Design Specification

Description

The Flow Rate Device is as technology that allows the barista to measure the flow rate of the espresso machine, thus achieving the perfect espresso with a flow rate of 1ml/s.

The Flow Rate Device achieves this by using three operational amplifiers to create a high impedance instrumentation amplifier. This is connected to the load cell's differential output to precisely amplify the low voltage signal by 30dB gain so it can be measured by the microcontrollers (ESP8266) ADC (Analog to Digital Converter).

Specifications

Parameter	Min	Typ	Max	Units
Supply Voltage	±5	±12	±20	V
Measurable Weight	0	--	160	g
Battery Life	1	1.5	2	hrs
Refresh Rate	--	500	--	ms
Mass Resolution	0	0.05	0.1	g

System Diagram

In Fig.2 we have the design of the device. The load cell's (equivalent to a Wheatstone Bridge) output is precisely amplified by the instrumentation amplifier circuit, so it can be measured by the microcontroller's ADC.

The ESP8266 has a 10 bit ADC, so it has a minimum voltage step of 3mV. The ESP8266 then converts this raw ADC value into the corresponding mass in grams using a linear relationship calculated in MATLAB (eq.1).

$$Mass(g) = 0.155 \times ADC \ (eq. 1)$$

This change in mass is calculated every 500ms and used to calculate the flow rate. This is sent to the LCD to give feedback the barista.

There are three input buttons that are used to navigate the screens and reset the scale. The screens are made using a Finite State Machine (Fig.1).

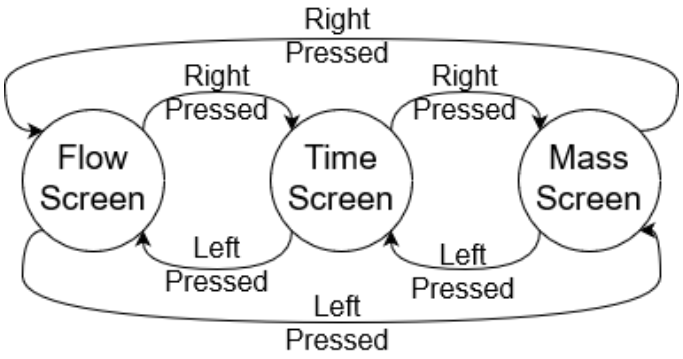


Figure 1 State Diagram of Screens

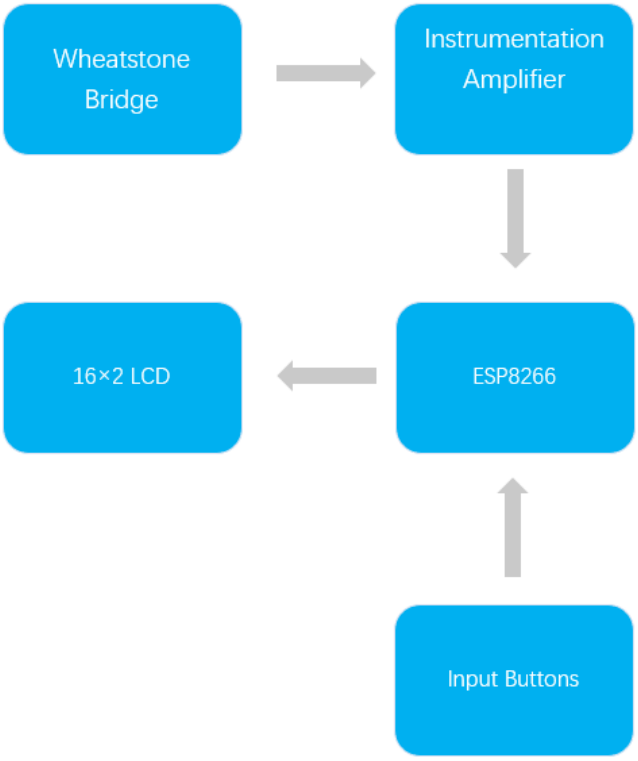


Figure 2 System Diagram

User Requirements

- Measuring Mass, Time and Flow rate
- Mass accuracy of 0.1g
- Water and heat resistant using a silicone case and potting the electronics in an epoxy resin.

User Guide

Place the cup on the scale and press the start button that zeros the scale and starts the timer. Press the left and right buttons (Fig.1) to choose between the available screens (Time, Flow rate and Mass). The flow rate can be continuously monitored from any of the screens from any of the screens using the indicator in the top left of the screen. The device will automatically turn off if it has not been used for more than one minute.

Circuit Diagrams

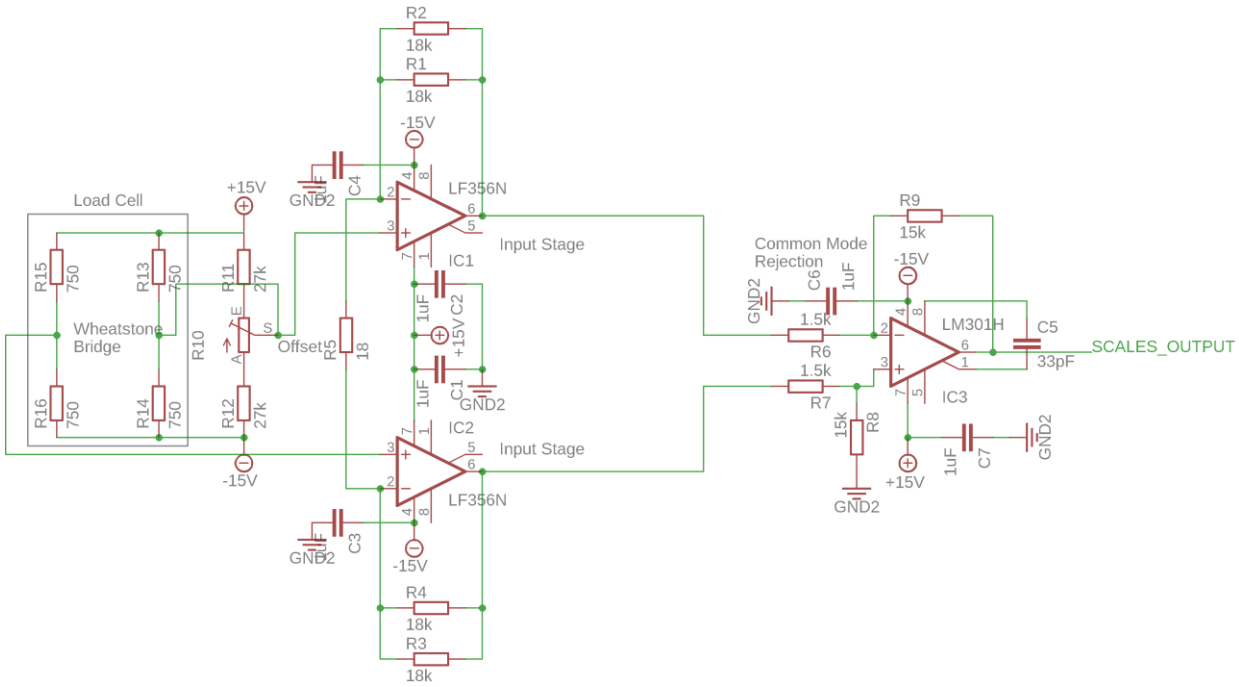


Figure 3 Instrumentation Amplifier

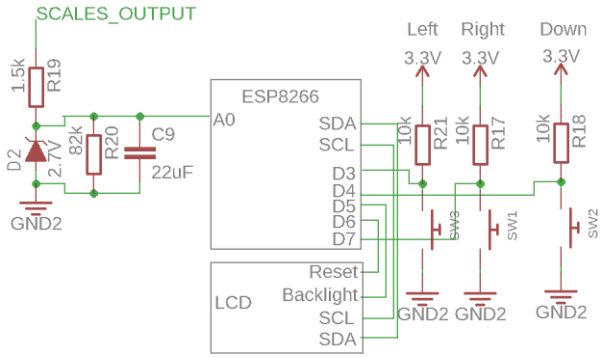


Figure 4 User Interface and Signal Conditioning

The signal coming out of the load cell is in the millivolts range. The ADC only has a step resolution of 3mV, so this signal must be amplified. This achieved by first removing DC offset with a potentiometer in parallel with the load cell and connecting it to the instrumentation amplifier (Fig.3). This amplifies the signal by 30dB so that it can be measured by the microcontroller. The 2.7V Zener diode and low pass filter conditions the signal (Fig.4) to remove noise and protect the microcontroller from high or negative voltages. The buttons have pull-up resistors, so when they are pressed, the signal goes low, and the ESP8266 responds by carrying out the requested function. The ESP8266 outputs the data via i2c to the LCD screen.

Structure of the code

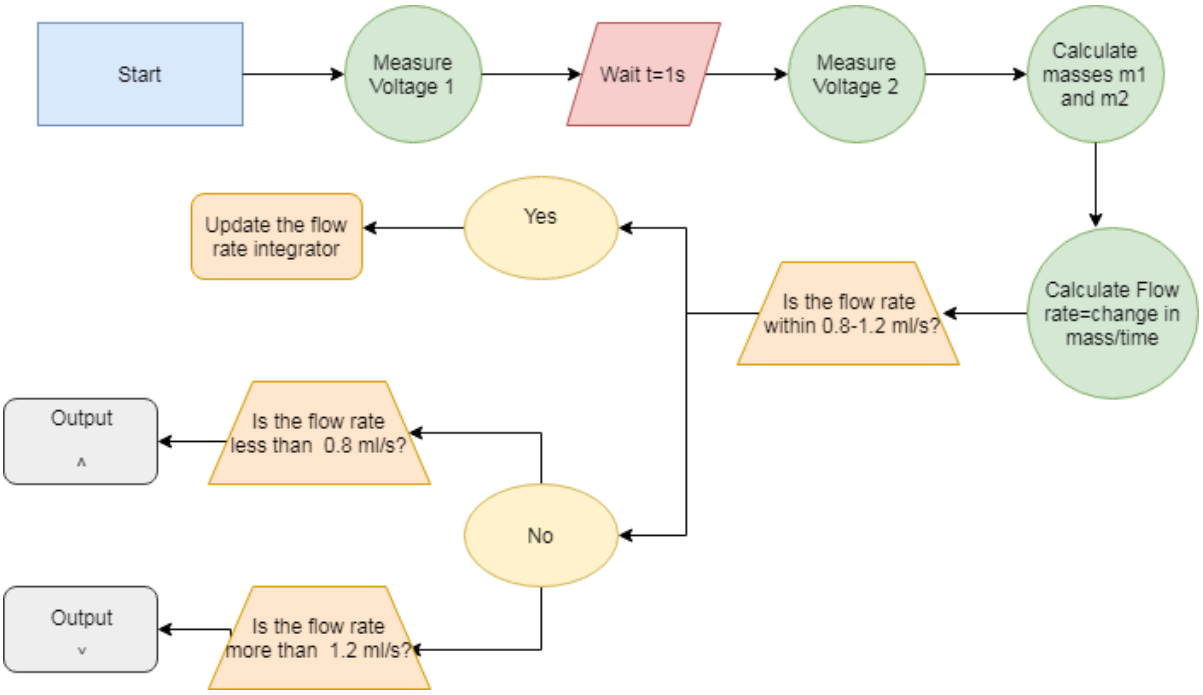


Figure 5 Flow rate Code diagram

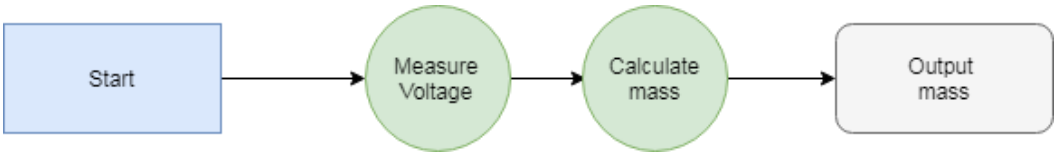


Figure 6 Mass Diagram

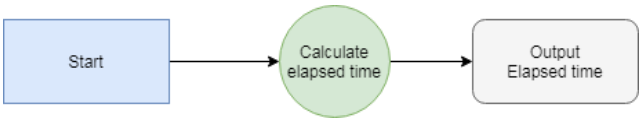
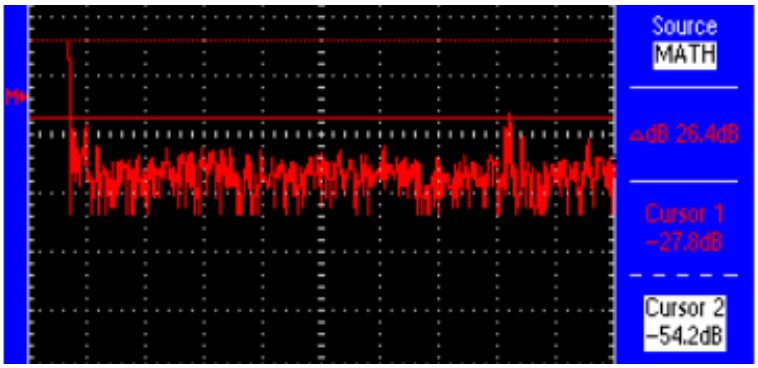


Figure 7 Time Diagram

Performance specifications

- The mass sensitivity: reads mass with 0.1g accuracy, it goes to 1 decimal place
- Noise rejection, signal to noise ratio is 26.4db



- Timing accuracy: measures a new voltage every 500ms, the timer menu displays the elapsed time with an accuracy of 1s
- There is no time lag when changing the mass on the load cell
- Power requirements: circuit is powered by ±5.02V at 40mA current

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Description	Specification	Values
LM301 Bipolar operational amplifier	Input resistance	2MΩ
	Input noise	23nV/√Hz
	Cost	£0.61
	Quantity	1
	Source	Farnell
LF356 high precision operation amplifier	Input resistance	10^{12} Ω
	Input noise	12nV/√Hz
	Cost	£0.55
	Quantity	2
	Source	Farnell
18Ω resistor	Cost	£0.03
	Quantity	1
	Source	Farnell
10kΩ resistor	Cost	£0.03
	Quantity	3
	Source	Farnell
1.5kΩ resistor	Cost	£0.03
	Quantity	3
	Source	Farnell
15kΩ resistor	Cost	£0.03
	Quantity	2
	Source	Farnell
18kΩ resistor	Cost	£0.03
	quantity	4
	Source	Farnell
27kΩ resistor	Cost	£0.03
	Quantity	2
	Source	Farnell
82kΩ resistor	Cost	£0.03

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	Quantity	1
	Source	Farnell
750 Ω resistor	Cost	£0.03
	Quantity	4
	Source	Farnell
100k Ω Potentiometer	Cost	£0.25
	Quantity	1
	Source	Farnell
1 μ F capacitor	Cost	£0.44
	quantity	6
	Source	Farnell
22 μ F capacitor	Cost	£0.04
	Quantity	1
	Source	Farnell
33pF capacitor	Cost	£0.55
	Quantity	1
	Source	Farnell
Load cell Bridge	Cost	£5
	Quantity	1
2.7V Zener Diode	Cost	£0.02
	Quantity	1
	Source	Farnell
Push Button	Cost	£0.02
	Quantity	3
	Source	Farnell
16x2 LCD	Cost	£7.40
	Quantity	1
	Source	Farnell
12V A23 Battery	Cost	£0.85
	Quantity	2
Total Cost	£19.93	