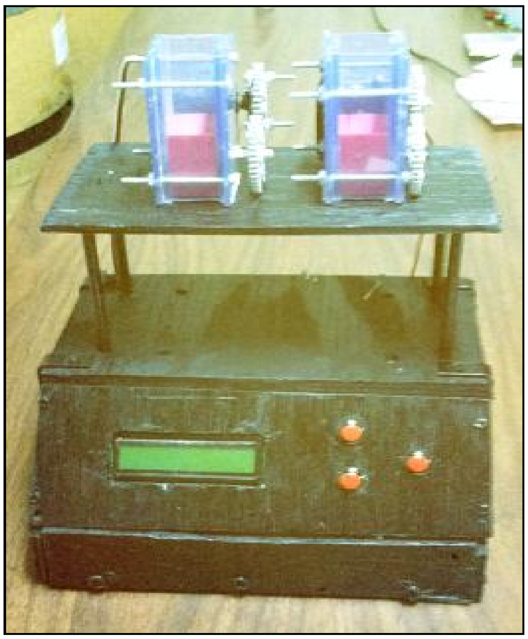
NYU Poly

Team 1 XTreme Spice Dispenser

ME 5643 Professor Kapila



Report Written by:

Akim Faisal

Andrew Cave

Sam Sangankar

Contents

Abstract

Last week you made your favorite chili of all time—but how did you make the spice mix? Or, you've found a great recipe in a magazine that calls for grams, ounces, or tablespoons of spice, but you don't have the time or measuring equipment to follow it exactly. Now, with Iller Robots Electronic Spice Dispensing Scale, all your problems are solved!

Key features:

- Multiple spice containers
- Automatic dispensing based on weight or volume
- Comes preprogrammed with delicious spice mix recipes, create and store your own!
- Can record a new spice composition that you manually create

The ESDS (Electronic Spice Dispense) is comprised of 3 or more spice dispensing nozzles. Underneath the row of nozzles is a rotating dispensing wheel which contains multiple small volume buckets. Initially, the first bucket is filled through the action of gravity. The wheel turns, positioning a new bucket underneath the nozzle and unloading the first bucket onto a scale beneath. The wheel action can be controlled by volume (the number of rotations of the dispensing wheel) or by feedback from the scale. An analog sensor will be incorporated in the form of the scale, which provides feedback to the dispensing wheel actuator. Digital sensors will be incorporated in the form of control buttons on the interface

Introduction

The idea of smart appliance has been around for many years, as time passed technology eventually began to catch up. What seemed to be science fiction during the "old days" is now a mundane part of our daily lives. We have all had the opportunity to interact with some sort of smart kitchen appliance in our lives. The "smart" kitchen appliances of the twentieth century include the automatic toaster, microwave, and coffeemaker. Sam Sangankar, Andrew Cave, and Akim Faisal are proud to present a smart kitchen appliance of the 21st: the Team 1 XTreme Spice Dispenser!

The Team 1 XTreme Spice Dispenser is a PIC-microcontrolled, servo-motor actuated, dispensing and weighing platform. Custom-made Maker Bot parts are paired with Lego NXT gears staged on a hand-painted wooden platform to create a design that is both futuristic and classically elegant. In this brief, we will describe the main components and functions of the Team 1 XTreme Spice Dispenser as well as go in depth for an "under the hood" look at what makes the difference between a salt shaker and an XTreme Spice Dispenser.

Dispenser Components

The components of the dispenser consisted of the following parts:

1. **Wooden frame**

The wooden frame was built with the capacity to hold the circuitry inside as well as to support the weight of the dispenser on the top. The base of the frame was made out of an 8″ x 8″ x ½″ thickness. The sides of the frame were put together with a 3/8″ thick plywood material.

2. **Spice container**

The containers that hold the spices are made of polyvinyl chloride (PVC) sheets. PVC is a widely-used, low-cost plastic. The dimensions of the plastic containers are roughly 1.4″ wide by 3″ x 2″ deep. The following photograph shows the spice container in mid-assembly. A dispenser wheel (shown in magenta below) is situated at the bottom of the container. The dispenser wheel has two wedge-shaped recesses on opposing sides which provide the means to dispense the spice onto a scale. Furthermore, the dispenser wheel is attached to a gear connected to a servo motor located outside of the box which allows full rotational motion for dispensing.

Figure 1: Spice Container

3. Actuators

Continuous servo motors

For each PVC spice container there is a continuous servo motor which drives the dispenser wheel through an idler gear pair. The intent of the idler is to reduce the footprint of the device.

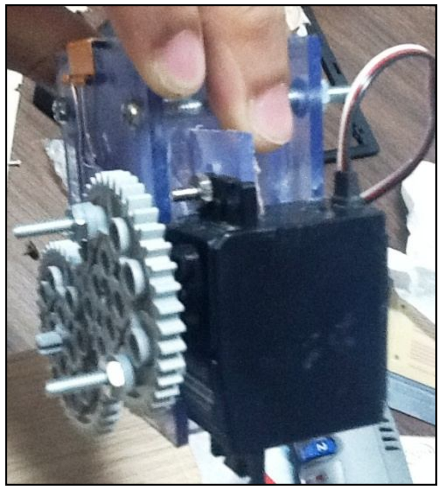


Figure 2: Servo motor attached to PVC plastic container

4. Sensors: *Bending Beam Load Cell.*

A bending beam load cell was utilized to properly measure the amount of dispensed spice. The bending beam load cell is an inexpensive, low capacity sensor. The measurable capacity of the load cell ranges from 0 grams to a maximum of 50 grams. The figure below depicts this type of sensor.

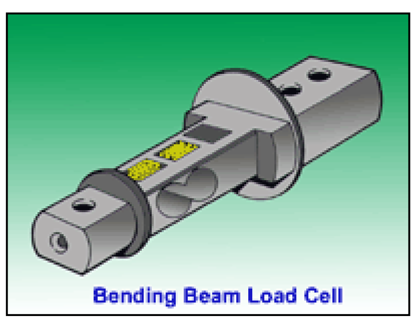


Figure 3: Bending Beam Load Cell

A load cell is a transducer that converts force acting on it to an electrical output signal. At the top and bottom of the surface, multiple strain gages are attached to measure tension and compression. For low-load applications, the beam is made of beryllium copper [2], however, for larger loads or more expensive applications, the beam is made of steel.

A strain gage inside the load cell will deform under tension varying its resistance to current. For the measuring range of the load cell, this change is linearly proportional to the strain. The strain gages are arranged in a Wheatstone bridge configuration. Typically four strain gages are employed and as weight is applied the electrical resistance changes proportionally with the applied load [3].

Pushbutton sensors

A total of 3 pushbuttons are used for providing a simplistic and easy-to-use interface. The main functions provided by the pushbuttons are Next, Back, and Enter.

5. Parallax Board of Education carrier board, Basic Stamp 2 micro-controller, and multiple breadboards were used for electrical and hardware design.

6. Integrated circuits: Three integrated circuits (IC) were used in the product design

   i. Op-Amp (1)
   ii. Analog to Digital Converter (2)

7. Electrical components:

   i. Resistors
   ii. Capacitors
   iii. Leads
   iv. Battery (9V)
   v. Pushbuttons

8. User interface: The dispenser contains a simple user interface that allows one to interact with the device. This interface allows user to tare the container that he/she would like the spice to dispense out of and also to dispense a specified amount of spice in grams.

Safety Guidelines

Operation of the spice dispenser does not pose any fatal health hazards to the user operating the device in a household environment. The device has the option of both running on battery power as well as to an AC adapter. In order to prevent structural damage to the device, small PVC plastic containers were used to hold the spice. Large containers cannot be used primarily because of the fragile wooden beams used to support the weight above it. Due to the weakness of the wooden beams holding the plastic container along with the spice limits the weight for optimal operation.

Safety is of highest concern to the engineers at Iller Robots, and we have done our best to ensure an intrinsically safe operation. However there will always be precautions the user must take with mechanized devices and the Smart Spicer is no exception. Here is a list of guidelines for safe operation of the Smart Spicer automatic dry ingredient dispenser:

1. Read the instruction manual carefully before turning on and operating the device. Develop an understanding of the basic interface and what each command will make the Smart Spicer do.

2. ALWAYS keep your hands and fingers away from the gears when the device is powered on. The spinning plastic gears were designed to not cause a serious injury; nonetheless it is possible to pinch your fingers if the gears were grabbed or otherwise handled during automatic dispensing.

3. Proper Hardware have been implemented in the device in order to prevent internal damage to IC components: Do not change hardware specification.

Mathematical Background

I. The Wheatstone bridge

The bending beam cell found in this invention is the same type found in ordinary modern digital scales. This particular cell features a full Wheatstone bridge circuit, which converts mechanical strain into a small change in DC voltage.

The general layout of a strain gauge Wheatstone bridge circuit is shown below.

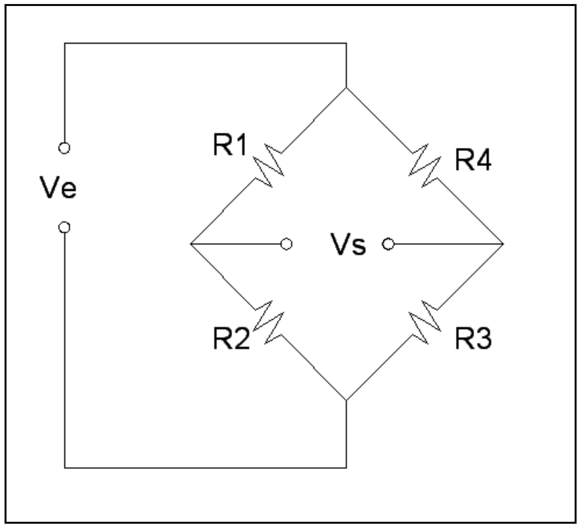


Figure 4: Wheatstone bridge circuitry

The Wheatstone bridge is given an excitation Voltage Ve, in the case of this invention +5 Volts DC. The signal voltage Vs is the quantity that is being measured in analog instrumentation such as the strain gage.

If R1 / R2 = R4 / R3, the bridge is said to be balanced and Vs = 0. However, when one of the resistors in either "arm" fluctuates, the bridge goes into imbalance and a voltage is produced at the output signal V_s.

This fact is often exploited by replacing one or more of the fixed resistors with a strain gauge that produces a small change in resistance when mechanical strain is imparted in the direction that the strain gauge has been installed.

The mathematics behind a strain gage Wheatstone bridge is well documented, and the basic equations are outlined here for a full – bridge circuit. The authors have found that reference number (4) gives a good introductory treatment to the topic, including basic theory and applications.

The fundamental parameter of a strain gauge is the gage factor, which is defined as change in resistance in ohms per ohm of nominal resistance, divided by strain.

$$GF = \frac{\Delta R / R}{\varepsilon}.$$

This defines the strain gauge sensitivity. The higher a gauge factor is, the more sensitive the gauge is said to be.

II. Full Bridge

The equation for strain in a full bridge circuit is

$$\frac{V_s}{V_e} = -GS \cdot \varepsilon$$

The signal voltage for the weight range we were interested in was around *Vs* = 1 mV. This amount of signal is too small to digitize with an A to D converter without some prior conditioning.

III. Operational Amplifier

In order to boost the signal from the Wheatstone bridge the device incorporates a dual operational amplifier IC chip, which is able to support two spices for each IC device.

The op amp was used in the difference amplifier mode, which takes the voltage difference between two leads and applies a gain to the difference. The gain was set by sizing the resistors in the feedback circuit.

The equation for output voltage in a difference op amp is [4]:

$$V_{out} = \frac{R_f}{R_1} * (V_2 - V_1)$$

The proportion of Rf to R1 is known as the "gain" of the system and difference in voltage from the bending beam load cell. Proper sizing of resistor was used to obtain a gain of 100, sensor one gave an output of V2 = 2.1 V and V1 = 2.0 volts whereas sensor two gave readings of 2.8 and 2.7 V respectively. The equation for Vout is theoretical; however, in practice the gain of the op-amp is not equal for the two inputs. In an ideal case if V+ and V- are identical the output is normally zero, in reality the output of a differential op amp is includes a common mode gain. The modified equation is therefore:

$$V_{out} = \frac{R_f}{R1} * (V_+ - V_-) + A_C * \left(\frac{V_+ - V_-}{2}\right)$$

"Ac" refers to common mode gain, in this case was approximately 4000.

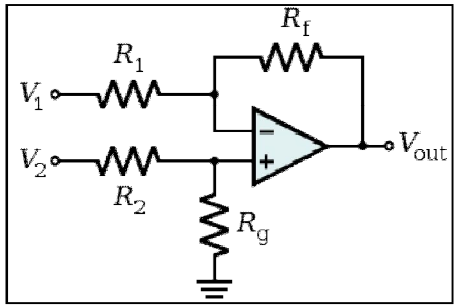


Figure 5: Differential op-amp

IV. Analog to Digital Converter

Two analog to digital converters were utilized in order to convert continuous voltage signal to a discrete digital representation. The signal from the op-amp was fed into an ADC integrated circuit. The voltage reading was digitized to a full resolution of 255. The dispenser design incorporated a dual differential op-amp and each required its own ADC. The bending beam load cell allowed a range of 0 to 50 minimum and maximum weight (in grams) reading respectively. Since 50 grams of spice is not too often used in cooking, the scale was digitized to utilize up to 20 grams in weight. That is, 0 grams corresponded to a digitized reading of 0 and 20 grams corresponded to 255. Furthermore, the zero reading was obtained by fine tuning a potentiometer. Sampling of ADC data is shown below:

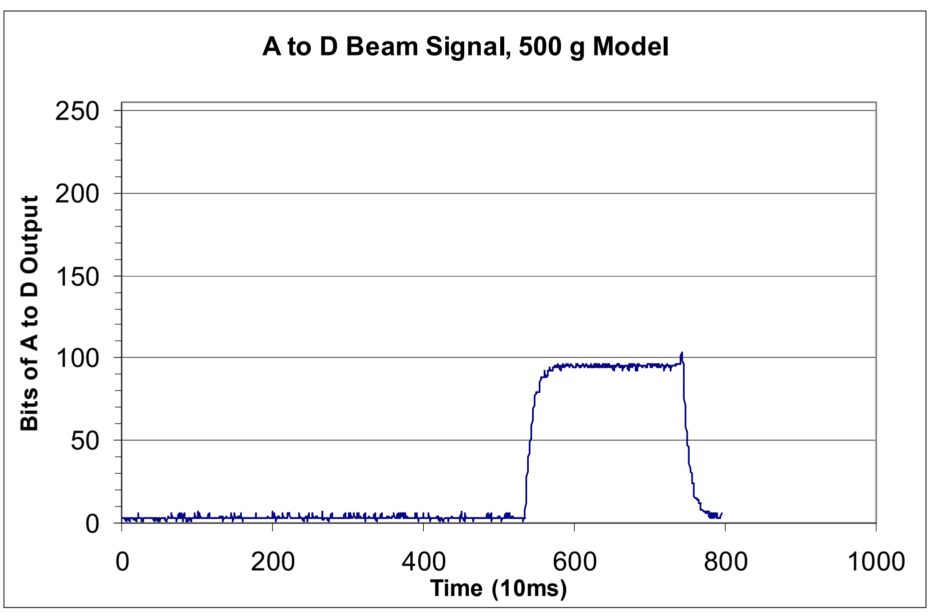


Figure 6: Beam signal of 50 g Model of scale 1

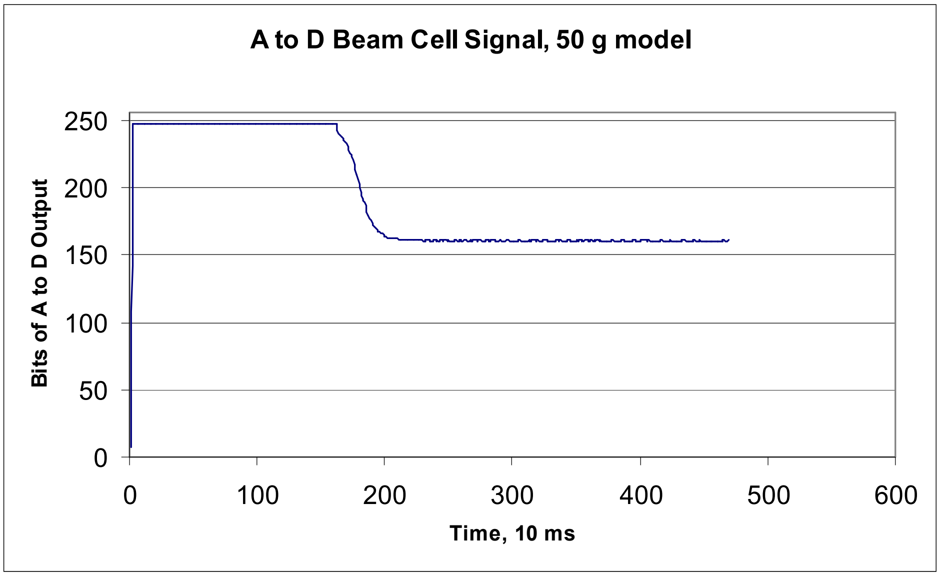


Figure 7: Beam signal of 50 g Model of scale 2

Electronic Circuit Diagram

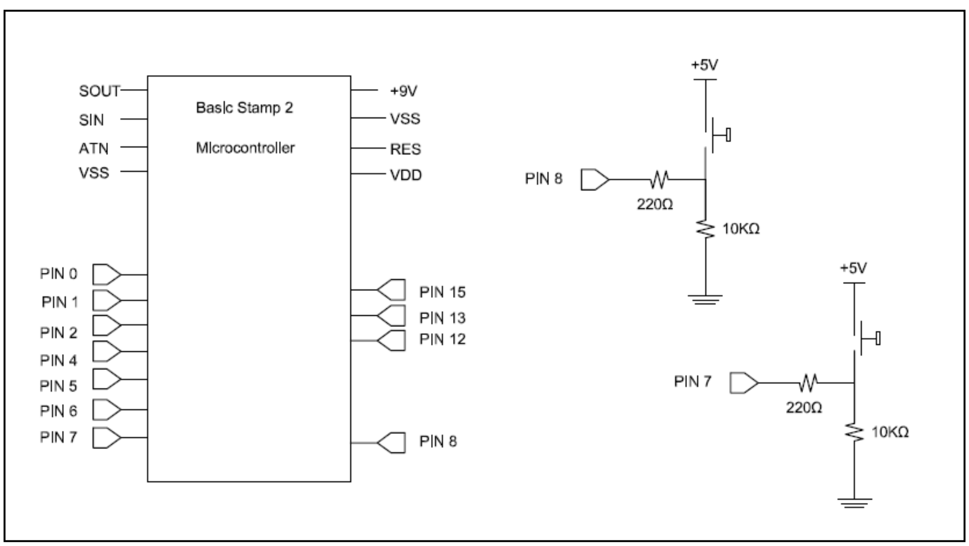


Figure 8: BS2 circuitry

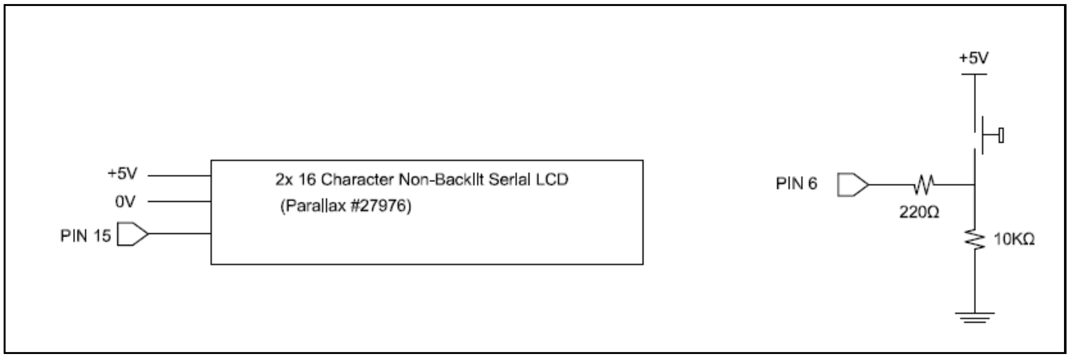


Figure 9: Parallax LCD circuitry

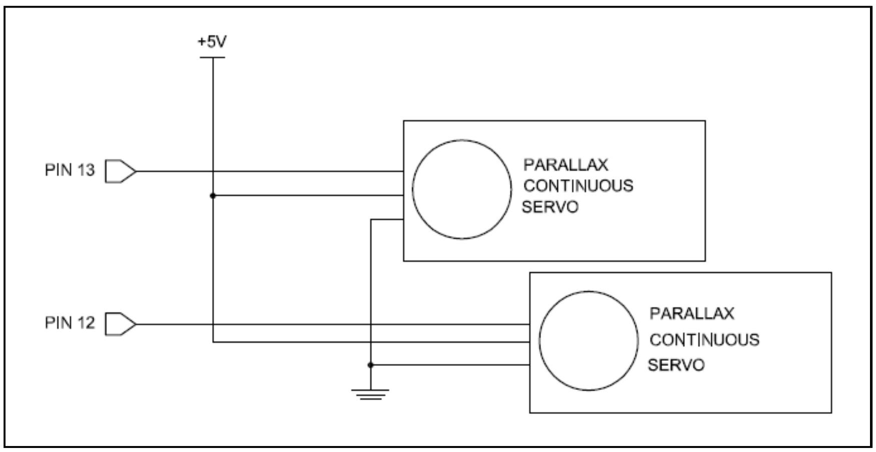


Figure 9: Parallax continuous servo motors circuitry

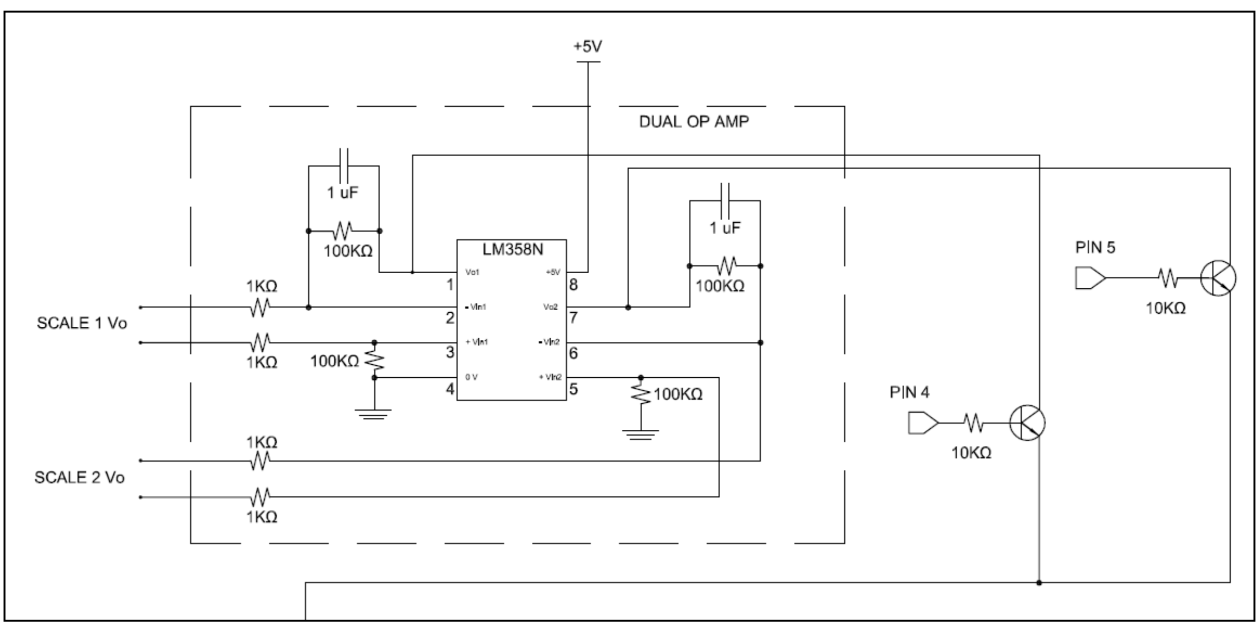


Figure 10: Dual op-amp circuitry

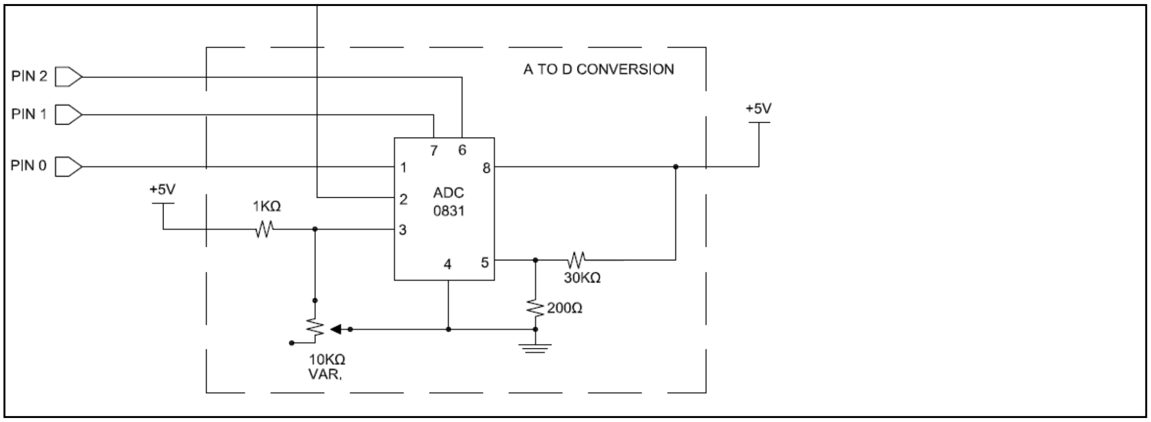


Figure 11: ADC circuitry

Cost

The cost associated with the spice dispenser is comprised mostly of material used for construction and the electrical components. Material used in the design consisted of mostly wood and minor accessories (e.g. screws, adhesive, etc.). The hardware of the spice dispenser comprised of two Basic Stamp boards, parts and accessories kits, and a load cell. The table below shows the cost of parts.

Material	Dimension	Quantity	Cost/Item	Cost
Load Cell	N/A	2	27.99	55.98
Ply wood	24"x24"x3/8"	1	25.5	25.5
Wood Slab	12"x12"	1	7.56	7.56
PVC sheets	12" x 24" x 1/2"	1	13.15	13.15
Board of Education Development Board	N/A	1	69.99	69.99
Continuous Servos	N/A	2	15.00	30.00
Push Buttons	N/A	3	3.19	9.57
Parallax Parts Kits (Accessories)	N/A	1	45.99	45.99
			Total Cost (USD)	257.74

Table 1: Material Cost

The total material cost for the construction of the device was approximately $257. Cost of manufacturing can be cheapened by printing circuitry with basic microcontrollers embedded.

Future Recommendations

Many features of the dispenser prototype can be modified in order to provide enhanced performance. First, the outer structure is entirely made of thin plywood which is relatively susceptible to being damaged or broken. In order to strengthen the structure of the frame a metal frame is recommended for future provisions. Secondly, another structural feature worthy of notice is the attachment of the motor to the PVC plastic. The attachment of the servo motor to the PVC containers was done through adhesive and screws. However, this attachment is not secure to permanently hold the motors and gear to the plastic container. Future recommendation for this aspect includes designing the container such that there is a secure attachment to the motor through epoxy resin and stronger adhesives.

Conclusion

The Team 1 XTreme Spice dispenser was successfully built and programmed with proper hardware. The device operates to dispense the correct amount of spice with an error of ±.1 grams as measured against a commercially available 0 – 50 gram digital scale with 0.01 gram resolution. However, it is quite difficult to obtain exact value of dispensed spice for amounts less than 1 gram. Errors accumulate due to calibration error as well as other parameters such as potentiometer drift. The device was successfully designed to operate and dispense two spices.

Although initial goals set before the design included three containers holding spice with simultaneous dispense mechanism was not achieved two containers were successfully designed. All project guidelines were met as well.

Appendix

See attached BS2 files for programs.

2.bs2: User interface for simultaneous dispensing using both scales

User interface.bs2: User interface for controlling Scale 1 (left scale when facing the device)

User interface Down.bs2: User interface for controlling Scale 2 (right scale)

UpscaleADTest.bs2: A file for viewing raw data from Scale 1 for calibrating its ADC offset and span values

DownscaleADTest.bs2: A file for viewing raw data from Scale 2 for calibrating its ADC offset and span values

Bibliography

1. IEEE Global History Network. (n.d.). Smart Appliance. *IEEE* .

2. (n.d.). Retrieved December 15, 2011, from Load Cell Design: http://www.omega.com/literature/transactions/volume3/load3.html

3. Omega Engineering Technical References. (n.d.). Retrieved December 2011, from Omega: http://www.omega.com/prodinfo/loadcells.html

4. Ron Mancini. (2002, August). *TI.* Retrieved December 16, 2011, from Texas Instruments: http://www.ti.com/lit/an/slod006b/slod006b.pdf