DIY Kitchen Scale

Weigh up to 49.05 $kg \cdot m/s^2$ with Arduino

Based on an idea by **Bera Somnath** (India)

The starting point for this article was a project posted on Elektor Labs describing the construction of a kitchen scale from an ATmega328 microcontroller, a load cell, a load cell interface board, an LCD, and some software. A bit of cutting and drilling of wood and metal was required to transform it all into a useable weighing scale.

Features

- Up to 5 kgs
- OLED display
- Arduino-based

At Elektor Labs, when we decided to post-engineer this project [3] for publication in *Elektor Magazine* and started looking for the parts, we discovered that one of our regular suppliers carries a kit for exactly such a scale in their catalog. This kit contains an Arduino Uno-compatible board, a load cell, an interface board for the load cell, an LCD and laser-cut plastic parts to make a nice, transparent kitchen scale, and so we ordered one for inspection. Because the kit comes without a shield to hold all the parts — everything is supposed to be hooked up with jumper wires (included) — we decided to enhance it with an OLED display, providing not only more display options and graphical fun, but also freeing up I/O pins that may come in handy when the scale has to be interfaced to some other equipment. We added a 'Hold' button too as that handy function that is missing from so many kitchen scales. To cap it all, a trimmer was added for easy calibration of the scale.
Shall we have a look at how it all works?

Weight or mass?

In modern science weight is defined as mass × gravitational force and as such it is a force, expressed in newton (N) or, in SI base units, $kg \cdot m \cdot s^{-2}$; the SI unit of mass is kilograms (kg; kgs). A weighing scale measures weight, not mass, hence

if it displays results in kilograms, strictly speaking it talks nonsense. But, since for most purposes the gravitational force can be considered the same everywhere on Earth (9.80665 $m \cdot s^{-2}$), the scientific community allows us to express weight in kilograms.
Because weight is a force, the weight of an object can be determined by measuring the force it exerts on another object, like a spring or a beam. A spring is compressed or stretched by an object's weight, while a beam is bent. The weight of an object can also be determined by a balance comparing it to a known reference weight.

The strain gage

Basically a kind of variable resistor, a strain gage (gauge in Br. E) is good for measuring mechanical deformations, its resistance being a function of mechanical compression or tension. The strain gage was invented in 1938 on the west coast at Caltech by Edgar E. Simmons Jr. (who liked to dress in tights, a tutu, a turban and white ballet slippers). Simultaneously the strain gage was invented at the east coast by Arthur Claude Ruge (pronounce as Roogee) at MIT. Simmons and Ruge share the original patent.
The basic strain gage consists of a long, thin folded "wire", a foil actually, printed on a flexible backing support (see **Figure 1**). When the device is stretched, the foil becomes more resistive; when it is compressed, its resistance decreases. The variation in resistance is small, and to measure it with any precision a Wheatstone bridge is the way to go. To eliminate the temperature factor it is best to use two strain gages for one leg of the bridge. When the other leg of the bridge is also made up of strain gages, the output signal level increases and we call it a full-bridge strain gage.
Strain gages are fragile devices and attaching them to the object of interest is difficult. That's why they often come mounted on some sort of easy-to-use carrier, the so-called load cell. Everything you ever wanted to know, and more, about strain gages can be found in the free book at [2].

For our kitchen scale we use a load cell shaped as parallel beams with four strain gages attached to it configured as a full bridge (**Figure 2**). One end of the beam is fixed to the scale's frame; the object to weigh is placed on the other end of the beam, effectively bending it. This unbalances the Wheatstone bridge and the resulting voltage difference appears at the load cell's output where it can be measured.
Even though we are using a bridge with four strain gages, the output signal is still very small, like a few tens of millivolts. Consequently an amplifier is required to take the signal to a level that can be digitized and processed further.

The circuit

Now that we know how our scale works, let's have a detailed look at its schematic in **Figure 3**. Since load cells are fairly common devices it is not surprising that specialized integrated circuits exist capable of amplifying and digitizing a load cell's weak output signal. For this project the HX711 from Avia Semiconductor was chosen, a 24-bit analog-to-digital converter (ADC)

PROJECT INFORMATION

Arduino
home & garden
measurement

➡ entry level
intermediate level
expert level

3 hours approx.

Soldering iron,
PC with Arduino IDE,
reference weight(s)

£35 / €40 / $45 approx.

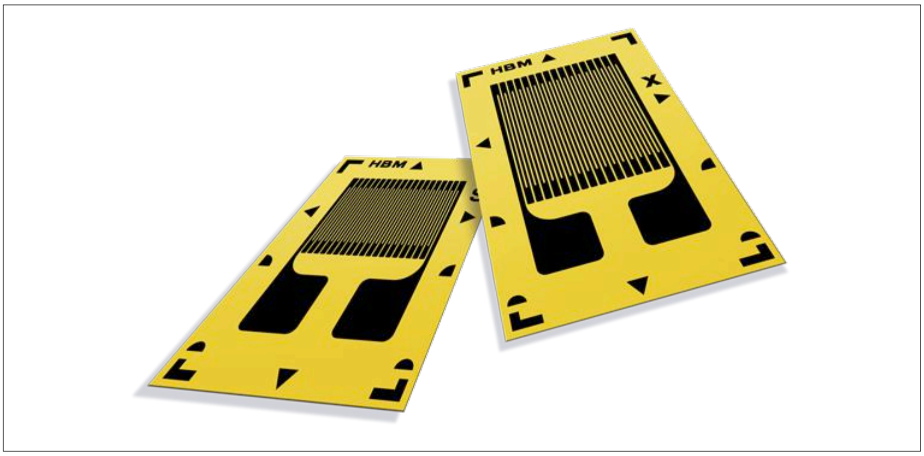


Figure 1. A strain gage is only sensitive in the longitudinal direction. (Photo: HBM)

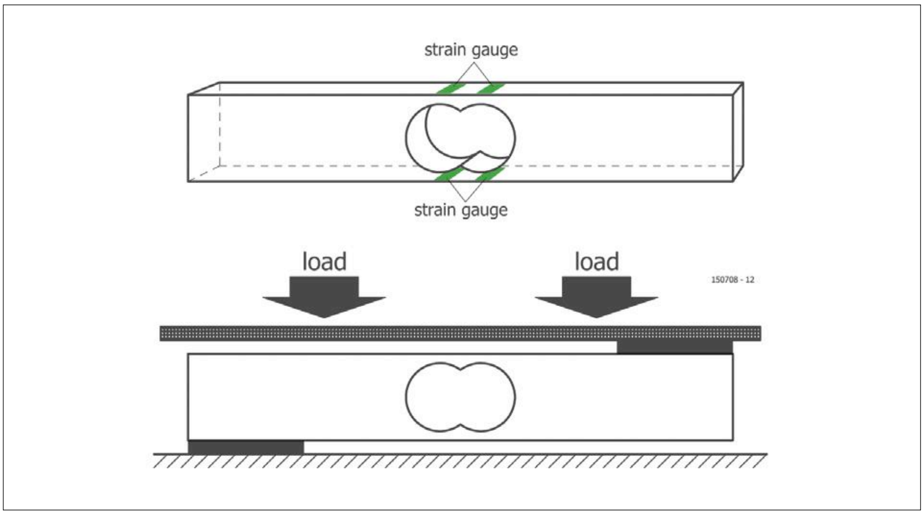


Figure 2. A parallel beam load cell carrying four strain gages in a full bridge configuration.

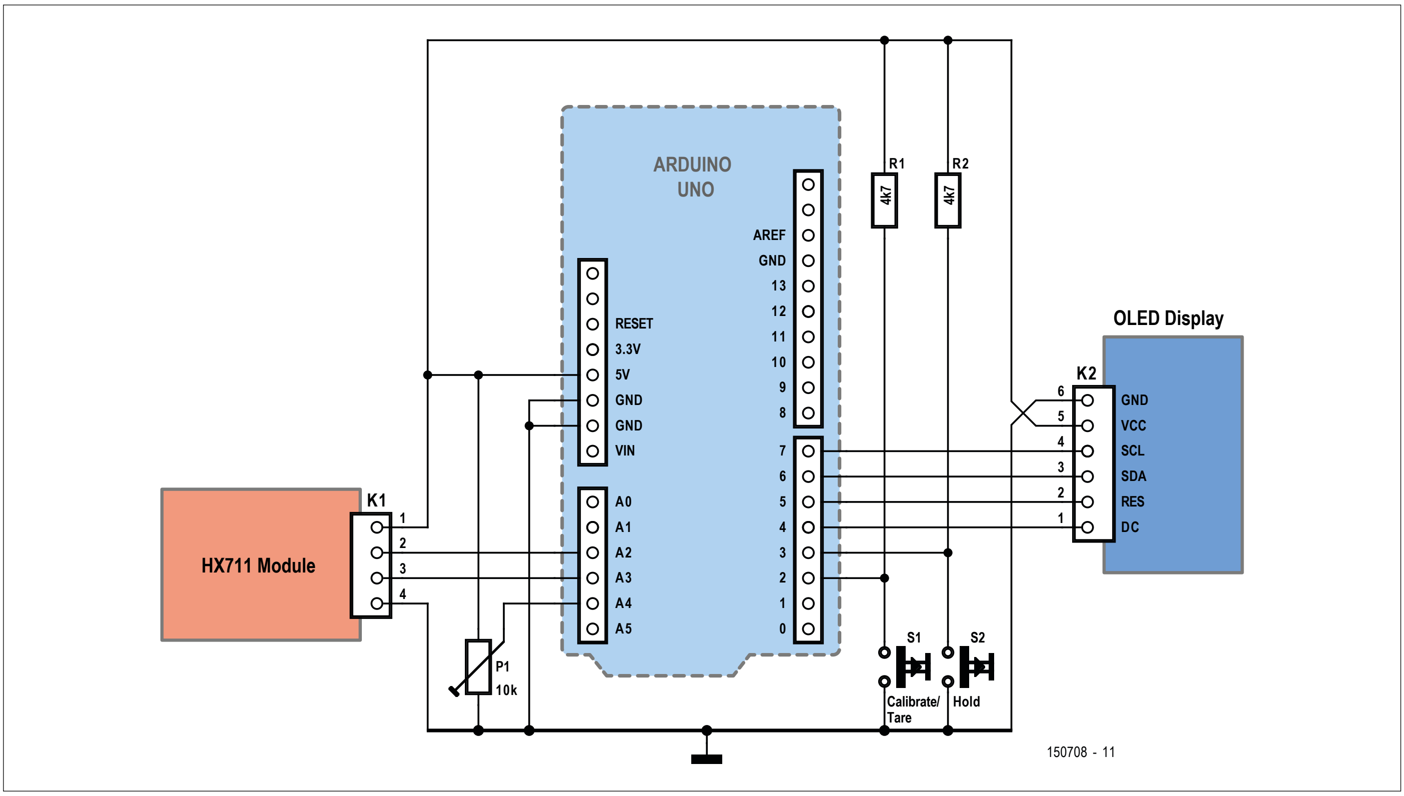


Figure 3. The schematic of the kitchen scale is very simple because all the clever stuff is done by the HX711 breakout board, the OLED display and the Arduino Uno.

for weighing scales, mainly because it is widely available on the Internet in the shape of breakout boards (it's actually quite difficult to obtain just the IC). The breakout board connects to K1. Note that this connector should be mounted floating above the PCB, otherwise the breakout board will not fit.

The output of the HX711 is a datastream (K1, pin 3) clocked (K1, pin 2) into the ATmega328 microcontroller living on an Arduino Uno board. The microcontroller also reads the position of a 15-turn trimmer for calibrating the scale.
The user interface consists of a graphic OLED display connected to K2, and two pushbuttons 'Tare' (S1) and 'Hold' (S2), pulled up by R1 and R2 respectively. K2 is mounted at an angle to improve readability.

Software

The microcontroller is executing a rather straightforward program or sketch, since we are using Arduino. Most of the sketch is actually dedicated to switching pixels on and off in the right places on the display; reading the load cell and converting the measured values to grams (g) and ounces (oz) is done in two lines of code.

```
gram = scale.get_units(10) *
   int(factor) / 1000;
ounce = gram * 0.0352739619;
bar = gram*40/5000;
```

This is a bit misleading, because the sketch heavily leans on a library that takes care of the communication with the HX711. The measured weight returned by `scale.get_units` is a 32-bit signed integer, converted to grams with the help of the calibration factor set with P1.
The graphics are handled by the 'Universal 8bit Graphics Library' (U8glib). The display shows the measured weight

Tare?

Relatively useless, the following information is great to have handy when a conversation stalls: […awkward silence…] *Say, do you know what 'Tare' means? You know, that pushbutton on a kitchen scale? No? Well…"* and you spill your knowledge. *"Jeez, I didn't know that, that's amazing! Imagine, all these years…"*, and the conversation will run smoothly for another hour (at least). So what does 'Tare' mean? It's the weight of the container in which something is placed, the weight of an unloaded transport vehicle, used to calculate the weight of the goods inside it. Now you finally know why you would want to press the Tare button after placing an empty beaker on a scale.

Table 1. How to wire the load cell to the HX711 breakout board. The B− and B+ inputs remain unconnected

Wire	Signal
Red	E+
Black	E−
Green	A+
White	A−

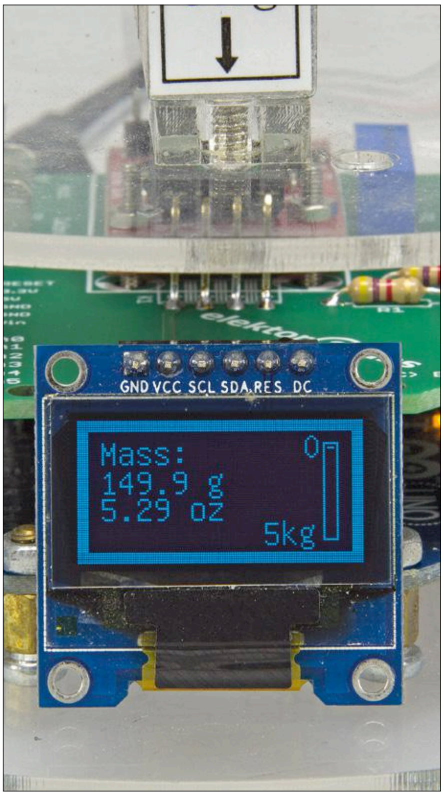


Figure 4. The OLED display shows the weight in grams and ounces, together with a bar graph.

in grams (g) and ounces (oz), and as a bar graph up to 5 kgs (**Figure 4**). When the Hold button (S2) is pressed, the display freezes and the object can be removed without losing the measured weight. Pressing Hold again will return the scale to normal operation.
S1 is the Tare button (see inset), pressing it will set the displayed weight to 0 grams no matter if an object is on the scale or not.
The software for this project is available free of charge from the *Elektor Magazine* website [1].

Calibration

Connecting the load cell to the HX711 module (see **Table 1**) completes the assembly of the scale. However, before it can be used in your next baking or cooking project (like tonight's dinner), it should be calibrated. This can be done with the sample weights included in the kit (or with other objects of which you know the exact weight):

1. Turn on the scale.
2. Press the Calibrate button (S1).
3. Place a reference weight on the scale, for example 150 grams.
4. Adjust trimmer P1 until the display shows the right weight in grams (150 in this case).
5. Remove the weight from the scale.
6. Push the Calibrate button (S1) again; the scale should display 0 grams.
7. Put the weights back on the scale. If the weight is right, the scale is set up correctly; if it isn't, repeat the calibration procedure starting from step 3.

That completes the calibration of the DIY kitchen scale project. Please note that the project is not approved for commercial use.

(150708)

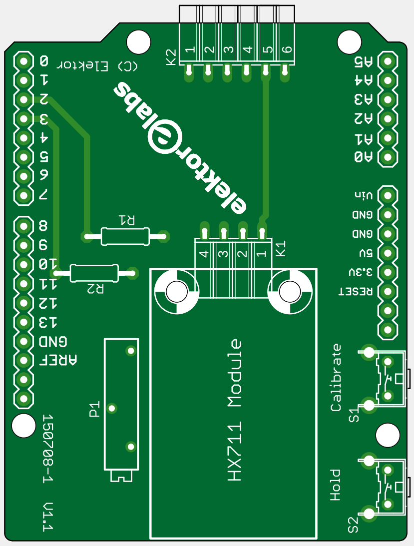
COMPONENT LIST

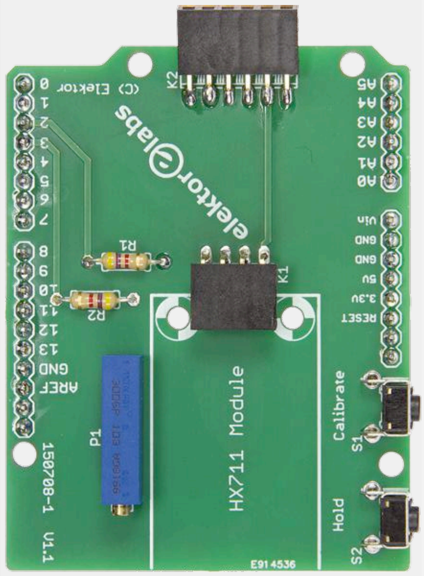
Resistors

R1,R2 = 4.7kΩ
P1 = 10kΩ 15-turn trimpot

Miscellaneous

K1 = 4-way SIL pinheader socket, 0.1" pitch, horizontal
K2 = 6-way SIL pinheader socket, 0.1" pitch, horizontal
1 pc 6-pin SIL pinheader, 0.1" pitch, vertical
2 pcs 8-pin SIL pinheader, 0.1" pitch, vertical
1 pc 10-pin SIL pinheader, 0.1" pitch, vertical
S1,S2 = tactile switch, PCB side mount
HX711 breakout board
2 pcs M2×10 mm bolt
4 pcs M2 nut
5 kg load cell, e.g. YZC-1B
PCB # 150708-1 from Elektor Store





Web Links

[1] www.elektormagazine.com/150708
[2] An Introduction to Stress Analysis and Transducer Design using Strain Gauges, www.hbm.com
[3] Original project: www.elektormagazine.com/labs/5-kg-kitchen-scale-built-on-arduino