Clever Coasters

Group C

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Motivation

- Busy restaurant
- Your drink is empty
- You haven’t seen the waiter in a long time
- Waiters are too busy
- Customer experience is

Rejected Ideas

Computer Vision System

- Expensive
- Static
- Lots of Interference

Sensor in Cup

- Difficult to Maintain
- Hard to Use and Charge

Full Table System for Detection

- Hard to Separate Signals
- Very Costly

Full Table System for Charging

- Lots of EM leakage
- Very Inefficient
- Inconvenient to Power

Goals and Objectives

- Wirelessly Communicating Smart Drink Coasters
- Automatic Drink Monitoring System
- Make Restaurant Staff More Efficient
- Improve Customer and Employee Experience

Marketing Requirements

- Smart
- Low Cost
- Easy to Use and Recharge
- Durable and Water Resistant
- Works All Day on a Single Charge

Responsibilities

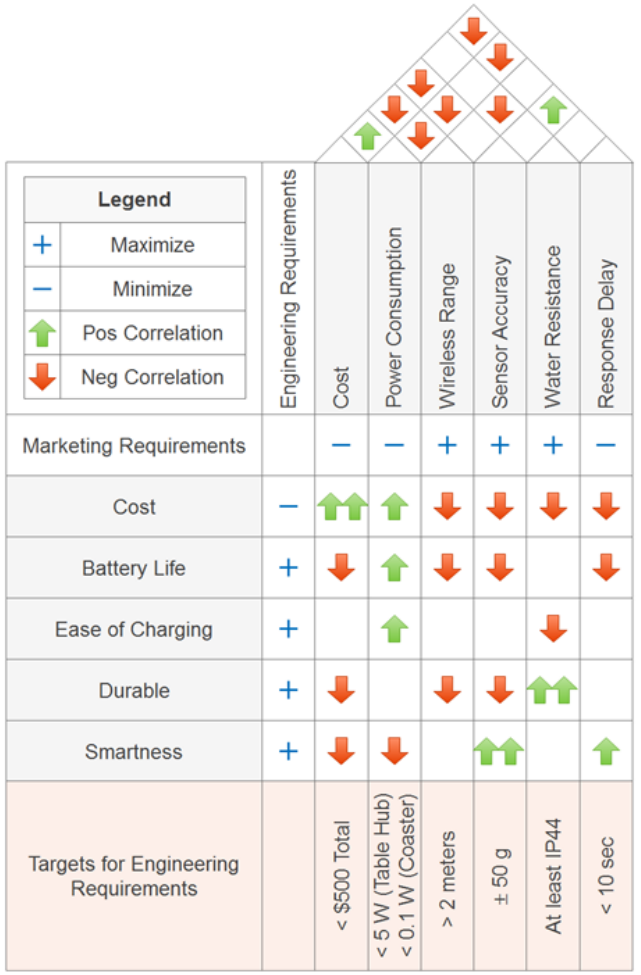
	Rubba	Mitchell	Ted
PCB Design	Primary	Secondary	
Microcontroller		Primary	Secondary
Wireless		Primary	Secondary
Power	Secondary		Primary
Programming	Secondary	Primary	Primary
Weight Sensor	Primary		Secondary
Housing	Secondary	Secondary	Primary
Interface	Primary	Secondary	

Engineering Specifications

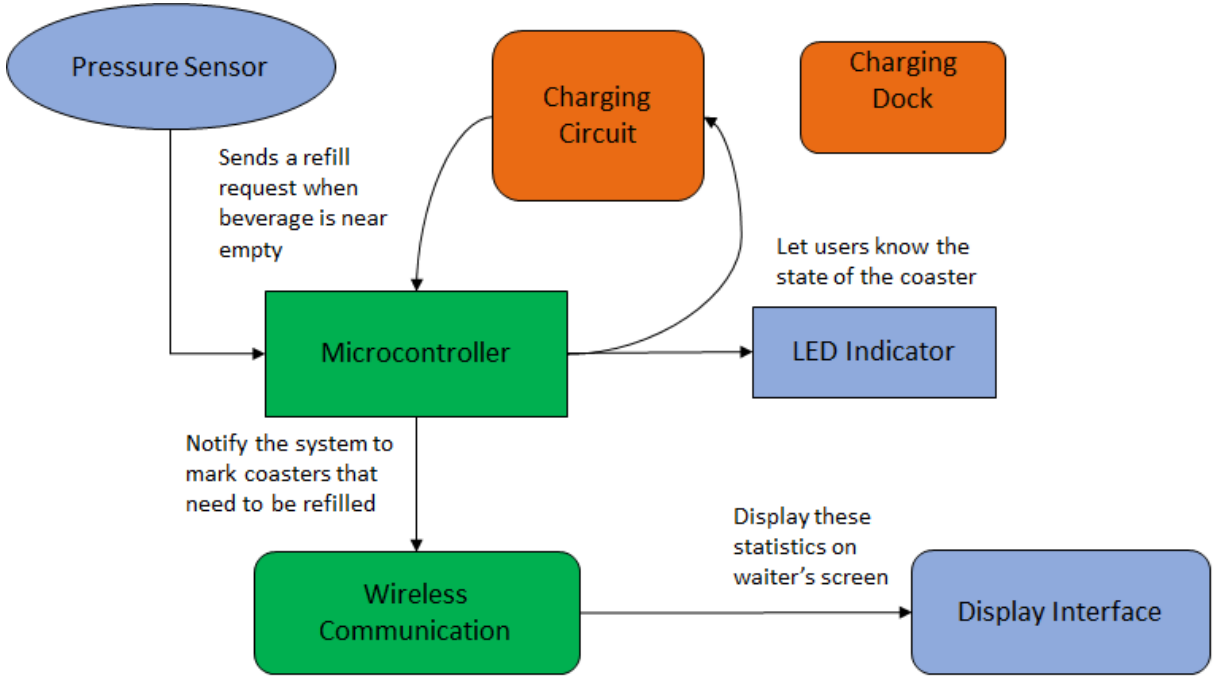
Cost	<$500 for Prototype System
Power:	<5w Total Usage
Wireless Range	>2 Meters
Weight Accuracy	+/- 50g
Water Resistance	At least IP44
Response Delay	<10 seconds

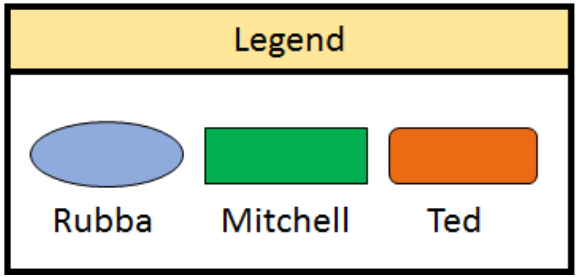
House of Quality

- Cheap Components are Important
- Good Battery Helps with Charging
- Accurate Sensors Important, but High Cost
- Waterproofing Important for Longevity
- Must Balance Power, Responsiveness, Cost



Hardware Block Diagram





Wireless Technology Selection

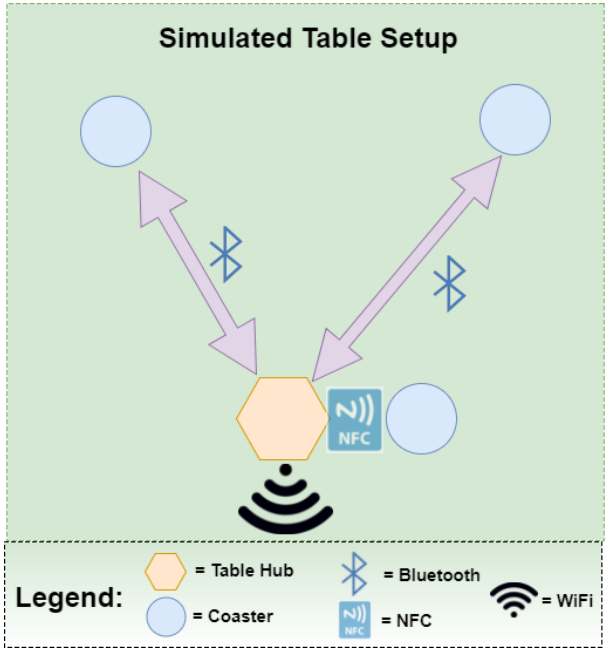
- Had to consider several design factors
  - Size of network: Table or Restaurant wide
  - Ease of moving coasters between areas
  - Usability
- Advantages and disadvantages to all options
  - Bluetooth LE: low power, but not enough range

	Bluetooth LE	ZigBee	Wi-Fi	RFID (passive)
Cost per tag or module	~$10	~$18	~ $7-20	~$2
Range (meters)	50	up to 100	50 - 250	< 3
Power Usage	Very low	Very low	High	None
Network Latency	< 1 sec	< 30 ms	< 100 ms	< 100 ms

Wireless Technology Selection

In the end, we decided to combine multiple wireless technologies, utilizing the best aspects of each

- The coasters communicate with the table hub via bluetooth
- They sync to the correct table hub via NFC
- The table hub communicates to the central hub via WiFi



Microcontroller Comparison

	MSP430	M24LR Discovery	Arduino Uno	ATtiny85	TI CC2540
Power consumption	0.851 mW	0.722 mW	0.740 mW	0.370 mW	0.851 mW
Max Clock	16 MHz	16 MHz	20 MHz	20 MHz	32 MHz
GPIO pin count	16	41	23	8	21
Current output per pin	48 mA	80 mA	100 mA	40 mA	20 mA
Flash memory size	16 KB	8 KB	32 KB	8 KB	256 KB
RAM size	512 B	2 KB	2 KB	512 B	8 KB
Cost	$2.32	$21.25	$24.95	$1.20	$4.73

Bluetooth Module Options

	RN42	TI CC2540	nRF51822
Cost	$18.95	$4.73	$4.62
Compatibility	UART	SPI/UART	SPI/UART
Bluetooth LE	No	Yes	Yes
Idle power consumption	26 µA	0.9 µA	2.6 µA
Active power consumption	45 mA	23.8 mA	8 mA

*TI CC2540 is an MCU with a built in Bluetooth module

NFC Module Comparison

	PN532	TRF7970A	MFRC522
Cost	$4.80	$5.82	$4.14
Maximum read distance	50 mm	N/A *	50 mm
Supports SPI	Yes	Yes	Yes
Supports UART	Yes	No	Yes
Supports I^2C	Yes	No	Yes
Idle power consumption	2 µA	0.5 µA	5 µA
Alert power consumption	45 µA	120 µA	10 µA
Active power consumption	50 mA	70 mA	60 mA

NFC Tag Support

	ISO/IEC 14443A	ISO/IEC 14443B	ISO/IEC 15693 & ISO/IEC 18000-3	ISO/IEC 18092 & ECMA 340 P2P	FeliCa	NTAG
PN532	Yes	Yes (Read only)	No	Yes	Yes	No
TRF7970A	Yes	Yes	Yes	No	Yes	No
MFRC522	Yes	No	No	No	No	Yes

ISO/IEC 14443A has a security issue where it can be hacked

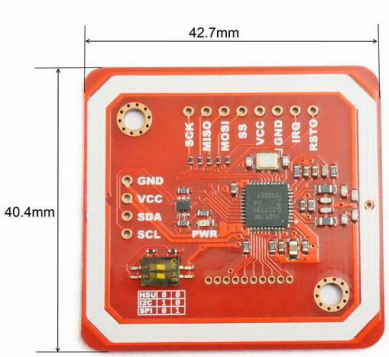
Final choices

Microcontroller: CC2540

- Built in bluetooth
- Low cost
- Moderate GPIO pins

NFC: PN532

- Supports all serial interfaces
- Relatively low power usage



Device Power - Requirements and Considerations

- Wireless - Mobility
- Long Lasting - Full Day of Service
- Easy Charging - Convenience and Time Saver
- Safe - Around Food and Drinks

Device Power - Battery Type - Comparison

	Energy Density (Wh/kg)	Internal Resistance (mΩ)	Cycle Life	Charge Time (Hours)	Overcharge Tolerance	Cell Voltage	Load Current (Optimal)	Maintenance Requirement
Alkaline	80	200-2000	50	2-3	Moderate	1.5V	<0.2C	None
Lead	30-50	<100	200-300	8-16	High	2V	0.2C	3-6 Months
NiCd	45-80	100-200	1500	1	Moderate	1.25V	1C	30-60 Days
NiMH	60-120	200-300	300-500	2-4	Low	1.25V	<0.5C	60-90 Days
Li-Ion	110-160	150-250	500-1000	2-4	Very Low	3.6V	<1C	None
LiPo	100-130	200-300	300-500	2-4	Low	3.6V	<1C	None

Device Power - Battery Type - Choice

Li-Ion VS LiPo

Li-Ion has more Cycles

LiPo has better Overcharge Tolerance

LiPo has better Form Factor

LiPo is the Winner

Device Power - Specific Battery Choice

800 mAh Capacity

$3.33 per Battery

25C Discharge Rate

240 mAh/Dollar

44mm X 24mm X 9mm Dimensions

Device Power - Charging Solution - Comparison

	Work for Employees	Reliability of Charge	Safety	Added Complexity	Long Term Cost	Scalability
Replaceable Batteries	Check and Replace	Low (could run out)	Liquid Exposure	Accessibility and Water-proof	Frequent Replacement and Disposal	Poor
Wired Charging	Collect and Plug in	High	Liquid Exposure	Water-proof, Cables, Circuit	Electricity and Wires	Poor-Medium
Charging Dock	Collect and Stack	High	Dock Short	Circuit, Current Limit	Electricity	High
Induction Charging	Collect and Stack	Medium (slow charge)	EM Interference	Circuit, Coil, HFAC->DC, Detection	Lots of Electricity	Medium-High

Device Power - Charging Method - Choice

Charging Dock

Cost Effective

Reliable

Easy to Use

Scalable

Device Power - Charging Method - Dock Design

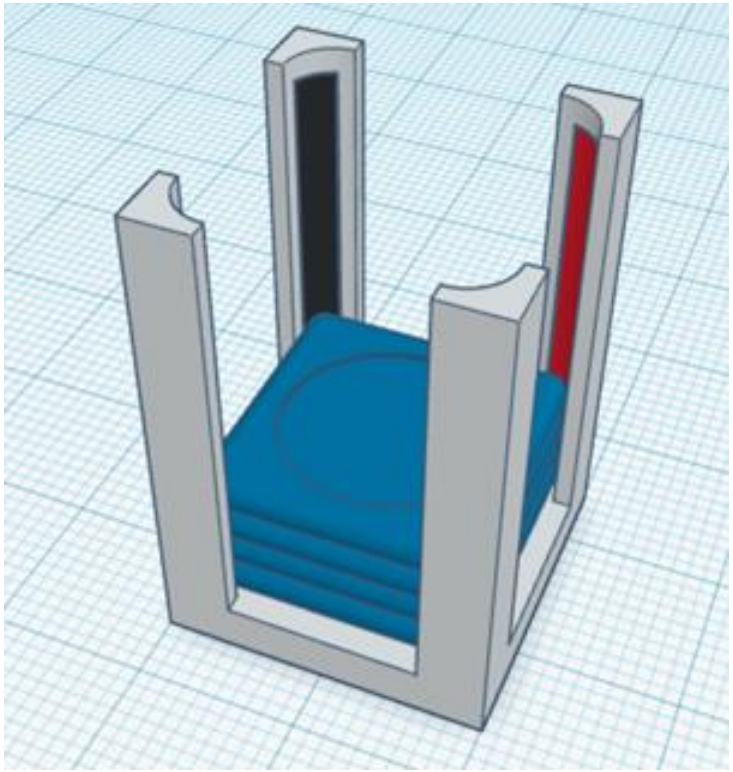
AC-DC Switching PSU

Short Circuit Prevention

Over-(Voltage, Current, Temperature) Protection

Two Rails

9V DC



Device Power - Charging Theory

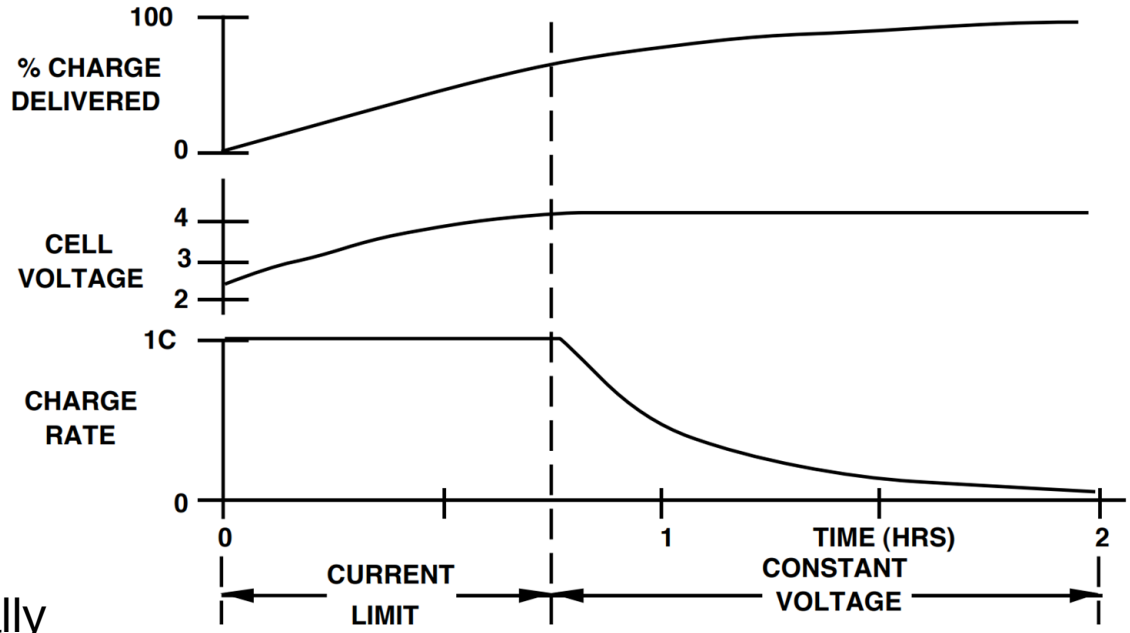
Two Stages

Current Limited

- Safe Charging Current
- Up to ~66% Charge

Constant Voltage

- Voltage at 4.2V
- Current Decays Exponentially

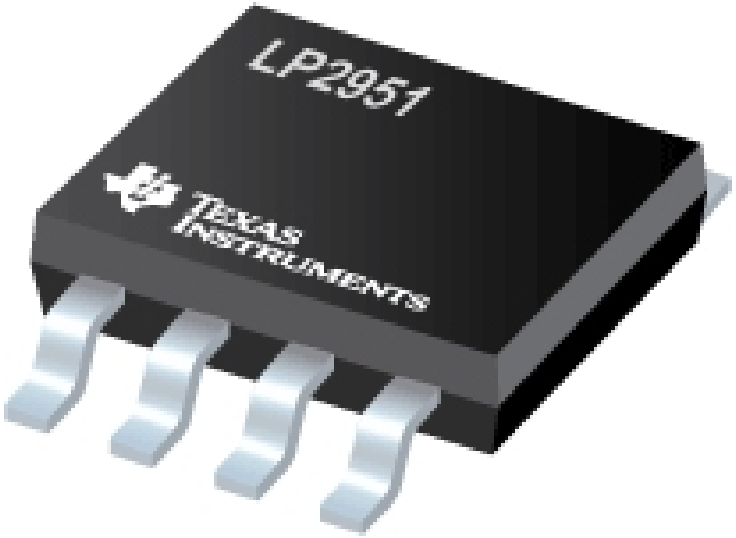


Device Power - Linear Regulator - Comparison

	Max Out Current (A)	Dropout Voltage (V)	Quiescent Current (mA)	Accuracy (%)	Pin Layout	Feedback Resistance	Cost per Unit
LP38798	0.8	0.200	1.4	2	12WSON	<250	$3.25
TLV1117	0.8	1.200	1.7	1.6	4SOT-233	1000+	$0.72
TPS7A19	0.45	0.240	0.015	2	8SON	<100	$1.61
TPS7A49	0.15	0.260	0.06	2.5	8SON	<780	$2.75
LP2951	0.1	0.380	0.075	2	8SOIC	1000+	$0.68

Device Power - Linear Regulator - Choice

LP2951



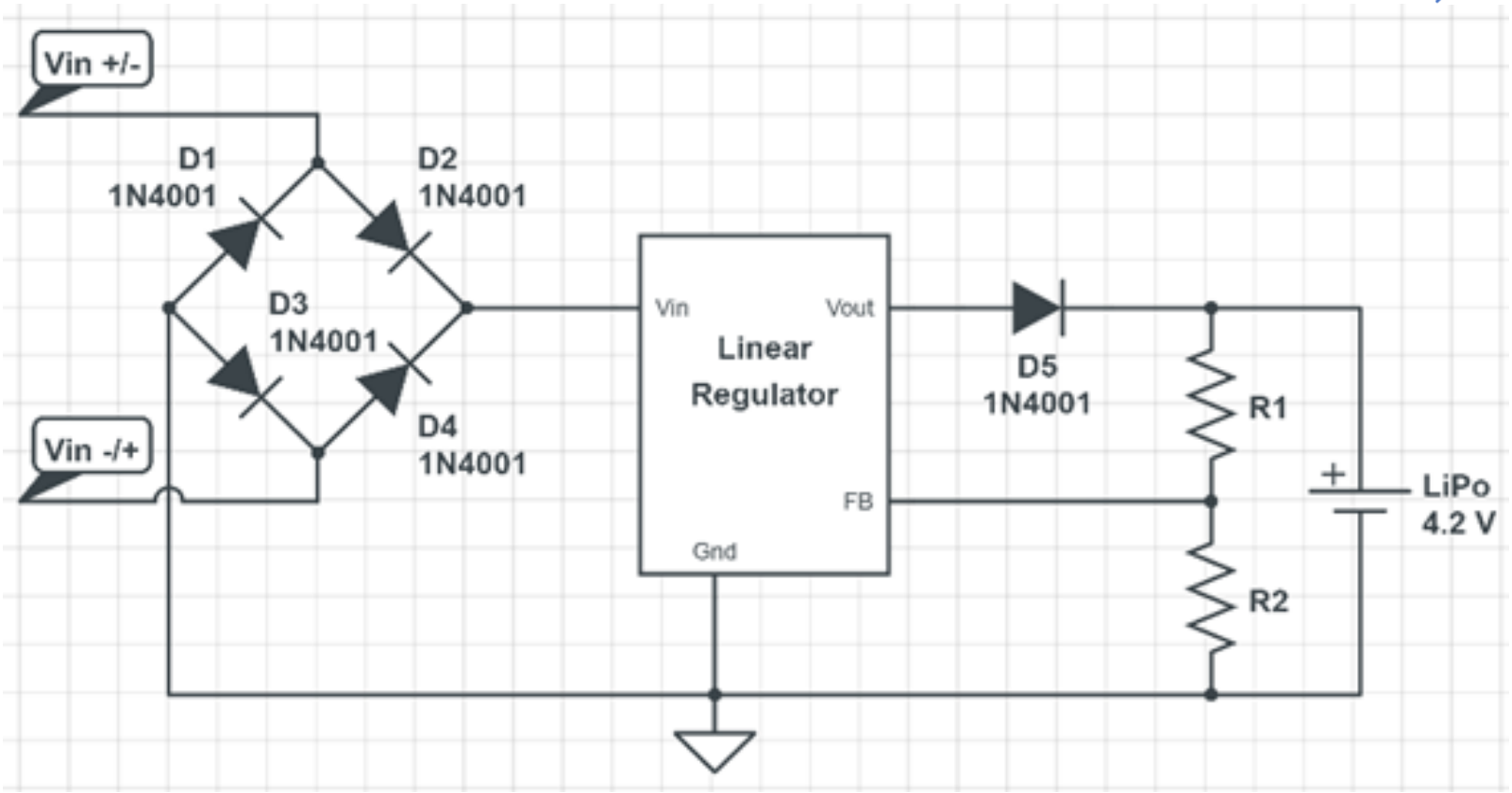
Lowest Cost

High Feedback Loop Resistance

Good Accuracy

Low Current Output - Results in Longer Charging Time

Device Power - Charging Circuit

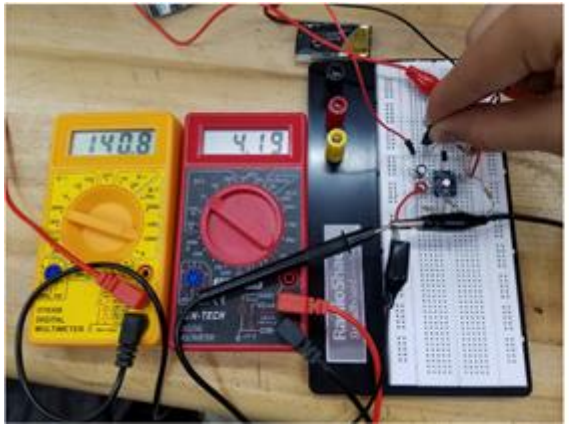


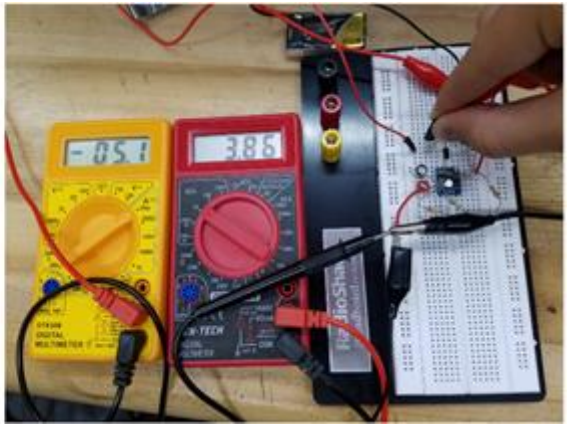
Power System Testing

Two Linear Regulators

TLV1117 VS LP2951

Reference Voltage Issue





LP2951 - Stable Output Voltage

Resistors must be adjusted for each Coaster

Circuit Works, Batteries Nominal, Diodes Functioning

Weight Sensors

FSR

Force-Sensitive Resistors (FSRs) are sensors that allow you to detect physical pressure, squeezing and weight.

- More expensive
- More accurate when pressed
- Did not detect weight of cup (Produced Resistance of 1)

Velostat

Velostat is a pressure-sensitive packaging material made of a polymeric foil with carbon black to make it electrically conductive.

- Very cheap (1 sheet ~ $5)
- Not as accurate
- Can cover a wider surface area

The better choice!

Testing the FSR

Test 1 – Pressing

Light Pressing *(Higher Resistance* ***Hard Pressing*** *(Lower Resistance)*

Test 2 – Mouse Weights

Weight (grams)	0	1.7	3.4	4.5	9	13.5
Resistance 2000k	infinite	infinite	infinite	infinite	infinite	infinite

Testing the Velostat

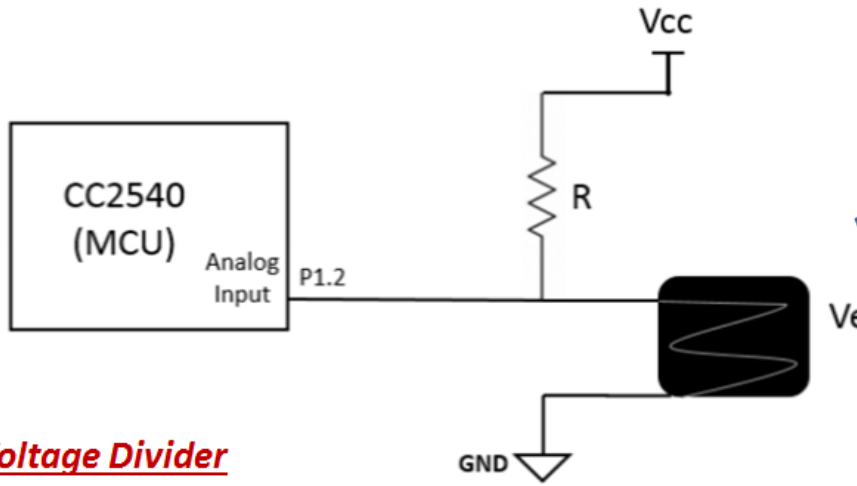
Test 1 – Pressing

Empty Cup *(Higher Resistance* ***Full Cup*** *(Lower Resistance)*

Test 2 – Mouse Weights

Weight (grams)	0	1.7	3.4	4.5	9	13.5
Resistance (2000k)	15	12	9	9	9	8

Weight Sensor Interface Design



Velostat Weight Sensor

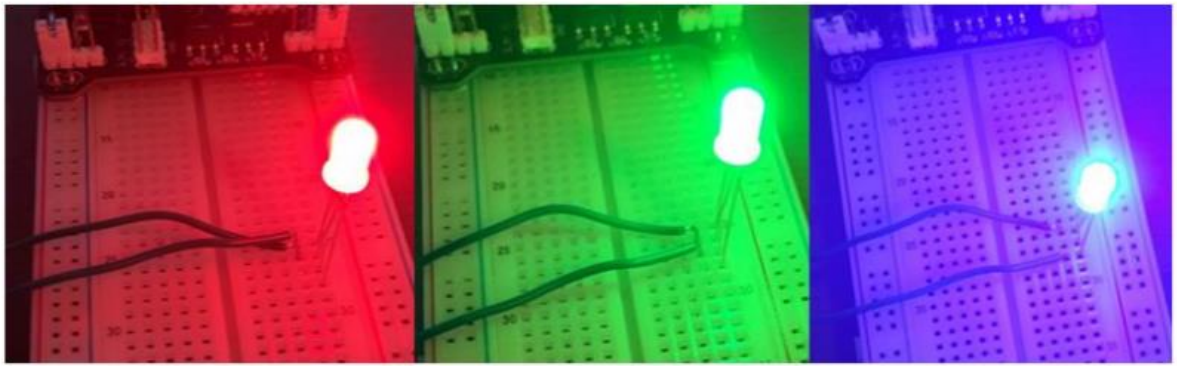
Use conductive thread to connect Velostat to circuit!

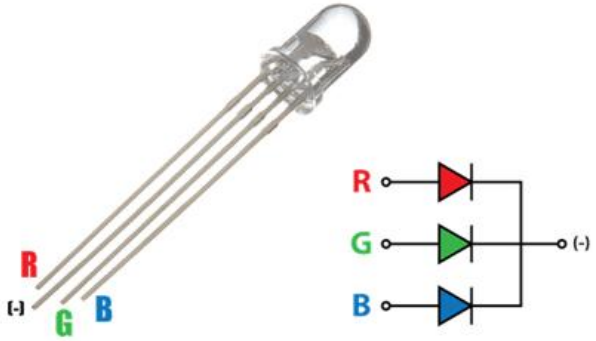
Voltage Divider

Testing the Voltage Divider

Since an increase in weight/pressure causes a decrease in resistance across the Velostat, there is a decrease in the voltage seen by the multimeter

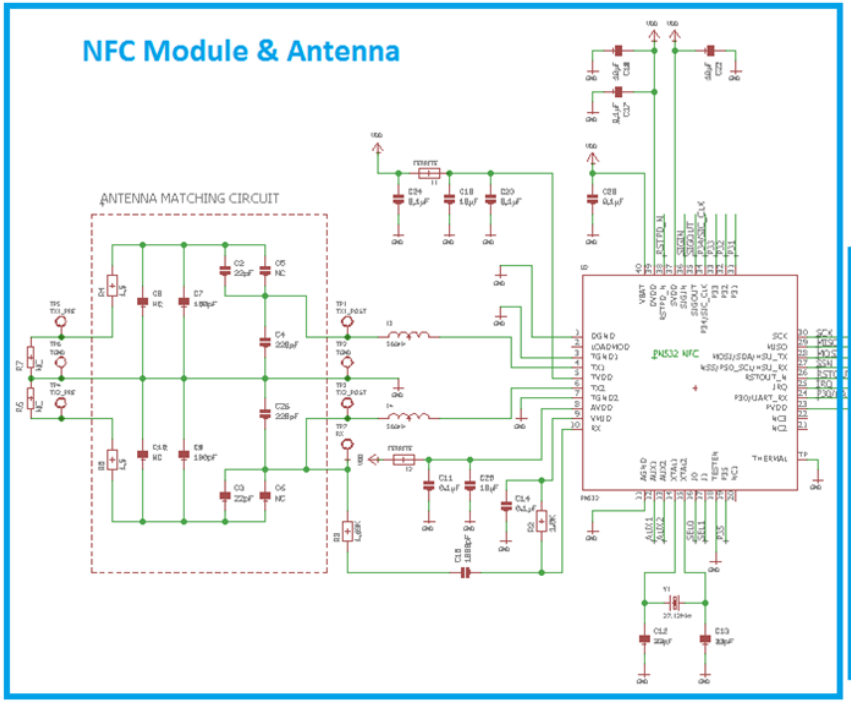
Testing the RGB LED

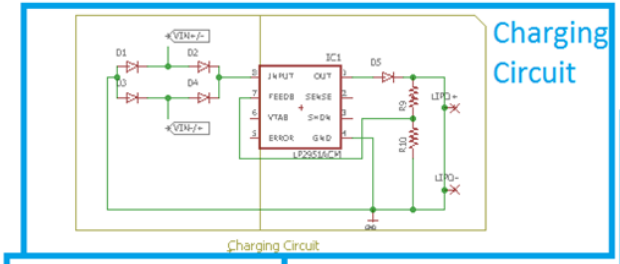


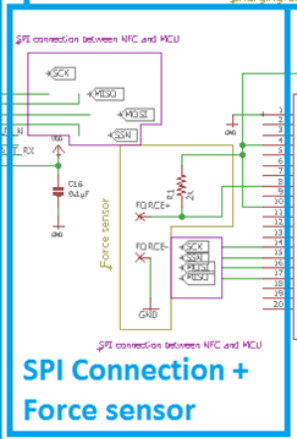


Green will indicate waiter request
Blue will indicate a cup that is at most 30% full
Red will indicate a Do Not Disturb mode

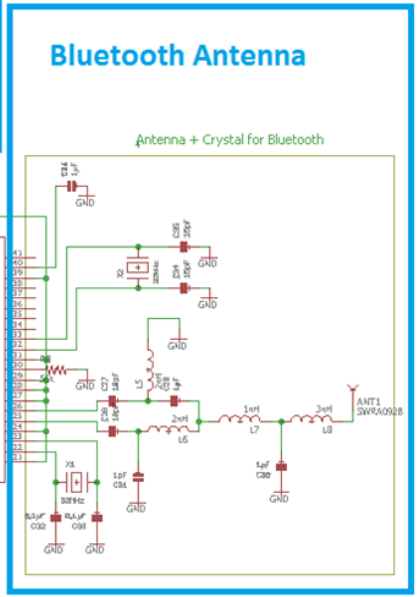
PCB Design


NFC Module & Antenna
ANTENNA MATCHING CIRCUIT


Charging Circuit
Charging Circuit


SPI connection between NFC and MCU
Force sensor
SPI connection between NFC and MCU
SPI Connection +
Force sensor


VOLTAGESOURCE
CC2540_RHA_40
CC2540 MCU + Bluetooth


Bluetooth Antenna
Antenna + Crystal for Bluetooth

Software Design

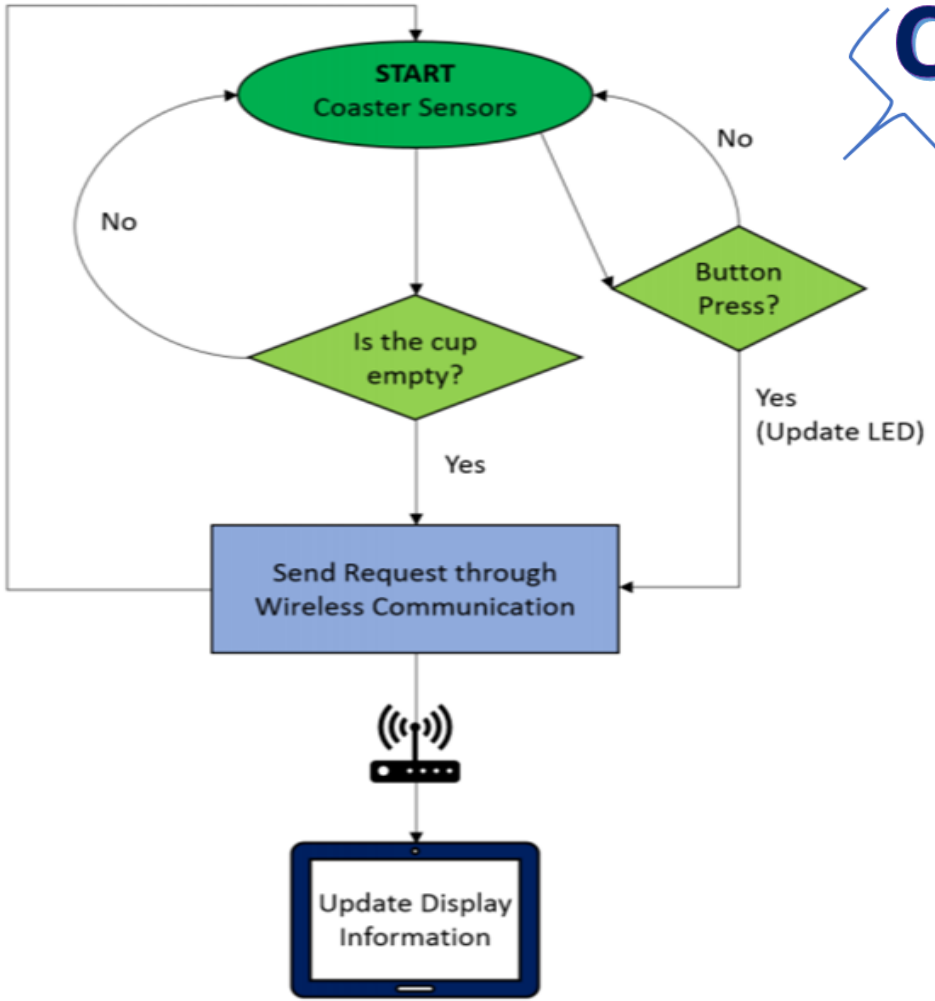
Calibration Mode

Sensor Monitoring

Wireless Communication - Bluetooth

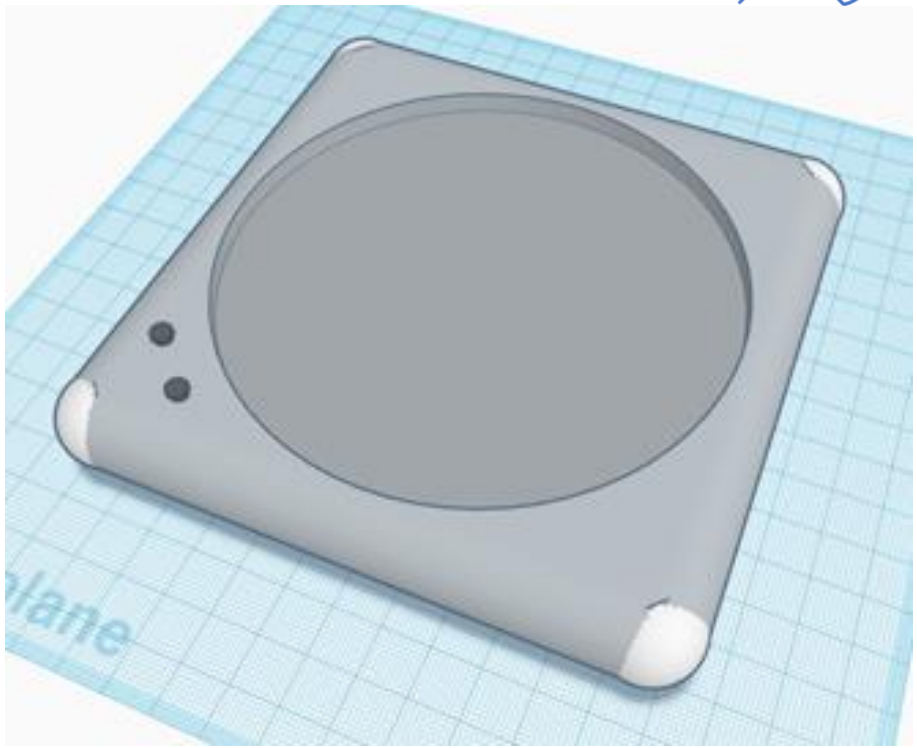
Wireless Communication - NFC

Software Block Diagram



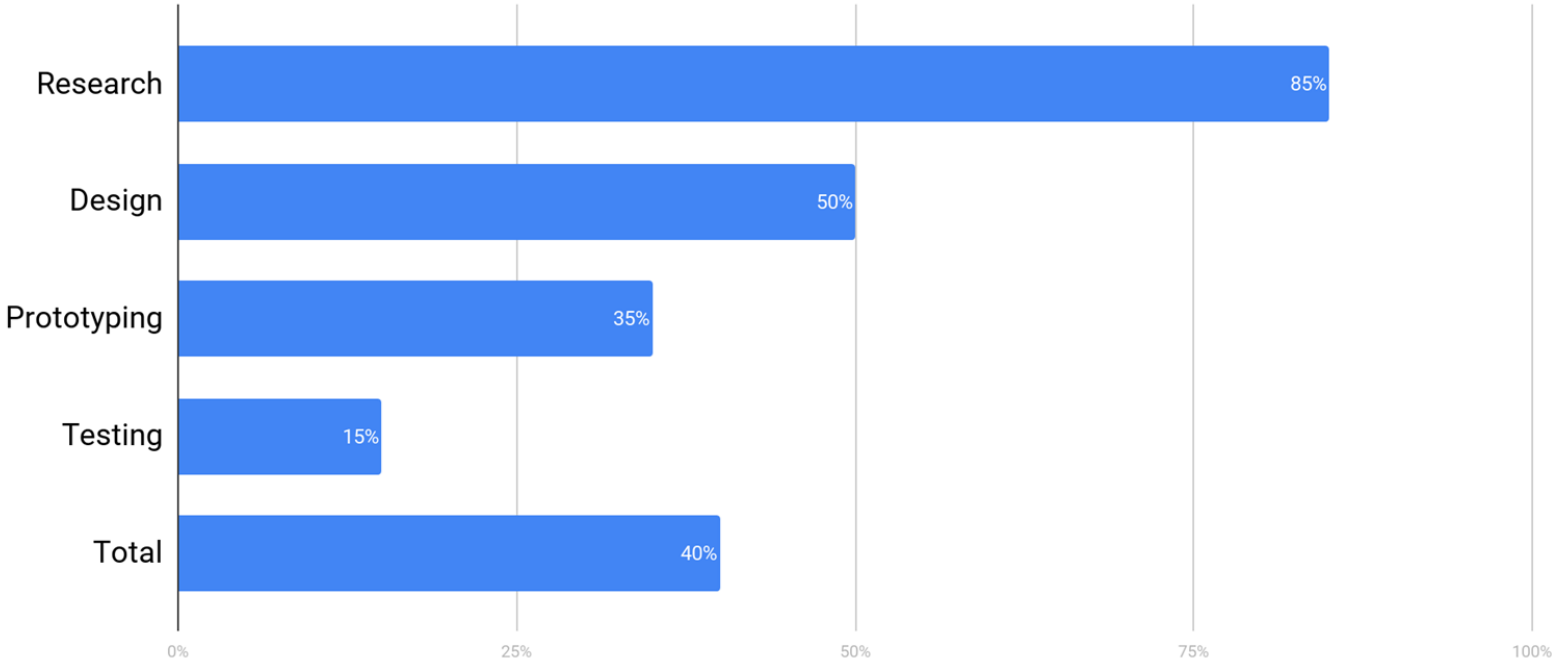
Coaster Housing

- 3D-Printed
- ABS
- Water Resistant
- Depressed Center
- Buttons
- Metal Corners



Description	Quantity	Estimated Cost (each)	Total Cost
Table/Display Device	3	$100 (already have)	-
PN532	6	$4.80	$28.80
TI CC2540	6	$4.73	$28.38
PCB	8	$12.50	$100
Battery pack	6	$6	$36
Coaster outer shell	6	$10	$60
LEDs (pack of 100)	1	$5	$5
Weight sensor	6	$7	$42
Button	6	$1	$6
Charging Station	1	$25	$25
Miscellaneous components	-	-	$25
TOTAL			**$422.18**

Progress


Research
85%
Design
50%
Prototyping
35%
Testing
15%
Total
40%
0%
25%
50%
75%
100%

Questions?