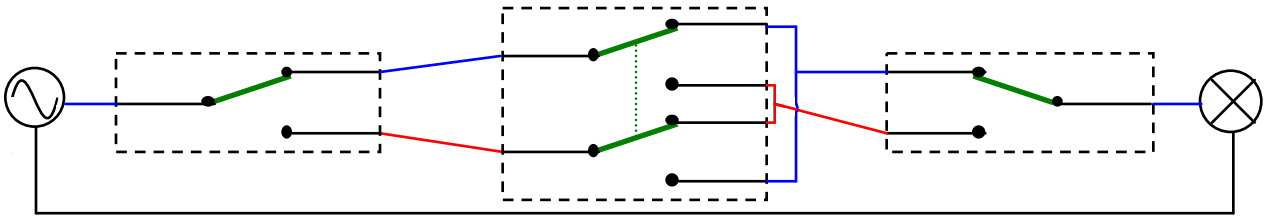
Two Circuits of Switches and Lightbulbs—C.E. Mungan, Spring 2019

Circuit #1: A power supply (say 120 V ac for specificity) is connected along a single line to a set of two or more switches ending in a lightbulb. The line consists of 3 wires (colored blue, red, and black) between switches, but only 2 wires (colored blue and black) running from the power supply to the first switch, and from the last switch to the lightbulb. All of the switches are either SPDT or DPDT. (If you prefer, all switches can be DPDT where the second pole is not connected for those switches which could use SPDT.) Flipping any switch starting from any configuration of closed and open switches will toggle the light on or off. How is the circuit wired?

Application: If there are $N-1$ switches, this circuit is a household *N*-way switching arrangement. Particularly common is a 3-way switch, where 2 different switches (say one at each end of a hallway or stairwell) can be used to control a light.

Hint: One of the wires (say the black one) is not connected to any switches. It runs from the power supply to the lightbulb, passing to the side of each switch. It is the return wire.

Solution: See the circuit diagram below for a 4-way switching arrangement. The switches nearest the power supply and the lightbulb are SPDT, with the rightmost one having its input and output terminals reversed horizontally. The center switch (which can be eliminated for a 3-way arrangement, or repeated $N-3$ times in all for an *N*-way arrangement) is DPDT, where the dotted green vertical line connecting the two solid green contacts indicates that they both move together—i.e., in the "open" switch position both contacts are up, whereas in the "closed" position both contacts are down. The blue and red wires running between adjacent switches are known as "traveling wires" and it is not uncommon to find that they have been wired incorrectly in houses. Thus, understanding this circuit diagram may enable you to fix some switching arrangements in your house, as I have had occasion to do! It is also possible to avoid having to wire together two pairs of outputs of the DPDT switches by using special X-style 4-way switches as shown at https://i.stack.imgur.com/o9kA4.gif. Incidentally, note that the lightbulb can be slid along the return wire so that it lies between any two of the other elements if you prefer.



Circuit #2: An ac power supply is connected by a single-wire loop in series to two SPST switches and two ordinary lightbulbs. Closing one switch turns on one bulb; closing the other switch turns on the other bulb; and closing both switches turns on both bulbs. The trick is that there is an extra element wired across the terminals of every switch and bulb; it is the same simple element in all four cases and involves no transmitter/detector or special encoding/decoding circuitry. What is the element and how does the circuit work?

Application: The element is a simple device taught in basic electronics courses, and so this circuit is a good example of out-of-the-box thinking. Many electronics circuits (such as flip-flops and the like) involve creative wiring of semiconductor components. Unfortunately this particular circuit is not generalizable to more switches and bulbs.

Hint: A dc power supply cannot be used in this case. The bulbs will not glow at their rated time-average brightness; in fact, some people may be able to detect a slight flicker.

Solution: The element is a diode, one wired forward and one wired backward across each pair of switches and bulbs. In the circuit diagram below, the left switch controls the left bulb (which is on only during the negative half of each ac sinusoidal cycle) and the right switch controls the right bulb (which is on during positive ac supply half-cycles). A YouTube demonstration can be viewed at https://www.youtube.com/watch?v=GYZwsZUdOJ0.