Current Calibration

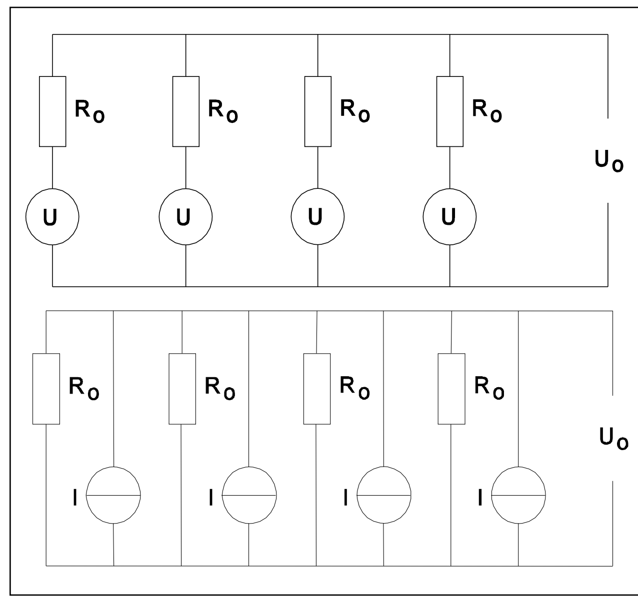
Conventional Calibration

The conventional method of rationalizing load cell outputs creates problems when load cells are connected in parallel. Multiple load cell systems normally require the individual adjustment of each load cell output to ensure that weight measurements are within tolerance for weight placements within prescribed areas. The individual load cell adjustments are very time-consuming, particularly for high-capacity systems or in hostile environments where containers may need to be emptied and filled several times during calibration.

Traditionally, load cell specification sheets quote the rated output of each load cell in voltage, usually mV/V, with a "rationalized" tolerance of 0.1% (2 ± 0.002 mV/V). However when connected in parallel, each load cell will be loaded with the output impedance of the other lo ad cells. As a result the system needs further adjustment in the field to be accurate.

The figure opposite shows the electrical diagram of four load cells, connected in parallel. Each load cell can be represented as a voltage source "*U*" with resistance "R_o" (output resistance).

Calculations are better understandable when the Norton equivalent circuit is used. The load cell is now represented as a current source, driving current through the parallel combination of the load cell source impedances, where $I = U / R_o$.



Example, the following four conventional calibrated load cells are connected in parallel and supplied with an excitation voltage of 10 Vdc:

LC	Capacity	Rated Output (mV/V)	Output (mV)	R_{out} (Ω)	Current (mA)
1	1000	2.001	20.01	350.50	0.0571
2	1000	2.001	20.01	352.00	0.0569
3	1000	2.000	20.00	351.50	0.0569
4	1000	2.002	20.02	351.00	0.0570
Total	4000	2.001(1)	20.01(1)	87.81(2)	0.2279

1) The combined load cell output equals the arithmetic mean value of the individual load cell outputs
2) $1/R_t = 1/R_1 + 1/R_2 + 1/R_3 + 1/R_4$

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The combined output can also be calculated by multiplying the total current with the combined resistance:

$$U = I_t * R_t = 0.2279 * 87.81 = 20.012 \approx 20.01\ mV$$

The reading when applying a test load of 500 kg on each individual load cell will be:

Load Applied on LC 1-2-3-4	Total Current I_t	Total Output U_o	Reading M
500-0-0-0	0.028545	2.5056	501.05
0-500-0-0	0.028423	2.4958	498.91
0-0-500-0	0.028450	2.4982	499.39
0-0-0-500	0.028519	2.5043	500.61

where:

$$I_t = T*S*E\ /\ R_o*E_{max}$$

$$U_o = I_t*R_t$$

$$M = U_o*N*E_{max}\ /\ U_{oc}$$

I_t	Total current (mA)	
T	Test load (kg)	= 500
S	Rated output LC_x (mV/V)	
E	Excitation voltage (V)	= 10
R_o	Output resistance LC_x (Ω)	
E_{max}	Rated capacity load cell (kg)	= 1000
U_o	Total output (mV)	
R_t	Combined resistance (Ω)	= 87.81
M	Reading (kg)	
N	Number of load cells	= 4
U_{oc}	Combined output (mV)	= 20.01

The readings are based on a full scale calibration. The zero balance (output at no-load) is considered to be 0 mV/V. Hence, if the load cell is not loaded, the current will also be 0 mA.

The example above considers a test load which only acts on one of the four load cells. In practice the test load will be unequally divided over all load cells because of the structure (platform/hopper) of the system. The absolute errors will therefore be smaller, but still considerable.

If all load cells were loaded with 500 kg, the total reading will be 501.05 + 498.91 + 499.39 + 500.61 = 1999.96 ≈ 2000 kg.

These calculations show clearly that the system needs further "corner" adjustment to be accurate. This is usually done in a junction box (signal- or excitation trim), using fixed or variable resistors. But this method has major disadvantages:

Additional temperature-sensitive resistors are being introduced into the system.

Selection of these resistors can be very time-consuming and require the use of deadweight's.

The process of adjustment must be repeated each time a load cell is exchanged.

A solution used by some load cell manufacturers to improve the overall result is to supply separate resistors with each load cell for use in the output lines to balance up the output resistances. However this does not solve the problem of fitting extra resistors and again these must be changed when any load cell is exchanged.

In General

Typical conventional calibration specifications are:

- Tolerance on rated output:
  ±0.1% (absolute error 0.2%)
- Tolerance on output resistance:
  ±1.0% (absolute error 2.0%)

By combining the three formulas above, it can be recognized that the maximum corner difference is based only on the tolerance on rated output and output resistance:

$$M = (T*E*R_t*N\ /\ U_{oc})*(S\ /\ R_o) = Const*(S\ /\ R_t)$$

Hence, the maximum corner difference will be:

$\sqrt{(0.22 + 2.02)}$ = **2.01%**

Current Calibration makes external balancing resistors unnecessary; allows much quicker on-site set up and calibration; and enables load cells to be replaced in the field without any need to readjust the system.

Current calibrated load cells are rationalized in terms of current output, rather than in terms of voltage output.

During production of load cell "LC_x", the output resistance "R_x" is measured. The desired output is then calculated by:

$$U_x = I_{ref} * R_x$$

After this calculation the required value for "U_x" is obtained by means of the internal calibration resistors to an accuracy of 0.05%, resulting in identical output current tolerances for each load cell.

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Example, the following four current calibrated load cells are connected in parallel and supplied with an excitation voltage of 10 Vdc:

LC	Capacity	Rated Output (mV/V)	Output (mV)	R_{out} (Ω)	Current (mA)
1	1000	1.9943	19.943	350.50	0.0569
2	1000	2.0029	20.029	352.00	0.0569
3	1000	2.0000	20.000	351.50	0.0569
4	1000	1.9972	19.972	351.00	0.0569
Total	4000	1.9986	19.986	87.81	0.2276

The total output can be calculated by multiplying the total current with the combined resistance:

$$U = I_t * R_t = 0.2276 * 87.81 = 19.986\ mV$$

The total output when applying a test load of 500 kg on each individual load cell will be:

Load Applied on LC 1-2-3-4	Total Current I_t	Total Output U_o	Reading M
500-0-0-0	0.028450	2.4982	499.99
0-500-0-0	0.028450	2.4982	499.99
0-0-500-0	0.028450	2.4982	499.99
0-0-0-500	0.028450	2.4982	499.99

The above calculations show clearly that the system needs **NO** further "corner" adjustment to be accurate.

In General

Typical current calibration specifications are:

- Tolerance on rated output: ±1.0%
- Tolerance on output resistance: ±1.0%
- Tolerance on output current, I_{ref}: ±0.05% (absolute error 0.1%)

This results in a maximum corner difference of **0.1%**, approximately 20 times better than conventional calibrated load cells.

The manner in which the load is transmitted through the load cell has a major impact on the accuracy and repeatability. Current calibrated load cells only perform without corner load differences in a multiple cell system when they are correctly installed:

- *All load cells should be placed on the same horizontal level (corrections can be made by placing thin plates underneath the load cell with minor output).*
- *The load should be transmitted vertically through the load cell (2° out of the perpendicular is already causing an error of approximately 0.061%).*

Load Cell Replacement

Although current calibrated load cells remove the need for corner adjustment, calibration should always be checked after replacing a load cell. If the load cell as a current source is considered to be a constant factor, it can be recognized that the calibration change is directly related to the change of combined resistance;

$$U_o = I_t * Rt = Const * R_t$$

Hence, the change of calibration can be calculated by:

$$(M / N) * a\ (\%)$$

Where:

M Number of load cells to be replaced

N Number of load cells in the system

a Resistance change in percentages:

$$((\Sigma_m R_{new} - \Sigma_m R_{old}) / \Sigma_m R_{old}) * 100\%$$

Example, a load cell with an output resistance of 350.5Ω will be replaced by a load cell with an output resistance of 353.0Ω. The application has a total of four load cells. The resistance change will be:

$$(353.0 - 350.5 / 350.5) * 100\% = 0.71\%$$

The calibration change will be:

$$(M/N) * 0.71\% = (1/4) * 0.71\% = 0.18\%$$