Newcomers' Notebook

Why's and wherefores of the Wheatstone Bridge

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Here's a simple explanation of this widely used measuring circuit, no complex maths.

This world is full of electrical sensors of varying types that measure fluid levels, pressure, humidity, temperature, weight, flow, pH, and speed, to name but a few. Many of these sensors provide readings by varying their resistance in response to a change in the variable quantity being measured. One of the most sensitive circuits used to detect small variations in resistance is the Wheatstone Bridge.

The circuit was originally invented by Samuel Hunter Christie in 1833. Moving on from his early success in developing the English concertina [1], in 1843 Sir Charles Wheatstone improved and popularised the circuit that is identified with his name. One of the Wheatstone bridge's initial uses was for soil analysis and comparison.

The Wheatstone bridge comprises four resistors, usually depicted in a diamond pattern as shown in **Figure 1**. One of the resistors is the item being tested or measured. This circuit configuration is still used widely in modern test and measuring equipment [2].

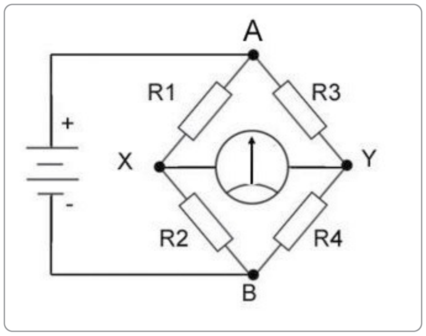


Figure 1: The basic Wheatstone bridge circuit.

The Wheatstone name is also linked to the English concertina, beloved of classical musicians and folkies.

How it works

In Figure 1, we assume that R1, R2, R3 and R4 all have identical values. A voltmeter is connected between points X and Y. This must be a high impedance voltmeter so as not to upset currents flowing in the circuit.

An emf (voltage) provided by the battery is applied across points A and B. The current entering at point A will split and flow evenly through R1 and R3, then through R2 and R4, respectively, to point B.

According to Ohm's law, the emf (or voltage) drop across R1 and R3 will be the same as that across R2 and R4. The emf at point X will be the same as at point Y, so the high impedance voltmeter reading will be zero.

When the voltages at X and Y are equal, the bridge is said to be '*balanced*'. A variation to any of the resistance values will result in an emf difference between X and Y causing the bridge to be '*unbalanced*', and produce a reading on the meter.

Let us now replace R4 with a strain gauge [3], then replace R1 and R3 with resistors matching the strain gauge resistance value at zero load/stress, and make R2 a variable resistor, as shown in **Figure 2**. The variable resistor R2 is there to *balance* the meter to take care of minor variations in real-life resistors.

If we calibrate the meter in kilograms, the result is an accurate electrical weighing device.

As the strain gauge stretches or compresses with a change in weight of the object being measured, the internal resistance of the strain gauge changes. The bridge is now '*unbalanced*', and a reading will appear on the voltmeter. This is a real-world application of the Wheatstone bridge.

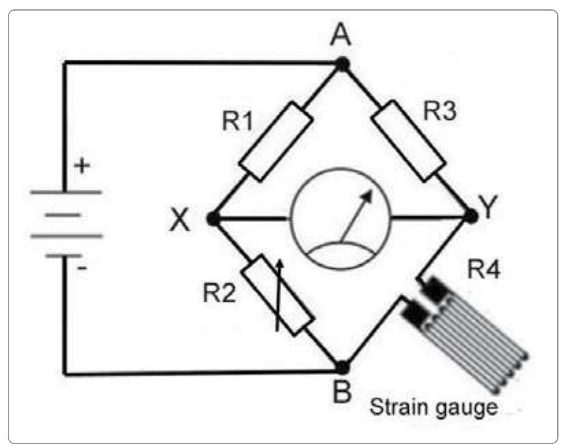


Figure 2: Electrical scales built from a Wheatstone bridge circuit.

In amateur radio?

What about an amateur radio application? In **Figure 3**, the battery has been substituted by a variable frequency signal generator, while R1 and R3 are now 50 ohm resistors. In addition, R2 is now a variable

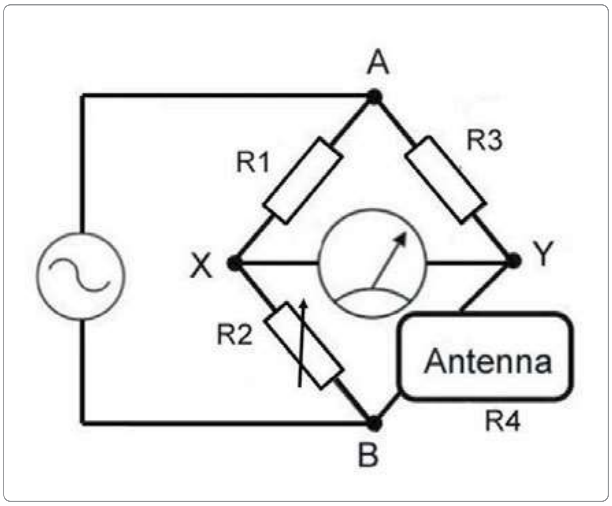


Figure 3: The Wheatstone bridge as an antenna analyser.

resistor that can be varied above or below 50 ohms. The voltmeter is now one that measures RF. Here, R4 is the new dipole antenna you built to have a feedpoint of 50 ohms, and you want to see what the feedpoint resistance (actually, impedance) really is at the frequency you wish to use it.

First, substitute the antenna with a 50 ohm dummy load to balance the meter. Now, with your antenna connected, as the signal generator is tuned (or swept) through the set frequency range you chose for your antenna, the meter will read zero when the bridge is balanced at 50 ohms. This is the backbone of a simple antenna analyser.

In a practical antenna analyser, additional circuitry is included to analyse and better display what is happening. The results could be calibrated in SWR readings. **Figure 4** is an excerpt from an antenna analyser project; the Wheatstone bridge circuit can be seen in R1, R2, R3 and the antenna port.

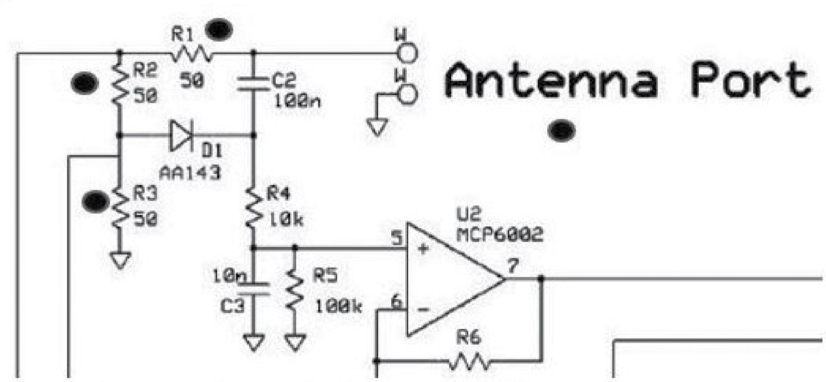
Have fun and stay safe.

Notes

(1) English concertina – see https://en.wikipedia.org/wiki/English_concertina

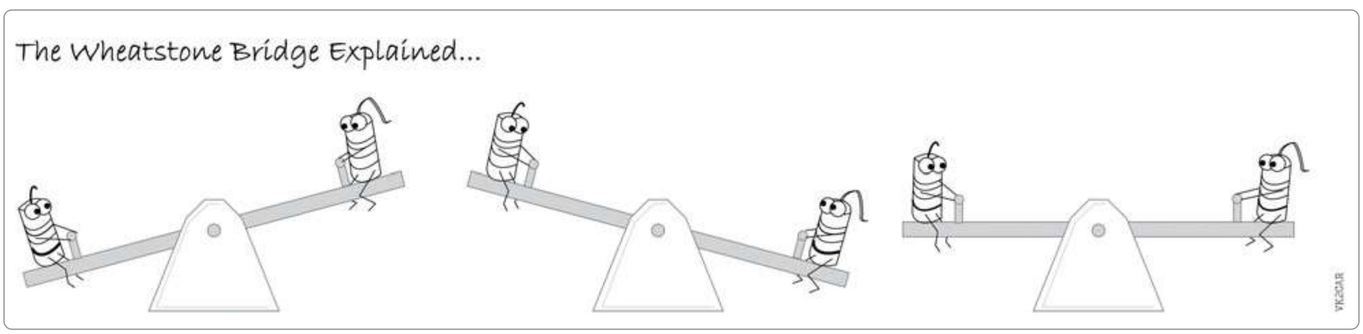
(2) Wheatstone bridge – see https://en.wikipedia.org/wiki/Wheatstone_bridge

(3) A device that changes its resistance with stress, often used in weight bridges, metal fatigue and stress measuring applications. 'Stress' is the causal force, 'strain' is the resultant effect.



Excerpt from the schematic for the project *"Build your own antenna analyser for under $50"* by Beric Dunn K6BEZ.

Figure 4: A practical application of the Wheatstone bridge circuit.



Operation of the Wheatstone bridge is all about balance. When the resistors at each end of the see-saw (R2 and R4) are the same, happiness is achieved! (Carmen, VK2CAR)