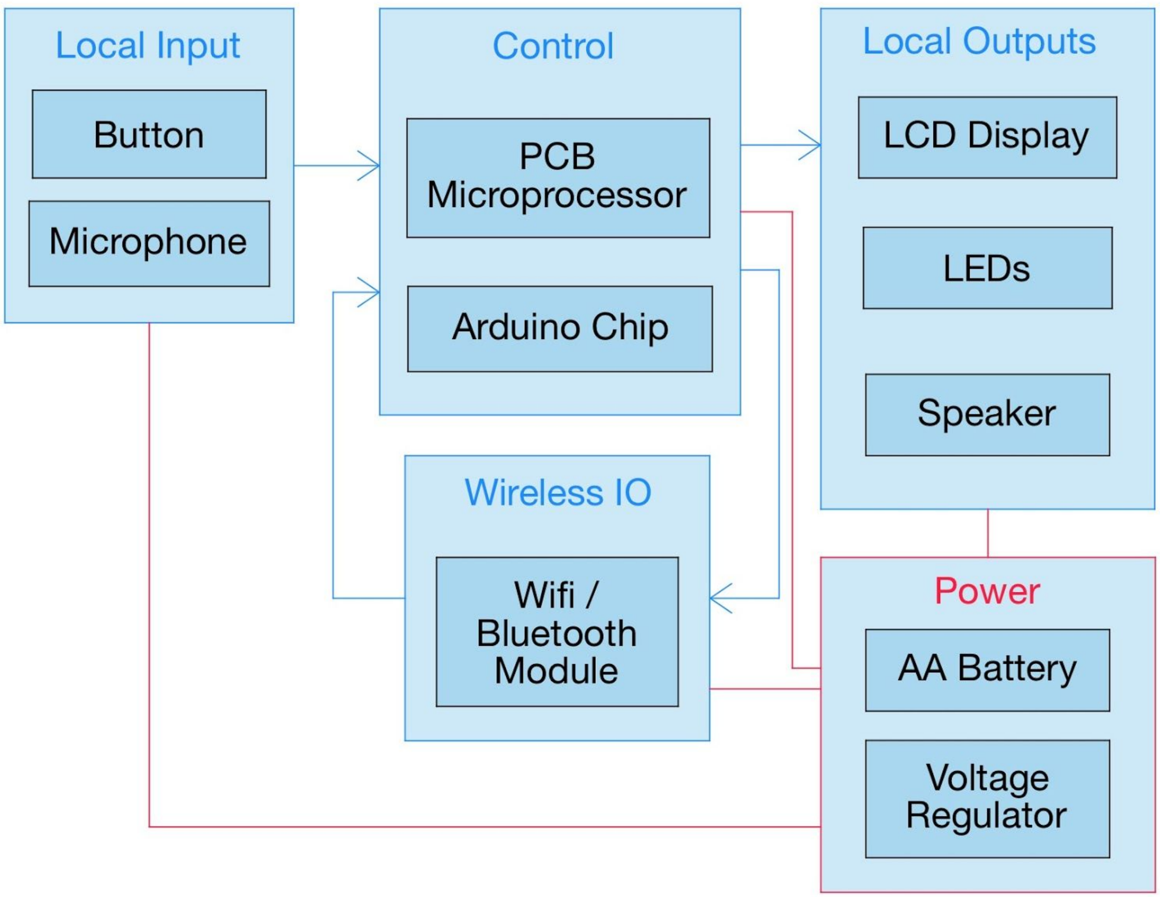
Multi-Function IoT Button

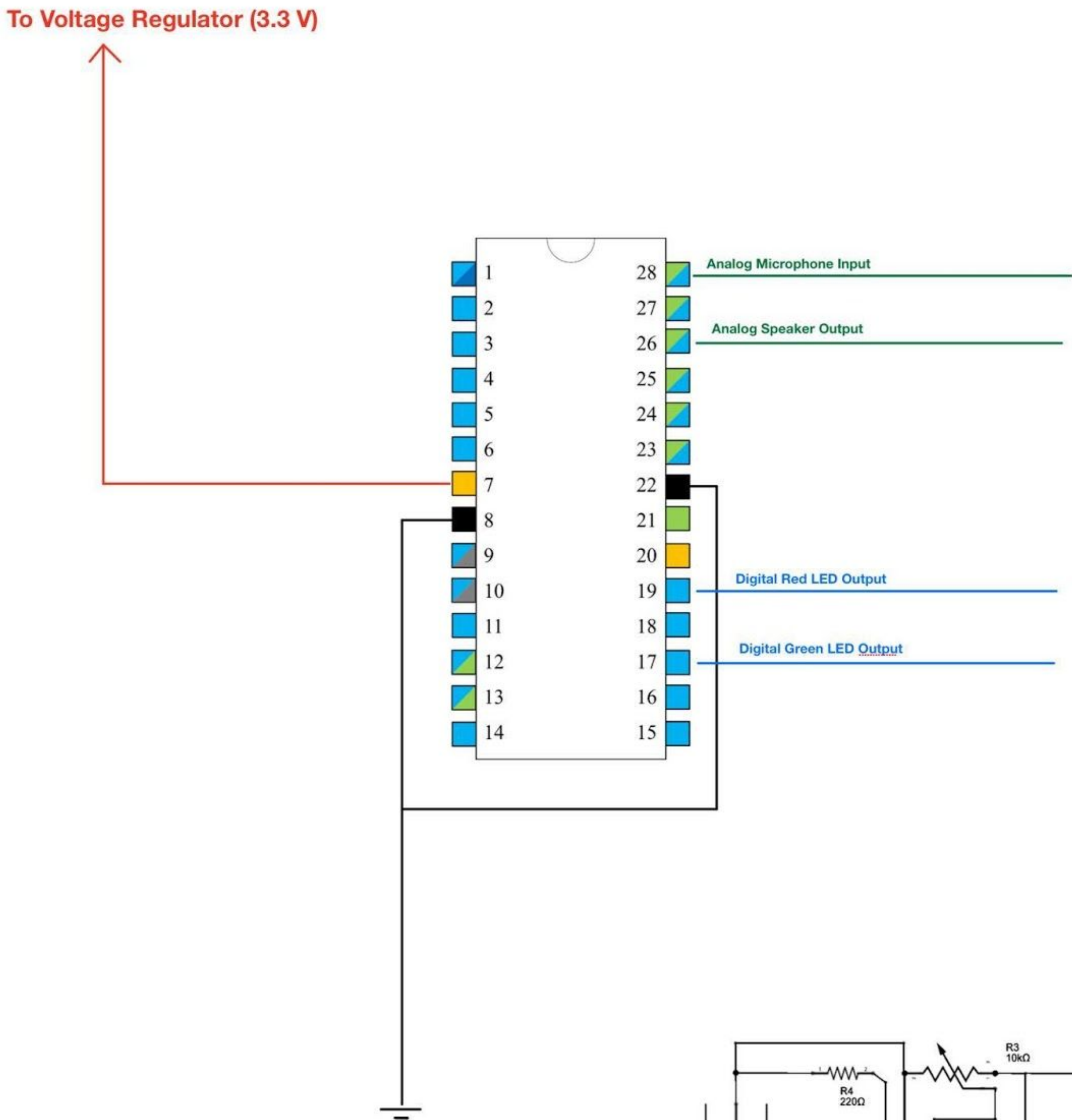
Mock Design Review
Team 88 - Naveed Jamali, Daryl Lim, Jin Li
ECE 445 — Spring 2017
TA: Eric Clark

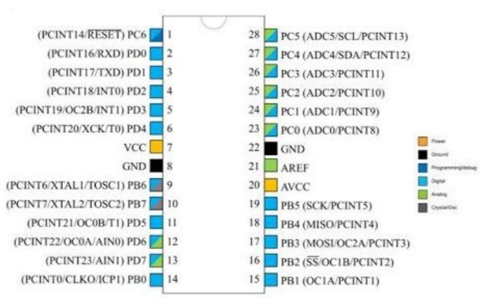
1. Block diagram

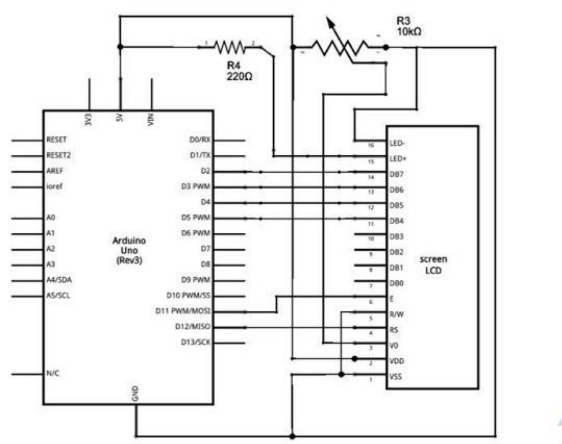


2. Circuit Schematic

Control Unit







3. Calculation

Power

One of the key intended features of our button is to be able to last for weeks to months before a battery change, as frequent battery changes on buttons would prove tedious. Thus, we decided to calculate the battery life of our buttons.
Our choice for batteries is a pack of four Alkaline AA battery connected in series, which has a combined output voltage of 6 V, and a capacity of about 2500 mAh. [2] The ATmega328P runs at 3.3V, 3.58 mA when active, and at 3.3V, 0.0045 mA when powered down. [3]
Assuming the most power consuming scenario of the ATmega328P being active around the clock, we have power consumption of:

3.58mA x 24h/day = 85.92 mAh/day

With our initial battery capacity of 2500 mAh, we find that the number of days our batteries should be able to supply power to the ATmega chip should be:

2500 mAh / 85.92 mAh/day = 29.09 days

Not only does this fit our requirement of the battery life lasting from weeks to months, but whenever the user leaves the house or commands the button to be inactive, the ATmega328p would power down, shifting to using 0.0045 mA instead. Given a scenario of a single individual working a standard 8-hour work day, the ATmega328p would power down during that time, giving us a power consumption instead of:

0.0045 mA x 8h/day = 0.036 mAh/day

3.58mA x 16h/day = 57.28 mAh/day

Or a total of 57.28 + 0.036 mAh/day = 57.316 mAh/day, or a battery lifespan of:

2500 mAh / 57.316 mAh/day = 43.618 days

4. Simulation Plot

Pattern Recognition

We simulated the procedure for word recognition. Below is a convergence plot for four different kinds of classifiers. As can be seen, a logistic classifier or a SVM classifier is more ideal than a linear classifier or a simple perceptron classifier in terms of how quickly the classification error plot converges.

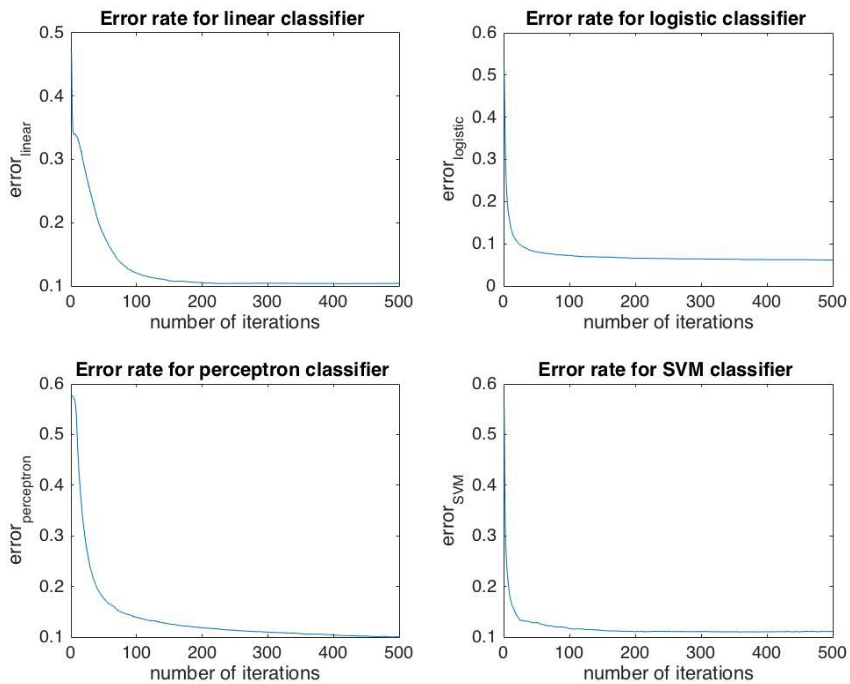


Figure: Classification Errors vs Number of Iterations

Theoretical basis:

The following table shows the error metric (different from the classification error rate) of the four different classifiers we explored, and their corresponding gradient equation for gradient descent.

	Error Metric	Gradient Equation
linear	$E = \sum_i((t_i - y_i)^2) = \sum_i((t_i - g(w'x_i + b))^2)$ $g(a) = a$	$\frac{dE}{dW_j} = -2 * \sum_i (t_i - (w'x_i + b)) * x_{ji}$
logistic	$E = \sum_i((t_i - y_i)^2) = \sum_i((t_i - g(w'x_i + b))^2)$ $g(a) = \frac{1}{1+exp(-a)}$	$\frac{dE}{dW_j} = -2 * \sum_i (t_i - y_i) * y_i * (1 - y_i) * x_{ji}$
Perceptron	$E = \sum_i(max(0, -(w'x_i + b) \cdot t_i))$	$\frac{dE}{dW_j} = \sum_{errors}(-x_i \cdot t_i)$ [1]
SVM	$E = C * (\|w\|^2 + \sum_i max(0, 1 - t_i * (w'x_i + b)))$	$\frac{dE}{dW_j} = C * (2w_j + \sum_{errors}(-x_i \cdot t_i))$ [1]

** t denotes true labels, y denotes predicted labels, g conventionally denotes a non-linearity, w denotes weights, b denotes biases, x denotes input data, and C is a tunable constant.*

5. Block Description

Control Unit

In the control unit, we will design a microcontroller using AutoDesk EAGLE. It will implement one large state machine used in the operation of the button. The state machine will have three main branches for each mode the button is set to. State transitions will react to button inputs as well as some sort of timekeeping chip on the PCB.

The PCB microcontroller should be powered by our batteries with the voltage stabilized by the voltage regulator, and should be the center of connection for all functional components in our design: the microphone input, button input, speaker output, LCD display, LED display, and bluetooth connection.

We intend to mount an Arduino chip (ATmega 328) onto our PCB, in order to utilize its processing powers to run word recognition algorithms on extracted features of the audio input. Our main approach is to pre-train the weights and biases of a fully-connected neural network on a laptop for specific words, and deploy those weights and biases onto Arduino for real-time recognition. Our alternative approaches can be a CNN, HMM (Hidden Markov Model) for the words to recognize, or even a simple K-Nearest-Neighbor classifier with a pre-recorded database for feature matching.

6. Requirements and verifications for one module from the block diagram

Control Unit

Below are the requirements and verifications of the control module in our block diagram design.

Requirement	Verification
1. *PCB microcontroller must be programmable to set the button to a certain mode and label*	*Test three times with three modes; has to successfully pass all three test cases. (for example, set to "counter for number of push-ups done", "hourly alarm for getting up to walk around when you're working", "cycling through family members to determine whose turn it is to do the designated chore")*
2. *PCB microcontroller must be able to correctly read the inputs (button press, bluetooth)*	*Button: create a simple counter program on the ATmega. Each button press should increment the counter by exactly one, verifying that the button is debounced and working.* *Bluetooth: for testing purposes, an LED should light up when a device is connected and turn off when it is out of range.*
3. *PCB microcontroller must set proper outputs to LCD display, LEDs, Speaker, and iPhone*	*LEDs: a blink should set the voltage to HI (3-5 V) for 1 second before returning to low (0-1.5 V). Can observe with oscilloscope.* *LCD Display: Display a hard coded test string of characters* *Speaker: must be able to Output two distinct audible frequencies with a 50 MHz tolerance*
4. *Arduino chip must be able to retrieve sound from the microphone*	*Test by comparing the incoming audio signal in the time domain in Arduino to the same audio signal displayed in time domain in MATLAB.*

5. *Arduino chip must be able to carry out algorithmic operations on audio input.*	*Test by comparing the output results of algorithmic operations on the same input, both on the Arduino chip and in MATLAB.*

7. Safety statement

Our button in and of itself is relatively low risk as it is intended to run on only a single battery as a power supply. The main points of concern would have to be more ethically related than physically - concerns such as users being dangerously reliant on the buttons, such as relying on solely the button to keep track of intake of medicine in which case malfunctions could be deadly. In accordance with the IEEE Code of Ethics, #1: “to accept responsibility in making decisions consistent with the safety, health, and welfare of the public” [4]. Also, if the use of an emergency help application were to malfunction and the user believes help is on the way when it isn’t, this would prove to be fatal as well. As stated in the ACM Code of Ethics and Professional Conduct #1.2: “One way to avoid unintentional harm is to carefully consider potential impacts on all those affected by decisions made during design and implementation.” [5]

Solutions to this issue, on top of making sure the button works as intended as often as possible through heavy testing, is to include cautions to not be overly reliant on the buttons in case malfunctions occur. Additionally, in the case of the emergency help application, we could include a message on the LCD screen assuring that the message ad been sent.

Citations

[1] Cortes, C., & Vapnik, V. (2014). Support-Vector Networks. Retrieved from

http://homepages.rpi.edu/ bennek/class/ mmld/papers/svn.pdf

[2] “Battery Myths vs Battery Facts”. 2017.[Online]. Available:

http://www.greenbatteries.com/battery-myths-vs-battery-facts-1/ [Accessed:

20-Feb-2017].

[3] “Arduino Low Power - How to Run a ATmega328p For a Year On Coin Cell Battery”, 2017.[Online].Available:http://www.home-automation-community.com/arduino-low-power-how-to-run-atmega328p-for-a-year-on-coin-cell-battery/. [Accessed: 21-Feb- 2017].

[4] Ieee.org, "IEEE Code of Ethics", 2016. [Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 08-Feb- 2017].

[5] acm.org, "ACM Code of Ethics and Professional Conduct", 1992. [Online]. Available: https://www.acm.org/about-acm/acm-code-of-ethics-and-professional-conduct. [Accessed: 08- Feb- 2017].