Wheatstone Bridge

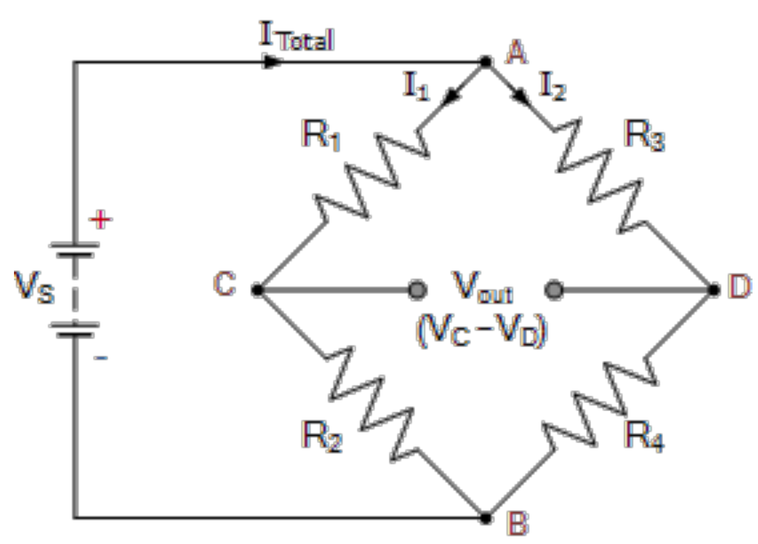
Wheatstone Bridge

The Wheatstone Bridge was originally developed by Charles Wheatstone to measure unknown resistance values and as a means of calibrating measuring instruments, voltmeters, ammeters, etc, by the use of a long resistive slide wire. Although today digital multimeters provide the simplest way to measure a resistance, The *Wheatstone Bridge* can still be used to measure very low values of resistances down in the milli-Ohms range.

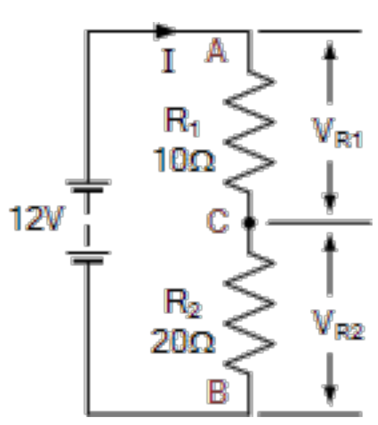
The Wheatstone bridge (or resistance bridge) circuit can be used in a number of applications and today, with modern Operational Amplifiers (http://www.amazon.co.uk/s/?field-keywords=Operational%20Amplifiers%2C%20Fifth%20Edition%20%28EDN%20Series%20for%20Design%20Engineers%29&tag=basicelecttut-21) we can use the *Wheatstone Bridge Circuit* to interface various transducers and sensors to these amplifier circuits.

The Wheatstone Bridge circuit is nothing more than two simple series-parallel arrangements of resistances connected between a voltage supply terminal and ground producing zero voltage difference between the two parallel branches when balanced. A Wheatstone bridge circuit has two input terminals and two output terminals consisting of four resistors configured in a diamond-like arrangement as shown. This is typical of how the Wheatstone bridge is drawn.

The Wheatstone Bridge



When balanced, the Wheatstone bridge can be analysed simply as two series strings in parallel. In our tutorial about **Resistors in Series (http://www.electronics-tutorials.ws/resistor/res_3.html)**, we saw that each resistor within the series chain produces an **IR** drop, or voltage drop across itself as a consequence of the current flowing through it as defined by Ohms Law. Consider the series circuit below.



As the two resistors are in series, the same current (i) flows through both of them. Therefore the current flowing through these two resistors in series is given as: V/R_T.

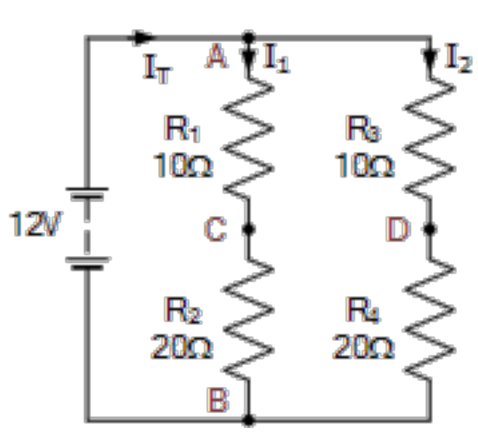
$$I = V \div R = 12V \div (10\Omega + 20\Omega) = 0.4A$$

The voltage at point C, which is also the voltage drop across the lower resistor, R_2 is calculated as:

$$V_{R2} = I \times R_2 = 0.4A \times 20\Omega = 8 \text{ volts}$$

Then we can see that the source voltage V_S is divided among the two series resistors in direct proportion to their resistances as V_{R1} = 4V and V_{R2} = 8V. This is the principle of voltage division, producing what is commonly called a potential divider circuit or voltage divider network.

Now if we add another series resistor circuit using the same resistor values in parallel with the first we would have the following circuit.



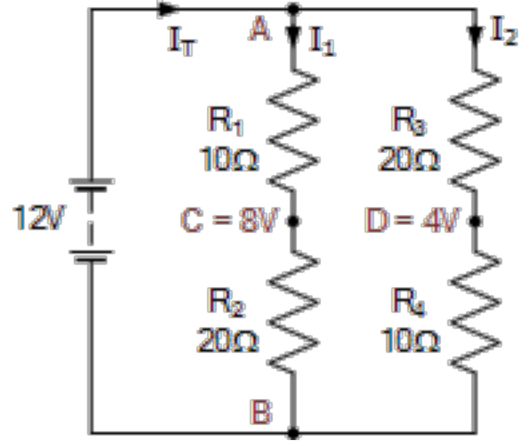
As the second series circuit has the same resistive values of the first, the voltage at point D, which is also the voltage drop across resistor, R_4 will be the same at 8 volts, with respect to zero (battery negative), as the voltage is common and the two resistive networks are the same.

But something else equally as important is that the voltage difference between point C and point D will be zero volts as both points are at the same value of 8 volts as: C = D = 8 volts, then the voltage difference is: 0 volts

When this happens, both sides of the parallel bridge network are said to be **balanced** because the voltage at point C is the same value as the voltage at point D with their difference being zero.

Now let's consider what would happen if we reversed the position of the two resistors, R_3 and R_4 in the second parallel branch with respect to R_1 and R_2.

With resistors, R_3 and R_4 reversed, the same current flows through the series combination and the voltage at point D, which is also the voltage drop across resistor, R_4 will be:



$$V_{R4} = 0.4A \times 10\Omega = 4 \text{ volts}$$

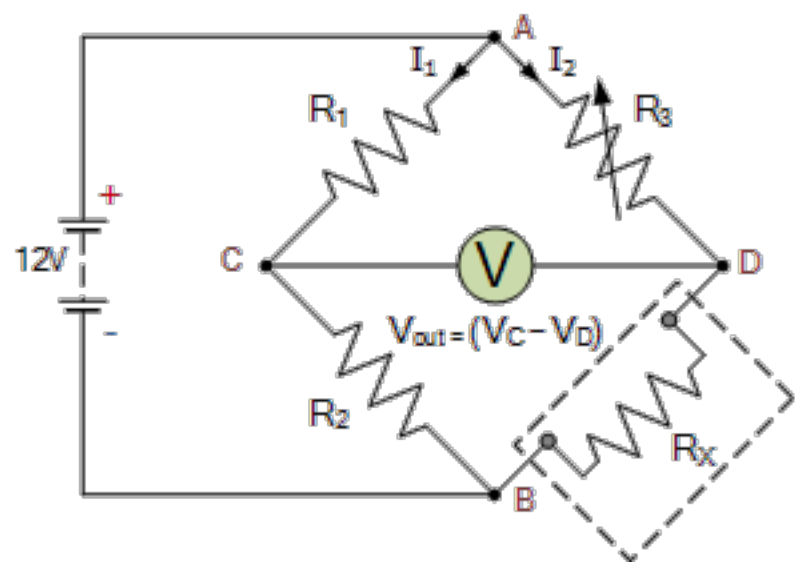
Now with V_{R4} having 4 volts dropped across it, the voltage difference between points C and D will be 4 volts as: C = 8 volts and D = 4 volts. Then the difference this time is: 8 - 4 = 4 volts

The result of swapping the two resistors is that both sides or “arms” of the parallel network are different as they produce different voltage drops. When this happens the parallel network is said to be **unbalanced** as the voltage at point C is at a different value to the voltage at point D.

Then we can see that the resistance ratio of these two parallel arms, ACB and ADB, results in a voltage difference between **0 volts** (balanced) and the maximum supply voltage (unbalanced), and this is the basic principal of the **Wheatstone Bridge Circuit**.

So we can see that a Wheatstone bridge circuit can be used to compare an unknown resistance R_X with others of a known value, for example, R_1 and R_2, have fixed values, and R_3 could be variable. If we connected a voltmeter, ammeter or classically a galvanometer between points C and D, and then varied resistor, R_3 until the meters read zero, would result in the two arms being balanced and the value of R_X, (substituting R_4) known as shown.

Wheatstone Bridge Circuit



By replacing R_4 above with a resistance of known or unknown value in the sensing arm of the Wheatstone bridge corresponding to R_X and adjusting the opposing resistor, R_3 to “balance” the bridge network, will result in a zero voltage output. Then we can see that balance occurs when:

$$\frac{R_1}{R_2} = \frac{R_3}{R_X} = 1 \text{ (Balanced)}$$

The Wheatstone Bridge equation required to give the value of the unknown resistance, R_X at balance is given as:

$$V_{OUT} = \left(V_C - V_D\right) = \left(V_{R2} - V_{R4}\right) = 0$$

$$R_C = \frac{R_2}{R_1 + R_2} \quad \text{and} \quad R_D = \frac{R_4}{R_3 + R_4}$$

$$\text{At Balance: } R_C = R_D \quad \text{So, } \frac{R_2}{R_1 + R_2} = \frac{R_4}{R_3 + R_4}$$

$$\therefore R_2\left(R_3 + R_4\right) = R_4\left(R_1 + R_2\right)$$

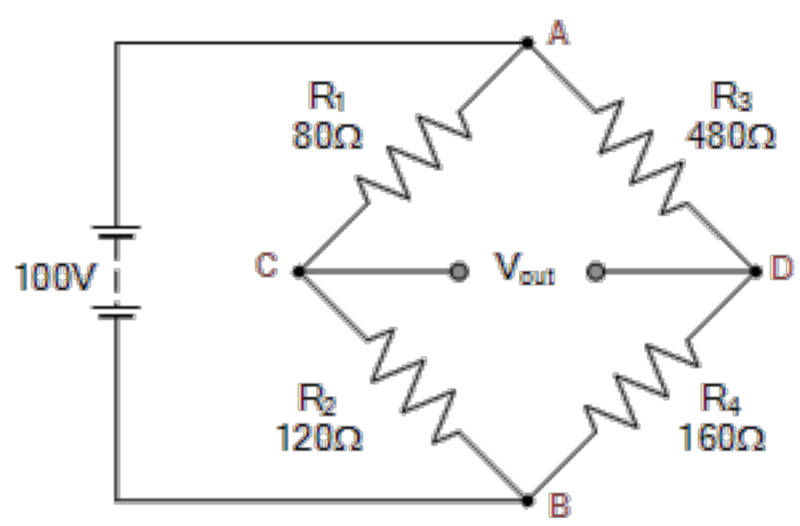
$$R_2 R_3 + \cancel{R_2 R_4} = R_1 R_4 + \cancel{R_2 R_4}$$

$$\therefore R_4 = \frac{R_2 R_3}{R_1} = R_X$$

Where resistors, R_1 and R_2 are known or preset values.

Wheatstone Bridge Example No1

The following unbalanced Wheatstone Bridge is constructed. Calculate the output voltage across points C and D and the value of resistor R_4 required to balance the bridge circuit.



For the first series arm, ACB

$$V_C = \frac{R_2}{(R_1+R_2)} \times V_S$$

$$V_C = \frac{120\Omega}{80\Omega + 120\Omega} \times 100 = 60\text{volts}$$

For the second series arm, ADB

$$V_D = \frac{R_4}{(R_3+R_4)} \times V_S$$

$$V_D = \frac{160\Omega}{480\Omega + 160\Omega} \times 100 = 25\text{volts}$$

The voltage across points C-D is given as:

$$V_{OUT} = V_C - V_D$$

$$\therefore V_{OUT} = 60 - 25 = 35\text{volts}$$

The value of resistor, R_4 required to balance the bridge is given as:

$$R_4 = \frac{R_2 R_3}{R_1} = \frac{120\Omega \times 480\Omega}{80\Omega} = 720\Omega$$

We have seen above that the **Wheatstone Bridge** has two input terminals (A-B) and two output terminals (C-D). When the bridge is balanced, the voltage across the output terminals is 0 volts. When the bridge is unbalanced, however, the output voltage may be either positive or negative depending upon the direction of unbalance.

Wheatstone Bridge Light Detector

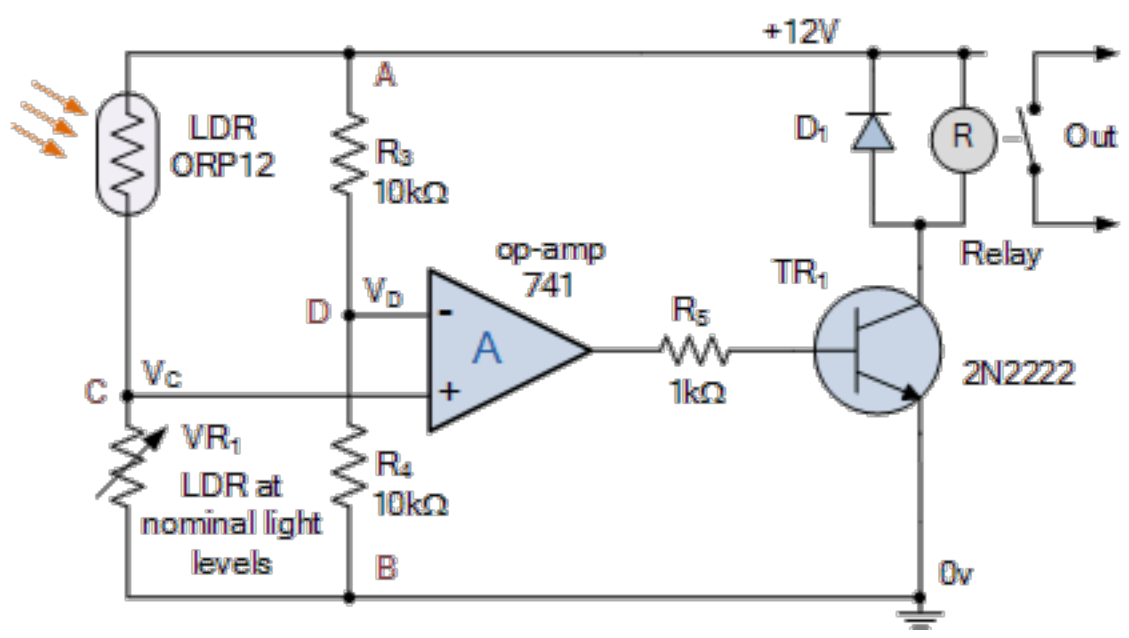
Balanced bridge circuits find many useful electronics applications such as being used to measure changes in light intensity, pressure or strain. The types of resistive sensors that can be used within a wheatstone bridge circuit include: photoresistive sensors (LDR's), positional sensors (potentiometers), piezoresistive sensors (strain gauges) and temperature sensors (thermistor's), etc.

There are many wheatstone bridge applications for sensing a whole range of mechanical and electrical quantities, but one very simple wheatstone bridge application is in the measurement of light by using a photoresistive device. One of the resistors within the bridge network is replaced by a light dependent resistor, or LDR.

An LDR, also known as a cadmium-sulphide (Cds) photocell, is a passive resistive sensor which converts changes in visible light levels into a change in resistance and hence a voltage. Light dependent resistors can be used for monitoring and measuring the level of light intensity, or whether a light source is ON or OFF.

A typical Cadmium Sulphide (CdS) cell such as the ORP12 light dependent resistor typically has a resistance of about one megaohms (MΩ) in dark or dim light, about 900Ω at a light intensity of 100 Lux (typical of a well lit room), down to about 30Ω in bright sunlight. Then as the light intensity increases the resistance reduces. By connecting a light dependant resistor to the Wheatstone bridge circuit above, we can monitor and measure any changes in the light levels as shown.

Wheatstone Bridge Light Detector



The LDR photocell is connected into the Wheatstone Bridge circuit as shown to produce a light sensitive switch that activates when the light level being sensed goes above or below the pre-set value determined by V_{R1}. In this example V_{R1} either a 22k or 47k potentiometer.

The op-amp is connected as a voltage comparator with the reference voltage V_D applied to the inverting pin. In this example, as both R_3 and R_4 are of the same 10kΩ value, the reference voltage set at point D will therefore be equal to half of Vcc. That is Vcc/2.

The potentiometer, V_{R1} sets the trip point voltage V_C, applied to the non-inverting input and is set to the required nominal light level. The relay turns “ON” when the voltage at point C is less than the voltage at point D.

Adjusting V_{R1} sets the voltage at point C to balance the bridge circuit at the required light level or intensity. The LDR can be any cadmium sulphide device that has a high impedance at low light levels and a low impedance at high light levels.

Note that the circuit can be used to act as a “light-activated” switching circuit or a “dark-activated” switching circuit simply by transposing the LDR and R_3 positions within the design.

The **Wheatstone Bridge** has many uses in electronic circuits other than comparing an unknown resistance with a known resistance. When used with **Operational Amplifiers (http://www.electronics-tutorials.ws/opamp/opamp_1.html)**, the Wheatstone bridge circuit can be used to measure and amplify small changes in resistance, R_X due, for example, to changes in light intensity as we have seen above.

But the bridge circuit is also suitable for measuring the resistance change of other changing quantities, so by replacing the above photo-resistive LDR light sensor for a thermistor, pressure sensor, strain gauge, and other such transducers, as well as swapping the positions of the LDR and V_{R1}, we can use them in a variety of other Wheatstone bridge applications.

Also more than one resistive sensor can be used within the four arms (or branches) of the bridge formed by the resistors R_1 to R_4 to produce “full-bridge”, “half-bridge” or “quarter-bridge circuit arrangements providing thermal compensation or automatic balancing of the Wheatstone bridge.

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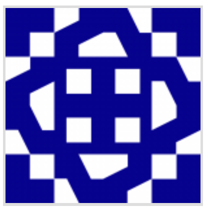

RAM

in fact i need a video to get the way how to perform

November 7th, 2015 (http://www.electronics-tutorials.ws/blog/wheatstone-bridge.html/comment-page-3#comment-8771)

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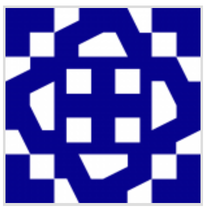

RAM

can i get the link in which it shows the exp of water level measurement using wheat stone bridge

November 7th, 2015 (http://www.electronics-tutorials.ws/blog/wheatstone-bridge.html/comment-page-3#comment-8770)

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R

“Note that the circuit can be used to act as a “light-activated” switching circuit or a “dark-activated” switching circuit simply by transposing the LDR and R3 positions within the design.”

Don’t you mean transposing the positions of LDR and VR1 to get the circuit to “dark activated”?

October 28th, 2015 (http://www.electronics-tutorials.ws/blog/wheatstone-bridge.html/comment-page-3#comment-8668)

Reply (http://www.electronics-tutorials.ws/blog/wheatstone-bridge.html?replytocom=8668#respond)

Wayne Storr (http://www.electronics-tutorials.ws)

The LDR, VR1, R3 and R4 are connected in the form of a Wheatstone Bridge across the op-amp, so transposing diagonal components either LDR to VR1 or LDR to R3 will reverse the switching action.

October 28th, 2015 (http://www.electronics-tutorials.ws/blog/wheatstone-bridge.html/comment-page-3#comment-8672)

Reply (http://www.electronics-tutorials.ws/blog/wheatstone-bridge.html?replytocom=8672#respond)

Anton

Hello!
Thanks for great artcile!

I can’t understand the following equatation:
(R1/R2)=(R3/Rx) =1
Why it is equal to 1? From it follows that R2=Rx but it is incorrect…

Thanks in advance.

September 30th, 2015 (http://www.electronics-tutorials.ws/blog/wheatstone-bridge.html/comment-page-3#comment-8326)

Reply (http://www.electronics-tutorials.ws/blog/wheatstone-bridge.html?replytocom=8326#respond)

Wayne Storr (http://www.electronics-tutorials.ws)

For the Wheatstone Bridge circuit to be balanced, (R1/R2) = (R3/Rx) then the ratio of the two arms of the bridge is 1 as in 1/1.

September 30th, 2015 (http://www.electronics-tutorials.ws/blog/wheatstone-bridge.html/comment-page-3#comment-8328)

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