UNIVERSIDAD INTERNACIONAL DEL ECUADOR

FACULTY OF TECHNICAL SCIENCES

SCHOOL OF MECHATRONIC ENGINEERING

Prototyping and Implementation of a PET Bottle Recycling Machine for 3D Printing Filament Production

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MECHATRONIC ENGINEER

Mónica Melissa Arias Hidalgo

Supervisor: Luis Gilmour Andrade Acosta

D. M. Quito,

CERTIFICATE OF AUTHORSHIP

I, Mónica Melissa Arias Hidalgo, hereby declare that this submission is my own work, it has not been previously submitted for any degree or professional qualification and that the detailed bibliography has been consulted.

I transfer my intellectual property rights to the Universidad Internacional del Ecuador, to be published and divulged on the internet, according to the provisions of the Ley de Propiedad Intelectual, its regulations and other legal dispositions.

Mónica Melissa Arias Hidalgo

ACKNOWLEDGMENTS

I would like to start thanking God for surrounding me with people that have supported me during all my way to full fill my dream of becoming a mechatronic engineer. I want to thank my family for supporting me in every phase of my life, including this one. To my father for working so hard in order to provide me with the education required to make this project and for always making a space in his day to take me to the University despite the distance. I would like to thank my mom for waking up so early everyday to prepare me the lunch so as to handle the long tired days of study and for being my assistant every time a needed help,I will never forget their sacrifice. I would like to thank my brother for encouraging me that all my robots can not be done just for fun, they can be a moneymaker. They have been my main motivation during my whole life, specially now. Next, I would like to thank my boyfriend José Daniel for joining me in the long nights of work and for helping me in everything I needed to make this machine showing that he is not only the best boyfriend, but also, the best project partner. Also, I want to thank my boyfriend's mom for selflessly helping me bringing all the components I needed from USA and making the prototype have a better quality. What's more, I want to thank my uncle Beto for recollecting all the PET bottles I experimented with, without him I couldn't have done such a great tested machine. In addition, I want to thank my classmates for sharing great experiences with me during the career, making this phase memorable. And last, but not least, I want to thank all the professors I had since the beginning of the career, for sharing their knowledge with me and helping me in every step I needed to be the professional I am now. All of these persons have somehow given to me the love and daily support I needed to never give up. I will always be grateful for having them in my life.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

DESIGN AND MATERIALS SELECTION

1. Electrical Design

1.1. Power Supply Sizing

In order to power up the whole machine without problems, is necessary to determine what is the higher voltage and how much current will consume all the circuit, this will help in the selection of the best power supply for the project. To do this, the Table 1 shows the main electronic components, their voltage and current consumption. At the end, the total current is calculated and the highest voltage is determined.

Table 1. Power Consumption of each Electronic Component

Component	Voltage[V]	Current [A]
Microcontroller: Arduino Nano	5	0.019
5V Single-Channel Relay Module	5	0.09
LCD Display 20X4: 2004A	5	0.042
Creality 4010 Axial Fan	12	0.1
Creality 4010 Blower Fan	12	0.1
DC Cooling Fan	12	0.13
Gear Motor DC 12RPM 70Kg.cm	12	1.6
Ceramic Cartridge Heater: 12V 40W	12	3.33
Raspberry Pi 3b	5	2.5
Arducam 5MP Camera for Raspberry Pi 3	5	0.25
TOTAL	**12**	**8.161**

Considering the calculations above, the best option is a 12V- 10A power supply. This supply will for sure cover all the current necessary and will power up the majority of the components, to power the 5V ones a voltage regulator from 12 to 5V can be easily included.

1.2. Circuit Design

Voltage Regulator Circuit

As can be seen in Fig. 1, this circuit uses a switch that will power ON or OFF completely the machine. The terminal block is the DC power supply of 12V-10A which, once the switch is closed, it will be the input of U1, which is the voltage regulator LM2596. The output of this device is 5V, the voltage necessary to power the LCD, relay module, and among other components.

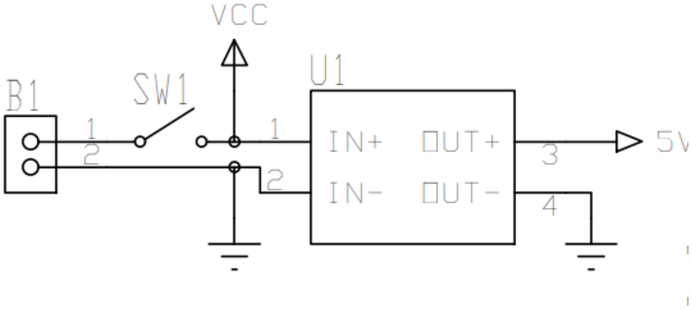

Figure 1. Voltage Regulator Circuit

Heater Circuit

This circuit is made out of the N-Channel MOSFET IRFZ44N and the ceramic cartridge heater represented with a terminal block. This configuration of the MOSFET allows it to work in the *switch mode*, it means that when the Arduino sends the PWM through the pin D9, this component will transform that 5V signal into a 12V one, required to change the heater temperature [1]. This circuit is completely necessary for the temperature control because it regulates the temperature by changing the PWM signal. The circuit is available in Fig. 2.

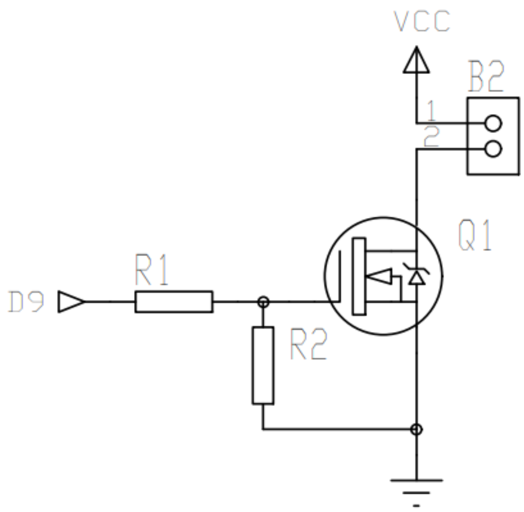

Figure 2. Heater Circuit

Buttons Circuit

The digital pins from 2 to 4 were declared as input pull-ups, then is not necessary to include a resistance since this pin declaration makes the Arduino detect digital signals by using the internal resistors of the micro-controller [2]. Then, the circuit to read the status of the buttons will be the one in Fig. 3.

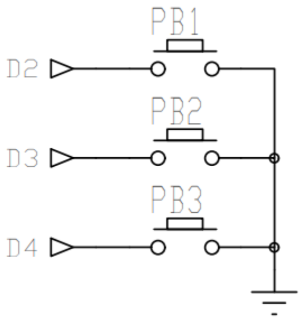

Figure 3. Buttons Circuit

LCD Circuit

This circuit joins two components: the LCD display 20x4 and the PCF8574, the I2C LCD backpack. This module has the necessary pins to directly connect with the LCD, establishing the I2C serial communication [3]. This module reduces the connections between the LCD and the Arduino to only 4 pins whose connections are described in the Fig. 4.

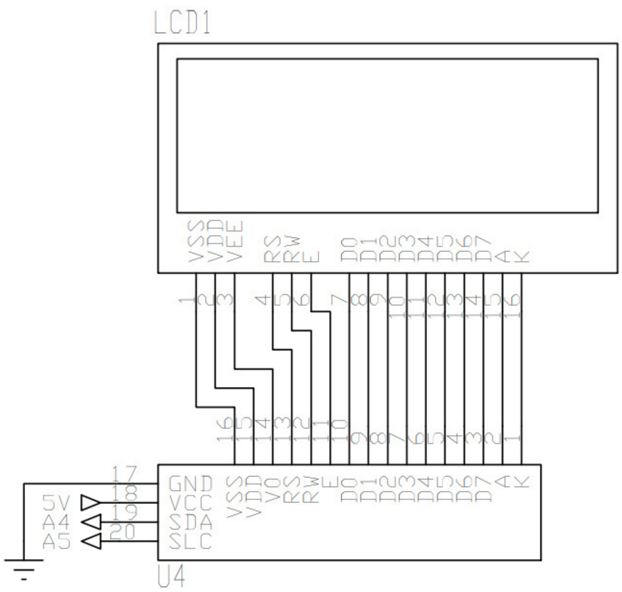

Figure 4. LCD Circuit

Gear Motor Circuit

Making the gear motor work is simply done by the activation of a 5V single-channel relay module whose switching operation is given by the digital pin 5. This module is active LOW, consequently it turn on when the pin is set to LOW. The connections between the module and the gear motor are given in Fig. 5.

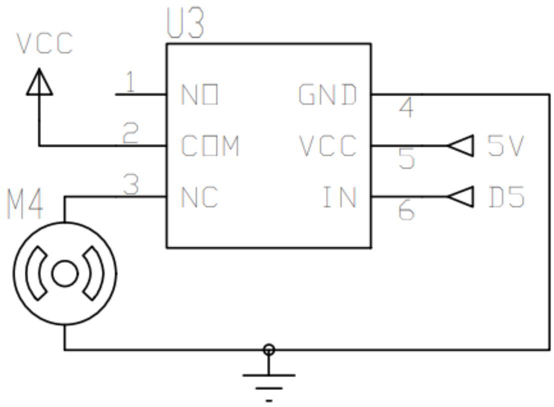

Figure 5. Gear Motor Circuit

Fans and Thermistor Circuit

The thermistor acts as a variable resistance that changes its value according to the temperature, considering it is an NTC type, when the temperature increases the resistance of the semiconductor reduces [4]. The thermistor is located in series with a static resistance of 100kΩ and, creating a voltage divider, the signal is send to the analog input pin 2, to measure the temperature according to the voltage drop.

On the other hand, two of the three fans are connected to the 12V power source so as soon as the machine is turned on, they will start working at their maximum speed. The other fan that is connected to 5V is the axial fan in charge of cooling the hot-end sink, its speed was reduced with this voltage change in order keep the sink zone a bit warmer to deform the plastic strip a bit before passing through the nozzle. This was done to improve the quality of the material, this change influenced in the amount of impurities present in the filament. The two described circuits are exposed in Fig. 6.

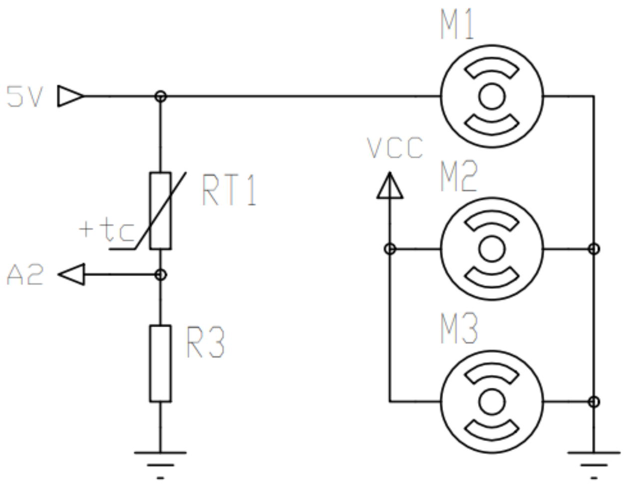

Figure 6. Fans and Thermistor Circuit

Arduino Circuit

Finally, the Arduino Nano is powered by the regulated 5V, all its analogical and digital connections are detailed in Fig. 7.

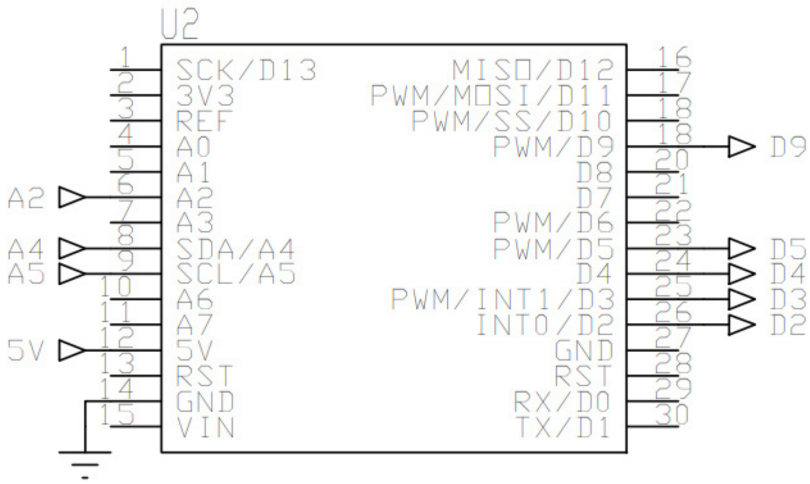

Figure 7. Arduino Circuit

2. Expenses

The design, manufacture and implementation of every stage that compund the machine, has affected the costs of production. Between the mechanical, electronic components, the manufacturing materials and other elements that were mandatory in this process, the total project cost is $ 413.49. The description in detail of every expense is visible in Table 2.

Table 2. Expenses done throughout the project

Element	Quantity	Price per Unit[$]	Total Price [$]
Threaded rod and nuts	1	7.5	7.5
Bearings 19x6mm	2	1.5	3
Bearings 25x10mm	2	2	4
Bolts and nuts	1	10	10
Hotend+fan+thermocouple+casing	1	30	30
LCD 20X4	1	10	10
Power supply 12V 10A	1	18	18
Microcontroller: Arduino Nano	1	9	9
5V Single-Channel Relay Module	1	2	2
Gear Motor DC 12V 12RPM 70Kg.cm	1	28.99	28.99
Button Switches (4 Pin)	5	0.35	1.75
DC Cooling Fan	1	5	5
Voltage regulator to 5V: Lm2596 (max 3A)	1	2.25	2.25
Arducam 5MP Camera for Raspberry Pi	1	10	10
Raspberry Pi 3b	1	50	50
PLA	1	24	24
Acid to burn the PCB	1	1	1
Copper Clad Laminate PCB	1	2	2
PCB Electronic components	1	5	5
Acrylic Structure	1	190	190
TOTAL			**$ 413.49**

REFERENCES

[1] S. Ryvkin, D. Izosimov, y S. Belkin, “Commutation laws transfer strategy for the feedforward switching losses optimal pwm for three-phases voltage source inverter,” in *IECON’98. Proceedings of the 24th Annual Conference of the IEEE Industrial Electronics Society (Cat. No. 98CH36200)*, vol. 2. IEEE, 1998, pp. 768–773.

[2] A. Due y A. Core, “Arduino due,” *Retrieved*, vol. 9, no. 16, p. 2019, 2017.

[3] O. Akinwole y T. Oladimeji, “Design and implementation of arduino microcontroller based automatic lighting control with i2c lcd display,” *J. Electr Electron Syst*, vol. 7, p. 258, 2018.

[4] N. Thermistors, “Ntc thermistors,” , vol. 16, no. 55, p. 125, 2016.