ECE 445 Senior Design Project

Electric Dog Teeth Cleaning Toy

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1. Introduction

1.1 Problem

Many dog owners don't put in the effort to manually brush their dog's teeth more than a couple of times a week. They either use a dog teeth cleaning treat or liquid that can remove some of the plaque rather than all. Nowadays, at least 80% of dogs over the age of three have oral problems [1]. To combat this pet health issue, dog owners need a tool that is able to conveniently clean dogs' teeth and regulates the frequency of cleaning.

1.2 Solution

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. When the timer reaches two minutes, the treat dispenser will produce a buzzer sound and dispense a treat. This will be used as a training mechanism, so the dog will eventually realize that biting the toy will dispense a treat. Treats are also used as the incentive in the dog toy to interest the dog to continue biting the bristles. The dog toy we developed specifically aims for small dogs (<30 lbs) that have a bite force less than 100 psi.

The dog toy has a nylon plastic encasing covered in dog-safe bristles. Under the exterior cover, there is a layer of thin pressure sensors to detect dog bites. Internally, the toy is equipped with a vibration motor that will create moderate motions in the dog's mouth for cleaning. When turned on and being bitten, the toy will vibrate and adjust the force according to the data from the pressure sensor. The dog toy will be attached to the separate box containing the treat dispenser and circuit components. It can be hand-held or left standing on the floor. When the treat is dispensed, the toy then enters a sleep state and stops responding to biting until a preset time interval has passed. After recess time, the toy will be available for cleaning again. Overall, the dog will be able to play with the toy and get their teeth cleaned two times a day.

1.3 Visual Aids

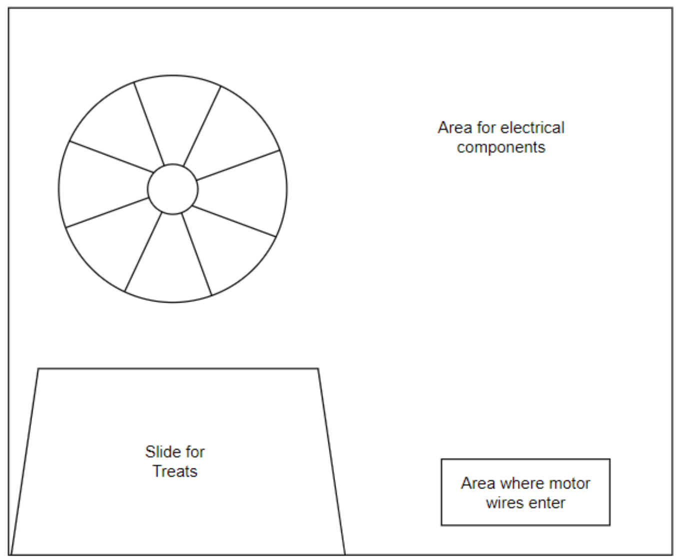

Fig. 1 Front View of Treat Dispensing System

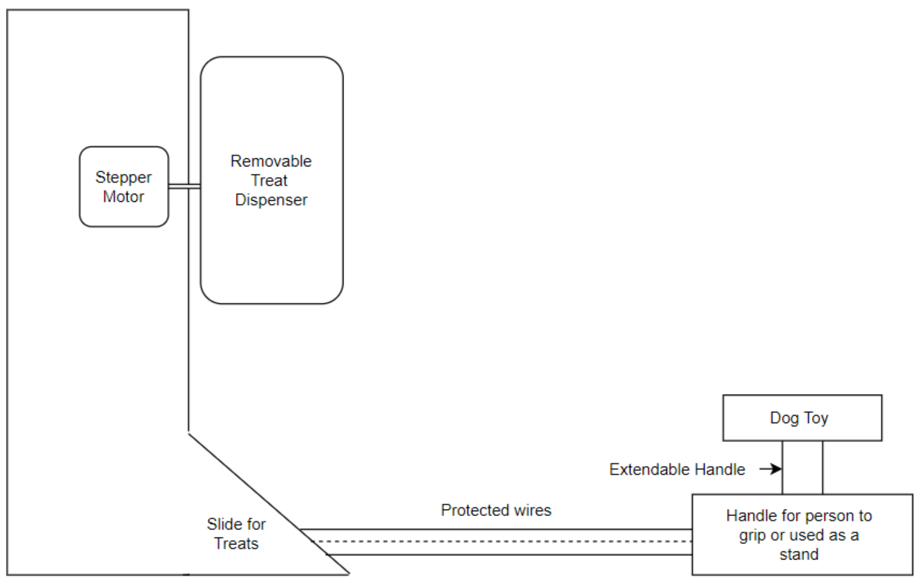

Fig. 2 Side View of System

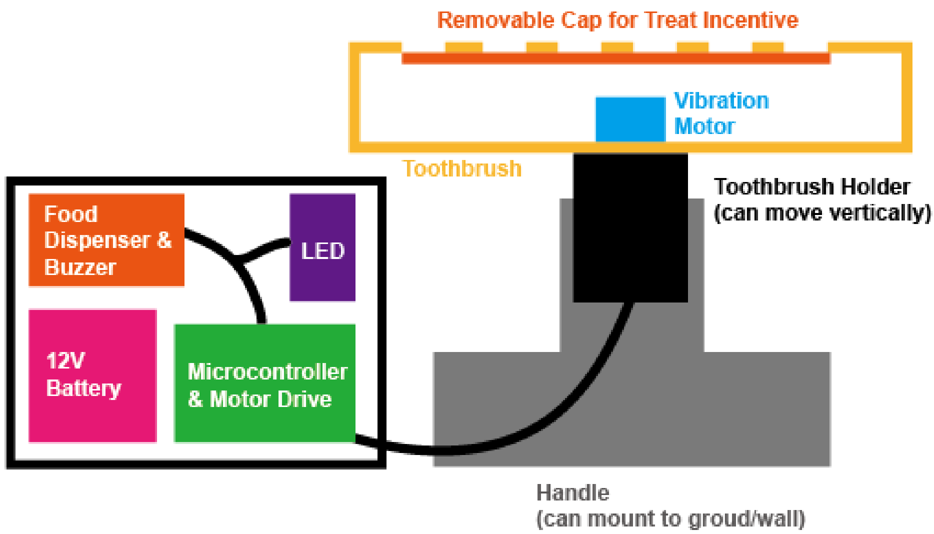

Fig 3. Visual Aid for Subsystems

1.4 High-Level Requirements List

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).

2. Design

2.1 Block Diagram

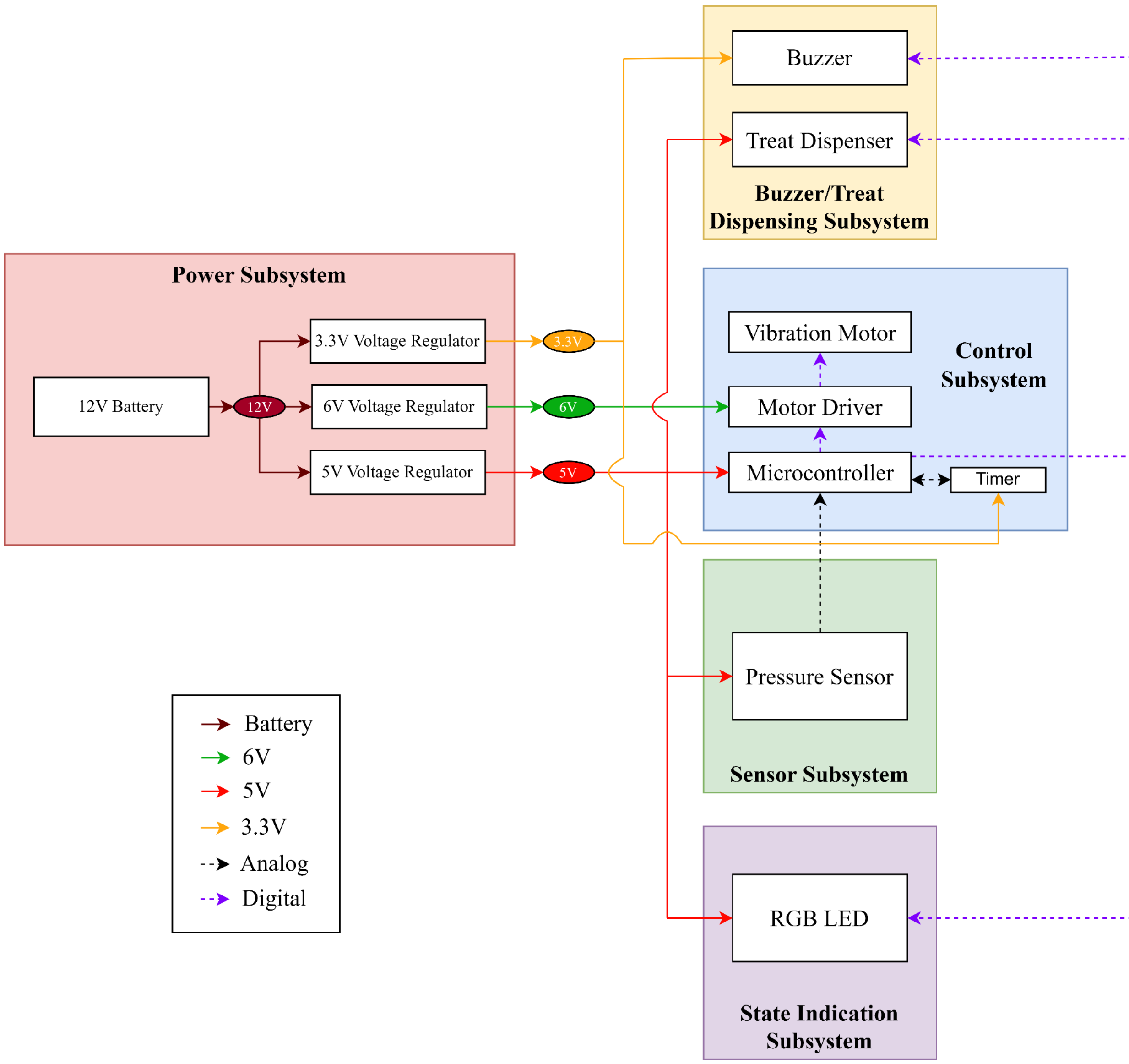

Fig. 4 High Level Block Diagram of the Solution

2.2 Subsystem Overview

2.2.1 Sensor Subsystem

The dog toy will use several flexible film pressure sensors that will be wrapped around the nylon plastic encasing and underneath the thick bristles. The pressure sensors are quintessentially resistors that change resistance according to the applied pressure. The sensors are used in a circuit that outputs an analog voltage level. By characterizing the pressure-resistance or pressure-voltage relationship, we can determine the applied force using an algorithm programmed in the microcontroller.

2.2.2 Control Subsystem

The dog toy will be using an ATmega328P microcontroller as its control system. The input of the controller will be analog voltages from the pressure sensors. When pressure data exceeds a certain threshold, indicating that the dog is biting the toy, the microcontroller will send a signal to the vibration motor to start the vibration process and start counting the actual brushing time (about two minutes, twice a day, depending on the strength of biting). When the time exceeds the brushing time for that bidaily cycle, the microcontroller will stop the vibration, send a signal to the buzzer/treat dispensing subsystem to dispense the treats, and light up the LED to indicate the end of that session.

2.2.3 Buzzer/Treat Dispensing Subsystem

After cleaning is complete, a buzzer will sound, and a treat will be released. The treat release is controlled by the microcontroller, and the microcontroller also counts the number of releases so that the toy can detect when there are no more treats left. This will light up an LED to let the owner know it's time to refill the dispenser.

2.2.4 State Indication Subsystem

The state indication subsystem consists of an RGB 4-pin LED and three current-limiting resistors. The LED is controlled by the microcontroller to produce the corresponding colors for different states by blending the three colors. A different color is assigned for each of the states described in the Control Subsystem section. In addition, users can be notified to replace the battery when the LED is off.

2.2.5 Power Subsystem

The power subsystem consists of one 12-V battery, one 3.3-V linear voltage regulator, one 5-V linear voltage regulator, and one 6-V linear voltage regulator. The purpose of the subsystem is to provide proper supply voltage to other subsystems. The 12-V battery directly provides an input voltage to the linear voltage regulators. The 3.3-V DC voltage will power the timer and the buzzer. The 5-V DC voltage would be the supply to the microcontroller, the pressure sensor, the treat dispenser, and the LED. The 6-V DC voltage is connected to the motor driver.

2.3 Subsystem Implementation

2.3.1 Sensor Subsystem

The sensor subsystem involves three 1738-SEN0293-ND thin film pressure sensors that will be wrapped around the nylon plastic encasing. The thin film pressure sensor is a variable resistor used in an inverting amplifier. Each inverting amplifier uses an OPA196 op-amp. The amplifier is the output device that provides an analog voltage depending on pressure. There will be three amplifier circuits, each containing one thin film pressure sensor. The circuit is shown in Fig. 5. The 5kΩ resistor in Fig. 5 is implemented by connecting two 10 kΩ in parallel. To provide the -1V reference voltage, an ADR510 voltage reference and an inverting amplifier is used, as shown in Fig. 6. To provide the -5V biasing for all the op-amps, a P7805-Q24-S5-S switching regulator is used, as shown in Fig.7.

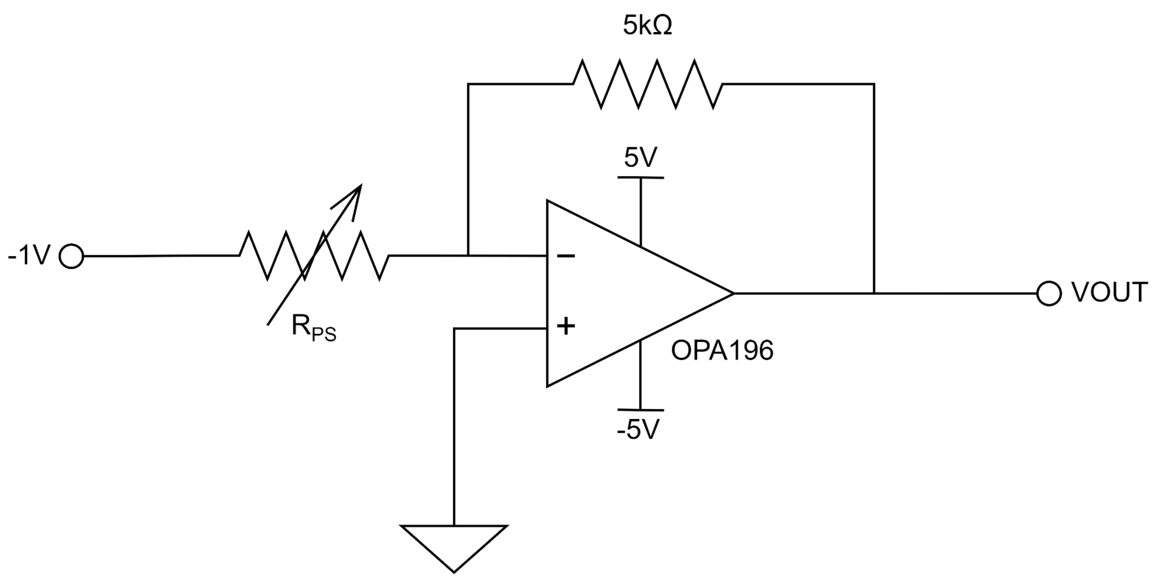

Fig. 5 Pressure Sensor Circuit

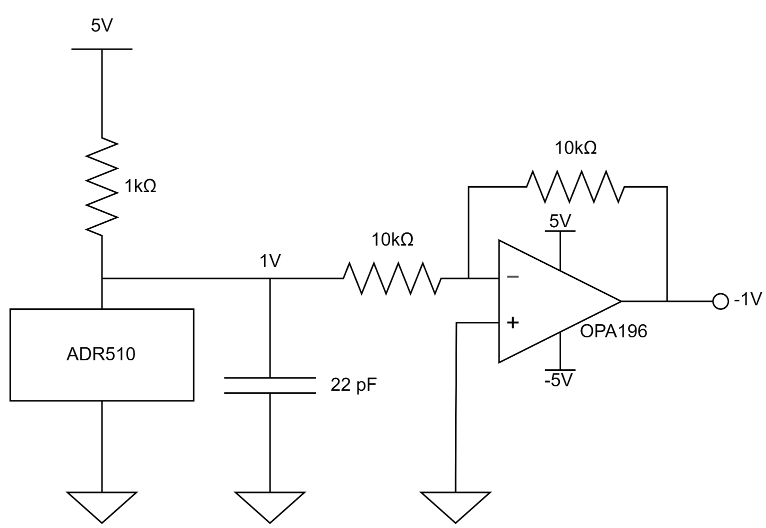

Fig. 6 -1V Reference Circuit

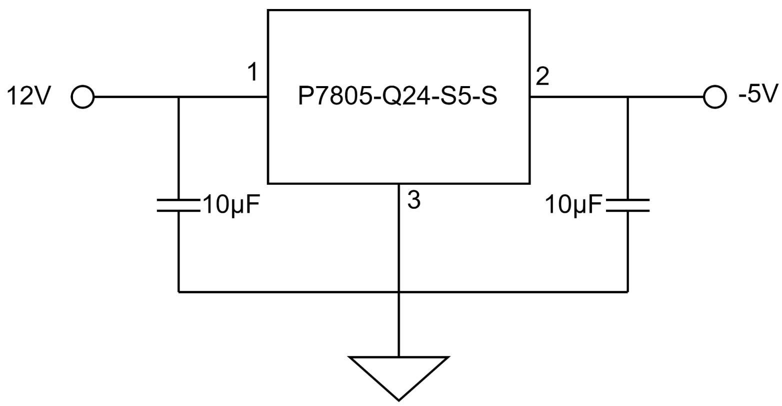

Fig. 7 -5V Regulator Circuit

The output of the amplifier is VOUT $= \frac{R}{R_{PS}}$ [V]. The specific range of VOUT depends on the specific resistor values, but it is within 0V - 5V, given the biasing. With R = 5kΩ and R_{PS} sweeping from 1kΩ to 9kΩ, a LTspice simulation of the output is shown in Fig. 8:

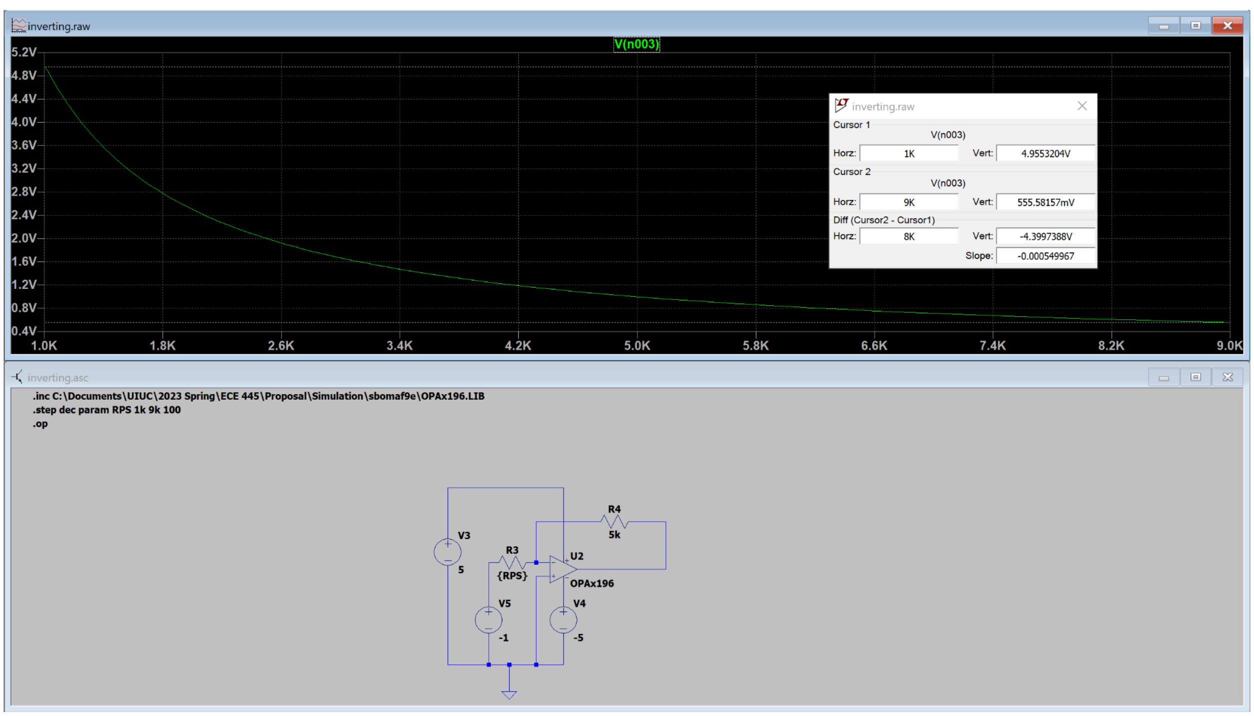

Fig. 8 Pressure Sensor Analog Output Simulation

The output is connected to the analog input of the microcontroller. The microcontroller will measure the voltage level and determine whether an external pressure is applied.

Requirement	Verification
Depending on the external pressure applied to the thin film pressure sensor, the output of the pressure sensor circuit should be able to at least swing from 0.5V to 4.9V to give an adequate resolution.	● Set the digital multimeter to DC voltage mode. Connect the positive probe to the output of the op-amp and the negative probe to the negative terminal of the battery. ● Ensure that no pressure is applied to the thin film pressure sensor and the toy is left on a hard surface. ● Note down the minimum voltage value measured by the digital multimeter. ● Then, place 10kg of weight on the thin film pressure sensor. ● Note down the maximum voltage value measured by the digital multimeter.
The maximum current draw of each pressure sensor circuit should not exceed 2 mA.	● Set the digital multimeter to DC current mode. Connect the positive probe to the 5V voltage supply. Connect the negative probe to the common node of 5V inputs of the pressure sensor circuit and -1V reference circuit. ● Place 10kg of weight on the thin film pressure sensor. ● Note down the maximum current values measured by the multimeter. ● Repeat the above procedure for -5V inputs. ● Sum the current values for 5V and -5V up and note down the value.

Tab. 1 Pressure Sensor Subsystem R&V Table

2.3.2 Control Subsystem

The control subsystem includes an ATmega328P microcontroller, a DS3231 timer, and one small DC/vibration motor that has at least 1000 RPM. The motor is in parallel with a reverse-biased 1N4148 diode to prevent inductive spiking. Both the motor and the diode are connected to the drain of an AOSS21311C PMOS. The gate of the PMOS receives PWM signal from the microcontroller, and its source is connected to the 6V supply voltage. As a high-side switch, the PMOS controls the power of the motor based on the duty cycle of the PWM signal input.

The system will be working in 4 states, description and transition algorithm is listed below:

State	Description	Processor Power Specification
IDLE	The system will be working in this state when the expected brushing time has not reached for the very brushing session (twice a day, each lasts for 12 hours). The LED will be set to red.	The microcontroller will be working at 5V and 16MHz. It will stay in sleep mode “ADC noise reduction” to listen to readings from the pressure sensor. The working current for this state will be ~10mA.
VIBRATION	The system will be working in this state when the pressure sensor detects that the dog is biting the toy. The LED will be set to blue. The control system will power the motor drive to start the vibration. It will also compute the remaining time of vibration based on the strength of biting. The remaining time will be written into RAM to provide flexibility.	The microcontroller will be working at 5V and 16MHz. The peak working current for the microcontroller will be around 80mA in this state.
COMPLETE	The system will be working in this state when the expected brushing time has reached for the very brushing session. The LED will be set to green. Food dispenser and buzzer will be triggered once.	The microcontroller will be working at 5V and 16MHz. It will stay in sleep mode “power down” since the interruption from the DS3231 timer chip is the only input during this state. The microcontroller will work at ~0.15 mA during this state.

ALARMSET	The system will be working in this state when there is an interrupt from the timer chip. A new 12-hour alarm will be set into the timer chip. And the remaining time of vibration will be reset.	The microcontroller will be working at 5V and 16MHz. The peak working current for the microcontroller will be around 80mA in this state.

Tab. 2 Microcontroller Software States

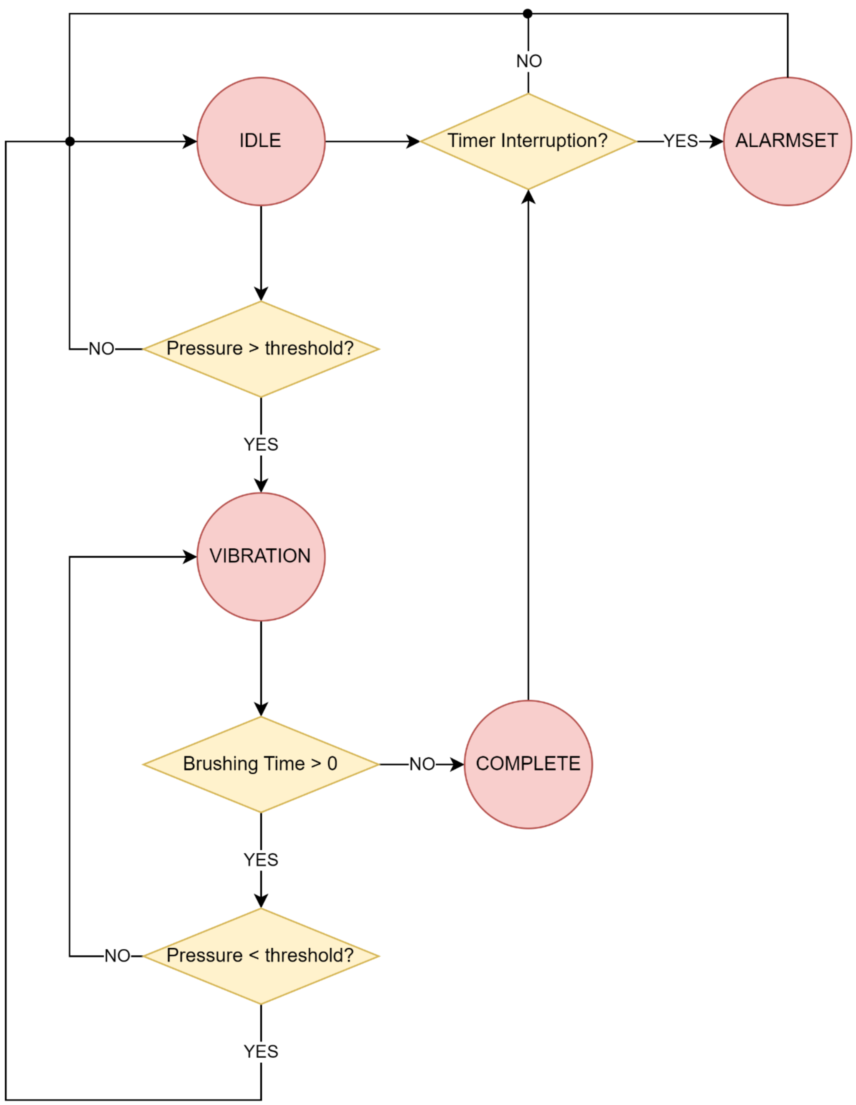

Fig. 9 State diagram

Except for the power subsystem, the control subsystem must connect with all the other subsystems for data communication. Three to three analog input ports should be used to read from the sensor subsystem. Five digital output ports should be used to control the buzzer/treat dispensing subsystem, with one controlling the buzzer and four controlling the stepper motor. Another three digital output ports are needed to control the state indication subsystem. At last, to communicate with the timer, two analog ports are necessary (pin 28 for SCL, pin 27 for SDA).

The circuit schematics are shown in Fig. 10, Fig. 11, and Fig. 12:

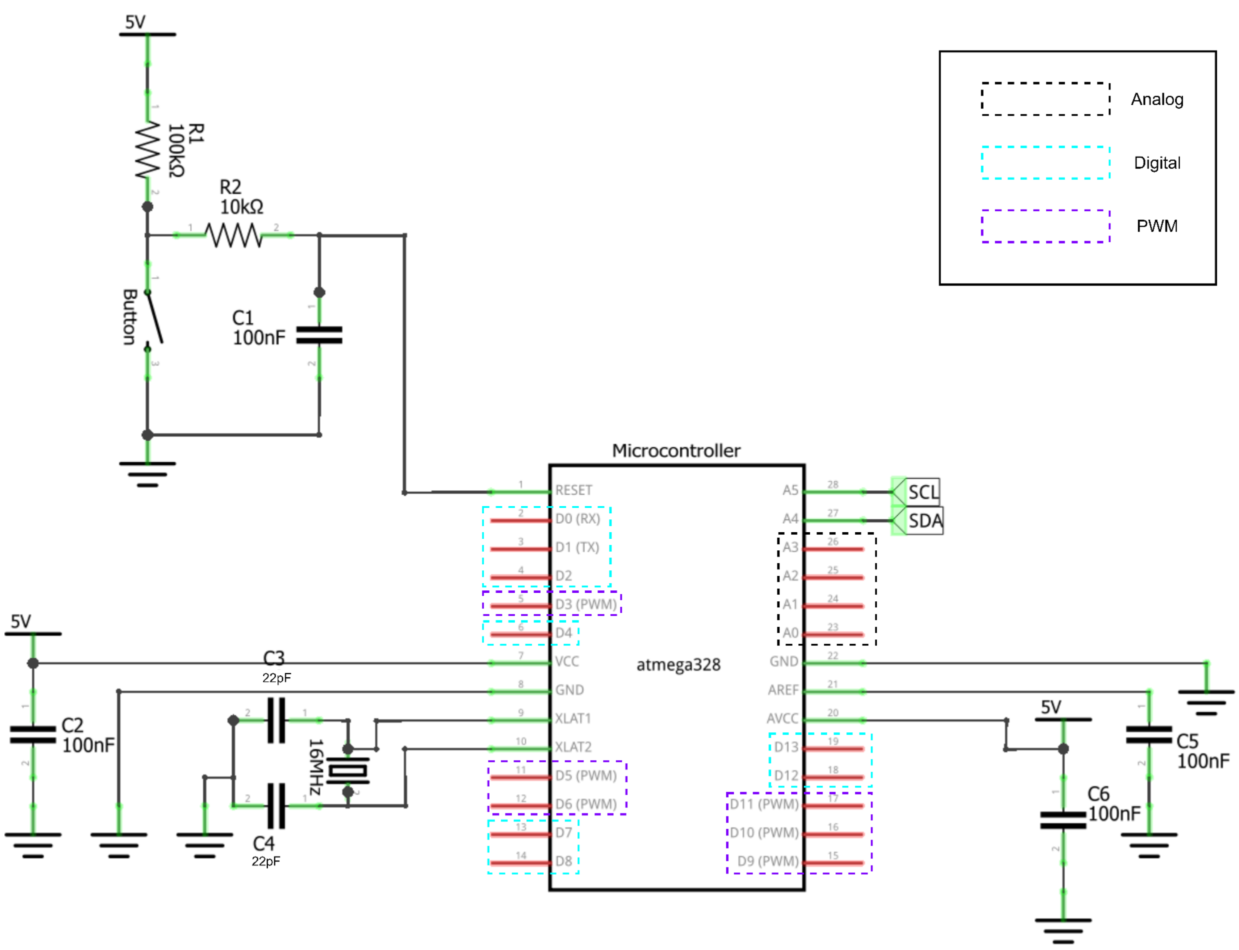

Fig. 10 Microcontroller Circuit

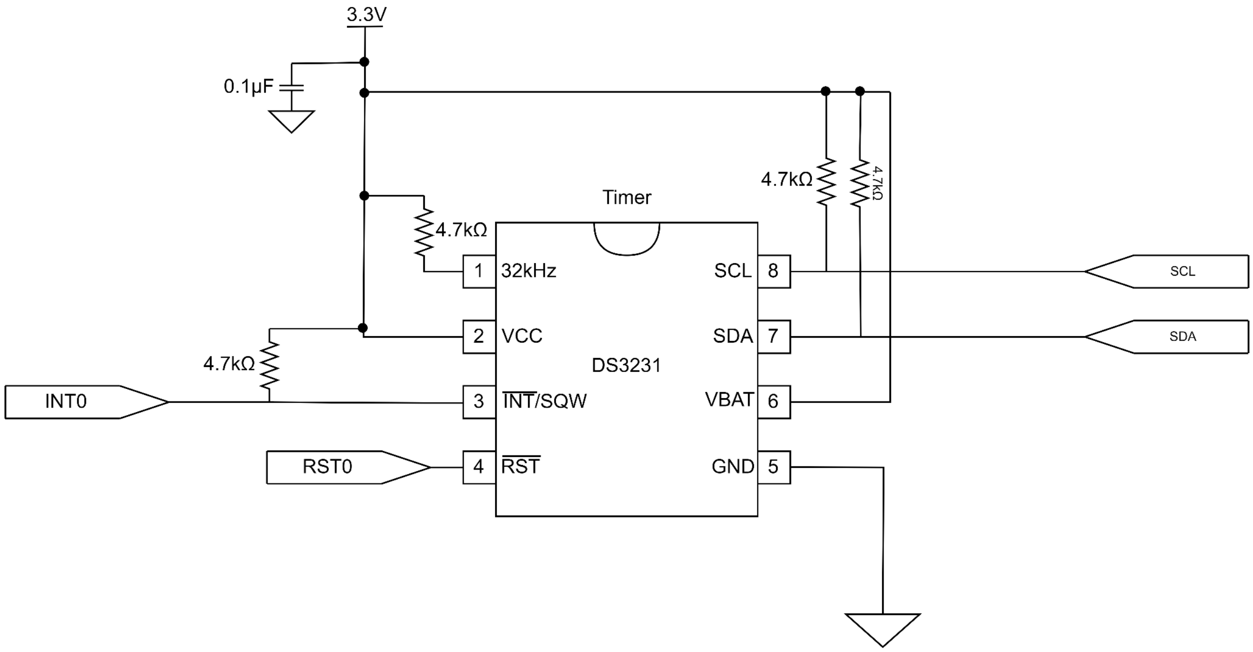

Fig. 11 Timer Circuit

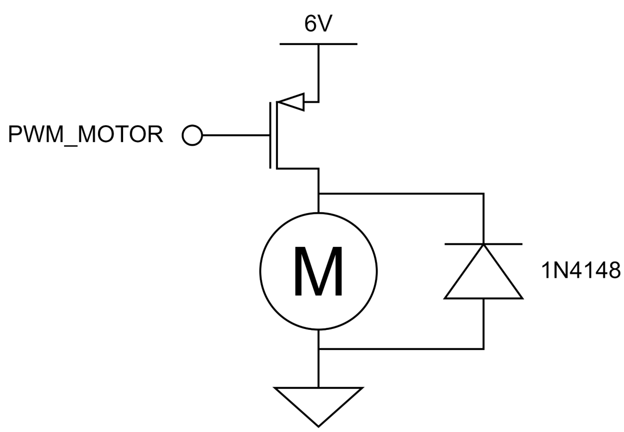

Fig. 12 Vibration Motor Circuit

Requirement	Verification
When the dog fails to brush enough time in a brushing session, the system will reset automatically.	● Start the system in IDLE state, conduct pressing with enough force to trigger vibration for 0 seconds, 30 seconds, 1 minute, or 1.5 minutes during a brushing session. Wait till the next brushing session to check if the remaining time is reset correctly. ● Adjusting alarm period from 12-hour to 5-minute for easier verification.
When the timer chip's alarm raises during vibration, the system will reset only after the vibration is stopped.	● Start the system in IDLE state, conduct pressing with enough force to trigger vibration for a specific length of time. ● Adjust the alarm period so that it will interrupt before the vibration stops. Observe the LED output to check if the state transition is correct.
When the required brushing time is reached, the pressure sensor will not trigger a transition in state.	● Start the system in COMPLETE state, check if pressing the toy will result in vibration or changes of color of the LED display.
The vibration motor should be able to rotate at least 1000 RPM when a weight of least 200g is attached.	● The vibration motor is connected to a that imitate what we use for the toy, and is controlled to vibrate for over 2-minute. ● A mobile app (e.g.VibraTestPro) will be used to measure the working frequency of the motor.

Tab. 3 Control Subsystem R&V Table

2.3.3 Buzzer/Treat Dispensing Subsystem

The Buzzer/Treat dispensing subsystem involves a PS1440P02BT buzzer, a stepper motor, a treat dispensing wheel, a L293DNE half H-bridge, and an AOSS21311C PMOS transistor. The step motor has four inputs, each connected to a driver output of the H-bridge. Each driver input receives a digital signal from the microcontroller in the control subsystem. The buzzer is connected in series with a PMOS to the 3.3 V supply voltage. This PMOS gate receives a PWM signal from the microcontroller. The treat dispenser will use a wheel of 5-9 compartments with an opening at one end. After a cleaning is done, the buzzer will sound, and the stepper motor will rotate to the next treat slot. The microcontroller will count the number of treat releases and light up the LED when it reaches a treat count of zero and reset. The circuits are shown in Fig. 13 and Fig. 14:

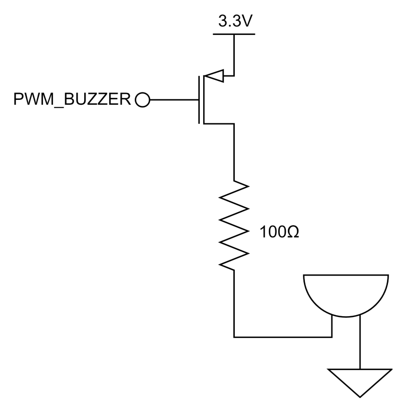

Fig. 13 Buzzer Circuit

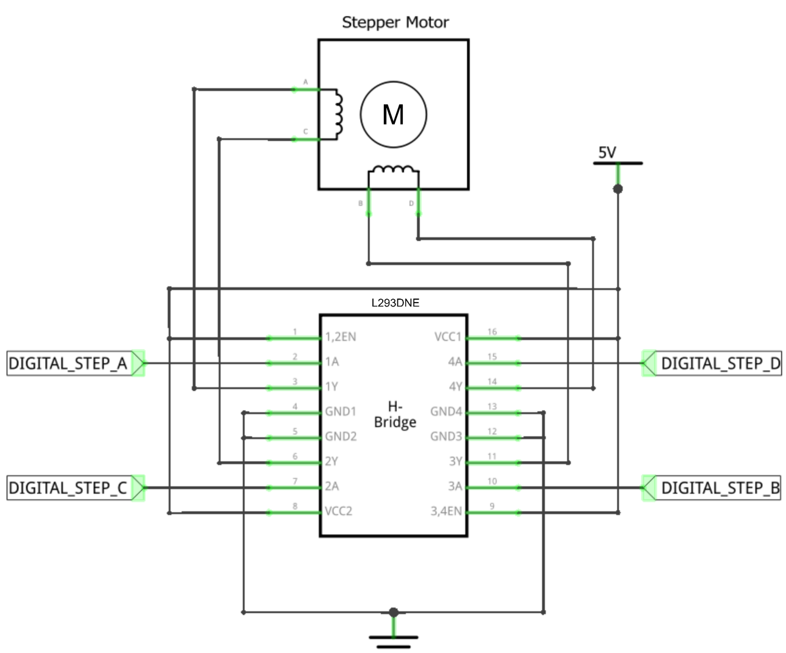

Fig. 14 Treat Dispenser Circuit

Requirement	Verification
Depending on the number of compartments in the final design, the treat dispenser should be able to rotate for 40° or 72° and release a treat correctly.	● Place a dummy treat in each compartment. ● Ensure that the toy is in IDLE state. ● Place 10kg of weight on the thin film pressure sensor. ● Wait for 2min until the toy enters COMPLETE state. ● Observe the rotation of the stepper motor and the releasing of the dummy treats.
The buzzer should draw ≤ 20 mA to obtain a reasonable battery life.	● Set the digital multimeter to DC current mode. Connect the positive probe to the 3.3V voltage supply. Connect the negative probe to the source of the PMOS that is in series with the buzzer. ● Ensure that the toy is in IDLE state. ● Place 10kg of weight on the thin film pressure sensor. ● Wait for 2min until the toy enters COMPLETE state. ● Note down the maximum current values measured by the multimeter when the buzzer is buzzing.

Tab. 4 Buzzer/Treat Dispensing Subsystem R&V Table

2.3.4 State Indication Subsystem

The state indication subsystem consists of a WP154A4SUREQBFZGC RGB LED and three AOSS21311C PMOS transistors in series with individual internal LEDs. Each PMOS transistor is connected to the 5V supply voltage, and its gate receives a distinct PWM signal from the microcontroller in the control subsystem. The circuit is shown in Fig. 15. The 150Ω resistor in Fig. 15 is implemented by connecting two 100Ω resistor in parallel and then connect them in series with another 100Ω resistor.

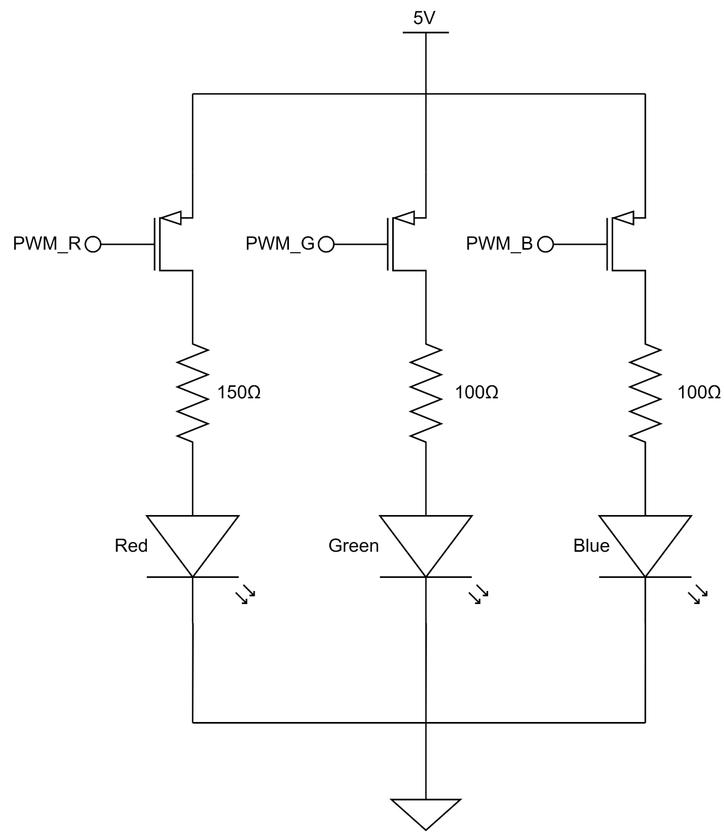

Fig 15. RGB LED Circuit

The LED will be able to convey if the cleaning requirement has been satisfied for each day through different colors.

Requirement	Verification
The brightness of individual red, green and blue LEDs in the RGB LED can be adjusted separately. The LED should be bright enough such that they are easy to identify.	● Ensure that the toy is in IDLE state. ● Observe the LED from a 45° viewing angle. Note down if the viewer can tell the LED is on. If so, note down the color of the LED. ● Place 10kg of weight on the thin film pressure sensor. ● Observe the LED from a 45° viewing angle. Note down if the viewer can tell the LED is on. If so, note down the color of the LED. ● Wait for 2min until the toy enters COMPLETE state. ● Observe the LED from a 45° viewing

	angle. Note down if the viewer can tell the LED is on. If so, note down the color of the LED.
The RGB LED should draw ≤ 60mA in total to obtain a reasonable battery life.	● Set the digital multimeter to DC current mode. Connect the positive probe to the 5V DC voltage. Connect the negative probe to the common node of PMOS sources. ● Ensure that the toy is in IDLE state. ● Note down the maximum current value measured by the multimeter. ● Place 10kg of weight on the thin film pressure sensor. ● Note down the maximum current value measured by the multimeter. ● Wait for 2 min until the toy enters COMPLETE state. ● Note down the maximum current value measured by the multimeter.

Tab. 5 State Indication Subsystem R&V Table

2.3.5 Power Subsystem

The power subsystem provides four levels of DC voltages–12V, 6V, 5V, and 3.3V. This subsystem is electrically connected to other subsystems as the power supply. The 12V is provided by a 12V battery, and it serves as the inputs to three internal voltage regulators that step the voltage down. The 6V is provided by an L7806CV-DG voltage regulator; it is the supply to the motor driver in the control subsystem. The 5V is provided by an LM7805 voltage regulator; it is the supply to the microcontroller in the control subsystem, the pressure sensors in the sensor subsystem, the LED in the state indication subsystem, and the treat dispenser in the buzzer/treat dispensing subsystem. Similarly, the 3.3V is provided by an LD1117V33 voltage regulator; it is the supply to the timer in the control subsystem and the buzzer in the buzzer/treat dispensing subsystem. The circuit for the power subsystem is shown in Fig 16.

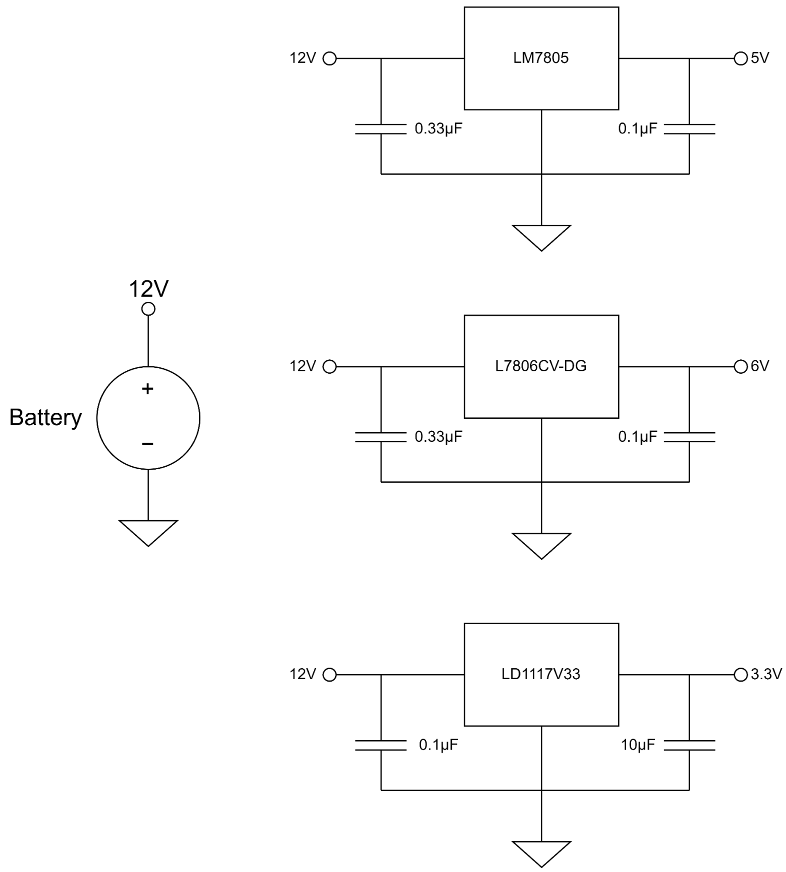

Fig 16. Power Circuit

Requirement	Verification
The battery should output 12V +/- 0.24V.	• Set the digital multimeter to DC voltage mode. Connect the positive probe to the positive terminal of the battery. Connect the negative probe to the negative terminal of the battery. • Note down the voltage value measured by the digital multimeter.
The 6V voltage regulator should output 6V +/- 0.12V.	• Set the digital multimeter to DC voltage mode. Connect the positive probe to the output terminal of the 6V voltage regulator. Connect the negative probe to the negative terminal of the battery. • Note down the voltage value measured by the digital multimeter.

The 5V DC voltage should be maintained at 5V +/- 0.1V. Also, the voltage ripple needs to be less than 50mV peak-to-peak.	● Set the oscilloscope to high-Z mode. Set the oscilloscope to measure average voltage and peak-to-peak voltage. ● Connect the positive probe of the oscilloscope to the output terminal of the voltage regulator. Connect the negative probe to the negative terminal of the battery. ● Note down the measured values of average voltage and peak-to-peak voltage.
The 3.3V voltage regulator should output 3.3V +/- 0.066V.	● Set the digital multimeter to DC voltage mode. Connect the positive probe to the output terminal of the 3.3V voltage regulator. Connect the negative probe to the negative terminal of the battery. ● Note down the voltage value measured by the digital multimeter.

Tab. 6 Power Subsystem R&V Table

2.4 Tolerance Analysis

Since our device is operating on a battery and is meant for long-term usage at home, it is vital that our device can operate for a reasonable period of time before the user has to recharge the battery. To confirm that our design is practical, a pessimistic estimation of the battery life is necessary.

First, the pessimistic idle current draw of subsystems that have significant power consumption is shown in the following tables. The current values are taken from respective datasheets.

Power Subsystem		
Device	Maximum Idle Current	Total Current
LM7806	8 mA	26.5 mA

LM7805	8.5 mA	
LD1117V33	10 mA	

Tab. 7 Power Subsystem Idle Current

Control Subsystem		
Device	Maximum Idle Current	Total Current
Microcontroller	0.15 mA	0.825 mA
Timer	0.65 mA	
Motor Driver	0.025 mA	
Vibration Motor	0 mA	

Tab. 8 Control Subsystem Idle Current

Sensor Subsystem		
Device	Maximum Idle Current	Total Current
Pressure Sensor Circuit	1.27 mA	3.81 mA
Pressure Sensor Circuit	1.27 mA	
Pressure Sensor Circuit	1.27 mA	

Tab. 9 SensorSubsystem Idle Current

State Indication Subsystem		
Device	Maximum Idle Current	Total Current
RGB LED	60 mA	60 mA

Tab. 10 State Indication Subsystem Idle Current

The current draw for the pressure sensor circuit is given by a LTspice simulation. The simulation result is shown in Fig. 17:

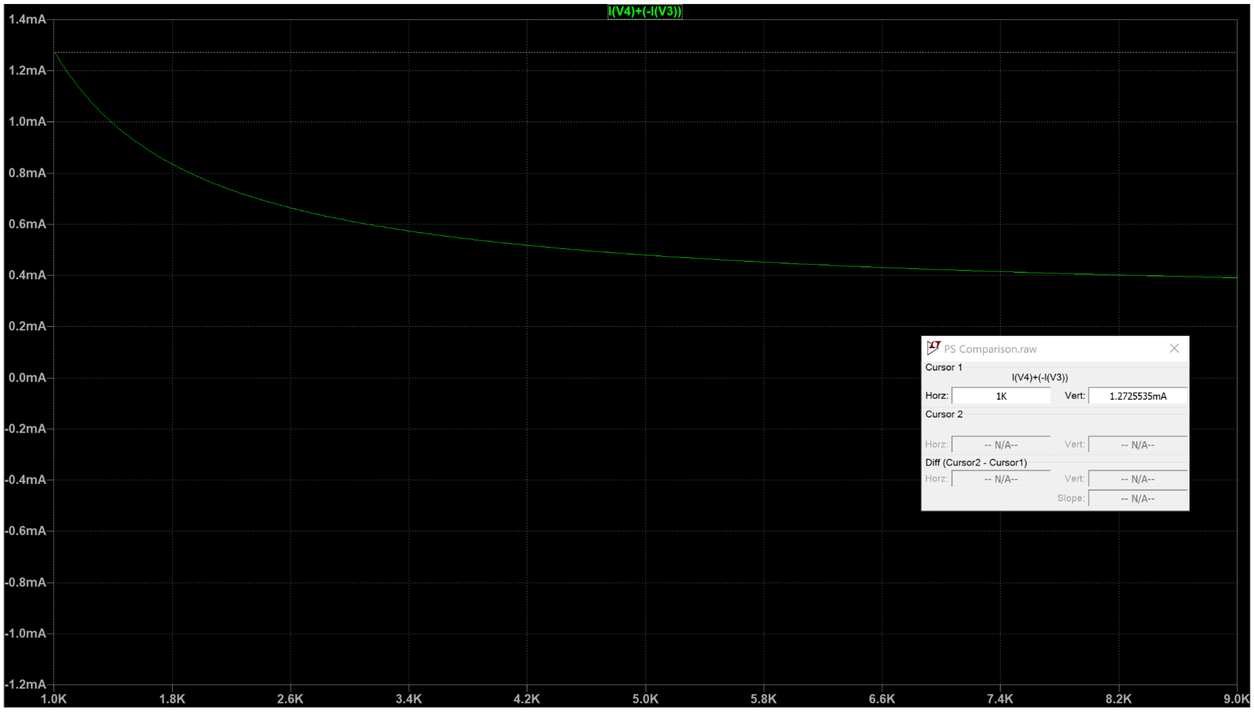

Fig. 17 Pressure Sensor Circuit Current Simulation

Since the Buzzer/Treat Dispensing Subsystem is controlled by PMOS switches and turned off when the device is idle, the current draw is negligible. Therefore, the total pessimistic idle current $I_{Idle,Tot} \approx 91.135$ mA. Under the assumption of using a 7 Ah battery,

$$t_{idle} = \frac{7\ Ah}{91.135 \times 10^{-3}} \approx 76.8\ h \approx 3.2\ days$$

Therefore, the device can run for approximately 3 days when powered on but not used.

Now, when it comes to the power consumption from the vibration motor, the current draw is 200 mA @ 14V. Then at 6V, an estimation would be

$$i_{Motor} = \frac{200\ mA \cdot 14V}{6V} \approx 467\ mA$$

Under the assumption that the device will be active for two times a day for two minutes each time,

$$Consumption_{Motor} = 2 \cdot 467 \times 10^{-3} A \cdot \frac{2\ min}{60\ min/h} = 0.03\ Ah/day$$

We assume that the Buzzer/Treat Dispensing Subsystem will have the same consumption for our pessimistic estimation. Therefore,

$$Consumption_{Dispenser} \approx Consumption_{Motor} \approx 0.03\ Ah/day$$

As for the idle consumption,

$$Consumption_{Idle} \approx 91.135 \times 10^{-3}\ A \cdot 24\ h/day \approx 2.19\ Ah/day$$

In total,

$$Consumption_{Total} \approx 2.19\ Ah + 0.03\ Ah + 0.03\ Ah \approx 2.25\ Ah/day$$

Hence the pessimistic battery life would be

$$t_{pessimistic} \approx \frac{7\ Ah}{2.25\ Ah/day} \approx 3.1\ days$$

Thus, pessimistically speaking, our device can run for approximately 3.1 days when operating under recommended cleaning cycles. In the actual implementation, the microcontroller should consume less current than the value listed above. Also, the pressure sensor subsystem should have a lower current draw since the resistance should be higher when it is not used. The LED should also draw less current than the listed value since it will not be run at 100% duty cycle. Thus, the real-world power consumption should be lower than the pessimistic estimation. Considering that the user has to refill the treat dispenser at approximately the same time, the battery life is long enough for practical usage.

3. Cost & Schedule

3.1 Cost Analysis

3.1.1 Parts/Materials

Description	Part Number	Quantity	Unit Price	Price for Quantity
12V Battery	Mighty Max (Amazon)	1	$19.99	$19.99
15000 RPM Mini Electric Motor (6 pack)	Topoox (Amazon)	1	$6.99	$6.99
OPA196 op-amp	296-48157-2-ND	3	$1.50	$4.50
30V PMOSFET	785-AOSS21311CTR-ND	5	$0.42	$2.10
Full Color LED Lamp	754-1615-ND	1	$1.68	$1.68
Thin film pressure Sensor	1738-SEN0293-ND	3	$6.08	$18.24
ATmega328P microcontroller	X000048	1	$7.20	$7.20
AVR ISP adaptor	1528-1189-ND	1	$0.95	$0.95
16MHZ crystal oscillator	X433-ND	1	$0.71	$0.71
Stepper Motor	SY35ST36-1004A	1	$21.95	$21.95
Dog-safe plush for bristles	Hyper Pet Store (Amazon)	1	$9.95	$9.95
DS 3231 Timer	DS3231MZ+-ND	1	$10.31	$10.31

Non-Isolated Switching Regulator	P7805-Q24-S5-S	1	$5.48	$5.48
100Ω resistor	100QBK-ND	6	$0.10	$0.60
1kΩ resistor	1.0KQBK-ND	1	$0.10	$0.10
4.7kΩ resistor	4.7KQBK-ND	4	$0.10	$0.40
10kΩ resistor	10.0KXBK-ND	5	$0.14	$0.70
100kΩ resistor	100KQBK-ND	1	$0.10	$0.10
0.1 uF capacitor	399-9867-2-ND	8	$0.49	$3.92
0.33 uF capacitor	399-9808-ND	2	$0.46	$0.92
10 uF capacitor	399-13968-ND	3	$0.79	$2.37
22 pF capacitor	399-8917-ND	3	$0.42	$1.26
Piezoelectronic Buzzer	445-5242-1-ND	1	$0.80	$0.80
L293DNE half H-bridge	296-9518-5-ND	1	$4.29	$4.29
L7806CV-DG voltage regulator	497-12405-ND	1	$0.89	$0.89
LM7805CT voltage regulator	926-LM7805CT	1	$2.57	$2.57
LD1117V33 voltage regulator	497-1491-5-ND	1	$0.84	$0.84
1N4148 diode	2368-1N4148-ND	1	$0.05	$0.05
			Total	$129.86

Tab. 11 Cost Analysis

3.1.2 Estimated Hours of Labor

Two members of our group are Computer Engineering students and one member is an Electrical Engineering student. According to the latest information published by the ECE department of the Grainger College of Engineering, Computer Engineering students make an average of $105,352 per year and Electrical Engineering students make $80,296 per year [3]. Assuming that we worked 40 hours per week, 52 weeks a year, this would average out to be $50.65 per hour for the former and $38.60 for the latter.

Considering each one of us work for 10 hours per week, the total cost of labor of the project will be ($38.60+$50.65*2)*10*9 = $12,591

3.1.3 Machine Shop

From the visual aid, it can be seen that there are many physical components to our project. The treat dispenser will consist of a box with a hole for the stepper motor/treat dispenser and the treat dispenser itself. The machine shop has made this type of treat dispenser before, so it would be rather simple for them. The more laborious task is the toothbrush portion. This will consist of about 2” rod of nylon plastic that will tightly encase our motor and have a removable top as well. We estimate it will take about 8-10 hours and were informed that an inch of the nylon rod is about $100.

3.1.4 Total Estimated Cost

The total estimated cost of the project will consist of the cost of parts ($129.86),the cost of labor ($12,591), and the cost of the machine shop ($200), which sum up to a total cost of $12,920.86.

3.2 Schedule

Week	Task	Person
2.20 - 2.26	Order parts for prototyping	Everyone
	PCB Design	Everyone
2.27 - 3.5	Design Review	Everyone
	Start breadboard assembly	Yilong
	Pressure sensor circuit testing	Yilong
	Vibration motor testing	Angela
	Arduino uno prototype programming	Youhan
	Keep in contact with machine shop about design updates	Angela
3.6 - 3.12	Continue breadboard assembly	Yilong, Angela
	Standalone ATmega328P setting up	Youhan
	Finalize revisions with machine shop	Angela
	First PCB ordering 3.7	
3.13 - 3.19	Start PCB assembly	Everyone
	ATmega328P sensor/timer input program verification	Youhan
3.20 -3.26	Revision to PCB design	Everyone
	ATmega328P motor output program verification	Youhan
3.27 - 4.2	Revision to PCB design	Everyone
	ATmega328p final verification on overall performance	Youhan
	Second PCB ordering 3.28	
4.3 - 4.9	Finalize assembly	Everyone
4.10 - 4.16	Integration Test	Everyone
	Fixing minor bugs	Everyone
4.17	**Demo**	

Tab. 12 Schedule

4. Ethics & Safety

According to the IEEE Code of Ethics, the safety and health of the public are to be held paramount [2]. We need to pay close attention to the safety aspect of the project due to the interactive nature of our proposed device. In our design, the motor is attached to the dog toy, and there are wires connecting the motor to the treat dispenser. Therefore, it is essential to make sure that the wires and motor are properly secured. Preventing exposure and damage to the battery is also necessary to satisfy the category of safety. Another aspect to keep cautious of is using dog-friendly materials. This is especially true for the bristles and the encasing of the dog toy. To ensure our product uses dog-friendly materials, we will be using materials that have already been used on dogs in the market.

When it comes to ethics, it is noteworthy that the treat dispenser is only compatible with certain kinds of treats, and the product is potentially directing the user to deem those treats as more desirable. One can regard this as an impairment to the user's welfare since the product is forcing the user to have a certain kind of supplementary product. Considering the prototype nature of the product, we should make endeavors to improve the treat dispenser in the future.

References

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