UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

Electric Dog Teeth Cleaning Toy

Electrical & Computer Engineering

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OVERVIEW

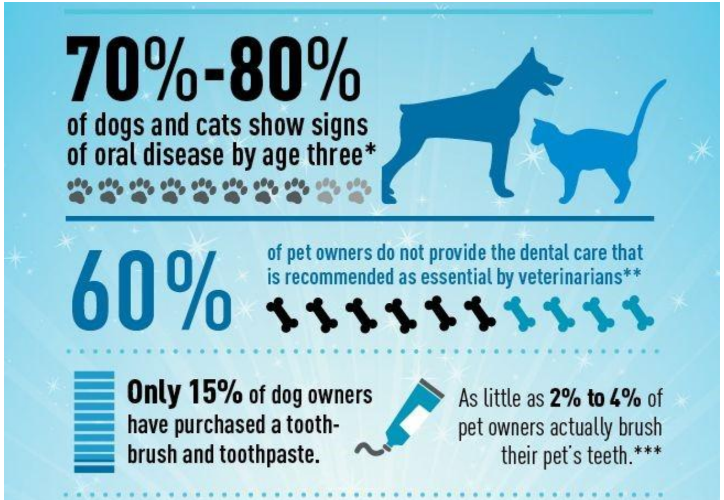


Figure 1: February is Pet Dental Month
Source: Adapted from [2]

Objective

- Problem: Pet Dog Dental Issues

  Many dog owners don't put in adequate effort to brush their dog’s teeth frequent enough or thorough enough. Nowadays, at least 80% of dogs over the age of three have oral problems [1].

Solutions

The solution we have is to develop a log-shaped electric dog toy that is capable of cleaning the dog's teeth and monitoring the cleaning.

There are two essential targets:

- Brush off plaque
- Build a habit

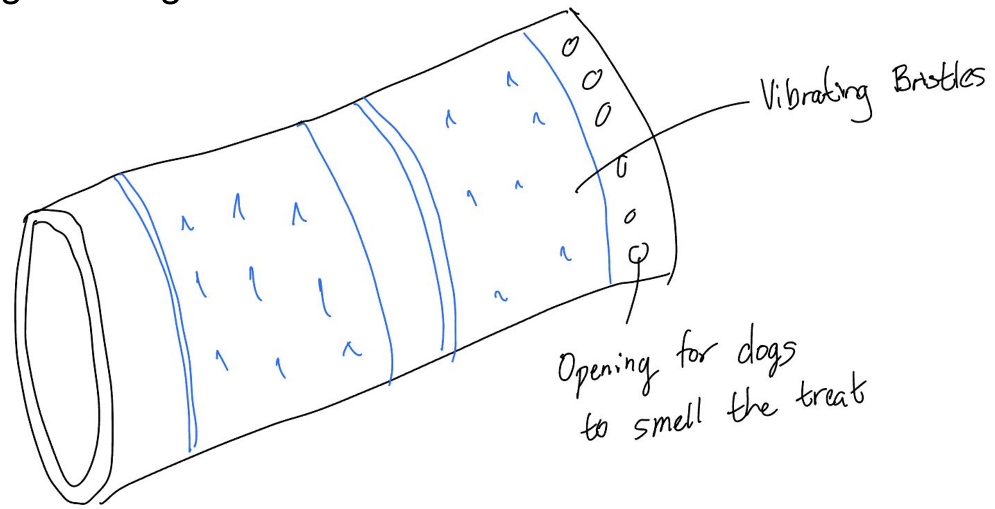


Figure 2: Original Draft

Original Mechanical Design

- The proposed system featured a log-shaped toothbrush for the dog to bite on.
- A mount was conceived so that the system can be safely stored.
- A ramp was present for the treat dispenser.

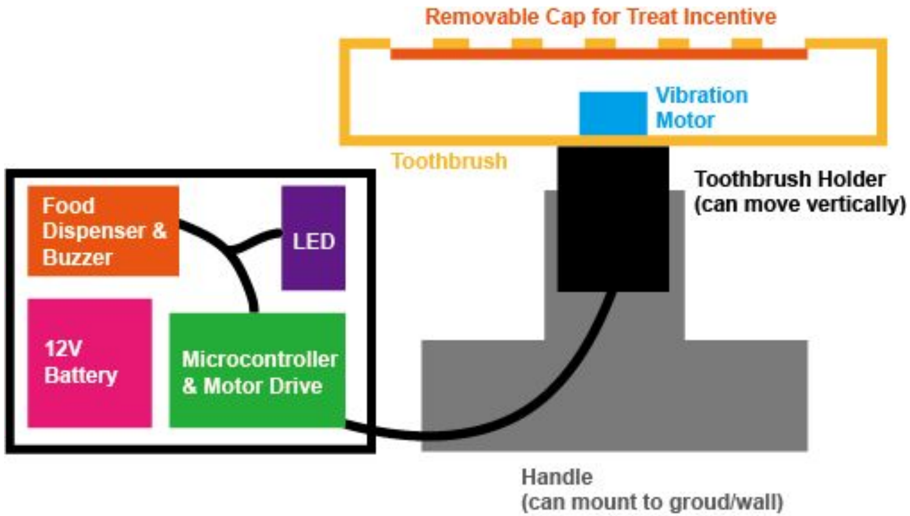


Figure 3: Original System

Revisions to Mechanical Design

The final system now takes a more refined form.

There are now three parts:

- Brush Handle
- Treat Dispenser (PCB Compartment)
- Battery Compartment

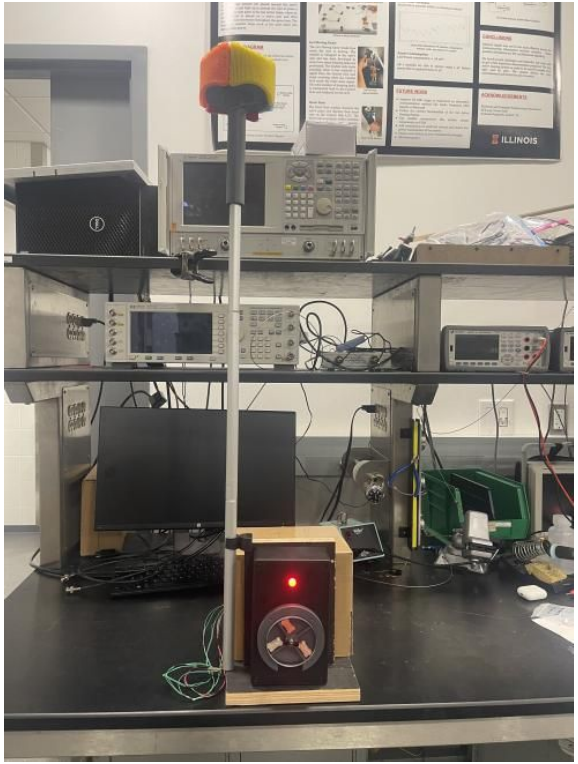


Figure 4: Final Design

High Level Requirements

1. The dog toy will be able to brush away food with similar properties of plaque off model teeth through the vibration of the bristles.
2. The dog toy will use treats and a buzzer sound to help make brushing their teeth a habit for dogs.
3. The electronic system will be solid enough to withstand the vibration, and the shell should be strong enough to withstand a small dog’s bite (about 100 psi).

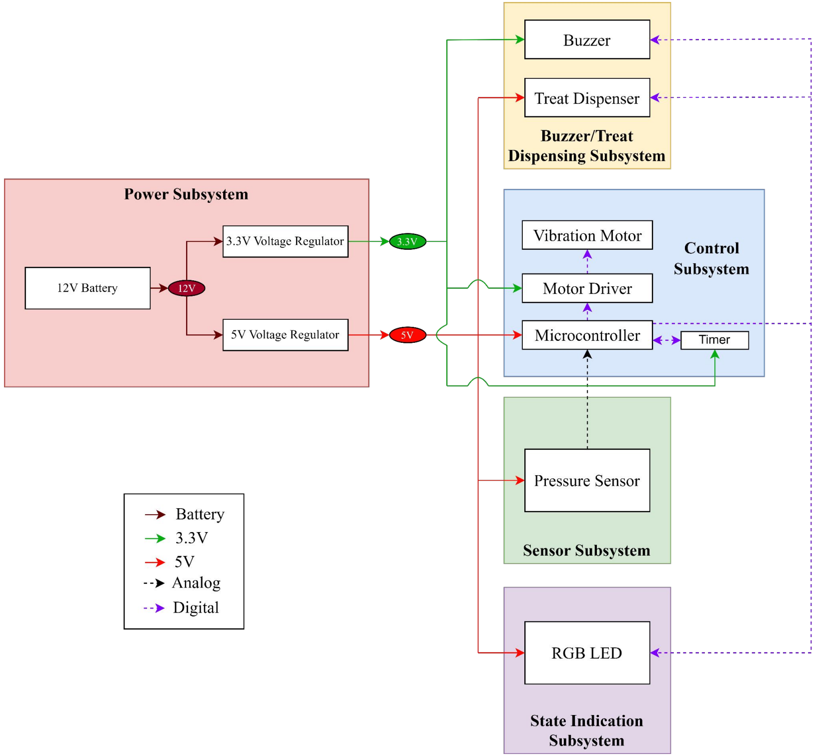


Figure 11: Block Diagram

Block Diagram

There are 5 subsystems:

1. Control Subsystem
2. Sensor Subsystem
3. Buzzer/Treat Dispensing Subsystem
4. State Indication Subsystem
5. Power Subsystem

CONTROL SUBSYSTEM

Software – Goals

- Control the toy automatically, help dogs to develop a habit of brushing their teeth constantly
- Analyze pressure readings
- Provide control signal to vibration motor, stepper motor, buzzer, LED
- Be able to enter sleep mode to save power

Software – Requirements

- When the required brushing time is reached, the pressure sensor will not trigger a transition in state
- When the timer’s alarm raises during vibration, the system will reset only after the vibration has stopped

Control Subsystem

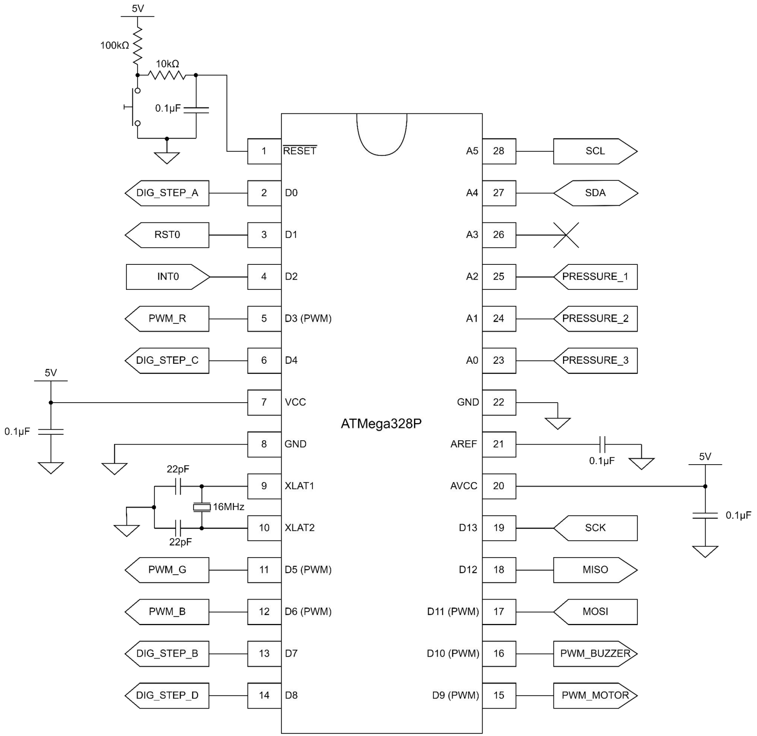


Figure 12: Microcontroller Circuit

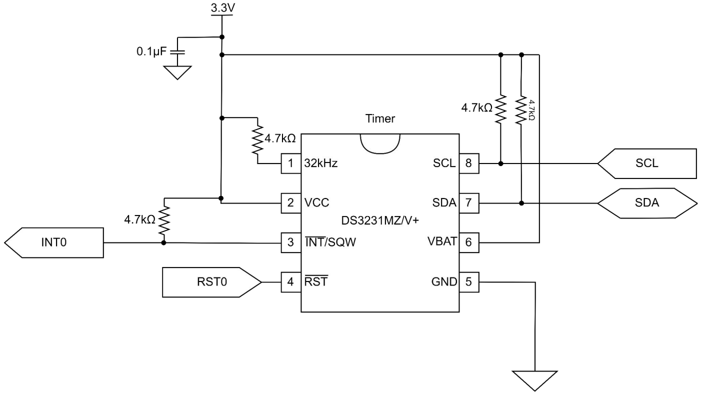


Figure 13: Timer Circuit

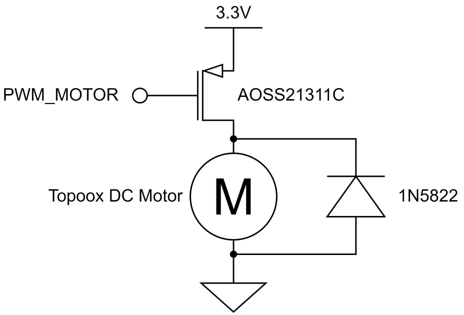


Figure 14: Vibration Motor Circuit

Software – Control Flow

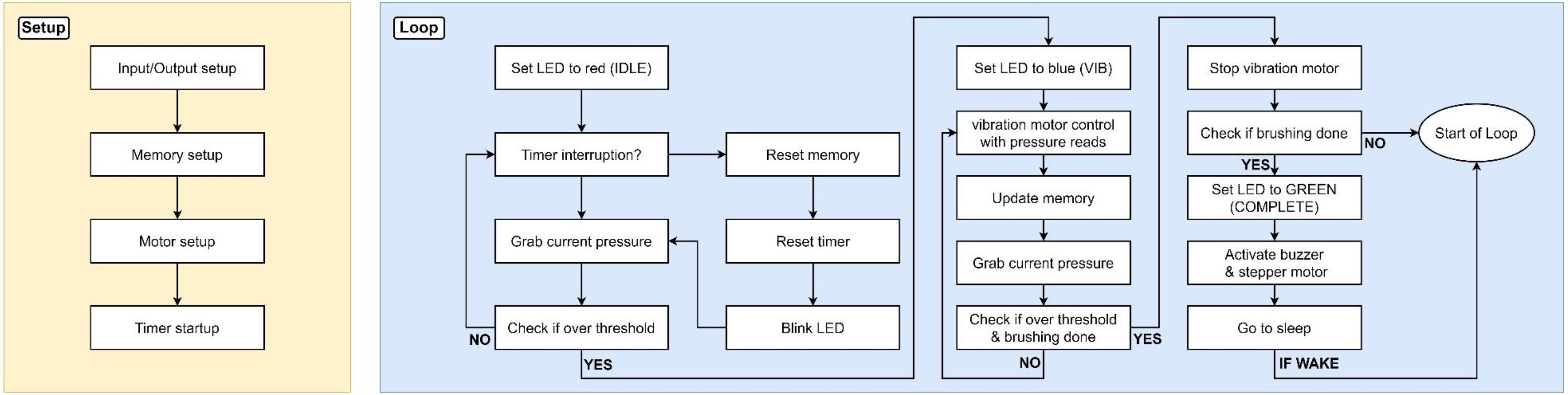


Figure 24: Software Flow Diagram

Software – Pressure vs. Vibration

As dog bites harder, frequency of vibration should increase

Range of pressure sensor readings: 0.5~1.6V

Vibration motor optimal dutycycle: 20~60% (details are covered in sensor subsystem).

A linear relationship can be generated.

When our system starts vibrating, it will adjust the vibration frequency in real time according to the pressure reading.

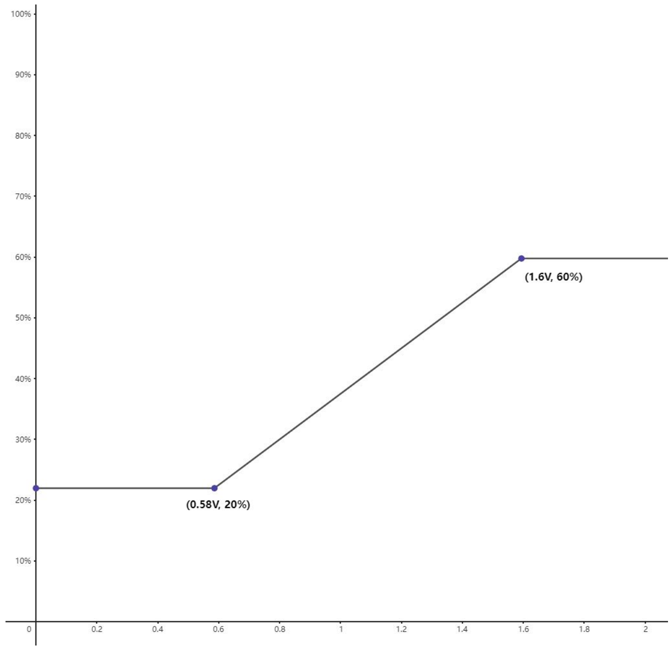


Figure 25: pressure - vibration speed relation

Software – Timer

Since the system work in a daily basis, it is appropriate to put the MCU into sleep if brushing goal is met before the next brushing session (i.e., 12hrs).

Two timers can be used to wake up MCU again after a deep sleep: external (DS3231) and internal (WD)

- DS3231 requires I2C communication, but requires no additional manipulation during sleep
- Watchdog is a built-in timer for ATmega328P, but its timing setting is only up to 8s (i.e., frequent reset is needed if we want to sleep MCU for a long time)

We implemented both to provide some degree of insurance, user can choose the one they want to use.

SENSOR SUBSYSTEM

Sensor – Goals

- Generate a voltage that varies according to the thin film resistance
- Consumes minimal current

Sensor – Requirements

- The output voltage should at least swing from 0.5V to 4.9V as thin film resistance varies from 10kΩ to 1kΩ
- Each sensor circuit should consume ≤2mA

Sensor Subsystem

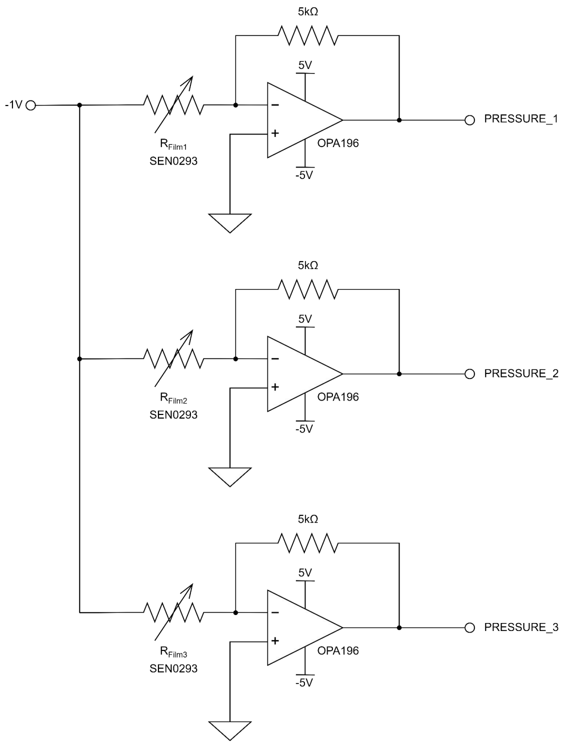


Figure 15: Pressure Sensor Circuit

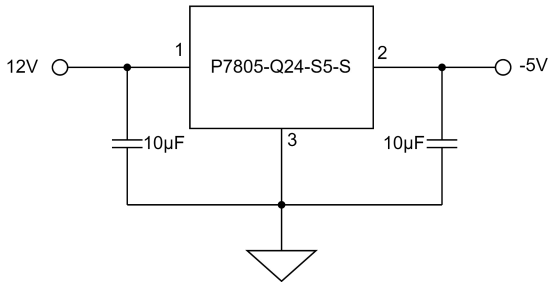


Figure 16: -5V Biasing Circuit

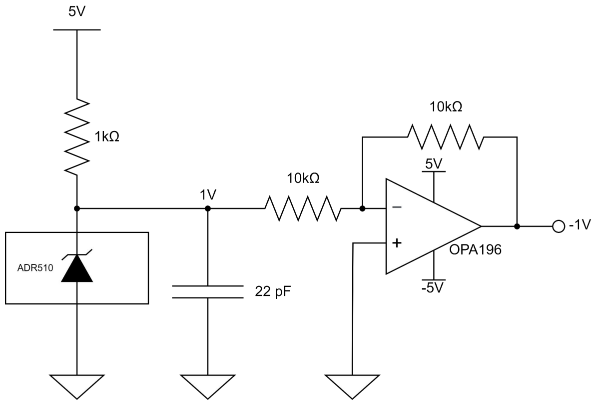


Figure 17: -1V Reference Circuit

Sensor Subsystem

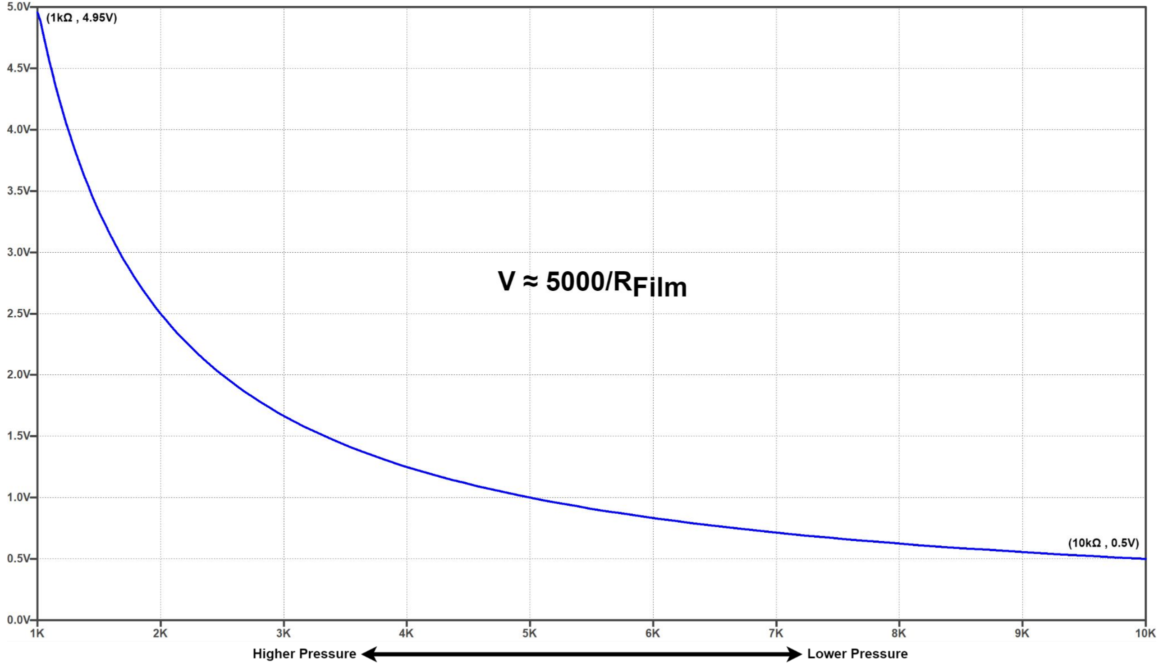


Figure 24: Pressure Sensor Circuit Output

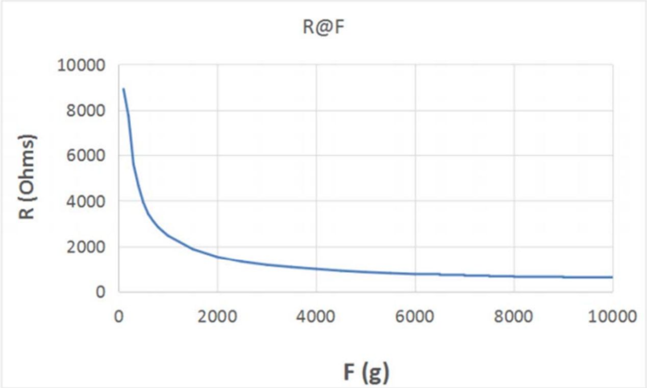


Figure 25: Thin Film Resistance
Source: Adapted from [4]

V_{MIN}	V_{MAX}	I
0.03V	4.95V	<2mA

Table 3: Pressure Sensor Performance

BUZZER/TREAT DISPENSING SUBSYSTEM

Buzzer/Treat Dispenser– Goals

- Create a loud sound when a the cleaning is done
- Rotates the wheel appropriately to dispense a treat when a cleaning is done
- Consumes minimal current

Buzzer/Treat Dispenser – Requirements

- The treat dispenser can rotate 90° at a time and releases a treat.
- The buzzer is audible enough to mark the end of a cleaning session.
- The buzzer should draw ≤20mA.

Buzzer/Treat Dispensing Subsystem

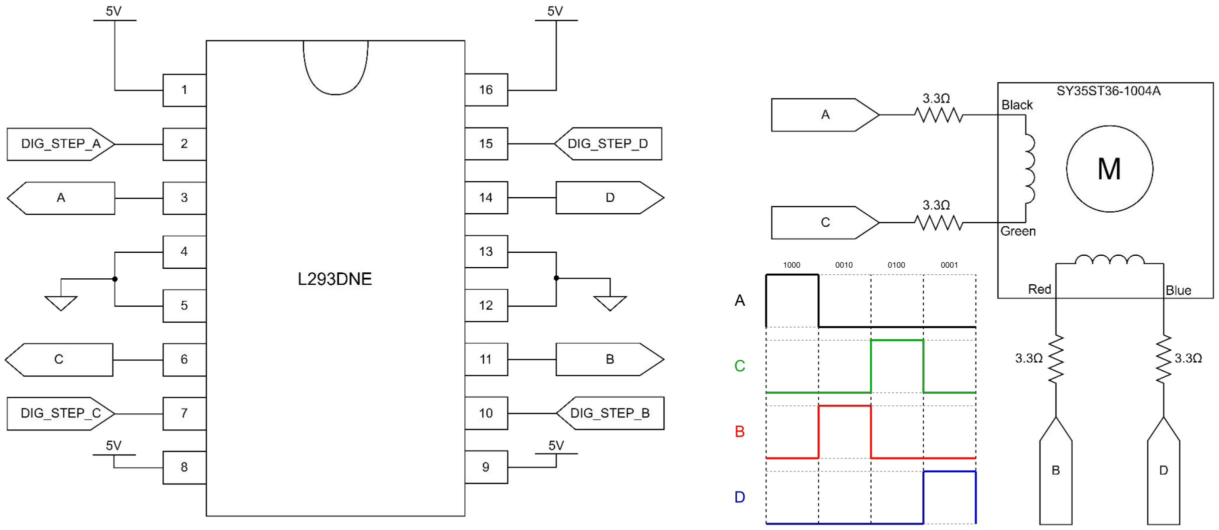


Figure 18: Stepper Motor Circuit & Stepping Sequence

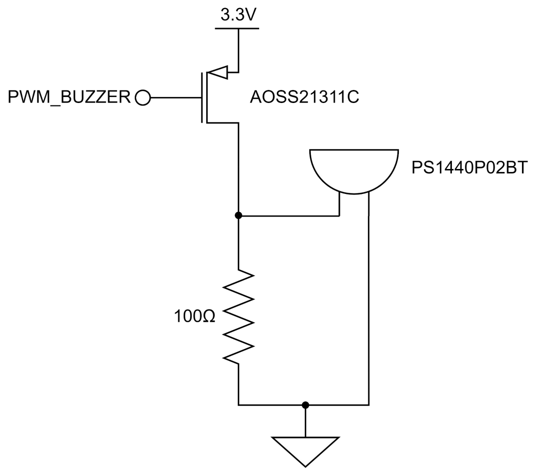


Figure 19: Buzzer Circuit

STATE INDICATION SUBSYSTEM

State Indication – Goals

- Communicates the current status to the user
- Consumes minimal current

State Indication – Requirements

- The LED should be bright enough so that they are easy to identify.
- Each color of the LED consumes ≤20mA

State Indication Subsystem

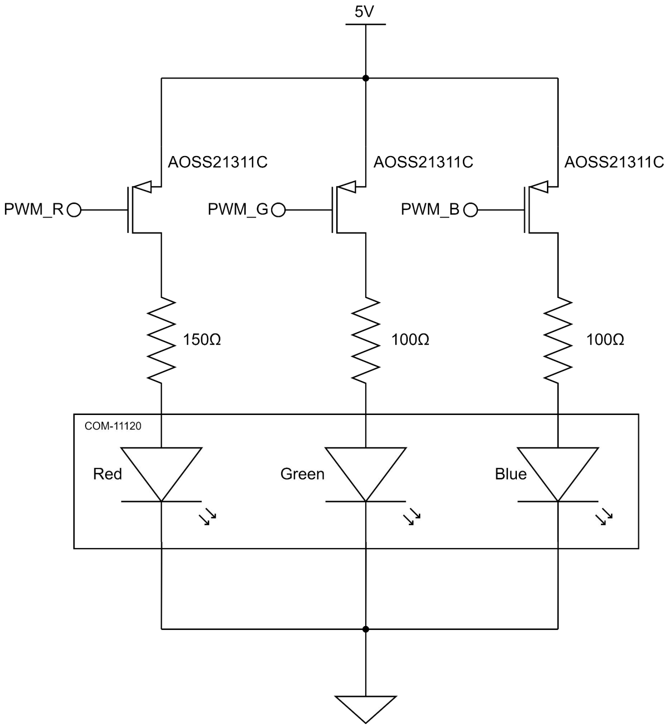


Figure 20: RGB LED Circuit

POWER SUBSYSTEM

Power – Goals

- The battery should be charged well over 12V
- 3.3V voltage regulator and 5V voltage regulator outputs the appropriate volatge

Power – Requirements

- The battery should output ≥12V +/- 2%.
- The 3.3V voltage regulator should output 3.3V +/- 0.066V.
- The 5V DC voltage should be maintained at 5V +/- 0.1V. Also, the voltage ripple needs to be less than 50mV peak-to-peak.

Power Subsystem

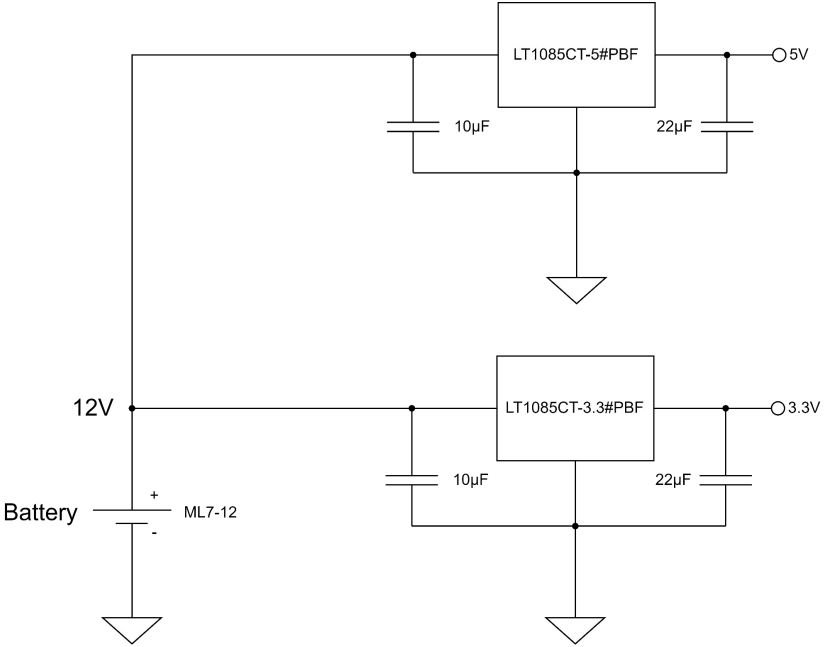


Figure 21: Power Supply Circuit

Power Supply Subsystem

Regulator	V_{OUT}	I_{MAX}	V_{Ripple}	$I_{Quiescent}$
LT1085CT-3.3#PBF	3.314V	3A	N/A	8mA
LT1085CT-5#PBF	5.000V	3A	<50mV	8mA

Table 1: Power Supply Performance

Condition	Battery Voltage
No Load	12.998V
Loaded	12.700V

Table 2: Battery Performance

PCB

PCB

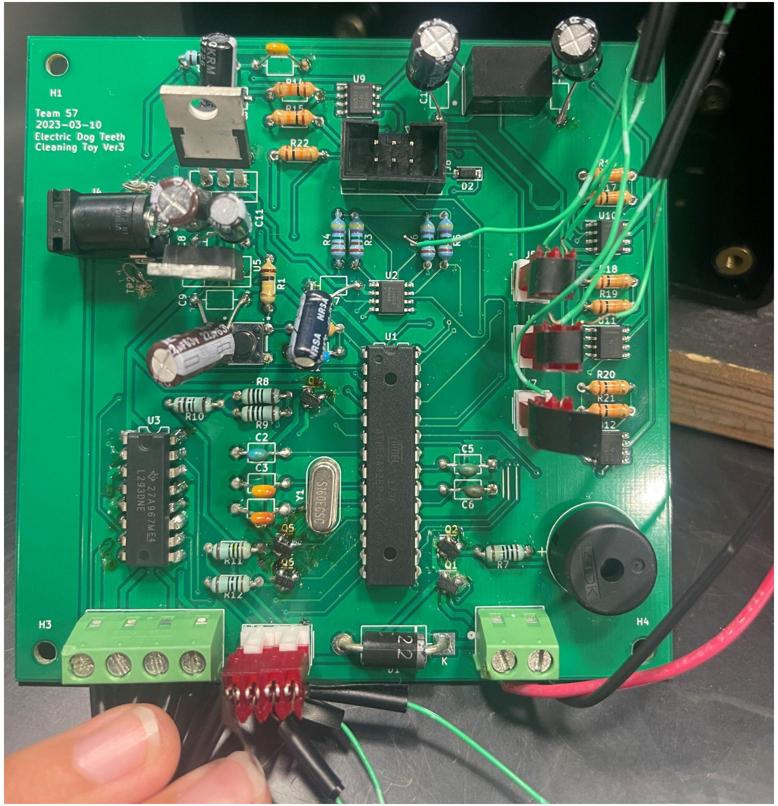


Figure 22: Finished PCB

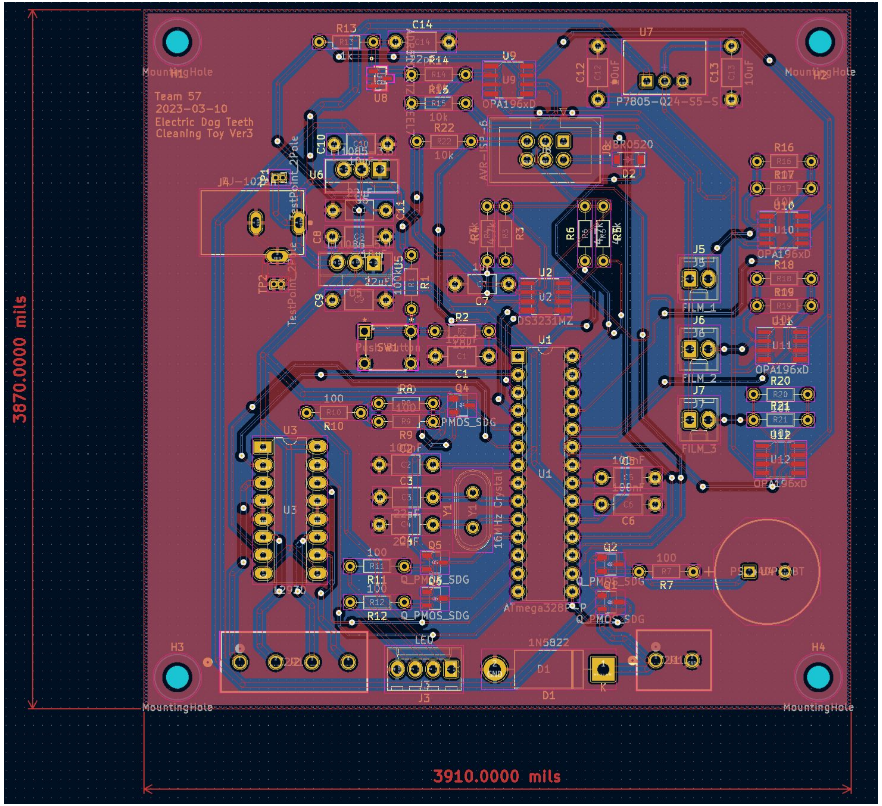
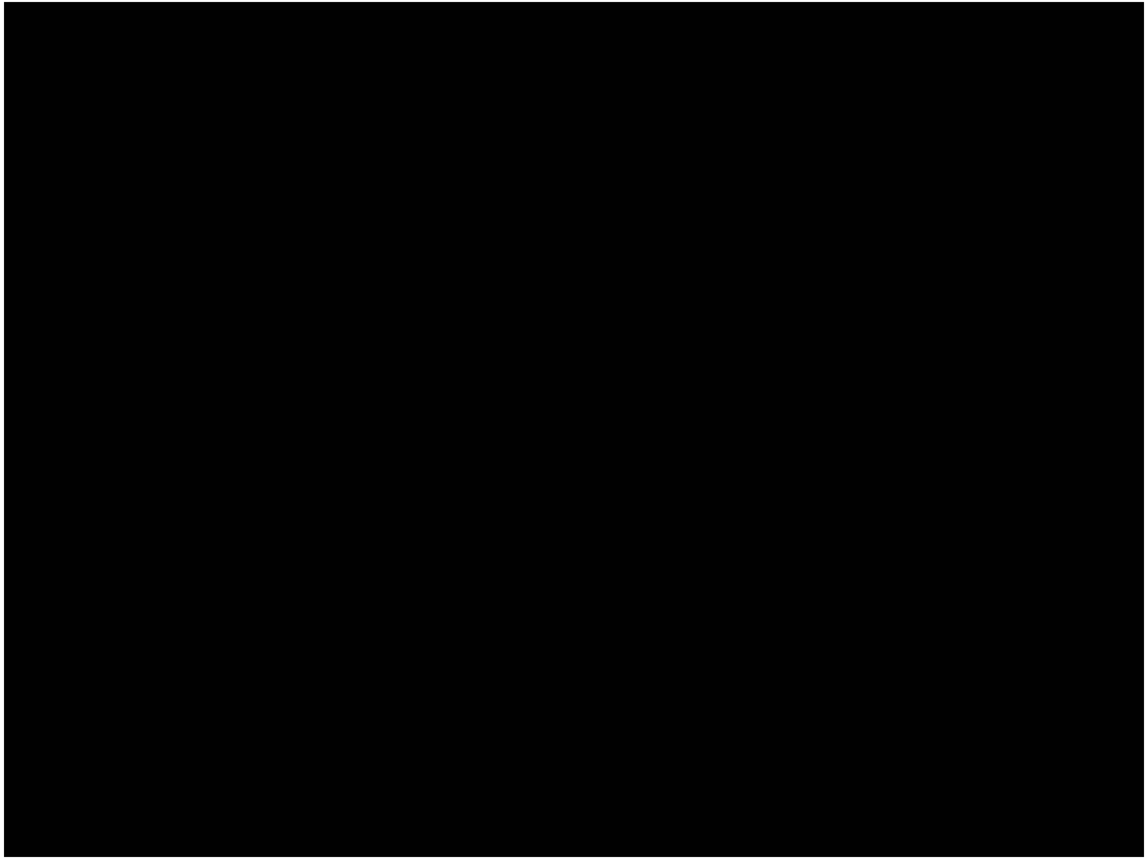


Figure 23: PCB Layout

RESULT

RESULT



Major Current Draw

Duty Cycle	%Power	Vibration Motor Current
85%	15%	0.893A
23.5%	76.5%	2.016A

Table 4: Vibration Motor Current Draw

Device	Current
Stepper Motor	<0.5A
Digital IC	50mA - 80mA
Buzzer	17mA
Red LED	20mA
Green LED	17mA
Blue LED	17mA

Table 5: Other Major Current Draws

CONCLUSION

Ethical Issue

- Major Issue

  The use of a large battery may be dangerous in a household environment. There is a potential fire hazard and a health hazard.

- Mitigation

  1. The battery itself and relevant wiring are properly concealed.
  2. The circuit board uses a barrel connector. If desired, any voltage source >6V can be used as long as it can supply 2-3A.

Success

- Met all of our high level requirements
- Able to protect our system to keep it user and dog friendly
- Able to prove concepts that would make this project a success in the real world
  - Vibration in the shape of a toy that a dog can play with
  - Used materials equivalent to dog friendly materials and proved that they can at least withstand a pressure of 100 psi

Challenges

- The total size of the circuit is large
- Inaccuracy and inconsistency of thin film sensors compromised resolution of sensor
- Inductive loads created interfering ripples that is higher than expected
- Potential heating issue when the vibration motor is operated at high power for a long time

Future Development

- Use dog friendly material
- Implement some user interfaces
    - Adjust brushing time/frequency; timer selection
- Integrate our project with existing dog food dispensing systems
- Make the brush portion more bone shaped and smaller
- Separate digital and analog components completely to different LDOs
- Add heat sink

QUESTIONS?

References

[1] K. B. Enlund *et al.*, "Dog Owners' Perspectives on Canine Dental Health—A Questionnaire Study in Sweden," *Front. Vet. Sci.*, vol. 7, p. 298, Jun. 2020, doi: 10.3389/fvets.2020.00298.

[2] B. Young, "Dental Month," *Companion Pet Clinic of North Phoenix*, 2019. [Online]. Available: https://www.companionpetclinicphoenix.com/archives/2017/02/04/dental-cleanings/.

[3] Institute of Electrical and Electronics Engineers, "IEEE Code of Ethics," *IEEE*. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html.

[4] DFRobot, "RP-L-170 Thin Film Pressure Sensor," SEN0293 datasheet, n.d.. Available: https://media.digikey.com/pdf/Data%20Sheets/DFRobot%20PDFs/SEN0293_Web.pdf.

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