Therapalz Collar

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Abstract

A smart collar for a smart therapeutic stuffed-animal used to provide both comfort and company to Alzheimer's patients. The collar is equipped with sensors to control the behavior of animal based on pre-programmed settings. Location tracking present in collar makes it possible to locate its distance from a phone-based application. The device is intended to make the animal as realistic as possible while keeping in mind the needs of patients. The device is compact and fits into an 8.33cm x 6.22cm sized box with a Velcro strap that attaches on the collar of the animal.

Contents

1. Introduction

1.1. Purpose

Alzheimer's is the most common form of dementia which causes problems with memory, thinking, and behavior. It is a progressive disease with symptoms usually developing slowly before getting worse over time. Patients in early stages have mild memory loss but as they get older, they begin to lose their ability to respond appropriately to their environment or even carry a conversation. Alzheimer’s affects about 5.5 million people older than 65 every year in the United States. It is the sixth leading cause of death in the United States [1]. Despite these startling numbers, there is currently no medical cure to Alzheimer's. This is the reason why several organizations and people have dedicated their lives to develop non-medical methods to improve the quality of life of these patients to the maximum extent they possibly can.

There are several studies that have proven that pets have a positive impact on patients suffering from Alzheimer's. Pets are a great companion for patients with dementia as they help reduce anxiety, agitation, irritability, depression, and loneliness [2]. However, it is not always feasible or practical to have and look after a pet in a long-term care facility.

Therapalz is a smart, therapeutic, companion stuffed-animal invented by Fiona Kalensky. It originally had a realistic heartbeat, calming vibrations and the ability to make a purring sound to replicate the behavior of a real cat. It was made to provide both comforts as well as company to patients suffering from Alzheimer's. We proposed to expand on this invention. In this report, we describe our attempts on making a smart collar for the animal and its functionality. We integrate sensors to change the behavior of the animal based on different scenarios, a location tracking system and a microphone to detect loudness of voice. Our aim was to aid in making the smart animal as realistic as possible to provide the illusion of it being a real pet so it could provide the maximum amount of comfort to the patient as possible.

1.2. Functionality

Our device consists of several sensors as well as Bluetooth and speakers all made to fit on a PCB that goes into a 8.33cm x 6.22cm sized box. Our sensors consist of a light sensor, which detects when the room is dark and goes into sleep mode thus reducing the device’s power intake, an accelerometer that detects when there is no motion over a period of time and sends the device to sleep, thus also preserving power and a microphone that has the ability to differentiate between the loud and the normal voice of a person. The Bluetooth and speaker are used to track the animal’s location. The Bluetooth gives the distance of the animal from a phone while the speaker emits a noise to help the user locate the animal

1.3. Subsystems Overview

Our design consists of three main subsystems. These are the power system, the control system and the communication system.

1.3.1. Power System Overview

Our initial design for the power system was fairly simple, containing two coin cell batteries to supply power and two voltage regulators to prevent voltage fluctuations in our components. Our voltage regulators were chosen to hold the power at 5V and 3.3V. We selected these two voltages because our chosen components all required one of these two levels. The microcontroller [3] and Bluetooth modules [4] required 5V to work at optimal levels, and all of the sensors required 3.3V to operate.

1.3.2. Control System Overview

Our initial design for the control system was simple, containing a microcontroller and all the required sensors. The sensor data is used as input, alongside the buttons, that are sent to the Bluetooth modules. The control system can also receive data from an app through Bluetooth.

1.3.3. Communication System Overview

At its beginning stages, our design for the communication system involved a singular Texas Instruments CC2564MODA Bluetooth module communicating with four separate Bluetooth beacons. The intent for this setup was to triangulate the position of the collar within a set range of space using relative signal strengths from each individual beacon.

Due to decisions based on practicality, this design was later changed to instead include two Jinan Huamao HM-10 Bluetooth modules. One module would be dedicated to communicating sensor data to the user's phone, through standard BLE scanner apps, and the second module would be used as an iBeacon to locate the collar on the user's phone, through standard beacon scanner apps.

The advantages of this change are that the final product is both easier to use for the user and easier to develop for us as a team. A single iBeacon inside the collar gets the job done and provides less hassle for the user than four separate beacons in the event of hardware malfunction. The change to a single beacon also relieves stress off the microcontroller since we no longer need to calculate the collar's position, but simply relay sensor data to the dedicated HM-10 module.

The drawbacks to this change are that we did not take into consideration the power requirements of this new communication system in our implementation. The previous CC2564MODA module had a current draw of less than 0.20 mA, while the separate beacons would have their own separate power sources. The iBeacon HM-10 had a similar current draw of 0.18 mA [5], but the HM-10 module for transmitting sensor data had a current draw of 50 mA. Both modules would share the same power source as everything else on the PCB. This resulted in problems where the final product would sometimes reset, or the modules would fail to turn on if too many sensors were being used at the same time.

Overall the communication system worked as intended as an isolated unit but created bugs when incorporated into the full product.

2. Design

2.1. Block Diagram

For the collar to work successfully, the power unit, the control unit, and the communication system must work harmoniously. The batteries provide the collar with power, which is then sent through the two voltage regulators that ensure that each component receives power within its requirements. The control unit contains all the sensors along with the microcontroller which behaves as described in pre-programmed settings. The Bluetooth is used to locate the animal as well as to communicate with the microcontroller to send sensor data to a separate app. Finally, the app will be used to track the animal as well as receive sensor data for other uses. The high level block diagram is shown in Figure 1.

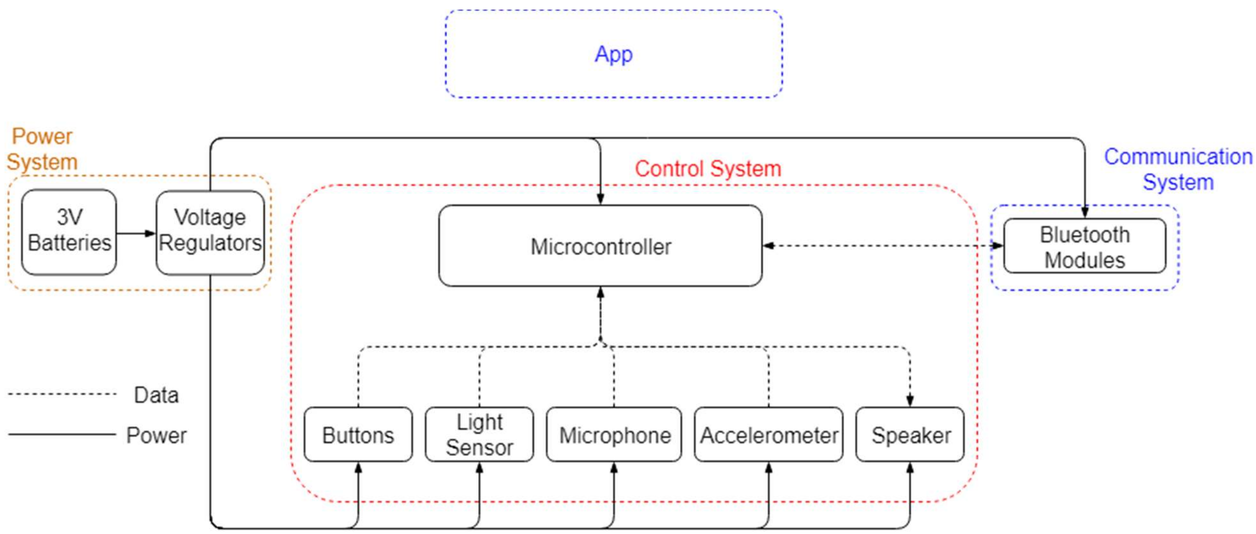

Figure 1: Block Diagram

2.2. Physical Design

When designing the physical case of our device, we kept in mind two main ideas: concealability and security. Concealability was a priority because the device was supposed to be an unobtrusive addition to a stuffed animal that was being used to comfort patients. Security was our other priority because we wanted to prevent any interference with device from the patient using it.

To achieve the two aforementioned goals, we settled on a design that had the accessible buttons to control the device, concealed behind a door that could be opened if necessary. Figure 2 shows the initial design of the outer casing of our device. Figure 3 shows the actual 3D printed case for our device.

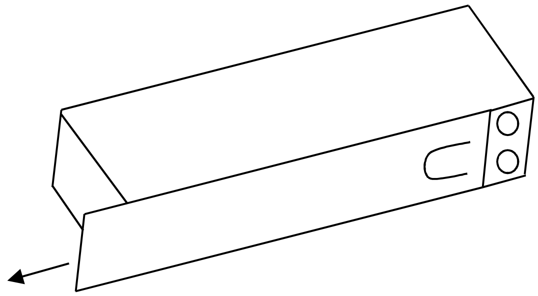

Figure 2: Schematic casing of device

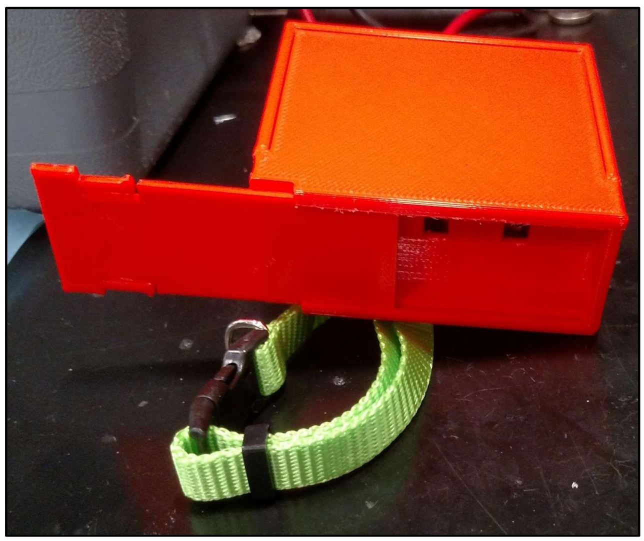

Figure 3: Actual casing of device

2.3. Power System

2.3.1. Battery

The battery we used was the CR2032, a readily available coin cell battery. It was chosen because it can easily be purchased at most stores for easy replacement, as well as for its small size, which aligned with our design to make the entire device as small and unobtrusive as possible. We planned to use 2 3V coin cell batteries to supply power to the device.

Once we began testing our system, we discovered that some of the changes we had made in other subsystems had drastically changed the power requirements of the device, and the two coin cell batteries we were using would not supply enough power for our brief code tests. To combat this problem, we altered our battery holder to accommodate four coin cell batteries, which supplied enough power to test the device. See table 1 for requirements and verifications.

Table 1: Battery Requirements and Verification

Requirement	Verification	Testing
Must power the device at a constant 6V±0.6V	Check battery voltage with multimeter in parallel with a resistor for 6V±0.6V	Battery voltage of two coin cells measured with multimeter to be 5.2V - 6.0V
Must keep the device powered for a minimum of 12 hours	Measure voltage after 12 hours of use and confirm that power is still supplied	Using the batteries in testing resulted in the batteries being drained in less than 12 hours of use

2.3.2. Voltage Regulators

The voltage regulators take in the power from the batteries and supply a voltage of 5V to operate the microcontroller and Bluetooth modules, and 3.3V to operate the accelerometer, microphone, and light sensor.

During testing, the voltage regulators behaved as expected, providing the necessary voltage for the various components. One problem that arose during our testing was a shorting and subsequent burning out of our 3.3V regulator while we were investigating other power issues on our device. See table 2 for requirements and verifications.

Table 2: Voltage Regulators Requirements and Verification

Requirement	Verification	Testing
Must power the device at a constant 3.3V±0.3V	Check voltage with multimeter in parallel with a resistor for 3.3V±0.3V	Verified with multimeter that voltage was within requirements

2.4. Control System

2.4.1. Microcontroller

The microcontroller we used was the ATmega328/P. It was chosen because of the ease of using Arduino code on it, allowing for a faster transition from prototyping to final product. It receives inputs from the buttons and sensors and sends the necessary data through Bluetooth to be received by the external app. It also receives commands through Bluetooth to activate the speaker. See table 3 for requirements and verifications.

Table 3: Microcontroller Requirements and Verification

Requirement	Verification	Testing
Can be used with Bluetooth module through UART protocols	Check that messages are received from Bluetooth module with <10% packet loss	While the circuit remained powered correctly, all packets were received

2.4.2 Light sensor

The light sensor we used in this project was the APDS-9301. It measures the illuminance of the surrounding area and returns this lux value as a digital signal to the microcontroller through the I2C communications protocol. This lux value is used to determine the intensity of the light, and when the conditions indicate it is nighttime the pet enters a sleep mode to conserve battery.

In our final device, the light sensor that we used was not able to communicate with the microcontroller, as the pads on the bottom of the sensor did not properly align with the pads it was designed to be soldered to on the final printed circuit board (PCB). Despite this problem, we were able to test the code we developed with a separate breakout module and development board and verify that the sensor correctly distinguished between lit and darkened rooms. See table 4 for requirements and verifications.

Table 4: Light Sensor Requirements and Verification

Requirement	Verification	Testing
The lux value recorded for a room at night time should be within a 10% range of 5 lux [6]	Test light sensor in a dark room to simulate a bedroom at night. Confirm lux value is within a reasonable range from 5 lux.	Verified through serial monitor on development board that a dark room would provide a reading of 0 lux, and a lit room 33 lux.

2.4.3 Accelerometer

The MMA8452Q accelerometer was used to determine when the animal was in active use. In the event that the animal was not used for an extended period, ten seconds in our tests, the accelerometer would signal for the collar to go into sleep mode to conserve power. At sudden rises in acceleration during sleep mode, the pet will resume normal operation.

In the final product, our accelerometer failed to communicate with our microcontroller on the PCB. This is because in our prototype we used level shifting registers to allow communication between the sensor and microcontroller, but in our design of the PCB we neglected to include them. See table 5 for requirements and verifications.

Table 5: Accelerometer Requirements and Verification

Requirement	Verification	Testing
Accelerometer can accurately detect sudden rises in acceleration.	Move pet suddenly and confirm that accelerometer data correctly records the movement.	Accelerometer could successfully detect sudden rises in acceleration down to 0.0625g’s in the prototype. This cannot be said for the final product.
Sensor can detect no motion	Leave pet stationary, and confirm that accelerometer data correctly records a lock of movement	Accelerometer successfully entered sleep mode in prototype. This cannot be said for the final product.

2.4.4. Power/Mute buttons:

Two small push buttons allow caregivers to easily change important settings, intended for power and mute. See table 6 for requirements and verifications.

Table 6: Button Requirements and Verification

Requirement	Verification	Testing
Power button turns animal on/off	Button sends signal when pressed	Verified on development board via serial monitor
Mute button turns off sound in animal	Button sends signal when pressed	Verified on development board via serial monitor

2.4.5. Microphone

The microphone we used in the project was the ADMP401. The microphone takes a reading of the ambient sound pressure and converts it to decibels (dB). If the sound reaches a designated threshold, the pet is to use one of a set of pre-programmed settings for vibration and purring.

On our final PCB, the microcontroller could not receive a signal from the microphone as the traces for the input voltage and output signal on the microphone were switched. We were able to test code for the microphone on a separate development board with a breakout board for the microphone and confirmed that it could distinguish between different volume levels. See table 7 for requirements and verifications.

Table 7: Microphone Requirements and Verification

Requirement	Verification	Testing
Differentiate between normal talking (~60 dB) and raised voice (~70 dB) [7]	Take measurements at these noise levels and compare frequency responses	Verified through dividing dB ranges into ranges from 1-10. If microphone picked up noise in below a level of 6 a string saying “normal volume” was received Bluetooth module, and if noise is greater than level of 6 a string saying “loud volume” was received by Bluetooth module.

2.4.6. Speaker

The speaker in our project was the CMR-12062S-67. The intended use was that the user, as a secondary choice to the Bluetooth tracking, could send a signal via Bluetooth to produce a sound to locate the animal. The speaker is listed to be able to reach 117 dB in its standard settings [8], but in the final product the speaker did not produce sound greater than 40dB. See table 8 for requirements and verifications.

Table 8: Speaker Requirements and Verification

Requirement	Verification	Testing
Can produce sound at least 70 dB	Measure output of speaker volume and verify that it is at least 70 dB	Speaker did not produce volume greater than 40 dB

2.5. Communication System

2.5.1. Bluetooth Transceiver:

The HM-10 Bluetooth module is used to send/receive data from caregiver through a BLE scanner app. See table 9 for requirements and verifications.

Table 9: Bluetooth Transceiver Requirements and Verification

Requirement	Verification	Testing
Can receive data to and from up to 6 devices (beacons, app, other sections of pets)	Connect devices consecutively and see if any become disconnected/interfere with any and other.	Due to change in design this requirement no longer aligned well with our project. The new HM-10 module succeeded in transmitting sensor data to the app.

2.5.2. Bluetooth Beacons:

The HM-10 iBeacon will be used to locate the collar from a wide range. See table 10 for requirements and verifications.

Table 10: Bluetooth Beacons Requirements and Verification

Requirement	Verification	Testing
Maintain constant transmission interval of 10 sec. or less	Check that a signal is received from beacons at set rate of 10 sec. or less	Due to change in design this requirement no longer aligned with our project. The HM-10 module successfully advertised its location every half-second, allowing for tracking.

3. Cost

3.1. Cost of parts

Table 11: Parts Costs

Part	Part Number	Unit Cost ($)	Quantity	Actual Cost ($)
Button	MPB-43	0.43	2	0.86
Light sensor	APDS-9301	2.91	1	2.91
Microphone	INMP401	4.19	1	4.19
Accelerometer	MMA8452Q	2.64	1	2.64
Battery Retainer	Keystone Electronics/ 3035	0.36	1	0.36
Battery	CR2032	2.37	4	9.49
Speaker	CMR-12062S-67	2.57	1	2.57
Bluetooth Modules	HM-10	12.99	2	25.98
Microcontroller	ATMEGA328P	2.14	1	2.14
Voltage Regulator (3.3V)	LD1117V33	1.95	1	1.95
Op-Amp	LM324AD	0.44	1	0.44
Voltage Regulator (5.0V)	L7805	0.95	1	0.95
3D Printed Case	N/A	2.00	2	4.00
Total				58.48

3.2. Labor

The total cost due to labor is calculated as (3 * $40.00/hr * 10 hr/week * 15 weeks * 2.5) which is equal to $45,500.00.

3.3. Total cost

The total cost due to labor plus cost of parts is equal to $45,558.48.

4. Conclusion

4.1. Accomplishments & Uncertainties

Overall, our project had all its individual components working as intended. Each of the sensors as well as the speaker and Bluetooth worked as intended by themselves. The sensors also successfully communicated back and forth with the phone application using Bluetooth. However, we had some problems integrating the system as whole. We faced several problems with our PCB design. Apart from soldering issues for our light sensor we also forgot to account for certain resistors for the accelerometer while designing the PCB. We also burnt our voltage regulator during testing which caused some problems. In conclusion, most of the issues we faced could be fixed by a revised design of the PCB and by ordering multiple parts in advance in case a replacement was needed.

4.2. Ethical considerations

All aspects of the IEEE code of ethics were reviewed by each team member thoroughly and kept in mind both while implementing the project as well as while presenting it [9].

There were a few ethical considerations we found especially relevant while designing and developing this device. The first one was the possible flammability of the battery which could lead to the animal catching on fire thus endangering the patients as well as caretakers. However, since we put the device into a non-flammable case, we believe to have solved this hypothetical issue. Another consideration we had in mind was the loudness of the speaker affecting the hearing of patients [10]. However, we solved this issue by making sure the speaker was not loud enough to damage hearing. The last consideration we had to take note of was the possible breach of privacy that could be caused by the collar as it tracked the movements as well location of the patients. However, we justified this by making sure the location of the patient is not stored anywhere and only sudden changes in the movement were recorded by our device.

4.3. Future work

We hope to iterate on our design to eliminate the original mistakes made on the PCB so that the device works as intended. We hope that the work we have done is developed and tested by our sponsor to reach her requirements. Ultimately, we hope it has a positive and important impact on the Alzheimer’s community.

5. Appendix A

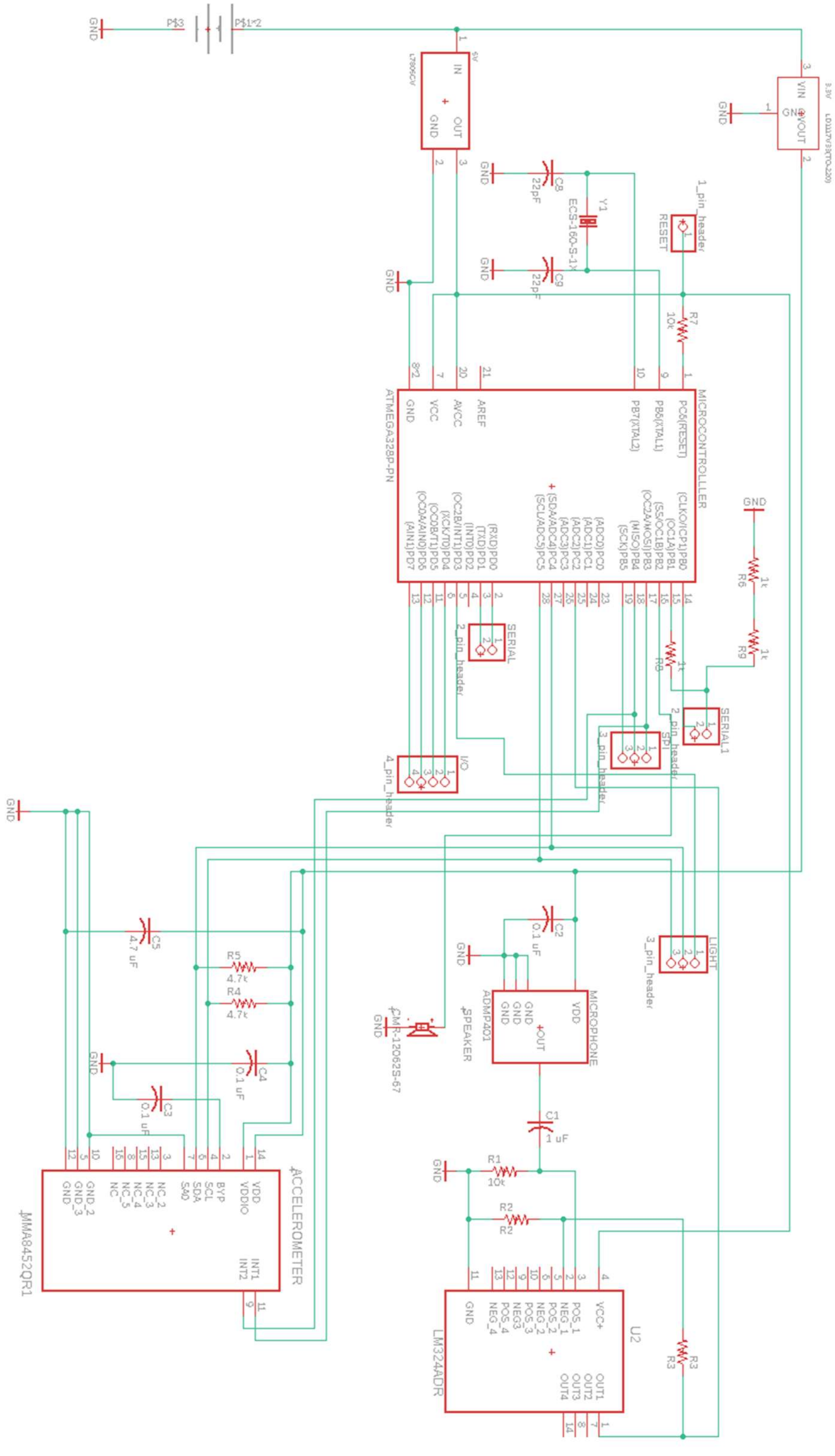

Figure 4: Main PCB Schematic

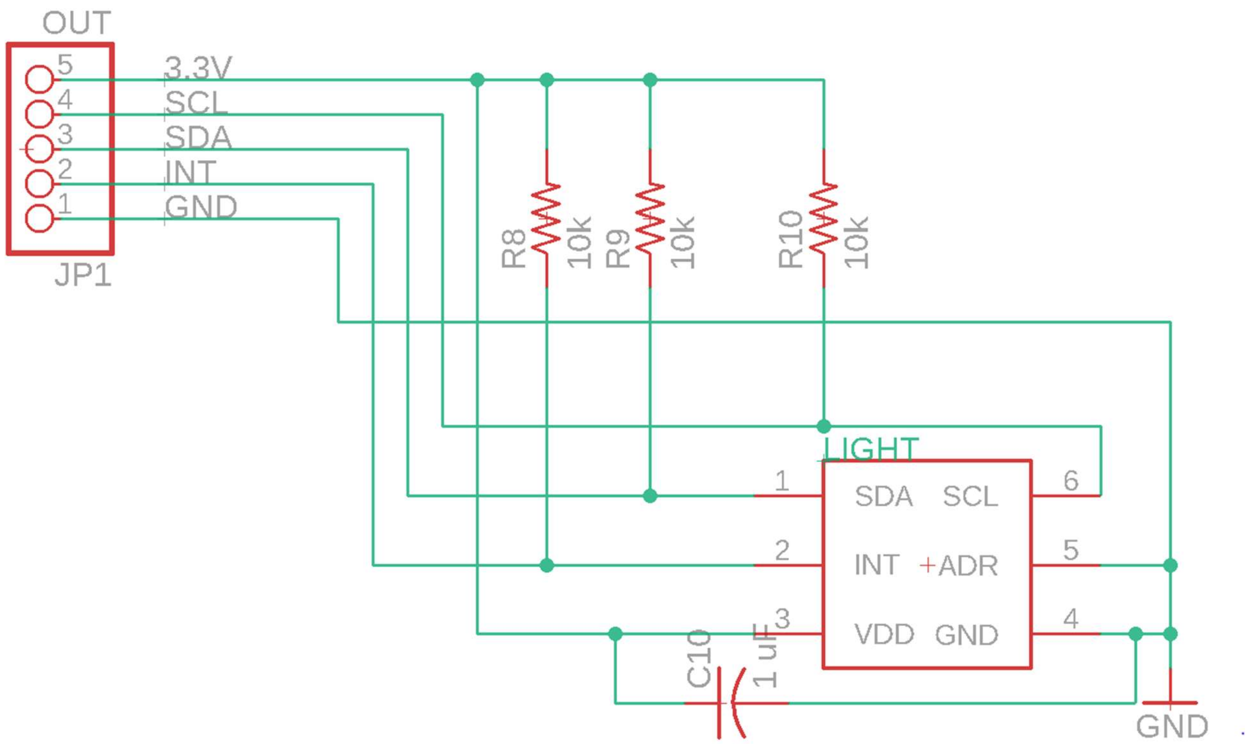

Figure 5: Light Sensor PCB Schematic

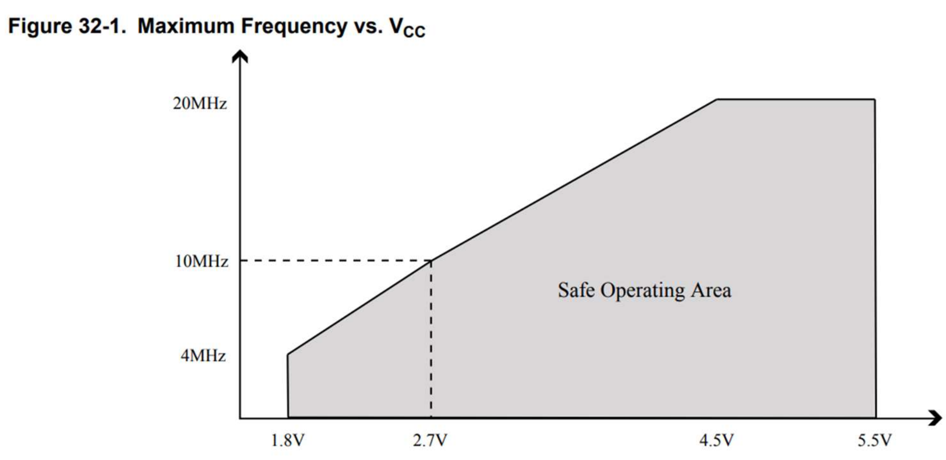

Figure 6: Speed grade for microcontroller [3]

6. References

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