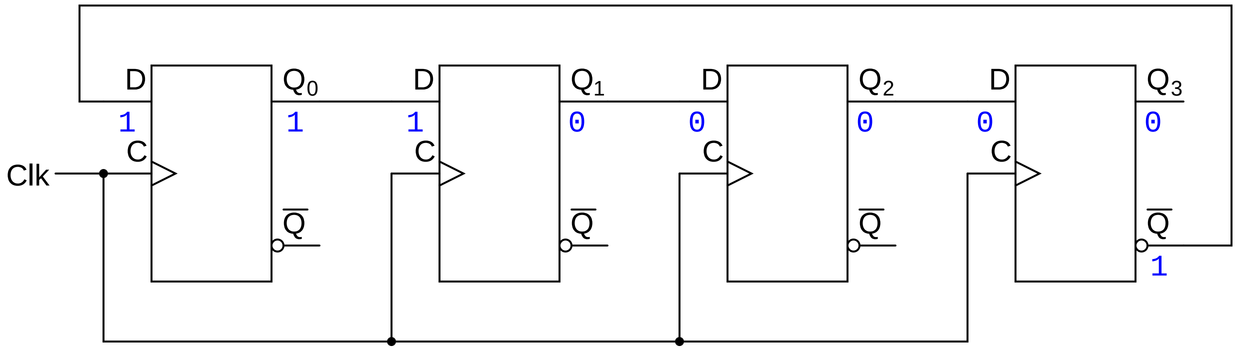
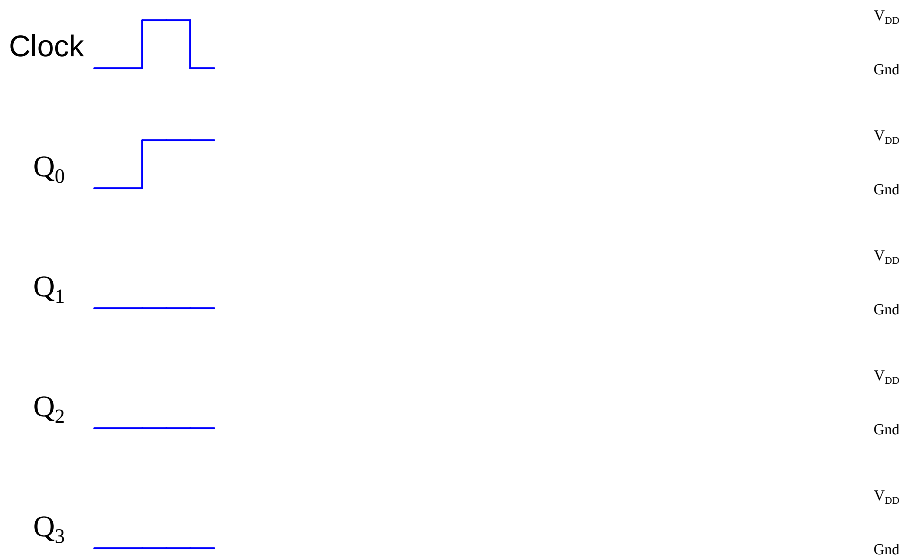
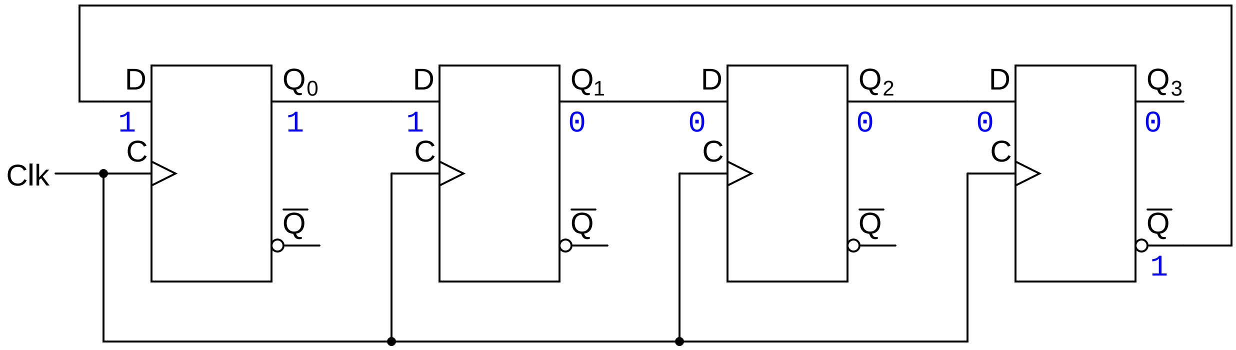
0
0
0
0
1

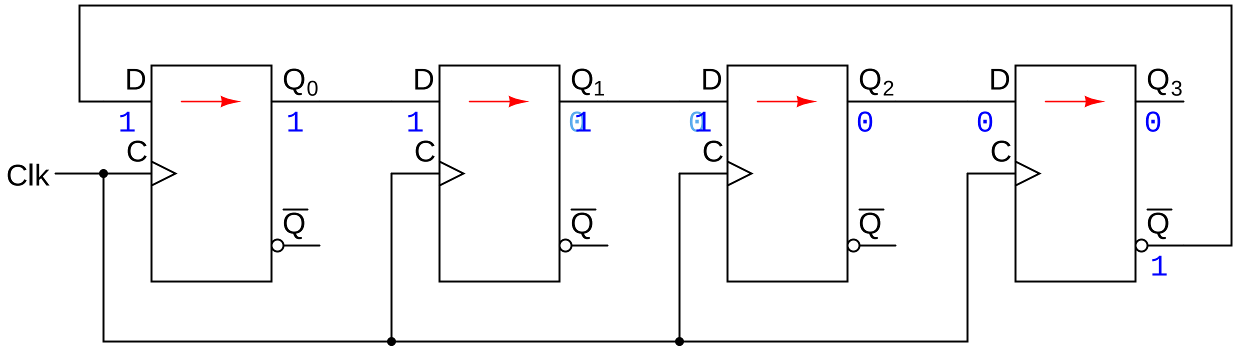

Clock
Q0
Q1
Q2
Q3
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd

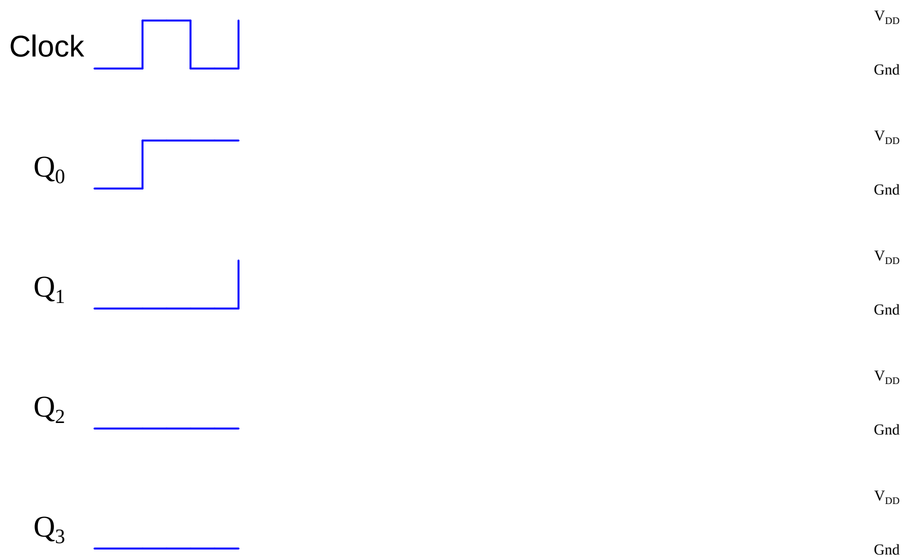

D
Q0
D
Q1
D
Q2
D
Q3
1
1
1
0
0
0
0
0
C
C
C
C
Clk
Q
Q
Q
Q
1

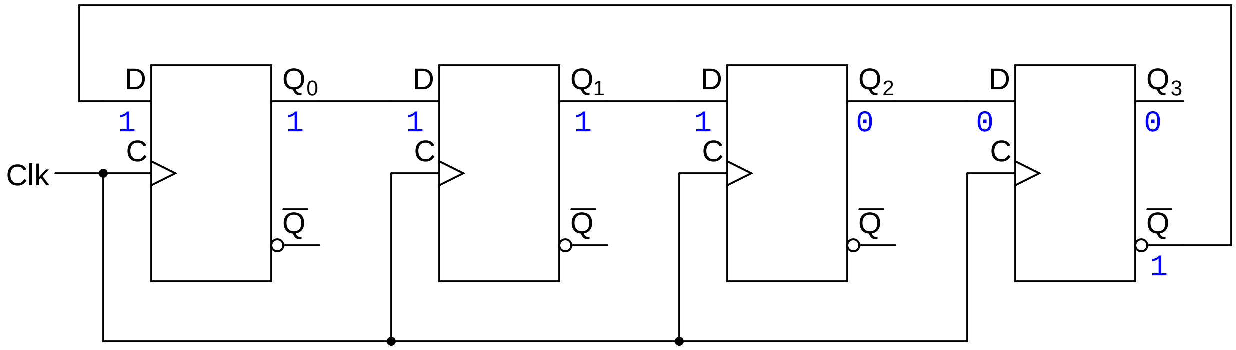

Clock
Q0
Q1
Q2
Q3
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd

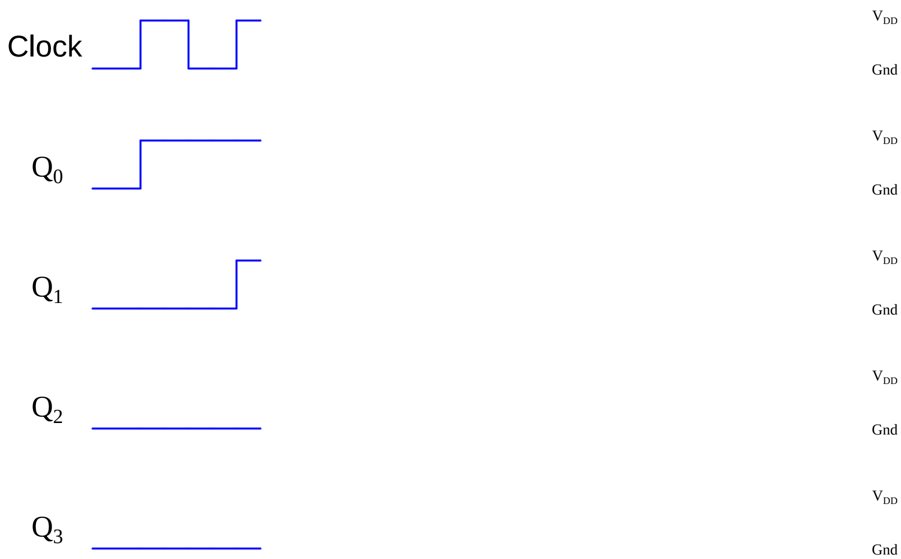

D
Q0
D
Q1
D
Q2
D
Q3
1
1
1
0
0
0
0
0
C
C
C
C
Clk
Q
Q
Q
Q
1

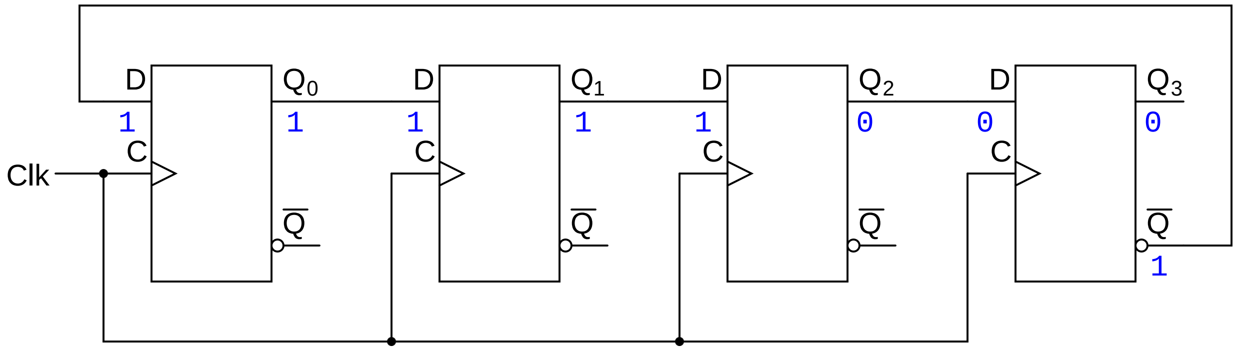

Clock
Q0
Q1
Q2
Q3
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd


D
Q0
Q1
Q2
Q3
C
Clk
Q
1
0


Clock
Q0
Q1
Q2
Q3
VDD
Gnd


D
Q0
D
Q1
D
Q2
D
Q3
1
1
1
1
1
0
0
0
C
C
C
C
Clk
Q
Q
Q
Q
1


Clock
Q0
Q1
Q2
Q3
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd


D
Q0
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Q1
D
Q2
D
Q3
1
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1
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0
0
0
C
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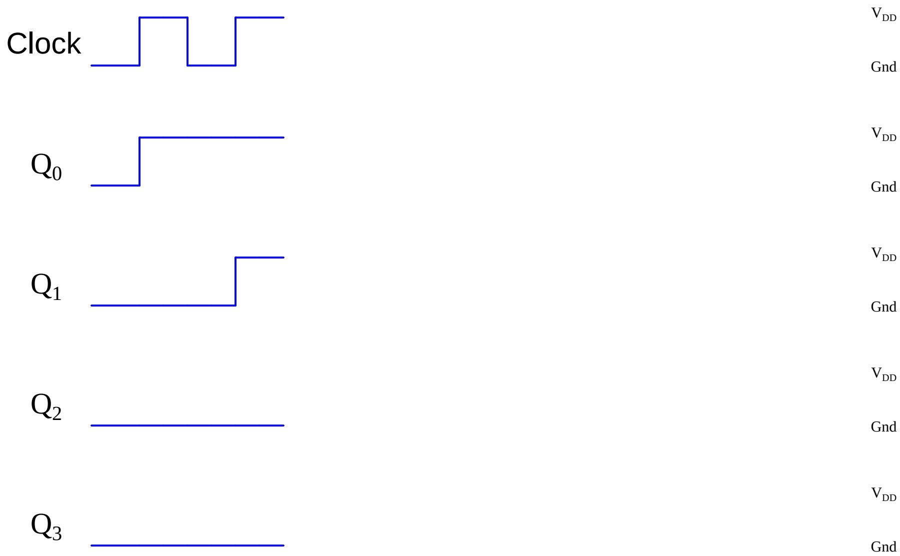
C
C
Clk
Q
Q
Q
Q
1


Clock
VDD
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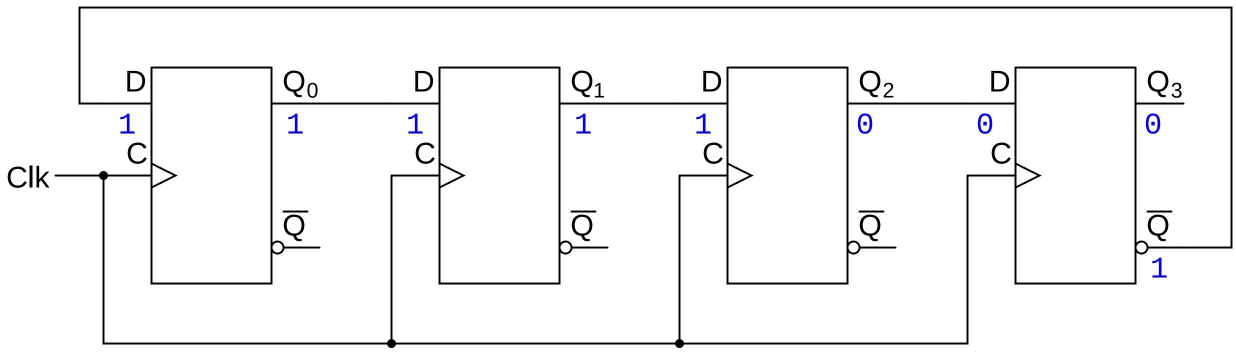
Q0
VDD
Gnd
Q1
VDD
Gnd
Q2
VDD
Gnd
Q3
VDD
Gnd


D
Q0
D
Q1
D
Q2
D
Q3
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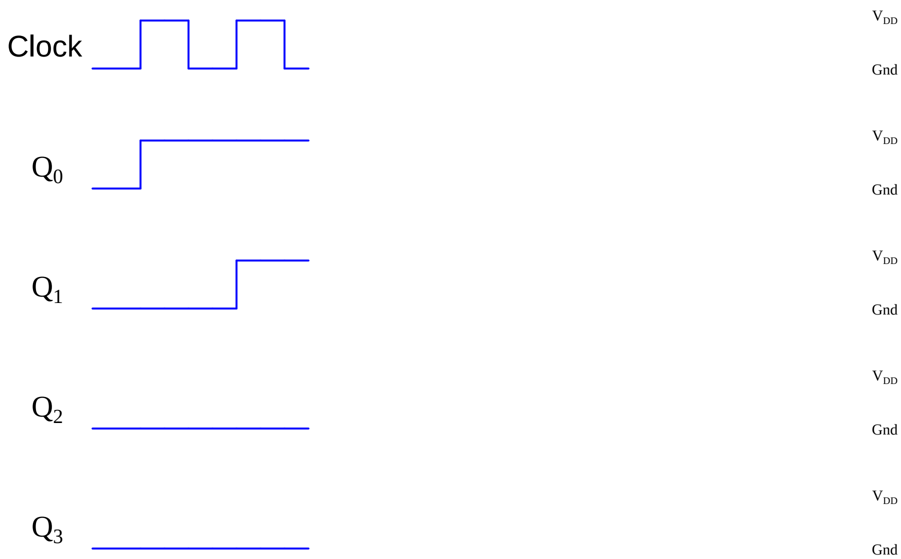
1
1
1
0
0
0
C
C
C
C
Clk
Q
Q
Q
Q
1


Clock
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Q1
Q2
Q3
VDD
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VDD
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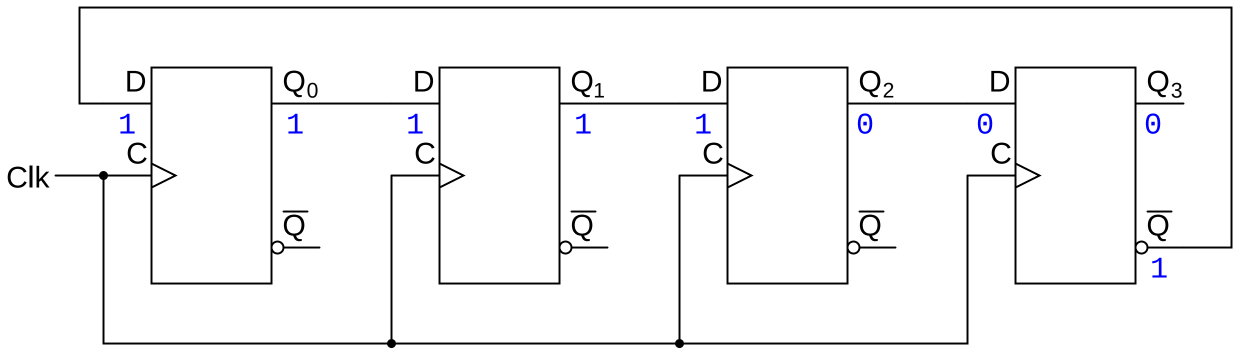
VDD
Gnd
VDD
Gnd
VDD
Gnd


D
Q0
D
Q1
D
Q2
D
Q3
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1
1
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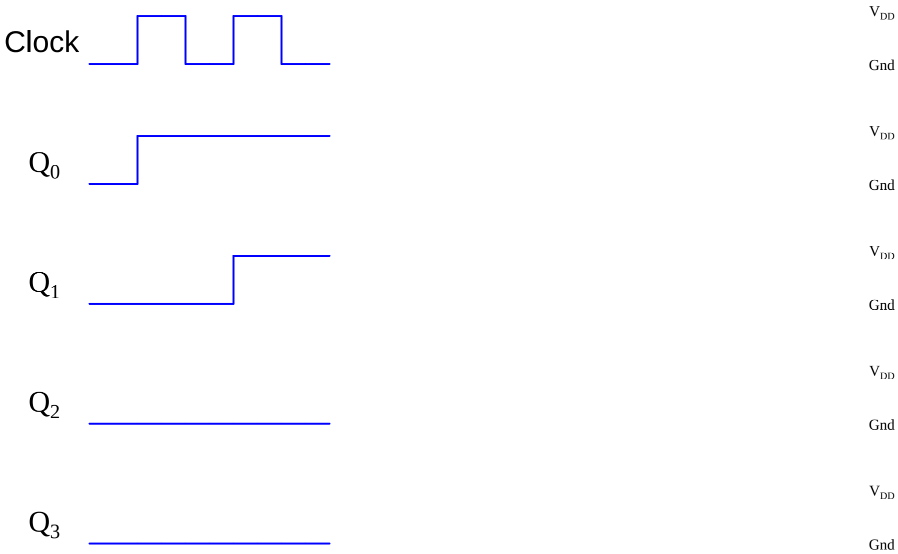
1
0
0
0
C
C
C
C
Clk
Q
Q
Q
Q
1


Clock
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Q2
Q3
VDD
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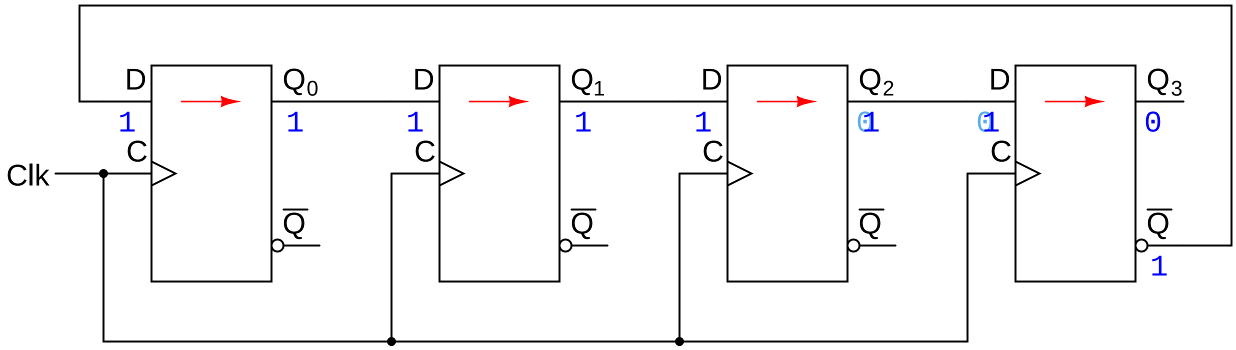
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd


D
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1
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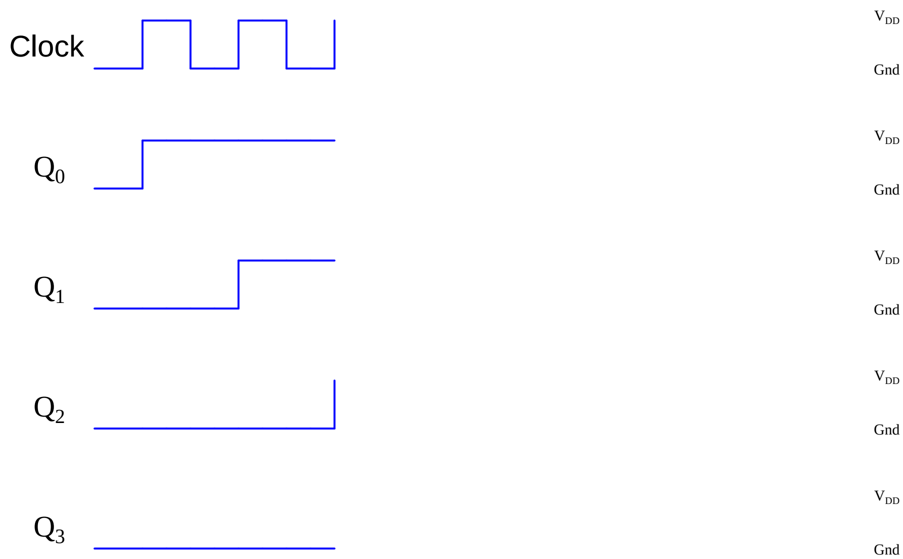
Clk
Q
D
Q1
D
Q2
D
Q3
0


Clock
Q0
Q1
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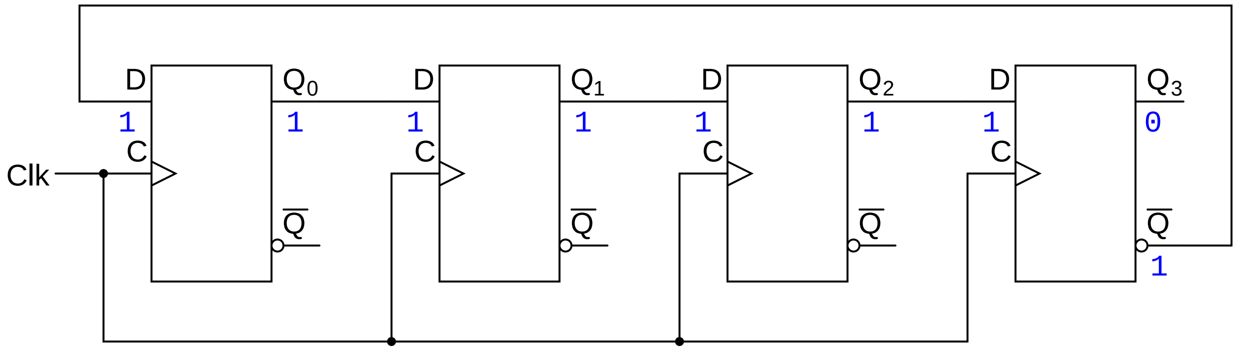
Q3
VDD
Gnd


D
Q0
D
Q1
D
Q2
D
Q3
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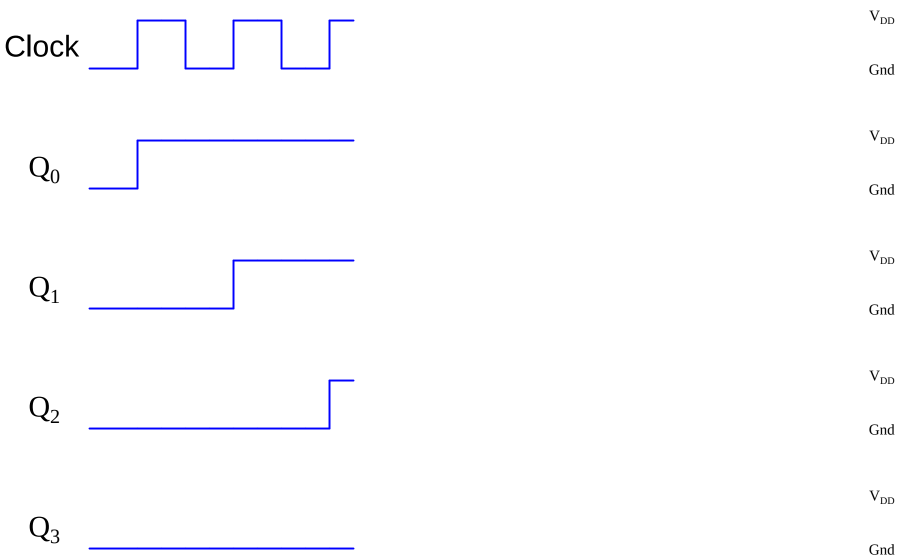
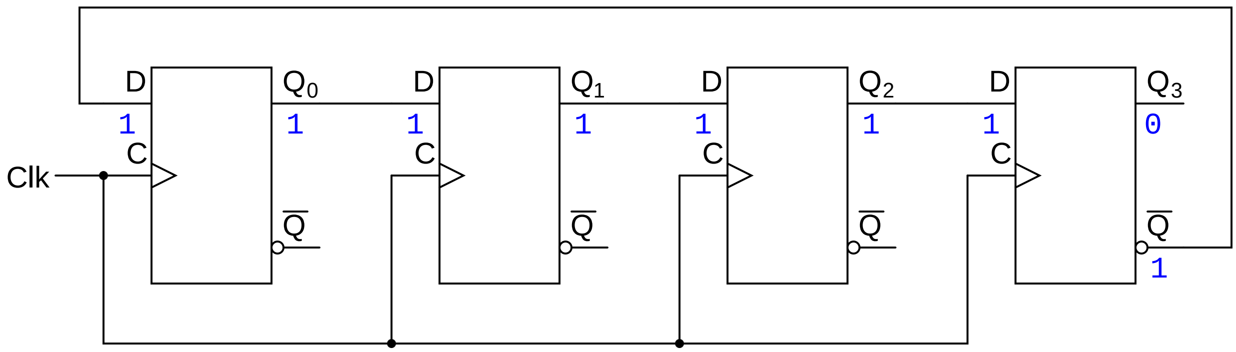
1
1
1
1
1
1
0
Clk
C
C
C
C
Q
Q
Q
Q
1


Clock
Q0
Q1
Q2
Q3
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd


D
Q0
D
Q1
D
Q2
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Q3
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Q
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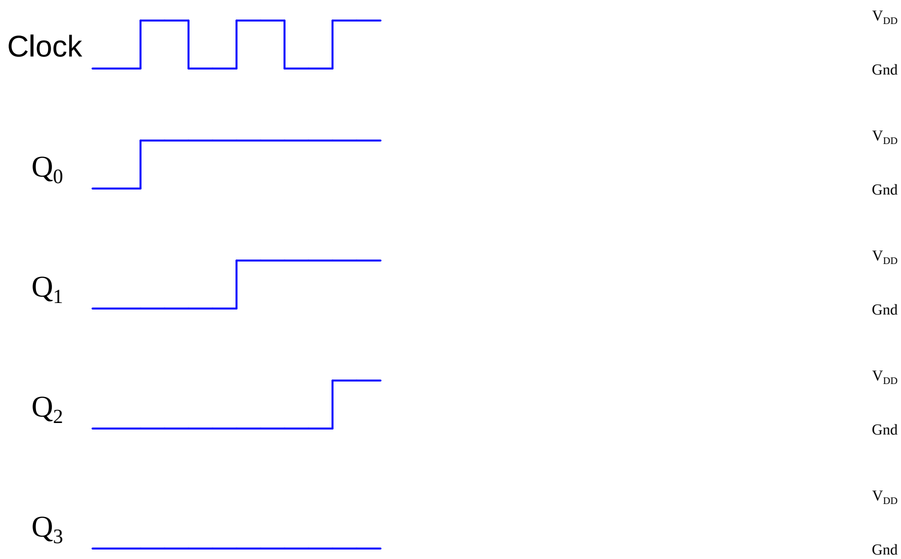
Clock
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Q3
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VDD
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VDD
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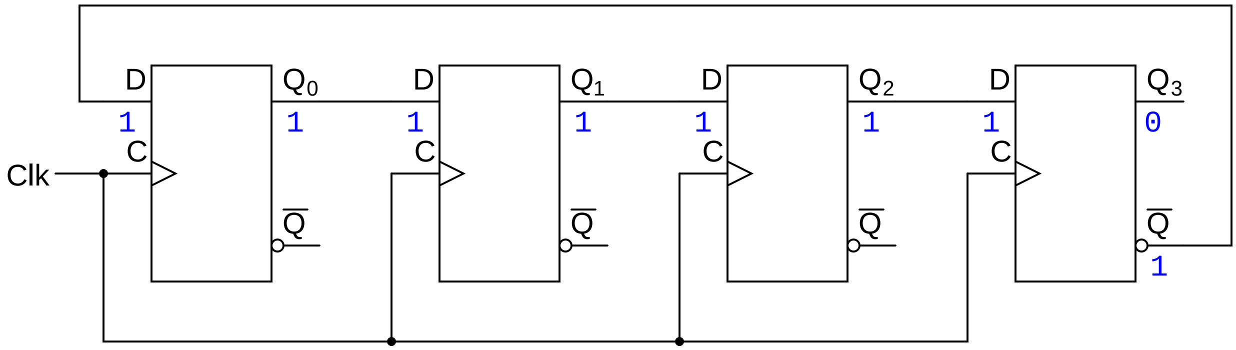
Gnd
VDD
Gnd


D
Q0
D
Q1
D
Q2
D
Q3
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1
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1
0
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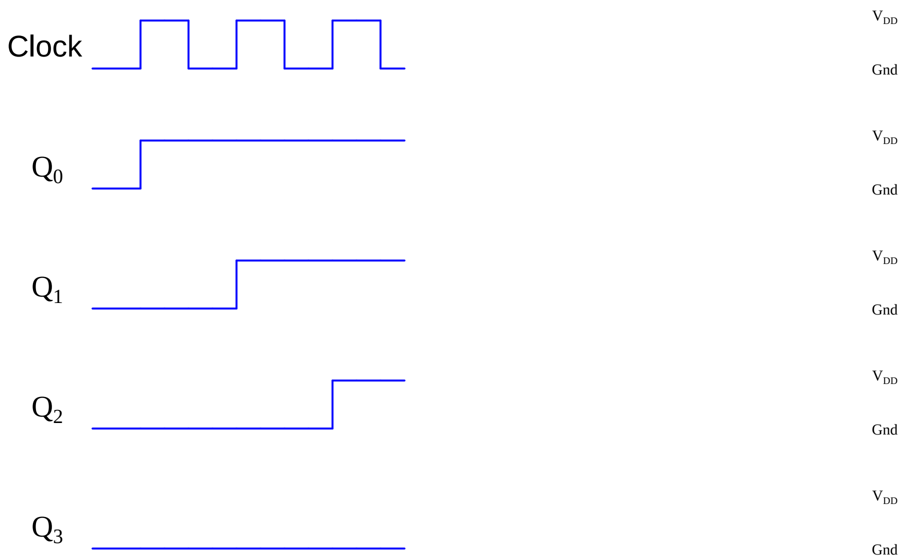
C
C
C
Clk
Q
Q
Q
Q
1


Clock
Q0
Q1
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Q3
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VDD
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VDD
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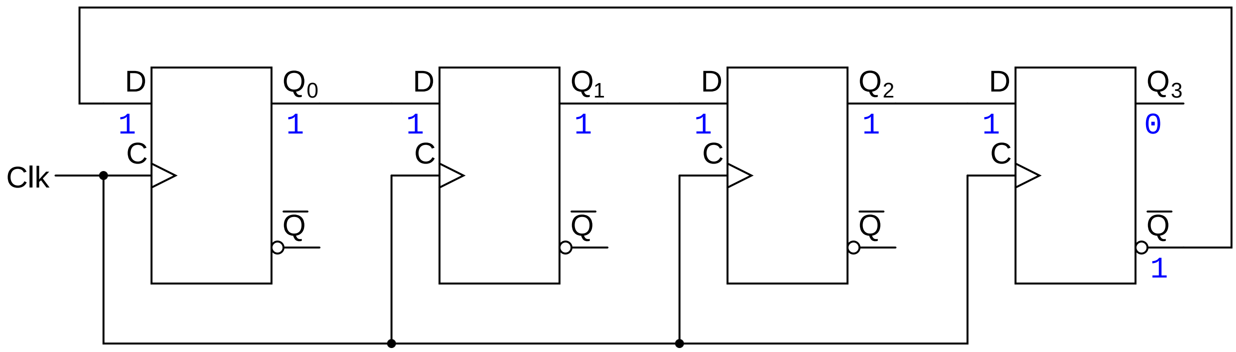
Gnd
VDD
Gnd


D
Q0
D
Q1
D
Q2
D
Q3
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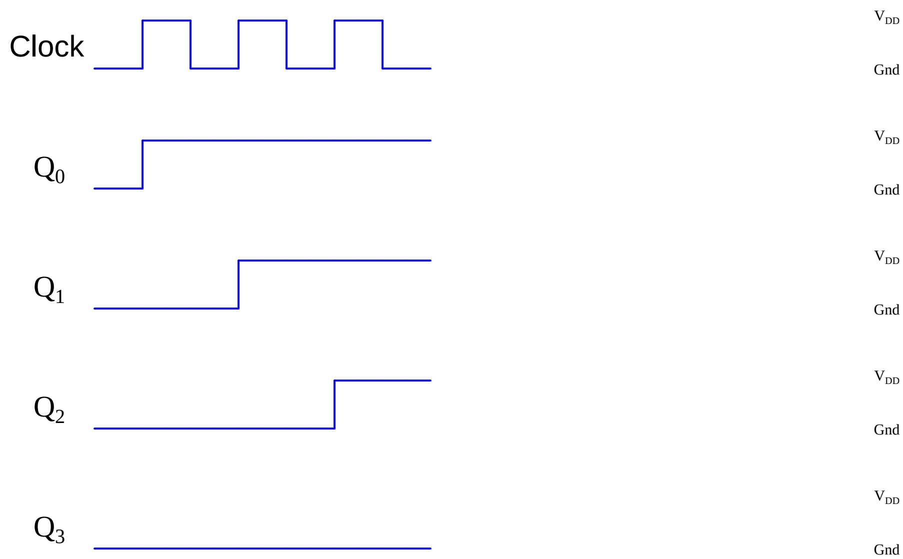
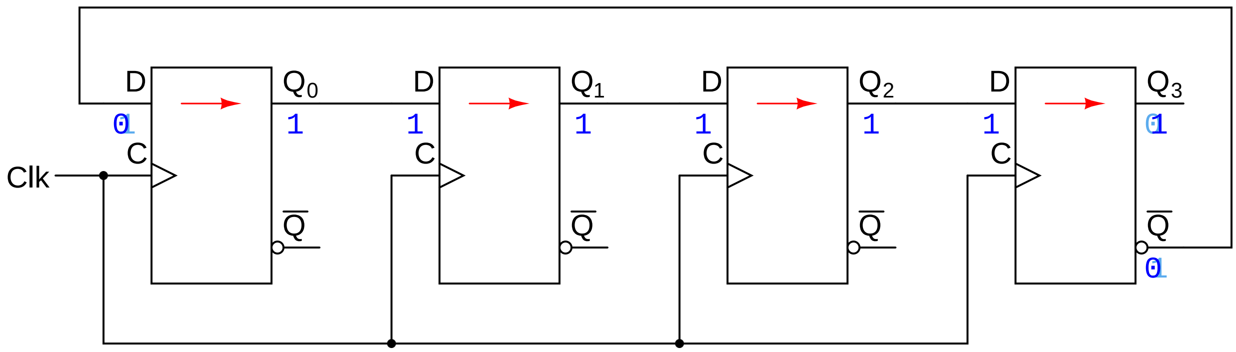
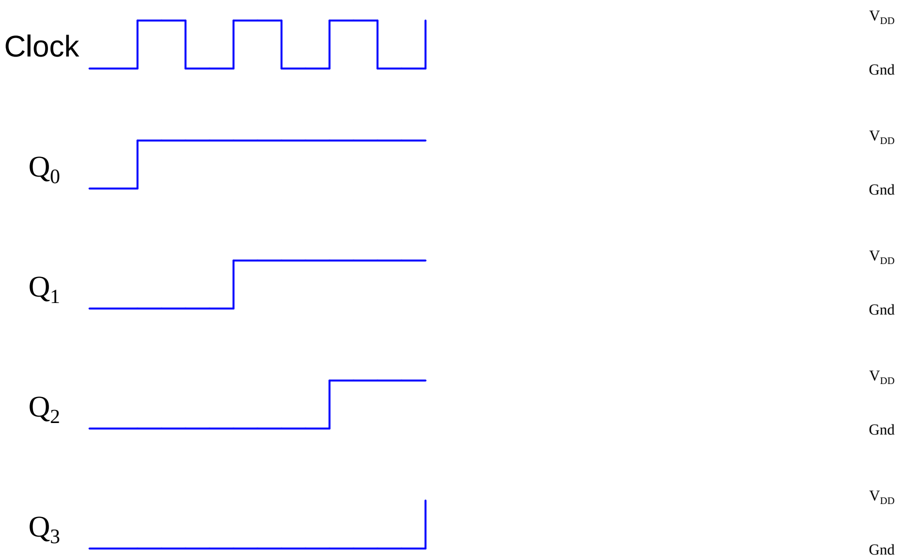
1
1
1
1
1
0
C
C
C
C
Clk
Q
Q
Q
Q
1

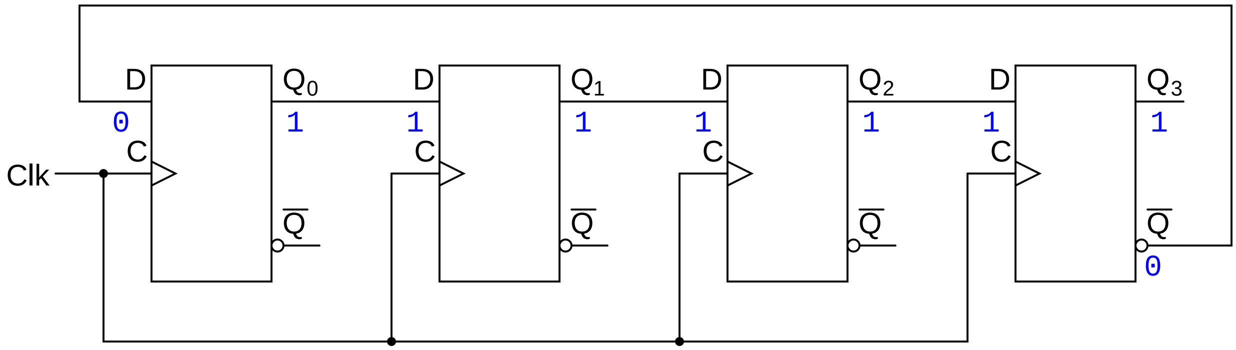

Clock
Q0
Q1
Q2
Q3
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd



D
Q0
D
Q1
D
Q2
D
Q3
C
C
C
C
Clk
Q
Q
Q
Q



Clock
Q0
Q1
Q2
Q3
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd


D
Q0
D
Q1
D
Q2
D
Q3
0
1
1
1
1
1
1
1
C
C
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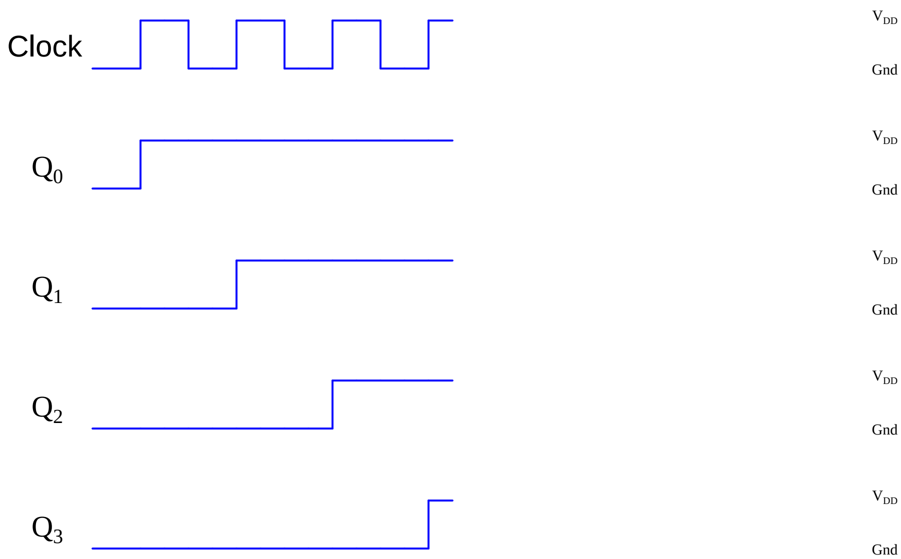
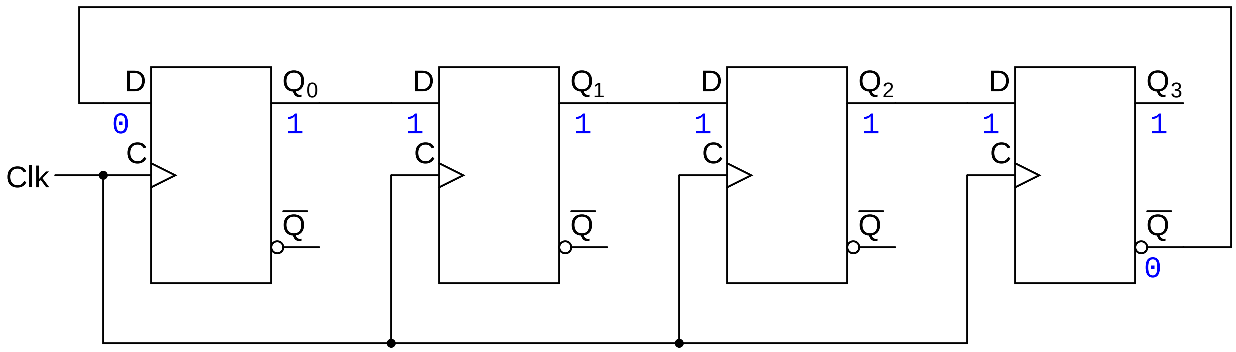
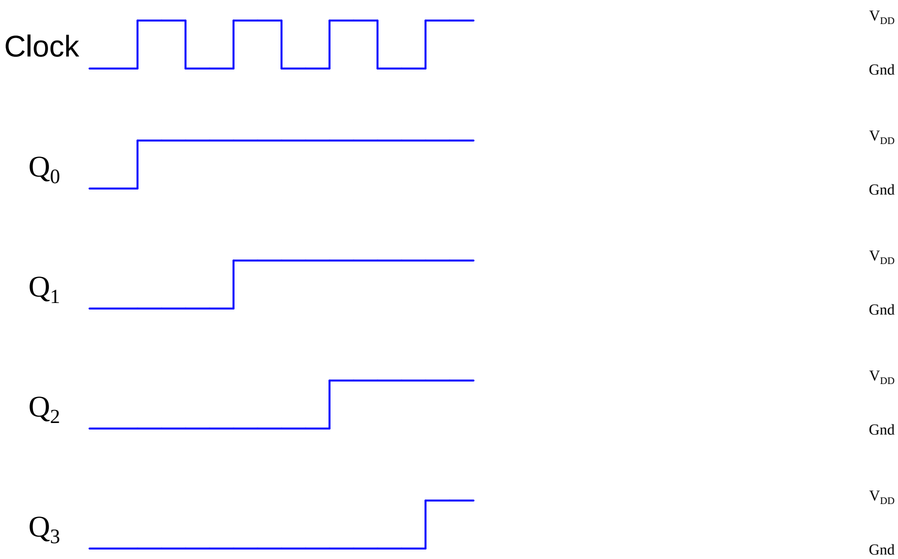
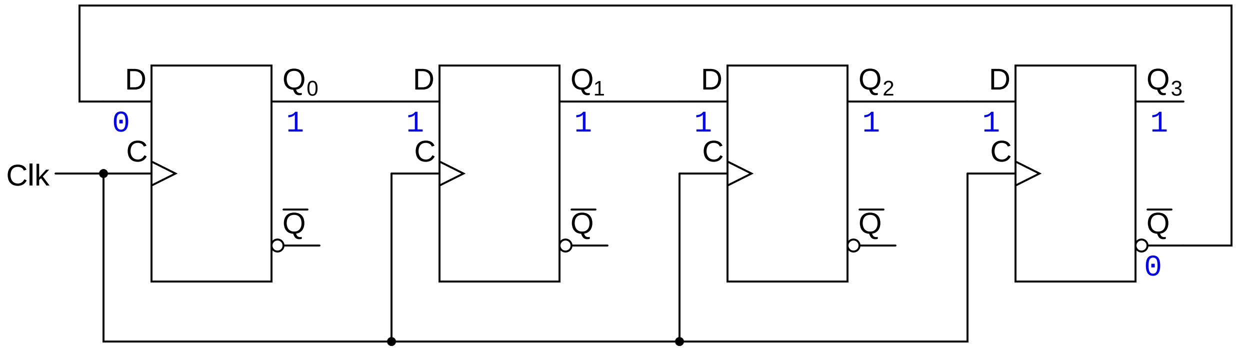
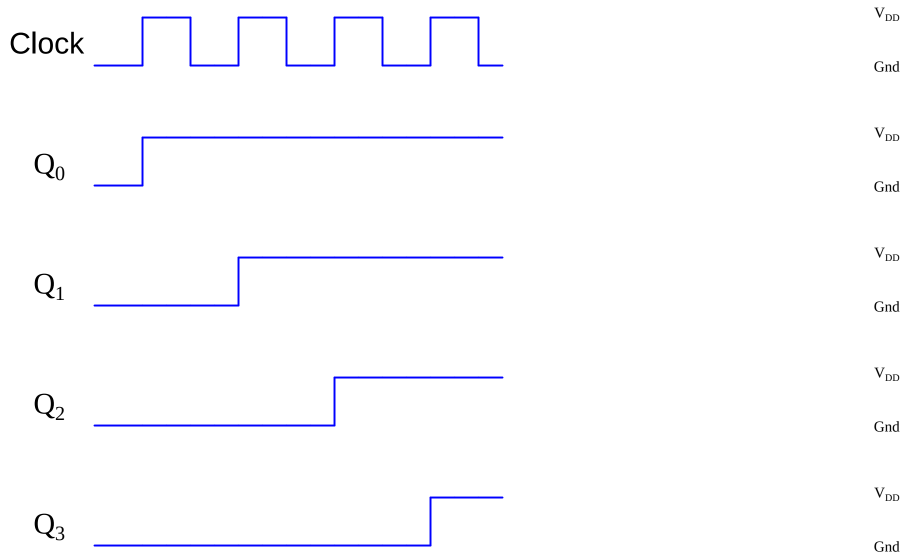
Q
Q
Q
Q
0

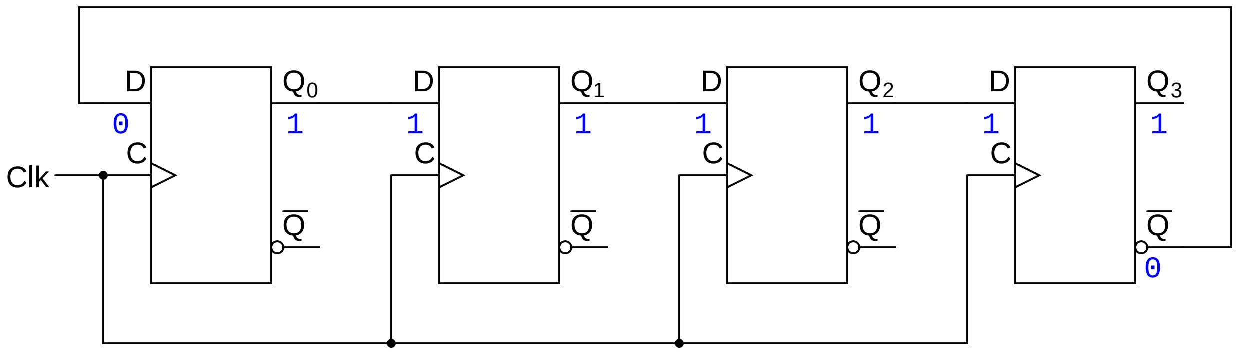

Clock
Q0
Q1
Q2
Q3
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd

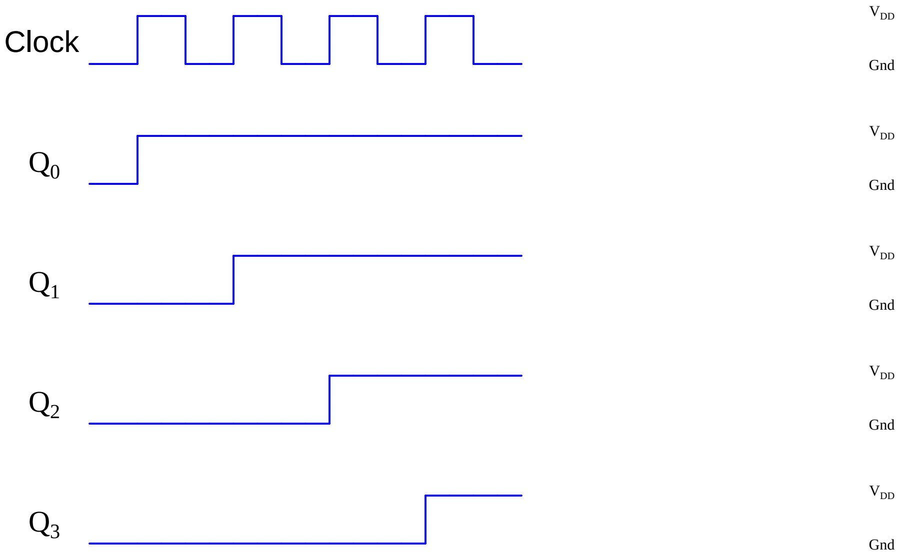

D
Q0
D
Q1
D
Q2
D
Q3
0
1
1
1
1
1
1
1
C
C
C
C
Clk
Q
Q
Q
Q
0

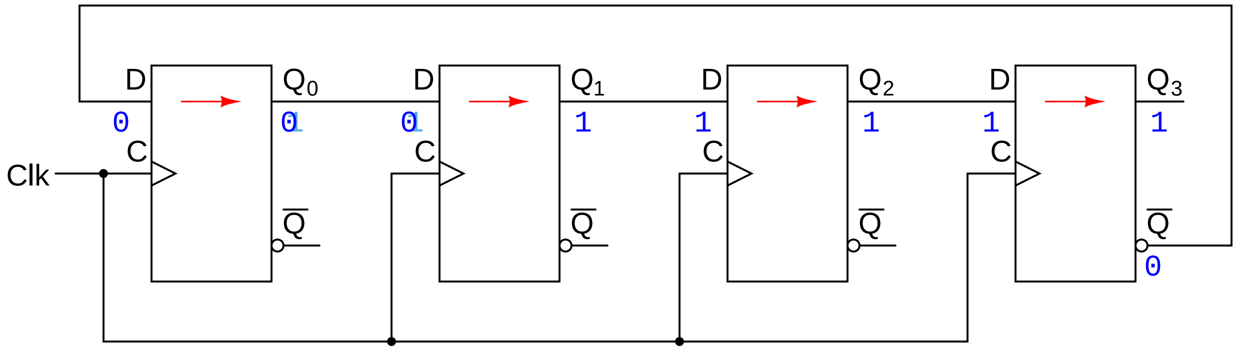

Clock
Q0
Q1
Q2
Q3
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd

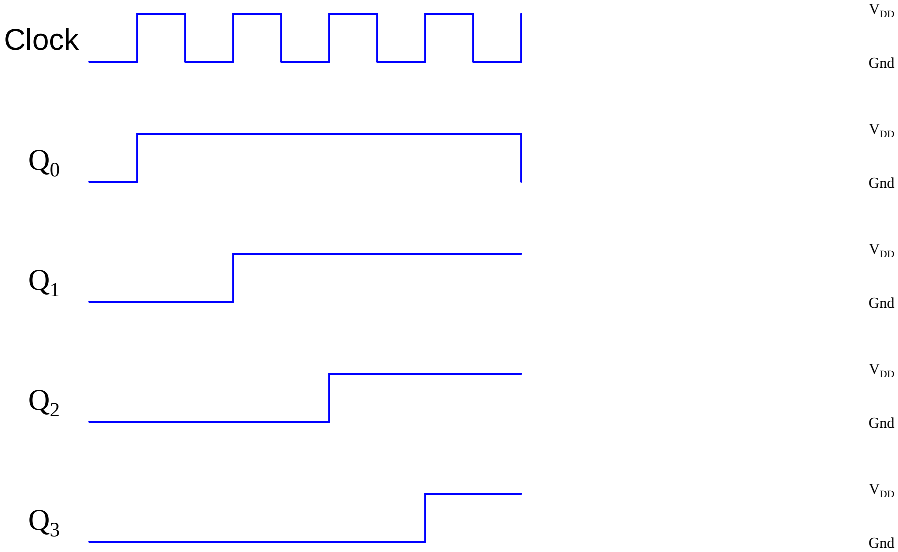

D
Q0
D
Q1
D
Q2
D
Q3
0
1
1
1
1
1
1
1
C
C
C
C
Clk
Q
Q
Q
Q
0

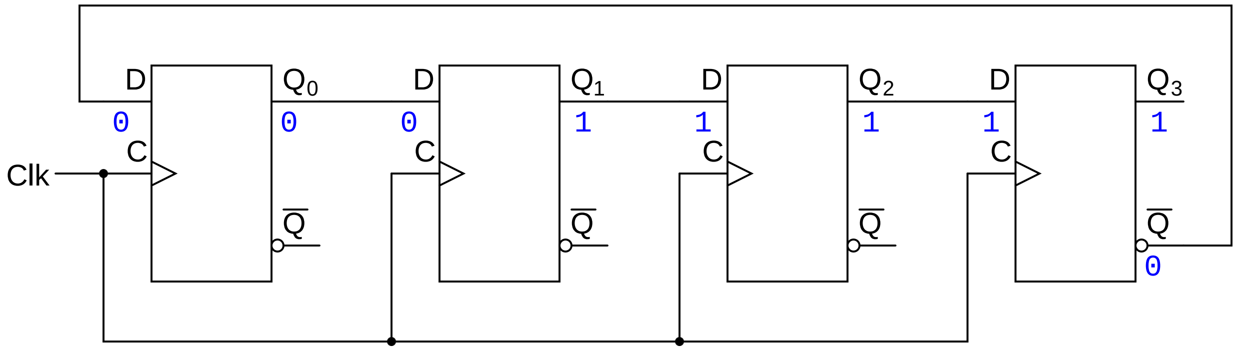

Clock
Q0
Q1
Q2
Q3
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd

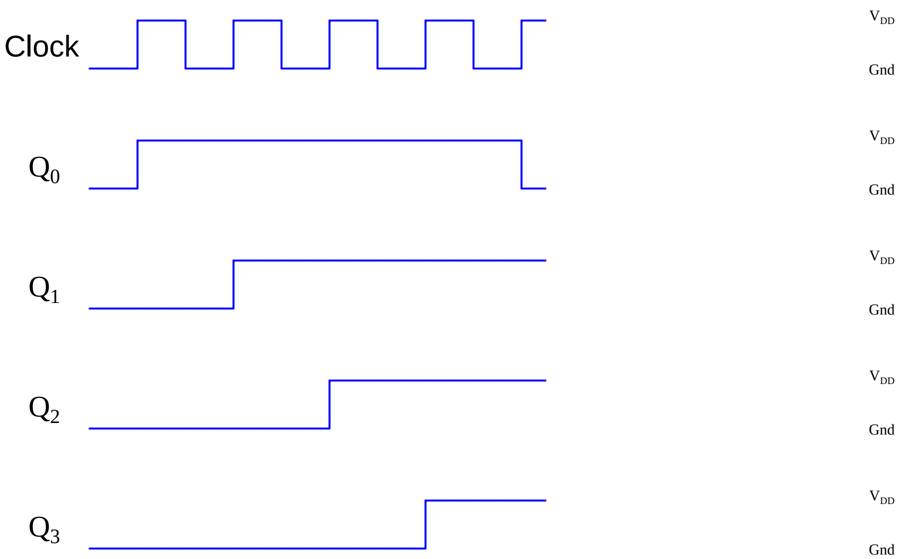

D
Q0
D
Q1
D
Q2
D
Q3
0
1
1
1
1
1
1
1
C
C
C
C
Clk
Q
Q
Q
Q
0

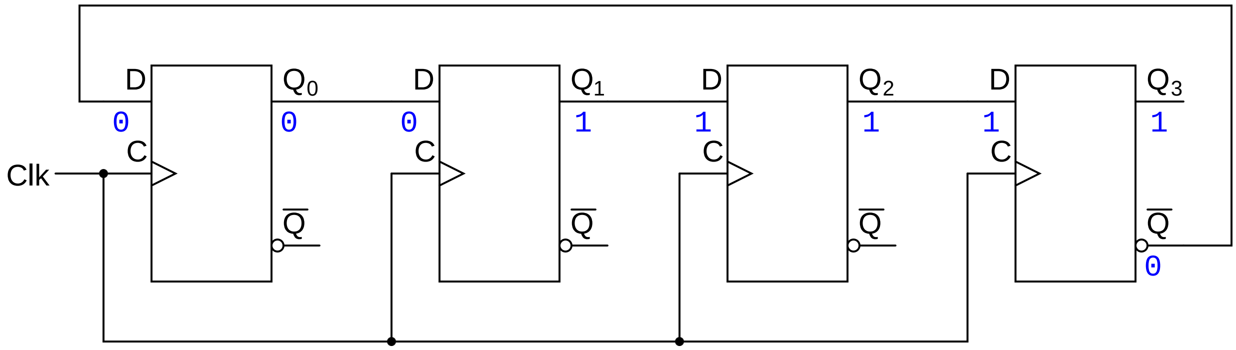

Clock
Q0
Q1
Q2
Q3
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd


D
Q0
D
Q1
D
Q2
D
Q3
0
0
0
1
1
1
1
1
C
C
C
C
Clk
Q
Q
Q
Q
0

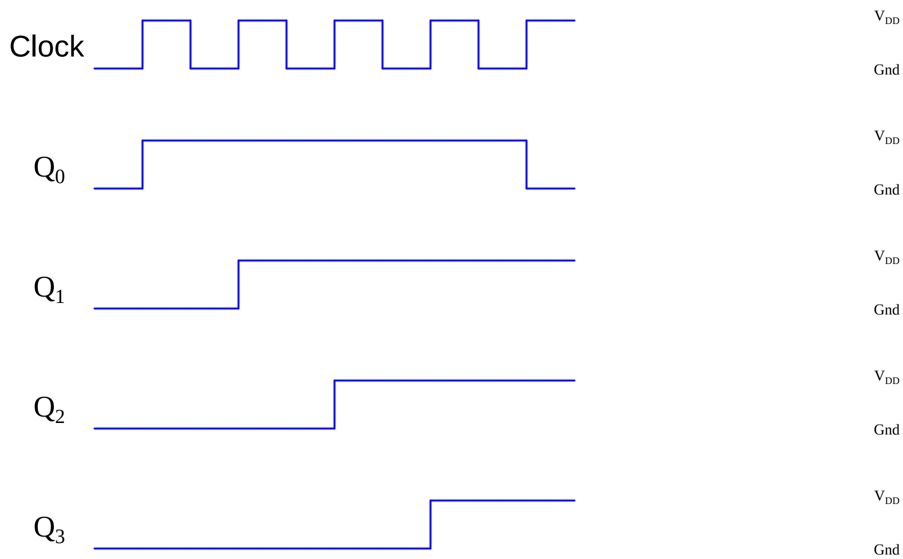

Clock
Q0
Q1
Q2
Q3
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd


D
Q0
D
Q1
D
Q2
D
Q3
C
C
C
C
Clk
Q
Q
Q
Q
0
0
0
1
1
1
1
1
0

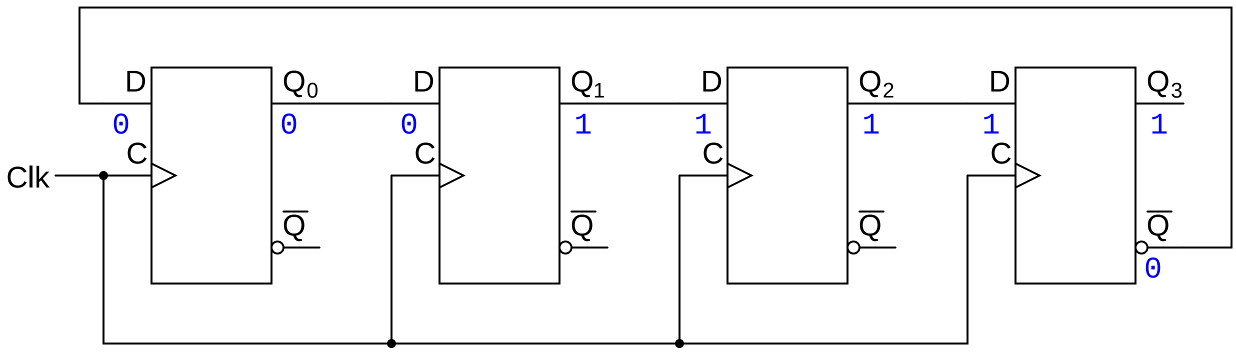

Clock
Q0
Q1
Q2
Q3
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd

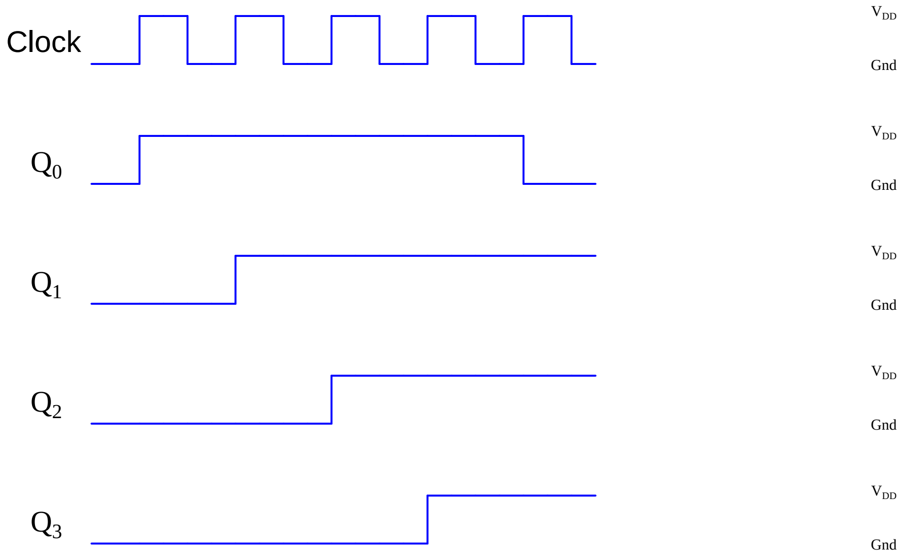


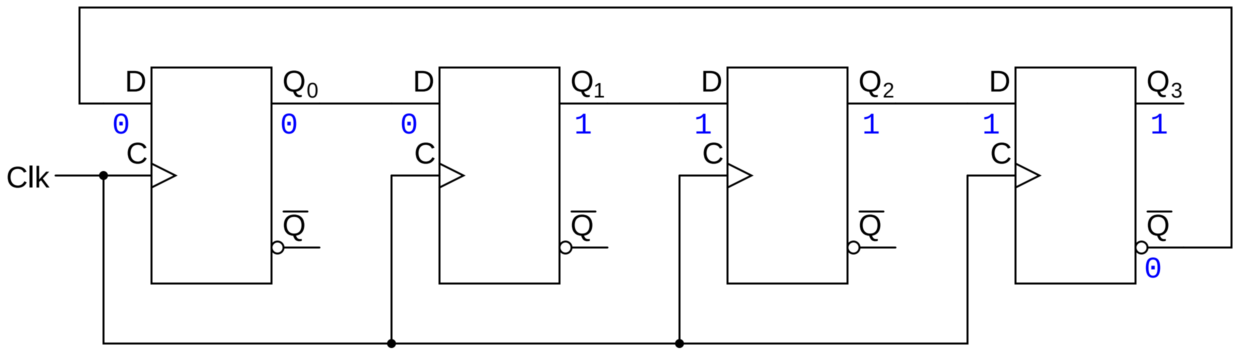
D
Q0
D
Q1
D
Q2
D
Q3
0
0
0
1
1
1
1
1
C
C
C
C
Clk
Q
Q
Q
Q
0

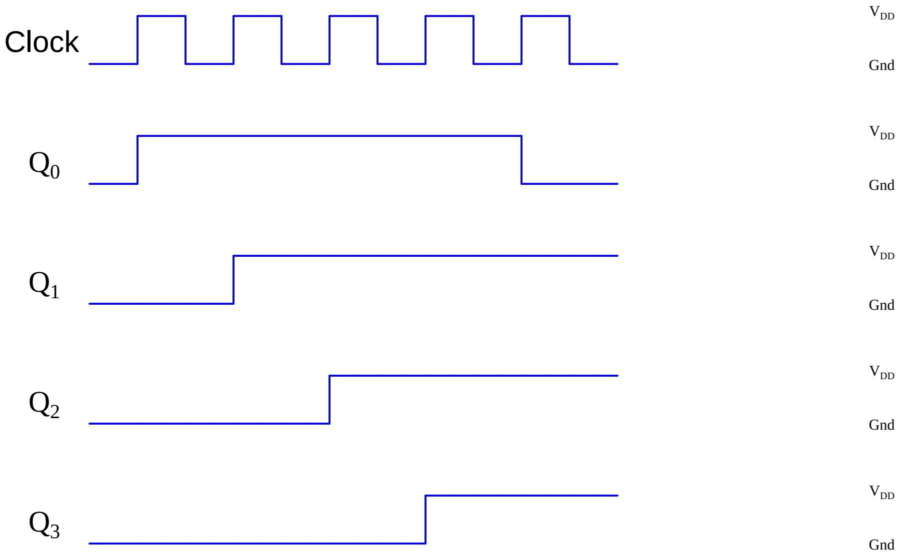


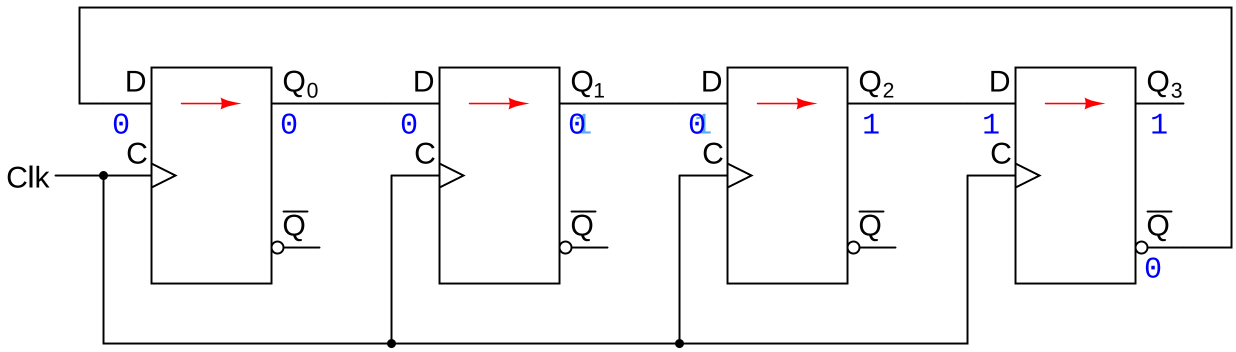
Clock
Q0
Q1
Q2
Q3
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd

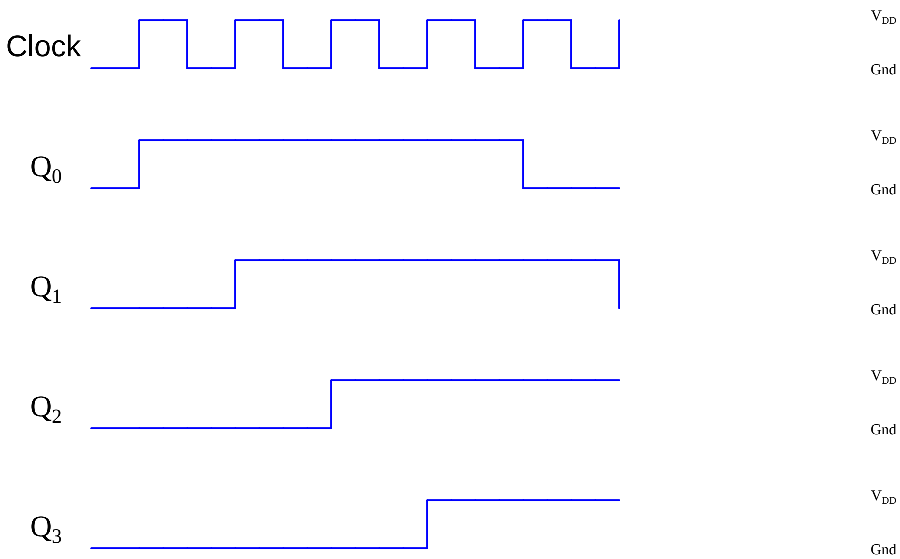

D
Q0
D
Q1
D
Q2
D
Q3
0
0
0
1
1
1
1
1
C
C
C
C
Clk
Q
Q
Q
Q
0

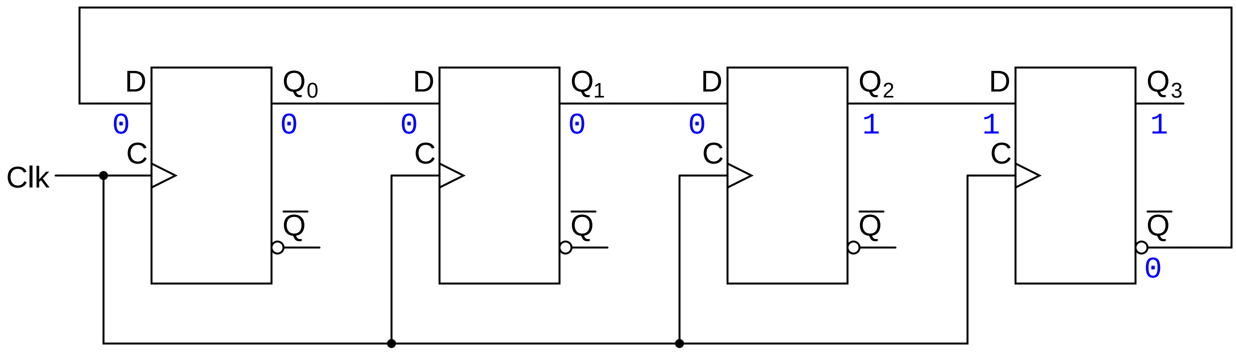

Clock
Q0
Q1
Q2
Q3
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd


D
Q0
D
Q1
D
Q2
D
Q3
0
0
0
1
1
1
1
1
C
C
C
C
Clk
Q
Q
Q
Q
0

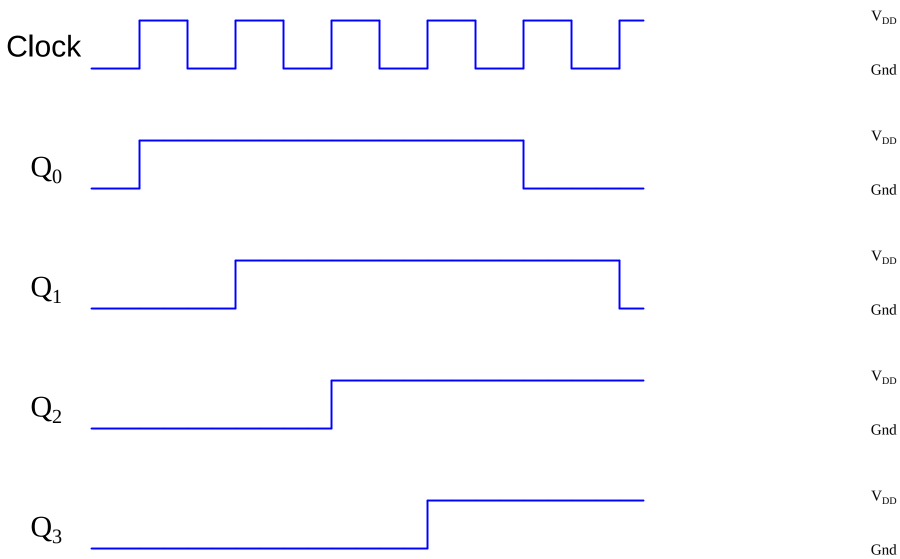

Clock
Q0
Q1
Q2
Q3
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd


D
Q0
0
0
0
C
Clk
Q
D
Q1
C
Q
D
Q2
1
1
C
Q
D
Q3
1
C
Q
0

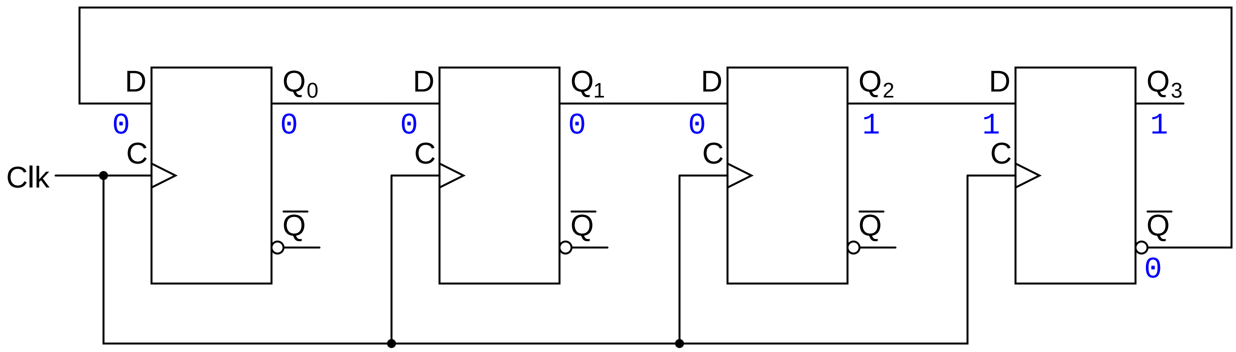

Clock
Q0
Q1
Q2
Q3
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd

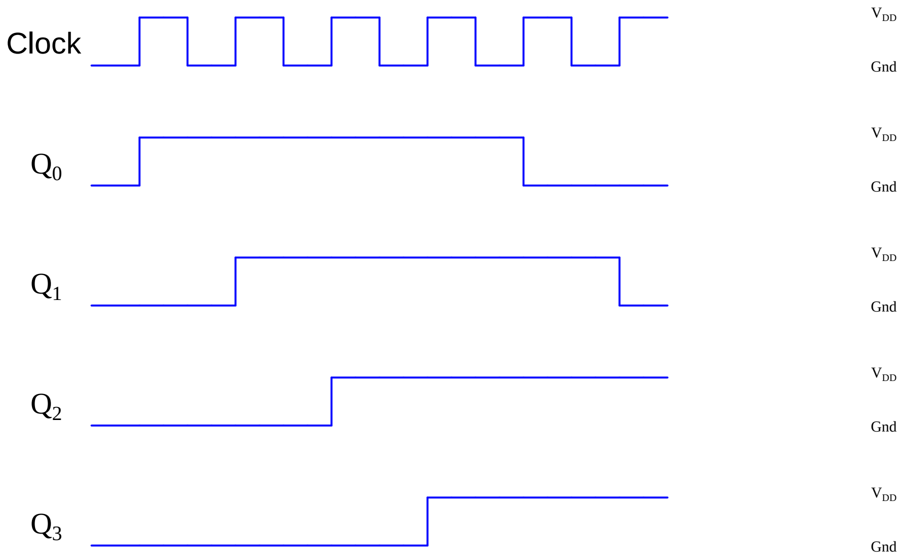


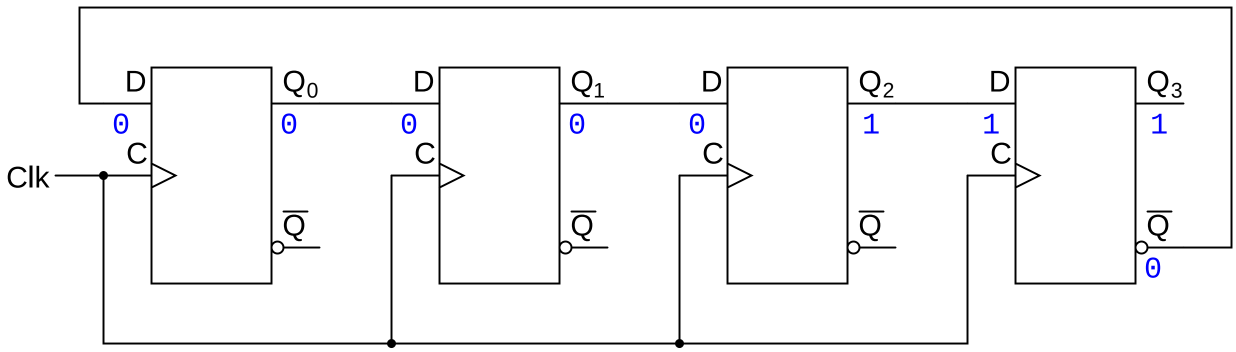
D
Q0
D
Q1
D
Q2
D
Q3
0
0
0
0
0
1
1
1
C
C
C
C
Clk
Q
Q
Q
Q
0

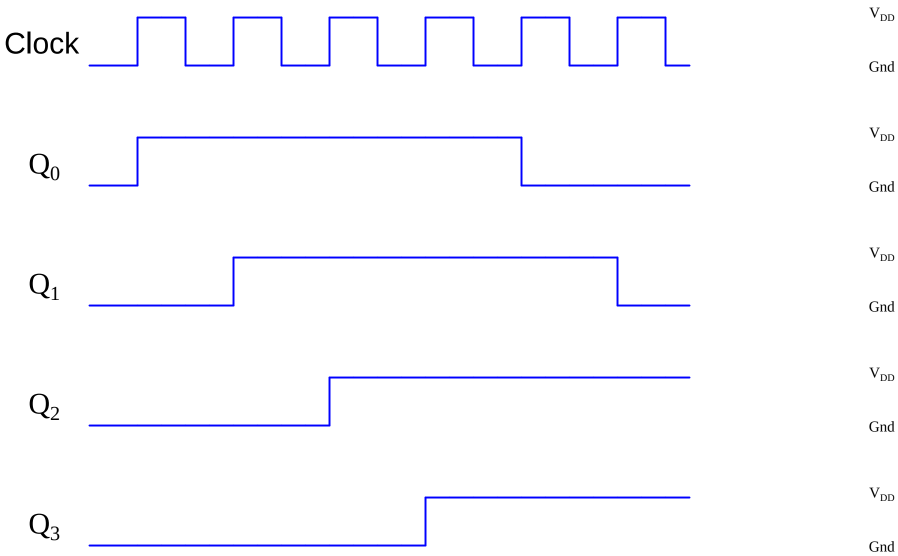


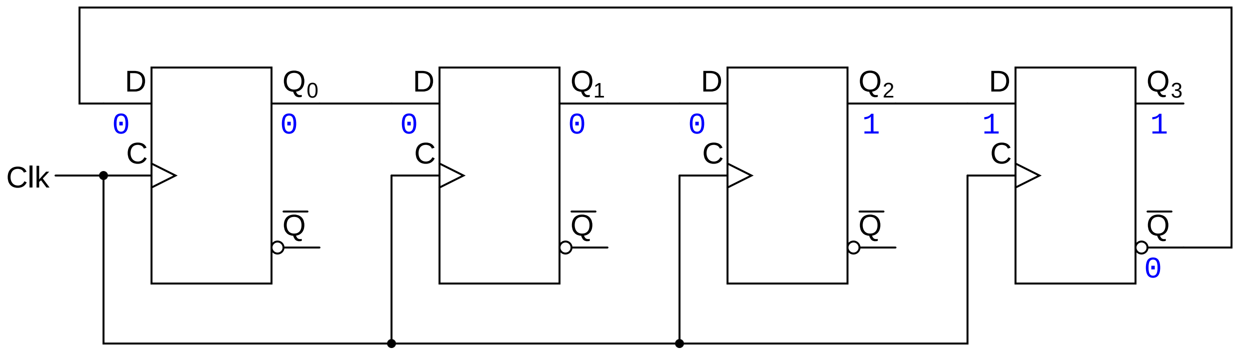
Clock
Q0
Q1
Q2
Q3
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd

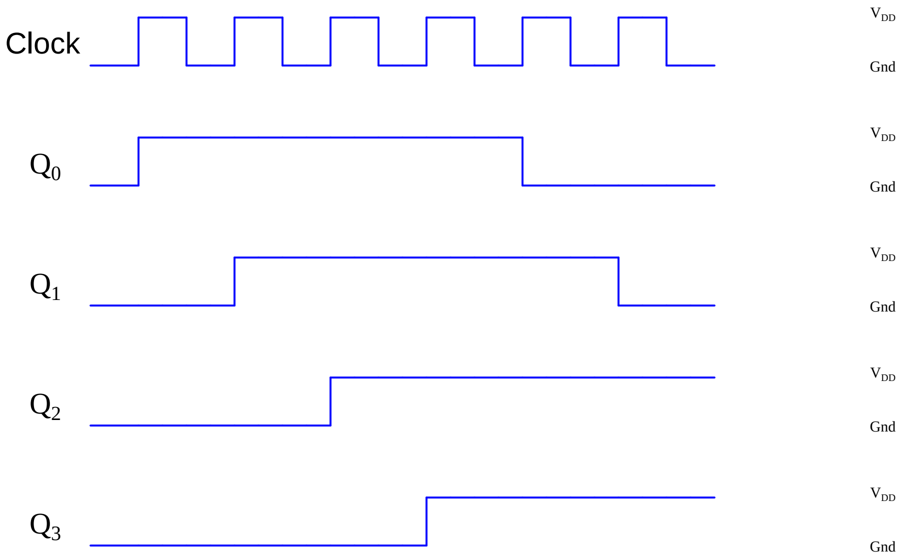

D
Q0
D
Q1
D
Q2
D
Q3
0
0
0
0
0
1
1
1
C
C
C
C
Clk
Q
Q
Q
Q
0

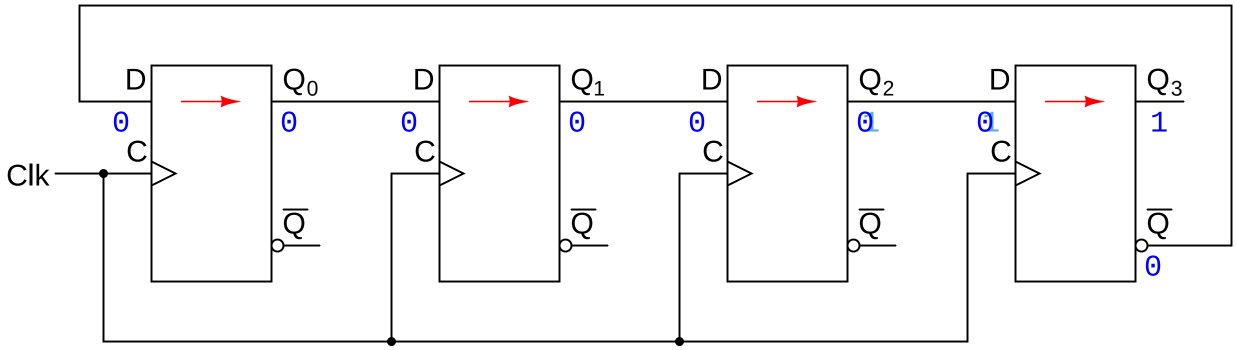

Clock
Q0
Q1
Q2
Q3
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd


D
Q0
D
Q1
D
Q2
D
Q3
0
0
0
0
0
1
1
1
C
C
C
C
Clk
Q
Q
Q
Q
0

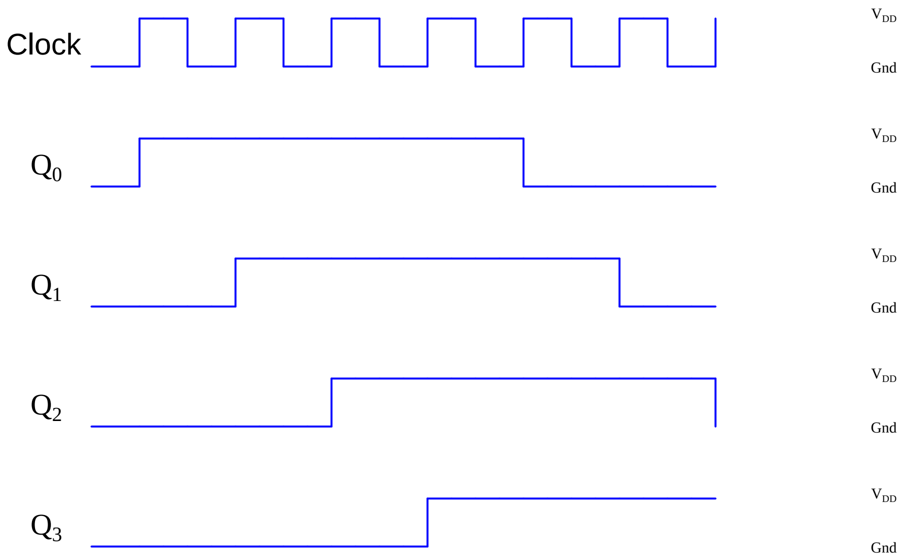

Clock
Q0
Q1
Q2
Q3
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd


D
Q0
D
Q1
D
Q2
D
Q3
0
0
0
0
0
1
1
1
C
C
C
C
Clk
Q
Q
Q
Q
0

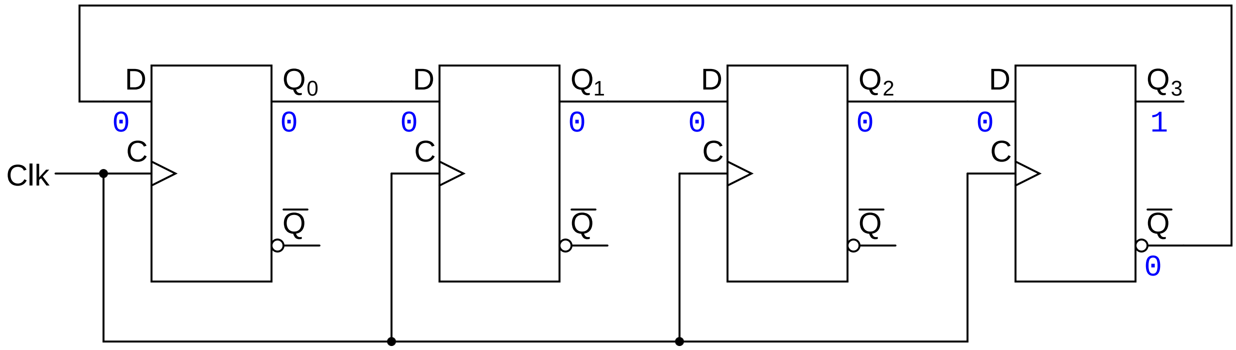

Clock
Q0
Q1
Q2
Q3
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd

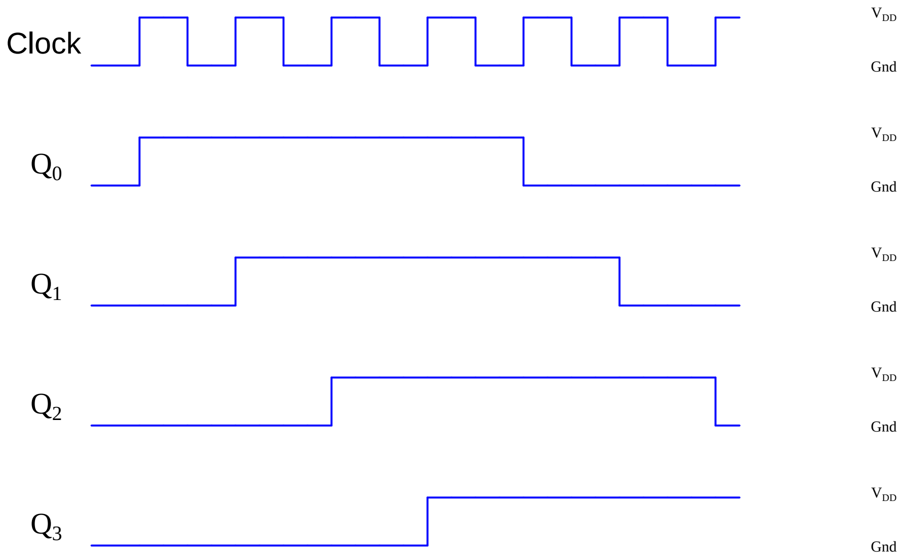


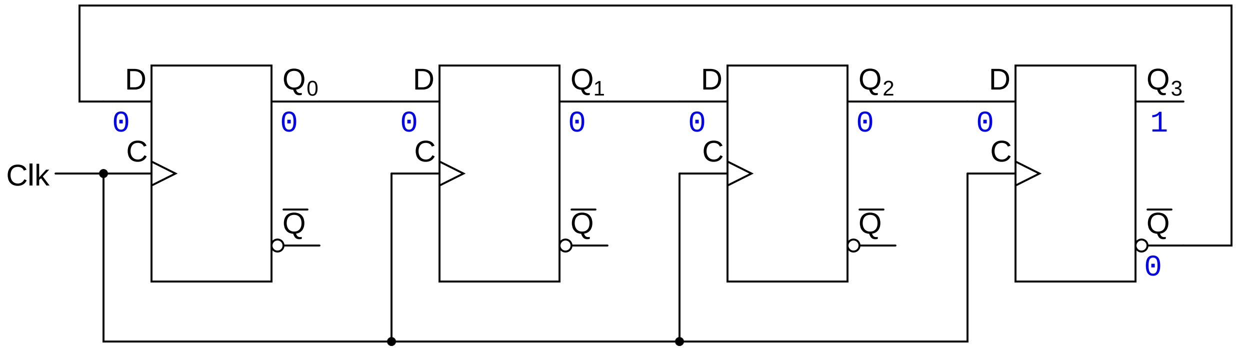
D
Q0
D
Q1
D
Q2
D
Q3
Clk
C
C
C
C
Q
Q
Q
Q
0
0
0
0
0
01
01
1
0

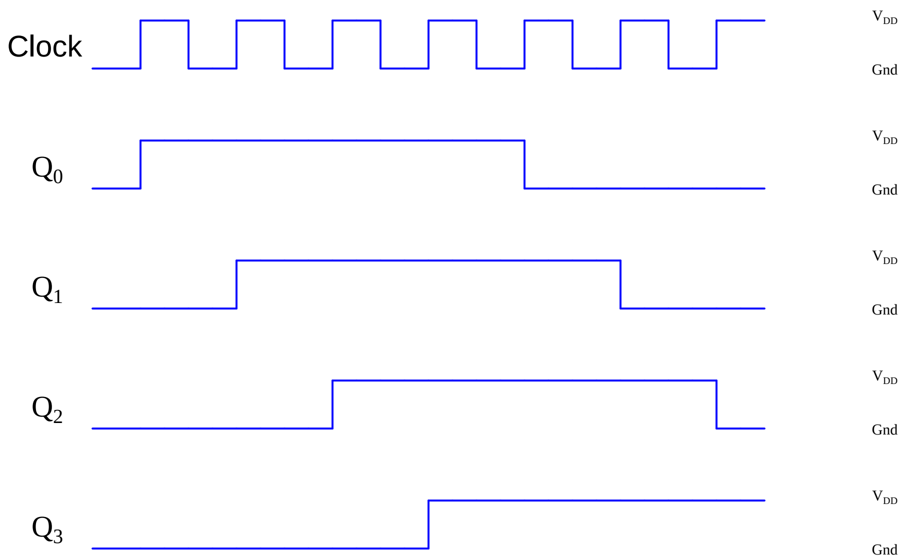


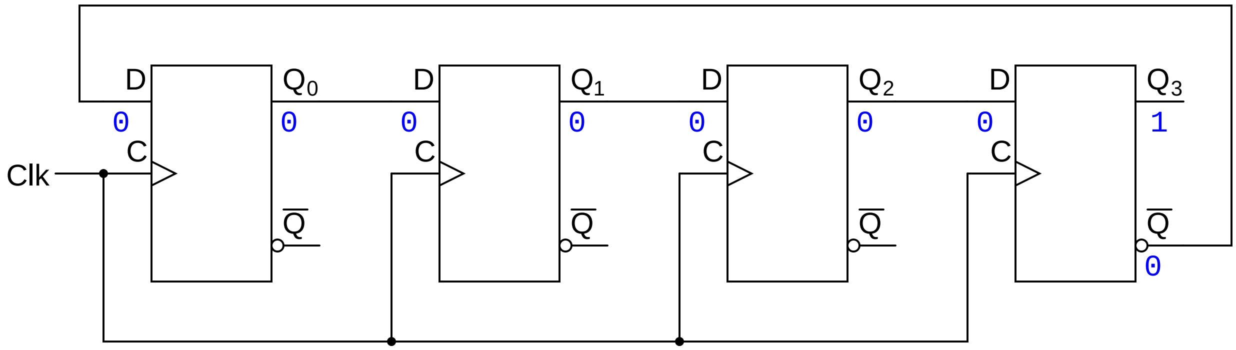
Clock
Q0
Q1
Q2
Q3
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd


D
Q0
Q1
Q2
Q3
C
Clk
0
1

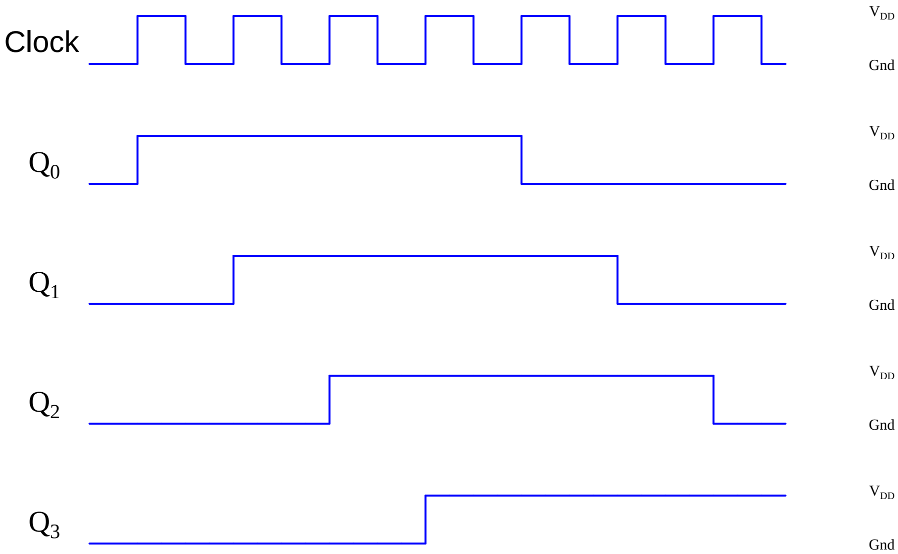

Clock
Q0
Q1
Q2
Q3
VDD
Gnd


D
Q0
D
Q1
D
Q2
D
Q3
0
0
0
0
0
0
0
1
C
C
C
C
Clk
Q
Q
Q
Q
0

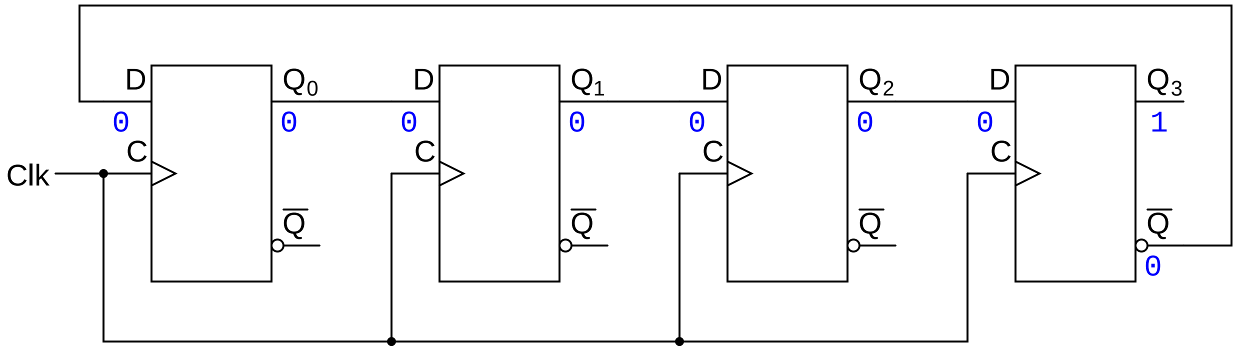

Clock
Q0
Q1
Q2
Q3
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd

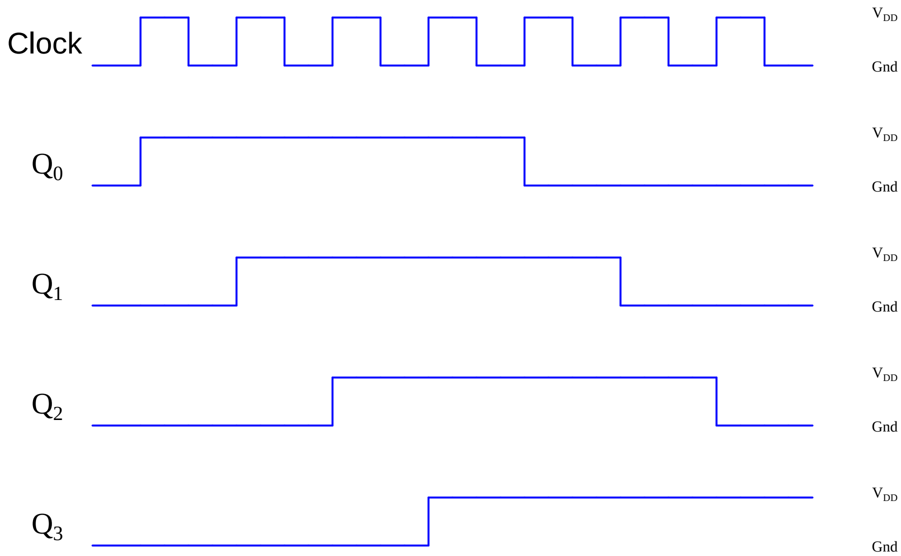


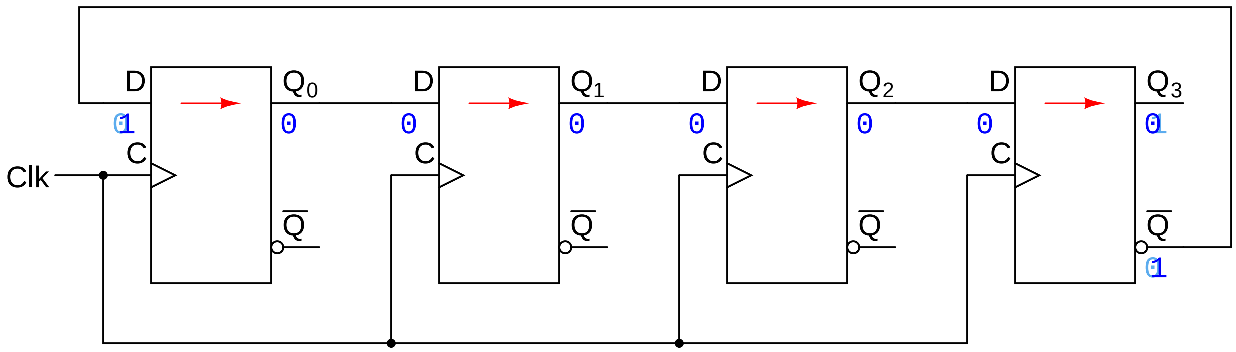
D
Q0
D
Q1
D
Q2
D
Q3
0
0
0
0
0
0
0
1
C
C
C
C
Clk
Q
Q
Q
Q
0

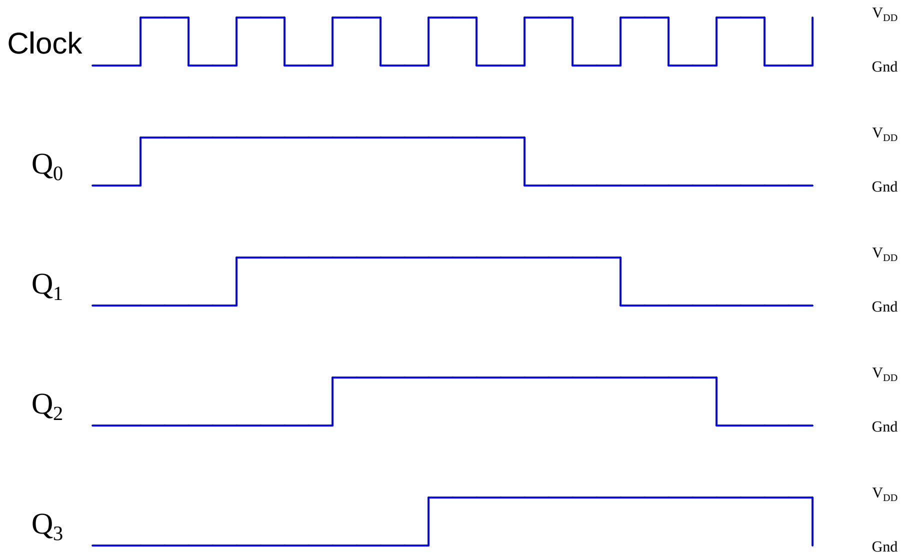


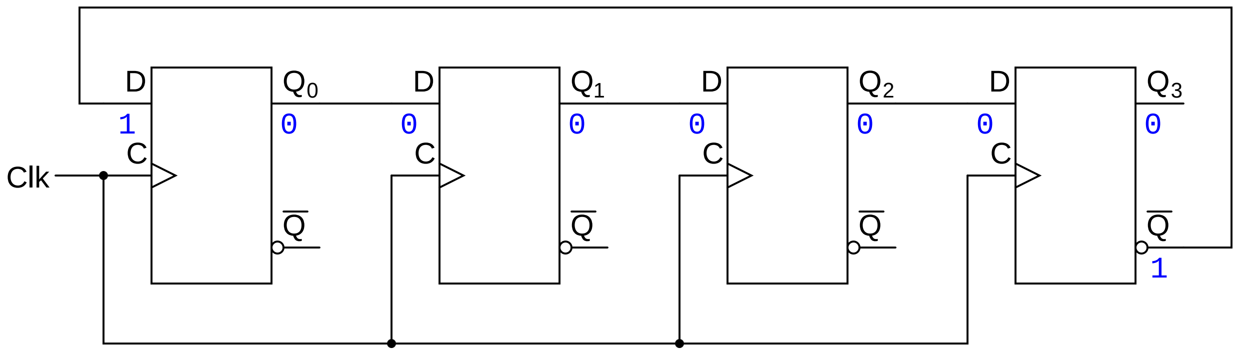
Clock
Q0
Q1
Q2
Q3
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd

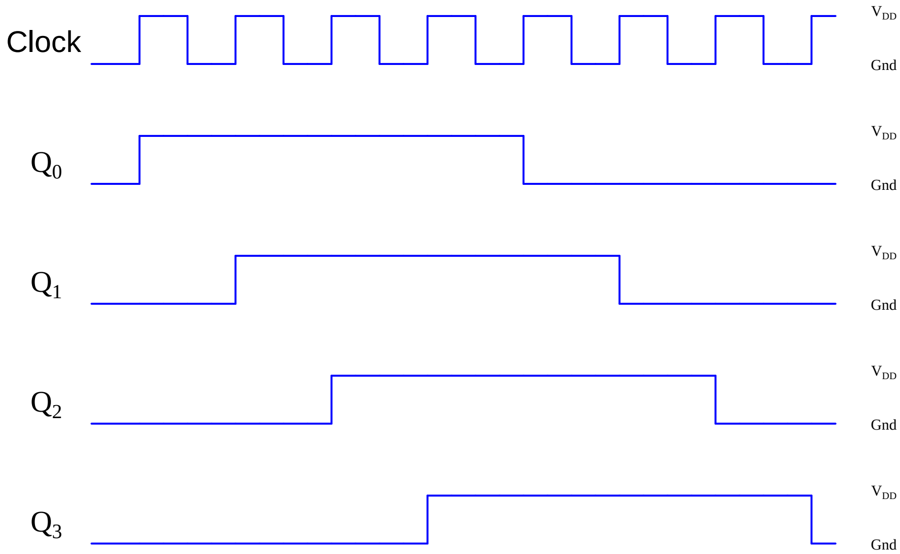

D
Q0
Q1
Q2
Q3
C
Clk
Q
0
1


Clock
Q0
Q1
Q2
Q3
VDD
Gnd


D
Q0
D
Q1
D
Q2
D
Q3
C
C
C
C
Clk
Q
Q
Q
Q


Clock
Q0
Q1
Q2
Q3
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd
VDD
Gnd


D
Q0
D
Q1
D
Q2
D
Q3
1
0
0
0
0
0
0
0
C
C
C
C
Clk
Q
Q
Q
Q
1


Clock
VDD
Gnd
Q0
VDD
Gnd
Q1
VDD
Gnd
Q2
VDD
Gnd
Q3
VDD
Gnd

file 03234

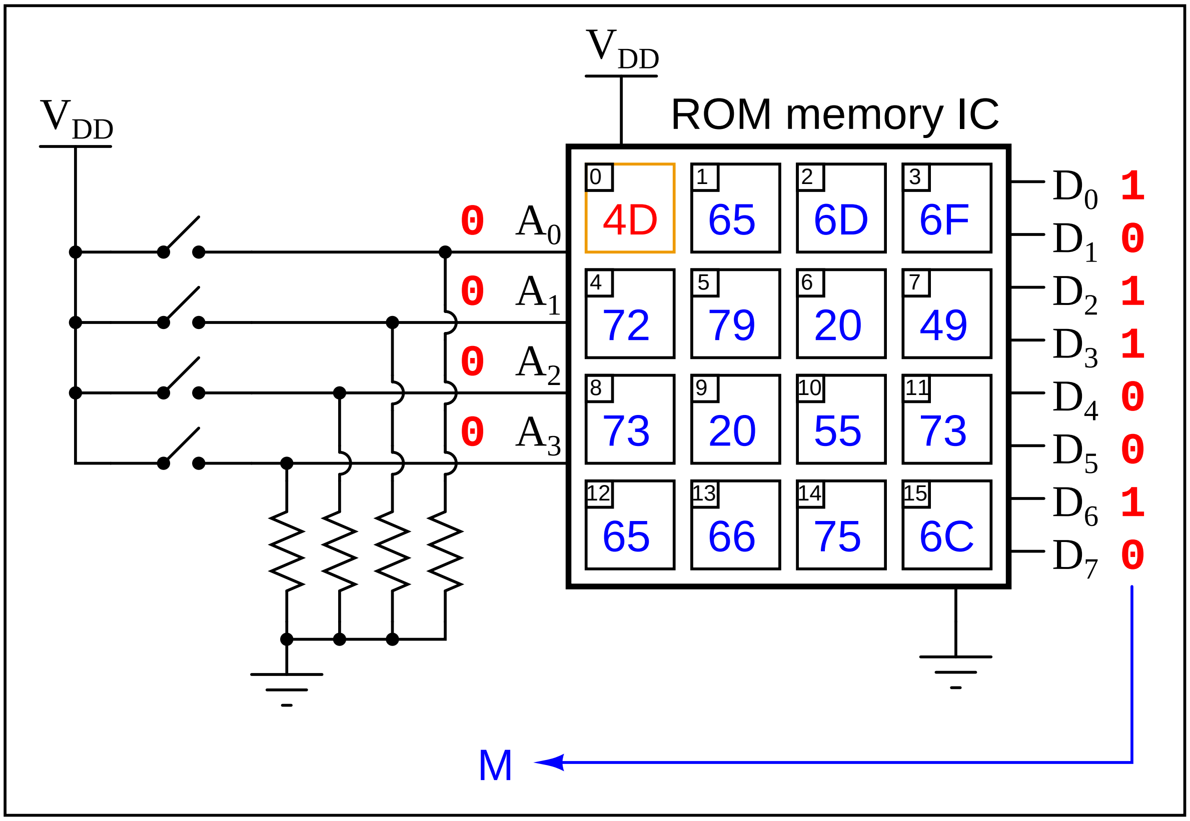
Question 14

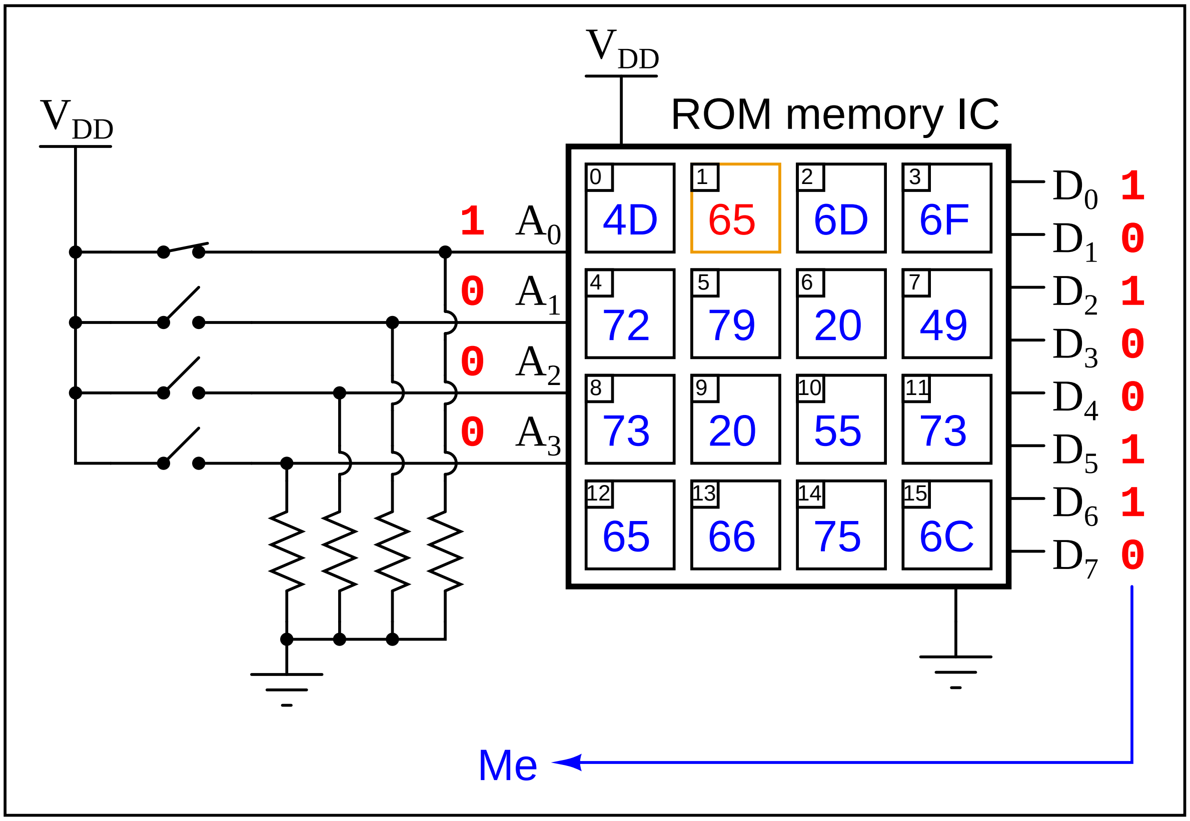
Animation: addressing 16 $\times$ 8 bit ROM memory

This question consists of a series of images (one per page) that form an animation. Flip the pages with your fingers to view this animation (or click on the "next" button on your viewer) frame-by-frame.

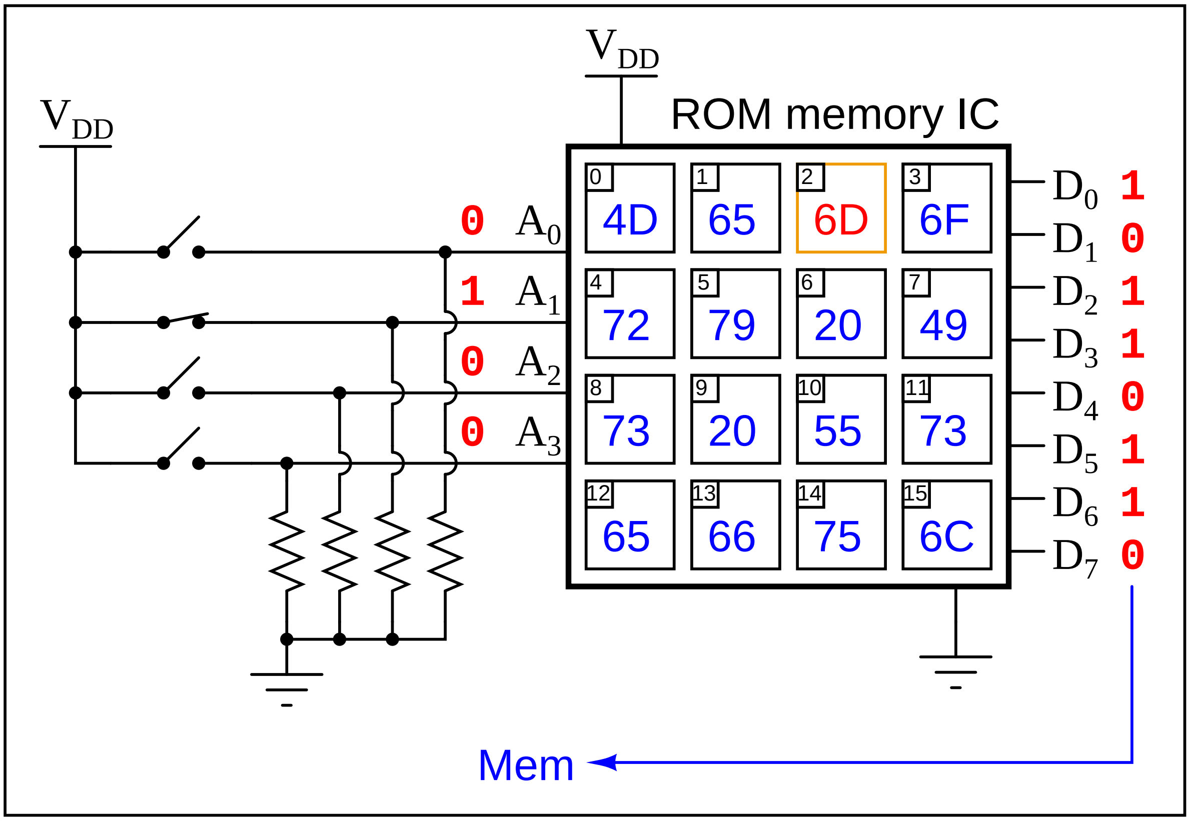
The following animation shows how setting the input (address) switches in particular combinations selects individual memory "cells" inside the ROM, resulting in data stored within those cells to appear at the output (data) lines. Questions to ponder:

- What is the organization of this particular ROM chip? (e.g. 256 $\times$ 4, 1k $\times$ 1, etc.)
- What is the relationship between the hexadecimal numbers stored inside each cell and the alphabetical characters shown below the chip? What code is being used to represent these characters?
- What character is represented by the hexadecimal code 20? (Hint: this code is used twice in the sequence shown.)

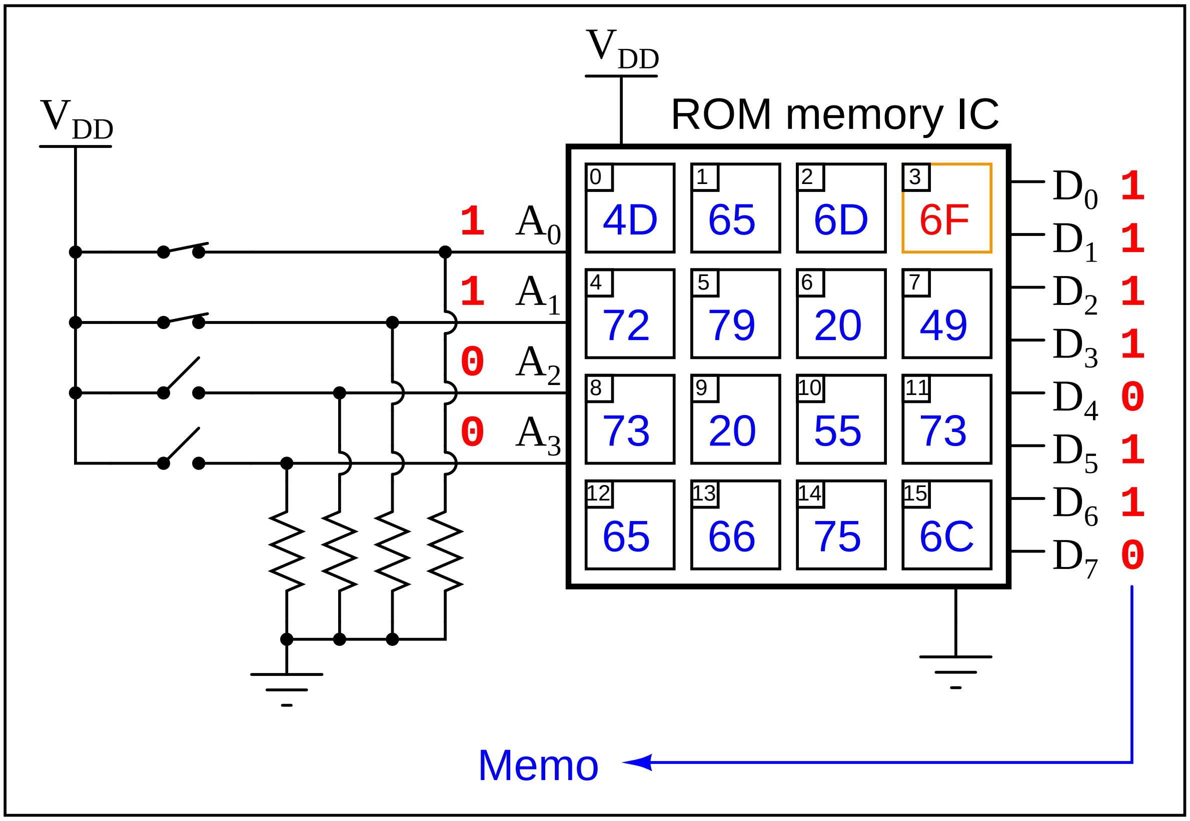

VDD
VDD
ROM memory IC
0 A0
0 A1
0 A2
0 A3
0
4D
1
65
2
6D
3
6F
4
72
5
79
6
20
7
49
8
73
9
20
10
55
11
73
12
65
13
66
14
75
15
6C
D0 1
D1 0
D2 1
D3 1
D4 0
D5 0
D6 1
D7 0
M



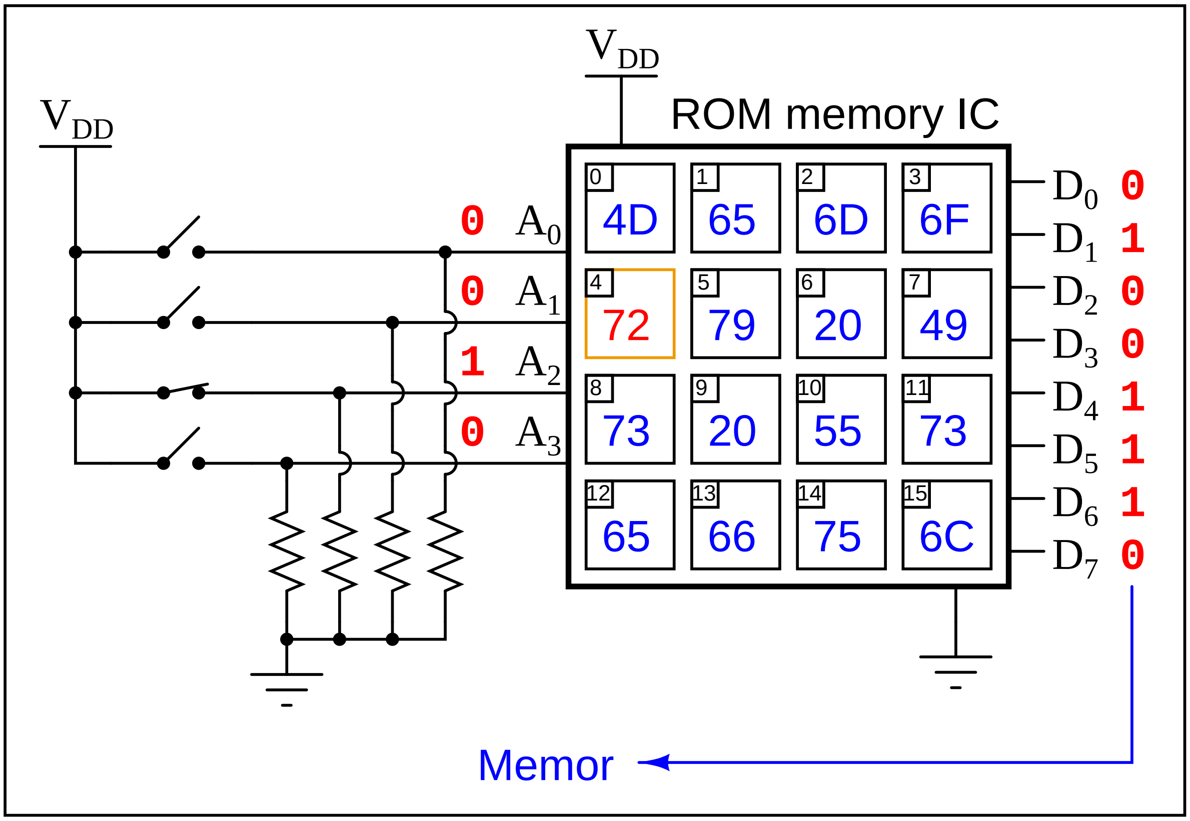
VDD
VDD
ROM memory IC
1 A0
0 A1
0 A2
0 A3
0
4D
1
65
2
6D
3
6F
4
72
5
79
6
20
7
49
8
73
9
20
10
55
11
73
12
65
13
66
14
75
15
6C
D0 1
D1 0
D2 1
D3 0
D4 0
D5 1
D6 1
D7 0
Me



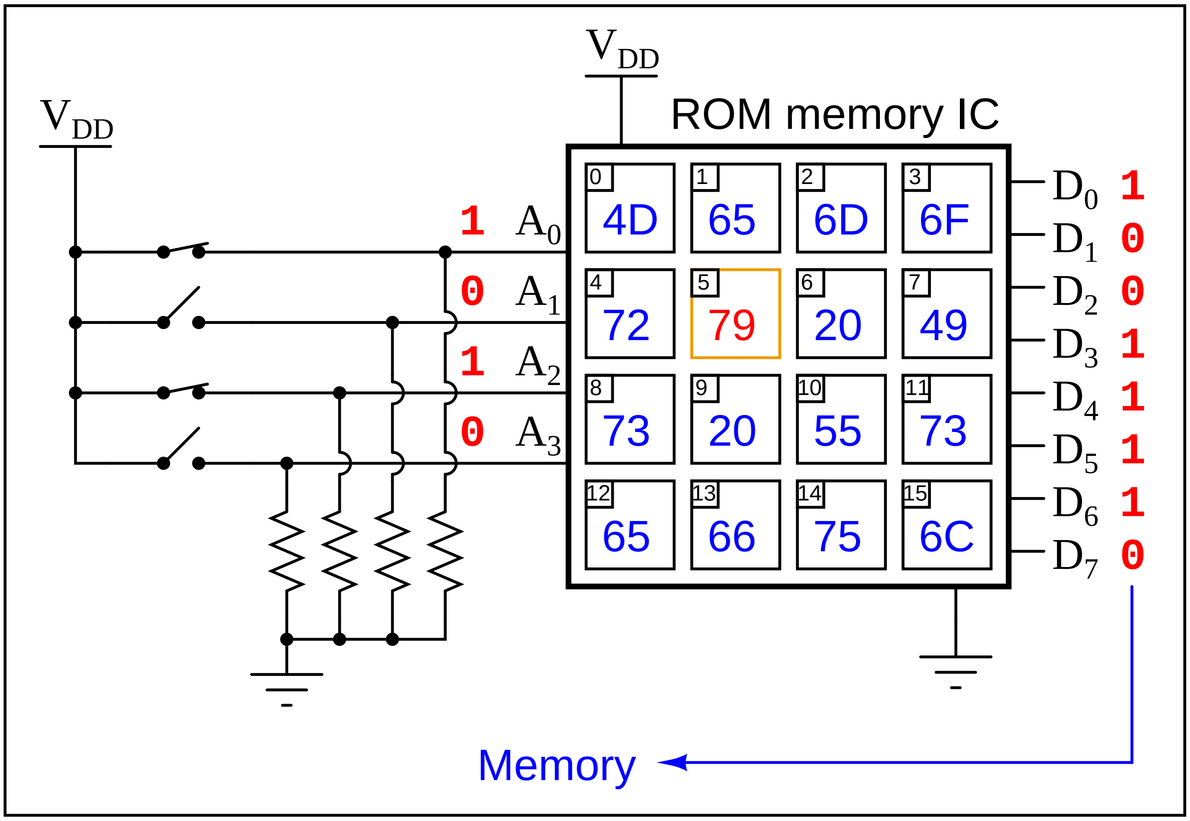
V DD
ROM memory IC
0 A0
1 A1
0 A2
0 A3
0 4D
1 65
2 6D
3 6F
4 72
5 79
6 20
7 49
8 73
9 20
10 55
11 73
12 65
13 66
14 75
15 6C
D0 1
D1 0
D2 1
D3 1
D4 0
D5 1
D6 1
D7 0
Mem

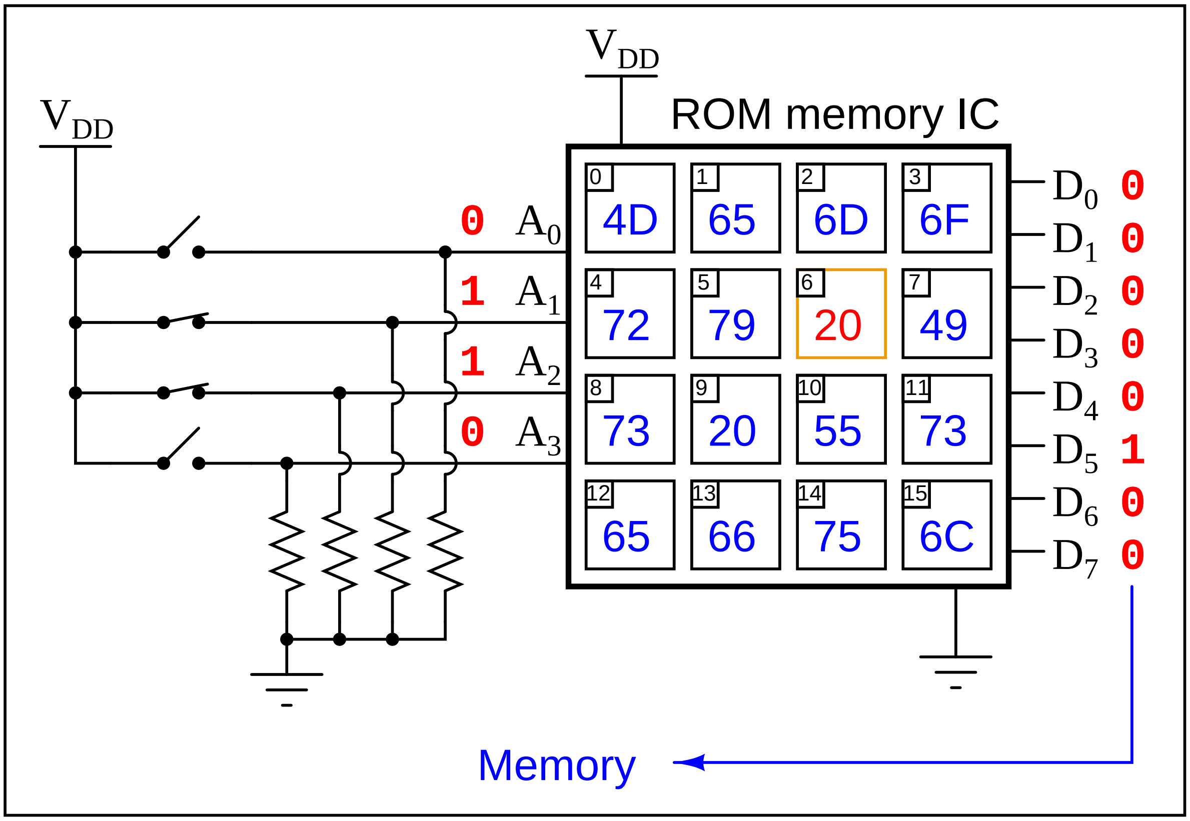


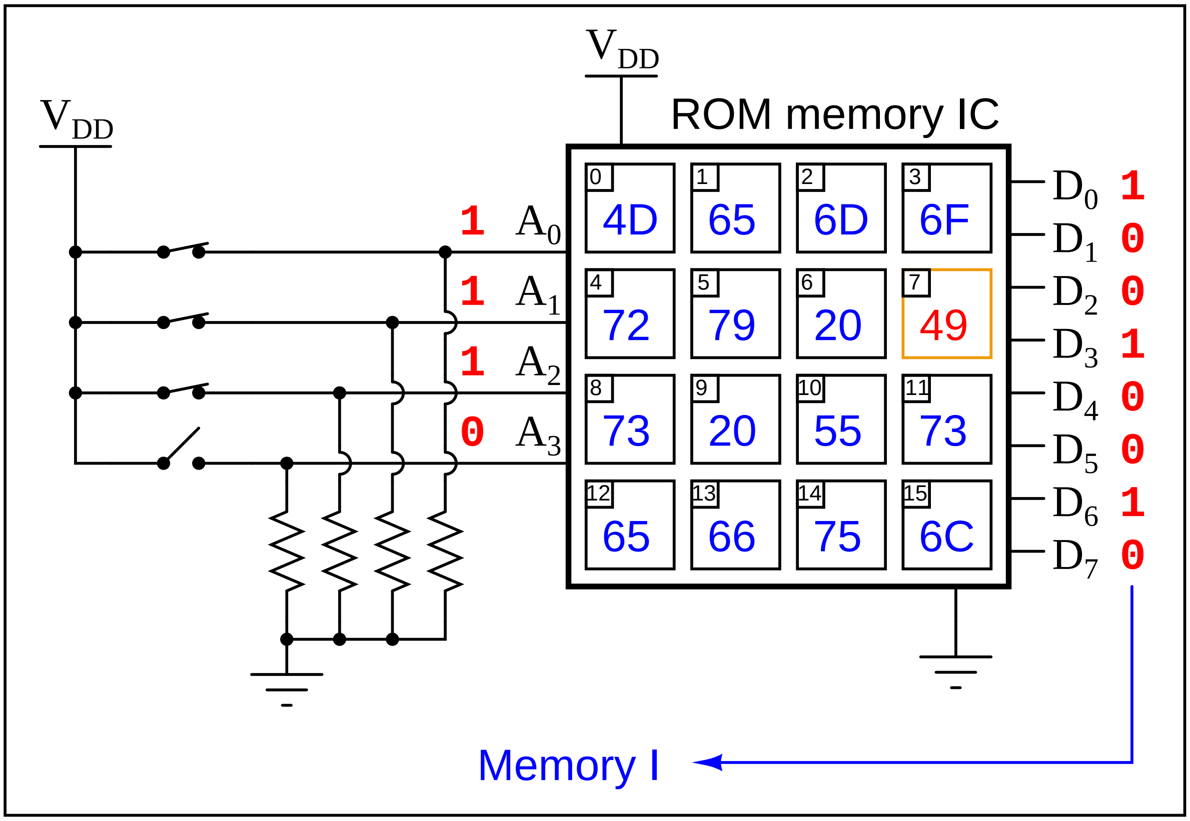
V_DD
V_DD
ROM memory IC
1 A0
1 A1
0 A2
0 A3
0 4D
1 65
2 6D
3 6F
4 72
5 79
6 20
7 49
8 73
9 20
10 55
11 73
12 65
13 66
14 75
15 6C
D0 1
D1 1
D2 1
D3 1
D4 0
D5 1
D6 1
D7 0
Memo



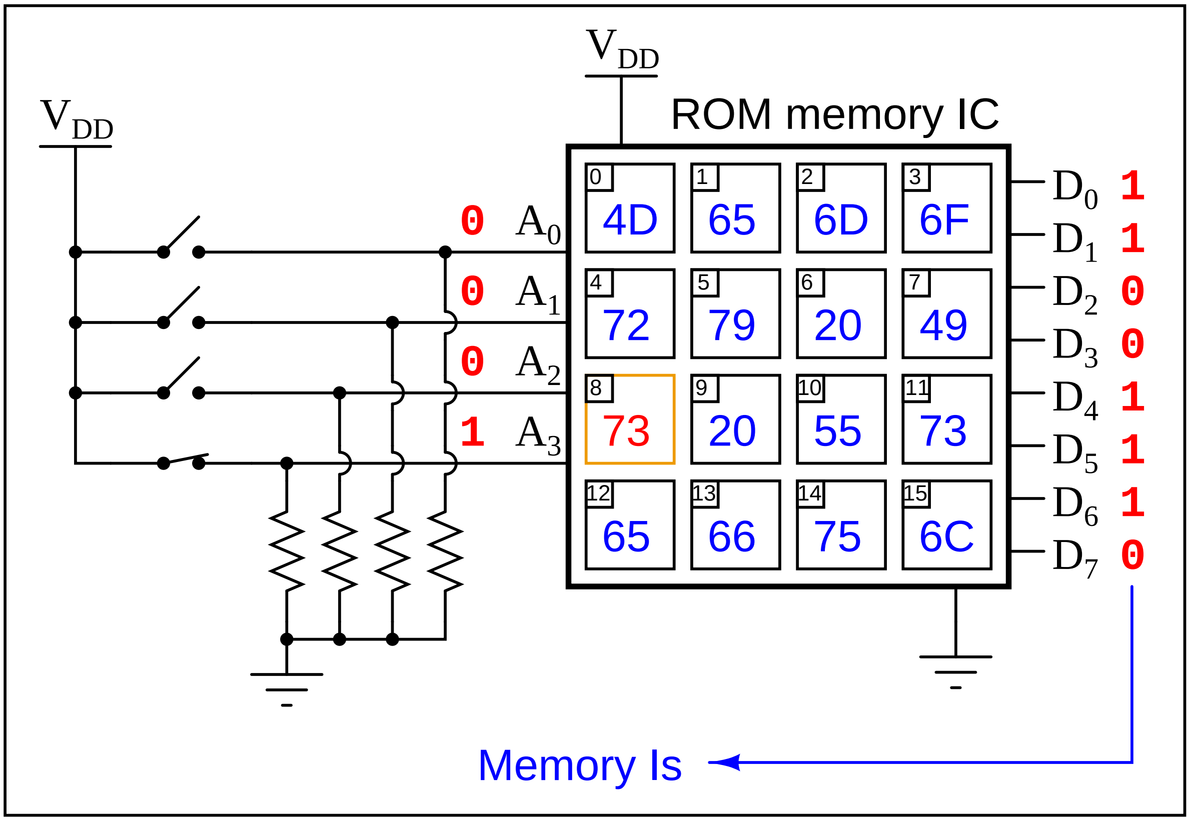
V_DD
V_DD
ROM memory IC
0 A0
0 A1
1 A2
0 A3
0
4D
1
65
2
6D
3
6F
4
72
5
79
6
20
7
49
8
73
9
20
10
55
11
73
12
65
13
66
14
75
15
6C
D0 0
D1 1
D2 0
D3 0
D4 1
D5 1
D6 1
D7 0
Memor


VDD
VDD
ROM memory IC
1 A0
0 A1
1 A2
0 A3
0 4D
1 65
2 6D
3 6F
4 72
5 79
6 20
7 49
8 73
9 20
10 55
11 73
12 65
13 66
14 75
15 6C
D0 1
D1 0
D2 0
D3 1
D4 1
D5 1
D6 1
D7 0
Memory

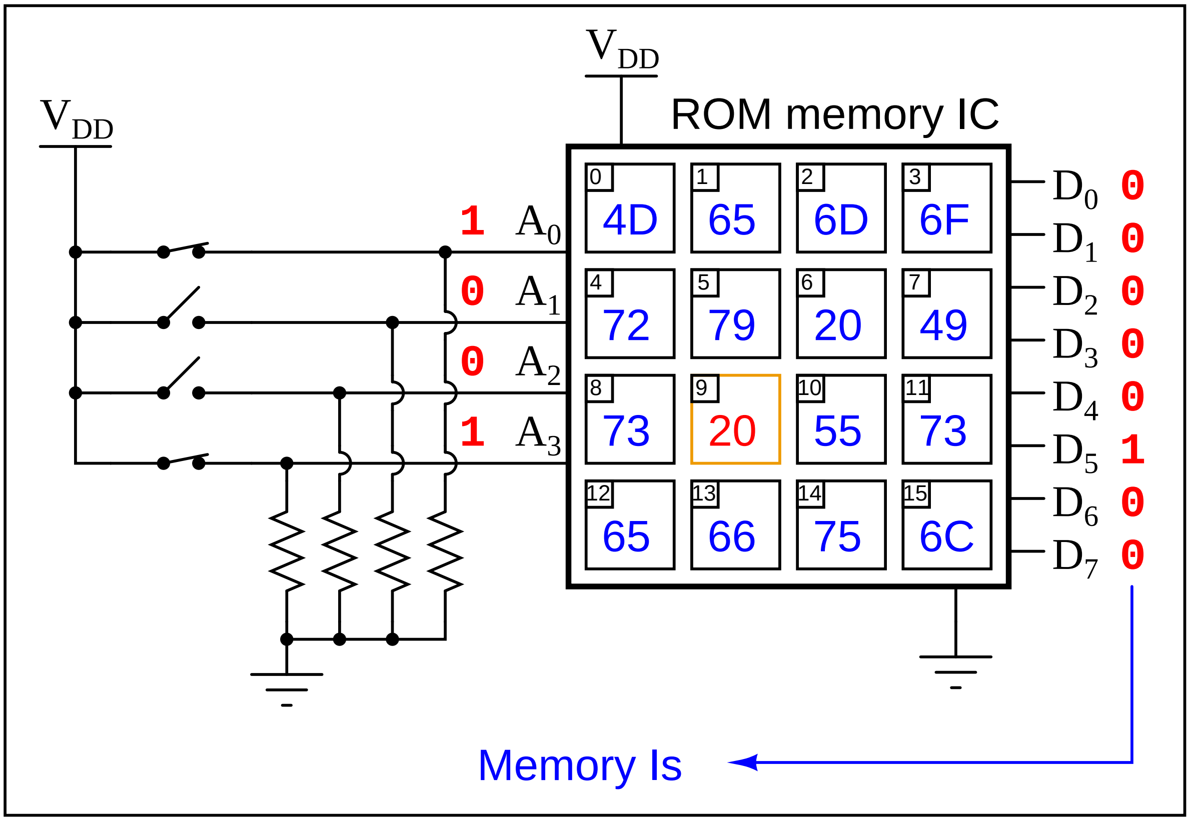

ROM memory IC
V_{DD}
V_{DD}
0 A_0
1 A_1
1 A_2
0 A_3
0
4D
1
65
2
6D
3
6F
4
72
5
79
6
20
7
49
8
73
9
20
10
55
11
73
12
65
13
66
14
75
15
6C
D_0 0
D_1 0
D_2 0
D_3 0
D_4 0
D_5 1
D_6 0
D_7 0
Memory



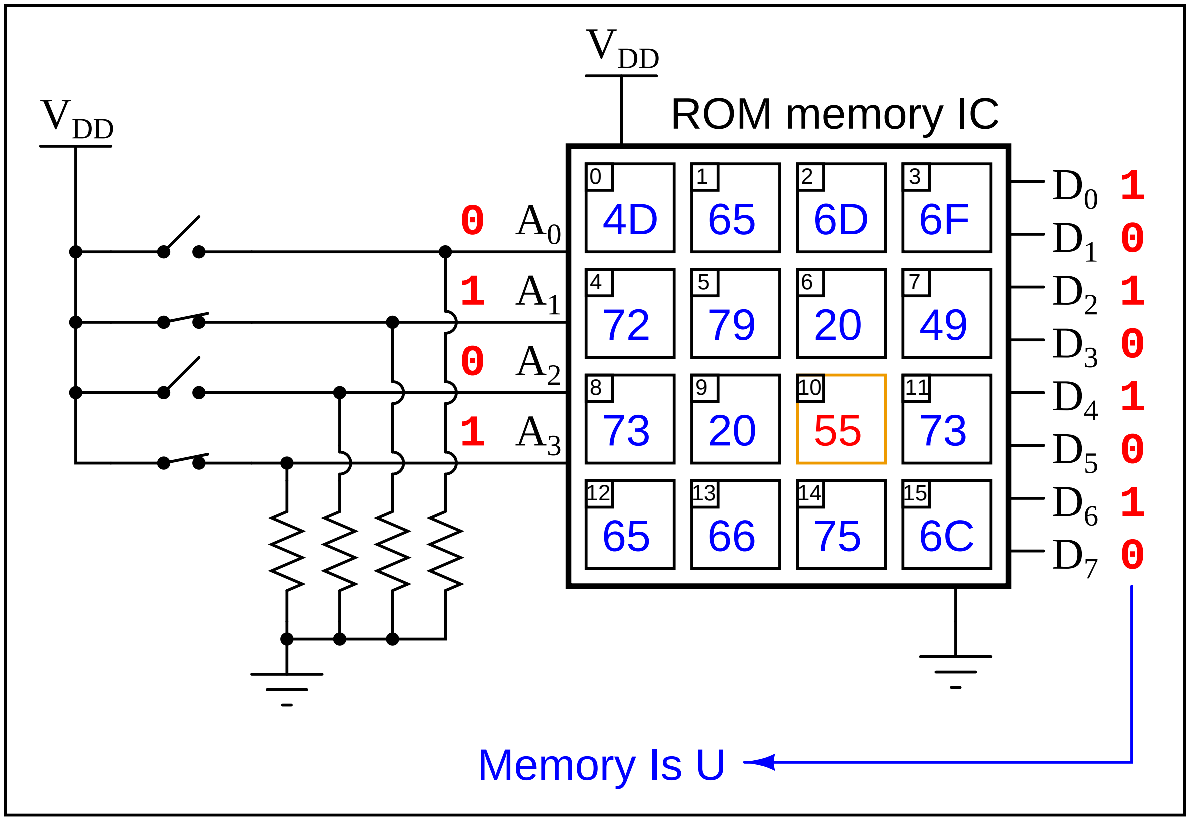
V_{DD}
ROM memory IC
0 4D
1 65
2 6D
3 6F
4 72
5 79
6 20
7 49
8 73
9 20
10 55
11 73
12 65
13 66
14 75
15 6C
1 A0
1 A1
1 A2
0 A3
D0 1
D1 0
D2 0
D3 1
D4 0
D5 0
D6 1
D7 0
Memory I



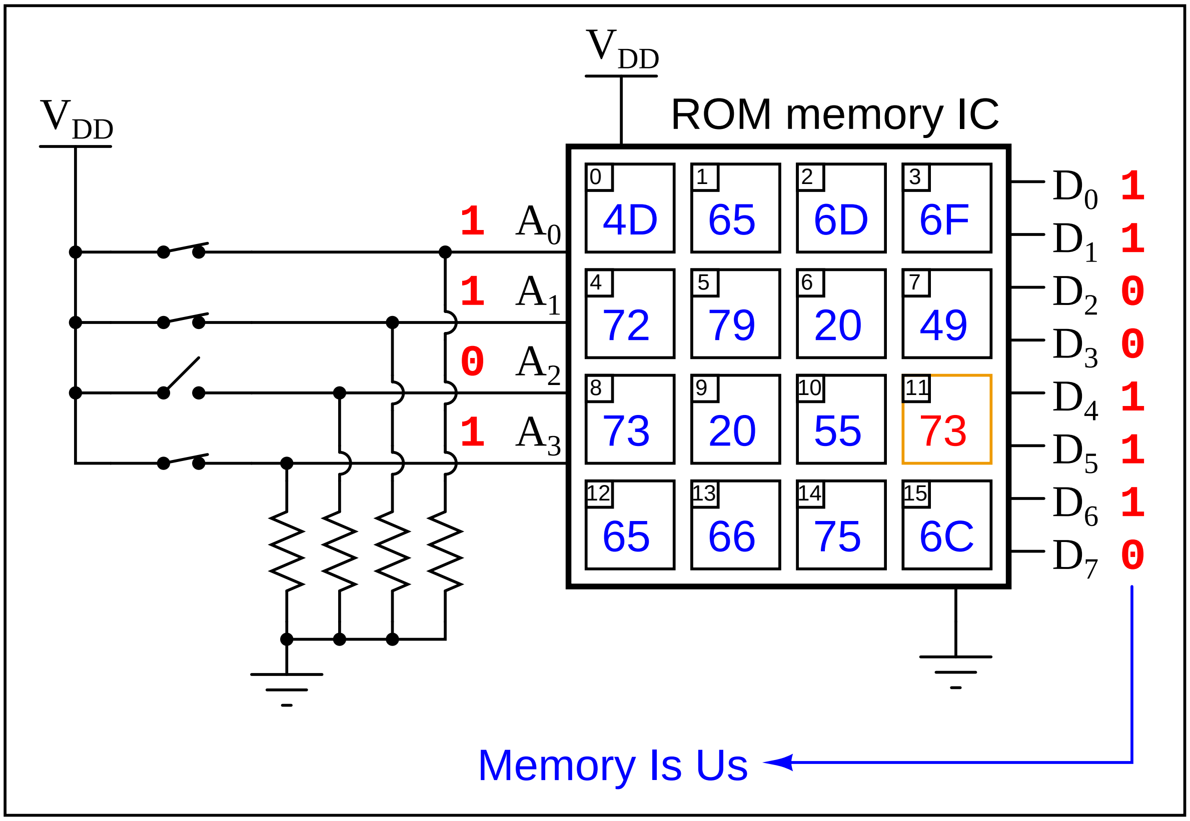
VDD
VDD
ROM memory IC
0 A0
0 A1
0 A2
1 A3
0 4D
1 65
2 6D
3 6F
4 72
5 79
6 20
7 49
8 73
9 20
10 55
11 73
12 65
13 66
14 75
15 6C
D0 1
D1 1
D2 0
D3 0
D4 1
D5 1
D6 1
D7 0
Memory Is



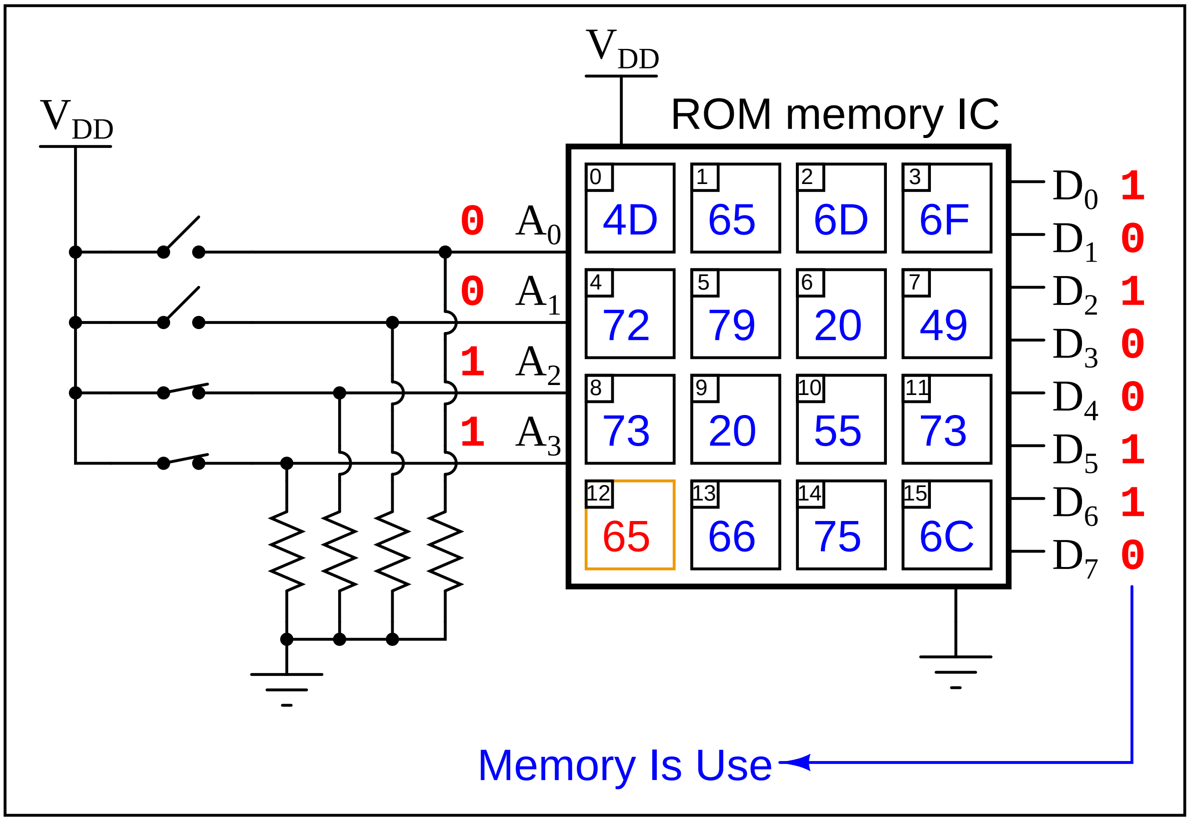
V_DD
V_DD
ROM memory IC
1 A0
0 A1
0 A2
1 A3
0 4D
1 65
2 6D
3 6F
4 72
5 79
6 20
7 49
8 73
9 20
10 55
11 73
12 65
13 66
14 75
15 6C
D0 0
D1 0
D2 0
D3 0
D4 0
D5 1
D6 0
D7 0
Memory Is

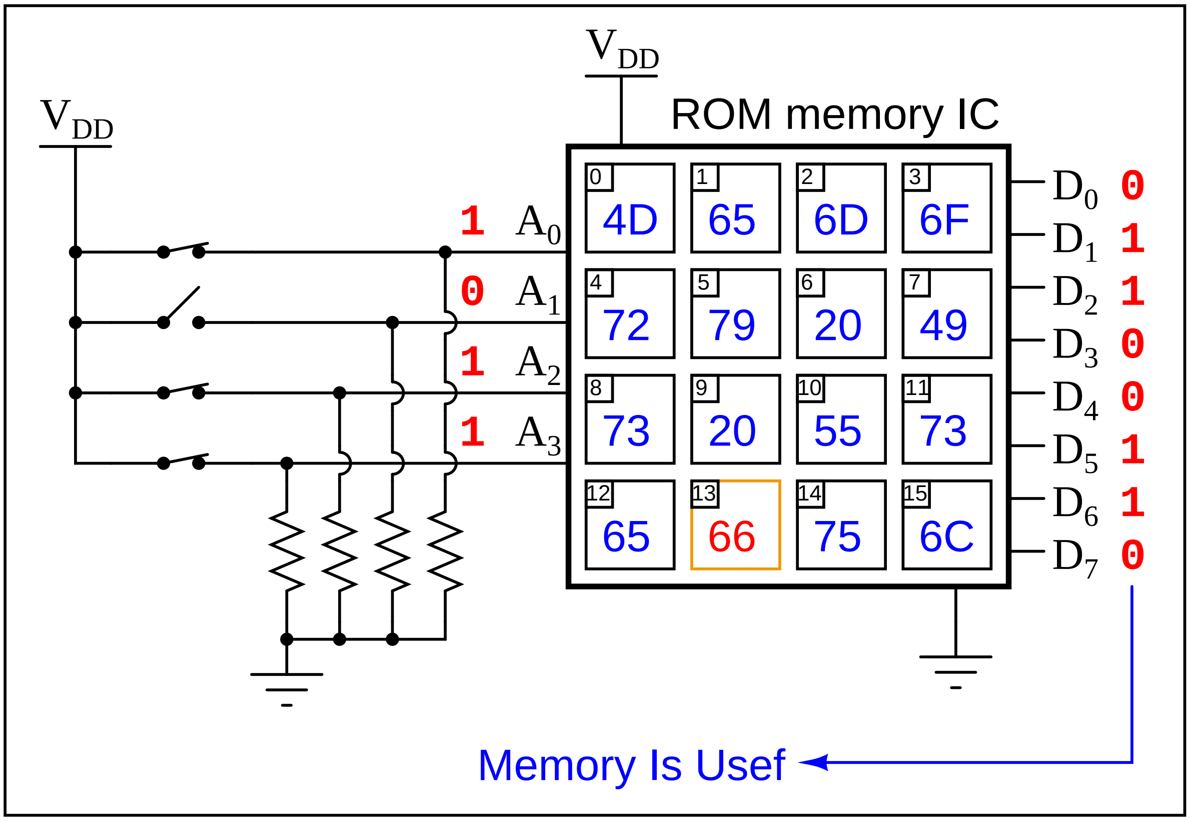


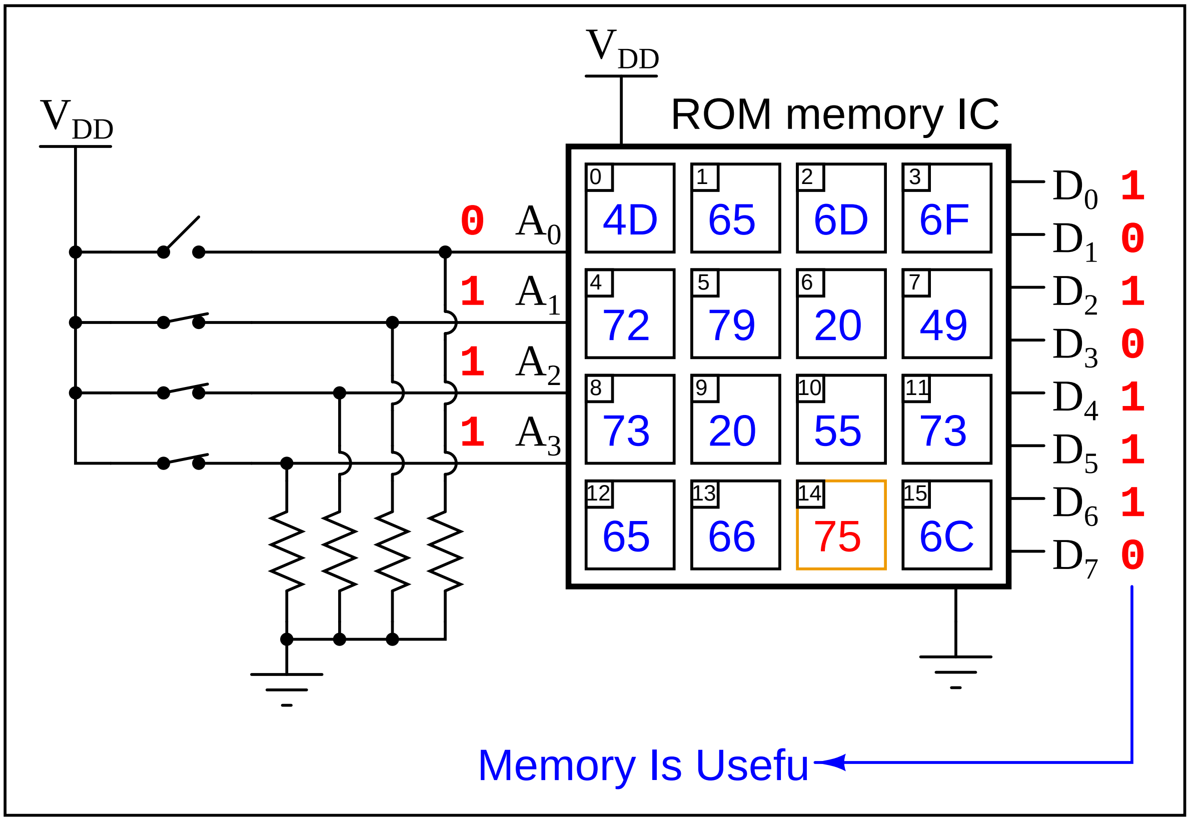
V_{DD}
V_{DD}
ROM memory IC
0 A_0
1 A_1
0 A_2
1 A_3
0 4D
1 65
2 6D
3 6F
4 72
5 79
6 20
7 49
8 73
9 20
10 55
11 73
12 65
13 66
14 75
15 6C
D_0 1
D_1 0
D_2 1
D_3 0
D_4 1
D_5 0
D_6 1
D_7 0
Memory Is U



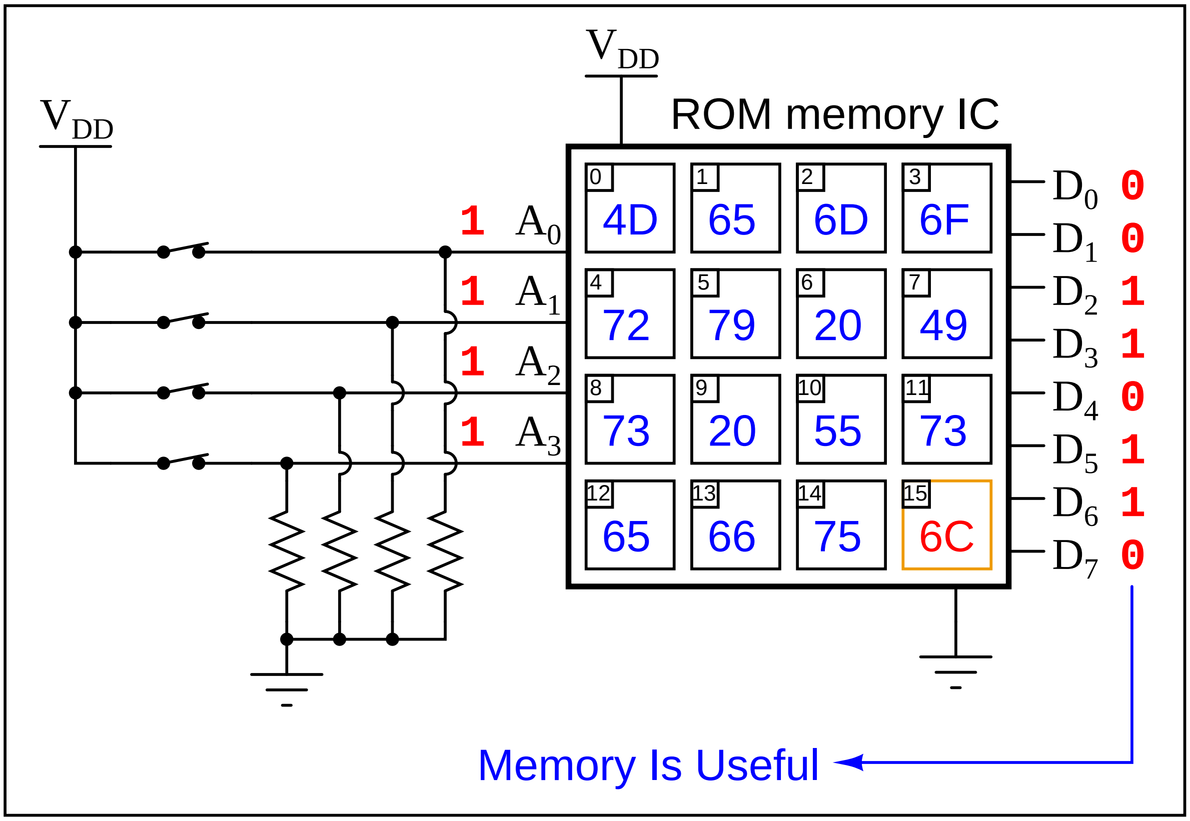
V_DD
V_DD
ROM memory IC
1 A0
1 A1
0 A2
1 A3
0 4D
1 65
2 6D
3 6F
4 72
5 79
6 20
7 49
8 73
9 20
10 55
11 73
12 65
13 66
14 75
15 6C
D0 1
D1 1
D2 0
D3 0
D4 1
D5 1
D6 1
D7 0
Memory Is Us


VDD
VDD
ROM memory IC
0 A0
0 A1
1 A2
1 A3
0 4D
1 65
2 6D
3 6F
4 72
5 79
6 20
7 49
8 73
9 20
10 55
11 73
12 65
13 66
14 75
15 6C
D0 1
D1 0
D2 1
D3 0
D4 0
D5 1
D6 1
D7 0
Memory Is Use


VDD
VDD
ROM memory IC
1 A0
0 A1
1 A2
1 A3
0 4D
1 65
2 6D
3 6F
4 72
5 79
6 20
7 49
8 73
9 20
10 55
11 73
12 65
13 66
14 75
15 6C
D0 0
D1 1
D2 1
D3 0
D4 0
D5 1
D6 1
D7 0
Memory Is Usef



V_{DD}
V_{DD}
ROM memory IC
0 A_0
1 A_1
1 A_2
1 A_3
0 4D
1 65
2 6D
3 6F
4 72
5 79
6 20
7 49
8 73
9 20
10 55
11 73
12 65
13 66
14 75
15 6C
D_0 1
D_1 0
D_2 1
D_3 0
D_4 1
D_5 1
D_6 1
D_7 0
Memory Is Usefu



VDD
VDD
ROM memory IC
1 A0
1 A1
1 A2
1 A3
0
4D
1
65
2
6D
3
6F
4
72
5
79
6
20
7
49
8
73
9
20
10
55
11
73
12
65
13
66
14
75
15
6C
D0 0
D1 0
D2 1
D3 1
D4 0
D5 1
D6 1
D7 0
Memory Is Useful

file 03244

Answer 1

Note how the opening of either switch is sufficient to halt current throughout the entire circuit. Note also how a voltage drop appears across the greatest circuit resistance (and the battery terminals, of course).

Answer 2

Nothing to note here.

Answer 3

Nothing to note here.

Answer 4

Nothing to note here.

Answer 5

Nothing to note here.

Answer 6

Nothing to note here.

Answer 7

Nothing to note here.

Answer 8

Note how each pole pair (A and A', B and B', C and C') develops its peak magnetic field at different times.

Answer 9

Nothing to note here.

Answer 10

For silicon transistors, the crossover distortion amounts to approximately 1.4 volts (from +0.7 to -0.7 volts) in the input waveform.

Follow-up question: in terms of percentage, do you think crossover distortion increases as the input signal increases in peak-to-peak magnitude, or decreases? Explain your reasoning.

Answer 11

Nothing to note here.

Answer 12

This animation must be played with a *very* fast frame rate to do the principle justice. If this is not possible, imagine the mux/demux pair moving at a blinding speed – so fast that your eyes could not follow the motions of the selector switches. What do you suppose the words next to the output lines (Conversation A, Conversation B, etc.) would look like?

Answer 13

Note that each rising edge of the clock pulse has its own frame in the animation sequence, to better show you what happens at those crucial times.

Answer 14

Nothing to note here!

Notes 1

The purpose of this animation is to let students study the behavior of this switch circuit and reach their own conclusions. Similar to experimentation in the lab, except that here all the data collection is done visually rather than through the use of test equipment, and the students are able to ”see” things that are invisible in real life.

Notes 2

The purpose of this animation is to let students see proper soldering technique: applying heat to the ”work” and not the solder directly is the most important element of the technique.

Notes 3

The purpose of this animation is to let students see how Thévenin’s theorem may be applied to the simplification of a resistor network.

Notes 4

The purpose of this animation is to let students study the evolution of Lissajous figures and see how they are created from the interrelationship between two sinusoidal waveforms. Similar to experimentation in the lab, except that here all the data collection is done visually rather than through the use of test equipment, and the students are able to ”see” things that are invisible in real life.

Notes 5

The purpose of this animation is to let students study the evolution of Lissajous figures and see how they are created from the interrelationship between two sinusoidal waveforms. Similar to experimentation in the lab, except that here all the data collection is done visually rather than through the use of test equipment, and the students are able to ”see” things that are invisible in real life.

Notes 6

The purpose of this animation is to let students study the evolution of Lissajous figures and see how they are created from the interrelationship between two sinusoidal waveforms. Similar to experimentation in the lab, except that here all the data collection is done visually rather than through the use of test equipment, and the students are able to ”see” things that are invisible in real life.

Notes 7

The purpose of this animation is to let students study the evolution of Lissajous figures and see how they are created from the interrelationship between two sinusoidal waveforms. Similar to experimentation in the lab, except that here all the data collection is done visually rather than through the use of test equipment, and the students are able to ”see” things that are invisible in real life.

Notes 8

The purpose of this animation is to let students study the evolution of the rotating magnetic field and reach their own conclusions. Similar to experimentation in the lab, except that here all the data collection is done visually rather than through the use of test equipment, and the students are able to ”see” things that are invisible in real life.

Notes 9

The purpose of this animation is to let students study the generation of characteristic curves and reach their own conclusions. Similar to experimentation in the lab, except that here all the data collection is done visually rather than through the use of test equipment, and the students are able to ”see” things that are invisible in real life.

Notes 10

The purpose of this animation is to let students study the behavior of this amplifier circuit and reach their own conclusions. Similar to experimentation in the lab, except that here all the data collection is done visually rather than through the use of test equipment, and the students are able to ”see” things that are invisible in real life.

Notes 11

The purpose of this animation is to let students study the behavior of this comparator circuit and reach their own conclusions. Similar to experimentation in the lab, except that here all the data collection is done visually rather than through the use of test equipment, and the students are able to ”see” things that are invisible in real life.

Notes 12

The purpose of this animation is to let students study the behavior of this multiplexer circuit and reach their own conclusions. Similar to experimentation in the lab, except that here all the data collection is done visually rather than through the use of test equipment, and the students are able to ”see” things that are invisible in real life.

Notes 13

The purpose of this animation is to let students study the behavior of this counter circuit and reach their own conclusions. Similar to experimentation in the lab, except that here all the data collection is done visually rather than through the use of test equipment, and the students are able to ”see” things that are invisible in real life.

In this animation, I show each rising edge of the clock signal in its own frame, whereas the falling edge of the clock shares a frame with the first half of the ”low” state. I do this because these are positive edge-triggered flip-flops, and so the rising edge of the clock pulse is most important. I could have slowed things down on the falling edge of the clock as well, but since there is little ”action” happening then, I decided to save a frame and make it a shorter animation.

Notes 14

The purpose of this animation is to let students study the behavior of this switch circuit and reach their own conclusions. Similar to experimentation in the lab, except that here all the data collection is done visually rather than through the use of test equipment, and the students are able to ”see” things that are invisible in real life.