# Nonlinearity Correction by Semiconductor Strain Gauges (SG) for Column Load Cells (LC)

Column load cells (LC), such as 14-series from BCM SENSOR, have inherent nonlinearity (NL) error. This is because that, under either compression or tension force, its longitudinal strain is about three times more than its transversal strain (i.e., Poisson ratio is about 0.3).

This inherent NL error of column LC is more significant than the NL errors caused by other factors (such as material defects and side load effects) and must be corrected. To correct this inherent NL error, one can integrate semiconductor SG into the Wheatstone bridge circuit of column LC on which the metal foil SGs have been bonded.

The principle of this correction employs the high gauge factor of semiconductor SG to modulate effective excitation voltage of the bridge circuit of the column LC. The typical technique to practice this principle and achieve the NL correction is explained as follows:

**Situation-1: Negative NL of Column LC under Compression Force**
When the column LC is under compression, it exhibits inherently negative NL error in its input-output characteristics, as shown by the curve in Fig. 1.

**Column load cell under compression force:**

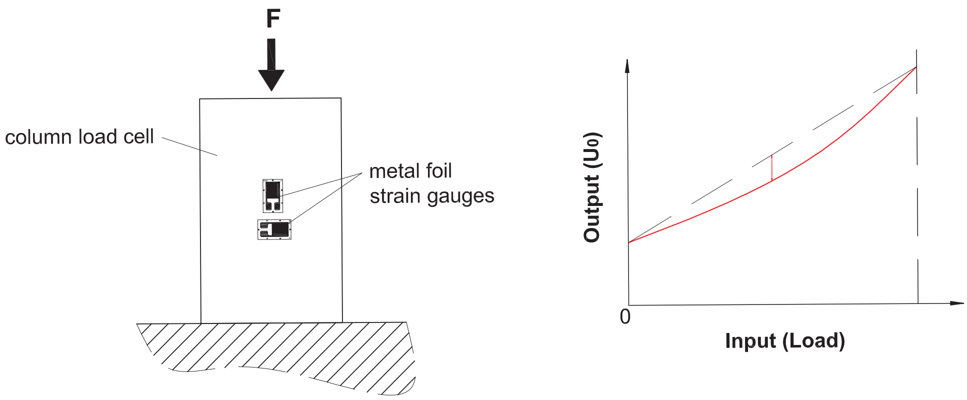


**Fig. 1: Negative NL of Compression Column LC**

If one connects two semiconductor SG in the Wheatstone bridge circuit as shown in Fig. 2, the effective-excitation-voltage over the bridge circuit will be reduced, as shown in Fig. 3, compared to the original case when the two semiconductor SGs are not yet introduced in the circuit. In this case, the two curves have the same curvature, i.e., the same NL error.


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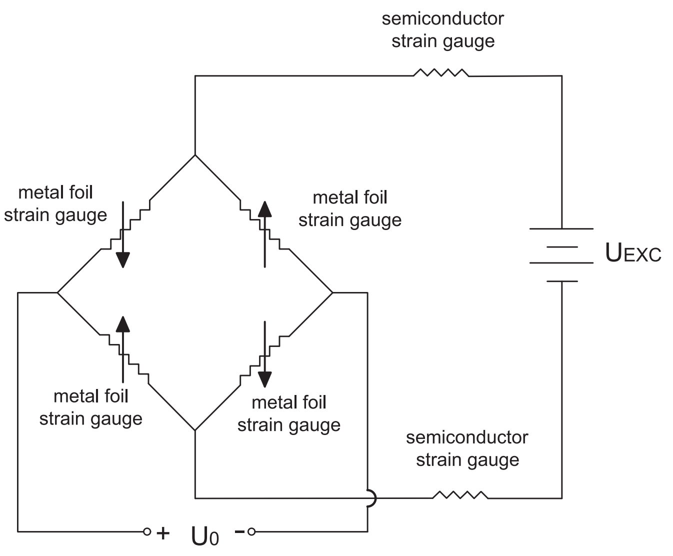
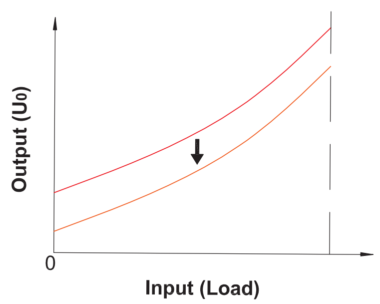



**Fig. 2: Schematic Circuit Diagram**




Legend: The upper curve is the column LC not yet connected to semiconductor SG;
The upper curve is the column LC connected to semiconductor SG, but
the semiconductor SG have not yet bonded on the LC body.

**Fig. 3: Change of Effective-Excitation-Voltage after Connected Semiconductor SG**

To correct the NL error, one can bond the two semiconductor SGs on the LC body transversally next to the bonded metal foil SG, and connect the semiconductor SG in the Wheatstone bridge circuit as shown in Fig. 4.

Since the two semiconductor SGs are bonded transversally, when the compression force applies to the compression column LC, the resistance of the two semiconductor SGs will be increased and the resultant effective-excitation-voltage at the Wheatstone bridge will be reduced. The higher the compression force, the bigger increase in the resistance of the two semiconductor SGs and the bigger decrease in the output signal of the compression column LC (the lower curve in Fig 4), compared to the scenario where the resistance of the two semiconductor SGs is kept no change, which is the case that the two semiconductor SGs are dummy, i.e., they are not bonded on the LC body but are simply connected in the circuit only (the upper curve in Fig 4).

Therefore, the lower curve is obtained representing the resultant output of the compression column LC, in which the NL of the original curve (as shown in Fig. 1) has been corrected to some extent (the lower curve in Fig. 4).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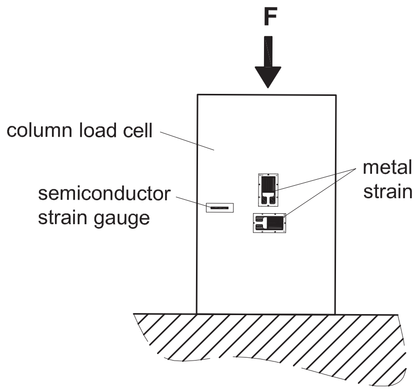
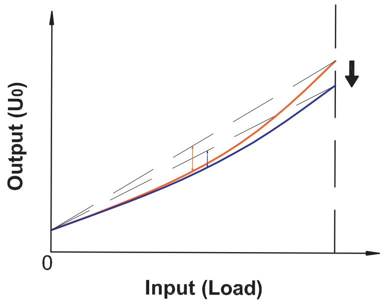
**Column load cell under compression force:**




Legend: The upper curve has a larger NL error, while the lower curve represents smaller NL error thanks to semiconductor strain gauges.

**Schematic circuit diagram:**

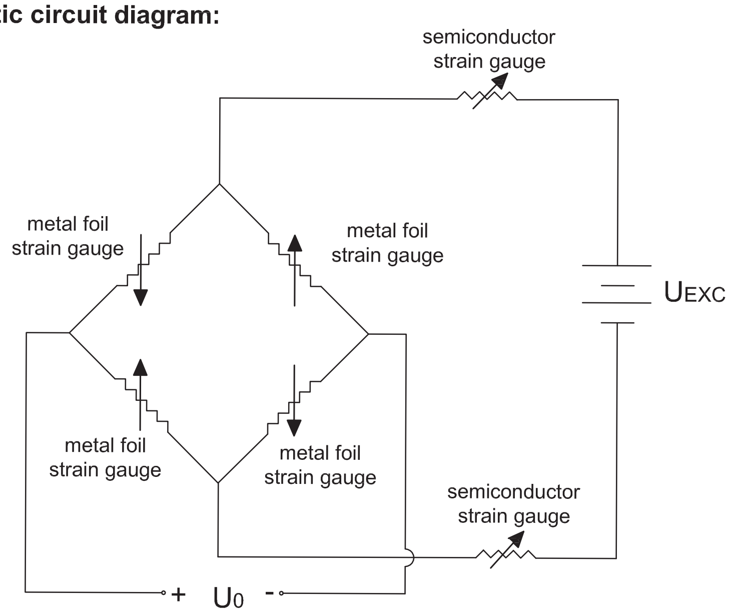



**Fig. 4: Correction of Negative NL of Compression Column LC**

**Situation-2: Positive NL of Column LC under Tension Force**

Under tension force the column LC exhibits positive NL, as shown by the curve in Fig. 5. To correct this NL error, one can bond two semiconductor SGs on the LC body transversally next to the bonded metal foil SG, and connect them in the Wheatstone bridge circuit, as shown in Fig. 5.



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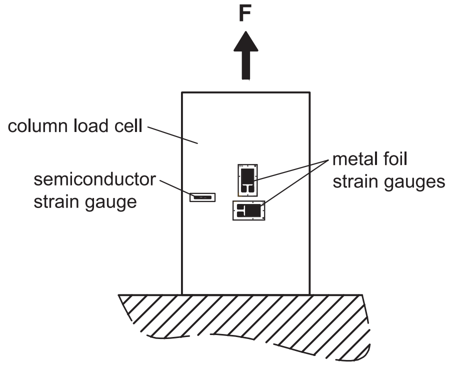
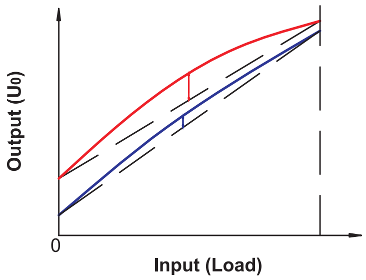
**Column load cell under tension force:**




Legend: The upper curve has a larger NL error, while the lower curve represents smaller NL error thanks to semiconductor strain gauges.

**Schematic circuit diagram:**

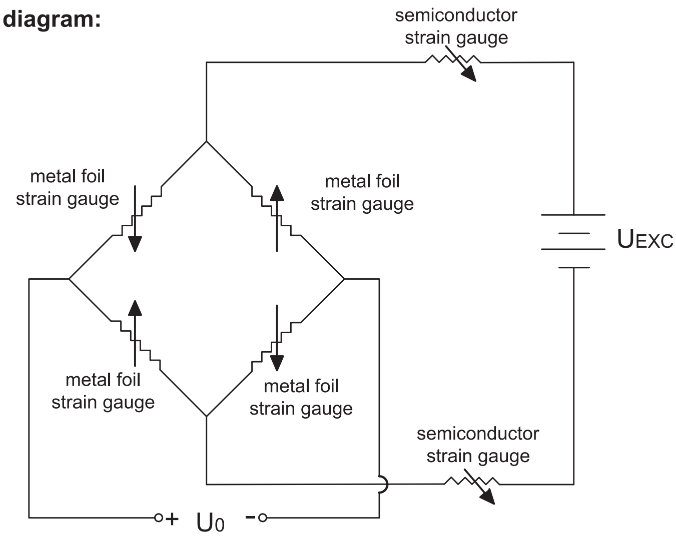



**Fig. 5: Correction of Positive NL of Tension Column LC**

In Fig. 5 the two bonded semiconductor SGs work as part of the load cell circuit and cause a voltage drop respectively. Due to this drop, the effective-excitation-voltage over the bridge circuit is reduced compared to the original case when the two semiconductor SGs are not yet introduced in the circuit.

Unlike the Situation-1, when the tension force applies to the LC, the resistance of the two bonded semiconductor SGs will be decreased and the resultant effective-excitation-voltage of the bridge circuit will be increased. As such, the LC output will be higher compared to the scenario where the resistance of the two semiconductor SGs is kept no change.

Therefore, the lower curve is obtained representing the resultant output of the tension column LC, in which the NL of the original curve has been corrected to some extent.

For detailed engineering advice on utilizing the semiconductor SG to correct the NL error of column LCs, one can contact BCM SENSOR.



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