Circuit Shop v1.09 - March 2000

This manual is a printed version of Circuit Shop's help file. There are two parts to the manual:

- The first part lists the help topics which make up Circuit Shop's reference manual. Pages in this portion are numbered **1** through **95**.
- The second part lists the topics which make up Circuit Shop's tutorial. Pages in this portion are numbered **200** through **297**.

In the on-line help system, help topics are selected by clicking on a highlighted word or set of words in a topic. In this manual, topics are referenced as page number footnotes. In other words, a footnote specifies the page number where the topic can be found. For example, the footnote on the following text, Purchasing information[7] indicates the topic can be found on page **7**.

Circuit Shop Help

Before You Begin

Getting Started

Tutorials

Circuit Analysis

References

Topic Tree

The following topic tree shows the structure of and provides quick access to Circuit Shop's help topics.

What is Circuit Shop

Circuit Shop allows you to design, simulate and learn about digital[84] and analog[81] electronic circuits. Circuit Shop is an easy to use graphical CAD tool to allow simple digital and analog electronic circuits to be constructed and analyzed. It includes:

- Device and drawing toolkits[51] to construct simple electronic circuit schematics consisting of digital and analog devices such as logic gates,[34] flip-flops,[34] op amps,[88] dependent sources,[84] ICs,[89] transistors,[94] resistors,[92] batteries,[82] etc.
- A tutorial[201] which teaches basic digital and analog electronic concepts.
- Digital circuit[84] design and analysis[32] capability using digital sources,[33] logic gates,[34] flip-flops,[34] digital displays[36] and ICs.[89]
- Analog circuit[81] design and simulation capability to perform DC analysis,[22] sinusoidal steady state analysis[25] and frequency response.[27] Frequency response includes magnitude, Bode, phase, dB and group delay plots.
- A simple paint toolkit[54] to allow text, lines, ovals and rectangles to be added as circuit annotations.
- A printable version of Circuit Shop's on-line help file can be downloaded from the Circuit Shop home page.[10] The fully indexed document consists of a reference manual and tutorial.

Circuit Shop runs on Windows 3.1/95/98/NT.

Keywords: circuit design analysis simulation electric electrical electronic educational tutorial digital analog device logic gate flip-flop op amp dependent source DC AC sinusoidal steady state frequency response Bode phase dB group delay IC schematic CAD drawing paint toolkit

Related Topics:

Frequently asked questions[5]
Topic tree[3]
Creating and editing diagrams[11]
Tutorial help topics[201]
Circuit analysis help topics[22]
Purchasing information[7]

Frequently Asked Questions

If you have a question or are having a problem with Circuit Shop, browse the following questions and answers, it is possible that your question may be answered below.

1. What device types are supported by Circuit Shop's circuit analysis function?[22]

   A list of supported devices for each analysis type can be found in:

   - DC analysis supported devices[23]
   - Sinusoidal steady state analysis supported devices[26]
   - Frequency response supported devices[26]
   - Digital analysis supported devices[32]

2. How do I create circuits in Circuit Shop?

How do I become familiar with Circuit Shop features?
How do I use Circuit Shop's circuit analysis capabilities?

To become familiar with how to build and analyze circuits you can follow the step-by-step instructions in one or more of the following tutorial[201] demonstration topics.

- Ohm's law demonstration circuit[207]
- Series circuit demonstration circuit[215]
- Parallel circuit demonstration circuit[225]
- Series RLC demonstration circuit[264]
- Logic gate demonstration circuit[287]

Instructions on how to use Circuit Shop's circuit analysis[22] functions can be found in the following help topics.

- DC analysis[22]
- Sinusoidal steady state analysis[25]
- Frequency response[27]
- Digital analysis[32]

Two help topic trees are also provided as an index to easily navigate between topics and to show how Circuit Shop help topics are organized.

- Help topic tree[3]
- Tutorial topic tree[203]

3. Is a reference manual available?

Yes. A printable version of Circuit Shop's on-line help file can be downloaded from the Circuit Shop home page.[10] The fully indexed document consists of a reference manual and tutorial.

4. Why won't my circuit work?
Why won't the device meter[29] voltage appear?
...

Some variant of the above circuit analysis[22] related questions are the number one reported "problems" with two main causes:

a) Attempting to analyze a circuit with unsupported devices.
A list of supported devices can be found in:

- DC analysis supported devices[23]
- Sinusoidal steady state analysis supported devices[26]
- Frequency response supported devices[26]
- Digital analysis supported devices[32]

b) Attempting to analyze a circuit with unconnected devices.
Sometimes devices are placed very near or over each other but are not correctly connected by wires.[95] An easy way to determine if two or more devices are correctly connected is to hold down the left mouse button over one of the devices and drag it to another diagram location (see moving devices[17] for additional information). If a wire does not move to keep the devices connected, the devices are not electrically connected in the circuit (see connecting devices[14] for additional information). Circuit Shop also detects disconnected wires and devices, and displays a warning when the Tool | Analyse command[46] is invoked.

5. Is there a user creatable toolkit capability?
Is there a customized symbol capability?
Is there a way to create a library of customized symbols and common circuits?

There are no immediate plans to implement user creatable toolkits. One alternative is to create a library of customized symbols and common circuits in one or more Circuit Shop files[75] and use the edit command's[43] cut[44] and paste[44] facility between diagrams.

Also, Circuit Shop allows you to create unlimited analog[81] and digital[84] circuits inside integrated circuit (IC)[89] devices. The circuits inside ICs can also imbed additional ICs and thus very complex circuits can be created. This capability is sometimes called circuit macros in other programs. See creating circuits inside integrated circuits.[20]

A library example is the standard digital logic ICs, 7400 through 7449, contained in L7400.CS1 which is included in the Circuit Shop distribution files. You can cut and paste the ICs from this library to your own circuits.

6. How do I register Circuit Shop?

You can register Circuit Shop by:
1. Sending the required registration fee by post office mail.
2. Web transaction using a credit card.

See purchasing information.[7] When the registration notification or mail is received, you will be sent a registration key.

7. What Circuit Shop features become available after registration?

The additional features that become available after registration are listed in purchasing information.[7]

8. How can a circuit be transferred to another application such as a word processor or a general graphics program?

The File | Output BMP file[41] draws the circuit in the currently active window into a bitmap file. The bitmap file can be imported to other applications.

Related topics:
Technical support[10]
Topic tree[3]

Purchasing Information

You may purchase Circuit Shop

- by cheque or money order[8]
- by web transaction[9]
- by purchase order[9]

On receipt of payment, you will be sent a registration key. The File | Register[41] menu command and the Registration dialog box[72] are then used to register your copy of Circuit Shop.

Registration entitles you to

- Free upgrades to new versions of Circuit Shop for a period of 2 years.
- Technical support.[10]
- Load Circuit Shop files[75] which are greater than 30 days old.
- Create circuits containing greater than 20 devices. Note, the count includes devices inside integrated circuits.[89]
- Ability to print[40] diagrams.
- Ability to output diagrams to BMP files[41] for import into other applications.
- Access advanced Circuit Shop features including:

1. Ability to plot additional frequency response[27] information:

  - Phase (Degrees)
  - Magnitude (dB)
  - Group Delay (Seconds)

Note: Frequency response Magnitude (Volts) plots are available to non-registered users.

2. Ability to analyze circuits containing

  - Transformers[94]
  - Ideal operational amplifiers[88]
  - Dependent voltage and current sources[84]

using Circuit Shop's sinusoidal steady state analysis[25] and frequency response[27] graph generation capabilities.

3. Ability to use additional device meter[29] functions including ability to measure

  - Terminal[93] voltages.[95]
  - Terminal[93]-to-terminal[93] voltage[95] differences.
  - Power[91] dissipated by resistors,[92] capacitors[82] and inductors.[89]

4. Ability to analyze circuits containing diodes[85] using Circuit Shop's DC analysis[22] function.

Related topics:
Technical support[10]
Warranty[10]

Purchasing by Cheque or Money Order

To purchase Circuit Shop by cheque or money order, complete the following form and send to Cherrywood Systems at the indicated address. (To make a copy of the form, select the above Circuit Shop Help window File | Print Topic menu command.)

Registration price

- The USA registration price is $29 U.S. and can be made by cheque or money order.
- The Canadian registration price is $39 Canadian and can be made by cheque or money order.
- Outside of USA and Canada, the registration price is the equivalent of $29 U.S. and can be made by international money order only.

On receipt of payment, you will be sent a registration key. If an e-mail address is included below, the key will be sent to the specified address.

```
NAME           ____________________________________

COMPANY        ____________________________________

STREET         ____________________________________

CITY           ____________________________________

STATE/PROV.    ______________  ZIP/P.C.  ___________

COUNTRY        ____________________________________

TELEPHONE      ____________________________________

E-MAIL         ____________________________________


Product:        Price       Copies            Total

Circuit Shop   ______   x   ______   =   $ _________


Make cheque payable to: Cherrywood Systems

               Mail to: Cherrywood Systems
                        5143 Galway Dr.
                        Tsawwassen B.C.
                        Canada
                        V4M 3R4
```

Purchasing by Web Transaction

You may purchase Circuit Shop by credit card (Master Card, Visa, American Express or Discover) over the web by navigating to DigiBuy at

http://www.digibuy.com

From this page, to navigate to Circuit Shop's order page

- select Shop DigiBuy
- select Alphabetical listing
- select the letter C for Circuit Shop
- scroll down and select the Circuit Shop link

Or directly at

http://www.digibuy.com/cgi-bin/product.html?93357317861

The cost is $29 U.S. per copy.

The above pages can also be found via the Cherrywood Systems home page at

http://ourworld.compuserve.com/homepages/Cherrywood/

On notification of receipt of payment, you will be sent a registration key. The File | Register[41] menu command and the Registration dialog box[72] are then used to register your copy of Circuit Shop.

Purchasing by Purchase Order

Purchase orders are accepted from institutions and companies. Purchase orders should be sent to

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Cherrywood Systems
5143 Galway Dr.
Tsawwassen B.C.
Canada
V4M 3R4
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The cost is $29 U.S. per copy and a minimum 4 copies plus 10% for shipping and handling.

Technical Support

If you have product questions or suggestions, you can contact the developers via e-mail at

Cherrywood@compuserve.com

Our web page is located at

http://ourworld.compuserve.com/homepages/Cherrywood/

Product suggestions from registered and unregistered users are always welcome. If you have any suggestions or comments which would make Circuit Shop a useful tool to you or in your environment, please send them along. We will analyze your request and attempt to schedule/add any feature that fits into the product vision and our development resources permit.

If you are having a problem with Circuit Shop, frequently asked questions[5] may help.

Related topics:

Purchasing information[7]
Warranty[10]

Warranty

"Circuit Shop" is licensed without any warranty of merchantability, fitness of particular purpose, performance, or otherwise. All warranties are disclaimed. By using "Circuit Shop", you agree that neither Cherrywood Systems nor any of its employees, affiliates, owners, or other related parties will be liable to you or any third party for any use of (or inability to use) this software, or for any damages whatsoever, even if Cherrywood Systems and/or the authors are apprised of the possibility of such damages occurring. Cherrywood Systems and/or the authors assume no liability for losses or damages, of a physical, financial, or of whatever nature, direct or consequential, resulting from the use of, or purported use of "Circuit Shop" or any of the files in the package, for any purpose whatsoever.

You use "Circuit Shop" entirely at your own risk.

Starting and Exiting Circuit Shop

Starting Circuit Shop

Circuit Shop can be started from the:

Program Manager
File Manager
Command Line

When you start Circuit Shop, it will open its Main Window.

Starting from the Program Manager

Like most Windows applications, you can start Circuit Shop by double-clicking on its icon. The location of the icon depends on how Circuit Shop was installed. If the default setup was used, the icon is in the Circuit Shop group.

Starting from the File Manager

Circuit Shop is started from the File Manager by double-clicking on CIRC.EXE, or by highlighting it and pressing <Enter>. CIRC.EXE can be found in the drive and directory that was selected during installation. If the default setup was used, CIRC.EXE is in C:\CSHOP1.

Starting from the Command Line

To start Circuit Shop from the Windows command line:

1. Select "File" in the menubar, then select "Run".
2. Enter Circuit Shop's full filename path, i.e. Circuit Shop's drive and directory, followed by "CIRC.EXE". If the default setup was used, type "C:\CSHOP1\CIRC.EXE".
3. Click the OK Button or press <Enter>.

Exiting

Exit Circuit Shop like most Windows programs:

1. Select "Exit" in Circuit Shop's File Menu.
2. Double-click Circuit Shop's Main Window Control Box.
3. Press <Alt> + <F4>.
4. Select "Exit" in Circuit Shop's Main Window's Control Menu.

Creating and Editing Diagrams

The following topics describe Circuit Shop's diagram creation and editing capabilities:

Creating a new diagram window[15]
Opening an existing diagram[18]

Adding devices or objects to a diagram[12]
Deleting devices or objects from a diagram[15]
Adding text objects to a diagram[13]

Selecting objects[18]
Modifying device values or other object attributes[16]
Moving devices or objects[17]
Rotating devices or objects[18]

Edit | Undo[45] - Redo[45]
Edit | Cut[44] - Copy[43] - Paste[44] - Append[43] - Select all[45]

Connecting devices - adding wires[14]

Adding[12] - moving[16] - deleting a wire vertex[15]

Creating circuits inside integrated circuits[20]

Viewing circuit voltage and current values - adding meters[20]
Analysing a circuit[19]

Adding a Vertex to a Wire or Line Object

To add a vertex[95] to a wire[95] or line object:

1. Using the mouse, choose the pointer icon  on the toolbar[37] or the analog device toolkit.[52]
2. Move the mouse onto the diagram over the wire or line object portion where the vertex is to be added.
3. Press the left mouse button and drag the wire or line object to the desired vertex location.
4. Release the mouse button.

Line vertices are placed on the current drawing grid.

Wire[95] vertices are placed as follows

1. If the selected vertex location is within one grid unit of an adjacent vertex or wire end, the wire vertex will be automatically positioned so that the resulting wires are horizontal or vertical.
2. Otherwise, if the selected vertex location is not within one grid unit, the vertex is placed on the current drawing grid.

The size and visibility of the drawing grid are controlled using the Tool | Drawing Grid command[48] and the Edit Drawing Grid dialog box.[65]

Related topics:

Moving a vertex[16]
Deleting a vertex[15]
Edit | Undo[45] - Redo[45]
Creating and editing diagrams[11]
Connecting devices - adding wires[14]
Menu commands[37]
Device and drawing toolkits[51]

Adding a Device or Object

To add a device or object to a diagram:

1. Ensure the device or object toolkit[51] is visible. (hint1)[76]
2. Using the left mouse button, click a device or object icon on the toolkit.
3. Move the mouse onto the diagram to where the device or object is to be located.
4. Click the left mouse button to place the selected device or object on the diagram.

Devices and objects are centered on the current drawing grid. The size and visibility of the drawing grid are controlled using the Tool | Drawing Grid command[48] and the Edit Drawing Grid dialog box.[65]

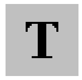
Related topics:

Edit | Undo[45] - Redo[45]
Creating and editing diagrams[11]
Menu commands[37]

Device and drawing toolkits[51]

Adding a Text Object

To add a text object to a diagram:

1. Ensure the paint toolkit[54] is visible. (hint2)[76]
2. Using the mouse, choose  on the toolkit.
3. Move the mouse onto the diagram to where the text is to be located.
4. Click the mouse to place the text object on the diagram. The initial value of the text object will be "(empty)".

To modify a text object's value:

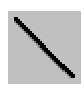
1. Using the mouse, choose the pointer icon  on the toolbar[37] or the analog device toolkit.[52]
2. Move the mouse onto the diagram over the object to be modified.
3. Double click the left mouse button to display the object's dialog box. Double clicking on a text object will open the Edit Text dialog box.[70]
4. Enter the desired text value and press OK.

Related topics:

Edit | Undo[45] - Redo[45]
Moving devices or objects[17]
Edit Text dialog box[70]
Modifying object values and attributes[16]
Diagram annotations[15]
Creating and editing diagrams[11]
Adding devices or objects to a diagram[12]
Menu commands[37]
Device and drawing toolkits[51]

Adding a Line Object

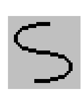
To add a straight line object to a diagram

1. Ensure the paint toolkit[54] is visible. (hint2)[76]
2. Using the mouse, choose the straight line icon  on the toolkit.
3. Move the mouse onto the diagram over the desired start location of the line.
4. Press the left mouse button and drag the line to the desired end location of the line.
5. Release the mouse button.

Line vertices

Vertices[95] can be added,[12] moved[16] or deleted[15] from a straight or curved line.

To add a curved line object to a diagram

1. Ensure the paint toolkit[54] is visible. (hint2)[76]
2. Using the mouse, choose the curved line icon  on the toolkit.
3. Move the mouse onto the diagram over the desired start location of the line.
4. Press the left mouse button and drag the line to the desired end location of the line.
5. Release the mouse button.

6. Using the mouse, choose the pointer icon  on the toolbar[37] or the analog device toolkit.[52]
7. Move the mouse onto the diagram over the line object portion where the vertex is to be added.
8. Press the left mouse button and drag the line object to the desired vertex location.
9. Release the mouse button.
10. Repeat steps (6) through (9) to add as many vertices as desired. Circuit Shop draws a cubic spline curve for each set of 3 points in a line.

To move an entire line object

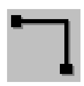
Detailed instructions on how to move an entire line object can be found in moving an entire line object.[18]

Related topics:

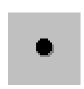
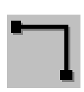
Edit | Undo[45] - Redo[45]
Diagram annotations[15]
Creating and editing diagrams[11]
Adding devices or objects to a diagram[12]
Moving devices or objects[17]
Modifying object values and attributes[16]
Menu commands[37]
Device and drawing toolkits[51]

Connecting Devices - Adding Wires and Connectors

Adding a wire to connect two devices:

1. Using the mouse, choose the wire icon  on the toolbar[37] or the analog device toolkit.[52]
2. Move the mouse onto the diagram over a device terminal. When Circuit Shop detects that the cursor is over a device terminal, the cursor symbol will change to a pointer .
3. Press and hold down the left mouse button over the device terminal.
4. Hold down the left mouse button and drag the wire to another device terminal. When Circuit Shop detects that the cursor is over a device terminal, the cursor symbol will change to a pointer .
5. Release the mouse button.

Adding a connector to connect multiple devices:

1. Using the mouse, choose the connector icon  on the toolbar[37] or the analog device toolkit.[52]
2. Move the mouse onto the diagram to where the connector is to be located and click the mouse to place the connector on the diagram.
3. Using the mouse, choose the wire icon  on the toolbar[37] or the analog device toolkit.[52]
4. Move the mouse onto the diagram over a device terminal to be connected to the connector object.
5. Press the left mouse button and drag the wire to the connector.
6. Release the mouse button.
7. Repeat steps (4) through (6) on the other devices to be connected to the connector object.

Related topics:

- Edit | Undo[45] - Redo[45]
- Creating and editing diagrams[11]
- Adding[12] - moving[16] - deleting a wire vertex[15]
- Menu commands[37]
- Device and drawing toolkits[51]

Creating a New Diagram Window

Use 

on the toolbar[37] or menu command File | New[39] to create a new diagram window.

Related topics:

- Creating and editing diagrams[11]
- Menu commands[37]
- Device and drawing toolkits[51]

Deleting a Vertex From a Wire or Line Object

To delete a vertex[95] from a wire or line object:

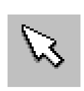
1. Using the mouse, choose the pointer icon  on the toolbar[37] or the analog device toolkit.[52]
2. Move the mouse onto the diagram over the vertex to be deleted.
3. Press the left mouse button and drag the vertex so that the wire or line segments connected to the vertex form a straight line.
4. Release the mouse button. The vertex will be deleted from the wire.

Related topics:

- Edit | Undo[45] - Redo[45]
- Adding a vertex[12]
- Moving a vertex[16]
- Creating and editing diagrams[11]
- Connecting devices - adding wires[14]
- Deleting devices or objects from a diagram[15]
- Menu commands[37]
- Device and drawing toolkits[51]

Deleting a Device or Object

To delete a device or object from a diagram:

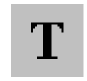
1. Using the mouse, choose the pointer icon  on the toolbar[37] or the analog device toolkit.[52]
2. Move the mouse onto the diagram to the device or object to be deleted.
3. Click the mouse to select the device or object.
4. Use Edit | Delete[44] menu command to delete the device or object.

Related topics:

- Edit | Undo[45] - Redo[45]
- Creating and editing diagrams[11]
- Menu commands[37]
- Device and drawing toolkits[51]

Diagram Annotations

Circuit Shop allows annotations to be added to circuit diagrams. To add an annotation:

1. Ensure the paint toolkit[54] is visible. (hint2)[76]
2. Using the mouse, choose the desired annotation. For example, choosing  on the paint toolkit will allow you to add a text annotation to the diagram.
3. Move the mouse onto the diagram to where the annotation is to be located.
4. Click the mouse to place the annotation object on the diagram.

See adding text objects[13] for detailed instructions to add text annotations.

See adding line objects[13] for detailed instructions to add line annotations.

Related topics:

- Moving devices or objects[17]
- Modifying object values and attributes[16]
- Creating and editing diagrams[11]
- Adding devices or objects to a diagram[12]
- Menu commands[37]
- Device and drawing toolkits[51]

Modifying Device or Object Attributes

Circuit Shop allows devices to be updated via dialog boxes.[62] To modify a device's value or attribute:

1. Using the mouse, choose the pointer icon  on the toolbar[37] or the analog device toolkit.[52]
2. Move the mouse onto the diagram over the device or object to be modified.
3. Double click the left mouse button to display the device or object's dialog box. For example, double clicking on a resistor will open the Edit Device dialog box.[64]

Related topics:

- Edit | Undo[45] - Redo[45]
- Creating and editing diagrams[11]
- Dialog boxes[62]
- Menu commands[37]
- Device and drawing toolkits[51]

Moving a Wire or Line Object Vertex

To move a wire[95] or line object vertex[95]:

1. Using the mouse, choose the pointer icon  on the toolbar[37] or the analog device toolkit.[52]
2. Move the mouse onto the diagram over the vertex to be moved.
3. Press the left mouse button and drag the vertex to the desired location.
4. Release the mouse button. The wire or line object will be redrawn with the vertex in its new location.

Line vertices are placed on the current drawing grid.

Wire[95] vertices are placed as follows

1. If the selected vertex location is within one grid unit of an adjacent vertex or wire end, the wire vertex will be automatically positioned so that the resulting wires are horizontal or vertical.
2 Otherwise, if the selected vertex location is not within one grid unit, the vertex is placed on the current drawing grid.

The size and visibility of the drawing grid are controlled using the Tool|Drawing Grid command[48] and the Edit Drawing Grid dialog box.[65]

Note: If the new vertex location causes the wire or line object to be straight, the vertex will be automatically deleted. See deleting a vertex.[15]

Related topics:

Edit|Undo[45] - Redo[45]
Adding a vertex[12]
Creating and editing diagrams[11]
Connecting devices - adding wires[14]
Menu commands[37]
Device and drawing toolkits[51]

Moving an Object

To move most devices or objects

1. Using the mouse, choose the pointer icon  on the toolbar[37] or the analog device toolkit.[52]
2. Move the mouse onto the diagram over the device or object to be moved.
3. Press the left mouse button and drag the device to the new location.
4. Release the mouse button.

Devices and objects are centered on the current drawing grid. The size and visibility of the drawing grid are controlled using the Tool|Drawing Grid command[48] and the Edit Drawing Grid dialog box.[65]

To move multiple devices or objects

5. Use the mouse to select the devices or objects to be moved. See selecting objects[18] for additional information.
6. Move the mouse onto the diagram over one of the selected devices or objects to be moved.
7. Press and hold the left mouse button down. A rectangle will be displayed enclosing the selected devices and objects.
8. Holding the left mouse button down, drag the enclosing rectangle to the desired location.
9. Release the mouse button.

To move objects with keyboard cursor keys

10. Use the mouse to select the devices or objects to be moved. See selecting objects[18] for additional information.
11. Press one of the four keyboard cursor keys, left arrow, right arrow, up arrow, or down arrow. The selected objects will be moved by one x or y grid increment in the desired direction. The size and visibility of the drawing grid are controlled using the Tool|Drawing Grid command[48] and the Edit Drawing Grid dialog box.[65]

Alternatively, if the Ctrl key is held down at the same time as the cursor key is pressed, the selected objects will be moved by one pixel in the desired direction.

To move an entire line object

On line objects, the normal pointer operation is to add vertices.[95] See adding,[12] moving[16] and deleting a vertex.[15] To move an entire line object, hold the Shift key and perform the operations listed above. See moving entire line objects.[18]

Related topics:

- Edit | Undo[45] - Redo[45]
- Selecting objects[18]
- Modifying device values or other object attributes[16]
- Rotating devices or objects[18]
- Creating and editing diagrams[11]
- Menu commands[37]
- Device and drawing toolkits[51]

Moving a Line Object

To move an entire line object

1. Using the mouse, choose the pointer icon  on the toolbar[37] or the analog device toolkit.[52]
2. Move the mouse onto the diagram over the line object to be moved.
3. Hold the Shift button down.
4. Press the left mouse button and drag the line to the new location.
5. Release the mouse button.

Related topics:

- Adding[12] - moving[16] - deleting a line vertex[15]
- Edit | Undo[45] - Redo[45]
- Selecting objects[18]
- Modifying device values or other object attributes[16]
- Moving devices or objects[17]
- Rotating devices or objects[18]
- Creating and editing diagrams[11]
- Menu commands[37]
- Device and drawing toolkits[51]

Opening an Existing Diagram

Use 

on the toolbar[37] or menu command File | Open[39] to invoke the Select File dialog box.[72] On successful completion of the dialog box, a new diagram window will be opened with an existing circuit shop file.[75]

Related topics:

- Creating and editing diagrams[11]
- Menu commands[37]
- Device and drawing toolkits[51]
- Dialog boxes[62]

Rotating a Device

To rotate a device:

1. Using the mouse, choose the pointer icon  on the toolbar[37] or the analog device toolkit.[52]
2. Move the mouse onto the diagram over a device terminal.
3. Press the left mouse button and drag the device terminal to the new location.
4. Release the mouse button.

Related topics:

Edit | Undo[45] - Redo[45]
Creating and editing diagrams[11]
Menu Commands[37]
Toolbar commands[37]
Device and drawing toolkits[51]

Selecting Objects

To select an object

1. Using the mouse, choose the pointer icon  on the toolbar[37] or the analog device toolkit.[52]
2. Move the mouse onto the diagram over the device or object to be selected.

3. Click the left mouse button to select the object. The smallest object under the pointer will be selected and will be redrawn in its selected form. For example, devices will highlight their node locations. Any objects that were previously selected will be unselected.

To select multiple objects

4. Follow steps (1) and (2) above.
5. Hold down the Shift button and click the left mouse button to select the object. The selected object will be redrawn in its selected form. Any objects that were previously selected will remain selected.

   Note, the select operation can be reversed, holding the Shift button down and clicking the left mouse button on a selected object will unselect the object.

To select multiple objects with a selection area

6. Follow step (1) above.
7. Move the mouse onto the diagram slightly left and slightly above the objects to be selected.
8. Hold the left mouse button down and drag the mouse to create a selection area rectangle which completely covers the objects to be selected.
9. Release the mouse button. The selected objects will be redrawn in their selected form.

   Note, normally the selection area operation will unselect objects outside of the selection area. To maintain existing selections, hold the Shift button down while performing steps (7), (8) and (9).

To select all objects

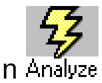
10. Use Edit | Select All[45] menu command or the keyboard sequence Ctrl+A to select all objects. All objects will be redrawn in their selected form.

To unselect all objects

11. Follow step (1) above.
12. Move the mouse onto the diagram over an area with no objects.
13. Click the left mouse button. All previously selected objects will be redrawn in their normal form.

Related topics:
Edit | Select All command[45]
Edit | Cut command[44]
Edit | Copy command[43]
Edit | Append command[43]
Edit | Delete command[44]
Creating and editing diagrams[11]
Menu commands[37]
Toolbar commands[37]
Device and drawing toolkits[51]

Analysing a Circuit

Once a circuit has been constructed, use Tool | Analyse[46] menu command or toolbar[37] icon 

to analyse the circuit.

Depending on the objects in the circuit, this command will invoke one of Circuit Shop's analysis functions:

- DC analysis[22]
- Sinusoidal steady state analysis[25]
- Frequency response[27]
- Digital analysis[32]

As a side effect of the analysis:

- device meters[29] are updated. See DC analysis[22] and sinusoidal steady state analysis.[25]
- circuit analyzers[30] are evaluated and generate frequency response[27] graphs.
- digital sources[33] and logic gates[34] and flip-flops[34] are evaluated, and digital displays[36] are updated. See digital analysis.[32]

Related topics:
Circuit analysis help topics[22]
Creating and editing diagrams[11]
Viewing circuit voltage and current values[20]
Circuit analysis help topics[22]
Menu commands[37]
Toolbar commands[37]
Device and drawing toolkits[51]

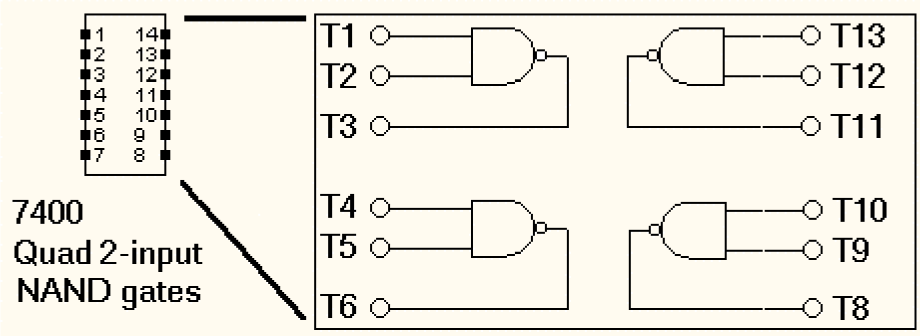
Viewing Circuit Voltage and Current Values

Circuit Shop provides the following meter types to view circuit voltage and current values.

- Device meter[29] provides information on how to add a meter to a diagram and link it to a device. A device meter can measure a device's voltage,[95] current,[84] impedance[88] and power.[91]

Related topics:
Analysing a circuit[19]
Tool | Analyse command[46]
Creating and editing diagrams[11]

Creating Circuits Inside Integrated Circuits



Circuit Shop allows you to create unlimited analog[81] and digital[84] circuits inside integrated circuit (IC)[89] devices. The circuits inside ICs can also include imbedded ICs, i.e. ICs inside ICs and thus very complex circuits can be created. This capability is sometimes called circuit macros in other programs.

ICs can be used in the following analysis functions.

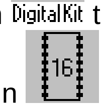
- DC analysis[22] - supported devices[23]
- Sinusoidal steady state analysis[25] - supported devices[26]
- Frequency response[27] - supported devices[26]
- Digital analysis[32] - supported devices[32]

Note, devices inside the IC must be consistent with the analysis type. Devices that are not supported by the analysis type will not be used by the analysis function.

ICs can be created to hold industry standard circuits such as the digital logic 7400 series or "common" circuit components that you use in your application. The ICs can be stored in Circuit Shop .CS1 files[75] which allows you to create user specific IC libraries. You can use Circuit Shop's Edit | Cut,[44] Copy[43] and Paste[44] commands to copy ICs within a diagram, and from one diagram (e.g. from a user specific IC library) to another diagram.

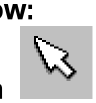
To add an integrated circuit to a diagram:

1. Ensure the digital device toolkit[51] is visible. If the toolkit is not visible, use the View | Digital Device Toolkit[49] menu command or the toolbar[37] icon  to display it.

2. Using the mouse, click the integrated circuit (IC)[89] icon  on the digital device toolkit.[51]

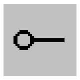
3. Move the mouse onto the diagram where the IC is to be placed.
4. Click the mouse to place the IC on the diagram. Adding devices[12] provides additional details.

To open the integrated circuit's internal circuit window:

1. Using the mouse, choose the pointer icon  on the toolbar[37] or the analog device toolkit.[52]
2. Move the mouse onto the diagram over the integrated circuit (IC).[89]
3. Double click the left mouse button over the IC to open the Edit IC dialog box.[66] This dialog box is where the device id, name, part number, number of side and top/bottom pins, and pin visibility are defined. This is also where the command to open the IC's internal circuit is located.

4. Press the View circuit button in the Edit IC dialog box[66] to open the IC's internal circuit diagram window. Normal Circuit Shop commands and graphical operations can be used to construct the IC's internal circuit in this diagram. The IC's internal circuit will be automatically saved when the surrounding circuit is saved.

To connect the IC's internal circuit to the outside world:

1.  Terminals[93] are used to associate the IC pins to input/output points of the IC's internal circuit. For example, in the above diagram, pin 3 of the 7400 IC is associated with terminal T3 of the internal circuit. Terminal T3 is the output of one of the IC's NAND gates.[82] (Terminals can be found in the terminal and plug toolkit).[57]
2. Select the Show pins and Show pin numbers check boxes in the Edit IC dialog box[66] to help connect wires to the correct IC pin in the parent circuit.

Related topics:

Creating and editing diagrams[11]
Connecting devices - adding wires[14]
Menu commands[37]
Device and drawing toolkits[51]

Circuit Analysis Help Topics

Circuit Shop contains the following circuit analysis capabilities:

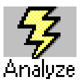
- DC analysis[22] (supported devices)[23]
- Sinusoidal steady state analysis[25] (supported devices)[26]
- Frequency response[27] (supported devices)[26]
- Digital analysis[32] (supported devices)[32]

Device meters[29]

DC analysis and sinusoidal steady state analysis capabilities use device meters.[29] A device meter's measured/displayed voltage[95] and current[84] values are set when a circuit is analysed.[46]

Circuit analyzers[30]

Frequency response capability uses circuit analyzers.[30] A frequency response plot is generated when a circuit is analysed.[46]

Use 

on the toolbar[37] or menu command Tool | Analyse[46] to analyse a circuit.

Related topics:

Creating and editing diagrams[11]
Topic tree[3]
Tutorial topic tree[203]

DC Analysis

DC or direct current[86] analysis allows you to determine circuit voltages[95] and currents[84] in circuits composed of

- resistors[92]
- batteries[82]
- diodes[85]
- integrated circuits[89] or ICs composed of the above devices

See supported devices[23] for a full list of devices supported by Circuit Shop's DC analysis capability.

Diode analysis

Diode model[85] describes how diodes are modelled by Circuit Shop's DC Analysis function. Circuit Shop uses an iterative analysis approach when diodes are part of a circuit. It first assumes a forward bias state for all diodes. The circuit is analyzed and voltages across the diodes are compared to the model state voltage requirements. If the voltage is not consistent with the model state, a new state is selected and the circuit is re-analyzed. This process is continued until no state changes occur or the maximum number of iterations is reached. Note: depending on the configuration, some diode circuits may not converge to a solution. After a solution is found, one of the following bias state characters is displayed beside the diode.

F - Forward bias (on).
R - Reverse bias (off).
B - Breakdown bias.

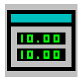
Steps to perform DC analysis

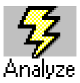
1. Open a diagram window, add circuit devices, orient and connect as desired. See

Creating a new diagram window[15]

View | Analog Device Toolkit[49]
Adding[12] - moving[17] - rotating devices[18]
Connecting devices[14]

2. Using the Edit Device dialog box,[64] set circuit device values. To open the dialog box, move the mouse onto the diagram over the device or object to be modified and double click the left mouse button. See also modifying device values.[16]

3. Add one or more  device meters.[29] Using the Edit Meter dialog box[68] select the meter type, display format and link to the desired circuit devices. To open the dialog box, move the mouse onto the diagram over the device meter to be modified and double click the left mouse button.

4. Use 

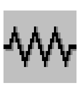
on the toolbar[37] or menu command Tool | Analyse[46] to analyse the circuit. As a side effect, device meters are updated. See also analysing a circuit.[19]

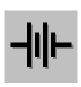
A detailed circuit construction example for a simple circuit can be found in Ohm's law demonstration circuit construction.[209]

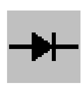
Related topics:
Circuit analysis help topics[22]
Sinusoidal steady state analysis[25]
Creating and editing diagrams[11]
Topic tree[3]
Tutorial topic tree[203]

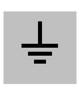
DC Analysis Supported Devices

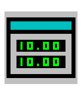
Circuit Shop supports direct current[86] (DC) circuit analysis with the following devices.

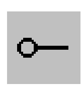
 *1 resistor[92]

 *1 battery[82]

 *2 diode[85]

 *1 *3 ground[87]

 *1 device meter[29]

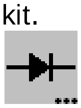
 *4 terminal[93]

***1** These devices can be found on the Analog device toolkit.[52]

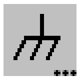
Use 

on the toolbar[37] or menu command View | Analog device toolkit[49] to display or dismiss this toolkit.

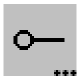
***2** Diodes[85] can be found on the diode toolkit[56] which is a sub-toolkit of the analog device toolkit.

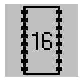
Use  on the analog device toolkit to open the diode toolkit.

***3** Earth[87] and chassis ground[87] can also be found on the ground toolkit[56] which is a sub-toolkit of the analog device toolkit.

Use  on the analog device toolkit to open the ground toolkit.

***4** Terminals[93] can be found on the terminal & plug toolkit[57] which is a sub-toolkit of the analog device toolkit.

Use  on the analog device toolkit to open the terminal toolkit.

DC analysis also supports  integrated circuits[89] or ICs containing circuits composed of the above device types and can include imbedded ICs, i.e. ICs inside ICs. ICs with devices not shown above, will not be used by the DC analysis[22] function. ICs can be found on the digital device toolkit.[51] See creating circuits inside integrated circuits.[20]

Related topics:

- DC analysis[22]
- Circuit analysis help topics[22]
- Creating and editing diagrams[11]
- Topic tree[3]
- Tutorial topic tree[203]

Sinusoidal Steady State Analysis

Sinusoidal steady state analysis allows you to determine alternating current (AC)[81] voltages[95] and currents[84] in circuits composed of

- resistors[92]
- inductors[89]
- capacitors[82]
- transformers[94]
- AC voltage sources[81]
- AC current sources[81]
- dependent voltage and current sources[84]
- ideal operational amplifiers[88]
- integrated circuits[89] or ICs composed of the above devices

See supported devices[26] for a full list of devices supported by Circuit Shop's sinusoidal steady state analysis capability.

Steps to perform sinusoidal steady state analysis

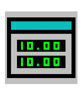
1. Open a diagram window, add circuit devices (see chart below for supported devices), orient and connect as desired. See

   Creating a new diagram window[15]
   View | Analog Device Toolkit[49]
   Adding[12] - moving[17] - rotating devices[18]
   Connecting devices[14]

2. Using the Edit Device dialog box,[64] set values for resistors,[92] capacitors[82] and inductors.[89] To open the dialog box, move the mouse onto the diagram over the device or object to be modified and double click the left mouse button. See also modifying device values.[16]

3. Using the Edit Source dialog box,[69] set magnitude, phase and frequency values for AC voltage[81] and AC current sources.[81] To open the dialog box, move the mouse onto the diagram over the source to be modified and double click the left mouse button. See also modifying device values.[16]

   Note: The circuit frequency[87] should only be set on one source per circuit.

4. Add one or more  device meters.[29] Using the Edit Meter dialog box[68] select the meter type, display format and link to the desired circuit devices. To open the dialog box, move the mouse onto the diagram over the device meter to be modified and double click the left mouse button. See also modifying device values.[16]

5. Use 

 on the toolbar[37] or menu command Tool | Analyse[46] to analyse the circuit. As a side effect, device meters are updated. See also analysing a circuit.[19]

A detailed circuit construction example for a simple circuit can be found in Ohm's law demonstration circuit construction.[209]

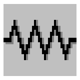
Related topics:

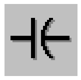
Circuit analysis help topics[22]
DC analysis[22]
Frequency response[27]

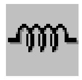
Creating and editing diagrams[11]
Topic tree[3]
Tutorial topic tree[203]

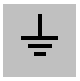
Sinusoidal Steady State Analysis Supported Devices

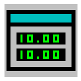
Circuit Shop supports sinusoidal steady state circuit analysis with the following devices

 *1
resistor[92]

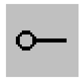
 *1
capacitor[82]

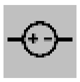
 *1
inductor[89]

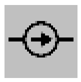
 *1 *3
ground[87]

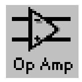


*1
device meter[29]

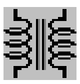
 *4
terminal[93]

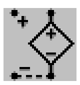
 *2
AC voltage[81] source[81]

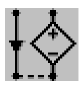
 *2
AC current[81] source[81]

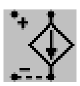


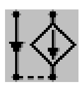
*5
ideal op amp[88]

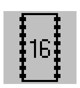
 *6
transformer[94]

 *2
voltage-controlled[95] voltage source[95]

 *2
current-controlled[83] voltage source[83]

 *2
voltage-controlled[95] current source[95]

 *2
current-controlled[83] current source[83]



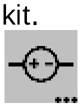
*7
integrated circuit[89]

***1** These devices can be found on the analog device toolkit.[52]

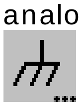
Use 

on the toolbar[37] or menu command View | Analog device toolkit[49] to display or dismiss this toolkit.

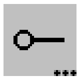
***2** These devices can be found on the source toolkit[58] which is a sub-toolkit of the analog device toolkit.

Use  on the analog device toolkit to open the source toolkit.

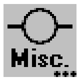
***3** Earth[87] and chassis ground[87] can also be found on the ground toolkit[56] which is a sub-toolkit of the analog device toolkit.

Use  on the analog device toolkit to open the ground toolkit.

***4** Terminals[93] can be found on the terminal & plug toolkit[57] which is a sub-toolkit of the analog device toolkit.

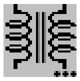
Use  on the analog device toolkit to open the terminal toolkit.

***5** Ideal operational amplifiers[88] can be found on the miscellaneous device toolkit[61] which is a sub-toolkit of the analog device toolkit.

Use 

on the analog device toolkit to open the miscellaneous device toolkit.

***6** Transformers[94] can be found on the inductor toolkit[60] which is a sub-toolkit of the analog device toolkit.

Use  on the analog device toolkit to open the inductor toolkit.

***7** Integrated circuits[89] or ICs can be found on the digital device toolkit.[51] The sinusoidal steady state analysis[25] function supports ICs composed of any of the above devices and can include imbedded ICs, i.e. ICs inside ICs. ICs with devices not shown above, will not be used by the analysis function. See creating circuits inside integrated circuits.[20]

Related topics:

Sinusoidal steady state analysis[25]
Frequency response[27]
Circuit analysis help topics[22]
Creating and editing diagrams[11]
Topic tree[3]
Tutorial topic tree[203]

Frequency Response

Circuit Shop's frequency response capability allows you to graphically plot an alternating current (AC)[81] circuit's voltage[95] magnitude and phase[91] at arbitrary locations in a circuit. Circuit Shop can generate the following plot types:

- magnitude (volts) vs frequency
- phase (degrees) vs frequency
- magnitude (dB) vs frequency
- group delay (seconds) vs frequency

Plots can be in the following forms:

- linear vs linear
- linear vs logarithmic
- logarithmic vs linear
- logarithmic vs logarithmic

Also, each axis can be independently scaled either manually or automatically. A full description of Circuit Shop's frequency response capability can be found in Edit Analyzer dialog box.[62]

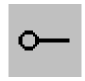
See supported devices[26] for a full list of devices supported by Circuit Shop's frequency response capability.

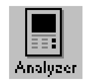
A detailed circuit construction example for a simple resistor-inductor-capacitor (RLC) circuit can be found in detailed instructions.[266] This circuit uses Circuit Shop's frequency response capability to demonstrate an RLC circuit's resonant frequency.[92]

Steps to generate a frequency response graph

1. Create a circuit. Open a diagram window, add circuit devices (see chart below for supported devices), orient and connect as desired. See

   Creating a new diagram window[15]
   View | Analog Device Toolkit[49]
   Adding[12] - moving[17] - rotating devices[18]
   Connecting devices[14]

   While drawing the circuit, be sure to add one or more  terminals[93] where the frequency response is to be measured.

   Also, while drawing the circuit, be sure to add one or more 

   circuit analyzers[30] to control the generation of frequency response graphs.

2. Using the Edit Device dialog box,[64] set values for resistors,[92] capacitors,[82] inductors,[89] terminals,[93] and other circuit devices. To open the dialog box, move the mouse onto the diagram over the device or object to be modified and double click the left mouse button. See also modifying device values.[16]

   Note: To allow circuit analyzers[30] to link to the correct circuit location, ensure the terminal(s)[93] have defined device ids.

3. Using the Edit Source dialog box,[69] set magnitude, phase and frequency values for AC voltage[81] and AC current sources.[81] To open the dialog box, move the mouse onto the diagram over the source to be modified and double click the left mouse button. See also modifying device values.[16]

4. Using the Edit Analyzer dialog box,[62] set:

   - the analyzer name
   - analyzer type, i.e. frequency response
   - terminal id, i.e. the frequency response measurement point
   - frequency minimum, maximum and calculation points per decade
   - output plot type, e.g. Magnitude (Volts) or Phase (Degrees)

   To open the dialog box, move the mouse onto the diagram over the analyzer object to be modified and double click the left mouse button. See also modifying device values.[16]

   Notes:
   1) The terminal id specified in the circuit analyzer[30] must be the same as the terminal[93] device id specified in step (2) above.
   2) The greater the number of calculation points per decade, the smoother the output graph and the longer the analysis will take.
   3) If multiple plot types, e.g. both Magnitude (Volts) and Phase (Degrees) are desired, place 2 circuit analyzer[30] objects on the diagram and specify Plot type: Magnitude (Volts) on one and Plot type: Phase (Degrees) on the other.
   4) Non-registered users can only generate frequency response graphs with Plot type: Magnitude (Volts). See purchasing information.[7]

5. Use 

on the toolbar[37] or menu command Tool | Analyse[46] to analyse the circuit. After the analysis is complete, a frequency response graph will be displayed. See also analysing a circuit.[19]

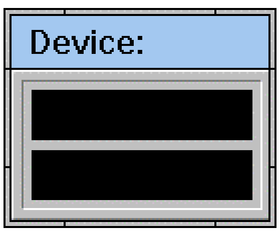
To print a frequency response

1. After the frequency response graph has been generated, ensure the graph window is in focus, i.e. it is the active window. To make it the active window, single click the mouse somewhere over the graph window.

2. Use menu command[37] File | Print[40] or File | Print preview[41] to print or preview respectively, the frequency response.

Related topics:

Circuit analysis help topics[22]
Sinusoidal steady state analysis[25]
DC analysis[22]
Creating and editing diagrams[11]
Topic tree[3]
Tutorial topic tree[203]



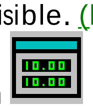
Device Meter

Device meters support DC analysis[22] and sinusoidal steady state analysis.[25] A device meter can be used to view resistor,[92] capacitor[82] and inductor[89] voltage,[95] current,[84] and impedance[88] and power.[91]

Device meters can also measure terminal[93] and terminal[93]-to-terminal[93] voltage.[95]

Various display formats are supported, including magnitude and phase in degrees or radians, and real and imaginary phasor. A full description of the measurement capabilities and supported display formats can be found in Edit Meter dialog box.[68]

To add a device meter to the diagram

1. Ensure the analog device toolkit[52] is visible. (hint1)[76]
2. Using the mouse, click the meter icon 

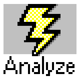
on the toolkit.
3. Move the mouse onto the diagram to where the meter is to be placed.
4. Click the mouse to place the meter on the diagram. Adding objects[12] provides additional details.

To link the meter to a device

1. Using the mouse, click the pointer icon  on the toolbar[37] or the analog device toolkit.[52]
2. Move the mouse onto the diagram over the meter.
3. Double click the mouse on the meter to open the Edit Meter dialog box.[68] Additional details on changing device values can be found in modifying object values.[16]
4. To link the meter to a device, select the device type and enter the device's id.

To set device meter values

A device meter's measured voltage[95] and current[84] values are set when a circuit is analysed.[46]

Use 

on the toolbar[37] or menu command Tool | Analyse[46] to analyse the circuit.

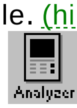
Related topics:

- Analysing a circuit[19]
- Circuit analysis help topics[22]
- DC analysis[22]
- Sinusoidal steady state analysis[25]
- Frequency response[27]
- Viewing circuit voltage and current values[20]
- Creating and editing diagrams[11]
- Tool | Analyse command[46]

Circuit Analyzer

Circuit analyzers support the generation of frequency response[27] graphs. A description of a circuit analyzer's capabilities and supported output graph types can be found in Edit Analyzer dialog box.[62]

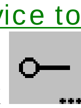
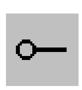
To add a circuit analyzer to the diagram

1. Ensure the analog device toolkit[52] is visible. (hint1)[76]
2. Using the mouse, click the analyzer icon 

on the toolkit.
3. Move the mouse onto the diagram to where the analyzer is to be placed.
4. Click the mouse to place the analyzer on the diagram. Adding objects[12] provides additional details.

To add a terminal to the circuit

Analyzers measure circuits at terminals.[93] Before a frequency response (or other analysis) graph can be generated, one or more terminals must be added to the circuit.

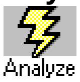
1. Ensure the analog device toolkit[52] is visible. (hint1)[76]
2. Using the mouse, click  on the analog device toolkit to display the terminal & plug sub-toolkit.[57]
3. Using the mouse, click  on the sub-toolkit to select a terminal object.
4. Move the mouse onto the diagram to where the terminal is to be placed.
5. Click the mouse to place the terminal on the diagram. Adding objects[12] provides additional details.
6. Connect the terminal to a desired point in the circuit. See moving devices or objects[17] and connecting devices - adding wires[14] for additional details.

To link the analyzer to a terminal

1. Using the mouse, click the pointer icon  on the toolbar[37] or the analog device toolkit.[52]
2. Move the mouse onto the diagram over the analyzer.
3. Double click the mouse on the analyzer to open the Edit Analyzer dialog box.[62]

4. To link the analyzer to a terminal, enter the terminal's id.
5. While the dialog box is open, you may set other analyzer values or use Circuit Shop's defaults.

To analyze the circuit

Use 

on the toolbar[37] or menu command Tool | Analyse[46] to analyse the circuit. For example, if selected in the edit analyzer dialog box,[62] a frequency response[27] graph is generated when a circuit is analysed.

Related topics:

- Analysing a circuit[19]
- Circuit analysis help topics[22]
  - DC analysis[22]
  - Sinusoidal steady state analysis[25]
  - Frequency response[27]
  - Digital analysis[32]
- Viewing circuit voltage and current values[20]
- Creating and editing diagrams[11]
- Tool | Analyse command[46]

Digital Analysis

Digital analysis allows you to analyse digital circuits[84] composed of:

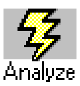
- Digital sources[33]
  (logic level 0,[85] logic level 1[85] and switch)[85]
- Logic gates[34]
  (AND,[82] OR,[91] NOT,[90] EXCLUSIVE-OR,[86] NAND,[82] NOR[91] and EXCLUSIVE-NOR)[86]
- Flip-flops[34]
- Digital displays[36]
  (lamp,[84] seven segment)[85]
- Integrated circuits[89] or ICs composed of the above devices

See supported devices[32] for a full list of devices supported by Circuit Shop's digital analysis capability.

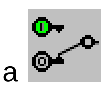
Steps to perform digital analysis

1. Open a diagram window, add circuit devices, orient and connect as desired. See
   Creating a new diagram window[15]
   View | Digital Device Toolkit[49]
   Adding[12] - moving[17] - rotating devices[18]
   Connecting devices[14]

   Note, you must include at least one digital source[33] in the circuit diagram to make Circuit Shop execute its digital analysis function when the Analyse command[46] is invoked.

2. Use 

on the toolbar[37] or menu command Tool | Analyse[46] to analyse the circuit. During the analysis, digital sources[33] and logic gates[34] and flip-flops[34] are evaluated, and digital displays[36] are updated. Also, wires[95] that are HIGH or logic level 1 are highlighted.

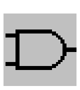
   The digital analysis function is also directly invoked by a single mouse click on a  digital source switch.[85]

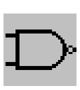
A detailed circuit construction example for a simple circuit can be found in Logic gate demonstration circuit construction.[288]

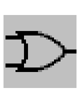
Related topics:
   Creating circuits inside integrated circuits[20]
   Circuit analysis help topics[22]
   Creating and editing diagrams[11]
   Topic tree[3]
   Tutorial topic tree[203]

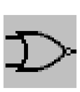
Digital Analysis Supported Devices

Circuit Shop supports digital analysis[32] with the following devices

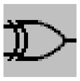
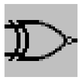

AND gate[82]


NAND gate[82]

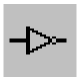
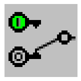




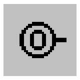
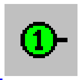
OR gate[91] NOR gate[91]

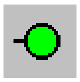
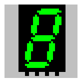
EXCLUSIVE-OR gate[86] EXCLUSIVE-NOR gate[86]

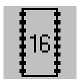
NOT gate[90] Digital source switch[85]

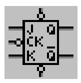
 

Level 0 source[85] Level 1 source[85]

Digital display lamp[84] Seven segment display[85]





Integrated circuit[89] Flip-flop[34]

These devices can be found on the digital device toolkit.[51]

Use  DigitalKit on the toolbar[37] or menu command View | Digital device toolkit[49] to display or dismiss this toolkit.

The digital analysis[32] function supports integrated circuits[89] or ICs composed of any of the above devices and can include imbedded ICs, i.e. ICs inside ICs. ICs with devices not shown above, will not be used by the analysis function. See creating circuits inside integrated circuits.[20]

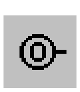
Related topics:

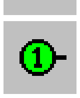
- Digital sources[33]
- Logic gates[34]
- Flip-flops[34]
- Digital displays[36]
- Circuit analysis help topics[22]
- Creating and editing diagrams[11]
- Topic tree[3]
- Tutorial topic tree[203]

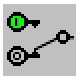
Digital Source (toolkit)[51]

Digital sources supply LOW or HIGH signals (logic level 0 or 1 respectively) to digital circuits.[84]

Circuit Shop supports digital analysis[32] with the following digital sources

 Level 0 source[85]

 Level 1 source[85]

 Digital source switch[85]

These devices can be found on the digital device toolkit.[51]

Use 

on the toolbar[37] or menu command View | Digital device toolkit[49] to display or dismiss this toolkit.

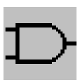
Related topics:

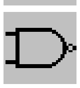
- Circuit analysis help topics[22]
- Creating and editing diagrams[11]
- Topic tree[3]
- Tutorial topic tree[203]

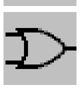
Logic Gate (toolkit)[51] (dialog box)[67]

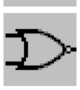
Logic gates evaluate LOW and HIGH input signals (logic level 0 or 1 respectively) to produce a LOW or HIGH output signal in digital circuits.[84]

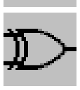
Circuit Shop supports digital analysis[32] with the following logic gates

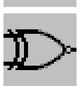
 AND gate[82]

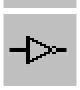
 NAND gate[82]

 OR gate[91]

 NOR gate[91]

 EXCLUSIVE-OR gate[86]

 EXCLUSIVE-NOR gate[86]

 NOT gate[90]

These devices can be found on the digital device toolkit.[51]

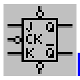
Use 

on the toolbar[37] or menu command View | Digital device toolkit[49] to display or dismiss this toolkit.

The number of inputs on a logic gate[34] can be changed using the Edit Logic Gate dialog box.[67] (hint5)[76] To open the dialog box, move the mouse onto the diagram over the device to be modified and double click the left mouse button. See also modifying device values.[16]

Related topics:

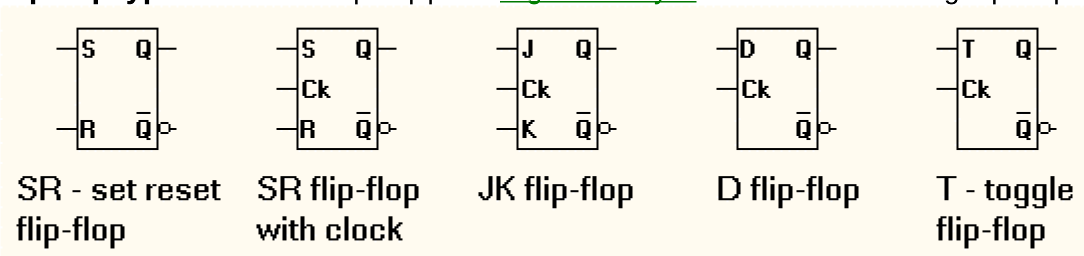
- Circuit analysis help topics[22]
- Creating and editing diagrams[11]
- Topic tree[3]
- Tutorial topic tree[203]



Flip-Flop (toolkit)[51] (dialog box)[65]

Flip-flops provide memory elements in digital circuits.[84] Using their stored state, flip-flops evaluate LOW and HIGH input signals (logic level 0 or 1 respectively) to produce a LOW or HIGH output signal Q and a complimented (i.e. opposite) output signal ~Q.

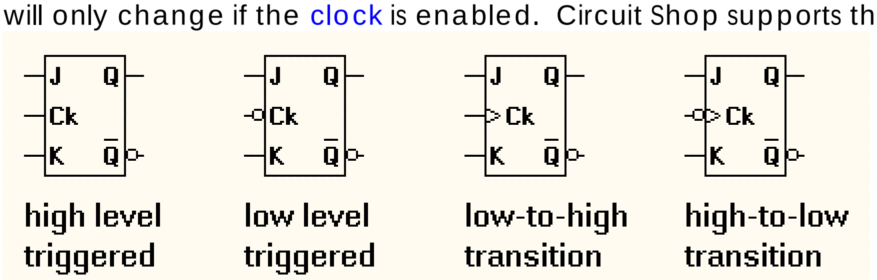
Flip-flop types Circuit Shop supports digital analysis[32] with the following flip-flop types:



The truth table[94] for each flip-flop type is shown below.

```
SR          SR w Clock     JK w Clock      D w Clock    T w Clock
S R | Q     S R | Q-new    J K | Q-new     D | Q-new    T | Q-new
=======     ============   ============    ==========   ==========
0 0 | ?     0 0 | Q-prev   0 0 | Q-prev    0 | 0        0 | Q-prev
0 1 | 0     0 1 | 0        0 1 | 0         1 | 1        1 | ~Q-prev
1 0 | 1     1 0 | 1        1 0 | 1
1 1 | ?     1 1 | ?        1 1 | ~Q-prev
```

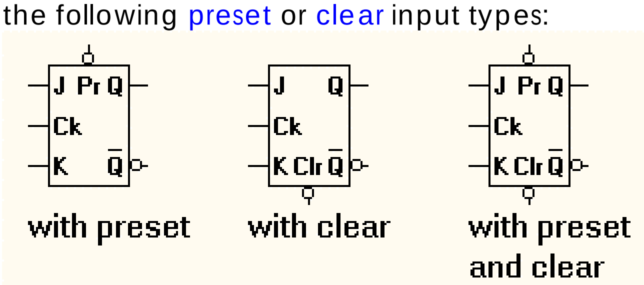
Clock input Flip-flops are enabled with clock inputs. I.e. if a flip-flop has a clock input, the output Q will only change if the clock is enabled. Circuit Shop supports the following clock types:



Preset and clear inputs Flip-flops can be initialized to HIGH or LOW output values by using preset or clear inputs respectively.

- If a flip-flop has a preset input and it is enabled, the output Q will be set to HIGH.
- If a flip-flop has a clear input and is enabled, the output Q will be set to LOW.

Preset and clear inputs are enabled when they are set to LOW. Flip-flops can be configured with the following preset or clear input types:



Flip-flops can be found on the digital device toolkit.[51]

Use 

on the toolbar[37] or menu command View | Digital device toolkit[49] to display or dismiss this toolkit.

The flip-flop type, outputs, clock type, preset and clear attributes can be changed using the Edit Flip-flop dialog box.[65] (hint6)[77] To open the dialog box, move the mouse onto the diagram over the device to be modified and double click the left mouse button. See also modifying device values.[16]

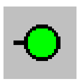
Related topics:

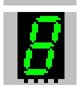
- Circuit analysis help topics[22]
- Creating and editing diagrams[11]
- Topic tree[3]
- Tutorial topic tree[203]

Digital Display (toolkit)[51]

Digital displays convert input LOW and HIGH signals (logic levels 0 and 1 respectively) into visual representations in digital circuits.[84]

Circuit Shop supports digital analysis[32] with the following digital displays

 Digital display lamp[84]

 Seven segment display[85]

These devices can be found on the digital device toolkit.[51]

Use 

on the toolbar[37] or menu command View | Digital device toolkit[49] to display or dismiss this toolkit.

Related topics:

- Circuit analysis help topics[22]
- Creating and editing diagrams[11]
- Topic tree[3]
- Tutorial topic tree[203]

Menu Commands

The menu bar at the top of the Circuit Shop main window provides access to the menus. To go to the menu bar, press F10 or click anywhere on it. You can choose any of the following commands on the menu bar:

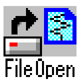
File commands[39]
Edit commands[43]
View commands[49]
Tool commands[46]
Help commands[49]

Related topics:
Toolbar commands[37]

Toolbar Commands

The toolbar at the top of the Circuit Shop main window provides quick access to common menu commands. It also provides pointer, wire[95] and connector[83] tools. To execute a toolbar command, click the mouse on the desired icon. You can choose any of the following commands on the toolbar:

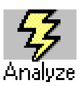
File | New command[39]



File | Open command[39]

File | Save command[39]

File | Save as command[40]

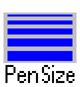


Tool | Analyse command[46]

View | Digital device toolkit command[49]

View | Analog device toolkit command[49]

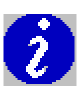
View | Paint toolkit command[49]



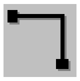
Tool | Pen Size command[47]

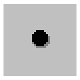
Tool | Pen foreground color command[47]

Tool | Font command[47]


Help | Contents command[2]

 pointer tool - allows device selection

 wire tool[95] - connects devices

 connector tool[83] - provides a connection point for wires

Related topics:

Menu commands[37]

File menu

The File menu provides commands for creating new circuit shop files,[75] opening existing files, saving files, printing files, creating BMP files, registering and exiting Circuit Shop.

New[39]
Open[39]
Save[39]
Save as[40]
Revert to saved[40]
Close[40]

Print[40]
Print preview[41]
Printer setup[41]

Output BMP file[41]

Register[41]

Exit[42]

File | New Command

This command opens a new circuit shop file[75] drawing window with the default name (Untitled). (Untitled) windows are used as temporary edit buffers. Circuit Shop prompts for a filename when the window is closed or saved.

The toolbar icon 

or the keyboard sequence Ctrl+N can also be used to execute this command.

Related topics:

File commands[39]
Menu commands[37]
Toolbar commands[37]

File | Open Command

This command displays the Select File dialog box.[72] In this dialog box, you select the existing circuit shop file[75] you want to open. When the file is successfully opened, a drawing window is opened.

The toolbar icon 

or the keyboard sequence Ctrl+O can also be used to execute this command.

Related topics:

File commands[39]
Menu commands[37]
Toolbar commands[37]

File | Save Command

This command saves a Circuit Shop file[75] to disk.

If the file has not been named, Circuit Shop opens the Select File dialog box.[72] This dialog box allows you to specify the filename and optionally save it in a different directory or different drive.

If an existing filename is used to name the file, Circuit Shop will ask if you want to overwrite the existing file.

The toolbar icon 

or the keyboard sequence Ctrl+S can also be used to execute this command.

Related topics:
- File commands[39]
- Menu commands[37]
- Toolbar commands[37]

File | Save As Command

This command opens the Select File dialog box.[72] This dialog box allows the active drawing window to be saved under a different name, different directory or different drive.

If an existing filename is used to name the file, Circuit Shop will ask if you want to overwrite the existing file.

The toolbar icon 

or the keyboard F12 key can also be used to execute this command.

Related topics:
- File commands[39]
- Menu commands[37]
- Toolbar commands[37]

File | Revert To Saved Command

This command deletes the current contents of the drawing window and reloads the window from the last saved Circuit Shop file.[75]

Any changes made since the last time the file was saved will be lost.

Related topics:
- File commands[39]
- Menu commands[37]

File | Close Command

This command deletes the current drawing window.

If the drawing window has been modified, Circuit Shop prompts to save the Circuit Shop file[75] before deleting the drawing window.

Related topics:
- File commands[39]
- Menu commands[37]

File | Print Command

This command displays the Print dialog box.[71] In this dialog box, you select the print quality, optionally output to a file, and set the number of copies.

The OK button on the dialog box will generate the printout.

The keyboard sequence Ctrl+P can also be used to execute this command.

Related topics:

- File | Print preview command[41]
- File | Printer setup command[41]
- File | Output BMP file[41]
- File commands[39]
- Menu commands[37]

File | Print Preview Command

This command opens a window with a rendition of what will be sent to the printer if the File | Print command[40] was invoked.

The preview window must be closed before further Circuit Shop commands can be invoked.

Related topics:

- File | Print command[40]
- File | Printer setup command[41]
- File commands[39]
- Menu commands[37]

File | Printer Setup Command

This command displays the Printer Setup dialog box.[71] In this dialog box, you select the default or specific printer, the orientation of portrait or landscape, and paper size and source.

The OK button on the dialog box will save the current settings to be used in subsequent print commands.

Related topics:

- File | Print command[40]
- File | Print preview command[41]
- File commands[39]
- Menu commands[37]

File | Output BMP File Command

This command opens the Select File dialog box.[72] This dialog box allows you to set or select the filename and directory location for the bitmap (BMP) file. On successful completion of the dialog, Circuit Shop draws the circuit in the currently active window into the selected bitmap file.

The bitmap file is automatically sized so that all of the circuit is displayed, i.e. even if the screen window only covers a portion of the circuit, all of the circuit will be drawn into the bitmap.

The bitmap file can be imported to other applications such as word processors or general graphics programs.

Related topics:

- File | Print command[40]
- File commands[39]
- Menu commands[37]

File | Register Command

This command displays the Registration dialog box.[72] In this dialog box, you enter the registered user's name and key.

The OK button on the dialog box will validate the entered name and key and if valid, the name and key will be saved so that subsequent Circuit Shop executions will be started as a registered copy.

Related topics:

Purchasing information[7]
File commands[39]
Menu commands[37]

File | Exit Command

This command exits Circuit Shop.

If you have modified a Circuit Shop file[75] without saving it, Circuit Shop prompts you to do so before exiting.

The keyboard sequence Alt+F4 can also be used to execute this command.

Related topics:

File commands[39]
Menu commands[37]

Edit menu

The Edit menu provides commands undo previous commands, redo undo operations, move objects to and from the cut/paste buffer, delete selected objects or clear the diagram window.

Undo[45]
Redo[45]

Cut[44]
Copy[43]
Paste[44]
Append[43]
Select all[45]

Delete[44]
Clear all[43]

Related topics:
Menu commands[37]

Edit|Append Command

This command copies selected objects[18] from the current diagram and adds them to the cut/paste buffer. Existing objects in the cut/paste buffer are not changed or deleted.

The Edit|Paste command[44] can be used to copy the objects from the cut/paste buffer to the current diagram.

Related topics:
Edit|Cut command[44]
Edit|Copy command[43]
Edit|Paste command[44]
Edit|Select All command[45]
Edit commands[43]
Menu commands[37]

Edit|Clear All Command

This command deletes all objects from the diagram.

The Edit|Undo command[45] can be used to restore the deleted objects.

Related topics:
Edit commands[43]
Menu commands[37]

Edit|Copy Command

This command copies selected objects[18] from the current diagram to the cut/paste buffer. Any existing objects in the cut/paste buffer are deleted.

The Edit|Paste command[44] can be used to copy the objects from the cut/paste buffer to the current diagram.

The keyboard sequence Ctrl+C can also be used to execute this command.

Related topics:

- Edit|Cut command[44]
- Edit|Paste command[44]
- Edit|Append command[43]
- Edit|Select All command[45]
- Edit commands[43]
- Menu commands[37]

Edit|Cut Command

This command removes selected objects[18] from the current diagram and moves them to the cut/paste buffer. Any existing objects in the cut/paste buffer are deleted.

The Edit|Paste command[44] can be used to copy the objects from the cut/paste buffer to the current diagram.

The Edit|Undo command[45] can be used to restore the deleted objects.

The keyboard sequence Ctrl+X can also be used to execute this command.

Related topics:

- Edit|Copy command[43]
- Edit|Paste command[44]
- Edit|Append command[43]
- Edit|Select All command[45]
- Edit commands[43]
- Menu commands[37]

Edit|Delete Command

This command removes selected objects[18] from the diagram.

The Edit|Undo command[45] can be used to restore the deleted objects.

The keyboard Del key can also be used to execute this command.

Related topics:

- Edit commands[43]
- Menu commands[37]

Edit|Paste Command

This command copies objects from the cut/paste buffer to the current diagram. The command can be repeated any number of times and can be used to transfer objects from one diagram to another.

The Edit|Undo command[45] can be used to remove the objects added to the diagram with the Edit|Paste command.

The keyboard sequence Ctrl+V can also be used to execute this command.

Related topics:

- Edit|Cut command[44]
- Edit|Copy command[43]

Edit | Append command[43]
Edit | Select All command[45]
Edit commands[43]
Menu commands[37]

Edit | Select All Command

This command selects all objects on the current diagram.

The keyboard sequence Ctrl+A can also be used to execute this command.

Related topics:

Selecting objects[18]
Edit | Cut command[44]
Edit | Copy command[43]
Edit | Append command[43]
Edit | Delete command[44]
Edit commands[43]
Menu commands[37]

Edit | Undo Command

This command restores the diagram in the current window to the way it was before the most recent object addition, deletion or change operation(s). The command can be repeated multiple times to reverse the last set of object operations.

After one or more "undo" operations, the Edit | Redo command[45] can be used to "redo" the operation(s).

The keyboard sequence Ctrl+Z can also be used to execute this command.

Related topics:

Edit commands[43]
Menu commands[37]

Edit | Redo Command

This command reverses the last Edit | Undo command(s).[45] It restores the diagram in the current window to the way it was before the most recent undo commands were executed, objects may be added, deleted or changed. The command can be repeated multiple times to reverse the last set of undo operations.

The keyboard sequence Ctrl+Y can also be used to execute this command.

Related topics:

Edit commands[43]
Menu commands[37]

Tool menu

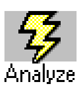
The Tool menu provides commands to analyse a circuit, and control drawing tools such as pen size, pen color, font, and drawing grid size and visibility.

Tool|Analyse Command

This command invokes Circuit Shop's circuit analysis[22] function.

The type of circuit analysis depends on the device types in the circuit.

- If the diagram contains any digital sources,[33] Circuit Shop interprets the diagram as a digital circuit[84] will invoke its digital analysis[32] function.
- Otherwise, Circuit Shop interprets the diagram as an analog circuit[81] and will invoke its DC analysis,[22] sinusoidal steady state analysis,[25] or frequency response[27] function.

The toolbar[37] icon 

can also be used to execute this command.

Digital circuits

As stated above, if the diagram contains any digital sources,[33] Circuit Shop interprets the diagram as a digital circuit[84] will invoke its digital analysis[32] function. I.e. Digital sources[33] and logic gates[34] and flip-flops[34] are evaluated, and digital displays[36] are updated. Also, wires[95] that are HIGH or logic level 1 are highlighted.

Analog circuits

On the first execution of this command or if the previous analysis window has been closed, an iconified analysis window is opened to report analysis results. On subsequent executions of this command the analysis window is updated.

Before the circuit is analyzed, Circuit Shop looks for disconnected objects, e.g. wires that are not correctly terminated or devices that are not connected to other parts of the circuit. If disconnected objects are found, a message box is displayed which asks if you would like to highlight the disconnected objects. The following options are available:

- Yes - Highlights the objects and completes the analysis.
- No - Completes the analysis (no objects are highlighted).
- Cancel - Aborts the analysis.

As part of the analysis, device meter[29] voltage and current values are updated and circuit analyzer[30] graphs are generated.

Related topics:

- Menu commands[37]
- Toolbar commands[37]
- Circuit analysis help topics[22]

Tool|Digital Analysis On Command

In this version of Circuit Shop, this command invokes Circuit Shop's Tool|Analyse command.[46]

Related topics:

- Digital analysis[32]
- Menu commands[37]
- Toolbar commands[37]
- Circuit analysis help topics[22]

Tool|Digital Analysis Off Command

In this version of Circuit Shop, this command removes any wire[95] highlighting that was done by the last Tool|Analyse command.[46]

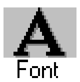
Related topics:

- Digital analysis[32]
- Menu commands[37]
- Toolbar commands[37]
- Circuit analysis help topics[22]

Tool|Font Command

This command opens the Select font dialog box[74] to set a new default font. New devices or objects placed on the drawing after selecting a new default font will be drawn with the new font.

If a device or object with text has been selected prior to executing this command, its font will also be changed.

The toolbar icon 

can also be used to execute this command.

Related topics:

- Menu commands[37]
- Toolbar commands[37]

Tool|Pen Size Command

This command opens a dialog box to set a new pen size. New devices and objects placed on the drawing will be drawn with the new size.

The toolbar icon 

can also be used to execute this command.

Related topics:

- Menu commands[37]
- Toolbar commands[37]

Tool|Pen Foreground Color Command

This command opens a dialog box to set a new foreground color. New devices and objects placed on the drawing will be drawn with the new color.

The toolbar icon 

can also be used to execute this command.

Related topics:

- Menu commands[37]
- Toolbar commands[37]

Tool|Pen Background Color Command

This command opens a dialog box to set a new background color. New objects such as filled rectangles placed on the drawing will be drawn with the new color.

Related topics:

- Menu commands[37]
- Toolbar commands[37]

Tool|Drawing Grid Command

This command opens the Edit Drawing Grid dialog box[65] which controls the size and visibility of the drawing grid. When added to a drawing, devices and objects are centered on drawing grid intersection points.

Related topics:

- Menu commands[37]
- Toolbar commands[37]
- Creating and editing diagrams[11]

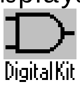
View Menu

The View menu provides commands display or dismiss a device or tool toolkit.[51]

Digital device toolkit[49]
Analog device toolkit[49]
Paint toolkit[49]

View | Digital Device Toolkit Command

This command displays or dismisses the digital device toolkit.[51]

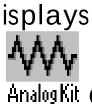
The toolbar icon 

can also be used to execute this command.

Related topics:
Menu commands[37]
Toolbar commands[37]
Device and drawing toolkits[51]

View | Analog Device Toolkit Command

This command displays or dismisses the analog device toolkit.[52]

The toolbar icon 

can also be used to execute this command.

Related topics:
Menu commands[37]
Toolbar commands[37]
Device and drawing toolkits[51]

View | Paint Toolkit Command

This command displays or dismisses the paint toolkit.[54]

The toolbar icon 

can also be used to execute this command.

Related topics:
Menu commands[37]
Toolbar commands[37]
Device and drawing toolkits[51]

Help menu

The Help menu provides commands to obtain information on how to use Circuit Shop.

Contents[2]
- Displays Circuit Shop help contents.

Search For Help On[Error! Bookmark not defined.]
- Displays the help search dialog box.

How to Use Help
- Displays the standard How To Use Help information.

About Circuit Shop
- Displays the About Circuit Shop dialog box.

Purchasing information[7]
- Displays purchasing information.

Device and Drawing Toolkits

Circuit Shop provides the following device and drawing toolkits:

Digital Device Toolkit

The digital device toolkit[51] allows the following digital devices to be added to a diagram.

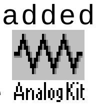
- Logic gates (AND,[82] OR,[91] NOT,[90] EXCLUSIVE-OR,[86] NAND,[82] NOR[91] and EXCLUSIVE-NOR)[86]
- Digital sources (logic level 0,[85] logic level 1[85] and switch)[85]
- Digital displays (lamp,[84] seven segment)[85]
- Integrate circuits[89] composed of the above devices

Use 

on the toolbar[37] or menu command View | Digital device toolkit[49] to display or dismiss this toolkit.

Analog Device Toolkit

The analog device toolkit[52] allows basic analog devices such as resistors, batteries and transistors to be added to a diagram.

Use 

on the toolbar[37] or menu command View | Analog device toolkit[49] to display or dismiss this toolkit. The analog device toolkit contains a number of sub-toolkits.[53]

Paint Toolkit

The paint toolkit[54] allows simple objects such as text, lines, ovals and rectangles to be added to a diagram.

Use 

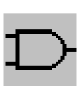
on the toolbar[37] or menu command View | Paint toolkit[49] to display or dismiss this toolkit.

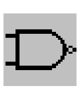
Related topics:

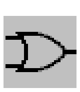
- Creating and editing diagrams[11]
- Adding devices or objects to a diagram[12]
- Diagram annotations[15]
- Connecting devices - adding wires[14]
- View commands[49]

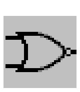
Digital Device Toolkit

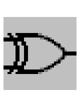
The digital device toolkit provides access to digital devices. To select a device or tool, click the mouse on the desired icon. You can choose any of the following:

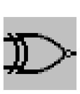

AND gate[82]

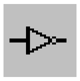

NAND gate[82]

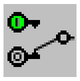

OR gate[91]

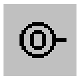

NOR gate[91]

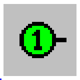

EXCLUSIVE-OR gate[86]

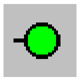

EXCLUSIVE-NOR gate[86]

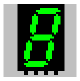

NOT gate[90]

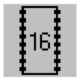

Digital source switch[85]


Level 0 source[85]

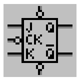

Level 1 source[85]


Digital display lamp[84]


Seven segment display[85]



Integrated circuit[89]



Flip-flop[34]

Notes:

- The number of inputs on a logic gate[34] can be changed using the Edit Logic Gate dialog box.[67] (hint5)[76]

- Flip-flop[34] parameters: type, clock, outputs and inputs can be changed using the Edit Flip-flop dialog box.[65] (hint6)[77]

- The number of pins on an integrated circuit[89] can be changed using the Edit IC dialog box.[66] (hint4)[76]

Use 

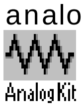
on the toolbar[37] or menu command View | Digital device toolkit[49] to display or dismiss this toolkit.

Related topics:

Connecting devices - adding wires[14]
Creating circuits inside integrated circuits[20]
Analog device toolkit[52]
Creating and editing diagrams[11]
Adding devices or objects to a diagram[12]
Rotating devices or objects[18]
Device and drawing toolkits[51]
View commands[49]

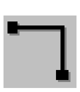
Analog Device Toolkit

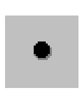
The analog device toolkit provides access to analog devices, associated tools sub-toolkits.

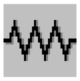
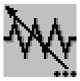
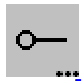
Use 

on the toolbar[37] or menu command View | Analog device toolkit[49] to display or dismiss this toolkit. The analog device toolkit contains a number of sub-toolkits.[53] To select a device or sub-toolkit, click the mouse on the desired icon. You can choose any of the following:

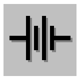
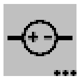
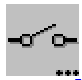

pointer tool


wire tool[95]

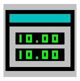
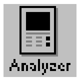

connector tool[83]

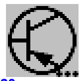
  

resistor[92] resistor toolkit[59] terminal & plug toolkit[57]

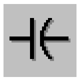
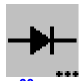
  

battery[82] source toolkit[58] switch toolkit[59]

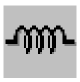
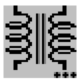
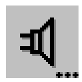
 



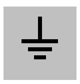
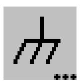
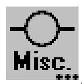
device meter[29] circuit analyzer[30] transistor toolkit[55]

capacitor[82] capacitor toolkit[60] diode toolkit[56]

inductor[89] inductor toolkit[60] audio toolkit[57]

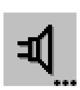
ground[87] ground toolkit[56] miscellaneous toolkit[61]

Related topics:

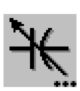
- Connecting devices - adding wires[14]
- Digital device toolkit[51]
- Creating and editing diagrams[11]
- Adding devices or objects to a diagram[12]
- Rotating devices or objects[18]
- Device and drawing toolkits[51]
- View commands[49]

Analog Device Sub-toolkit

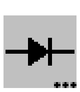
The analog device toolkit[52] contains a number of sub-toolkits. Use the indicated icon on the analog device toolkit to display or dismiss the sub-toolkit.

 **Audio Toolkit**

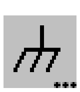
The audio toolkit[57] provides access to the different audio device types such as speakers[93] and earphones.[86]

 **Capacitor Toolkit**

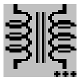
The capacitor toolkit[60] provides access to fixed and variable capacitor[82] types.

 **Diode Toolkit**

The diode toolkit[56] provides access to the different diode[85] device types.

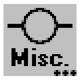
 **Ground Toolkit**

The ground toolkit[56] provides access to the different ground[87] and antenna[82] device types.



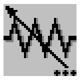
Inductor Toolkit

The inductor toolkit[60] provides access to the different inductor[89] and transformer[94] types.



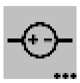
Miscellaneous Toolkit

The miscellaneous toolkit[61] provides access to the miscellaneous devices such as general meters,[87] DC motors,[84] AC generators,[81] lamps,[89] crystals,[83] ideal operational amplifiers (op amps)[88] and general amplifiers.[81]



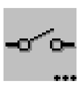
Resistor Toolkit

The resistor toolkit[59] provides access to the different resistor[92] device types.



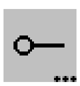
Source Toolkit

The source toolkit[58] provides access to the different voltage and current source types, including: batteries,[82] AC voltage sources,[81] AC current sources[81] and dependent voltage and current sources.[84]



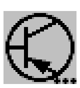
Switch Toolkit

The switch toolkit[59] provides access to the different switch[93] types, including push buttons,[92] fuses[87] and relays.[92]



Terminal and Plug Toolkit

The terminal and plug toolkit[57] provides access to different terminal[93] and plug[91] types, including plug ins,[91] receptacles[92] and 2 & 3 prong female and male plugs.[91]



Transistor Toolkit

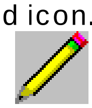
The transistor toolkit[55] provides instant access to the different transistor[94] related device types and orientations.

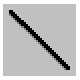
Related topics:

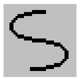
- Connecting devices - adding wires[14]
- Digital device toolkit[51]
- Creating and editing diagrams[11]
- Adding devices or objects to a diagram[12]
- Rotating devices or objects[18]
- Device and drawing toolkits[51]
- View commands[49]

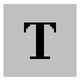
Paint Toolkit

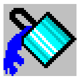
The paint toolkit provides access to simple drawing tools. To select a tool, click the mouse on the desired icon. You can choose any of the following tools:

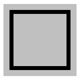
 free form pen tool - draws a free form line

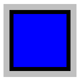
 straight line tool - draws a straight line

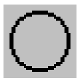
 curved line tool - draws a curved line

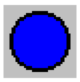
 text tool - adds a text object

 fill tool - fills an area with a color

 rectangle tool - draws a rectangle

 filled rectangle tool - draws a filled rectangle

 ellipse tool - draws an ellipse

 filled ellipse tool - draws a filled ellipse

Use  on the toolbar[37] or menu command View | Paint Toolkit[49] to display or dismiss this toolkit.

Related topics:

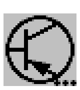
- Adding line objects to a diagram[13]
- Adding[12] - moving[16] - deleting a line vertex[15]
- Moving an entire line object[18]
- Diagram annotations[15]
- Adding text objects to a diagram[13]
- Creating and editing diagrams[11]
- Adding devices or objects to a diagram[12]
- Device and drawing toolkits[51]
- View commands[49]

Transistor Toolkit

The transistor toolkit is an extension of the analog device toolkit[52] to add the following devices to circuits.

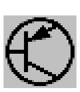
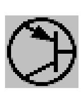
- Transistors.[94]
- Junction field effect transistors (FETs).[86]
- MOSFETs.[89]

This toolkit provides instant access to the different transistor related device types and orientations.

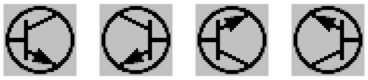
Use  on the analog device toolkit to display or dismiss this toolkit. (hint1)[76]

To select a transistor type and initial orientation, click the mouse on the desired icon. Rotating devices or objects[18] describes how to change the orientation.

PNP transistors:

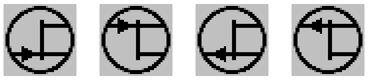
   

NPN transistors:



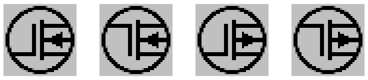
Junction FETs:

N channel P channel



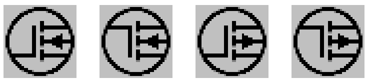
Depletion mode MOSFETs:

N channel P channel



Enhancement mode MOSFETs:

N channel P channel

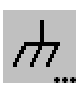


Related topics:

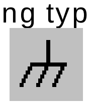
- Creating and editing diagrams[11]
- Adding devices or objects to a diagram[12]
- Rotating devices or objects[18]
- Device and drawing toolkits[51]
- View commands[49]

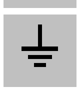
Ground Toolkit

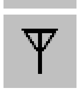
The ground toolkit is an extension of the analog device toolkit[52] to add ground[87] points and antennas[82] to circuits.

Use  on the analog device toolkit to display or dismiss this toolkit. (hint1)[76]

To select a ground or antenna, click the mouse on the desired icon. You can choose from the following types:

 chassis ground[87]

 earth ground[87]

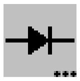
 antenna[82]

Related topics:

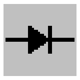
- Creating and editing diagrams[11]
- Adding devices or objects to a diagram[12]
- Device and drawing toolkits[51]
- View commands[49]

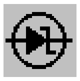
Diode Toolkit

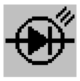
The diode toolkit is an extension of the analog device toolkit[52] and provides access to the different diode[85] related device types.

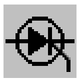
Use  on the analog device toolkit to display or dismiss this toolkit. (hint1)[76]

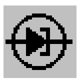
To select a diode device type, click the mouse on the desired icon. You can choose from the following types:

 diode[85]

 zener diode[95]

 LED - light emitting diode[89]

 SCR - silicon controlled rectifier[93]

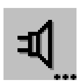
 Tunnel diode[94]

Related topics:

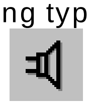
- Creating and editing diagrams[11]
- Adding devices or objects to a diagram[12]
- Rotating devices or objects[18]
- Device and drawing toolkits[51]
- View commands[49]

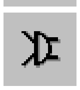
Audio Toolkit

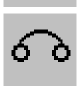
The audio toolkit is an extension of the analog device toolkit[52] and provides access to the different audio device types.

Use  on the analog device toolkit to display or dismiss this toolkit. (hint1)[76]

To select an audio device type, click the mouse on the desired icon. You can choose from the following types:

 speaker[93]

 microphone[89]

 earphones[86]

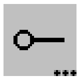
Related topics:

- Creating and editing diagrams[11]
- Adding devices or objects to a diagram[12]
- Rotating devices or objects[18]
- Device and drawing toolkits[51]
- View commands[49]

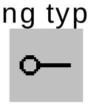
Terminal and Plug Toolkit

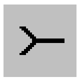
The terminal and plug toolkit is an extension of the analog device toolkit[52] and provides access to the different terminal[93] and plug[91] types.

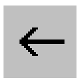
In Circuit Shop, terminals[93] receptacles,[92] and plug ins[91] are also used as connection points for circuit analyzers.[30]

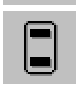
Use  on the analog device toolkit to display or dismiss this toolkit. (hint1)[76]

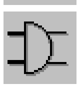
To select a terminal or plug type, click the mouse on the desired icon. You can choose from the following types:

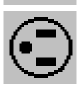
 terminal[93]

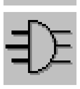
 receptacle[92]

 plug in[91]

 2 prong female plug[91]

 2 prong male plug[91]

 3 prong female plug[91]

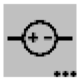
 3 prong male plug[91]

Related topics:

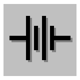
- Creating and editing diagrams[11]
- Adding devices or objects to a diagram[12]
- Rotating devices or objects[18]
- Device and drawing toolkits[51]
- View commands[49]

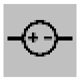
Source Toolkit

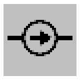
The source toolkit is an extension of the analog device toolkit[52] and provides access to the different voltage and current source types.

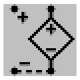
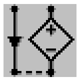
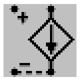
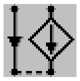
Use  on the analog device toolkit to display or dismiss this toolkit. (hint1)[76]

To select a voltage or current source type, click the mouse on the desired icon. You can choose from the following source types:

 battery[82]

 AC voltage source[81]

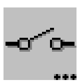
 AC current source[81]

 Voltage-controlled voltage source (VCVS)[95]
 Current-controlled voltage source (CCVS)[83]
 Voltage-controlled current source (VCCS)[95]
 Current-controlled current source (CCCS)[83]

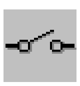
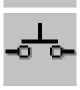
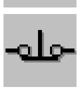
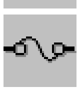
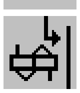
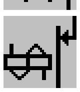
Related topics:
- Creating and editing diagrams[11]
- Adding devices or objects to a diagram[12]
- Device and drawing toolkits[51]
- View commands[49]

Switch Toolkit

The switch toolkit is an extension of the analog device toolkit[52] and provides access to the different switch[93] types.

Use  on the analog device toolkit to display or dismiss this toolkit. (hint1)[76]

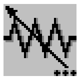
To select a switch type, click the mouse on the desired icon. You can choose from the following types:

 single-throw single-pole switch[93]
 normally open push button[92]
 normally closed push button[92]
 fuse[87]
 normally open relay[92]
 normally closed relay[92]

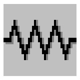
Related topics:
- Creating and editing diagrams[11]
- Adding devices or objects to a diagram[12]
- Rotating devices or objects[18]
- Device and drawing toolkits[51]
- View commands[49]

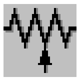
Resistor Toolkit

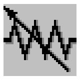
The resistor toolkit is an extension of the analog device toolkit[52] and provides access to the different resistor[92] device types.

Use  on the analog device toolkit to display or dismiss this toolkit. (hint1)[76]

To select a resistor type, click the mouse on the desired icon. You can choose from the following types:

 fixed resistor[92]

 potentiometer[91]

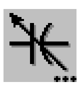
 variable resistor[92]

Related topics:

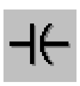
- Creating and editing diagrams[11]
- Adding devices or objects to a diagram[12]
- Rotating devices or objects[18]
- Device and drawing toolkits[51]
- View commands[49]

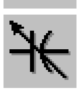
Capacitor Toolkit

The capacitor toolkit is an extension of the analog device toolkit[52] and provides access to fixed and variable capacitor[82] device types.

Use  on the analog device toolkit to display or dismiss this toolkit. (hint1)[76]

To select a capacitor type, click the mouse on the desired icon. You can choose from the following types:

 fixed capacitor[82]

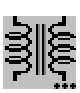
 variable capacitor

Related topics:

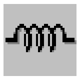
- Creating and editing diagrams[11]
- Adding devices or objects to a diagram[12]
- Rotating devices or objects[18]
- Device and drawing toolkits[51]
- View commands[49]

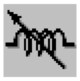
Inductor Toolkit

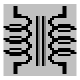
The inductor toolkit is an extension of the analog device toolkit[52] and provides access to the different inductor[89] and transformer[94] device types.

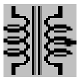
Use  on the analog device toolkit to display or dismiss this toolkit. (hint1)[76]

To select an inductor or transformer type, click the mouse on the desired icon. You can choose from the following types:

 fixed inductor[89]

 variable inductor

 transformer[94]

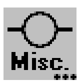
 tapped transformer

Related topics:

Creating and editing diagrams[11]
Adding devices or objects to a diagram[12]
Rotating devices or objects[18]
Device and drawing toolkits[51]
View commands[49]

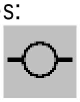
Miscellaneous Toolkit

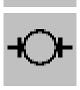
The miscellaneous toolkit is an extension of the analog device toolkit[52] and provides access to a variety of miscellaneous analog devices.

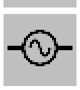
Use 

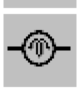
on the analog device toolkit to display or dismiss this toolkit. (hint1)[76]

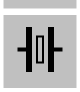
To select a device, click the mouse on the desired icon. You can choose from the following devices:

 General meter[87]

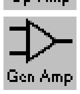
 DC motor[84]

 AC generator[81]

 Lamp[89]

 Crystal[83]

Ideal operational amplifier[88]



General amplifier[81]

Related topics:

Creating and editing diagrams[11]
Adding devices or objects to a diagram[12]
Rotating devices or objects[18]
Device and drawing toolkits[51]
View commands[49]

Circuit Shop Dialog Boxes

Circuit Shop includes the following dialog boxes:

Related topics:

Modifying device values [16]
Creating and editing diagrams [11]
Menu commands [37]
Toolbar commands [37]

Edit Analyzer Dialog Box

The Edit Analyzer dialog box is where a circuit analyzer's [30] attributes are initialised or modified. To open the dialog box, move the mouse onto the diagram over the analyzer object to be modified and double click the left mouse button. See also modifying device values. [16]

Name Input Box

Where an optional text description for the analyzer is entered.

Analyzer Type Input Box

Where the analyzer type is defined. Circuit Shop currently supports the following analyzer type:

- Frequency response [27]

Terminal Id Input Box

Where a numeric identifier for the circuit terminal [93] to be analyzed is entered. This is the circuit test point for the analyzer. Examples of valid terminal Ids: 1, 5, 27 and 1039.

Frequency Min Input Box

Where a numeric value is entered for the minimum frequency [87] in hertz. [88] Examples: 1, 100, 2500 and 1e5.

Frequency Max Input Box

Where a numeric value is entered for the maximum frequency [87] in hertz. [88] Examples: 1, 100, 2500 and 1e5.
Note: Frequency Max must be greater than Frequency Min.

Frequency Points/Decade Input Box
Where a numeric value is entered for the frequency points per decade, i.e. the number of frequencies that will be used in the circuit analysis per frequency decade. The greater the number, the smoother the output graph and the longer the analysis will take. Examples: 2, 5 and 10.

Plot Type Input Box
Where the frequency response[27] plot type is defined. Circuit Shop supports the following plot types.

- Magnitude (Volts)
- Phase (Degrees)
- Magnitude (dB)
- Group Delay (Seconds)

The Magnitude (dB) frequency response[27] plot type uses the following equation.

```
                    Vmag
dB  =  20.0 x log10( ---- )
                    Vref

where Vmag = voltage magnitude at the circuit test point
      Vref = zero dB reference
```

The Group Delay (Seconds) frequency response[27] plot type uses the following equation.

```
                  1      dPhase
group delay   =  --- x ----------
                 360   dFrequency

where dPhase     = change in phase in degrees
      dFrequency = change in frequency in hertz
```

Group delay is a measure of the change in phase[91] for a change in frequency.[87]

Zero dB Ref Input Box
Where the zero decibel (dB)[84] reference is defined. This value is only used by the Magnitude (dB) frequency response[27] plot type. The zero dB[84] reference must be greater than zero. Examples: 1, 1.5 and 5.

OK Button
Saves the current dialog box settings.

Cancel Button
Closes the dialog window without changing the current analyzer values and attributes.

X and Y Axis Buttons
Opens the Edit Axis Information dialog box[64] for either the X or Y axis. This dialog box controls the axis title, auto or manual scaling, min and max values, and axis type (linear or logarithmic).

Help Button
Displays this help topic.

Related topics:

Analysing a circuit[19]
Circuit analysis help topics[22]
Frequency response[27]
Sinusoidal steady state analysis[25]
Creating and Editing Diagrams[11]

Dialog boxes[62]

Edit Axis Information Dialog Box

The Edit Axis Information dialog box is where a graph axis' attributes are set or revised.

Title Input Box
Where an optional text description for the axis is entered.

Auto Scale Check Box
Where axis scaling behaviour (manual or automatic) is defined.

Min and Max Input Boxes
Where numeric values are entered for the axis minimum and maximum. Examples: 1, 100, 2500 and 1e5.
Note: These values have no effect if the Auto Scale Check Box has been selected.

Axis Type Input Box
Where the axis type is defined. Circuit Shop currently supports the following axis types:

- linear
- logarithmic

OK Button
Saves the current dialog box settings.

Cancel Button
Closes the dialog window without changing the current axis values and attributes.

Help Button
Displays this help topic.

Related topics:
Dialog boxes[62]

Edit Device Dialog Box

The Edit Device dialog box is where device values and other attributes are initialised or modified. To open the dialog box, move the mouse onto the diagram over the device or object to be modified and double click the left mouse button. See also modifying device values.[16]

Device Id Input Box
Where a numeric identifier for the device is entered. A numeric value of zero will suppress the output of the device Id. Examples of valid device Ids: 1, 5, 27 and 1039.

Device Value Input Box
Where an optional numeric value for the device is entered. Examples of valid device values: 1, 500, 1000, 55000, 1e3, 1e-12, 1.5k and 2.5M.

As shown in the above examples, you can optionally use a single character scaling suffix[75] to scale the input value.

Device Name Input Box
Where an optional text description for the device is entered.

Value Slider Check Box

Where a value slider[76] can be enabled or disabled for the device.

OK Button
Saves the current dialog box settings.

Cancel Button
Closes the dialog window without changing the current device values and attributes.

Help Button
Displays this help topic.

Related topics:
- Modifying device values or other object attributes[16]
- Creating and Editing Diagrams[11]
- Dialog boxes[62]

Edit Drawing Grid Dialog Box

The Edit Drawing Grid dialog box is where the size and visibility attributes of the drawing grid are set or revised. These attributes are saved with the diagram and restored when the diagram is read back in.

X - Horizontal Size Input Box
Where the horizontal grid size in pixels is entered. Examples: 1, 5, 10 and 25.

Y - Vertical Size Input Box
Where the vertical grid size in pixels is entered. Examples: 1, 5, 10 and 25.

Display Grid Lines Check Box
When checked, the drawing grid is displayed in the drawing window.

OK Button
Saves the current dialog box settings.

Cancel Button
Closes the dialog window without changing the current drawing grid values.

Help Button
Displays this help topic.

Related topics:
- Dialog boxes[62]

Edit Flip-flop Dialog Box

The Edit Flip-flop dialog box is where flip-flop[34] attributes are initialised or modified. To open the dialog box, move the mouse onto the diagram over the flip-flop to be modified and double click the left mouse button. See also modifying device values.[16]

Device Id Input Box Where an optional numeric identifier for the device is entered. A numeric value of zero will suppress the output of the device Id. Examples of valid device Ids: 1, 5, 27 and 1039.

Device Name Input Box Where an optional text description for the device is entered.

Flip-flop Type Input Box Where the flip-flop[34] type is defined. Circuit Shop supports the following flip-flop types:

- SR - Set Reset
- JK
- D
- T - Toggle

Outputs Input Box Where the flip-flop[34] outputs are defined. Circuit Shop supports the following flip-flop output types:

- Q and ~Q
- Q only
- ~Q only

Clock Type Input Box Where the flip-flop[34] clock input is defined. Circuit Shop supports the following flip-flop clock input types:

- No clock
- High level triggered
- Low level triggered
- Low-to-high transition
- High-to-low transition

Preset Type Input Box Where the flip-flop[34] preset input is defined. Circuit Shop supports the following flip-flop preset input types:

- No preset
- With preset

Clear Type Input Box Where the flip-flop[34] clear input is defined. Circuit Shop supports the following flip-flop clear input types:

- No clear
- With clear

OK Button Saves the current dialog box settings.

Cancel Button Closes the dialog window without changing the existing values and attributes.

Help Button Displays this help topic.

Related topics:

Modifying device values or other object attributes[16]
Creating and Editing Diagrams[11]
Dialog boxes[62]

Edit IC Dialog Box

The Edit IC dialog box is where integrated circuit[89] device values and other attributes are initialised or modified. To open the dialog box, move the mouse onto the diagram over the IC device to be modified and double click the left mouse button. See also modifying device values.[16]

Id Input Box
Where an optional numeric identifier for the device is entered. A numeric value of zero will suppress the output of the device Id. Examples of valid device Ids: 1, 5, 27 and 1039.

Name Input Box
Where an optional text description for the device is entered.

Part Num Input Box
Where an optional part number text string for the device is entered.

Inputs: Side & Top/Bottom Input Boxes
Where the number of pins or inputs is specified for the sides and top/bottom.

Show Pins Check Box
When this box is checked, the pins are drawn on the screen.

Show Pin Numbers Check Box
When this box is checked, the pin numbers are drawn on the screen.

OK Button
Saves the current dialog box settings.

Cancel Button
Closes the dialog window without changing the current device values and attributes.

View Circuit Button
Opens a new drawing window and displays the circuit inside the integrated circuit.[89] Any Circuit Shop device or object, including additional integrated circuits, can be placed in this diagram. See creating circuits inside ICs.[20]

Help Button
Displays this help topic.

Related topics:

Modifying device values or other object attributes[16]
Creating and Editing Diagrams[11]
Dialog boxes[62]

Edit Logic Gate Dialog Box

The Edit Logic Gate dialog box is where logic gate[34] attributes are initialised or modified. To open the dialog box, move the mouse onto the diagram over the logic gate to be modified and double click the left mouse button. See also modifying device values.[16]

Device Id Input Box
Where an optional numeric identifier for the device is entered. A numeric value of zero will suppress the output of the device Id. Examples of valid device Ids: 1, 5, 27 and 1039.

Device Name Input Box
Where an optional text description for the device is entered.

Inputs Box
Where a numeric value for the number of logic gate inputs is entered.

OK Button
Saves the current dialog box settings.

Cancel Button

Closes the dialog window without changing the existing values and attributes.

Help Button
Displays this help topic.

Related topics:
- Modifying device values or other object attributes[16]
- Creating and Editing Diagrams[11]
- Dialog boxes[62]

Edit Meter Dialog Box

The Edit Meter dialog box is where a device meter's[29] attributes are initialised or modified. To open the dialog box, move the mouse onto the diagram over the meter object to be modified and double click the left mouse button. See also modifying device values.[16]

Meter Type Input Box
Where the meter type and output display format is defined. Circuit Shop supports the measurement of voltage,[95] current,[84] impedance[88] and power[91] using the following display formats.

- Voltage and current - magnitudes
- Voltage and current - RMS

- Voltage - magnitude and phase (degrees)
- Voltage - magnitude and phase (radians)
- Voltage - real and imaginary phasor

- Current - magnitude and phase (degrees)
- Current - magnitude and phase (radians)
- Current - real and imaginary phasor

- Impedance - magnitude and phase (degrees)
- Impedance - magnitude and phase (radians)
- Impedance - real and imaginary phasor

- Power - magnitude and phase (degrees)
- Power - magnitude and phase (radians)
- Power - real and imaginary phasor

Device Type Input Box
Where the type of device to be metered is defined. Circuit Shop can link device meters[29] to the following circuit device types.

- Resistors[92]
- Capacitors[82]
- Inductors[89]
- Terminals[93]
- Terminal[93]-to-terminal[93]

Note:

- Device meters linked to terminals[93] can only measure voltage.[95]
- The terminal[93]-to-terminal[93] device type selection can be used to measure voltage[95] difference between two terminals.[93]

Device Id Input Box

Where a numeric identifier for the device to be metered is entered. Examples of valid device Ids: 1, 5, 27 and 1039.

The terminal[93]-to-terminal[93] device type selection has a special number-number format. Examples of valid terminal[93]-to-terminal[93] device Ids: 1-2, 5-4, 27-35 and 1039-2001.

OK Button
Saves the current dialog box settings.

Cancel Button
Closes the dialog window without changing the current meter values and attributes.

Help Button
Displays this help topic.

Related topics:

- Viewing circuit voltage and current values - adding meters[20]
- Sinusoidal steady state analysis[25]
- Creating and Editing Diagrams[11]
- Dialog boxes[62]

Edit Source Dialog Box

The Edit Source dialog box is where alternating current[81] (AC) voltage[95] and current[84] source values and other attributes are initialised or modified. To open the dialog box, move the mouse onto the diagram over the source device to be modified and double click the left mouse button. See also modifying device values.[16]

Device Id Input Box
Where an optional numeric identifier for the device is entered. A numeric value of zero will suppress the output of the device Id. Examples of valid device Ids: 1, 5, 27 and 1039.

Device Name Input Box
Where an optional text description for the device is entered.

Magnitude Input Box
Where a numeric magnitude value for the source is entered.

- For voltage sources,[81] this value specifies the magnitude of the voltage in volts[95] applied to the circuit.
- For current sources,[81] this value specifies the magnitude of the current in amperes[81] applied to the circuit.

Examples of valid source values: 0.05, 1, 500, 1000, 1.5m and 2.4k.

As shown in the above examples, you can optionally use a single character scaling suffix[75] to scale the input value.

Phase Input Box
Where a numeric phase[91] value, in degrees for the source is entered. Examples of valid phase values: 0, 30, 45, 180 and 360.

Frequency Input Box
Where a numeric frequency[87] value, in hertz[88] for the source is entered. Examples of valid phase values: 1, 60, 1000 and 50000.

As shown in the above examples, you can optionally use a single character scaling suffix[75] to scale the input value.

OK Button
Saves the current dialog box settings.

Cancel Button
Closes the dialog window without changing the existing values and attributes.

Help Button
Displays this help topic.

Related topics:

- Modifying device values or other object attributes[16]
- Creating and Editing Diagrams[11]
- Dialog boxes[62]

Edit Text Dialog Box

The Edit Text dialog box is where a text object's value is modified. To open the dialog box, move the mouse onto the diagram over the text object to be modified and double click the left mouse button. See also modifying device values.[16]

New Value Input Box
Where the new text value is entered.

OK Button
Saves the current dialog box value.

Cancel Button
Closes the dialog window without changing the current text object value.

Related topics:

- Adding text objects to a diagram[13]
- Creating and Editing Diagrams[11]
- Dialog boxes[62]

Edit Transformer Dialog Box

The Edit Transformer dialog box is where transformer[94] attributes are initialised or modified. To open the dialog box, move the mouse onto the diagram over the device or object to be modified and double click the left mouse button. See also modifying device values.[16]

Device Id Input Box
Where an optional numeric identifier for the device is entered. A numeric value of zero will suppress the output of the device Id. Examples of valid device Ids: 1, 5, 27 and 1039.

Device Name Input Box
Where an optional text description for the device is entered.

Primary, Secondary and Mutual Inductance Input Boxes
Where the transformer's primary, secondary and mutual inductance[88] values are entered. Examples of valid inductance values: 0.05, 1.0, 0.55, 1.5m and 240u.

As shown in the above examples, you can optionally use a single character scaling suffix[75] to scale the input value.

Polarity Input Box
Where the transformer's polarity is defined. The following polarity types are available:

- None (same as Positive in sinusoidal steady state analysis[25]).
- Positive
- Negative

Core Type Input Box
Where the transformer's core type is defined. The following core types are available:

- Iron
- Air

OK Button
Saves the current dialog box settings.

Cancel Button
Closes the dialog window without changing the existing values and attributes.

Help Button
Displays this help topic.

Related topics:
Modifying device values or other object attributes[16]
Creating and Editing Diagrams[11]
Dialog boxes[62]

Print Dialog Box

The Print dialog box sets the printout parameters and generates a printout of the contents of a circuit shop window.

The Print Quality input box is where the printer resolution is specified.

The Print to File check box is where the printer output can be directed to a file. If this check box is selected a dialog box will be opened to specify the output filename.

The Copies input box is where the number of printed copies is specified.

The OK button will generate the printout and send it to the selected printer or file.

The Cancel button will close the dialog window without generating a printout.

The Setup button invokes the Printer Setup dialog box[71] to select the default or specific printer, the page orientation of portrait or landscape, and paper size and source.

Related topics:
File | Print command[40]
File | Printer setup command[41]
Dialog boxes[62]

Printer Setup Dialog Box

The Printer Setup dialog box sets printer parameters for subsequent print commands. Parameters include using the windows default or a specific printer, the page orientation of portrait or landscape, and paper size and source.

The Printer radio button box is where the printer is specified. If Default Printer is selected, the current windows default printer is used. If Specific Printer is selected, the drop down selection box can be used to select a specific printer from the known set of printers.

The Orientation radio button box is where the page orientation of Portrait or Landscape is selected.

The Paper input box is where the paper size and source is selected.

The OK button will save the current dialog box settings to be used in subsequent print commands.

The Cancel button will close the dialog window without changing the printer settings.

The Options button will display a dialog box to set additional printer details including dithering and intensity.

Related topics:

File | Print command[40]
File | Print preview command[41]
File | Printer setup command[41]
Dialog boxes[62]

Registration Dialog Box

The Registration dialog box is where you enter the registered user name and key. The name and key are sent in a registration mail message after you purchase Circuit Shop. The name and key must be entered exactly as shown in the registration mail.

Registration Name Input Box
Where the name of the registered user is entered. The name must be entered exactly as shown in the registration mail.

Registration Key Input Box
Where the registered user's key is entered. The key must be entered exactly as shown in the registration mail.

OK Button
Validates the Registration Name and Key, and if valid, saves the current dialog box settings.

Cancel Button
Closes the dialog window without changing the existing values.

Help Button
Displays this help topic.

Related topics:

File | Register menu command[41]
Purchasing information[7]
Dialog boxes[62]

Select File Dialog Box

The Select File dialog box is where you enter or select a file. It is used by various commands including:

- File | Open[39]
- File | Save[39]
- File | Save As[40]
- File | Output BMP file[41]

The File Name input box[73] is where you enter the name of the file, or a filename mask to use as a filter for the Files list box.

The Files list box[73] displays the names of files in the current directory that match the filename mask in the File Name input box.

The Directories list box[73] displays the parent and sub directories above and below the current directory. You can navigate to other directories by selecting a directory name in the Directories list box.

The OK button performs the desired operation and closes the dialog box.

The Cancel button closes the dialog box without performing the desired operation.

Related topics:
File commands[39]
Dialog boxes[62]

File Name Input Box

The File Name input box is where you enter the name of the file, or the filename mask to use as a filter for the Files list box.

To select a file you can choose any of these actions:

- Type in a file name (if the file is not in your current directory, include the full path name) and choose OK or press Enter.

- Type in a file name with * (multiple character) and ? (single character) wildcards, which filters the files in the Files list box to match your specifications when you choose OK or press Enter.

Related topics:
Select File dialog box[72]
Dialog boxes[62]

Files List Box

The Files list box displays the names of files in the current directory that match the filename mask in the File Name input box.[73]

When the File Name input box is changed or a different directory is selected, the Files list box is updated to show the files in the currently chosen directory.

If the desired file is displayed in the list box, you may double-click on it to select the file.

If you are using the keyboard, use the Tab key to move to the Files list box and use the Up or Down arrow to reach the desired file. Press Enter to select the file.

Press the Spacebar or an arrow key to select the first item. Press Enter to select the item.

Related topics:
Select File dialog box[72]
Dialog boxes[62]

Directories list box

The Directories list box displays the names of available directories and drives.

To work with directories, press Alt+D. The first directory in the Directories list box will be outlined.

Double-click directories in the Directories list box to change to a different directory.

If you are using your keyboard, use the arrow keys to select the directory or drive you want to open and choose OK or press Enter.

If you see and double-click the [..] symbol, the directory will change to the parent directory of the current subdirectory.

Related topics:
Select File dialog box[72]
Dialog boxes[62]

Select Font Dialog Box

The Select Font dialog box is where a font is selected.

The Font input box is where the font is selected.

The Font Style input box is where a style is selected. Examples of font styles: Regular, Italic, Bold and Bold Italic.

The Size input box is where the point size is specified.

Related topics:
Tool|Font command[47]
Creating and editing diagrams[11]
Dialog boxes[62]

Circuit Shop Files

Circuit Shop files hold device and schematic information, and diagram annotations. By default, they have the file type .CS1.

Scaling Suffix

Circuit Shop allows device values to be entered with and without scaling suffixes. Examples of valid device values: 1, 500, 1000, 55000, 1e3, 1e-12, 1.5k and 2.5M.

As shown in the above examples, you can optionally use the following single character suffixes to scale the input value.

```
Suffix    Multiplier
======    ==========
  G          1e9
  M          1e6
  K or k     1e3
  m          1e-3
  u          1e-6
  n          1e-9
  p          1e-12
```

Unit conversion[75] describes the standard unit abbreviations.

Related topics:

- Modifying device values or other object attributes[16]
- Creating and Editing Diagrams[11]
- Dialog boxes[62]

Unit Conversion

The standard unit abbreviations, prefixes and their equivalent multipliers used in electronics are shown below:

```
G  giga  1,000,000,000.0                 1e9
M  mega      1,000,000.0                 1e6
k  kilo          1,000.0                 1e3
m  milli             0.001               1e-3
µ  micro             0.000,001           1e-6
p  pico              0.000,000,000,001   1e-12
```

For example, 10M ohm means 10 mega or million ohms and 3µA means 3 micro or 3-millionths of an ampere.

When using Ohm's law[90] and other equations, the values for voltage,[95] current[84] and resistance[92] must be in the same basic units, volts,[95] amperes[81] and ohms[90] respectively. For example: given a current of 1.5 µA (micro amperes) and a resistance of 5 M ohms (mega ohms) in a circuit, what is the applied voltage?

```
E = I x R                 I = 1.5 µA
  = 1.5e-6  x  5e6          = 1.5  x  1e-6 amps
  = 7.5 volts               = 1.5e-6 amps

                          R = 5 M ohms
                            = 5  x  1e6 ohms
                            = 5e6 ohms
```

Also, when adding device values, a common unit must be used. For example: given three resistors in series with values 10, 1.2K and 2.5M ohms, what is the total resistance?

```
R (total)              R1 = 10 ohms
  =  R1 + R2 + R3
  =       10           R2 = 1.2 K ohms
      +1200               = 1.2  x  1000 ohms
   +2500000               = 1200 ohms
  =  2501210 ohms
                       R3 = 2.5 M ohms
                          = 2.5  x  1000000 ohms
                          = 2500000
```

Related topics:

Scaling suffix[75]
Modifying device values or other object attributes[16]

Value Slider

The value slider is not implemented in this version of Circuit Shop.

Hints

Hint1[76] - to display the analog device toolkit.
Hint2[76] - to display the paint toolkit.
Hint3[76] - to display the digital device toolkit.
Hint4[76] - to change the number of pins on an integrated circuit.
Hint5[76] - to change the number of inputs on a logic gate.
Hint6[77] - to change flip-flop attributes.

Hint1

Use 

on the toolbar[37] or menu command View | Analog device toolkit[49] to display the analog device toolkit.[52]

Hint2

Use 

on the toolbar[37] or menu command View | Paint toolkit[49] to display the paint toolkit.[54]

Hint3

Use 

on the toolbar[37] or menu command View | Digital device toolkit[49] to display the digital device toolkit.[51]

Hint4

To change the number of pins, or inputs on an integrated circuit,[89] move the pointer over the integrated circuit, double-click to open the Edit IC dialog box,[66] modify the Inputs: box and press OK.

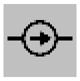
Hint5

To change the number of inputs on an logic gate,[34] move the pointer over the logic gate, double-click to open the Edit Logic Gate dialog box,[67] modify the Inputs: box and press OK.

Hint6

To change flip-flop[34] attributes move the pointer over the flip-flop, double-click to open the Edit Flip-flop dialog box,[65] modify the inputs boxes and press OK.

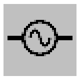
Glossary



AC Current Source (toolkit[52] - sub-toolkit)[58]

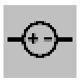
Definition: A device connected into an electrical circuit to introduce a specified alternating current[81] (AC). An AC current has a phase[91] and a frequency.[87]

AC current sources can be used in Circuit Shop's sinusoidal steady state analysis[25] and frequency response[27] capabilities.



AC Generator (toolkit[52] - sub-toolkit)[61]

Definition: A rotating machine which converts mechanical energy into electrical energy[86] in the form of alternating current[81] (AC).



AC Voltage Source (toolkit[52] - sub-toolkit)[58]

Definition: A device connected into an electrical circuit to introduce a specified alternating current[81] (AC) voltage.[95] An AC voltage has a phase[91] and a frequency.[87]

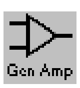
AC voltage sources can be used in Circuit Shop's sinusoidal steady state analysis[25] and frequency response[27] capabilities.

Alternating Current (AC)

Definition: A variable valued current[84] which repeatedly increases to a maximum flow in one direction, decreases to zero, reverses, then increases to a maximum flow in the other direction. The number of times this cycle this is repeated per second is called the frequency. The average current over one cycle is zero.

Ampere

Definition: The usual measure of current in an electric circuit. One Ampere of current is produced by an electromotive force of one volt[95] acting through a resistance[92] of one ohm.[90]



Amplifier (toolkit[52] - sub-toolkit)[61]

Definition: A circuit designed to increase the voltage,[95] current[84] or power[91] of an input signal.

Analog Circuit

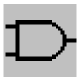
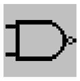
Definition: A circuit composed of devices that operates at many non-discrete voltage[95] values.

Examples of analog circuit devices can be found in Circuit Shop's analog device toolkit.[52]

Circuit Shop's circuit analysis[22] function includes the following analog circuit analysis functions:

- DC analysis[22]
- Sinusoidal steady state analysis[25]
- Frequency response[27]

Also see digital circuits.[84]

 **AND Gate**  **NAND Gate** (toolkit)[51]

Definition: An AND gate is a digital device with a HIGH output (logic level 1) if all inputs are HIGH. If any input is LOW, (logic level 0) the output will be LOW.

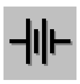
A NAND (NOT AND) gate is an inverted AND gate.

Input 1	Input 2	AND Output	NAND Output
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0

AND and NAND gates can be used in Circuit Shop's digital analysis[32] function.

 **Antenna** (toolkit[52] - sub-toolkit)[56]

Definition: A device to radiate or receive radio waves.

 **Battery** (toolkit[52] - sub-toolkit)[58]

Definition: A device connected into an electrical circuit to introduce a specified direct current[86] (DC) voltage.[95]

Batteries can be used in Circuit Shop's DC analysis[22] function.

Boolean Expression

Definition: A mathematical expression using variables with values 0 and 1. The basic operations are AND, OR, NOT and EXCLUSIVE-OR. (Inverted, or reversed operations are NAND, NOR and EXCLUSIVE-NOR.) The operations have direct logic gate[34] equivalents.

NOT : $B = \overline{A}$

AND : $C = AB$ or $C = A \cdot B$

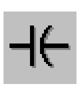
NAND : $C = \overline{AB}$ or $C = \overline{A \cdot B}$

OR : $C = A + B$

NOR : $C = \overline{A + B}$

EXCLUSIVE-OR : $C = A \oplus B$

EXCLUSIVE-NOR : $C = \overline{A \oplus B}$

 **Capacitor** (toolkit[52] - sub-toolkit)[60]

Definition: A device connected into an electrical circuit to introduce a specified capacitance.[83]

Capacitors can be used in Circuit Shop's sinusoidal steady state analysis[25] and frequency response[27] capabilities.

Capacitance

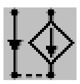
Definition: The property of a circuit which impedes a change in voltage.[95] Capacitors[82] are the usual source of capacitance. Capacitance is measured in farads[86] in honor of Michael Faraday. In electronic circuits, the usual measure of capacitance is microfarads (µF) or picofarads (pF), 1e-6 or 1e-12 farads respectively.

Capacitive Reactance

Definition: The opposition to the flow of alternating current[81] by a capacitor.[82] Capacitive reactance is inversely proportional to the amount capacitance[83] of the capacitor and the circuit frequency.[87] In other words, as the capacitance or frequency increases, the opposition to AC current flow reduces. Like resistance,[92] capacitive reactance is measured in ohms.[90]

$$Xc = \frac{1}{2\pi fC}$$

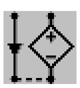
Where: Xc = capacitive reactance in ohms
$2\pi \cong 6.28$ (radians in 360 degrees)
f = frequency in hertz
C = capacitance in farads



Current-Controlled Current Source (CCCS) (toolkit[52] - sub-toolkit)[58]

Definition: A special type of current[84] source whose output current is equal to the input current multiplied by a constant. In the above icon, the output current flowing between the two right hand side terminals is equal to the input current flowing between the two left hand terminals multiplied by a constant.

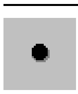
Current-controlled current sources can be used in Circuit Shop's sinusoidal steady state analysis[25] and frequency response[27] capabilities.



Current-Controlled Voltage Source (CCVS) (toolkit[52] - sub-toolkit)[58]

Definition: A special type of voltage[95] source whose output voltage is equal to the input current[84] multiplied by a constant. In the above icon, the output voltage across the two right hand side terminals is equal to the input current flowing between the two left hand terminals multiplied by a constant.

Current-controlled voltage sources can be used in Circuit Shop's sinusoidal steady state analysis[25] and frequency response[27] capabilities.



Connector (toolbar[37] - toolkit)[52]

Definition: A device to allow one or more wires[95] or devices to be electrically connected together.

Crystal (toolkit[52] - sub-toolkit)[61]

Definition: A thin plate of quartz which is ground to a certain thickness to vibrate at a specific frequency when energy[86] is applied.

Current

Definition: The rate of flow of electrons in a circuit measured in amperes.[81]

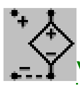
Decibel (dB)

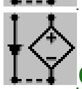
Definition: The standard unit of measurement of a circuit's gain (or loss). The number of decibels for a given power ratio is

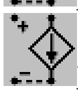
```
                        P2
dB  =  10.0 x log10(  ---- )
                        P1
```

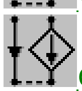
Dependent Voltage and Current Sources (toolkit[52] - sub-toolkit)[58]

Definition: A special type of voltage[95] or current[84] source whose output is equal to the input voltage or current multiplied by a constant. There are four types of dependent sources:

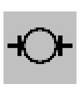
Voltage-controlled voltage source (VCVS)[95]

Current-controlled voltage source (CCVS)[83]

Voltage-controlled current source (VCCS)[95]

Current-controlled current source (CCCS)[83]

Dependent voltage and current sources can be used in Circuit Shop's sinusoidal steady state analysis[25] and frequency response[27] capabilities.



DC Motor (toolkit[52] - sub-toolkit)[61]

Definition: A rotating machine which converts direct current[86] (DC) electrical energy[86] into mechanical energy.

Dielectric

Definition: The insulating material between the two plates of a capacitor.[82]

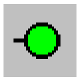
Digital Circuit

Definition: A circuit composed of devices that operate at two discrete values, LOW and HIGH (logic levels 0 and 1 respectively).

Examples of digital circuit devices can be found in digital sources,[33] logic gates,[34] flip-flops[34] and digital displays.[36]

Circuit Shop's circuit analysis[22] function includes digital circuit analysis.[32]

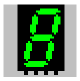
Also see analog circuits.[81]



Digital Display Lamp (toolkit)[51]

Definition: A digital display device whose display is off or on if the input logic level is LOW or HIGH respectively.

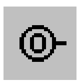
Digital display lamps can be used in Circuit Shop's digital analysis[32] function.



Seven Segment Display (toolkit)[51]

Definition: A digital device which displays 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, b, C, d, E or F depending on the input binary logic level at its four inputs.

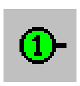
Seven segment displays can be used in Circuit Shop's digital analysis[32] function.



Digital Source Logic Level 0 (toolkit)[51]

Definition: A digital device with a constant LOW output (logic level 0).

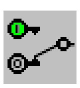
Digital sources can be used in Circuit Shop's digital analysis[32] function.



Digital Source Logic Level 1 (toolkit)[51]

Definition: A digital device with a constant HIGH output (logic level 1).

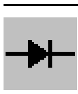
Digital sources can be used in Circuit Shop's digital analysis[32] function.



Digital Source Switch (toolkit)[51]

Definition: A digital device with a constant LOW or HIGH output (logic level 0 or 1) depending on its current switch setting. The output is toggled between LOW and HIGH by single mouse clicks on the switch.

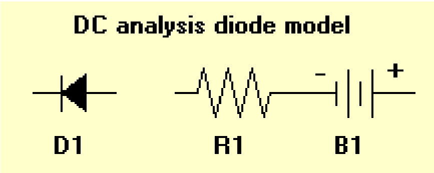
Digital source switches can be used in Circuit Shop's digital analysis[32] function. Also, the digital analysis function is invoked each time the switch is toggled.



Diode (toolkit[52] - sub-toolkit)[56]

Definition: A semiconductor[93] device with two electrodes which allows current[84] to flow in one direction. In the above icon, the left and right electrodes are called the anode and cathode respectively.

Diodes can be used in Circuit Shop's DC analysis[22] function. Diode model[85] describes how diodes are modelled in Circuit Shop.



Diode Model

The above diagram shows Circuit Shop's DC analysis[22] diode model.

Diodes[85] are modelled as a resistor[92] R1 and battery[82] B1 in series.[93]

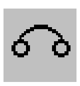
The diode has three states and each state has a different resistor and battery resistance[92] and voltage[95] values respectively.

State	R1 (ohms)	B1 (volts)	Diode Voltage
Forward	5	-0.7	> 0.7
Reverse	500 M	0.0	> -25.0
Breakdown	5	25.0	< -25.0

Circuit Shop determines the diode state based on the voltage across the diode. For example, when the voltage across the diode is greater than 0.7 volts, the diode is in the Forward bias state.

Direct Current (DC)

Definition: A constant valued current[84] which flows in one direction.

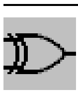


Earphones (toolkit[52] - sub-toolkit)[57]

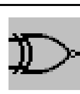
Definition: An electroacoustic transducer intended to be used near the ears which converts electrical power[91] into acoustic power with approximately the same waveform as the electrical input.

Energy

Definition: The amount of work performed. Whereas power[91] is the rate at which work is done, energy is the amount of work actually performed in a period of time. In an electrical circuit, energy is equal to the power times the time duration. Electrical energy is measured in watt-hours,[95] one watt-hour is equivalent to one watt[95] of power used for one hour.



EXCLUSIVE-OR Gate



EXCLUSIVE-NOR Gate (toolkit)[51]

Definition: An EXCLUSIVE-OR gate is a digital device with a HIGH output (logic level 1) if one and only one input is HIGH.

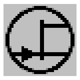
An EXCLUSIVE-NOR (NOT EXCLUSIVE-OR) gate is an inverted EXCLUSIVE-OR gate.

Input 1	Input 2	EXCLUSIVE-OR Output	EXCLUSIVE-NOR Output
0	0	0	1
0	1	1	0
1	0	1	0
1	1	0	1

EXCLUSIVE-OR and EXCLUSIVE-NOR gates can be used in Circuit Shop's digital analysis[32] function.

Farad

Definition: The measure of capacitance in an electric circuit. One Farad of capacitance[83] causes one ampere[81] of current[84] to flow when the applied voltage[95] is changing at a rate of one volt per second.



Field Effect Transistor (FET) (toolkit[52] - sub-toolkit)[55]

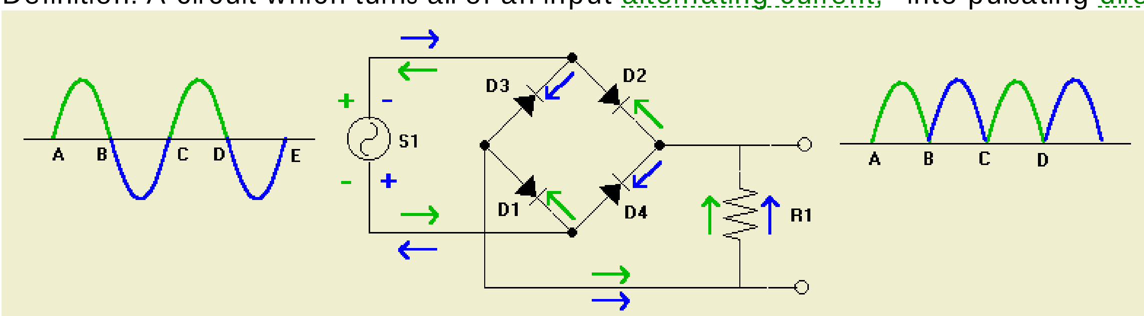
Definition: An active semiconductor[93] device having three electrodes. In the above icon, starting with the electrode with the arrow, in a clockwise direction, the electrodes are called the gate, drain and source. The resistance[92] between the drain and the source depends the voltage[95] applied to the gate.

Frequency

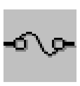
Definition: The number of cycles per second of an alternating current[81] measured in hertz.[88]

Full-wave Rectifier

Definition: A circuit which turns all of an input alternating current,[81] into pulsating direct current.[86]

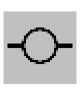


Further full-wave rectifier circuit details can be found in diode exercise examples.[271]



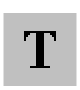
Fuse (toolkit[52] - sub-toolkit)[59]

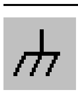
Definition: A protective device which breaks the path in an electrical circuit when the current[84] exceeds the rated value.



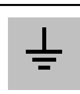
General Meter (toolkit[52] - sub-toolkit)[61]

Definition: A graphical representation of a circuit meter.

Note: Use the text tool  on the paint toolkit[54] to add V, A or OHM annotations to the center of the general meter to indicate a voltmeter, ammeter or ohmmeter respectively.



Chassis Ground



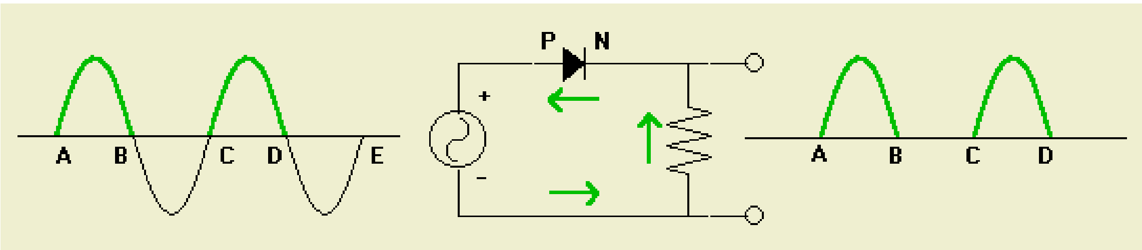
Earth Ground (toolkit[52] - sub-toolkit)[56]

Definition: The voltage reference in the circuit. There may or may not be an actual connection to the earth.

Ground points can be used in Circuit Shop's DC analysis,[22] sinusoidal steady state analysis[25] and frequency response[27] capabilities.

Half-wave Rectifier

Definition: A circuit which turns one half of an input alternating current,[81] into pulsating direct current.[86]



Further half-wave rectifier circuit details can be found in diode exercise examples.[271]

Henry

Definition: The measure of inductance in an electric circuit. One Henry of inductance[88] causes one volt[95] of counter electromotive force when the circuit current[84] is changing at a rate of one ampere[81] per second.

Hertz

Definition: The usual measure of frequency[87] in an alternating current[81] circuit. One hertz is equal to one cycle per second.

Ideal Operational Amplifier (Op Amp) (toolkit[52] - sub-toolkit)[61]

Definition: A model of an operational amplifier[90] used in circuit analysis. An ideal operational amplifier has infinite gain, infinite input resistance and zero output resistance.

Ideal operational amplifiers can be used in Circuit Shop's sinusoidal steady state analysis[25] and frequency response[27] capabilities.

Impedance

Definition: The total resistance[92] and reactance[92] a device or circuit offers to an alternating current[81] at a specific frequency.[87] Impedance is measured in ohms.[90]

Inductance

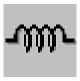
Definition: The property of a circuit which impedes a change in current.[84] Inductors[89] are the usual source of inductance. Inductance is measured in henrys.[88] In electronic circuits, the usual measure of inductance is henrys (H), milihenrys (mH) or microhenrys (µH), 1, 1e-3 or 1e-6 henrys respectively.

Inductive Reactance

Definition: The opposition to the flow of alternating current[81] by a inductor.[89] Inductive reactance is proportional to the amount inductance[88] of the inductor and the circuit frequency.[87] In other words, as the inductance or frequency increases, the opposition to AC current flow increases. Like resistance,[92] inductive reactance is measured in ohms.[90]

$$Xl = 2\pi fL$$

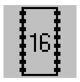
Where: Xl = inductive reactance in ohms
$2\pi \cong 6.28$ (radians in 360 degrees)
f = frequency in hertz
L = inductance in henries



Inductor (toolkit[52] - sub-toolkit)[60]

Definition: A device connected into an electrical circuit to introduce a specified inductance.[88]

Inductors can be used in Circuit Shop's sinusoidal steady state analysis[25] and frequency response[27] capabilities.



Integrated Circuit (IC) (toolkit)[51]

Definition: An electronic circuit composed of many transistors[94] and other devices on a single, very small silicon chip or wafer. The silicon chip is encased in a protective package with connecting pins that are used to connect to other external devices.

Circuit Shop allows devices and objects, including other integrated circuits, to be imbedded inside an integrated circuit. See creating circuits inside ICs.[20]

ICs can also be used in Circuit Shop's circuit analysis[22] functions:

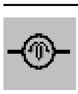
- DC analysis[22]
- Sinusoidal steady state analysis[25]
- Frequency response[27]
- Digital analysis[32]

Kirchoff's Current Law

Definition: The sum of the branch currents[84] entering a node is equal to the sum of the currents leaving a node.

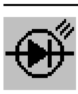
Kirchoff's Voltage Law

Definition: The sum of the voltage[95] rises around a circuit loop is equal to the sum of the voltage drops around the loop.



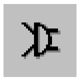
Lamp (toolkit[52] - sub-toolkit)[61]

Definition: A light producing device.



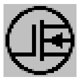
Light Emitting Diode (LED) (toolkit[52] - sub-toolkit)[56]

Definition: A special type of diode[85] which produces light when current[84] flows in the forward direction.



Microphone (toolkit[52] - sub-toolkit)[57]

Definition: An electroacoustic transducer which converts acoustic power into electrical power[91] with approximately the same waveform as the acoustic input.

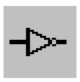


Metal-Oxide-Semiconductor Field Effect Transistor (MOSFET) (toolkit[52] - sub-toolkit)[55]

Definition: A special type of field effect transistor[86] with a higher input impedance.[88]

Mutual Inductance

Definition: The property between two current[84] carrying coils, or inductors,[89] when the magnetic field of one coil links with the magnetic field of the second coil. For a given rate of change of current in one coil, the amount of mutual inductance determines the amount of electromotive force, or voltage[95] induced in the second coil.



NOT Gate (toolkit)[51]

Definition: A single input digital device whose output level is the reverse of the input level. For example, if the input level is HIGH, (logic level 1) the output is LOW, (logic level 0).

Input	Output
0	1
1	0

NOT gates can be used in Circuit Shop's digital analysis[32] function.

Ohm

Definition: The usual measure of resistance in an electric circuit. One Ohm of resistance[92] in a conductor allows one ampere[81] of current[84] to flow when one volt[95] of electromotive force is applied.

Ohm's Law

Definition: The current[84] in an electric circuit is inversely proportional to the resistance[92] of the circuit and is directly proportional to the electromotive force (or voltage[95]) in the circuit.

In equation form

```
                    E (volts)
I (amperes)   =   -----------
                    R (ohms)

Where: I = the circuit current in amperes
       E = the applied voltage in volts
       R = the circuit resistance in ohms
```

(amperes[81], volts[95], ohms[90])

Alternative equation forms

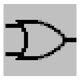
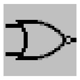
```
E (volts)   =  I (amperes) x R (ohms)

                 E (volts)
R (ohms)    =  -----------
                 I (amps)
```

Operational Amplifier (Op Amp) (toolkit[52] - sub-toolkit)[61]

Definition: A general purpose high-gain amplifier to which feedback components are added in various configurations to perform various functions such as differential amplifier, differentiator and integrator.

Related topic:

Ideal operational amplifier[88]

 **OR Gate** 

NOR Gate (toolkit)[51]

Definition: An OR gate is a digital device with a HIGH output (logic level 1) if any input is HIGH.

A NOR (NOT OR) gate is an inverted OR gate.

Input 1	Input 2	OR Output	NOR Output
0	0	0	1
0	1	1	0
1	0	1	0
1	1	1	0

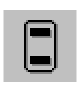
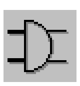
OR and NOR gates can be used in Circuit Shop's digital analysis[32] function.

Parallel Circuit

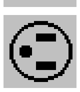
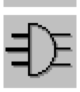
Definition: A circuit which contains more than one path for the current[84] to flow through.

Phase

Definition: In a periodic function or sine wave, the fraction of the total period measured from a fixed point. E.g. a sine wave traverses through 360 degrees, if a cycle starts, i.e. crosses the zero axis 1/4 of the way into a period, it is said to have a phase of 90 degrees.

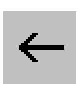
 

Two Prong Female and Male Plug

Three Prong Female and Male Plug (toolkit[52] - sub-toolkit)[57]

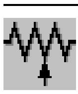
Definition: A device, with pins or receptacles which can complete a connection in an electrical circuit usually associated with 120 or 220 volts.



Plug In (toolkit[52] - sub-toolkit)[57]

Definition: A device, usually with pins which can complete a connection in an electrical circuit. A plug in device is usually associated with a receptacle.[92]

In Circuit Shop, plug ins are also used as connection points for circuit analyzers.[30]

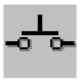


Potentiometer (POT) (toolkit[52] - sub-toolkit)[59]

Definition: A three terminal electromechanical resistive device with two fixed end terminals and one terminal connected to an adjustable contact. The adjustable contact provides a variable resistance.[92]

Power

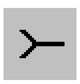
Definition: The rate of doing work. In an electrical circuit, power is equal to the applied voltage[95] times the resulting current.[84] Power is measured in watts[95] in honor of James Watt, the Scottish mechanical engineer who invented the steam engine. One watt of electrical power is equal to one volt[95] multiplied by one ampere.[81]

Push Button  - Normally Open  - Normally Closed **(toolkit[52] - sub-toolkit)[59]**

Definition: A device which momentarily completes (normally open) or breaks (normally closed) the current[84] path in an electrical circuit.

Reactance

Definition: The opposition to the flow of alternating current[81] by capacitors[82] (capacitive reactance)[83] and inductors[89] (inductive reactance).[88]



Receptacle **(toolkit[52] - sub-toolkit)[57]**

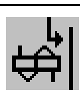
Definition: A device, usually stationary with sockets which can complete a connection in an electrical circuit. A receptacle is usually associated with a plug in.[91]

In Circuit Shop, receptacles are also used as connection points for circuit analyzers.[30]

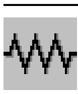
Rectification

Definition: The process of turning alternating current,[81] i.e. current[84] that flows in both directions, into pulsating direct current,[86] i.e. current that only flows in one direction.

Example half-wave rectifier[87] and full-wave rectifier[87] circuits can be found in diode exercise examples.[271]

Relay  - Normally Open  - Normally Closed **(toolkit[52] - sub-toolkit)[59]**

Definition: An electromechanical switching device consisting of a coil and an armature. Depending on the relay type, the armature has contacts which are normally open or closed. A voltage[95] applied to the coil causes the armature to move and the contacts are either closed (from normally open) or opened (from normally closed).



Resistor **(toolkit[52] - sub-toolkit)[59]**

Definition: A device connected into an electrical circuit to introduce a specified resistance.[92]

Resistors can be used in Circuit Shop's DC analysis,[22] sinusoidal steady state analysis[25] and frequency response[27] capabilities.

Resistance

Definition: The property of a conductor which impedes the passage of electric current.[84] Resistance is measured in ohms[90] in honor of the German physicist George Simon Ohm who investigated and formulated the relationship between voltage,[95] current[84] and resistance[92] (Ohm's law[90]).

Resonant Frequency

Definition: The value of frequency,[87] which causes the circuit's inductive reactance[88] to equal the capacitive reactance.[83] The resonant frequency can be calculated using the following formula

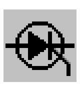
```
               1
fr  =   -------------
        2π x SQRT(LC)

Where: fr = resonant frequency in hertz
       2π ≅ 6.283 (radians in 360 degrees)
       L  = inductance in henries
       C  = capacitance in farads
```

Semiconductor

Definition: A material with a resistance[92] between metals and insulators. In other words, a semiconductor has a resistance somewhere between that of a good conductor and poor conductor.

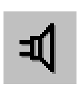
Series Circuit

Definition: A circuit which contains only one possible path for the current[84] to flow through.



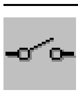
Silicon Controlled Rectifier (SCR) (toolkit[52] - sub-toolkit)[56]

Definition: A special type of diode[85] with an additional electrode called a gate. A voltage[95] applied to the gate will turn the SCR on and allow current[84] to flow. In the above icon, the left, right and bottom electrodes are called the anode, cathode and gate respectively.



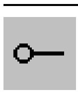
Speaker (toolkit[52] - sub-toolkit)[57]

Definition: An electroacoustic transducer which converts electrical power[91] into acoustic power into the air with approximately the same waveform as the electrical input.



Switch (toolkit[52] - sub-toolkit)[59]

Definition: A device which breaks or completes the current[84] path in an electrical circuit, or depending on the type of switch, sends the current in a different path. The above icon shows a single-pole single-throw (SPST) switch.

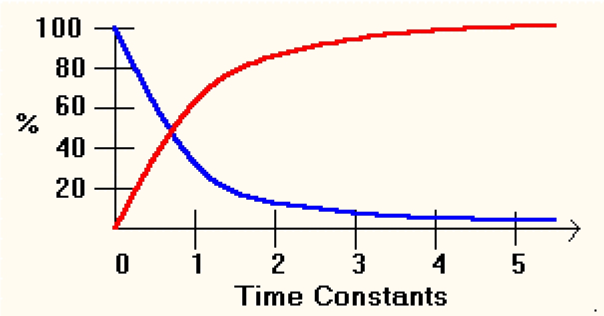


Terminal (toolkit[52] - sub-toolkit)[57]

Definition: A point of connection for two or more electrical circuit conductors.

Terminals can be used in Circuit Shop's sinusoidal steady state analysis[25] and frequency response[27] capabilities. In Circuit Shop, terminals are used as connection points for device meters[29] and circuit analyzers.[30]

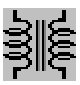
Terminals are also used to associate integrated circuit (IC)[89] pins to input/output points of the IC's internal circuit. See creating circuits inside integrated circuits.[20]



Time Constant

Definition: For a resistor-capacitor circuit

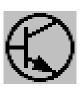
- if charging, one time constant is the amount time for the capacitor voltage[95] to reach 63% of its final value. After five time constant seconds, the capacitor will reach 99% of its final value.
- if discharging, one time constant is the amount of time for the capacitor voltage[95] to reach 37% of its initial value. After five time constant seconds, the capacitor will reach 1% of its initial value.



Transformer (toolkit[52] - sub-toolkit)[60]

Definition: A device which uses electromagnetic induction to transfer energy[86] from one circuit to another at the same frequency but with different voltage[95] and current.[84]

Transformers can be used in Circuit Shop's sinusoidal steady state analysis[25] and frequency response[27] capabilities.

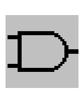


Transistor (toolkit[52] - sub-toolkit)[55]

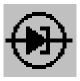
Definition: An active semiconductor[93] device, usually made of silicon and usually having three electrodes. In the above icon, starting with the electrode with the arrow, in a clockwise direction, the electrodes are called the emitter, base and collector.

Truth Table

Definition: A table usually used in digital circuits[84] to show a device's output(s) for all possible input values.

For example, the truth table for an  AND gate[82] is shown below.

Input 1	Input 2	AND Output
0	0	0
0	1	0
1	0	0
1	1	1



Tunnel Diode (toolkit[52] - sub-toolkit)[56]

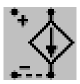
Definition: A special type of diode[85] which has the characteristic that for a certain voltage[95] range, as the voltage increases the current[84] decreases. In other words, for a certain voltage range, as the voltage increases the resistance[92] also increases, thus allowing less current to flow. This voltage range is called the "negative resistance region."

Vertex

Definition: A point along a wire[95] or line where the direction changes.

Voltage

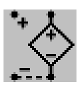
Definition: The usual measure of electromotive force in a circuit. One Volt is the amount of energy supplied to an electric circuit in one second to produce one ampere[81] of electric current[84] in the circuit.



Voltage-Controlled Current Source (VCCS) (toolkit[52] - sub-toolkit)[58]

Definition: A special type of current[84] source whose output current is equal to the input voltage[95] multiplied by a constant. In the above icon, the output current flowing between the two right hand side terminals is equal to the input voltage across the two left hand terminals multiplied by a constant.

Voltage-controlled current sources can be used in Circuit Shop's sinusoidal steady state analysis[25] and frequency response[27] capabilities.



Voltage-Controlled Voltage Source (VCVS) (toolkit[52] - sub-toolkit)[58]

Definition: A special type of voltage[95] source whose output voltage is equal to the input voltage multiplied by a constant. In the above icon, the output voltage across the two right hand side terminals is equal to the input voltage across the two left hand terminals multiplied by a constant.

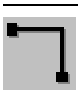
Voltage-controlled voltage sources can be used in Circuit Shop's sinusoidal steady state analysis[25] and frequency response[27] capabilities.

Watt

Definition: The usual measure of power[91] in an electric circuit. One watt of electrical power is equal to one volt[95] multiplied by one ampere.[81]

Watt-hour

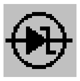
Definition: The usual measure of energy[86] in an electric circuit. One watt-hour is equivalent to one watt[95] of power used for one hour.



Wire (toolbar[37] - toolkit)[52]

Definition: One solid conductor or several conductors stranded together with a low resistance[92] to current[84] flow. Usually made from copper and insulated.

In Circuit Shop, the digital analysis[32] function will highlight wires that are HIGH (logic level 1).



Zener Diode (toolkit[52] - sub-toolkit)[56]

Definition: A special type of diode[85] which maintains a constant voltage[95] across its terminals. Zener diodes are used in voltage[95] regulator circuits. In the above icon, the left and right electrodes are called the anode and cathode respectively.

Circuit Shop Tutorial v1.09 - March 2000

This manual is a printed version of Circuit Shop's help file. There are two parts to the manual:

- The first part lists the help topics which make up Circuit Shop's reference manual. Pages in this portion are numbered **1** through **95**.

- The second part lists the topics which make up Circuit Shop's tutorial. Pages in this portion are numbered **200** through **297**.

In the on-line help system, help topics are selected by clicking on a highlighted word or set of words in a topic. In this manual, topics are referenced as page number footnotes. In other words, a footnote specifies the page number where the topic can be found. For example, the footnote on the following text, Purchasing information[7] indicates the topic can be found on page **7**.

Tutorial Help Topics

An overview and structure of Circuit Shop tutorials can be found in general tutorial introduction and instructions.[201]

Circuit Shop contains the following tutorials:

- Resistors and simple circuits[205]
- Capacitors, inductors and transformers[237]
- Alternating Current[255]
- Semiconductors[270]
- Digital circuits[282]

A roadmap of Circuit Shop's tutorial help topics can be found in tutorial topic tree[203]

Related topics:
Topic tree[3]

General Tutorial Introduction and Instructions

Each tutorial is structured in a consistent manner and consists of several exercises, and each exercise consists of several topics. For example the

Resistors and Simple Circuits Tutorial[205] consists of:

Ohm's law exercise[205]
Series circuit exercise[212]
Parallel circuit exercise[221]
Power and energy exercise[230]

Each exercise is structured in a consistent manner. Where applicable, the exercise consists of the following topics: theory, examples, demonstration circuit and detailed demonstration circuit construction. Each exercise also has a knowledge test topic with answers to selected questions. For example the

Ohm's law exercise[205] consists of:

Theory[206]
Examples[206]
Demonstration circuit[207]
Demonstration circuit construction[209]
Knowledge test[210]

To keep track of where you are in a tutorial, print the tutorial topic tree[203] using the above Circuit Shop Help window File | Print Topic menu command and tick off the exercises as they are completed.

Within a tutorial, each exercise builds on the previous, thus it is recommended that the tutorial be completed from beginning to end.

If your terminal screen is large enough, move the help window to one side and the Circuit Shop application window to the other. If both the help window and the Circuit Shop application window cannot be shown without an overlap, resize the help window to cover approximately one half of the screen. While working through the tutorial, you will have to switch from one window to another.

Alternatively, before starting an exercise, select the topic on the tutorial topic tree[203] and print the exercise using the above File | Print Topic command. The hardcopy can be used to add personal notes to the exercise.

Related topics:

Tutorial topic tree[203]

Tutorial Topic Tree

The following topic tree shows the structure of and provides quick access to the various tutorial topics.

Related Topics:

Topic tree 3

Resistors and Simple Circuits Tutorial

This tutorial covers the following topics:

- Ohm's law[90] and the relationship between resistance,[92] voltage[95] and current.[84]
- The properties of series[93] and parallel[91] circuits.
- Power[91] and energy.[86]

Exercises:

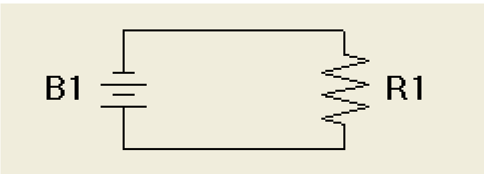
Ohm's Law[205]
Series Circuits[212]
Parallel Circuits[221]
Power and Energy[230]

Related topics:

General tutorial introduction and instructions[201]
Tutorial topic tree[203]

Resistors and Simple Circuits Tutorial

Ohm's Law Exercise



Theory

The Ohm's law equation and the relationship between voltage, current and resistance can be found in theory.[206]

Examples

The use of Ohm's law to determine a circuit's current, voltage or resistance can be found in examples.[206]

Demonstration

Ohm's law demonstration[207] provides instructions to construct a simple Circuit Shop circuit to show the relationships between voltage, current and resistance.

Knowledge test

Review questions can be found in knowledge test.[210]

Related topics:

Ohm's law theory[206]
Ohm's law examples[206]
Ohm's law demonstration circuit[207]
Ohm's law demonstration circuit construction[209]
Ohm's law knowledge test[210]
Ohm's law[90]
Voltage[95]
Current[84]
Resistance[92]
Tutorial topic tree[203]

Resistors and Simple Circuits Tutorial
Ohm's Law Exercise
Theory

The relationship between voltage,[95] current[84] and resistance[92] is fundamental to electricity and electronics. Ohm's law[90] defines this relationship. Ohm's law states

- The current in a circuit is directly proportional to the applied voltage. In other words, the greater the voltage, the greater the current.
- The current in a circuit is inversely proportional to the resistance in the circuit. In other words, the greater the resistance, the lower the current.

In equation form

$$I \text{ (amperes)} = \frac{E \text{ (volts)}}{R \text{ (ohms)}}$$

where

I = the circuit current in amperes[81]
E = the applied voltage in volts[95]
R = the circuit resistance in ohms[90]

The above equation can be arranged as

$$E = I \times R \qquad I = \frac{E}{R} \qquad R = \frac{E}{I}$$

Using the various forms of the Ohm's law equation, if any two variables are known, the third variable can be determined. See Ohm's law examples.[206]

When using Ohm's law, all variable values must be in the same basic units, for example **E** in volts, **I** in amperes and **R** in ohms. See unit conversion.[75]

Related topics:
Ohm's law exercise[205]
Ohm's law examples[206]
Ohm's law demonstration circuit[207]
Ohm's law knowledge test[210]
Ohm's law[90]
Voltage[95]
Current[84]
Resistance[92]

Resistors and Simple Circuits Tutorial
Ohm's Law Exercise
Examples

Example 1

Given a current of 1 ampere and a resistance of 100 ohms in a circuit, what is the applied voltage?

$$E = I \times R = 1 \times 100 = 100 \text{ volts}$$

Example 2

Given a voltage of 200 volts and a resistance of 50 ohms in a circuit, what is the current in the circuit?

$$I = \frac{E}{R} = \frac{200}{50} = 4 \text{ amperes}$$

Example 3

Given a voltage of 150 volts and a current of 25 amperes in a circuit, what is the resistance in the circuit?

$$R = \frac{E}{I} = \frac{150}{25} = 6 \text{ ohms}$$

Related topics:

- Ohm's law theory[206]
- Ohm's law exercise[205]
- Ohm's law knowledge test[210]
- Ohm's law[90]
- Voltage[95]
- Current[84]
- Resistance[92]

Resistors and Simple Circuits Tutorial

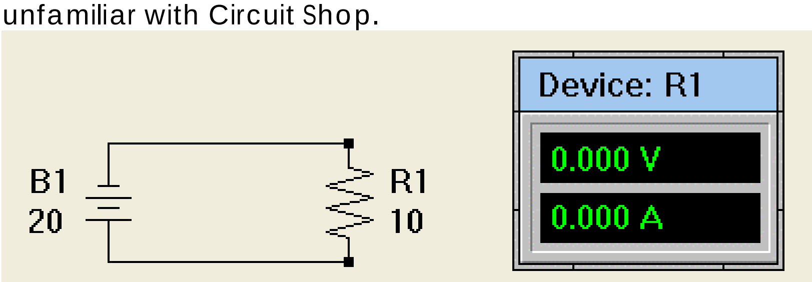
Ohm's Law Exercise

Demonstration Circuit

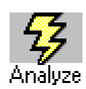
This circuit demonstrates Ohm's law[90] and shows the relationship between voltage,[95] current[84] and resistance.[92]

Step 1 - construct the circuit

Use Circuit Shop tools to construct the following circuit. See detailed instructions[209] if you are unfamiliar with Circuit Shop.



Step 2 - analyse the circuit

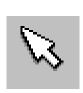
Use the Tool | Analyse[46] menu command or the toolbar[37] icon 

to analyse the circuit. Analysing a circuit[19] provides additional details.

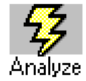
If the circuit has been correctly constructed and the device meter correctly linked to the resistor, after the analyse command has been executed, the device meter should display 20 volts[95] and 2 amps.[81] In the circuit, battery B1 applies 20 volts across resistor R1 causing a current of 2 amps to flow. Using Ohm's law,[90] the current[84] through the resistor may be calculated as follows:

$$I = \frac{E}{R} = \frac{20}{10} = 2 \text{ amperes}$$

Step 3 - increase the voltage

1. Using the mouse, click the pointer icon  on the toolbar[37] or the analog device toolkit.[52]
2. Move the mouse onto the diagram over the battery.
3. Double click the mouse on the battery to open the Edit Device dialog box.[64] Modifying device values[16] provides additional details.

4. In the value field, enter 30 as the battery's new value.

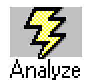
5. Use the Tool | Analyse[46] menu command or the toolbar[37] icon  to analyse the circuit.
6. After the analyse command has been executed, the device meter should display 30 volts[95] and 3 amps.[81] In the circuit, battery B1 now applies 30 volts across resistor R1's 10 ohms causing a current of 3 amps to flow. Using Ohm's law,[90] the current[84] through the resistor may be calculated as follows:

$$I = \frac{E}{R} = \frac{30}{10} = 3 \text{ amperes}$$

As stated by Ohm's law,[90] the increase in voltage has increased the current flow in the circuit.

Step 4 - increase the resistance

1. Using the mouse, click the pointer icon  on the toolbar[37] or the analog device toolkit.[52]
2. Move the mouse onto the diagram over the resistor.
3. Double click the mouse on the resistor to open the Edit Device dialog box.[64] Modifying device values[16] provides additional details.
4. In the value field, enter 60 as the resistor's new value.

5. Use the Tool | Analyse[46] menu command or the toolbar[37] icon  to analyse the circuit.
6. After the analyse command has been executed, the device meter should display 30 volts[95] and 500 milli amps.[81] In the circuit, battery B1 applies 30 volts across resistor R1's 60 ohms causing a current of 500 milli amps to flow. Using Ohm's law,[90] the current[84] through the resistor may be calculated as follows:

$$I = \frac{E}{R} = \frac{30}{60} = 0.5 \text{ amperes}$$
$$= 500 \text{ milli amps}$$

As stated by Ohm's law,[90] the increase in resistance has decreased the current flow in the circuit.

Related topics:

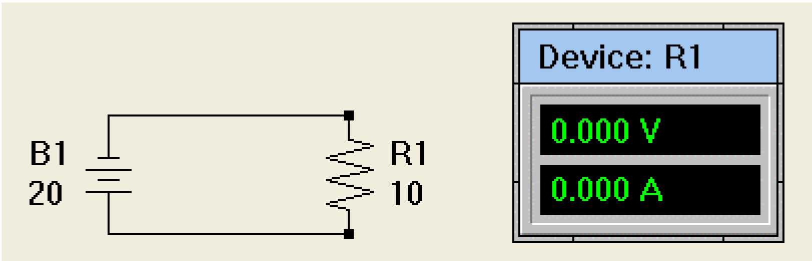
Resistors and Simple Circuits - Tutorial[205]
Ohm's law exercise[205]
Ohm's law theory[206]
Ohm's law examples[206]
Ohm's law demonstration circuit construction[209]
Ohm's law knowledge test[210]
Ohm's law[90]
Voltage[95]
Current[84]
Resistance[92]

Resistors and Simple Circuits Tutorial

Ohm's Law Exercise

Demonstration Circuit

Circuit Construction

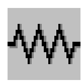


This topic provides detailed instructions to construct the Ohm's law demonstration circuit shown in the title bar above.

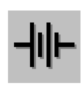
Open a diagram window and display the analog device toolkit:

1. Use the File | New[39] menu command or the toolbar[37] icon  to open a new diagram window. Creating a new diagram window[15] provides additional details.
2. Ensure the analog device toolkit[52] is visible. If the toolkit is not visible, use the View | Analog Device Toolkit[49] menu command or the toolbar icon  to display it.

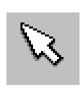
Add a resistor to the diagram:

1. Using the mouse, click the resistor icon  on the analog device toolkit.[52]
2. Move the mouse onto the diagram to approximately the center of the diagram window.
3. Click the mouse to place the resistor on the diagram. Adding devices[12] provides additional details.

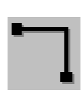
Add a battery to the diagram:

1. Using the mouse, click the battery icon  on the analog device toolkit.[52]
2. Move the mouse onto the diagram to where the battery is to be located. See circuit layout in title bar.
3. Click the mouse to place the battery on the diagram.

Layout the circuit and rotate the devices:

1. Using the mouse, click the pointer icon  on the toolbar[37] or the analog device toolkit.[52]
2. If necessary, move either the resistor or battery so they are horizontally aligned. See circuit layout in title bar. To move a device, press the left mouse button over a device and drag it to the new location. Moving devices[17] provides additional details.
3. By default, Circuit Shop places resistors and batteries on a diagram in a horizontal orientation. To rotate the resistor, press the left mouse button over one of the resistor terminals and drag it to a vertical orientation. Rotating devices[18] provides additional details.
4. Repeat step (3) to rotate the battery. After this step, both devices should be side by side and vertically aligned as shown in the title bar above.

Add wires to connect the devices:

1. Using the mouse, click the wire icon  on the toolbar[37] or the analog device toolkit.[52]
2. Move the mouse onto the diagram over the top battery terminal.

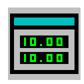
3. Press the left mouse button and drag the wire to the top resistor terminal. Connecting devices[14] provides additional details.
4. Repeat steps (2) and (3) to connect the bottom device terminals. At this point the circuit connections are complete and should look as shown in the title bar above.

Add ids and values to the devices:

1. Using the mouse, click the pointer icon  on the toolbar[37] or the analog device toolkit.[52]
2. Move the mouse onto the diagram over the resistor.
3. Double click the mouse on the resistor to open the Edit Device dialog box.[64] Modifying device values[16] provides additional details.
4. Enter 1 as the resistor id and 10 ohms as its value.
5. Repeat step (3) on the battery and enter 1 as the battery id and 20 volts as its value.
6. Because of the vertical device orientation, the displayed ids and values, called annotations, need to be moved. See the circuit layout in title bar above for suggested annotation locations. To move an annotation, press the left mouse button over the annotation and drag it to the new location. Moving objects[17] provides additional details.

   At this point the circuit is complete. The devices have been added, wires have been added to connect the devices, and their ids and values have been defined.

Add a device meter to the diagram:

1. Using the mouse, click the device meter[29] icon  on the analog device toolkit.[52]
2. Move the mouse onto the diagram to a position just to the right of the resistor as shown in the title bar above.
3. Click the mouse to place the meter on the diagram. Adding objects[12] provides additional details.

Link the meter to the resistor:

1. Using the mouse, click the pointer icon  on the toolbar[37] or the analog device toolkit.[52]
2. Move the mouse onto the diagram over the device meter.[29]
3. Double click the mouse on the meter to open the Edit Meter dialog box.[68] Modifying object values[16] provides additional details.
4. To link the meter to the resistor, select Resistor as the device type and 1 as the id.

   At this point the circuit construction is complete. Return to Ohm's law demonstration[207] to complete the exercise.

Related topics:

- Creating and editing diagrams[11]
- Menu commands[37]
- Toolbar commands[37]
- Device and drawing toolkits[51]
- Dialog boxes[62]

Resistors and Simple Circuits Tutorial

Ohm's Law Exercise

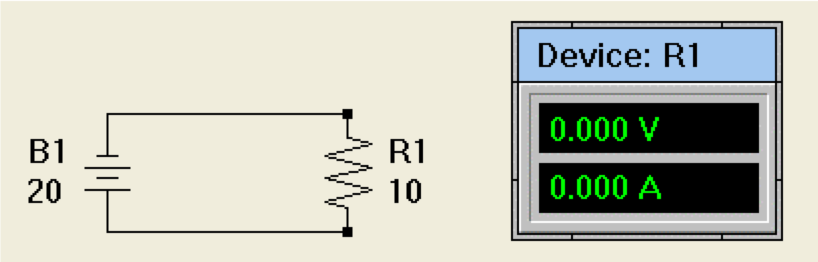
Knowledge test

1. Ohm's law states, the greater the voltage, the _______ the current. (answer)(3)[291]
2. Ohm's law states, the greater the resistance, the _______ the current. (answer)(4)[291]

3. Given a current of 0.5 amperes and a resistance of 2000 ohms in a circuit, what is the applied voltage? (answer)(5)[291]
4. Given a current of 3 amperes and a resistance of 50 ohms in a circuit, what is the applied voltage?

5. Given a voltage of 50 volts and a resistance of 200 ohms in a circuit, what is the current in the circuit? (answer)(6)[291]
6. Given a voltage of 150 volts and a resistance of 25 ohms in a circuit, what is the current in the circuit?

7. Given a voltage of 500 volts and a current of 50 amperes in a circuit, what is the resistance in the circuit? (answer)(7)[291]
8. Given a voltage of 12 volts and a current of 0.05 amperes in a circuit, what is the resistance in the circuit?



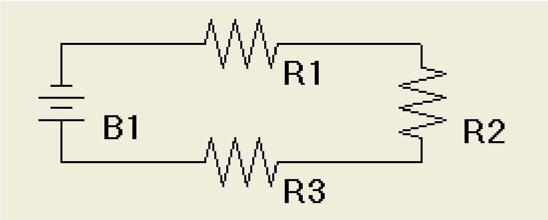
9. Using the Ohm's law demonstration circuit[207] with the following values
   B1 = 24.5 volts
   R1 = 215 ohms
   What is the current through R1? (answer)(8)[291]
10. Confirm the above answer using the Ohm's law equation.

Related topics:

- Ohm's law theory[206]
- Ohm's law examples[206]
- Ohm's law exercise[205]
- Resistors and Simple Circuits - Tutorial[205]

Resistors and Simple Circuits Tutorial

Series Circuit Exercise



Theory

The relationship between voltage, current and resistance in a series circuit[93] can be found in theory.[212]

Examples

The use of Ohm's law to determine a series circuit's current, voltage or resistance can be found in examples.[213]

Demonstration

Series circuit demonstration[215] provides instructions to construct a simple Circuit Shop circuit to show the relationships between voltage, current and resistance in a series circuit.

Knowledge test

Review questions can be found in knowledge test.[219]

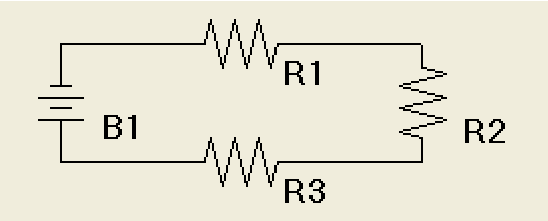
Related topics:

- Series circuit theory[212]
- Series circuit examples[213]
- Series circuit demonstration circuit[215]
- Series circuit demonstration circuit construction[217]
- Series circuit knowledge test[219]
- Parallel circuit exercise[221]
- Ohm's law exercise[205]
- Series circuit[93]
- Parallel circuit[91]
- Ohm's law[90]
- Voltage[95]
- Current[84]
- Resistance[92]
- Tutorial topic tree[203]

Resistors and Simple Circuits Tutorial

Series Circuit Exercise

Theory



A series circuit[93] is composed of circuit components connected end-to-end. A characteristic of a series circuit is that all circuit current flows through each circuit component. In other words, the same amount of current flows through each series circuit component.

Series circuit resistance
The total resistance in a series circuit is the sum of the individual resistances. In the above circuit

```
R (total)  =  R1 + R2 + R3
```

In general, the total resistance for a series circuit with resistances R1, R2, R3, R4, ... is

```
R (total)  =  R1 + R2 + R3 + R4 + ...
```

Series circuit current
Using Ohm's law,[90] the total current in a series circuit is equal to the total applied voltage divided by the total resistance. In the above circuit

```
                 E (total)
I (total)  =   -----------
                 R (total)
```

Voltage drop
Using Kirchoff's voltage law,[89] the sum of voltage drops around a series circuit is equal to the applied voltage.[95] Using the fact the same circuit current flows through each device, Ohm's law can be used to determine the voltage drop across each resistor.

```
E (R1)  =  I (total) x R1
E (R2)  =  I (total) x R2
E (R3)  =  I (total) x R3
```

The sum of the of the voltage drops equal the applied voltage.

```
E (B1)  =  E (R1)  +  E (R2)  +  E (R3)
```

Series circuit examples[213] works through an example of the use of the above equations.

Power
Series circuit power[232] describes how power[91] is calculated in a series circuit.

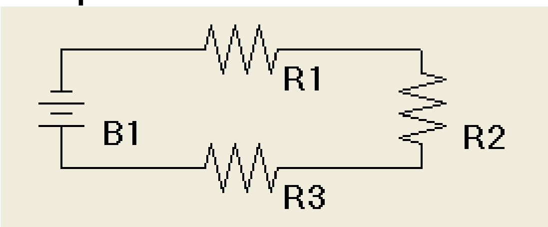
Related topics:
- Kirchoff's voltage law[89]
- Series circuit exercise[212]
- Series circuit examples[213]
- Series circuit demonstration circuit[215]
- Series circuit knowledge test[219]
- Power and energy exercise[230]

Resistors and Simple Circuits Tutorial

Series Circuit Exercise

Examples

Example 1



Circuit values

```
B1 = 120 volts
R1 =  10 ohms
R2 =  20 ohms
R3 =  30 ohms
```

The total resistance[92] in a series circuit[93] is the sum of the individual resistances. In the above circuit

```
R (total)  =  R1  +  R2  +  R3
           =  10  +  20  +  30
           =  60 ohms
```

Using Ohm's law,[90] the total current[84] in a series circuit is equal to the total applied voltage[95] divided by the total resistance. In the above circuit

```
I (total)  =  E (total) / R (total)
           =  120 / 60
           =  2 amps
```

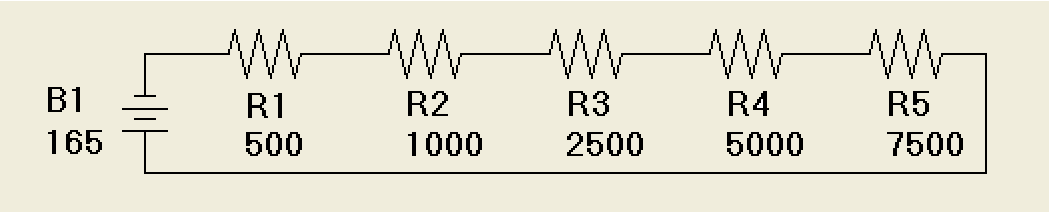
Using the fact the same circuit current flows through each device, Ohm's law can be used to determine the voltage drop across each resistor.

```
E (R1)  =  I (total) x R1
        =  2 x 10
        = 20 volts

E (R2)  =  I (total) x R2
        =  2 x 20
        = 40 volts

E (R3)  =  I (total) x R3
        =  2 x 30
        = 60 volts
```

Kirchoff's voltage law[89] states the sum of voltage drops around a series circuit is equal to the applied voltage.

```
E (drops)    =  E (R1)  +  E (R2)  +  E (R3)
             =  20 + 40 + 60
             =  120 volts

E (applied)  =  B1
             =  120 volts
```

Example 2



Given a series circuit[93] with five resistors as shown and an applied voltage[95] of 165 volts, determine the circuit current.[84]

The total resistance[92] in a series circuit is the sum of the individual resistances. In the above circuit

```
R (total)  =  R1  + R2   + R3   + R4   + R5
           =  500 + 1000 + 2500 + 5000 + 7500
           =  16500 ohms
```

Using Ohm's law,[90] the total current in a series circuit is equal to the total applied voltage divided by the total resistance.

```
I (total)  =  E (total) / R (total)
           =  165 / 16500
           =  0.01 amps
           =  10 mA
```

Related topics:

- Series circuit theory[212]
- Series circuit exercise[212]
- Series circuit knowledge test[219]
- Series circuit[93]

Resistors and Simple Circuits Tutorial

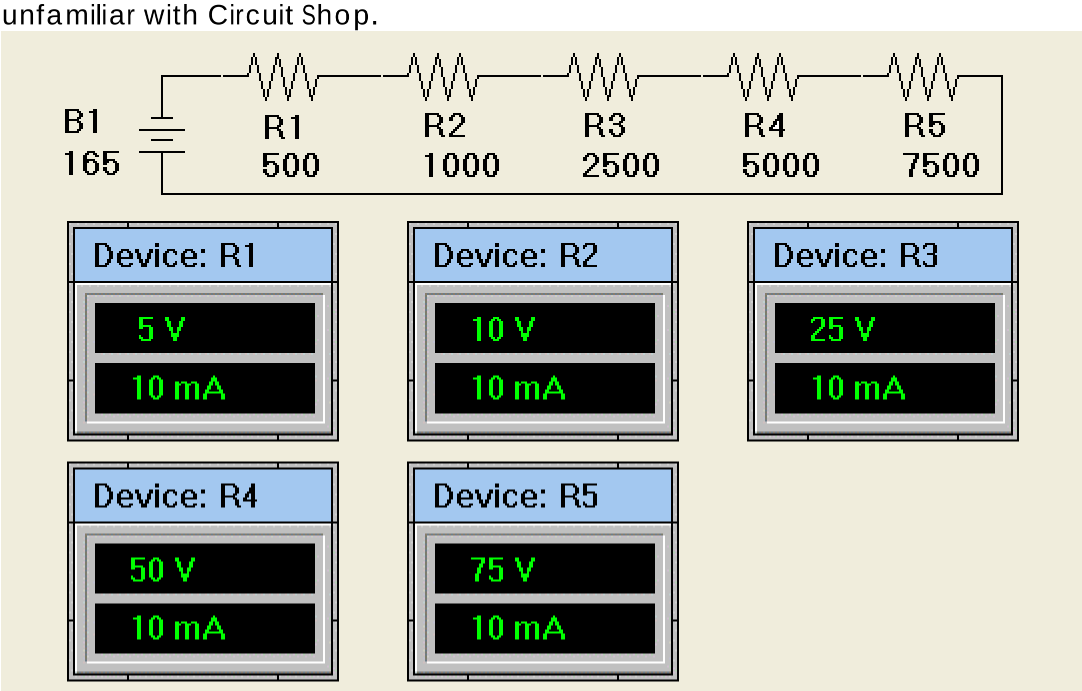
Series Circuit Exercise

Demonstration Circuit

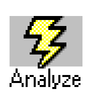
This circuit demonstrates the relationship between voltage,[95] current[84] and resistance[92] in a series circuit.[93]

Step 1 - construct the circuit

Use Circuit Shop tools to construct the following circuit. See detailed instructions[217] if you are unfamiliar with Circuit Shop.



Step 2 - analyse the circuit

Use the Tool | Analyse[46] menu command or the toolbar[37] icon  to analyse the circuit. Analysing a circuit[19] provides additional details.

If the circuit has been correctly constructed and the device meters correctly linked to the resistors, after the analyse command has been executed, the device meters should display the following voltages[95] and currents.[84]

```
Voltage     Current
(volts)      (mA)
```

R1	5	10
R2	10	10
R3	25	10
R4	50	10
R5	75	10
	===	
	165	

As stated in Kirchoff's voltage law,[89] the sum of the device meter voltages, 165 volts is equal to the applied voltage by battery B1.

The total resistance in a series circuit is the sum of the individual resistances.

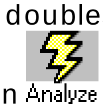
```
R (total)  =  R1   + R2   + R3   + R4   + R5
           =  500 + 1000 + 2500 + 5000 + 7500
           =  16500 ohms
```

Using Ohm's law,[90] the total current in a series circuit is equal to the total applied voltage divided by the total resistance.

```
I (total)  =  E (total) / R (total)
           =  165 / 16500
           =  0.01 amps
           =  10 mA
```

As shown in each device meter, this current flows through each resistor. Series circuits have the property that the current is the same through each device.

Step 2 - increase the voltage

1. Using the mouse, click the pointer icon  on the toolbar[37] or the analog device toolkit.[52]
2. Move the mouse onto the diagram over the battery.
3. Double click the mouse on the battery to open the Edit Device dialog box.[64] Modifying device values[16] provides additional details.
4. In the value field, enter 200 as the battery's new value. This doubles the applied voltage.
5. Use the Tool | Analyse[46] menu command or the toolbar[37] icon 

to analyse the circuit.
6. After the analyse command has been executed, the device meter should display the following voltages and currents.

	Voltage (volts)	Current (mA)
R1	10	20
R2	20	20
R3	50	20
R4	100	20
R5	150	20
	===	
	300	

As expected, since the applied voltage was doubled, the resulting circuit current doubled to 20 mA and the voltage across each resistor doubled. Using Ohm's law, the total current in a series circuit is equal to the total applied voltage divided by the total resistance.

```
I (total)  =  E (total) / R (total)
           =  300 / 16500
           =  0.02 amps
           =  20 mA
```

Related topics:

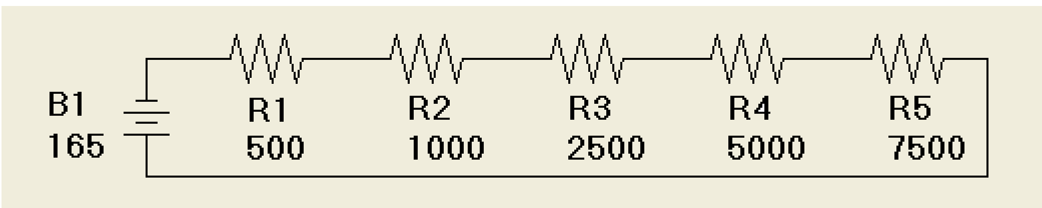
- Resistors and Simple Circuits - Tutorial[205]
- Series circuit exercise[212]
- Series circuit theory[212]
- Series circuit examples[213]
- Series circuit demonstration circuit construction
- Series circuit knowledge test[219]
- Parallel circuit exercise[221]
- Ohm's law exercise[205]
- Ohm's law[90]
- Voltage[95]
- Current[84]
- Resistance[92]

Resistors and Simple Circuits Tutorial

Series Circuit Exercise

Demonstration Circuit

Circuit Construction



This topic provides detailed instructions to construct the series circuit demonstration circuit shown in the title bar above.

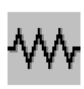
Open a diagram window and display the analog device toolkit:

1. Use the File | New[39] menu command or the toolbar[37] icon 

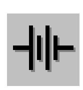
to open a new diagram window. Creating a new diagram window[15] provides additional details.
2. Ensure the analog device toolkit[52] is visible. If the toolkit is not visible, use the View | Analog Device Toolkit[49] menu command or the toolbar icon 

to display it.

Add resistors to the diagram:

1. Using the mouse, click the resistor icon  on the analog device toolkit.[52]
2. Move the mouse onto the diagram to approximately the center of the diagram window.
3. Click the mouse to place the resistor on the diagram. Adding devices[12] provides additional details.
4. Repeat step (3) to add five resistors to the diagram as shown in the title bar above.

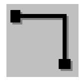
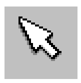
Add a battery to the diagram:

1. Using the mouse, click the battery icon  on the analog device toolkit.[52]
2. Move the mouse onto the diagram to where the battery is to be located. See circuit layout in title bar.
3. Click the mouse to place the battery on the diagram.

Layout the circuit and rotate the devices:

1. Using the mouse, click the pointer icon  on the toolbar[37] or the analog device toolkit.[52]
2. If necessary, move the resistors so they are horizontally aligned. See circuit layout in title bar. To move a device, press the left mouse button over a device and drag it to the new location. Moving devices[17] provides additional details.
3. By default, Circuit Shop places resistors and batteries on a diagram in a horizontal orientation. To rotate the battery, press the left mouse button over one of the battery terminals and drag it to a vertical orientation. Rotating devices[18] provides additional details.
4. Move the battery so the top battery terminal is aligned with the left-most resistor terminal. See circuit layout in title bar.

Add wires to connect the devices:

1. Using the mouse, click the wire icon  on the toolbar[37] or the analog device toolkit.[52]
2. Move the mouse onto the diagram over the top battery terminal.
3. Press the left mouse button and drag the wire to the left-most resistor terminal. Connecting devices[14] provides additional details.
4. Repeat steps (2) and (3) to connect each of the resistor terminals to form a "string" of resistors.
5. Repeat steps (2) and (3) to connect the right-most resistor terminal to the bottom battery terminal.
6. To "square" up the circuit, a vertex[95] needs to be added to the wire. Using the mouse, click the pointer icon  on the toolbar[37] or the analog device toolkit.[52] To add a vertex, move the pointer over the wire added in step (5), press the left mouse button and drag the wire to the new location. Adding a wire vertex[12] provides additional details.

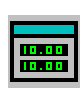
   At this point the circuit connections are complete and should look as shown in the title bar above.

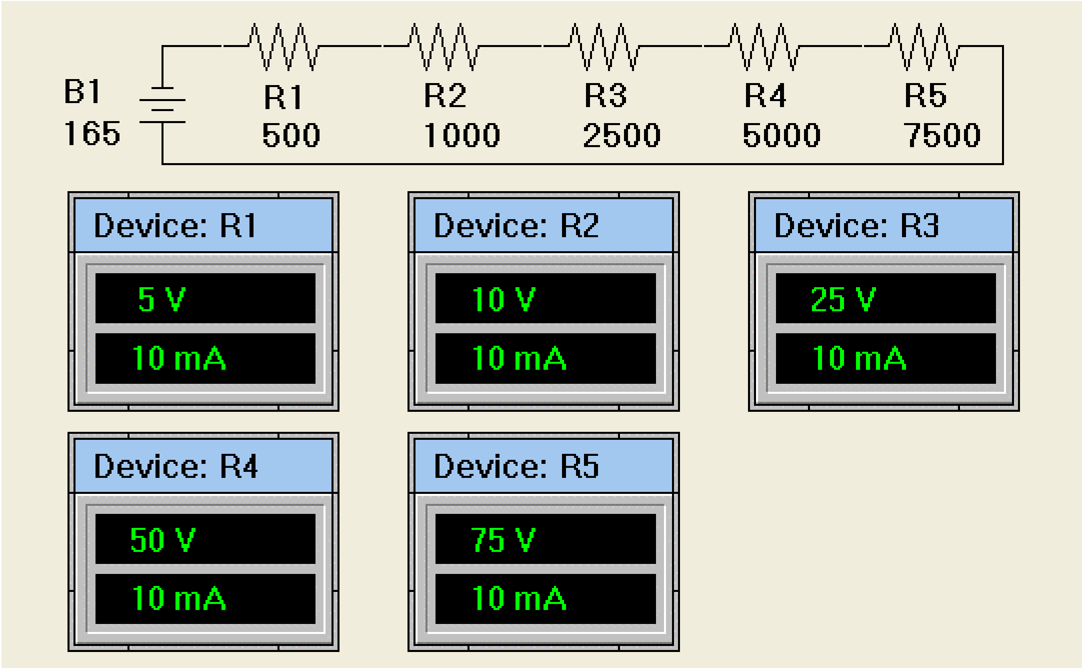
Add ids and values to the devices:

1. Using the mouse, click the pointer icon  on the toolbar[37] or the analog device toolkit.[52]
2. Move the mouse onto the diagram over the left-most resistor.
3. Double click the mouse on the resistor to open the Edit Device dialog box.[64] Modifying device values[16] provides additional details.
4. Enter 1 as the resistor id and 500 ohms as its value.
5. Repeat steps (3) and (4) on the other resistors, enter 2, 3, 4 and 5 as the resistor ids and 1000, 2500, 5000, 7500 ohms as their values.
6. Repeat step (3) on the battery and enter 1 as the battery id and 165 volts as its value.
7. Because of the vertical device orientation of the battery, the displayed id and value, called annotations, need to be moved. See the circuit layout in title bar above for suggested annotation locations. To move an annotation, using the pointer, press the left mouse button over the annotation and drag it to the new location. Moving objects[17] provides additional details.

   At this point the circuit is complete. The devices have been added, wires have been added to connect the devices, and their ids and values have been defined.

Add device meters to the diagram:

1. Using the mouse, click the device meter[29] icon  on the analog device toolkit.[52]
2. Five device meters need to be added to the diagram as shown below.



To add the first meter, move the mouse onto the diagram to a position just under the battery as shown in the title bar above.

3. Click the mouse to place the meter on the diagram. Adding objects[12] provides additional details.
4. Repeat step (3) to add the other four meters as shown above.

Link the meters to the resistors:

1. Using the mouse, click the pointer icon  on the toolbar[37] or the analog device toolkit.[52]
2. Move the mouse onto the diagram over the first device meter.[29]
3. Double click the mouse on the meter to open the Edit Meter dialog box.[68] Modifying object values[16] provides additional details.
4. To link the meter to the resistor, select Resistor as the device type and 1 as the id.
5. Repeat steps (2), (3) and (4) on the other meters, select Resistor as the device type and enter 2, 3, 4 and 5 as the device ids.

At this point the circuit construction is complete. Return to series circuit demonstration[215] to complete the exercise.

Related topics:

Creating and editing diagrams[11]
Menu commands[37]
Toolbar commands[37]
Device and drawing toolkits[51]
Dialog boxes[62]

Resistors and Simple Circuits Tutorial

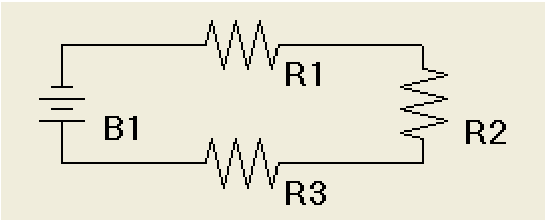
Series Circuit Exercise

Knowledge test

1. The total resistance in a series circuit is the _______ of the individual resistances.
2. In a series circuit, the _______ current flows through each device.

3. Given a series circuit with 3 resistors with values 100, 150, and 500 ohms, what is the total resistance? (answer)(9)[291]

4. Given a series circuit with 3 resistors with values 500, 750, and 1000 ohms, what is the total resistance?



5. In the above series circuit, what is the circuit current, with device values:

```
B1 =  12 volts
R1 = 250 ohms
R2 = 500 ohms
R3 = 750 ohms
```

(answer)(10)[292]

6. In the above series circuit, what is the circuit current, with device values:

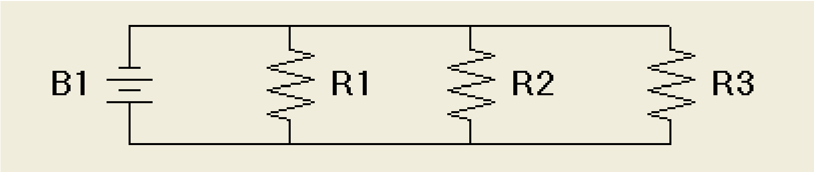
```
B1 =  120 volts
R1 =   50 ohms
R2 =  450 ohms
R3 = 1000 ohms
```

Related topics:

Series circuit theory[212]
Series circuit examples[213]
Series circuit exercise[212]
Resistors and Simple Circuits - Tutorial[205]

Resistors and Simple Circuits Tutorial

Parallel Circuit Exercise



Theory

The relationship between voltage, current and resistance in a parallel circuit[91] can be found in theory.[221]

Examples

The use of Ohm's law to determine a parallel circuit's current, voltage or resistance can be found in examples.[223]

Demonstration

Parallel circuit demonstration[225] provides instructions to construct a simple Circuit Shop circuit to show the relationships between voltage, current and resistance in a parallel circuit.

Knowledge test

Review questions can be found in knowledge test.[228]

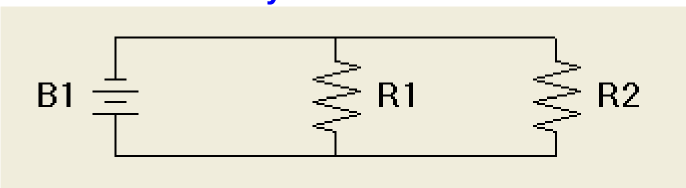
Related topics:

Parallel circuit theory[221]
Parallel circuit examples[223]
Parallel circuit demonstration circuit[225]
Parallel circuit demonstration circuit construction[226]
Parallel circuit knowledge test[228]
Series circuit exercise[212]
Ohm's law exercise[205]
Parallel circuit[91]
Series circuit[93]
Ohm's law[90]
Voltage[95]
Current[84]
Resistance[92]
Tutorial topic tree[203]

Resistors and Simple Circuits Tutorial

Parallel Circuit Exercise

Theory



A parallel circuit[91] is composed of circuit components connected side-by-side such that the circuit current[84] has multiple paths.

Parallel circuit current

In the above circuit, R1 and R2 are connected in "parallel" to battery B1, i.e. battery B1 applies its voltage[95] equally across resistors R1 and R2.

Using Ohm's law,[90] the current in each branch of the parallel circuit is equal to the voltage applied across the branch divided by the branch resistance. In the above circuit, the current through R1's branch is the voltage applied by B1 divided by the resistance of the branch. The current through R2's branch may be found in a similar manner.

```
I (R1)  =  E (B1) / R1
I (R2)  =  E (B1) / R2
```

Kirchoff's current law[89] states the total current in a parallel circuit is equal to the sum of the branch currents. In the above circuit, the total current is the sum of the currents through each branch.

```
I (total)  =  I (R1)  +  I (R2)
```

In general, the total current in a parallel circuit with branch currents I1, I2, I3, ... is

```
I (total)  =  I1 + I2 + I3 + ...
```

Parallel circuit resistance

The general formula for finding the total resistance of resistances in parallel (sometimes called the reciprocal of reciprocals) is

```
                         1
R (total) = --------------------
             1     1     1
            --- + --- + --- + ...
             R1    R2    R3
```

Note: The total resistance of resistors in parallel is always less than the lowest branch resistance value. This is because the total current for a parallel circuit is always greater than the current through any individual branch.

For two resistors in parallel, the formula can be arranged as

```
              R1 x R2
R (total) = -----------
             R1  +  R2
```

For N parallel resistors of equal value R, another special case formula can be used

```
             R
R (total) = ---
             N
```

A second approach to determining the total resistance of a parallel circuit:

1. Use Ohm's law to determine the current through each branch.
2. Sum the branch currents to determine the total circuit current.
3. Use Ohm's law again to determine the total resistance based on the applied voltage divided by the total circuit current.

For example, a circuit with a voltage source E1 and three parallel resistors, R1, R2 and R3.

```
1.      I1  =  E1 / R1
        I2  =  E1 / R2
        I3  =  E1 / R3

2.      I (total)  =  I1 + I2 + I3

3.      R (total)  =  E1 / I (total)
```

Parallel circuit examples[223] works through an example of the use of the above equations.

Power

Parallel circuit power[233] describes how power[91] is calculated in a parallel circuit.

Related topics:

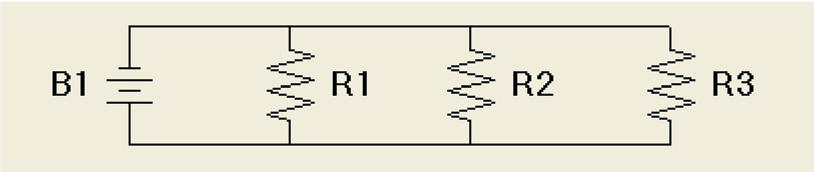
- Kirchoff's current law[89]
- Parallel circuit exercise[221]
- Parallel circuit examples[223]
- Parallel circuit demonstration circuit[225]
- Power and energy exercise[230]

Resistors and Simple Circuits Tutorial

Parallel Circuit Exercise

Examples

Example 1



Circuit values

```
B1 =  120 volts
R1 =  100 ohms
R2 =  500 ohms
R3 = 2000 ohms
```

As described in parallel circuit theory,[221] the total resistance[92] in a parallel circuit[91] may be found using the following general formula.

```
                          1
R (total) = ---------------------
             1     1     1
            --- + --- + --- + ...
             R1    R2    R3
```

Using the circuit values

```
R (total)
  = 1 / ( 1/R1  + 1/R2  + 1/R3   )
  = 1 / ( 1/100 + 1/500 + 1/2000 )
  = 1 / ( 0.01  + 0.002 + 0.0005 )
  = 1 / 0.0125
  = 80 ohms
```

Using Ohm's law,[90] the total current[84] in a parallel circuit is equal to the total applied voltage[95] divided by the total resistance. In the above circuit

```
I (total)  =  E (total) / R (total)
           =  120 / 80
           =  1.5 amps
```

The total resistance and total current of a parallel circuit may be verified as follows:

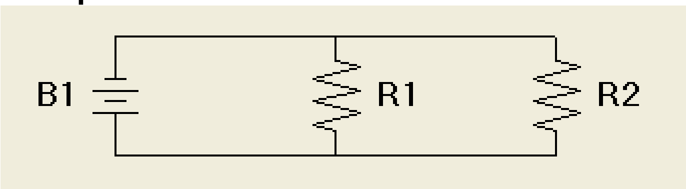
1. Use Ohm's law to determine the current through each branch.
2. Sum the branch currents to determine the total circuit current.

3. Use Ohm's law again to determine the total resistance based on the applied voltage divided by the total circuit current.

In the above circuit

```
1.      I1  =  E1 / R1  =  120 /  100  =  1.2  amps
        I2  =  E1 / R2  =  120 /  500  =  0.24 amps
        I3  =  E1 / R3  =  120 / 2000  =  0.06 amps

2.      I (total)  =   I1 +   I2 +   I3
                   =  1.2 + 0.24 + 0.06
                   =  1.5 amps

3.      R (total)  =   E1 / I (total)
                   =  120 / 1.5
                   =  80 ohms
```

Example 2



Circuit values

```
B1 =  120 volts
R1 =  100 ohms
R2 =  400 ohms
```

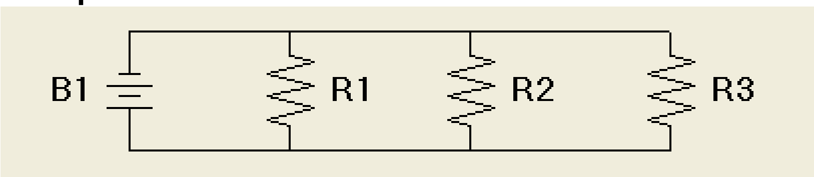
As described in parallel circuit theory,[221] the total resistance[92] in a parallel circuit[91] containing two resistors may be found using the following special case formula.

```
R (total) = -----------
              R1 x R2
             R1  +  R2
```

In the above circuit

```
R (total)
  = (100 x 400) / (100 + 400)
  = 40000 / 500
  = 80 ohms
```

Example 3



Circuit values

```
B1 =  120 volts
R1 =  150 ohms
R2 =  150 ohms
R3 =  150 ohms
```

As described in parallel circuit theory,[221] the total resistance[92] in a parallel circuit[91] containing resistors of equal value may be found using the following special case formula.

R

```
R (total) = ---
             N
```

In the above circuit

```
R (total) = 150 / 3
          = 50 ohms
```

Related topics:

- Parallel circuit theory[221]
- Parallel circuit exercise[221]
- Parallel circuit[91]

Resistors and Simple Circuits Tutorial

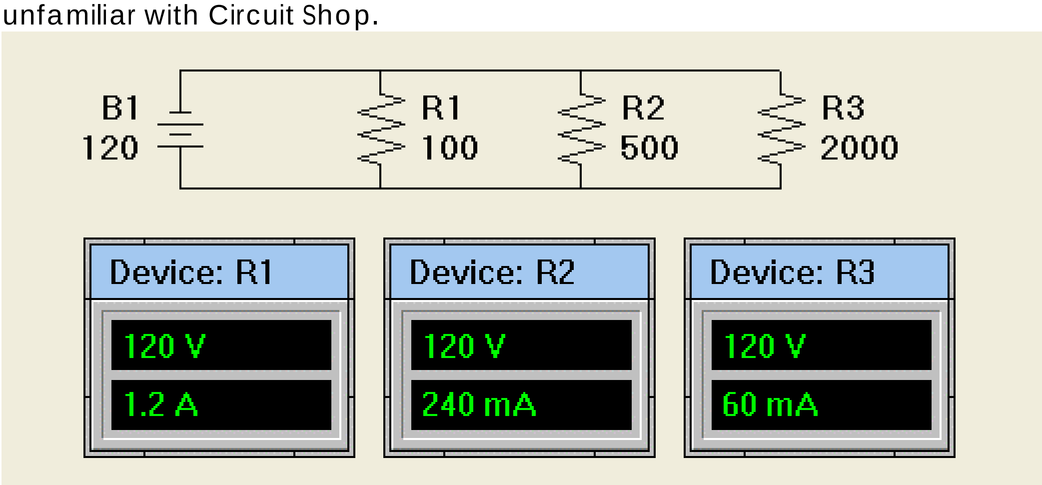
Parallel Circuit Exercise

Demonstration Circuit

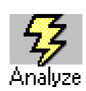
This circuit demonstrates the relationship between voltage,[95] current[84] and resistance[92] in a parallel circuit.[91]

Step 1 - construct the circuit

Use Circuit Shop tools to construct the following circuit. See detailed instructions[226] if you are unfamiliar with Circuit Shop.



Step 2 - analyse the circuit

Use the Tool | Analyse[46] menu command or the toolbar[37] icon 

to analyse the circuit. Analysing a circuit[19] provides additional details.

If the circuit has been correctly constructed and the device meters correctly linked to the resistors, after the analyse command has been executed, the device meters should display the following voltages[95] and currents.[84]

	Voltage (volts)	Current (mA)
R1	120	1200
R2	120	240
R3	120	60
		====
		1500 = 1.5 amps

As stated in Kirchoff's current law,[89] the sum of the branch currents as shown by the device meter currents, 1.5 amps, is the total current in the parallel circuit.

Using Ohm's law,[90] the total resistance in a parallel circuit is equal to the total applied voltage divided by the total current. For the above circuit

```
R (total)  =  E (total) / I (total)
           =  120 / 1.5
           =  80 ohms
```

As described in parallel circuit theory,[221] the total resistance[92] in a parallel circuit[91] is always less than any individual branch resistance. In the above circuit, the total resistance is 80 ohms which is less than the lowest branch resistance, 100 ohms.

Related topics:

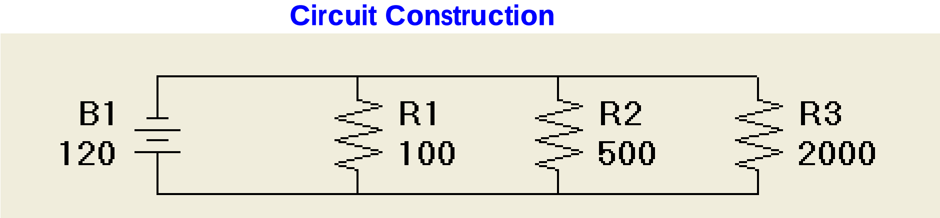
- Resistors and Simple Circuits - Tutorial[205]
- Parallel circuit exercise[221]
- Parallel circuit theory[221]
- Parallel circuit examples[223]
- Parallel circuit demonstration circuit construction
- Series circuit exercise[212]
- Ohm's law exercise[205]
- Ohm's law[90]
- Voltage[95]
- Current[84]
- Resistance[92]

Resistors and Simple Circuits Tutorial

Parallel Circuit Exercise

Demonstration Circuit

Circuit Construction



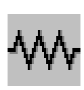
This topic provides detailed instructions to construct the parallel circuit demonstration circuit shown in the title bar above.

Open a diagram window and display the analog device toolkit:

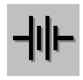
1. Use the File | New[39] menu command or the toolbar[37] icon 

to open a new diagram window. Creating a new diagram window[15] provides additional details.
2. Ensure the analog device toolkit[52] is visible. (hint1)[76]

Add resistors to the diagram:

1. Using the mouse, click the resistor icon  on the analog device toolkit.[52]
2. Move the mouse onto the diagram to approximately the center of the diagram window.
3. Click the mouse to place the resistor on the diagram. Adding devices[12] provides additional details.
4. Repeat step (3) to add two more resistors to the diagram as shown in the title bar above.

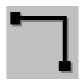
Add a battery to the diagram:

1. Using the mouse, click the battery icon  on the analog device toolkit.[52]
2. Move the mouse onto the diagram to where the battery is to be located. See circuit layout in the title bar above.
3. Click the mouse to place the battery on the diagram.

Use the pointer tool to layout the circuit and rotate the devices:

1. Using the mouse, click the pointer icon  on the toolbar[37] or the analog device toolkit.[52]
2. As necessary, move the battery and resistors so they are side-by-side, horizontally aligned. See circuit layout in the title bar above. To move a device, press the left mouse button over a device and drag it to the new location. Moving devices[17] provides additional details.
3. By default, Circuit Shop places resistors and batteries on a diagram in a horizontal orientation. To rotate the battery and each resistor, press the left mouse button over one of the device's terminals and drag it to a vertical orientation. Rotating devices[18] provides additional details.

Add wires to connect the devices:

1. Using the mouse, click the wire icon  on the toolbar[37] or the analog device toolkit.[52]
2. Move the mouse onto the diagram over the top battery terminal.
3. Press the left mouse button and drag the wire to the left-most resistor top terminal. Connecting devices[14] provides additional details.
4. Repeat steps (2) and (3) to connect each top resistor terminal, the bottom battery terminal to the left-most resistor bottom terminal, and each bottom resistor terminal.

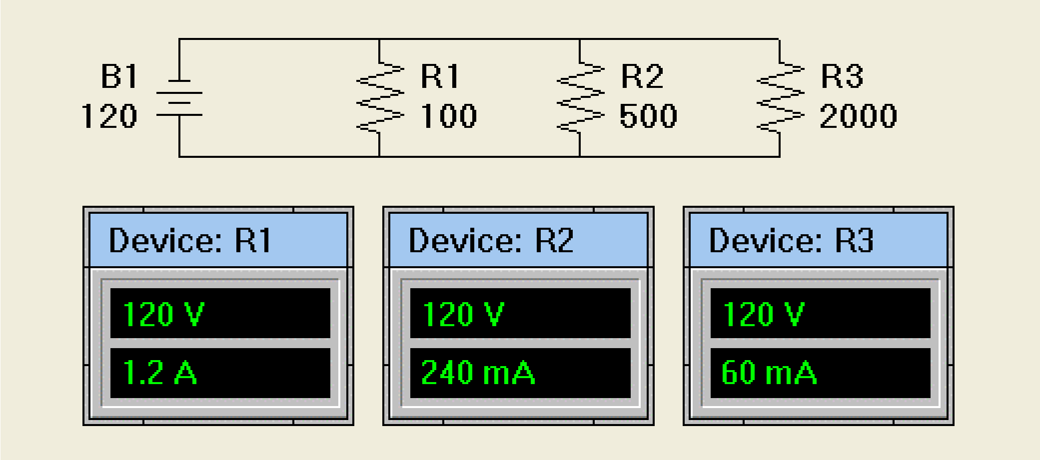
   At this point the circuit connections are complete and should look as shown in the title bar above.

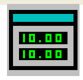
Add ids and values to the devices:

1. Using the mouse, click the pointer icon  on the toolbar[37] or the analog device toolkit.[52]
2. Move the mouse onto the diagram over the left-most resistor.
3. Double click the mouse on the resistor to open the Edit Device dialog box.[64] Modifying device values[16] provides additional details.
4. Enter 1 as the resistor id and 100 ohms as its value.
5. Repeat steps (3) and (4) on the other resistors, enter 2 and 3 as the resistor ids and 500, 2000 ohms as their values.
6. Repeat step (3) on the battery and enter 1 as the battery id and 120 volts as its value.
6. Because of the vertical device orientation of the devices, the displayed ids and values, called annotations, need to be moved. See the circuit layout in title bar above for suggested annotation locations. To move an annotation, using the pointer, press the left mouse button over the annotation and drag it to the new location. Moving objects[17] provides additional details.

   At this point the circuit is complete. The devices have been added, wires have been added to connect the devices, and their ids and values have been defined.

Add device meters to the diagram:



1. Using the mouse, click the device meter[29] icon  on the analog device toolkit.[52]
2. Three device meters need to be added to the diagram. To add the first meter, move the mouse onto the diagram to a position just under the battery as shown above.
3. Click the mouse to place the meter on the diagram. Adding objects[12] provides additional details.
4. Repeat step (3) to add the other two meters as shown above.

Link the meters to the resistors:

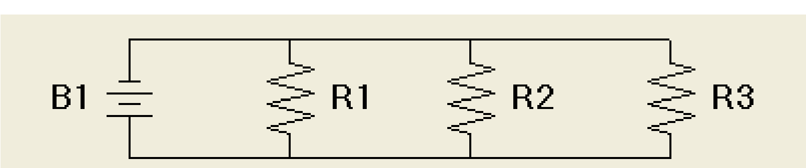
1. Using the mouse, click the pointer icon  on the toolbar[37] or the analog device toolkit.[52]
2. Move the mouse onto the diagram over the first device meter.[29]
3. Double click the mouse on the meter to open the Edit Meter dialog box.[68] Modifying object values[16] provides additional details.
4. To link the meter to the resistor, select Resistor as the device type and 1 as the id.
5. Repeat steps (2), (3) and (4) on the other meters, select Resistor as the device type and enter 2 and 3 as the device ids.

   At this point the circuit construction is complete. Return to parallel circuit demonstration[225] to complete the exercise.

Related topics:
- Creating and editing diagrams[11]
- Menu commands[37]
- Toolbar commands[37]
- Device and drawing toolkits[51]
- Dialog boxes[62]

Resistors and Simple Circuits Tutorial
Parallel Circuit Exercise
Knowledge test

1. The total current in a parallel circuit is the _______ of the individual currents.
2. In a parallel circuit composed of resistors with different values, a _______ amount of current flows through each resistor.



3. Given a parallel circuit with 3 resistors with values 100, 250, and 500 ohms, what is the total resistance? (answer)(11)[292]
4. Given a parallel circuit with 3 resistors with values 500, 750, and 1000 ohms, what is the total resistance?

5. In the above parallel circuit, what is the circuit current, with device values:
```
B1 =   15 volts
R1 =  250 ohms
R2 =  500 ohms
R3 = 1500 ohms
```
(answer)(12)[292]
6. In the above parallel circuit, what is the circuit current, with device values:
```
B1 =  120 volts
R1 =   50 ohms
R2 =  450 ohms
R3 = 1000 ohms
```

Related topics:

Parallel circuit theory[221]
Parallel circuit examples[223]
Parallel circuit exercise[221]
Resistors and Simple Circuits - Tutorial[205]

Resistors and Simple Circuits Tutorial

Power and Energy Exercise

Power

Theory

The equation for power[91] in an electrical circuit and the relationship between voltage, current and resistance can be found in theory.[230]

Examples

The use of the equation for power to determine a circuit's power consumption can be found in examples.[231]

Energy

Theory

The equation for energy[86] in an electric circuit and the relationship to power can be found in theory.[234]

Examples

The use of the equation for energy to determine a circuit's energy consumption can be found in examples.[235]

Knowledge test

Review questions can be found in knowledge test.[235]

Related topics:

- Ohm's law[90]
- Voltage[95]
- Current[84]
- Resistance[92]
- Tutorial topic tree[203]

Resistors and Simple Circuits Tutorial

Power and Energy Exercise

Power - Theory

Power is the rate of doing work. Electrical power in a resistance[92] is turned into heat. The greater the power, the faster heat is generated.

- The power in a circuit is directly proportional to the product of the applied electromotive force and the resulting circuit current. In other words, the greater the voltage and current, the greater the power.

- The power in watts in a circuit is equal to the voltage[95] in volts times the circuit current[84] in amperes.

Power is measured in watts,[95] named after James Watt, the Scottish mechanical engineer who invented the steam engine.

In equation form

P (watts) = E (volts) x I (amperes)

where

P = the circuit power in watts

E = the applied voltage in volts
I = the circuit current in amperes

By substituting the Ohm's law[90] equivalent for **E, I** and **R,** (see Ohm's law theory)[206] the above equation can be arranged as

```
      E**2
P = ------     P = I**2 x R
       R
```

Using the various forms of the above equations, if any two variables is known, the third variable can be determined. See power examples.[231]

When using any of the above equations, all variable values must be in the same basic units, for example **E** in volts, **I** in amperes and **R** in ohms. See unit conversion.[75]

Power[91] calculation in a series [93] and parallel circuits[91] is described in series circuit power[232] and parallel circuit power[233] respectively.

Related topics:

- Power examples[231]
- Power and energy exercise[230]
- Voltage[95]
- Current[84]
- Resistance[92]

Resistors and Simple Circuits Tutorial

Power and Energy Exercise

Power - Examples

Example 1

Given a voltage of 10 volts and a current of 5 amperes, what is the power in the circuit?

```
P = E x I
  = 10 x 5
  = 50 watts
```

Example 2

Given a voltage of 20 volts and a resistance of 50 ohms, what is the power in the circuit?

```
      E**2     20**2    400
P = ------ =  ----- = ----- = 20 watts
       R        50       50
```

Example 3

Given a current of 10 amperes and a resistance of 20 ohms, what is the power in the circuit?

```
P = I**2  x R
  = 10**2 x 20
  = 100   x 20
  = 2000 watts
```

Related topics:

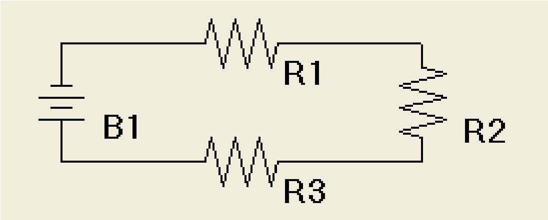
- Power theory[230]
- Power and energy exercise[230]
- Series circuit power[232]
- Parallel circuit power[233]

Voltage[95]
Current[84]
Resistance[92]

Resistors and Simple Circuits Tutorial

Power and Energy Exercise

Series Circuit Power



Power can be calculated as the product of the total voltage[95] times the total current.[84] In the above circuit, using the following circuit values

```
B1 = 120 volts
R1 =  10 ohms
R2 =  20 ohms
R3 =  30 ohms
```

The total resistance[92] in a series circuit[93] is the sum of the individual resistances. In the above circuit

```
R (total)  =  R1  +  R2  +  R3
           =  10  +  20  +  30
           =  60 ohms
```

Using Ohm's law,[90] the total current[84] in a series circuit is equal to the total applied voltage[95] divided by the total resistance.[92] In the above circuit

```
I (total)  =  E (total) / R (total)
           =  120 / 60
           =  2 amps
```

When the total voltage and current is known, the power may be determined as

```
P (total)  =  E (total)    x I (total)
           =  120 (volts) x 2 (amps)
           =  240 watts
```

Alternatively, power can be calculated as the sum of the power requirements for each device. In the above circuit, using the same circuit values, power may be calculated using the P = I**2 x R formula developed in the power theory topic.[230] Note, this formula can be used because the same current flows through each device.

```
P (R1)  =  I (total)**2 x R1
        =  2**2 x 10
        =  4    x 10
        =  40 watts

P (R2)  =  I (total)**2 x R2
        =  2**2 x 20
        =  80 watts

P (R3)  =  I (total)**2 x R3
        =  2**2 x 30
        =  120 watts
```

```
P (total)  =  P (R1)  +  P (R2)  +  P (R3)
           =  40      +  80      +  120
           =  240 watts
```

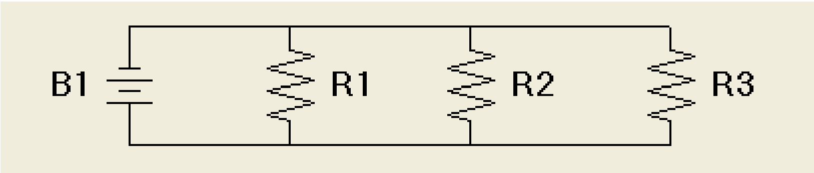
Related topics:

- Power theory[230]
- Power and energy exercise[230]
- Series circuit exercise[212]
- Parallel circuit power[233]

Resistors and Simple Circuits Tutorial

Power and Energy Exercise

Parallel Circuit Power



Power can be calculated as the product of the total voltage[95] times the total current.[84] In the above circuit, using the following circuit values

```
B1 =  120 volts
R1 =  100 ohms
R2 =  500 ohms
R3 = 2000 ohms
```

As described in parallel circuit theory,[221] the total resistance[92] in a parallel circuit[91] may be found using the following general formula.

```
                        1
R (total) = --------------------
              1     1     1
             --- + --- + --- + ...
              R1    R2    R3
```

Using the circuit values

```
R (total)
  = 1 / ( 1/R1  + 1/R2  + 1/R3   )
  = 1 / ( 1/100 + 1/500 + 1/2000 )
  = 1 / ( 0.01  + 0.002 + 0.0005 )
  = 1 / 0.0125
  = 80 ohms
```

Using Ohm's law,[90] the total current[84] in a parallel circuit is equal to the total applied voltage[95] divided by the total resistance.[92] In the above circuit

```
I (total)  =  E (total) / R (total)
           =  120 / 80
           =  1.5 amps
```

When the total voltage and current is known, the power may be determined as

```
P (total)  =  E (total)   x I (total)
           =  120 (volts) x 1.5 (amps)
           =  180 watts
```

Alternatively, power can be calculated as the sum of the power requirements for each device. In the above circuit, using the same circuit values, power may be calculated using the `P = E**2 / R` formula developed in the power theory topic.[230] Note, this formula can be used because the same voltage is applied to each device.

```
P (R1)  =  E (total)**2 / R1
        =  120**2       / 100
        =  14400        / 100
        =  144 watts

P (R2)  =  I (total)**2 / R2
        =  120**2       / 500
        =  28.8 watts

P (R3)  =  I (total)**2 / R3
        =  120**2       / 2000
        =  7.2 watts

P (total)  =  P (R1)  +  P (R2)  +  P (R3)
           =  144     +  28.8    +  7.2
           =  180 watts
```

Related topics:

- Power theory[230]
- Power and energy exercise[230]
- Parallel circuit exercise[221]
- Series circuit power[232]

Resistors and Simple Circuits Tutorial

Power and Energy Exercise

Energy - Theory

Whereas power[91] is the rate at which work is done, energy[86] is the amount of work actually performed in a period of time. In other words, a small amount of power for a long period of time can use the same amount of energy as a large amount of power for a short period of time.

- The energy used in a circuit is directly proportional to the product of the power and the time duration. In other words, the greater the power and time, the greater the energy.
- The energy in watt-hours used in a circuit is equal to the power in watts multiplied by the time duration in hours.

Energy is measured in watt-hours,[95] one watt-hour is equivalent to one watt of power used for one hour. The usual household measure of energy is kilowatt-hours which is 1000 watt-hours (1 watt for 1000 hours or 1000 watts for 1 hour).

In equation form

```
W (watt-hours)  =  P (watts)  x  t (hours)
```

where

W = the circuit energy in watt-hours
P = the circuit power in watts
t = the time duration in hours

Related topics:

- Power examples[231]
- Power and energy exercise[230]
- Power[91]

Resistors and Simple Circuits Tutorial

Power and Energy Exercise

Energy - Examples

Example 1

Given a power of 10 watts and a time duration of 3 hours, what is the energy used in the circuit?

```
W = P x t
  = 10 x 3
  = 30 watt-hours
```

Example 2

Given a power of 2000 watts and a time duration of 2 hours, what is the energy used in the circuit?

```
W = P x t
  = 2000 x 2
  = 4000 watt-hours
  = 4 kilowatt-hours
```

Example 3

Given a voltage of 12 volts and a current of 0.5 amperes and a time duration of 24 hours, what is the energy used in the circuit?

First calculate the circuit power

```
P = E x I
  = 12 x 0.5
  = 6 watts
```

Using the circuit power, calculate the energy used

```
W = P x t
  = 6 x 24
  = 144 watt-hours
```

Related topics:

Energy theory[234]
Power theory[230]
Power examples[231]
Power and energy exercise[230]
Energy[86]
Power[91]

Resistors and Simple Circuits Tutorial

Power and Energy Exercise

Knowledge Test

1. Given a voltage of 120 volts and a current of 2 amperes, what is the power in the circuit? (answer)(29)[295]
2. Given a voltage of 6 volts and a current of 0.005 amperes, what is the power in the circuit?
3. Given a voltage of 150 volts and a resistance of 1500 ohms, what is the power in the circuit? (answer)(30)[295]
4. Given a voltage of 1.5 volts and a resistance of 2 kilo ohms, what is the power in the circuit?
5. Given a current of 2 mA and a resistance of 2 M ohms, what is the power in the circuit? (answer)(31)[295]

6. Given a current of 55 mA and a resistance of 1.5 k ohms, what is the power in the circuit?

7. Given a power of 100 watts and a time duration of 12 hours, what is the energy used in the circuit? (answer)(32)[295]

8. Given a power of 2 watts and a time duration of 36 hours, what is the energy used in the circuit?

9. Given a voltage of 110 volts and a current of 2.5 amperes and a time duration of 48 hours, what is the energy used in the circuit? (answer)(33)[296]

10. Given a voltage of 35 volts and a current of 0.5 amperes and a time duration of 5 hours, what is the energy used in the circuit?

Related topics:

- Power - theory[230]
    - Series circuit power[232]
    - Parallel circuit power[233]
- Power - examples[231]
- Energy - theory[234]
- Energy - examples[235]
- Power and energy exercise[230]

Capacitors, Inductors and Transformers Tutorial

This tutorial covers the following topics:

- Capacitors[82] and the theory of capacitance.[83]
- The properties of capacitors in series[93] and parallel[91] circuits.
- Capacitor circuit time constant[94] and how voltage[95] increases and decreases across a capacitor.

- Inductors[89] and the theory of inductance.[88]
- The properties of inductors in series[93] and parallel[91] circuits.
- Inductor circuit time constant[94] and how current[84] increases and decreases through an inductor.

- Transformers[94] and the theory of mutual inductance.[90]

Exercises:

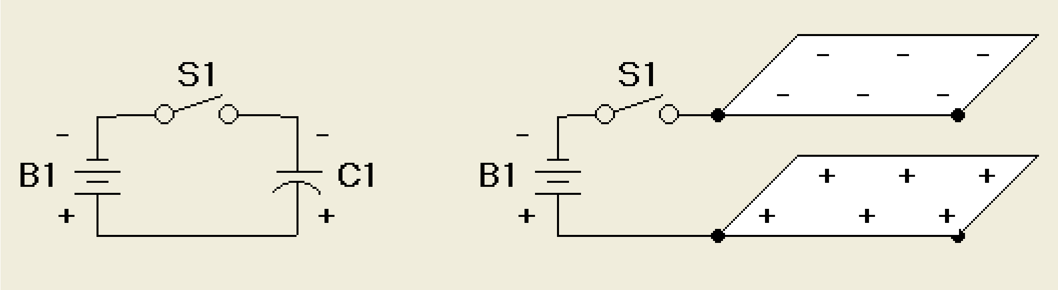
Capacitor exercise[237]
Inductor exercise[244]
Transformer exercise[251]

Related topics:

General tutorial introduction and instructions[201]
Tutorial topic tree[203]

Capacitors, Inductors and Transformers Tutorial

Capacitor Exercise



Theory

Capacitance[83] and the relationship to voltage[95] and current[84] can be found in capacitor theory.[238]

Capacitors in series and parallel[239] describes how to calculate the resulting capacitance of series[93] and parallel[91] connected capacitors.

Capacitor circuit time constant[240] describes how voltage increases and decreases across a capacitor.

Examples

The use of capacitors in series and parallel circuits and the calculation of a resistor-capacitor circuit's time constant can be found in examples.[240]

Knowledge test

Review questions can be found in knowledge test.[242]

Related topics:

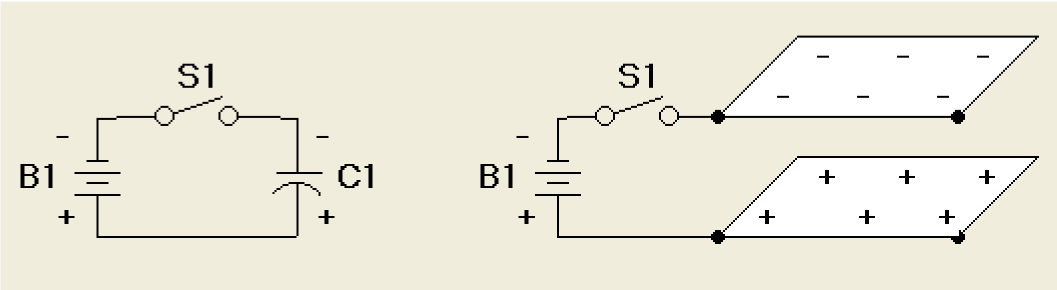
Inductor exercise[244]

Capacitors, inductors and transformers tutorial[237]
Tutorial topic tree[203]

Capacitors, Inductors and Transformers Tutorial

Capacitor Exercise

Theory



A capacitor[82] in its simplest form, is two metal plates placed very close together, but not touching. On the right hand side of the above diagram is a circuit composed of a battery B1, a switch S1 and two plates forming a capacitor C1.

When the switch is closed, the circuit path is completed, and an electric charge or current[84] will migrate from the battery to the capacitor. The electric current will flow until the voltage[95] across the capacitor equals the battery voltage. This charging process is usually very fast.

If the switch is opened, i.e. the circuit path is broken, the electric charge will remain on the capacitor. Energy[86] has been transferred from the battery to the capacitor.

The amount of charge or quantity of energy which can be placed on a capacitor is proportional to the applied voltage[95] and the capacitance[83] of the capacitor. The larger the metal plate area, the smaller the spacing between the plates, and the greater the ability of the material between the plates to store energy, the greater the capacitance.

In a capacitor, the material between the plates is called the dielectric.[84] Some materials are better at storing energy than others and are thus better dielectrics. For example, glass is 5 to 10 times better than air.

In a DC[86] circuit, current flows until the capacitor is charged. Once the capacitor is charged, i.e. the capacitor voltage equals the applied voltage, no further current flows.

In an AC[81] circuit, current flows in one direction until the capacitor is charged. When the current direction changes, the capacitor attempts to hold the voltage at the charged level and thus capacitance[83] has the property that it opposes a change in voltage.

Capacitance is measured in farads[86] in honor of Michael Faraday. In electronic circuits, the usual measure of capacitance is microfarads (µF) or picofarads (pF), 1e-6 or 1e-12 farads respectively.

Related topics:

Capacitors in series and parallel[239]
Capacitor circuit time constant[240]
Capacitor examples[240]
Capacitor knowledge test[242]
Capacitor exercise[237]
Capacitors, inductors and transformers tutorial[237]
Unit conversion[75]
Voltage[95]

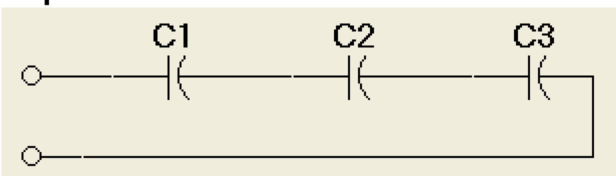
Current[84]

Capacitors, Inductors and Transformers Tutorial

Capacitor Exercise

Capacitors in Series and Parallel

Capacitors in series



Capacitors are sometimes connected in series[93] to allow the set of capacitors to withstand a larger voltage.[95] The general formula for finding the total capacitance of capacitors connected in series is

$$C\ (total) = \frac{1}{\frac{1}{C1} + \frac{1}{C2} + \frac{1}{C3} + \ldots}$$

Note: The total capacitance of capacitors in series is always less than the lowest individual capacitance value.

For two capacitors in series, the formula can be arranged as

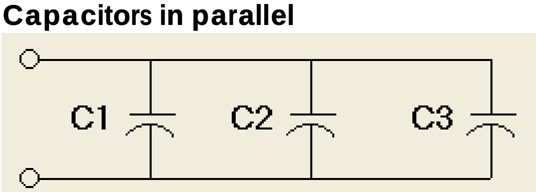
$$C\ (total) = \frac{C1 \times C2}{C1 + C2}$$

For N capacitors in series of equal value C, another special case formula can be used

$$C\ (total) = \frac{C}{N}$$

When capacitors are connected in series, the applied voltage[95] is divided between them in a similar manner to resistors in series.[212]

Capacitors in parallel



Capacitors[82] are connected in parallel[91] to obtain a larger total capacitance[83] than provided by each component. The total capacitance of capacitors connected in parallel is the sum of the individual capacitances. In the above circuit

$$C\ (total) = C1 + C2 + C3$$

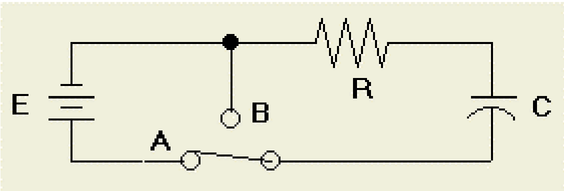
In general, the total capacitance for capacitors connected in parallel with capacitances C1, C2, C3, C4, ... is

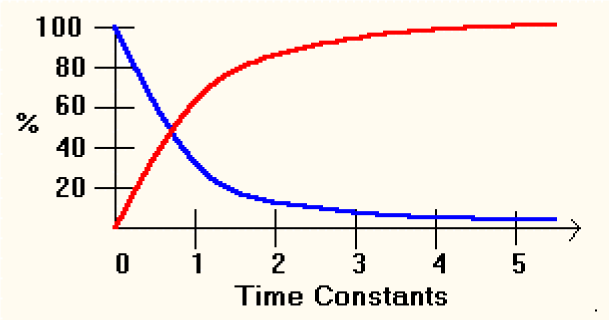
$$C\ (total) = C1 + C2 + C3 + C4 + \ldots$$

Related topics:

[Capacitor examples](240)
[Capacitor exercise](237)
[Capacitors, inductors and transformers tutorial](237)

Capacitors, Inductors and Transformers Tutorial
Capacitor Exercise
Capacitor Circuit Time Constant





If a voltage[95] is applied directly across a capacitor,[82] it will become fully charged almost instantly. However, if the circuit contains any resistance,[92] the current[84] flow will be limited and thus it will take a period of time before the capacitor becomes fully charged.

In the above circuit, when the switch is moved to position A, the capacitor will charge at a rate shown by the red line in the above graph. When the switch is moved to position B, the capacitor will discharge at a rate shown by the blue line in the above graph.

The rate of charge or discharge of a resistor-capacitor circuit is governed by the circuit's time constant.[94] The formula for a resistor-capacitor circuit time constant is shown below.

```
t = R x C

where t = time constant (seconds)
      R = resistance    (ohms)
      C = capacitance   (farads)
```

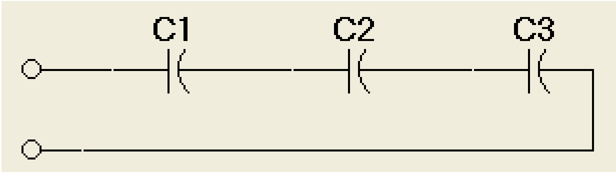
If charging (circuit position A above), after one time constant seconds, the capacitor will be 63% charged and after five time constant seconds, the capacitor will be 99% charged (see the red line in the above graph).

If discharging (circuit position B above), after one time constant seconds, the capacitor will have only 37% of its initial value and after five time constant seconds, the capacitor will have only 1% of its initial value (see the blue line in the above graph).

Related topics:
[Inductor circuit time constant](246)
[Capacitor examples](240)
[Capacitor knowledge test](242)
[Capacitor exercise](237)
[Capacitors, inductors and transformers tutorial](237)

Capacitors, Inductors and Transformers Tutorial
Capacitor Exercise
Examples

Series Example 1



Circuit values

```
C1 =  1 µF
C2 =  5 µF
C3 = 20 µF
```

As described in capacitors in series and parallel theory,[239] the total capacitance[83] of capacitors[82] in series[93] may be found using the following general formula.

```
                      1
C (total) = --------------------
             1     1     1
            --- + --- + --- + ...
             C1    C2    C3
```

Using the circuit values

```
C (total)
  = 1 / ( 1/1 + 1/5 + 1/20 )
  = 1 / ( 1   + 0.2 + 0.05 )
  = 1 / 1.25
  = 0.8 µF
```

Series Example 2

Given a circuit with two capacitors in series with circuit values

```
C1 =  10 µF
C2 =  40 µF
```

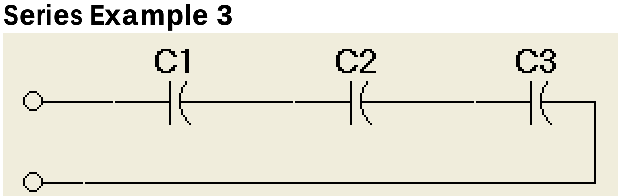
As described in capacitors in series and parallel theory,[239] the total capacitance[83] of two capacitors[82] in series[93] may be found using the following special case formula.

```
              C1 x C2
C (total) = -----------
             C1  +  C2
```

Using the above values

```
C (total)
  = (10 x 40) / (10 + 40)
  = 400 / 50
  = 8 µF
```

Series Example 3



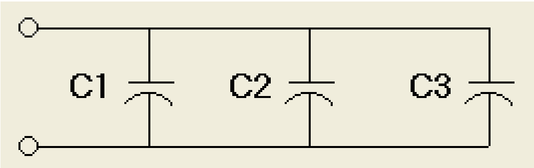
As described in capacitors in series and parallel theory,[239] the total capacitance[83] of equal value capacitors[82] in series[93] may be found using the following special case formula.

```
             C
C (total) = ---
             N
```

Given a circuit with three equal value capacitors in series, each with a value of 15 µF, using the above formula

```
C (total) = 15 / 3
          = 5 µF
```

Parallel Example 1



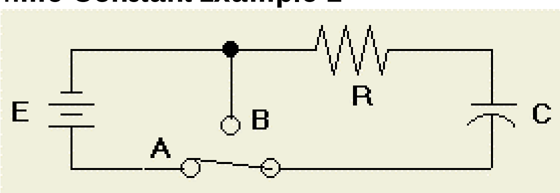
Circuit values

```
C1 =  10 µF
C2 =  20 µF
C3 =  30 µF
```

The total capacitance[83] of capacitors[82] in parallel[91] is the sum of the individual capacitances. In the above circuit

```
C (total)  =  C1  +  C2  +  C3
           =  10  +  20  +  30
           =  60 µF
```

Time Constant Example 1



Circuit values

```
R =  1000 ohms
C =  20 µF
```

The circuit's time constant[94] can be calculated as

```
t = R     x  C
  = 1000  x  20e-6
  = 0.02 seconds
```

Thus, if charging, it will take 0.02 seconds for the capacitor to reach 63% of its final value and 0.1 seconds (0.02 x 5) for the capacitor to reach 99% of its final value.

Related topics:

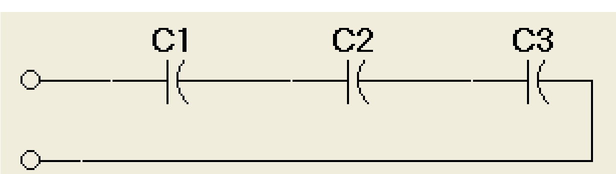
Capacitor theory[238]
Capacitor exercise[237]
Capacitor knowledge test[242]
Capacitors, inductors and transformers tutorial[237]

Capacitors, Inductors and Transformers Tutorial

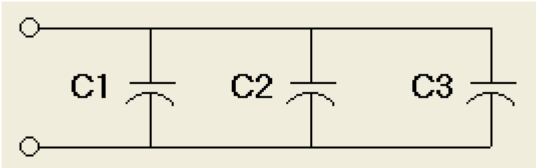
Capacitor Exercise

Knowledge Test

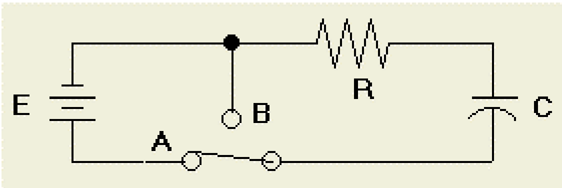
1. The total capacitance of capacitors in series is always ______ than the lowest individual capacitance value.



2. Given a series circuit with 3 capacitors with values 10, 25, and 50 µF, what is the total capacitance? (answer)(18)[293]
3. Given a series circuit with 3 capacitors with values 50, 75, and 100 µF, what is the total capacitance?



4. Given a parallel circuit with 3 capacitors with values 10, 25, and 50 µF, what is the total capacitance? (answer)(19)[293]
5. Given a parallel circuit with 3 capacitors with values 50, 75, and 100 µF, what is the total capacitance?



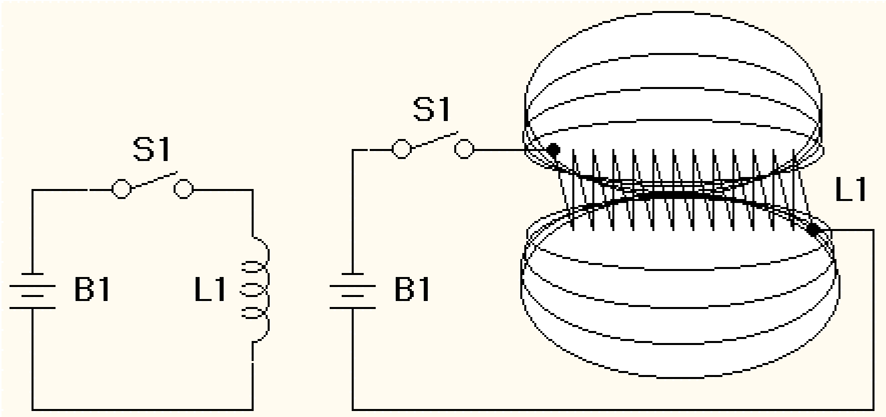
6. Given a resistor-capacitor circuit with values R = 2.5K and C = 2 µF, what is the circuit's time constant? (answer)(20)[293]
7. How long will it take this circuit to charge up to 99% of its final value?

Related topics:

Capacitor theory[238]
Capacitors in series and parallel[239]
Capacitor circuit time constant[240]
Capacitor examples[240]
Capacitor exercise[237]
Capacitors, inductors and transformers tutorial[237]

Capacitors, Inductors and Transformers Tutorial

Inductor Exercise



Theory

Inductance[88] and the relationship to voltage[95] and current[84] can be found in inductor theory.[244]

Inductors in series and parallel[245] describes how to calculate the resulting inductance of series[93] and parallel[91] connected inductors.

Inductor circuit time constant[246] describes how current increases and decreases through an inductor.

Examples

The use of inductors in series and parallel circuits and the calculation of a resistor-inductor circuit's time constant can be found in examples.[247]

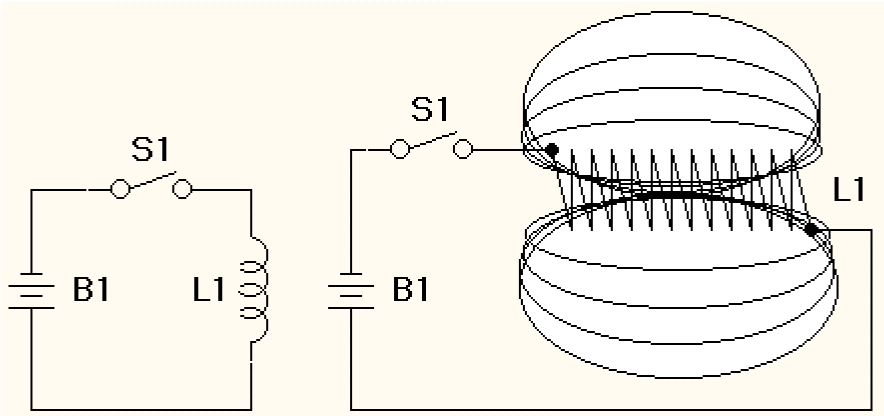
Knowledge test

Review questions can be found in knowledge test.[249]

Related topics:

- Transformer exercise[251]
- Capacitor exercise[237]
- Capacitors, inductors and transformers tutorial[237]
- Tutorial topic tree[203]

Capacitors, Inductors and Transformers Tutorial
Inductor Exercise
Theory



An inductor[89] in its simplest form, is a coil of wire. On the right hand side of the above diagram is a circuit composed of a battery B1, a switch S1 and a coil of wire forming an inductor L1.

When the switch is closed, the circuit path is completed, and an electric current[84] will flow from the battery, through the switch and through the inductor. When current flows through a coil, a magnetic field is generated. Energy[86] is transferred from the battery to the inductor to generate the magnetic field.

The amount of energy which can be placed in an inductor is proportional to the current[84] and the inductance[88] of the inductor. Inductance depends on the physical characteristics of the inductor. The greater the number of turns of wire, the greater the inductance. The greater the ability to form a magnetic field, the greater the inductance, i.e. a coil will have a greater inductance if placed on an iron core.

In a DC[86] circuit, current flows continuously and the inductor's magnetic field is constant.

In an AC[81] circuit, current flows in one direction until the magnetic field is fully formed. When the current direction changes, the magnetic field attempts to hold the current at the previous level and thus inductance[88] has the property that it opposes a change in current.

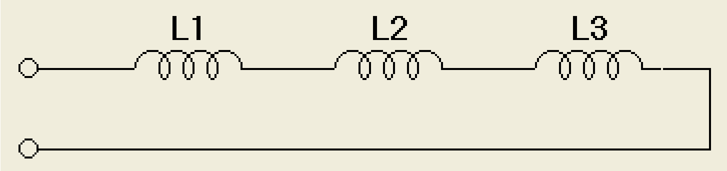
Inductance is measured in henrys.[88]

Related topics:

- Inductors in series and parallel[245]
- Inductor circuit time constant[246]
- Inductor examples[247]
- Inductor knowledge test[249]
- Inductor exercise[244]
- Capacitors, inductors and transformers tutorial[237]
- Voltage[95]
- Current[84]

Capacitors, Inductors and Transformers Tutorial
Inductor Exercise
Inductors in Series and Parallel

Inductors in series



The total inductance[88] of inductors[89] connected in series[93] is the sum of the individual inductances. In the above circuit

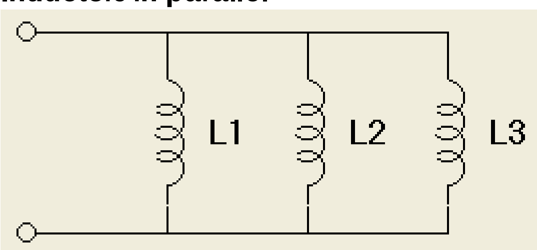
```
L (total)  =  L1 + L2 + L3
```

In general, the total inductance for inductors connected in series with inductances L1, L2, L3, L4, ... is

```
L (total)  =  L1 + L2 + L3 + L4 + ...
```

When inductors are connected in series, the applied voltage[95] is divided between them in a similar manner to resistors in series.[212]

Inductors in parallel



The general formula for finding the total inductance[88] of inductors[89] connected in parallel[91] is

```
                         1
L (total) = --------------------
              1      1      1
             --- +  --- +  --- + ...
              L1     L2     L3
```

Note: The total inductance of inductors in parallel is always less than the lowest individual inductance value.

For two inductors in parallel, the formula can be arranged as

```
               L1 x L2
L (total) = -----------
              L1  +  L2
```

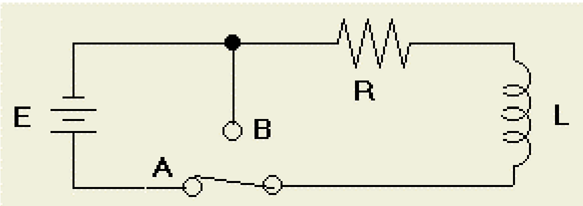
For N inductors in parallel of equal value L, another special case formula can be used

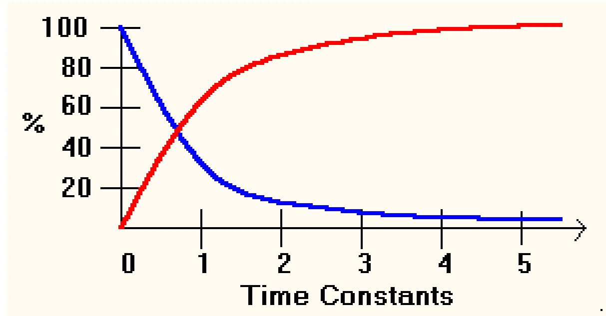
```
              L
L (total) = ---
              N
```

Related topics:

Inductor examples[247]
Inductor exercise[244]
Capacitors, inductors and transformers tutorial[237]

Inductor Circuit Time Constant





In the above circuit, when the switch is moved from position B, to position A, a current[84] will begin to flow through the inductor,[89] which causes the inductor's magnetic field to increase. This changing magnetic field causes a "back" voltage[95] that tends to counteract the initial applied voltage, thus slowing the instantaneous increase in current.

Assuming the inductor has a resistance[92] near zero, the final circuit current, given by Ohm's law[90] will be I = E/R. The current will exponentially increase to the final value as shown by the red line in the above graph.

When the switch is moved to position B, the inductor magnetic field will collapse and the current will decrease to zero at a rate shown by the blue line in the above graph.

The rate of change of current of a resistor-inductor circuit is governed by the circuit's time constant.[94] The formula for a resistor-inductor circuit time constant is shown below.

```
     L
t = ---
     R

where t = time constant (seconds)
      L = inductance    (henrys)
      R = resistance    (ohms)
```

With an applied voltage (circuit position A above), after one time constant seconds, the inductor current will be 63% of its final value and after five time constant seconds, the inductor current will be 99% of its final value (see the red line in the above graph).

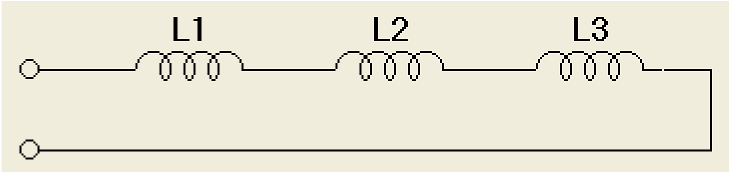
If allowed to discharge (circuit position B above), after one time constant seconds, the inductor current will be 37% of its initial value and after five time constant seconds, the inductor current will be 1% of its initial value (see the blue line in the above graph).

Related topics:

- Capacitor circuit time constant[240]
- Inductor examples[247]
- Inductor knowledge test[249]
- Inductor exercise[244]
- Capacitors, inductors and transformers tutorial[237]

Capacitors, Inductors and Transformers Tutorial
Inductor Exercise
Examples

Series Example 1



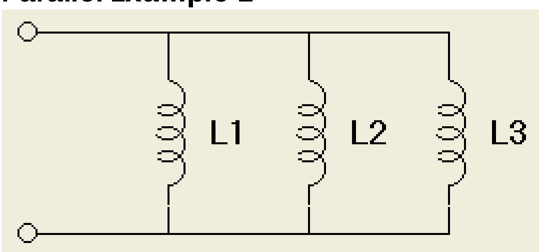
Circuit values

```
L1 =  10 mH
L2 =  20 mH
L3 =  30 mH
```

The total inductance[88] of inductors[89] in series[93] is the sum of the individual inductances. In the above circuit

```
L (total)  =  L1  +  L2  +  L3
           =  10  +  20  +  30
           =  60 mH
```

Parallel Example 1



Circuit values

```
L1 =  1 mH
L2 =  5 mH
L3 = 20 mH
```

As described in inductors in series and parallel theory,[245] the total inductance[88] of inductors[89] in parallel[91] may be found using the following general formula.

```
                          1
L (total) = ---------------------
             1     1     1
            --- + --- + --- + ...
             L1    L2    L3
```

Using the circuit values

```
L (total)
  = 1 / ( 1/1 + 1/5 + 1/20 )
  = 1 / ( 1   + 0.2 + 0.05 )
  = 1 / 1.25
  = 0.8 mH
```

Parallel Example 2

Given a circuit with two inductors in series with circuit values

```
L1 =  10 mH
L2 =  40 mH
```

As described in inductors in series and parallel theory,[245] the total inductance[88] of two inductors[89] in parallel[91] may be found using the following special case formula.

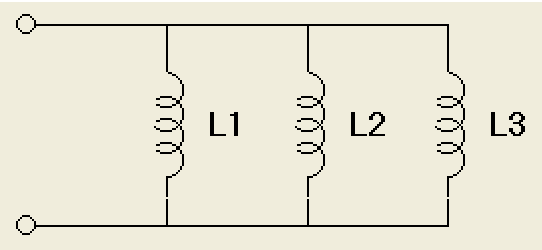
```
               L1 x L2
L (total) = -----------
             L1  +  L2
```

Using the above values

```
L (total)
  = (10 x 40) / (10 + 40)
```

```
        = 400 / 50
        = 8 mH
```

Parallel Example 3



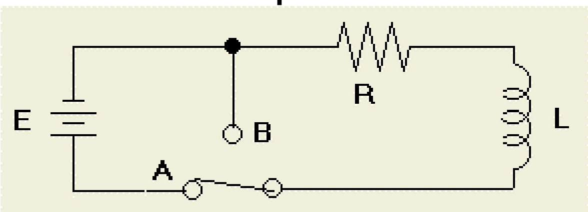
As described in inductors in series and parallel theory,[239] the total inductance[88] of equal value inductors[89] in parallel[91] may be found using the following special case formula.

```
                L
      L (total) = ---
                N
```

Given a circuit with three equal value inductors in series, each with a value of 15 mH, using the above formula

```
      L (total) = 15 / 3
                = 5 mH
```

Time Constant Example 1



Circuit values

```
   R =   1 K ohms
   l = 200 mH
```

The circuit's time constant[94] can be calculated as

```
      t = L / R
        = 200e-3 / 1e3
        = 200e-6 seconds
        = 200 µ seconds
```

Thus, if a voltage is applied, it will take 200 µ seconds for the inductor current to reach 63% of its final value and 0.1 milliseconds (200e-6 x 5) for the inductor current to reach 99% of its final value.

Related topics:

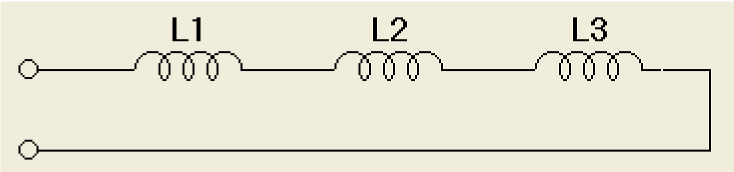
- Inductor theory[244]
- Inductors in series and parallel[245]
- Inductor circuit time constant[246]
- Inductor knowledge test[249]
- Inductor exercise[244]
- Capacitors, inductors and transformers tutorial[237]

Capacitors, Inductors and Transformers Tutorial

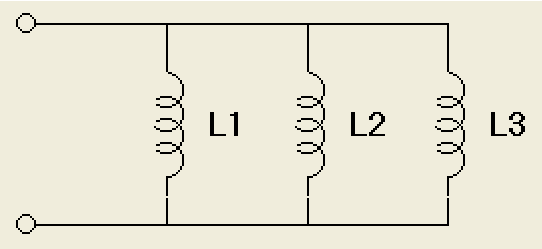
Inductor Exercise

Knowledge Test

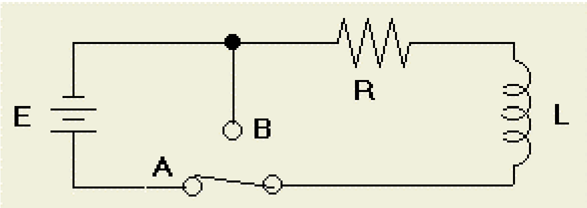
1. The total inductance of inductors in parallel is always _______ than the lowest individual inductance value.



2. Given a series circuit with 3 inductors with values 10, 25, and 50 mH, what is the total inductance? (answer)(21)[293]
3. Given a series circuit with 3 inductors with values 50, 75, and 100 mH, what is the total inductance?



4. Given a parallel circuit with 3 inductors with values 10, 25, and 50 mH, what is the total inductance? (answer)(22)[294]
5. Given a parallel circuit with 3 inductors with values 50, 75, and 100 mH, what is the total inductance?



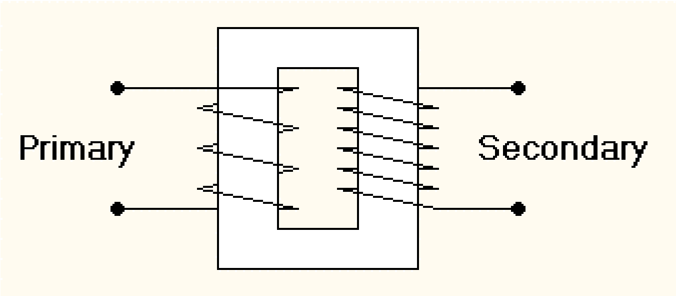
6. Given a resistor-inductor circuit with values R = 2.5K and L = 20 mH, what is the circuit's time constant? (answer)(23)[294]
7. How long will it take this circuit's current to increase up to 99% of its final value?

Related topics:

Inductor theory[244]
Inductors in series and parallel[245]
Inductor circuit time constant[246]
Inductor examples[247]
Inductor exercise[244]
Capacitors, inductors and transformers tutorial[237]

Capacitors, Inductors and Transformers Tutorial

Transformer Exercise



Theory

Basic transformer principles can be found in theory.[251]

Examples

Calculation of basic transformer parameters can be found in examples.[253]

Knowledge test

Review questions can be found in knowledge test.[253]

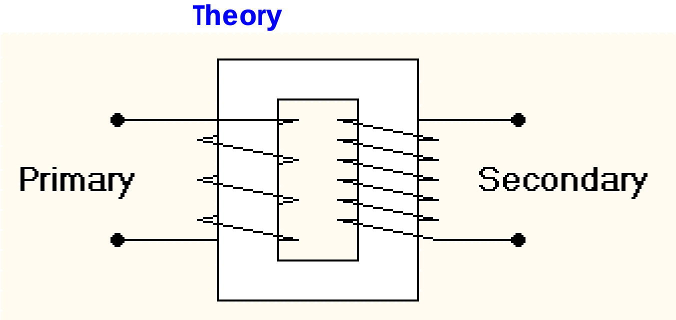
Related topics:

- Inductor exercise[244]
- Capacitors, inductors and transformers tutorial[237]
- Tutorial topic tree[203]

Capacitors, Inductors and Transformers Tutorial

Transformer Exercise

Theory



A transformer[94] in its simplest form, is two coils of wire, or inductors,[89] physically close or coupled together in some manner such that their magnetic fields can interact. In the above diagram, the two coils are wound on a shared core. An AC[81] voltage is applied to the transformer input, called the Primary. This causes a constantly changing magnetic field in the primary coil, the magnetic field transfers energy[86] to the output coil, called the Secondary via the transformer core. The changing magnetic field induces a voltage in the secondary coil.

Transformers transfer energy from one circuit to another without a direct connection and can increase or decrease voltage[95] levels.

Transformers work on the principle of mutual inductance.[90] Mutual inductance is the property between two current[84] carrying coils, when the magnetic field of one coil links with the magnetic field of the second coil. For a given rate of change of current in one coil, the amount of mutual inductance determines the amount of electromotive force, or voltage induced in the second coil.

Mutual inductance is greatest when all of the magnetic field of one coil "cuts" the windings of the second coil. The ratio of actual mutual inductance to the theoretical maximum is called the coefficient of coupling. This ratio can approach 1 or 100% if the coils are close together and wound on an shared iron core.

At low frequencies, for a given changing magnetic field, the induced voltage in a coil is proportional to the number of turns in the coil. In a transformer, the coil voltages are proportional to the number of turns in each coil and can be expressed in the following equation.

```
Ep     Np
--  =  --
Es     Ns

Where Ep = Primary (input) voltage
      Es = Secondary (output) voltage
      Np = Number of turns on primary
      Ns = Number of turns on secondary

Note  Np/Ns is known as the turns ratio.
```

If any three values are known, the above equation can be changed to determine the unknown fourth value. For example, if the input voltage and turns ratio are know, the following equation can be used to calculate the output voltage.

```
              Ns
Es  =  Ep  x  --
              Np
```

If the input voltage, the desired output voltage and primary coil turns are know, the following equation can be used to calculate the required secondary coil turns.

```
              Es
Ns  =  Np  x  --
              Ep
```

The turns ratio of an existing transformer can be determined by applying a known voltage to the primary winding and measuring the output voltage on the secondary and applying the following equation.

```
                 Np     Ep
Turns ratio  =   --  =  --
                 Ns     Es
```

A transformer transfers power[91] from the primary coil to the secondary coil according to the following formula.

```
Po  =  n x Pi

Where Po = Power output from the secondary
      Pi = Power input to the primary
      n  = Transformer efficiency factor
```

An ideal transformer would have an efficiency factor of 1.0. In reality, transformers have a lower efficiency factor due to copper, eddy current and hysteresis losses which vary depending on the operating frequency and current.

Related topics:

Transformer examples[253]
Transformer knowledge test[253]

Transformer exercise[251]
Capacitors, inductors and transformers tutorial[237]
Inductor exercise[244]
Voltage[95]
Current[84]

Capacitors, Inductors and Transformers Tutorial

Transformer Exercise

Examples

Example 1

Given an input voltage of 100 volts, a primary coil with 100 turns and a secondary coil of 150 turns, what is the output voltage?

```
Es  =  Ep   x   Ns/Np
    =  100  x  150/100
    =  150 volts
```

Example 2

Given an input voltage of 100 volts, a desired output voltage of 250 volts and a primary coil with 100 turns, what is the required number of turns for the secondary coil?

```
Ns  =  Np   x   Es/Ep
    =  100  x  250/100
    =  250 turns
```

Example 3

Given an input voltage of 100 volts and a measured output voltage of 500 volts, what is the turns ratio of the transformer?

```
Turns ratio  =   Ep/Es
             =  100/500
             =  0.2
```

Example 4

Given an input voltage of 100 volts, an input current of 2 amps and an efficiency factor of 0.85, what is the expected output power?

```
Po  =  n    x Pi
    =  0.85 x (Ei x Ii)
    =  0.85 x 100 x 2
    =  170 watts
```

Related topics:

Transformer theory[251]
Transformer knowledge test[253]
Transformer exercise[251]
Capacitors, inductors and transformers tutorial[237]

Capacitors, Inductors and Transformers Tutorial

Transformer Exercise

Knowledge test

1. What are the common names for transformer inputs and outputs? (answer)(1)[291]
2. Briefly describe how a transformer works.
3. Define mutual inductance. (answer)[90]
4. Define coefficient of coupling.

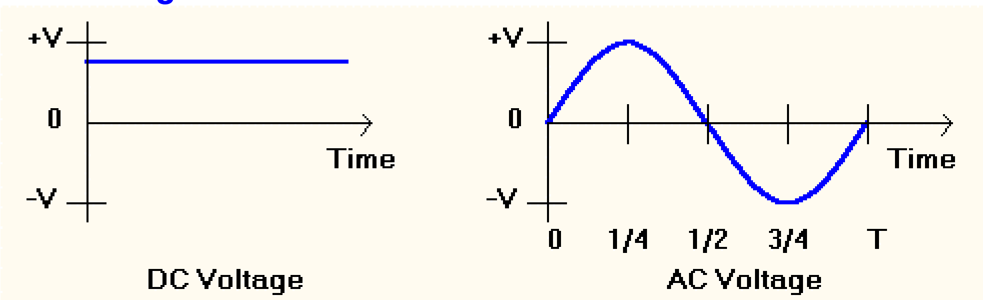
5. Given an input voltage of 750 volts, a primary coil with 100 turns and a secondary coil of 300 turns, what is the output voltage?
6. Given an input voltage of 15 volts, a desired output voltage of 45 volts and a primary coil with 100 turns, what is the required number of turns for the secondary coil?
7. Given an input voltage of 50 volts and a measured output voltage of 250 volts, what is the turns ratio of the transformer?

8. Given an input voltage of 120 volts, an input current of 5 amps and an efficiency factor of 0.9, what is the expected output power? (answer)(2)[291]
9. Given an input voltage of 50 volts, an input current of 0.5 amps, an output voltage of 25 volts and an output current of 0.8 amps, what is the transformer efficiency?

Related topics:

Transformer theory[251]
Transformer exercise[251]
Capacitors, inductors and transformers tutorial[237]

Alternating Current Tutorial



This tutorial covers the following topics:

- Alternating current[81] theory.
- The characteristics of capacitors[82] and inductors[89] in AC[81] circuits.
- Series resistor-inductor-capacitor (RLC) circuits and resonance.

Exercises:

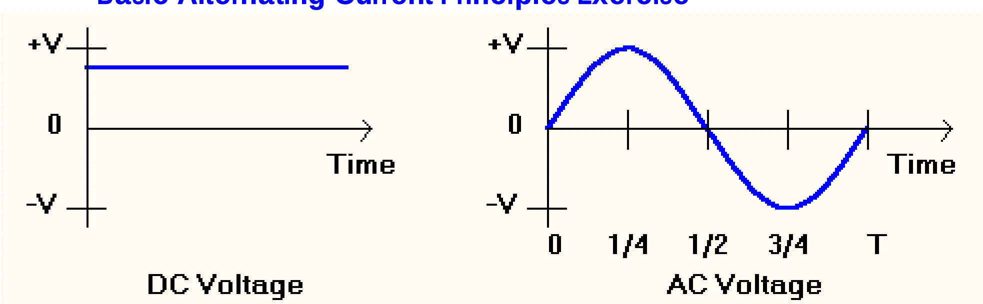
Basic alternating current principles exercise[255]
Capacitors and inductors in AC circuits exercise[261]
Series resistor-inductor-capacitor (RLC) circuits exercise[262]

Related topics:

General tutorial introduction and instructions[201]
Tutorial topic tree[203]

Alternating Current Tutorial

Basic Alternating Current Principles Exercise



Theory

Alternating current principles can be found in theory.[256]

Examples

Calculation of basic alternating current parameters can be found in examples.[257]

Knowledge test

Review questions can be found in knowledge test.[258]

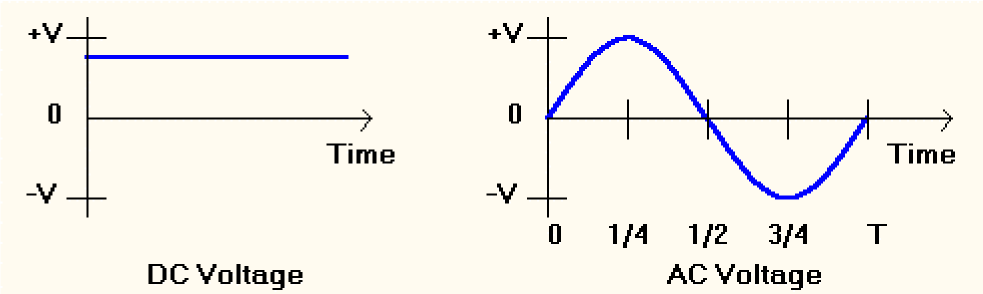
Related topics:

Inductor exercise[244]
Alternating current tutorial[255]
Tutorial topic tree[203]

Alternating Current Tutorial

Basic Alternating Current Principles Exercise

Theory



As shown in the left graph above, a direct current or DC[86] voltage is constant. Examples of DC voltage sources include household toy batteries and 12 volt automotive batteries.

As shown in the right graph above, an alternating current or AC[81] voltage is constantly changing in time. The most common AC voltage source is the 110-220 volt power supplied by the local power company.

The following sections describe alternating current principles and standard measurements.

Cycle

As shown above, an AC voltage increases to a maximum value in one direction, decreases to zero, reverses, increases to a maximum in the other direction, then changes back to zero. Each time this pattern is repeated, one cycle has occurred.

Frequency

The number of cycles per second is called frequency.[87] Frequency is measured in hertz.[88] One hertz is equal to one complete cycle per second. In North America, the standard AC voltage frequency supplied by the power company is 60 cycles per second or 60 hertz.

Wave period

The amount of time an alternating current takes to complete one cycle is called the wave period. In the above diagram, the AC voltage wave period is T seconds. The relationship between frequency and the wave period is shown below.

$$F\ (\text{hertz}) = \frac{1}{T\ (\text{seconds})}$$

Peak voltage

The peak voltage, Vp is measured from the zero reference to either the maximum positive or maximum negative value. In the above diagram Vp = V.

Peak-to-peak voltage

The peak-to-peak voltage, Vpp is measured from the maximum positive value to the maximum negative value. In the above diagram Vpp = 2*V.

Average voltage

The average voltage, Vavg of a sine wave may be calculated from the peak voltage as

$$Vavg = 0.637 * Vp$$

Effective or RMS voltage

The effective or RMS value of an AC voltage source supplies the same power as an equivalent valued DC source. The RMS voltage, Vrms of a sine wave may be calculated from the peak voltage as

```
              Vp             Vp
Vrms   =   --------   =   -------   =   0.707 * Vp
            sqrt(2)        1.414
```

Related topics:

[Alternating current examples][257]
[Alternating current knowledge test][258]
[Basic alternating current principles exercise][255]
[Alternating current tutorial][255]
[Voltage][95]
[Current][84]

Alternating Current Tutorial

Basic Alternating Current Principles Exercise

Examples

Example 1

Determine the frequency if one cycle takes 5 milliseconds to complete.

```
F (hertz) =  1 / T (seconds)
          =  1 / 0.005 seconds
          =  200 Hz
```

Example 2

Determine the wave period if the frequency is 60 Hz.

```
F (hertz)   =  1 / T (seconds)
   or
T (seconds) =  1 / F (hertz)
            =  1 / 60
            =  0.167 seconds
            =  167 milliseconds
```

Example 3

Given a sine wave with a peak voltage of 35 volts, determine the average voltage.

```
Vavg   =  0.637 * Vp
       =  0.637 * 35
       =  22.3 volts
```

Example 4

Given a sine wave with a peak voltage of 311 volts, determine the RMS voltage.

```
Vrms   =  0.707 * Vp
       =  0.707 * 311
       =  220 volts
```

Related topics:

[Alternating current theory][256]
[Alternating current knowledge test][258]
[Basic alternating current principles exercise][255]
[Alternating current tutorial][255]
[Voltage][95]
[Current][84]

Alternating Current Tutorial

Basic Alternating Current Principles Exercise

Knowledge test

1. A DC[86] voltage is _______.
2. An AC[81] voltage is _______ _______ in time.

3. The number of complete cycles per second is called _______ and is measured in _______. (answer)(13)[292]

4. Given a wave period of 1 millisecond, what is the frequency? (answer)(14)[292]
5. Given a wave period of 25 milliseconds, what is the frequency?

6. Given a frequency of 1 kilohertz, what is the wave period? (answer)(15)[293]
7. Given a wave period of 125 megahertz, what is the wave period?

8. Given a sine wave with a peak voltage of 100 volts, what is the average voltage? (answer)(16)[293]
9. Given a sine wave with a peak voltage of 55 volts, what is the average voltage?

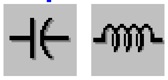
10. Given a sine wave with a peak voltage of 400 volts, what is the RMS voltage? (answer)(17)[293]
11. Given a sine wave with a peak voltage of 125 volts, what is the RMS voltage?

Related topics:

Alternating current theory[256]
Alternating current examples[257]
Alternating current knowledge test[258]
Basic alternating current principles exercise[255]
Alternating current tutorial[255]

Alternating Current Tutorial

Capacitors and Inductors in AC Circuits Exercise



Theory

The characteristics of capacitors and inductors in alternating current circuits, including capacitive[83] and inductive reactance[88] can be found in theory.[261]

Examples

Calculation of capacitive and inductive reactance can be found in examples.[261]

Knowledge test

Review questions can be found in knowledge test.[261]

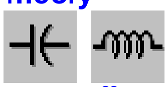
Related topics:

Basic alternating current principles exercise[255]
Alternating current tutorial[255]
Tutorial topic tree[203]

Alternating Current Tutorial

Capacitors and Inductors in AC Circuits Exercise

Theory



Resistors,[92] capacitors[82] and inductors[89] all oppose the flow of current[84] through an alternating current[81] circuit.

- Resistors have resistance.[92]
- Capacitors have capacitive reactance.[83]
- Inductors have inductive reactance.[88]

Capacitive reactance

When a capacitor is placed in an alternating current circuit, the current[84] flow will be reduced. The opposition caused by a capacitor is called capacitive reactance.[83] Capacitive reactance is inversely proportional to the amount capacitance[83] of the capacitor and the circuit frequency.[87] In other words, as the capacitance or frequency increases, the opposition to AC current flow increases. Like resistance,[92] capacitive reactance is measured in ohms.[90]

$$Xc = \frac{1}{2\pi fC}$$

Where: Xc = capacitive reactance in ohms
$2\pi \cong$ 6.283 (radians in 360 degrees)
f = frequency in hertz
C = capacitance in farads

Inductive reactance

When an inductor is placed in an alternating current circuit, the current[84] flow will be reduced. The opposition caused by an inductor is called inductive reactance.[88] Inductive reactance is proportional to the amount inductance[88] of the inductor and the circuit frequency.[87] In other words, as the inductance or frequency increases, the opposition to AC current flow increases. Like resistance,[92] inductive reactance is measured in ohms.[90]

```
Xl  =  2πfL

Where: Xl = inductive reactance in ohms
       2π ≅ 6.283 (radians in 360 degrees)
       f  = frequency in hertz
       L  = inductance in henries
```

Ohm's law

Capacitive reactance[83] or inductive reactance[88] can replace resistance[92] in the Ohm's law[90] equation to determine AC circuit voltage and currents.

```
       E                 E                 E
I  =  ---    or   I  =  ---    or   I  =  ---
       R                 Xc                Xl

Where: I = the circuit current in amperes[81]
       E = the applied voltage in volts[95]
       R = the circuit resistance in ohms[90]
       Xc = the circuit capacitive reactance in ohms[90]
       Xl = the circuit inductive reactance in ohms[90]
```

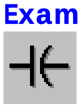
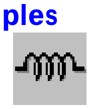
Related topics:

- Capacitors and inductors in AC circuits examples[261]
- Capacitors and inductors in AC circuits knowledge test[261]
- Capacitors and inductors in AC circuits exercise[261]
- Basic alternating current principles exercise[255]
- Alternating current tutorial[255]
- Ohm's law exercise[205]
- Resistors and Simple Circuits Tutorial[205]
- Voltage[95]
- Current[84]

Alternating Current Tutorial

Capacitors and Inductors in AC Circuits Exercise

Examples

Example 1

Determine the capacitive reactance[83] of a 2.5 µF capacitor at a frequency[87] of 800 Hz.

```
          1
Xc  =  ----
       2πfC

    =  1 / (6.283 x 800 x 2.5e-6)
    =  79.6 ohms
```

Example 2

Determine the inductive reactance[88] of a 10 mH inductor at a frequency[87] of 250 Hz.

```
Xl  =  2πfL
    =  6.283 x 250 x 10e-3
    =  15.7 ohms
```

Example 3

Using **Ohm's law,** what is the capacitor's current[84] if the applied voltage[95] is 75 volts and the capacitive reactance[83] is 5 ohms.

$$I = \frac{E}{X_c}$$

$$= 75 / 5$$

$$= 15 \text{ amperes}$$

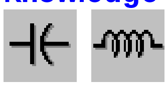
Related topics:

Capacitors and inductors in AC circuits theory[261]
Capacitors and inductors in AC circuits knowledge test[261]
Capacitors and inductors in AC circuits exercise[261]
Basic alternating current principles exercise[255]
Alternating current tutorial[255]
Ohm's law exercise[205]

Alternating Current Tutorial

Capacitors and Inductors in AC Circuits Exercise

Knowledge test



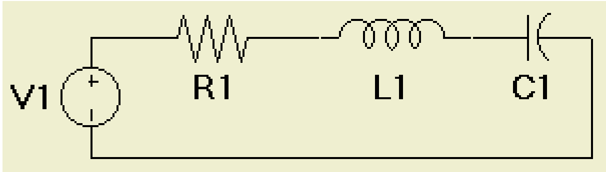
1. What is the capacitive reactance of a 0.5 µF capacitor at a frequency of 60 Hz? (answer)(24)[294]
2. What is the capacitive reactance of a 2.5 µF capacitor at a frequency of 1.5 KHz?
3. What is the inductive reactance of a 5 mH inductor at a frequency of 1.5 KHz? (answer)(25)[294]
4. What is the inductive reactance of a 12.5 mH inductor at a frequency of 0.5 MHz?
5. What is the current through a 4.5 µF capacitor when the applied voltage is 2.5 mV and the frequency is 25 KHz? (answer)(26)[294]
6. What is the current through a 100 µF capacitor when the applied voltage is 0.5 V and the frequency is 5 KHz?

Related topics:

Capacitors and inductors in AC circuits theory[261]
Capacitors and inductors in AC circuits examples[261]
Basic alternating current principles exercise[255]
Alternating current tutorial[255]
Ohm's law exercise[205]

Alternating Current Tutorial

Series Resistor-Inductor-Capacitor (RLC) Circuits Exercise



Theory

The characteristics of series RLC circuits, including resonant frequency[92] can be found in theory.[262]

Examples

Resonant frequency calculations can be found in examples.[264]

Demonstration

Demonstration[264] provides instructions to construct a simple Circuit Shop circuit to show the frequency response and resonant frequency of a series RLC circuit.

Knowledge test

Review questions can be found in knowledge test.[269]

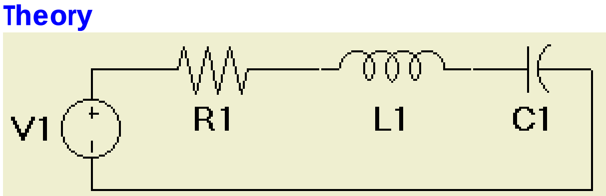
Related topics:

- Capacitors and inductors in AC circuits exercise[261]
- Basic alternating current principles exercise[255]
- Alternating current tutorial[255]
- Tutorial topic tree[203]

Alternating Current Tutorial

Series Resistor-Inductor-Capacitor (RLC) Circuits Exercise

Theory



In a series RLC circuit, the flow of alternating current[81] is opposed by the resistor's[92] resistance,[92] the inductor's[89] inductive reactance[88] and the capacitor's[82] capacitive reactance.[83]

Also, the effects of inductive reactance[88] and capacitive reactance[83] tend to cancel each other. (This can be shown with vector addition but is beyond the goals of this tutorial.) The total reactance[92] of a series RLC circuit can be expressed as

```
X  =  Xl - Xc

Where: X  = total reactance in ohms
       Xl = inductive reactance in ohms
       Xc = capacitive reactance in ohms
```

In a series RLC circuit, the opposition or impedance[88] to current flow is the vector sum of the resistance and reactance and can be calculated as

```
Z  =  SQRT( R**2 + (Xl - Xc)**2 )

Where: Z  = impedance in ohms
       R  = resistance in ohms
```

```
        Xl = inductive reactance in ohms
        Xc = capacitive reactance in ohms

Xl  =  2πfL

Xc  =  1 / 2πfC

Where: 2π ≅ 6.283 (radians in 360 degrees)
       f  = frequency in hertz
       L  = inductance in henries
       C  = capacitance in farads
```

Based on the above equations for Xl and Xc:

1. As frequency[87] increases, Xl, the inductive reactance[88] increases and Xc, the capacitive reactance[83] decreases. The circuit becomes more "inductive."

2. As frequency[87] decreases, Xl, the inductive reactance[88] decreases and Xc, the capacitive reactance[83] increases. The circuit becomes more "capacitive."

3. At a particular frequency,[87] Xl will equal Xc. This frequency is called the circuit's resonant frequency.[92]

Series RLC circuit resonance

At a particular frequency,[87] called the circuit's resonant frequency,[92] Xl will equal Xc and will cancel each other out. At this frequency, the only opposition to current flow will be the circuit's resistance.[92] By using the fact that Xl equals Xc at the resonant frequency, a resonant frequency equation in terms of the circuit's inductance[88] and capacitance[83] can be developed as follows

```
Step 1:  2πfL         =  1 / (2πfC)
     2:  f x f        =  1 / (2π x 2π x L x C)
     3:  f**2         =  1 / ((2π)**2 x L x C)
     4:  SQRT(f**2)   =  SQRT(1) / SQRT((2π)**2 x L x C))
     5:  f            =  1 / (2π x SQRT(LC))
```

Thus, a series RLC circuit's resonant frequency can be calculated using the following formula

```
              1
fr  =  -------------
       2π x SQRT(LC)

Where: fr = resonant frequency in hertz
       2π ≅ 6.283 (radians in 360 degrees)
       L  = inductance in henries
       C  = capacitance in farads
```

A series RLC circuit's resonant frequency is inversely proportional to the amount capacitance[83] or inductance[88] in the circuit. In other words, as the capacitance or inductance increases, the resonant frequency will decrease.

The resonant frequency equation may be rearranged to calculate the required inductance[88] or capacitance[83] to cause the circuit to resonate at a desired frequency.[87]

```
                1
L  =  ------------------
      (2π)**2 x f**2 x C

                1
C  =  ------------------
```

```
        (2π)**2 x f**2 x L

Where: f  = resonant frequency in hertz
       (2π)**2 ≅ 39.48
       L  = inductance in henries
       C  = capacitance in farads
```

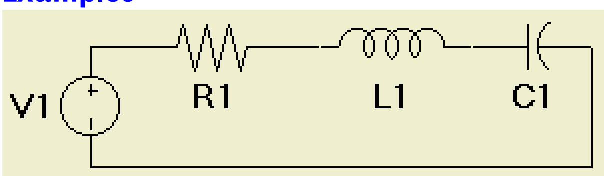
Related topics:

Series resistor-inductor-capacitor (RLC) circuits examples[264]
Series resistor-inductor-capacitor (RLC) circuits knowledge test[269]
Series resistor-inductor-capacitor (RLC) circuits exercise[262]
Capacitors and inductors in AC circuits exercise[261]
Basic alternating current principles exercise[255]
Alternating current tutorial[255]

Alternating Current Tutorial

Series Resistor-Inductor-Capacitor (RLC) Circuits Exercise

Examples



Example 1

Determine the resonant frequency[92] of a 4 mH inductor and a 2.5 µF capacitor.

```
               1
fr  =   -------------
        2π x SQRT(LC)

    = 1 / (2π x SQRT(4e-3 x 2.5e-6))
    = 1.59e3 Hz
    = 1.59 kHz
```

Example 2

Determine the capacitance[83] required to be in series with a 0.5 mH inductor to achieve a resonant frequency[92] of 500 kHz.

```
                 1
C  =  ------------------
      (2π)**2 x f**2 x L

   = 1 / ((2π)**2 x 500e3**2 x 0.5e-3)
   = 2.026e-10 F
   = 202.6 pF
```

Related topics:

Series resistor-inductor-capacitor (RLC) circuits theory[262]
Series resistor-inductor-capacitor (RLC) circuits knowledge test[269]
Series resistor-inductor-capacitor (RLC) circuits exercise[262]
Capacitors and inductors in AC circuits exercise[261]
Basic alternating current principles exercise[255]
Alternating current tutorial[255]

Alternating Current Tutorial

Series Resistor-Inductor-Capacitor (RLC) Circuits Exercise

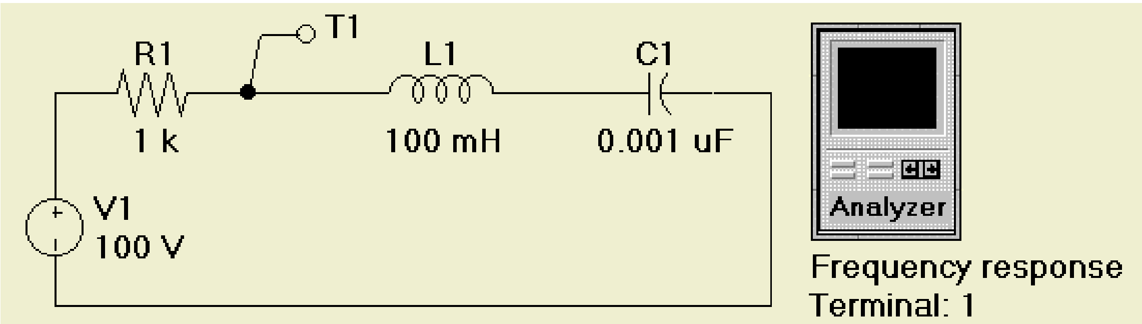
Demonstration Circuit

This circuit demonstrates resonant frequency[92] in a series resistor-inductor-capacitor (RLC) circuit.

Step 1 - construct the circuit

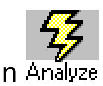
Use Circuit Shop tools to construct the following circuit. Set the circuit analyzer[30] parameters to the following values:

- analyzer type: Frequency response
- terminal id: 1
- frequency min, max, points/decade: 1e3, 1e5, 25
- plot type: Magnitude



See detailed instructions[266] if you are unfamiliar with Circuit Shop.

Step 2 - analyse the circuit

Use the Tool | Analyse[46] menu command or the toolbar[37] icon 

to analyse the circuit. Analysing a circuit[19] provides additional details.

If the circuit has been correctly constructed and the circuit analyzer correctly linked to the terminal, after the analyse command has been executed, a frequency response[27] graph window will be generated. The graph will show a peak at the resonant frequency.[92] An RLC circuit's resonant frequency was introduced in the theory[262] topic for this exercise. For this circuit the resonant frequency can be calculated as

$$fr = \frac{1}{2\pi \times SQRT(LC)}$$

$$= 1 / (2\pi \times SQRT(100e-3 \times 0.001e-6))$$
$$= 1.59e4 \text{ Hz}$$
$$= 15.9 \text{ kHz}$$

As expected, the peak on the graph occurs between 10 and 20 kHz.

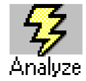
Step 3 - increase the capacitance to see the effect on resonant frequency

1. Using the mouse, click the pointer icon  on the toolbar[37] or the analog device toolkit.[52]
2. Move the mouse onto the diagram over the capacitor.[82]
3. Double click the mouse on the capacitor to open the Edit Device dialog box.[64] Modifying device values[16] provides additional details.

4. In the value field, enter **0.01e-6** as the capacitor's new value. Using this new value, the new resonant frequency can be calculated as

$$fr = \frac{1}{2\pi \times \mathrm{SQRT}(LC)}$$

$$= 1 / (2\pi \times \mathrm{SQRT}(100e\text{-}3 \times 0.01e\text{-}6))$$
$$= 5.03e3 \text{ Hz}$$
$$= 5.03 \text{ kHz}$$

5. Use the Tool | Analyse[46] menu command or the toolbar[37] icon 

to re-analyse the circuit.

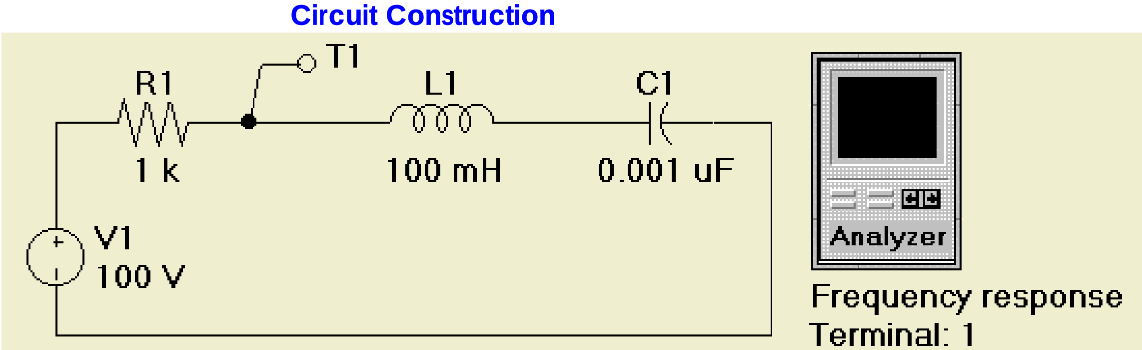
After the analyse command has been executed, the frequency response[27] graph window will be updated. As expected, the graph will show a new resonant frequency[92] peak at 5.03 Khz.

As stated in the theory[262] topic, if a circuit's capacitance[83] or inductance[88] is increased, the resonant frequency will decrease.

Related topics:

Series resistor-inductor-capacitor (RLC) circuits theory[262]
Series resistor-inductor-capacitor (RLC) circuits examples[264]
Series resistor-inductor-capacitor (RLC) circuits knowledge test[269]
Series resistor-inductor-capacitor (RLC) circuits exercise[262]
Capacitors and inductors in AC circuits exercise[261]
Basic alternating current principles exercise[255]
Alternating current tutorial[255]

Alternating Current Tutorial
Series Resistor-Inductor-Capacitor (RLC) Circuits Exercise
Demonstration Circuit
Circuit Construction



This topic provides detailed instructions to construct the series resistor-inductor-capacitor (RLC) demonstration circuit shown in the title bar above.

Open a diagram window and display the analog device toolkit:

1. Use the File | New[39] menu command or the toolbar[37] icon 

to open a new diagram window. Creating a new diagram window[15] provides additional details.
2. Ensure the analog device toolkit[52] is visible. If the toolkit is not visible, use the View | Analog Device Toolkit[49] menu command or the toolbar icon 

to display it.

Add a resistor, an inductor and a capacitor to the diagram:

1. Using the mouse, click the resistor[92] icon on the analog device toolkit.[52]
2. Move the mouse onto the diagram to approximately the center of the diagram window.
3. Click the mouse to place the resistor on the diagram. Adding devices[12] provides additional details.

4. Repeat steps (1), (2) and (3) but instead select the inductor[89] icon on the analog device toolkit.[52]

5. Repeat steps (1), (2) and (3) but instead select the capacitor[82] icon on the analog device toolkit.[52]

Add an AC voltage source to the diagram:

1. Using the mouse, click the source toolkit[58] icon on the analog device toolkit.[52]
2. Using the mouse, click the AC voltage source[81] icon on the source toolkit.[58]
3. Move the mouse onto the diagram to where the AC voltage source[81] is to be located. See circuit layout in title bar.
4. Click the mouse to place the AC voltage source on the diagram.

Add a terminal to the diagram:

Note: the terminal is used as a connection point for the circuit analyzer which will be added below.

1. Using the mouse, click the terminal & plug toolkit[57] icon on the analog device toolkit.[52]
2. Using the mouse, click the terminal[93] icon on the terminal & plug toolkit.[57]
3. Move the mouse onto the diagram to where the terminal[93] is to be located. See circuit layout in title bar.
4. Click the mouse to place the terminal on the diagram.

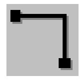
Add a connector to the diagram:

1. Using the mouse, choose the connector icon on the toolbar[37] or the analog device toolkit.[52]
2. Move the mouse onto the diagram to where the connector is to be located. See circuit layout in title bar.
3. Click the mouse to place the connector on the diagram.

Layout the circuit and rotate the devices:

1. Using the mouse, click the pointer icon on the toolbar[37] or the analog device toolkit.[52]
2. If necessary, move the diagram objects to locations approximately the same as the circuit layout in title bar. To move a device, press the left mouse button over a device and drag it to the new location. Moving an object[17] provides additional details.
3. By default, Circuit Shop places most objects on a diagram in a horizontal orientation. To rotate the voltage source, press the left mouse button over one of the source's terminals and drag it to a vertical orientation. Rotating an object[18] provides additional details.

Add wires to connect the devices:

1. Using the mouse, click the wire icon  on the toolbar[37] or the analog device toolkit.[52]
2. Move the mouse onto the diagram over the top source terminal.
3. Press the left mouse button and drag the wire to the left resistor terminal. Connecting devices[14] provides additional details.
4. Repeat steps (2) and (3) to connect the devices as shown in the circuit layout in title bar.

Add a vertex[95] to source-to-capacitor wire:

1. Using the mouse, choose the pointer icon  on the toolbar[37] or the analog device toolkit.[52]
2. Move the mouse onto the diagram over the wire portion where the vertex is to be added.
3. Press the left mouse button and drag the wire or line object to the desired vertex location.
4. Release the mouse button. Adding a vertex[12] provides additional details.

   At this point the circuit connections are complete and the circuit should look as shown in the title bar above.

Add ids and values to the devices:

1. Using the mouse, click the pointer icon  on the toolbar[37] or the analog device toolkit.[52]
2. Move the mouse onto the diagram over the resistor.[92]
3. Double click the mouse on the resistor to open the Edit Device dialog box.[64] Modifying device values[16] provides additional details.
4. Enter 1 as the resistor id and 1e3 ohms[90] as its value.

5. Repeat step (3) on the inductor[89] and enter 1 as the inductor id and 100e-3 henries[88] as its value.

6. Repeat step (3) on the capacitor[82] and enter 1 as the capacitor id and 0.001e-6 farads[86] as its value.

7. Repeat step (3) on the terminal[93] and enter 1 as the terminal id.

   Note: the terminal is used as a connection point for the circuit analyzer which will be added below. The terminal id is used to link the terminal to the circuit analyzer.

8. Repeat step (3) on the AC voltage source[81] and enter 1 as the source id and 100 volts[95] as its value.

9. Because of the vertical orientation of the AC voltage source,[81] the displayed id and value, called annotations, need to be moved. See the circuit layout in title bar above for suggested annotation locations. To move an annotation, press the left mouse button over the annotation and drag it to the new location. Moving an object[17] provides additional details.

   At this point the circuit is complete. The devices have been added, wires have been added to connect the devices, and their ids and values have been defined.

Add a circuit analyzer to the diagram:

1. Using the mouse, click the circuit analyzer[30] icon 

on the analog device toolkit.[52]

2. Move the mouse onto the diagram to a position just to the right of the circuit as shown in the title bar above.
3. Click the mouse to place the circuit analyzer on the diagram. Adding an object[12] provides additional details.

Set circuit analyzer parameters:

1. Using the mouse, click the pointer icon  on the toolbar[37] or the analog device toolkit.[52]
2. Move the mouse onto the diagram over the circuit analyzer.[30]
3. Double click the mouse on the analyzer to open the Edit Analyzer dialog box.[62] Modifying object values[16] provides additional details.
4. Set the circuit analyzer parameters to the following values:
   - analyzer type: Frequency response
   - terminal id: 1
   - frequency min, max, points/decade: 1e3, 1e5, 25
   - plot type: Magnitude

   At this point the circuit construction is complete. Return to series RLC circuits demonstration[264] to complete the exercise.

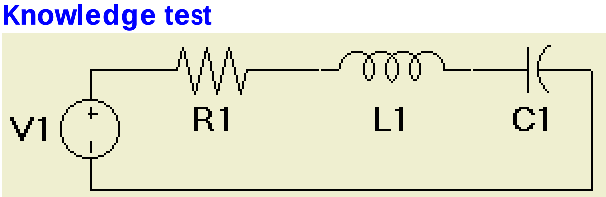
Related topics:

Series resistor-inductor-capacitor (RLC) circuits exercise[262]
Alternating current tutorial[255]
Creating and editing diagrams[11]
Menu commands[37]
Toolbar commands[37]
Device and drawing toolkits[51]
Dialog boxes[62]

Alternating Current Tutorial

Series Resistor-Inductor-Capacitor (RLC) Circuits Exercise

Knowledge test



1. What is the resonant frequency[92] of a 0.25 mH inductor and a 100 μF capacitor? (answer)(27)[295]
2. What is the resonant frequency[92] of a 0.05 mH inductor and a 50 μF capacitor?
3. What is the capacitance[83] required to be in series with a 750 mH inductor to achieve a resonant frequency[92] of 50 kHz. (answer)(28)[295]
4. What is the inductance[88] required to be in series with a 1 μF capacitor to achieve a resonant frequency[92] of 333 Hz.

Related topics:

Series resistor-inductor-capacitor (RLC) circuits theory[262]
Series resistor-inductor-capacitor (RLC) circuits examples[264]
Series resistor-inductor-capacitor (RLC) circuits exercise[262]
Capacitors and inductors in AC circuits exercise[261]
Basic alternating current principles exercise[255]
Alternating current tutorial[255]

Semiconductor Tutorial

This tutorial covers the following topics:

- How diodes[85] operate in a circuit.
- The use of diodes in half-wave rectifiers[87] and full-wave rectifiers.[87]

- How transistors[94] operate in a circuit.
- Biasing a transistor.
- Different types of transistor circuits.

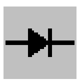
Exercises:

Diode exercise[270]
Transistor exercise[274]

Related topics:

General tutorial introduction and instructions[201]
Tutorial topic tree[203]

Semiconductor Tutorial



Diode Exercise

Theory

Basic diode[85] characteristics and operation can be found in theory.[270]

Examples

Two simple diode rectification[92] circuits, a half-wave rectifier[87] and a full-wave rectifier[87] can be found in examples.[271]

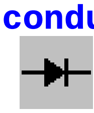
Knowledge test

Review questions can be found in knowledge test.[273]

Related topics:

Semiconductor tutorial[270]
Tutorial topic tree[203]

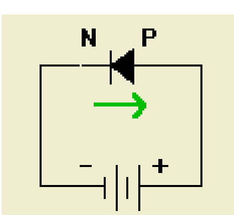
Semiconductor Tutorial



Diode Exercise

Theory

A diode[85] is a two terminal semiconductor[93] device which acts like a one-way gate in a circuit. A diode allows current[84] to easily flow in one direction and not the other. In other words, a diode has a very low resistance[92] in one direction and a very high resistance in the other.



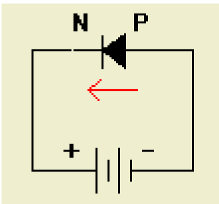
Forward bias turns a diode on

The above circuit shows a forward bias diode. I.e. the negative (-) battery terminal is connected to the N side of the diode and the positive (+) battery terminal is connected to the P side of the diode.

In a forward bias configuration, the diode will present a low resistance[92] to the circuit and current[84] will easily flow.

Note: P and N stand for semiconductor crystal types which have an excess of positive and negative charge respectively. Silicon P-N junction diodes are the most common diode device type. (Further semiconductor crystal and charge theory is very detailed and is beyond the goals of this tutorial.)

For a silicon P-N junction diode, when the forward bias voltage reaches +0.7 volts and above, the diode turns on and presents a very low resistance to the circuit and current begins to flow. The +0.7 value is called the threshold voltage.



Reverse bias turns a diode off

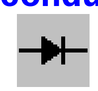
The above circuit shows a reverse bias diode. I.e. the positive (+) battery terminal is connected to the N side of the diode and the negative (-) battery terminal is connected to the P side of the diode. In a reverse bias configuration, the diode will present a very high resistance[92] to the circuit and current[84] will not easily flow.

A diode can only withstand a certain amount of reverse voltage before the diode one-way gate effect fails and current begins to flow in the reverse direction. For a silicon P-N junction diode, this normally occurs at -20 to -25 volts. The reverse bias point where the diode fails is normally called the breakdown voltage.

Related topics:

- Diode examples[271]
- Diode knowledge test[273]
- Diode exercise[270]
- Semiconductor tutorial[270]

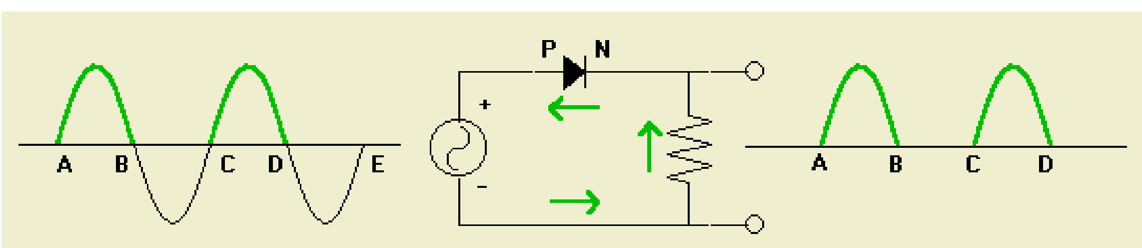
Semiconductor Tutorial



Diode Exercise Examples

Example 1 - Half-wave rectifier

Diodes[85] can be used to convert alternating current (AC)[81] into direct current (DC).[86] This conversion is called rectification.[92]



Half-wave rectification

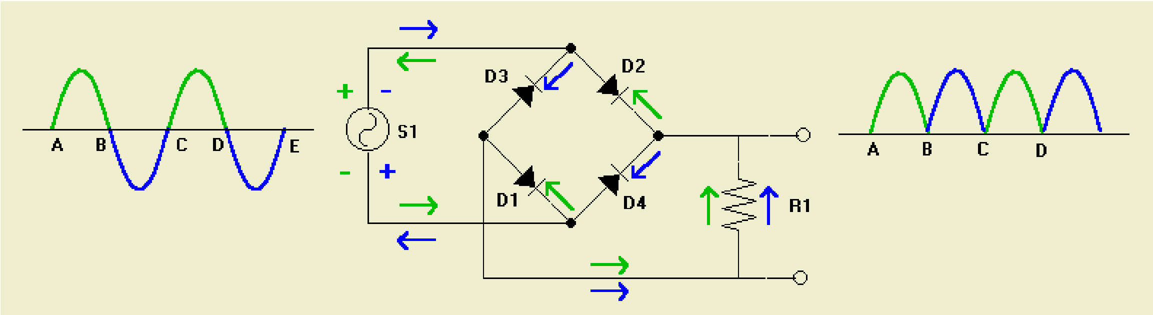
The above circuit is called a half-wave rectifier. The input source provides an alternating current (AC)[81] voltage.[95]

When the voltage source is transitioning through the positive half of the cycle (points A to B and C to D), the diode is forward biased, i.e. a positive (+) voltage is applied to the P side of the diode. When the diode is forward biased, the diode's resistance[92] is low and current will easily flow.

When the voltage source is transitioning through the negative half of the cycle (points B to C and D to E), the diode is reverse biased, i.e. a negative (+) voltage is applied to the P side of the diode. When the diode is reverse biased, the diode's resistance[92] is very high and no current will flow.

This results in a pulsating direct current (DC)[86] wave at the output terminal since the diode one-way gate action only allows 1/2 of the input wave through. Because only 1/2 of the input wave is used, this circuit is called a half-wave rectifier.

Example 2 - Full-wave rectifier
The following circuit is called a full-wave or bridge rectifier.



The input source provides an alternating current (AC)[81] voltage.[95]

When the voltage source is transitioning through the positive half of the cycle (points A to B and C to D), diodes D1 and D2 are forward biased, i.e. a negative (-) voltage is applied to the N side of D1 and a positive (+) voltage is applied to the P side of D2. Since D1 and D2 are forward biased, their resistance[92] is low and current will easily flow through their circuit branches.
Using the same reasoning, diodes D3 and D4 are negative biased and their resistance[92] is high and very little current will flow through their circuit branches.
In the above circuit, the current path while transitioning through the positive half of the cycle is shown by the green arrows.

When the voltage source is transitioning through the negative half of the cycle (points B to C and D to E), the other half of the bridge circuit becomes active. Diodes D3 and D4 become forward biased, i.e. a negative (-) voltage is applied to the N side of D3 and a positive (+) voltage is applied to the P side of D4. Since D3 and D4 are forward biased, their resistance[92] is low and current will easily flow through their circuit branches.
Using the same reasoning, diodes D1 and D2 become negative biased and their resistance[92] is high and very little current will flow through their circuit branches.
In the above circuit, the current path while transitioning through the negative half of the cycle is shown by the blue arrows.

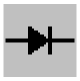
In summary, during the positive half of the cycle,
    diodes D1 and D2 turn on and
    diodes D3 and D4 turn off.
During the negative half of the cycle, the bridge circuit reverses, i.e.
    diodes D1 and D2 turn off and
    diodes D3 and D4 turn on.

This results in a pulsating direct current (DC)[86] wave at the output terminal. Half of the bridge allows the positive portion of the input wave through, and the other half of the bridge allows the negative portion of the input wave through. Because both the positive and negative portions of the input wave are passed through, this circuit is called a full-wave rectifier.

Related topics:

- Diode theory[270]
- Diode exercise[270]
- Diode knowledge test[273]
- Semiconductor tutorial[270]

Semiconductor Tutorial


Diode Exercise

Knowledge Test

1. A diode[85] is a two terminal device which acts like a _______ ____ in a circuit. A diode allows current[84] to easily flow in one direction and not the other. In other words, a diode has a very ___ resistance[92] in one direction and a very ____ resistance in the other. (answer)(34)[296]

2. Forward bias turns a diode __ and a reverse bias turns a diode ___.

3. For a silicon P-N junction diode, when the forward bias voltage reaches +0.7 volts and above, the diode turns on and presents a very low resistance to the circuit and current begins to flow. The +0.7 value is called the _________ _______. (answer)(35)[296]

4. A diode can only withstand a certain amount of reverse voltage before the diode one-way gate effect fails and current begins to flow in the reverse direction. For a silicon P-N junction diode, this normally occurs at -20 to -25 volts. The reverse bias point where the diode fails is normally called the _________ _______.

5. Diodes can be used to convert alternating current (AC)[81] into direct current (DC).[86] This conversion is called ____________. (answer)(36)[296]

Related topics:

- Diode theory[270]
- Diode examples[271]
- Diode exercise[270]
- Semiconductor tutorial[270]

Semiconductor Tutorial

Transistor Exercise

Theory

Basic transistor[94] characteristics and operation can be found in theory.[274]

Examples

Calculation of fixed and voltage divider bias resistor values can be found in examples.[276]

Knowledge test

Review questions can be found in knowledge test.[280]

Related topics:

Semiconductor tutorial[270]

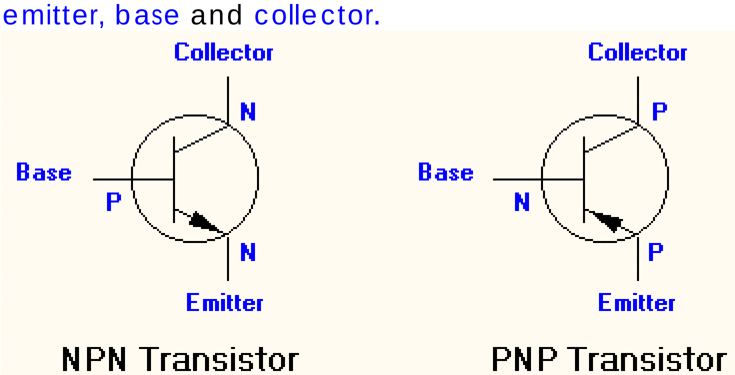
Tutorial topic tree[203]

Semiconductor Tutorial

Transistor Exercise

Theory

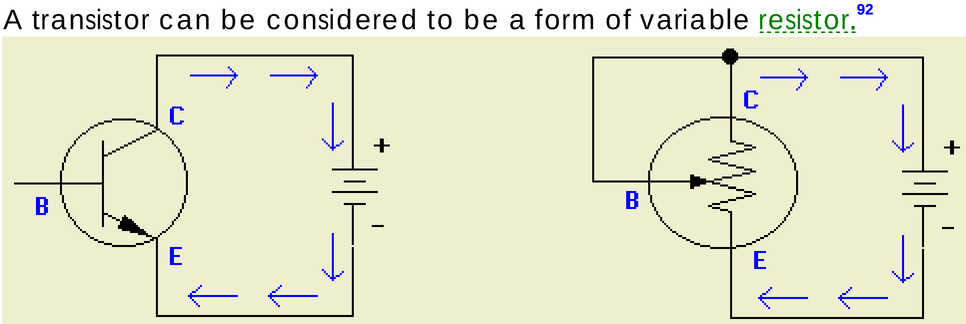
A transistor[94] is a three terminal device made of semiconductor[93] material. The terminals are named: emitter, base and collector.



There are two types of transistors, NPN and PNP. P and N stand for semiconductor crystal types which have an excess of positive and negative charge respectively. (Further semiconductor crystal and charge theory is very detailed and is beyond the goals of this tutorial. Most students will find further study of semiconductor theory to be interesting and rewarding, it is highly recommended!)

The base current controls the output collector current

A transistor can be considered to be a form of variable resistor.[92]

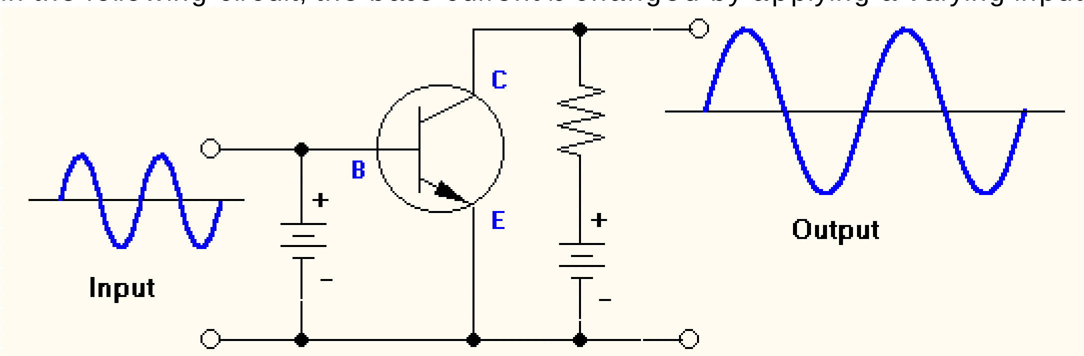


In the right hand circuit above, the base acts like the moveable contact of a variable resistor. The base current[84] controls the transistor's emitter-to-collector resistance[92] and thus the emitter-to-collector circuit current.

- When the base current is low, the transistor's emitter-to-collector resistance is high and very little current will flow. I.e. when the base current is turned off, the transistor's output current will be low.
- When the base current is high, the transistor's emitter-to-collector resistance is low and a current will flow in the circuit. I.e. when the base current is turned on, the transistor's output current will flow.

A transistor can amplify an input signal

In the following circuit, the base current is changed by applying a varying input signal.



The changing base current causes the transistor's emitter-to-collector resistance to vary which results in a changing emitter-to-collector circuit current. The changing emitter-to-collector current causes a varying output voltage.[95] A small change in the base current will cause a large change in the transistor's emitter-to-collector current. In other words, the input signal is amplified by the transistor circuit.

Current gain

As stated above, a small change in the base current will cause a large change in the transistor's emitter-to-collector current. The ratio of the transistor's emitter-to-collector current to the base current is called the transistor's current gain h_{FE}. In equation form

$$h_{FE} = \frac{I_C}{I_B}$$

where

h_{FE} = transistor current gain

I_C = collector current (amperes[81])

I_B = base current (amperes[81])

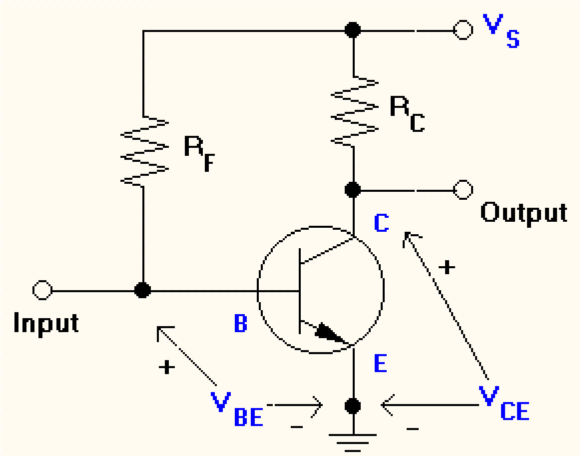
Typical transistor h_{FE} values range from 50 to 200. This means the transistor's output current, I_C will be 50 to 200 times greater than the input current I_B.

Note, because of the high current gains for most transistors, the base current is much lower than the collector current.
Since $I_C = I_E + I_B$ and I_B is negligible, the emitter current, I_E is approximately equal to the collector current, I_C. This fact is sometimes useful when analyzing transistor circuits.

Transistor biasing

To operate, a transistor's emitter-to-base terminals must be forward biased.

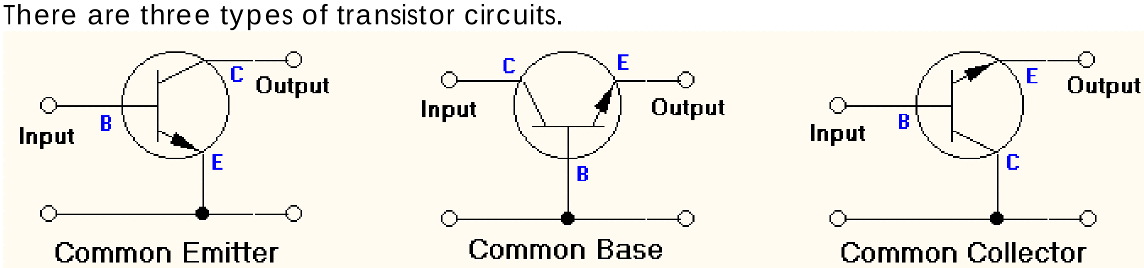
- For an NPN transistor, the base voltage must be more positive than the emitter voltage.
- For a PNP transistor, the base voltage must be more negative than the emitter voltage.



In the above NPN transistor circuit, the emitter is grounded and thus at 0 volts. Resistor R_F must be selected to forward bias the base with respect to the emitter, i.e. the emitter-to-base voltage V_{BE} must be greater than or equal to +0.7 volts. The +0.7 value is called the threshold voltage and is also discussed in diode theory.[270] How to calculate bias resistor values can be found in examples.[276]

Transistor circuit types

There are three types of transistor circuits.



The three circuit types have different amplification, input/output impedance,[88] and phase[91] characteristics.

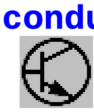
	Common Emitter	Common Base	Common Collector
Amplification	High	Medium	Low (< 1)
Input impedance	Medium	Low	High
Output impedance	Medium	High	Low
Phase shift	180 deg.	None	None

Generally, Common Emitter circuits are used in amplifier applications. Common Base and Common Collector circuits are used to match impedances with input/output devices such as microphones and speakers, and between different circuits.

Related topics:

- Transistor examples[276]
- Transistor knowledge test[280]
- Transistor exercise[274]
- Semiconductor tutorial[270]

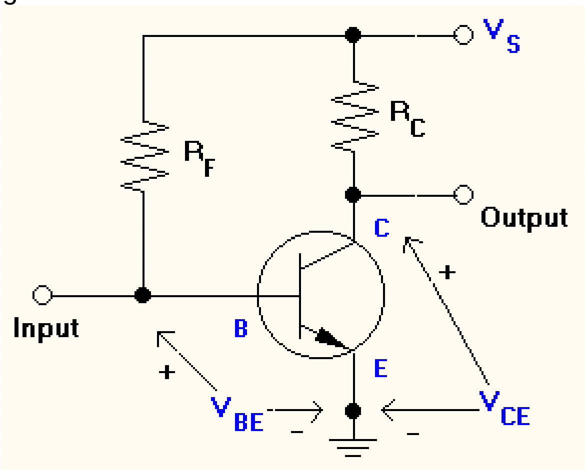
Semiconductor Tutorial



Transistor Exercise Examples

Example 1 - Fixed bias

In the following circuit, a "fixed bias" voltage is applied via resistor R_F to the base to ensure the emitter-to-base transistor terminals are forward biased, i.e. the base voltage is at least +0.7 volts greater than the emitter.



Given

V_S = 9.0 volts
R_C = 2500 ohms
V_{CE} = 1.5 volts (desired operating point)
h_{FE} = 100 (common emitter current gain)

Determine the required bias resistor, R_F value.

1. First determine the voltage[95] across the collector resistor R_C. V_{RC} is equal to the source voltage, V_S, minus the desired operating point voltage, V_{CE}.
   $V_{RC} = V_S - V_{CE}$
   $= 9.0 - 1.5$
   $= 7.5$ volts.

2. Using Ohm's law[90] determine the current[84] through R_C. This is the same as the collector current, I_C.
   $I_C = V_{RC} / R_L$
   $= 7.5 / 2500$
   $= 3.0$ mA.

3. Using the collector current, I_C determined in step (2) and the transistor's current gain, h_{FE}, the required base current,[84] I_B can be determined.

   $$h_{FE} = \frac{I_C}{I_B}$$

   or

   $I_B = I_C / h_{FE}$
   $= 3.0$ ma / 100
   $= 0.03$ ma

4. Next, determine the required voltage[95] across R_F. This is the transistor's base terminal bias voltage.

   To operate, the transistor must be forward biased, i.e. the emitter-to-base voltage, V_{BE} must be greater than or equal to +0.7 volts. (The +0.7 value is called the threshold voltage and is also discussed in diode theory.[270])
   For this example, we will select V_{BE} to be +0.725 volts.

   V_{RF} is equal to the source voltage, V_S minus the selected base terminal voltage, V_{BE}.
   $V_{RF} = V_S - V_{BE}$
   $= 9.0 - 0.725$
   $= 8.275$ volts.

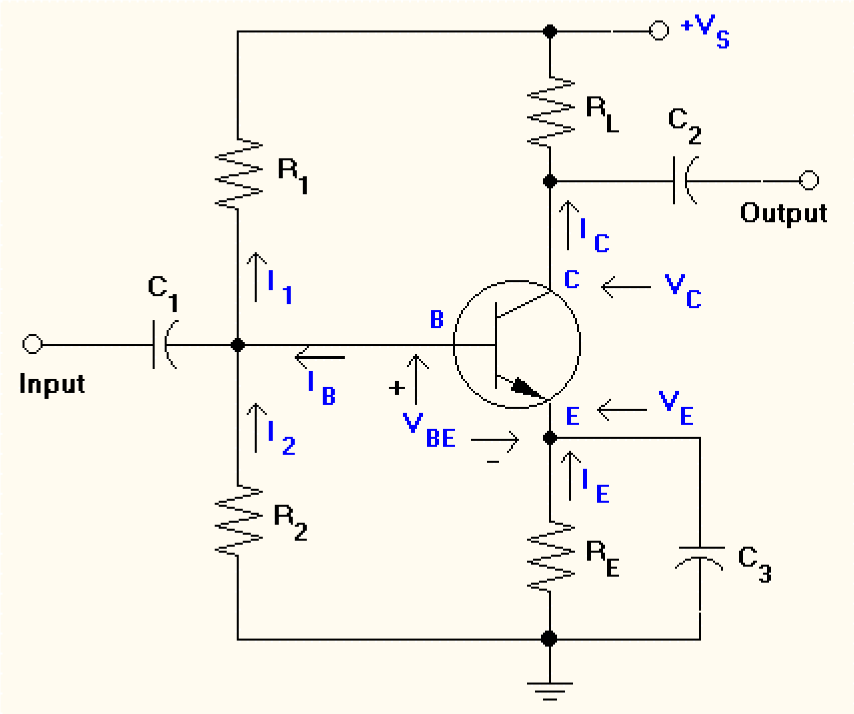
5. Finally, Ohm's law[90] can be used to determine RF's resistance[92] value.

$$R_F = \frac{V_{RF}}{I_B}$$

= 8.275 volts / 0.03 ma
= 8.275 volts / 0.03e-3 amps
= 276e3 ohms
= 276 kohms

Example 2 - Voltage divider bias

In the following circuit, a voltage divider consisting of R1 and R2 is used to ensure the emitter-to-base transistor terminals are forward biased, i.e. the base voltage is at least +0.7 volts greater than the emitter.



Given

V_S = 9.0 volts
V_C = 4.5 volts (desired operating point)
I_C = 1.0 milliamp (desired operating point)
V_E = 0.5 volts
h_{FE} = 100 (common emitter current gain)

Determine the values for RL, RE, R1 and R2 to ensure the base is forward biased.

1. First determine the voltage[95] across RL. VRL is equal to the source voltage, Vs, minus the desired operating point voltage, Vc.

$V_{RL} = V_S - V_C$
= 9.0 - 4.5
= 4.5 volts.

2. Using VRL obtained in step (1) and the desired operating point collector current, Ic, use Ohm's law[90] to determine RL's resistance[92] value.

$R_L = V_{RL} / I_C$
= 4.5 volts / 1.0 ma
= 4.5 / 1.0e-3
= 4500 ohms

3. Next, determine the emitter resistance[92] value, R_E.
Using the fact that for a transistor, the emitter current, I_E is approximately equal to the collector current, I_C, gives $I_E = 1.0$ ma.
Using the given emitter voltage, V_E and the estimated emitter current, I_E, use Ohm's law[90] to determine R_E's resistance[92] value.

$R_E = V_E / I_E$
= 0.5 volts / 1.0 ma
= 0.5 / 1.0e-3
= 500 ohms

4. Using the transistor's current gain, h_{FE} and the given collector current, I_C, the base current,[84] I_B can be determined.

$$h_{FE} = \frac{I_C}{I_B}$$

or

$I_B = I_C / h_{FE}$
= 1.0 ma / 100
= 0.01 ma

5. Next, determine the current[84] through the voltage divider resistors R_1 and R_2.
In general, to ensure the circuit is stable, the current through the voltage divider should be at least 10 times greater than the base current. The larger the voltage divider current, the more stable the circuit will be, this is traded against the continuous power[91] consumption of the voltage divider.
For this example, we will select resistor R_2's current, $I_2 = 0.25$ ma.

Resistor R_1's current, I_1 can be calculated as follows.

$I_1 = I_2 + I_B$
= 0.25 + 0.01
= 0.26 ma

6. Next, calculate the voltage[95] across resistor R_2.
To operate, the transistor must be forward biased, i.e. the emitter-to-base voltage V_{BE} must be greater than or equal to +0.7 volts. (The +0.7 value is called the threshold voltage and is also discussed in diode theory.[270])
For this example, we will select V_{BE} to be +0.725 volts.
Resistor R_2's voltage, V_{R2} can be calculated as follows.

$V_{R2} = V_E + V_{BE}$
= 0.5 + 0.725
= 1.225 volts

7. Using V_{R2} determined in step (6) and the selected bias current, I_{R2}, use Ohm's law[90] to determine R_2's resistance[92] value.

$R_2 = V_{R2} / I_{R2}$
= 1.225 volts / 0.25 ma
= 1.225 / 0.00025
= 4900 ohms

8. The voltage[95] across resistor R_1, can be calculated as follows.

$V_{R1} = V_S - V_{R2}$
= 9.0 - 1.225
= 7.775 volts

9. Finally, using Ohm's law,[90] determine R_1's resistance[92] value.

$R_1 = V_{R1} / I_{R1}$
= 7.775 volts / 0.26 ma
= 1.225 / 0.00026
= 29900 ohms

Related topics:

- Transistor theory[274]
- Transistor exercise[274]
- Transistor knowledge test[280]
- Semiconductor tutorial[270]

Semiconductor Tutorial

Transistor Exercise
Knowledge Test

1. The terminals on a transistor are named: _______, ____ and _________. (answer)(37)[296]
2. There are two types of transistors, ___ and ___.

3. The ____ current controls the output _________ current. (answer)(38)[296]
4. A transistor can amplify an input signal. A small change in the ____ current will cause a large change in the transistor's _________________ current.

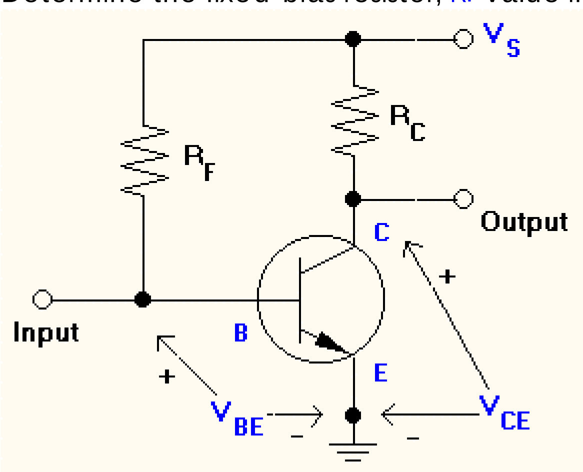
5. If a transistor's input base current, I_B is 2 ma and the output collector current, I_C is 220 ma, what is the transistor's current gain, h_{FE}? (answer)(39)[296]
6. If a transistor's input base current, I_B is 1.5 ma and the output collector current, I_C is 180 ma, what is the transistor's current gain, h_{FE}?
7. If a transistor's current gain, h_{FE} is 125, and the output collector current, I_C is 200 ma, what is the input base current, I_B?

8. Because of the high current gains for most transistors, the _______ current is approximately equal to the _________ current. (answer)(40)[296]

9. To operate, a transistor's emitter-to-base terminals must be ________ ______.

10. The three types of transistor circuits are ______ _______, ______ ____ and ______ _________. (answer)(41)[296]

11. Determine the fixed-bias resistor, R_F value in the following circuit.

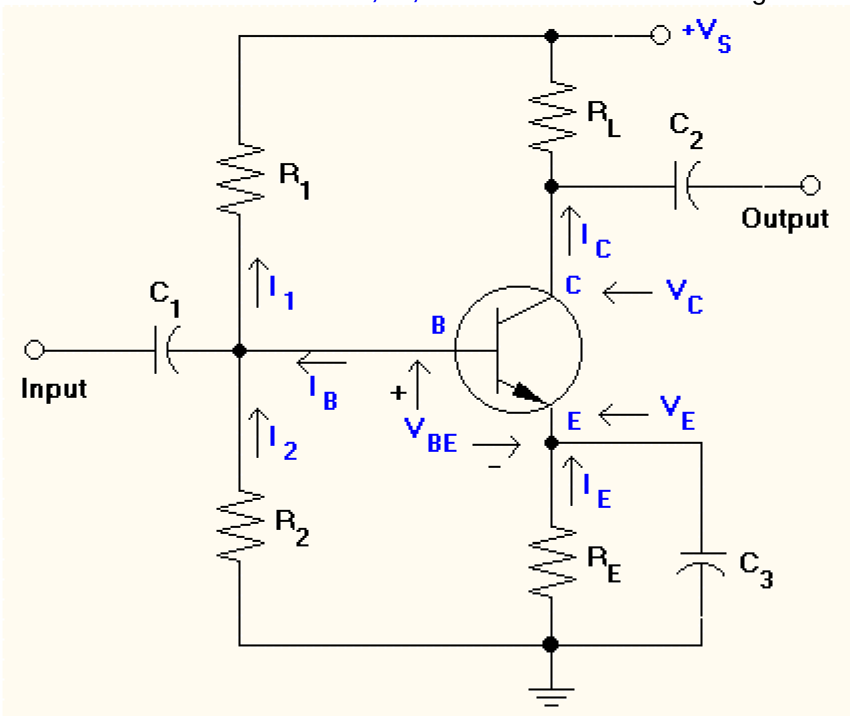


Given

V_S = 12.0 volts
R_C = 3000 ohms
V_{CE} = 2.5 volts (desired operating point)
h_{FE} = 120 (common emitter current gain)

Hint: follow the steps in Example 1 in the examples[276] topic.

12. Determine the values for R_L, R_E, R_1 and R_2 in the following circuit.



Given

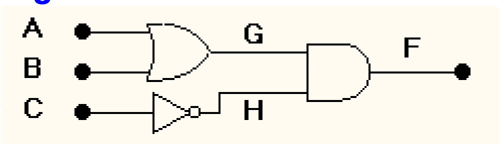
V_S = 12.0 volts
V_C = 3.5 volts (desired operating point)
I_C = 1.25 milliamp (desired operating point)
V_E = 0.75 volts
h_{FE} = 120 (common emitter current gain)

Hint: follow the steps in Example 2 in the examples[276] topic.

Related topics:

Transistor theory[274]
Transistor examples[276]
Transistor exercise[274]
Semiconductor tutorial[270]

Digital Circuits Tutorial



This tutorial covers the following topics:

- How logic gates[34] operate in digital circuits.[84]
- How boolean expressions[82] can be used to describe digital circuits.
- How to use the digital analysis[32] function.

Exercises:

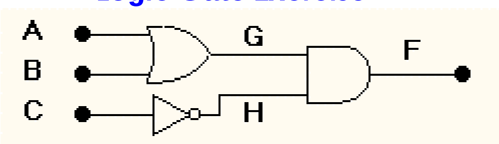
Logic gate exercise[282]

Related topics:

General tutorial introduction and instructions[201]
Tutorial topic tree[203]

Digital Circuits Tutorial

Logic Gate Exercise



Theory

Basic logic gate[34] characteristics and operation can be found in theory.[282]

Examples

Several simple logic gate[34] circuits can be found in examples.[285]

Demonstration

Logic circuit demonstration[287] provides instructions to construct a simple Circuit Shop circuit which simulates an automobile headlight alarm. This demonstration shows how to use Circuit Shop's digital device toolkit[51] and digital analysis[32] function.

Knowledge test

Review questions can be found in knowledge test.[290]

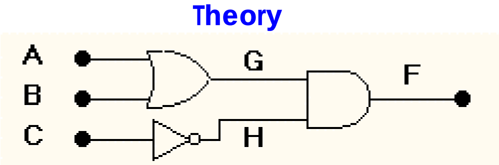
Related topics:

Digital circuits tutorial[282]
Tutorial topic tree[203]

Digital Circuits Tutorial

Logic Gate Exercise

Theory

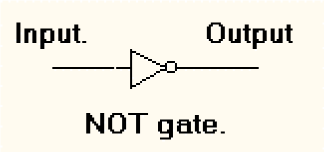


Logic gates[34] are the building blocks of digital circuits.[84] Logic gates can be connected together to make digital systems of any size and complexity, including large digital computers.

The following logic gates[34] are discussed below:

- NOT[90]
- AND[82] and NAND[82]
- OR[91] and NOR[91]
- EXCLUSIVE-OR[86] and EXCLUSIVE-NOR[86]

NOT gate



The NOT gate[90] is the simplest logic gate.[34] The NOT gate has a single input. The output level is the reverse of the input level.

- If the input level is HIGH, (logic level 1) the output is LOW (logic level 0).
- If the input level is LOW, (logic level 0) the output is HIGH (logic level 1).

In other words, a NOT gate[90] inverts its input.

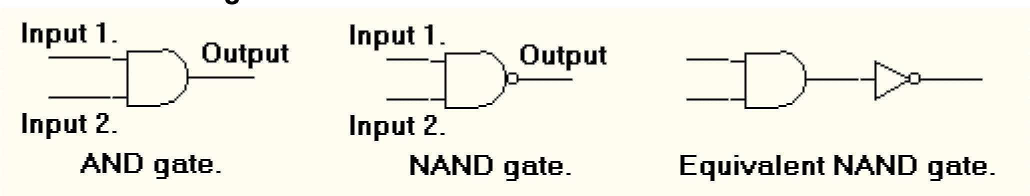
The behaviour of logic gates is usually represented in truth tables.[94] The truth table for a NOT gate is shown below.

Input	Output
0	1
1	0

Digital circuits can also be described using boolean expressions.[82] The boolean expression for a NOT gate where A is the input and B is the output is shown below

$$B = \overline{A}$$

AND and NAND gates



The AND gate[82] has 2 or more inputs. The output level depends on the input levels.

- If all input levels are HIGH, (logic level 1) the output is HIGH (logic level 1).
- If any input level is LOW, (logic level 0) the output is LOW (logic level 0).

In other words, for a 2 input AND gate,[82] the output is HIGH when input 1 is HIGH **AND** input 2 is HIGH.

The NAND gate[82] (NOT AND gate) is an inverted AND gate.[82] The above diagram shows how an AND gate[82] can be combined with a NOT gate[90] to form a NAND gate.[82]

The truth table[94] for 2 input AND and NAND gates is shown below.

Input 1	Input 2	AND Output	NAND Output

0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0

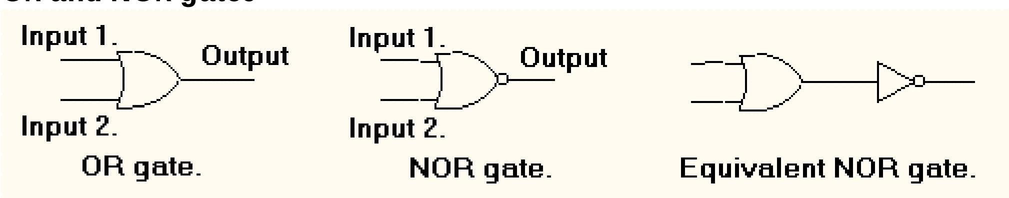
As can be seen above, the AND gate's[82] output is logic level 1 only when both inputs are logic level 1. Also, the NAND gate's[82] output, is the inverse of the AND gate.[82]

The boolean expressions[82] for AND and NAND gates where A and B are inputs and C is the output are shown below

AND : $C = AB$ **or** $C = A \bullet B$

NAND: $C = \overline{AB}$ **or** $C = \overline{A \bullet B}$

OR and NOR gates



The OR gate[91] has 2 or more inputs. The output level depends on the input levels.

- If any input level is HIGH, (logic level 1) the output is HIGH (logic level 1).
- If all input levels are LOW, (logic level 0) the output is LOW (logic level 0).

In other words, for a 2 input OR gate,[91] the output is HIGH when input 1 is HIGH **OR** input 2 is HIGH.

The NOR gate[91] (NOT OR gate) is an inverted OR gate.[91] The above diagram shows how an OR gate[91] can be combined with a NOT gate[90] to form a NOR gate.[91]

The truth table[94] for 2 input OR and NOR gates is shown below.

Input 1	Input 2	OR Output	NOR Output
0	0	0	1
0	1	1	0
1	0	1	0
1	1	1	0

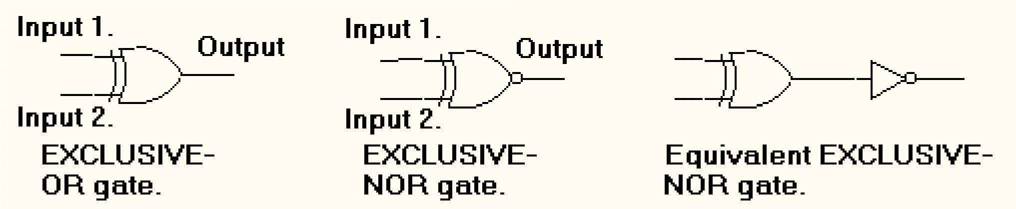
As can be seen above, the OR gate's[91] output is logic level 1 when either input is logic level 1. Also, the NOR gate's[91] output, is the inverse of the OR gate.[91]

The boolean expressions[82] for OR and NOR gates where A and B are inputs and C is the output are shown below

OR : $C = A + B$

NOR: $C = \overline{A + B}$

EXCLUSIVE-OR and EXCLUSIVE-NOR gates



The EXCLUSIVE-OR gate[86] has 2 or more inputs. The output level depends on the input levels.

- If one and only one input level is HIGH, (logic level 1) the output is HIGH (logic level 1).
- If all input levels are LOW, (logic level 0) the output is LOW (logic level 0).
- If more than one input level is HIGH, (logic level 1) the output is LOW (logic level 0).

In other words, for an EXCLUSIVE-OR gate,[86] the output is HIGH when one and only one input is HIGH.

The EXCLUSIVE-NOR gate[86] (NOT EXCLUSIVE-OR gate) is an inverted EXCLUSIVE-OR gate.[86] The above diagram shows how an EXCLUSIVE-OR gate[86] can be combined with a NOT gate[90] to form an EXCLUSIVE-NOR gate.[86]

The truth table[94] for 2 input EXCLUSIVE-OR and EXCLUSIVE-NOR gates is shown below.

Input 1	Input 2	EXCLUSIVE-OR Output	EXCLUSIVE-NOR Output
0	0	0	1
0	1	1	0
1	0	1	0
1	1	0	1

As can be seen above, the EXCLUSIVE-OR gate's[86] output is logic level 1 when only one input is logic level 1. Also, the EXCLUSIVE-NOR gate's[86] output, is the inverse of the EXCLUSIVE-OR gate.[86]

The boolean expressions[82] for EXCLUSIVE-OR and EXCLUSIVE-NOR gates where A and B are inputs and C is the output are shown below

EXCLUSIVE-OR : $C = A \oplus B$

EXCLUSIVE-NOR: $C = \overline{A \oplus B}$

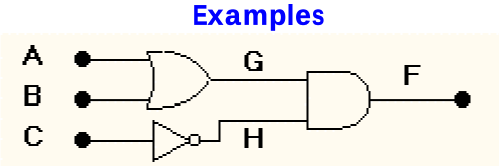
Related topics:

Logic gate examples[285]
Logic gate knowledge test[290]
Logic gate demonstration circuit[287]
Logic gate demonstration circuit construction[288]
Logic gate exercise[282]
Digital circuits tutorial[282]

Digital Circuits Tutorial

Logic Gate Exercise

Examples



Example 1

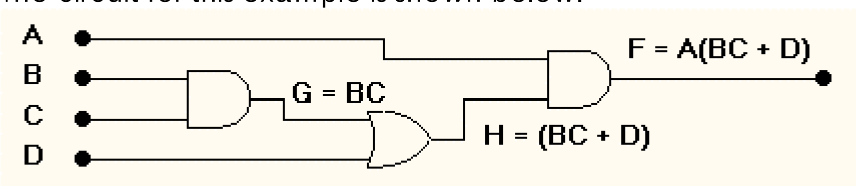
Create a digital circuit[84] for the following boolean expression.[82]

F = A(BC + D)

There are three steps:

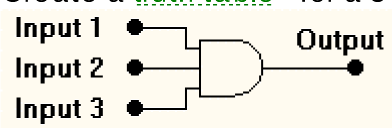
1. Use an AND gate[82] to evaluate BC and assign the output to G.
2. Use an OR gate[91] to evaluate (G + D) which is the same as (BC + D) and assign the output to H.
3. Use an AND gate[82] to evaluate AH which is the same as A(BC + D) and assign the output to F.

The circuit for this example is shown below.



Example 2

Create a truth table[94] for a 3 input AND gate.[82]



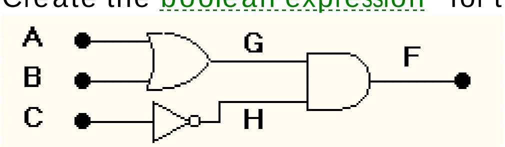
As described in Logic Gate Theory,[282] an AND gate's[82] output is logic level 1 only when all inputs are logic level 1. Using this fact, the following truth table can be created.

Input 1	Input 2	Input 3	AND Output
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	1

As can be seen above, the AND gate's[82] output is logic level 1 only when all inputs are logic level 1.

Example 3

Create the boolean expression[82] for the following digital circuit.[84]



There are three steps:

1. $G = A + B$
2. $H = \overline{C}$
3. $F = GH = (A + B) \bullet \overline{C}$

Related topics:

Logic gate theory[282]
Logic gate knowledge test[290]
Logic gate demonstration circuit[287]

Logic gate demonstration circuit construction[288]
Logic gate exercise[282]
Digital circuits tutorial[282]

Digital Circuits Tutorial
Logic Gate Exercise
Demonstration Circuit

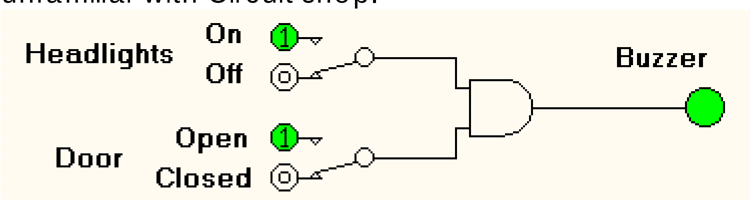
This topic demonstrates how to construct and analyze a digital circuit[84] composed of digital sources,[33] logic gates[34] and digital displays.[36]

The circuit simulates an automobile headlight alarm. I.e. when the headlights are on AND the door is open, the buzzer will sound.

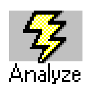
- Digital source switches[85] are used to simulate the headlight on/off switch and the door open/closed switch.
- A digital display lamp[84] is used to simulate the alarm buzzer.

Step 1 - construct the circuit

Use Circuit Shop tools to construct the following circuit. See detailed instructions[288] if you are unfamiliar with Circuit Shop.



Step 2 - analyse the circuit

Use the Tool | Analyse[46] menu command or the toolbar[37] icon 

to analyse the circuit. Analysing a circuit[19] provides additional details.

If the circuit has been correctly constructed and either digital source switch[85] is at logic level 0, the digital display lamp[84] should turn off.

Step 3 - toggle the headlight and door switches

1. Using the mouse, click the pointer icon  on the toolbar[37] or the analog device toolkit.[52]
2. Move the mouse onto the diagram over one of the digital source switches.[85]
3. Single click the mouse on the switch to toggle its output level. The digital analysis[32] function will be invoked.

   If the circuit has been correctly constructed, wires[95] connected to a digital source switch[85] which is set to logic level 1 will be highlighted. This indicates that that wire is also at logic level 1.

   If both digital source switch[85] outputs are set to logic level 1, (i.e. the headlights are on AND the door is open) both inputs to the AND gate[82] will be logic level 1. This will cause the output of the AND gate to also be at logic level 1 and will cause the digital display lamp[84] to turn on (i.e. in an automobile, the buzzer will sound).

Related topics:

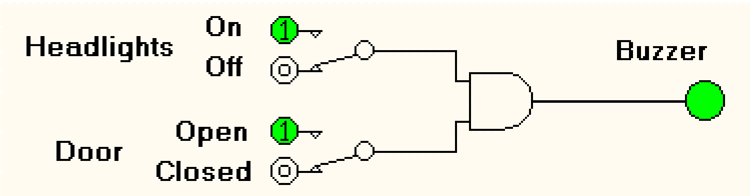
Logic gate theory[282]
Logic gate examples[285]
Logic gate knowledge test[290]
Logic gate exercise[282]
Digital circuits tutorial[282]

Digital Circuits Tutorial

Logic Gate Exercise

Demonstration Circuit

Circuit Construction



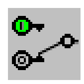
This topic provides detailed instructions to construct the logic gate demonstration circuit shown in the above title bar.

Open a diagram window and display the digital device toolkit:

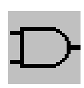
1. Use the File | New[39] menu command or the toolbar[37] icon  to open a new diagram window. Creating a new diagram window[15] provides additional details.

2. Ensure the digital device toolkit[51] is visible. If the toolkit is not visible, use the View | Digital Device Toolkit[49] menu command or the toolbar[37] icon  to display it.

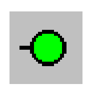
Add two digital source switches to the diagram:

1. Using the mouse, click the digital source switch[85] icon  on the digital device toolkit.[51]
2. Move the mouse onto the diagram to approximately the center of the diagram window.
3. Click the mouse to place the first digital source switch[85] on the diagram. This will simulate the automobile headlight switch. Adding devices[12] provides additional details.
4. As shown in the above title bar, place a second digital source switch[85] on the diagram just below the first. This will simulate the automobile door switch.

Add an AND gate to the diagram:

1. Using the mouse, click the AND gate[82] icon  on digital device toolkit.[51]
2. Move the mouse onto the diagram to where the AND gate[82] is to be located. See circuit layout in above title bar.
3. Click the mouse to place the AND gate[82] on the diagram.

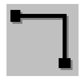
Add a digital display lamp to the diagram:

1. Using the mouse, click the digital display lamp[84] icon  on digital device toolkit.[51]
2. Move the mouse onto the diagram to where the digital display lamp[84] is to be located. See circuit layout in above title bar.
3. Click the mouse to place the digital display lamp[84] on the diagram.

Layout the circuit:

1. Using the mouse, click the pointer icon  on the toolbar[37] or the analog device toolkit.[52]
2. If necessary, move the devices so they are positioned as shown in the above title bar. To move a device, press the left mouse button over the device and drag it to the new location. Moving devices[17] provides additional details.

Add wires to connect the devices:

1. Using the mouse, click the wire[95] icon  on the toolbar[37] or the analog device toolkit.[52]
2. Move the mouse onto the diagram over the output terminal of the top digital source switch.[85]
3. Press the left mouse button and drag the wire to the top input terminal of the AND gate.[82] Connecting devices[14] provides additional details.
4. Repeat steps (2) and (3) to connect the output terminal of the bottom digital source switch[85] to the bottom input terminal of the AND gate.[82]
5. Repeat steps (2) and (3) to connect the AND gate[82] output terminal to the digital display lamp[84] input terminal.

   At this point the circuit connections are complete and the devices should be connected as shown in the above title bar.

Add wire vertices (optional):

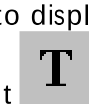
1. As shown in the circuit layout in above title bar, the wires[95] between the digital source switches[85] and the AND gate[82] inputs have "kinks" called vertices.[95]

   Using the mouse, click the pointer icon  on the toolbar[37] or the analog device toolkit.[52]
2. Move the mouse onto the diagram over the wire[95] portion where the vertex is to be added.
3. Press the left mouse button and drag the wire[95] to the desired vertex location.
4. Release the mouse button.
   Adding[12] - moving[16] and deleting a wire vertex[15] provides additional details.

Add text annotations (optional):

1. First add (empty) text objects for each annotation. The text annotations are Headlights, On, Off, Door, Open, Closed and Buzzer.

   Ensure the paint toolkit[54] is visible. If the toolkit is not visible, use the View | Paint Toolkit[49] menu command or the toolbar[37] icon 

   to display it.
2. Using the mouse, select the text object 

   on the paint toolkit.[54]
3. Move the mouse onto the diagram to where an (empty) text annotation is to be located.
4. Click the mouse to place a text object on the diagram.
5. Repeat steps (3) and (4) to add an (empty) text object for each annotation.

6. Next replace the (empty) text objects with the correct annotation text.

   Using the mouse, click the pointer icon  on the toolbar[37] or the analog device toolkit.[52]
7. Move the mouse onto the diagram over the text object.
8. Double click the mouse on an (empty) text object to open the Edit Text dialog box.[70] Enter the correct annotation text and press Ok.
9. Repeat step (8) for each annotation shown in the above title bar.

   To move an annotation, using the pointer, press the left mouse button over the annotation and drag it to the new location. Moving objects[17] provides additional details.

At this point the circuit construction is complete. Return to logic gate demonstration[287] to complete the exercise.

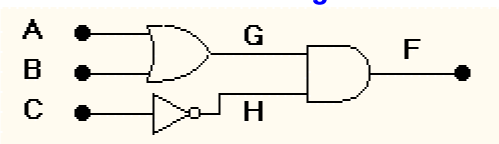
Related topics:

- Creating and editing diagrams[11]
- Menu commands[37]
- Toolbar commands[37]
- Device and drawing toolkits[51]
- Dialog boxes[62]

Digital Circuits Tutorial

Logic Gate Exercise

Knowledge Test

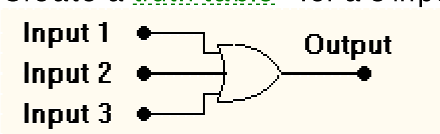


1. Create a digital circuit[84] for the following boolean expression.[82]

   F = (A + B)•(C + D)

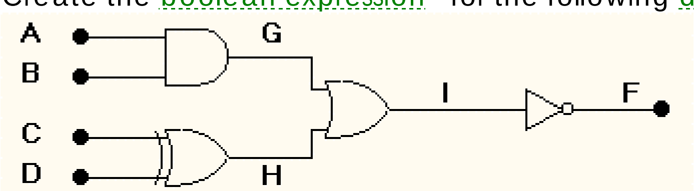
   Hint: Create the circuit in steps. See example 1 in the examples topic.[285]

2. Create a truth table[94] for a 3 input OR gate.[91]



   Hint: As described in the theory topic,[282] an OR gate's[91] output is logic level 1 when any input is logic level 1. Also, an example truth table can be found in example 2 in the examples topic.[285]

3. Create the boolean expression[82] for the following digital circuit.[84]

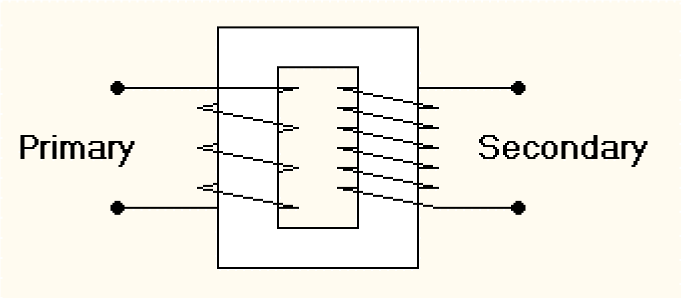


   Hint: Create the boolean expression in steps, first create expressions for G and H, then I, and finally F.

Related topics:

- Logic gate theory[282]
- Logic gate examples[285]
- Logic gate demonstration circuit[287]
  - Logic gate demonstration circuit construction[288]
- Logic gate exercise[282]
- Digital circuits tutorial[282]

Answers

Answer 1: 

The common names for transformer inputs and outputs are Primary and Secondary respectively.

Answer 2: Given an input voltage of 120 volts, an input current of 5 amps and an efficiency factor of 0.9, the expected output power can be calculated as:

```
Po  =  n   x Pi
    =  0.9 x (Ei x Ii)
    =  0.9 x 120 x 5
    =  540 watts
```

Answer 3: Ohm's law states, the greater the voltage, the greater the current.

Answer 4: Ohm's law states, the greater the resistance, the lower the current.

Answer 5: Given a current of 0.5 amperes and a resistance of 2000 ohms in a circuit, the applied voltage may be found as

```
E = I x R
  = 0.5 x 2000
  = 1000 volts
```

Answer 6: Given a voltage of 50 volts and a resistance of 200 ohms in a circuit, the current in the circuit may be found as

```
     E       50
I = ---  =  ---  =  0.25 amperes
     R      200
```

Answer 7: Given a voltage of 500 volts and a current of 50 amperes in a circuit, the resistance in the circuit may be found as

```
     E      500
R = ---  =  ---  =  10 ohms
     I       50
```

Answer 8: If the circuit is correctly constructed, the device meter should display 114 mA (milliamps).

Answer 9: The total resistance in a series circuit is the sum of the individual resistances.

```
R (total)  =   R1  +   R2  +   R3
           =  100  +  150  +  500
           =  750 ohms
```

Answer 10: The total resistance in a series circuit is the sum of the individual resistances.

```
R (total)  =  R1   +   R2  +   R3
           =  250  +  500  +  750
           =  1500 ohms
```

Using Ohm's law, the total current in a series circuit is equal to the total applied voltage divided by the total resistance.

```
I (total)  =  E (total) / R (total)
           =  12 / 1500
           =  0.008 amps
           =  8 milliamps
```

Answer 11: The total resistance in a parallel circuit may be found using the following general formula.

```
                          1
R (total) = ---------------------
             1     1     1
            --- + --- + --- + ...
             R1    R2    R3
```

Using the circuit values

```
R (total)
  = 1 / ( 1/R1  + 1/R2  + 1/R3  )
  = 1 / ( 1/100 + 1/250 + 1/500 )
  = 1 / ( 0.01  + 0.004 + 0.002 )
  = 1 / 0.016
  = 62.5 ohms
```

Answer 12: The total resistance in the parallel may be found as

```
R (total)
  = 1 / ( 1/R1  + 1/R2  + 1/R3     )
  = 1 / ( 1/250 + 1/500 + 1/1500   )
  = 1 / ( 0.004 + 0.002 + 0.000667 )
  = 1 / 0.00667
  = 150 ohms
```

Using Ohm's law, the total current in a parallel circuit is equal to the total applied voltage divided by the total resistance. In the above circuit

```
I (total)  =  E (total) / R (total)
           =  15 / 150
           =  0.1 amps
```

Answer 13: The number of complete cycles per second is called frequency[87] and is measured in hertz.[88]

Answer 14:
```
F (hertz) =  1 / T (seconds)
          =  1 / 0.001 seconds
          =  1000 Hz
```

Answer 15:
```
F (hertz)   =  1 / T (seconds)
   or
T (seconds) =  1 / F (hertz)
            =  1 / 1000
            =  0.001 seconds
            =  1 millisecond
```

Answer 16:
```
Vavg  =  0.637 * Vp
      =  0.637 * 100
      =  63.7 volts
```

Answer 17:
```
Vrms  =  0.707 * Vp
      =  0.707 * 400
      =  283 volts
```

Answer 18: The total capacitance in a series circuit may be found using the following general formula.

```
                         1
C (total) = --------------------
             1     1     1
            --- + --- + --- + ...
             C1    C2    C3
```

Using the circuit values

```
C (total)
  = 1 / ( 1/C1    + 1/C2    + 1/C3    )
  = 1 / ( 1/10e-6 + 1/25e-6 + 1/50e-6 )
  = 1 / ( 0.1e6   + 0.04e6  + 0.02e6  )
  = 1 / 0.16e6
  = 6.25e-6 farads
  = 6.25 µF
```

Answer 19: The total capacitance in a parallel circuit is the sum of the individual capacitances.

```
C (total)  =  C1     +  C2     +  C3
           =  10e-6  +  25e-6  +  50e-6
           =  85e-6 farads
           =  85 µF
```

Answer 20: The circuit's time constant can be calculated as

```
t = R      x  C
  = 2.5e3  x  2e-6
  = 5.0e-3 seconds
  = 0.005 seconds
```

Answer 21: The total inductance in a series circuit is the sum of the individual inductances.

```
L (total)  =  L1     +  L2     +  L3
```

```
              =  10e-3  +  25e-3  +  50e-3
              =  85e-3 henrys
              =  85 mH
```

Answer 22: The total inductance in a parallel circuit may be found using the following general formula.

```
L (total) = --------------------
                      1
              1     1     1
             --- + --- + --- + ...
              L1    L2    L3
```

Using the circuit values

```
L (total)
  = 1 / ( 1/L1    + 1/L2    + 1/L3    )
  = 1 / ( 1/10e-3 + 1/25e-3 + 1/50e-3 )
  = 1 / ( 0.1e3   + 0.04e3  + 0.02e3  )
  = 1 / 0.16e3
  = 6.25e-3 henrys
  = 6.25 mH
```

Answer 23: The circuit's time constant can be calculated as

```
t = L / R
  = 20e-3 / 2.5e3
  = 8e-6 seconds
  = 8 µ seconds
```

Answer 24: The capacitive reactance of a 0.5 µF capacitor at a frequency of 60 Hz can be calculated as

```
           1
Xc  =    ----
         2πfC

    =    1 / (6.283 x 60 x 0.5e-6)
    =    5.31e3 ohms
    =    5.31 kilo ohms
```

Answer 25: The inductive reactance of a 5 mH inductor at a frequency of 1.5 KHz can be calculated as

```
Xl  =    2πfL
    =    6.283 x 1.5e3 x 5e-3
    =    47.1 ohms
```

Answer 26: Step 1: The capacitive reactance of a 4.5 µF capacitor at a frequency of 25 KHz can be calculated as

```
           1
Xc  =    ----
         2πfC

    =    1 / (6.283 x 25e3 x 4.5e-6)
    =    1.41 ohms
```

Step 2: Given an applied voltage of 2.5 mV and using **Ohm's law,** the capacitor's current can be calculated as

```
        E
I  =   ---
        Xc

   =  2.5e-3 / 1.41
   =  1.77 mA
```

Answer 27: The resonant frequency of a 0.25 mH inductor and a 100 µF capacitor can be calculated as

```
              1
fr  =  -------------
       2π x SQRT(LC)

    = 1 / (2π x SQRT(0.25e-3 x 100e-6))
    = 1007 Hz
    = 1.007 kHz
```

Answer 28: The capacitance required to be in series with a 750 mH inductor to achieve a resonant frequency of 50 kHz can be calculated as

```
                1
C  =   ------------------
       (2π)**2 x f**2 x L

   = 1 / ((2π)**2 x 50e3**2 x 750e-3)
   = 13.5 pF
```

Answer 29: Given a voltage of 120 volts and a current of 2 amperes, the power in the circuit can be calculated as

```
P = E x I
  = 120 x 2
  = 240 watts
```

Answer 30: Given a voltage of 150 volts and a resistance of 1500 ohms, the power in the circuit can be calculated as

```
     E**2     150**2
P = ------ =  ------ = 15 watts
      R        1500
```

Answer 31: Given a current of 2 mA and a resistance of 2 M ohms, the power in the circuit can be calculates as

```
P = I**2 x R
  = 2e-3**2 x 2e6
  = 4e-6    x 2e6
  = 8 watts
```

Answer 32: Given a power of 100 watts and a time duration of 12 hours, the energy used in the circuit can be calculated as

```
W = P x t
  = 100 x 12
  = 1200 watt-hours
  = 1.2 kilowatt-hours
```

Answer 33: Given a voltage of 110 volts and a current of 2.5 amperes and a time duration of 48 hours, the energy used in the circuit can be calculated as

Step 1: calculate the circuit power

```
P = E x I
  = 110 x 2.5
  = 275 watts
```

Step 2: using the circuit power, calculate the energy used

```
W = P x t
  = 275 x 48
  = 13200 watt-hours
  = 13.2 kilowatt-hours
```

Answer 34: A diode[85] is a two terminal device which acts like a one-way gate in a circuit. A diode allows current[84] to easily flow in one direction and not the other. In other words, a diode has a very low resistance[92] in one direction and a very high resistance in the other.

Answer 35: For a silicon P-N junction diode, when the forward bias voltage reaches +0.7 volts and above, the diode turns on and presents a very low resistance to the circuit and current begins to flow. The +0.7 value is called the threshold voltage.

Answer 36: Diodes can be used to convert alternating current (AC)[81] into direct current (DC).[86] This conversion is called rectification.

Answer 37: The terminals on a transistor are named: emitter, base and collector.

Answer 38: The base current controls the output collector current.

Answer 39: A transistor's current gain can be calculated as follows.

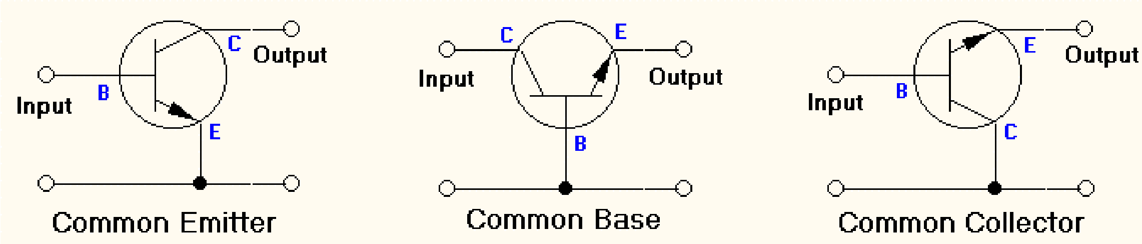
$$h_{FE} = \frac{I_C}{I_B}$$

= 220 ma / 2 ma

= 110

Answer 40: Because of the high current gains for most transistors, the emitter current is approximately equal to the collector current.

Answer 41: The three types of transistor circuits are common emitter, common base and common collector.


C
Output
Input
B
E
Common Emitter
C
E
Input
Output
B
Common Base
E
Output
Input
B
C
Common Collector

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