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A force transducer from a junk electronic balance

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Abstract
It is shown how the load cell from a junk electronic balance can be used as a force transducer for physics experiments. Recovering this device is not only an inexpensive way of getting a valuable laboratory tool but also very useful didactic work on electronic instrumentation. Some experiments on mechanics with this transducer are possible after a careful calibration and proper conditioning.

Introduction
An electronic balance is a typical apparatus in that when it becomes damaged after years of use one finds that repairing it is not feasible: it becomes junk. It is a pity that very often the ‘heart’ of the apparatus stays in good condition but can no longer be used. Therefore, dissecting the balance could become a didactic drill in electronic instrumentation and a very rewarding experience for low budget physics laboratories, since a diversity of experiments can be carried out using the load cell that many balances use as a force transducer. This kind of load cell consists of a cantilever metal beam with a tray over the free end. The mass to be weighted is placed over the tray. An arrangement of strain gauges [1] is fastened over the middle of the beam which measures the strains that the beam undergoes. If the strain is much less than the dimensions of the beam, this will be proportional to the applied force over the end of the beam. See figure 1.

We have dismantled an old damaged electronic balance model LS2000 from Ohaus [2] which has been stored as junk. We found that the load cell was of the cantilever type with four strain gauges arranged in a Wheatstone bridge. Four cables come out from the cell and are connected to the electronic board. In this board reside the amplifier, the controller and the display circuit. A picture of the cell is shown in figure 2 and the bridge circuit appears in figure 3.

Operating the load cell
There are a few configurations commonly used in the Wheatstone bridge depending on how the sensing gauges are positioned inside the bridge [3]. In one of the most common arrangements two strain gauges operate as sensing devices (active). In our case it seems that resistors $R_1$ and $R_4$ are the active gauges, and resistors $R_2$ and $R_3$ operate as temperature compensators. This is a configuration known as a half-bridge. For our purpose this issue is not very important since we only need...
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Figure 2. Balance load cell.

Figure 3. Strain gauge bridge circuit.

to know which terminal from the cell must be used for the excitation signal and which one for the output. Due to the way the wires connect to the electronic board we were able to identify the cables properly. It is a good drill in circuit theory trying to identify the values of each resistor in the Wheatstone bridge using only the resistivity measured between the four cables leaving the cell. Doing so, we were able to identify the following gauge values: $R_1 = R_2 = 658 \, \Omega$ and $R_3 = R_4 = 678 \, \Omega$.

Like with any Wheatstone bridge used for sensing resistivity, two things must be added to this bridge in order for it to work as expected: a means for balancing the circuit—when no load is present—and an electronic amplifier for the output signal. For the second task, we decided to make use of an integrated electronic differential amplifier. The LT1167 from Linear Technology [4] is an easy to use and affordable circuit. For balancing the bridge we used the potentiometer arrangement shown in figure 4 next to the bridge.

The differential amplifier has been set with a gain of 1000 by means of resistor $R_G$ (47 $\Omega$). The potentiometer circuit let us adjust a voltage offset span from $-10$ to $+10$ mV.

Before using the load cell in any experiment we proceeded to obtain the calibration graph. For this purpose we fastened the cell upside down under a shelf deck and hung different weights on it from the free side of the beam, and measured the circuit’s output voltage. We obtained the calibration graph shown in figure 5. We have restricted the applied weights to no more than 500 g even though this balance has a working range up to 2 kg. With regard to the resolution, with the circuit shown we could not get a stable
As an illustrative example of employing the force sensor we have implemented a spring–mass experiment. In this, the cell was used as the anchor for the spring, i.e. we measured the force exerted by the spring over the load cell as can be seen in figure 6. In figure 7 we show the data collected from the force sensor when a mass of 230 g and a spring with a constant of 75 N m$^{-1}$ were dangled from it. The oscillation frequency measured was 2.9 Hz.

There are many other experiments where the load cell can be used. Here are just a few:
- Impulse and momentum.
- Collisions.

## Conclusion

The load cells that one can find inside electronic balances are true technological jewels. When a balance becomes obsolete or sustains permanent damage, rescuing this jewel results in a very interesting drill in electronic instrumentation and at the same time yields a valuable laboratory tool. We have shown how to set up a load cell from a damaged electronic balance in order to carry out some laboratory experiments in mechanics. Since the load cell uses a strain gauge bridge circuit, a null balance and an amplification circuit have been shown. With this arrangement a calibration graph was obtained and, as an example from the many feasible mechanical experiments with the load cell, a spring–mass experiment was also shown.

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