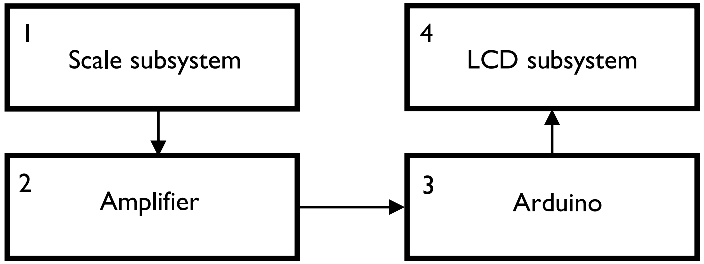
User guide

The first step in utilising the design is to calibrate the scale. This is done to increase measurement accuracy, in order to accommodate for changes in the environment around the device, which could influence its sensible components.

Upon initialising calibration (by pressing the leftmost push-push-button on the Arduino), no mass should be present on the scale. After initialisation, the user should follow the instructions printed on the display to be guided through the steps necessary for a successful calibration of the scale.

After calibration, a cup should be placed on the scale, and the coffee-making process can start! The device will automatically measure the amount of liquid being poured into the cup, and will thus calculate the coffee's flow rate: this data, combined with the knowledge of a skilled barista, is bound to result in an award-winning espresso!

System diagram



Component costs

The components costs shown below were gathered from the RS catalogue. The overall cost of the electronic circuit is slightly above 1£. This needs to be added to the cost of an Arduino board, and the price of the scale also needs to be taken into consideration.

Component	Cost	Amount
Resistor 1kΩ, 22kΩ, 33kΩ	0.005 £/piece	2
Resistor 1MΩ	0.01 £/piece	1
Resistor 680kΩ	0.023 £/piece	1
Resistor 10kΩ	0.005 £/piece	2
LM301 Op-amp	0.35 £/each	2
LF356 Op-amp	0.53 £/each	2
Capacitor 33 pF	0.086 £/each	1
Capacitor 0.47 µF	0.17 £/each	2

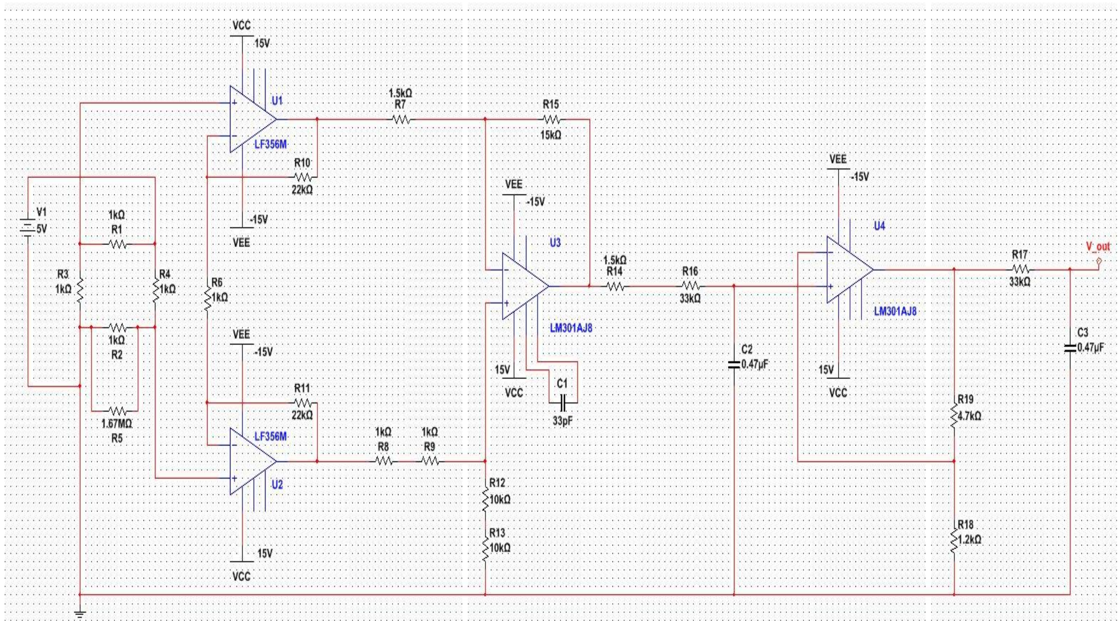
System specification

Parameter	Min	Max	Units
Measured weight	0	100	g
Supply voltage	+5, ±15	+5, ±15	V
Weight measurement error	±0.3	±0.5	g
Flow rate measurement error	±0.3	±0.5	ml/s
Timing error	±1	±2	s

Circuit diagram

The figure below shows the overall circuit schematic for the circuit. Starting from the left, we have a Wheatstone bridge, which acts as a weight sensor for the coffee being poured in the cup. The bridge was powered on with a 5V power supply.

In order to remove the offset of the scale (due to its poor quality), a high-value resistor (1.67MΩ) was added in parallel with one of the branches of the bridge, as shown above.



The signal was then passed through an instrumentation amplifier with a gain of around 1000 to be picked up by the arduino. This constitutes the middle section of the schematic shown in the image and was made up of two LF356 operational amplifiers in the amplifying stage and one LM301 op-amp in the common-mode rejection stage. After this step, the amplified signal was passed through a low-pass filter with a cut-off frequency of 10 Hz, in order to reduce the noise picked up by the system thus far. Next the signal was ampified again, to get it to the range 0-5V, optimal for the Arduino's *analogRead* function.

employing another LM301 operational amplifier set up in a non-inverting amplifier configuration, with a gain of 4.
Lastly, after this further amplification, the signal was again passed through an RC low-pass filter with a cut-off frequency of 10 Hz, to again get rid of the noise, as fluctuations in the signal passed to the Arduino could greatly reduce resolution.

How our software operates

At setup:
The program establishes connection with the LCD display via the pre-processed header file LiquidCrystal.h
Establishes the pin A1 on the Arduino to become our analog input pin from which the output voltage from the amplifier is read.
At the body of the code:
Establish variable and pin connections
Check whether any buttons are being pushed {
If the SELECT button is pressed
    Calibration function is initialized
    Take analog read values at no weight and average
    Return the HIGH and LOW values
If the LEFT button is pressed
    Set zero function is initialized
    LOW value of map is set to analog read of the current weight voltage
Printing the weight and flow rate {
Take analog read value from the pin
Map the value between the HIGH and LOW read values from the calibration function
Map that between no weight and 100g (meaning that beyond 100g the scale loses accuracy)
Take 20 readings over a second for the weight and calculate mean to account for fluctuations from equipment
LCD print that mean weight as the current weight to improve accuracy
Flow rate = (Current Weight – Previous Weight)/Time between readings
If the flow rate is above the threshold of $10cm^3/s$ then the flow rate is recorded as not being an anomaly
LCD print the flow rate

We hope this has informed you about your future purchase and thank you for choosing us!

COFFEE SCALE

PRECISE TO 0.1G
WATER AND STEAM PROOF
ACCURATE AND RELIABLE
FLOW RATE INCLUDED