WHITEPAPER

The Star Bridge

The star bridge, as an analysis tool, is a very useful representation of the Wheatstone bridge the latter used in virtually all strain gage load cells.

It affords the opportunity to make numerous calculations in a simpler manner than when dealing with the same calculations on the Wheatstone bridge itself.

For example, it allows one to "see" and calculate what is going on when the modulus gages change resistance with temperature such as the change in zero unbalance with temperature when there is a large initial unbalance.

It facilitates understanding the special problems associated with TCZ compensation of single modulus gage load cells using the G4 compensation technique.

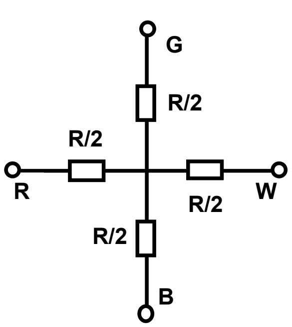
It is a very useful tool for single and multiple load cell analyses and should be understood by all load cell engineers.

When properly designed it can be used as a stable mV/V reference source.

The Star Bridge:

The star bridge representation of the Wheatstone bridge FIGURE 1, is shown with modulus gages and modulus shunt resistors omitted:

Figure 1:
Star Bridge representation of the Wheatstone bridge



The resistances R/2 above are one half the value of the G-B and W-R resistance, Rb, of the Wheatstone bridge which the star bridge represents. Accordingly, the G-B and W-R resistances of the star bridge are also Rb, the same as that of the Wheatstone bridge.

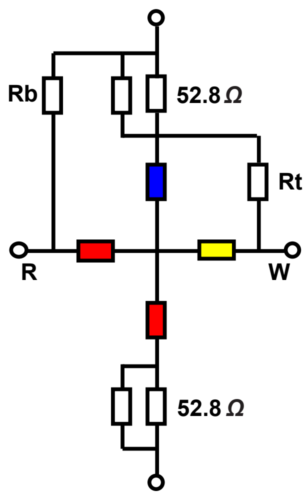
The star bridge has a perfect zero unbalance of zero which will not change with temperature when no auxiliary resistors have been added to the bridge for other reasons. That is, with excitation applied to the G-B terminals there can be no voltage across the W-R terminals at room temperature or at any other temperature.

As such, it can be used as a Wheatstone bridge simulator with a perfect "zero" when evaluating the zero stability of electronic strain gage instruments.

The Star Bridge as an Analysis Tool:

An example of how the star bridge can be used in load cell analysis is provided in the following *(see FIGURE 2)*.

Figure 2:
The Star Bridge Analysis Tool:



A 2 mv/v, 1,000 ohm, steel load cell has a positive going TCZ error of one per cent per 100F. Using the G4/3S method, as shown in a previous paper, a zero unbalance of +1 mV/V is required to eliminate the TCZ error. What value is required for the Rt resistor?

The star bridge resistors, in Red, Blue and Yellow are 500 ohms, half the 1,000 ohm load cell bridge resistance. The resistance of the parallel combination of the 70 ohm modulus gage and the 215 ohm modulus shunt resistor is 52.8, as shown in the diagram.

Assuming one volt excitation, the voltage across the blue star bridge resistor is:

$$V = 0.5\left(\frac{500}{500 + 52.8}\right) = 0.452\ Volts$$

The 0.5 value in the above equation is simply half the excitation voltage of 1.0 volts.

It is desired to have a voltage of 1 mV across the yellow star bridge resistance or 0.001 volts. This amounts to 1 mV/V or 0.001 volts per volt, given the 1 volt excitation.

The required value of the R_t resistor ($R_t >> R$) is calculated as follows:

$$0.452\left(\frac{500}{500 + R_t}\right) = 0.001\ Volts$$

Solving for Rt results in :

$$R_t = 225{,}500\ Ohms$$

Now it is required to have a voltage of 0.001 volts across the Red star bridge resistor of the opposite polarity and this voltage will be developed by the Rb resistor, its value calculated as follows:

$$0.5\left(\frac{500}{500 + Rb}\right) = 0.001\ Volts$$

And solving for Rb results in :

$$Rb = 249{,}500\ Ohms$$

This is just one of many examples of how the star bridge can be used as an analysis tool.

The Star Bridge as an Instrument Tool:

The star bridge can also be used as a strain gage bridge simulator to develop mV/V voltages with good precision and zero stability. Of course, when used as a bridge simulator no modulus gage are used and the simulator voltages are developed with two R_t resistors, one as shown above and another diagonally opposed and connected to the B excitation terminal.

Using two R_t resistors avoids developing common mode voltage changes which can cause undesirable errors on some instrumentation.

When using the star bridge in this application care has to be taken to properly form the electrical joint at the center of the star bridge in order to avoid development of spurious voltages. But this pertains only in very high accuracy applications of the star bridge.

The Star Bridge in Multi-Load Cell Applications:

Occasionally, electrical interaction problems develop in multi-load cell systems due to unintentional electrical asymmetries. These situations are much more easily analyzed by representing, say, two load cells by two star bridges wherein analysis of the interactions are quite straightforward because of the simplicity of the star bridge.

Conclusions:

The writer has solved many problems with the star bridge when analysis on the Wheatstone bridge seemed to defy solution. Use of the star bridge as an analysis tool is highly recommended. A little practice with it will demonstrate its utility and bring satisfying results.

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