Clever Coasters

Group C

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Motivation - IoT and Wireless Communication

You're at a very **busy restaurant,** and your **drink cup is empty** while eating the spiciest dish of your life. You haven't seen your waiter in a long time, as they are scrambling all over the place with new customers. You're getting angry and have **no way to get the waiter's attention**. You end up leaving the restaurant and giving them a bad review.

Goals and Objectives

- Wirelessly Communicating Electronic Drink Coasters
  - Keep track of the emptiness of a cup
  - Send that data back to the servers
- Automatic Drink Monitoring System
  - Make Restaurant Staff More Efficient
  - Improve Customer and Employee Experience

Engineering Specifications

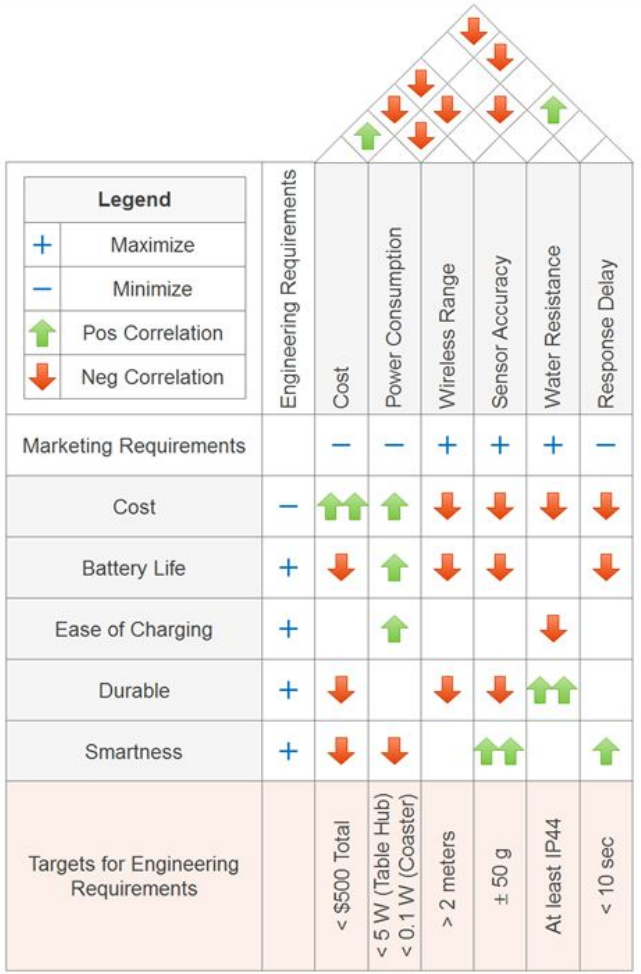
Cost	<$500 for Prototype System
Power:	<5w Total Usage
Wireless Range	>2 Meters
Weight Accuracy	+/- 50g
Water Resistance	At least IP44
Response Delay	<10 seconds

Marketing Requirements

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

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



Microcontroller Comparison

	MSP430	Arduino Uno	TI CC2540	TI CC2650MODA
Power consumption	0.851 mW	0.740 mW	0.851 mW	0.851 mW
Max Clock	16 MHz	20 MHz	32 MHz	48 MHz
GPIO pin count	16	23	21	15
Current output per pin	48 mA	100 mA	20 mA	20 mA
Flash memory size	16 KB	32 KB	256 KB	128 KB
RAM size	512 B	2 KB	8 KB	28 KB
Cost	$2.32	$24.95	$4.73	$11.17

CC2650MODA

Built in Bluetooth Antenna!

Weight Sensor Options and Choice

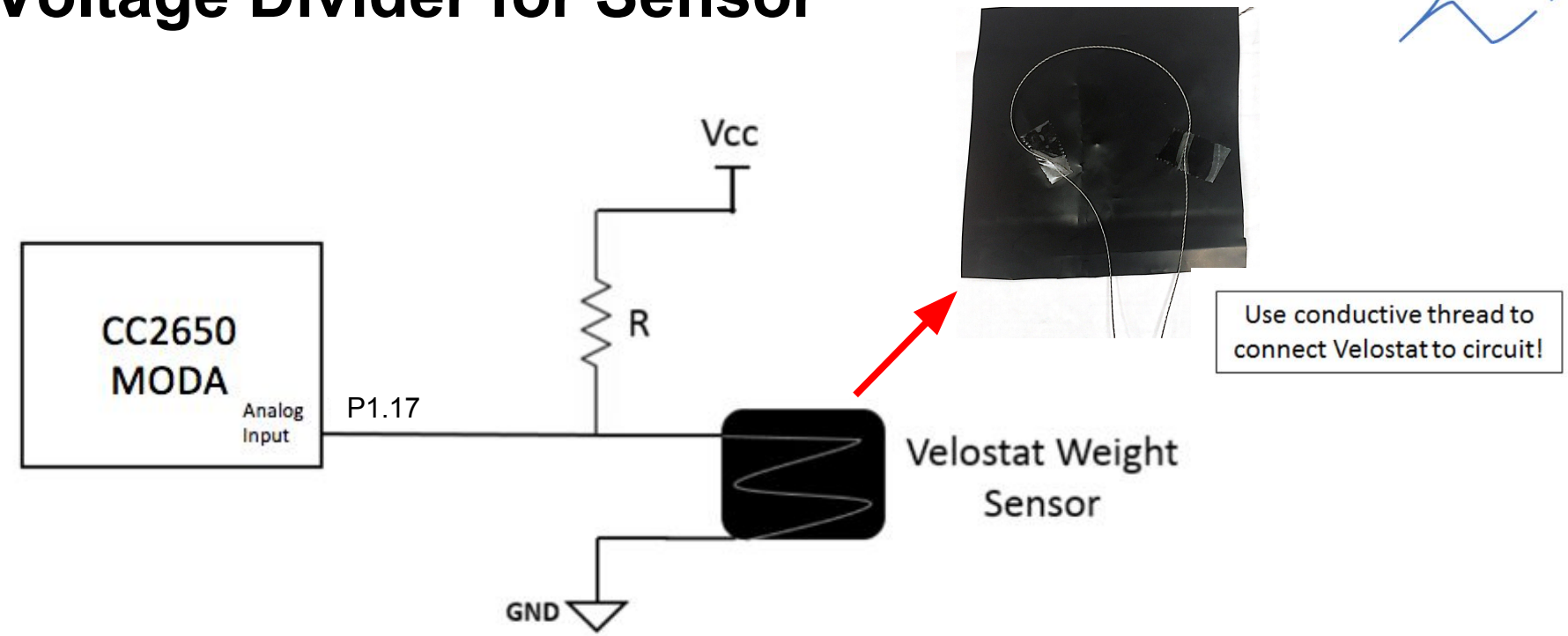
	FSR	Velostat	Load Cell
Cost	~$7	~$4	~$20
Accuracy	~25% error (not very accurate)	Not very accurate	< 0.1% (very accurate)
Force Range	0 –20lbs	~ 1000 g	0-10 kg

Velostat

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

The best choice!
Efficient and Large Surface Area

Voltage Divider for Sensor



Wireless Technology Selection

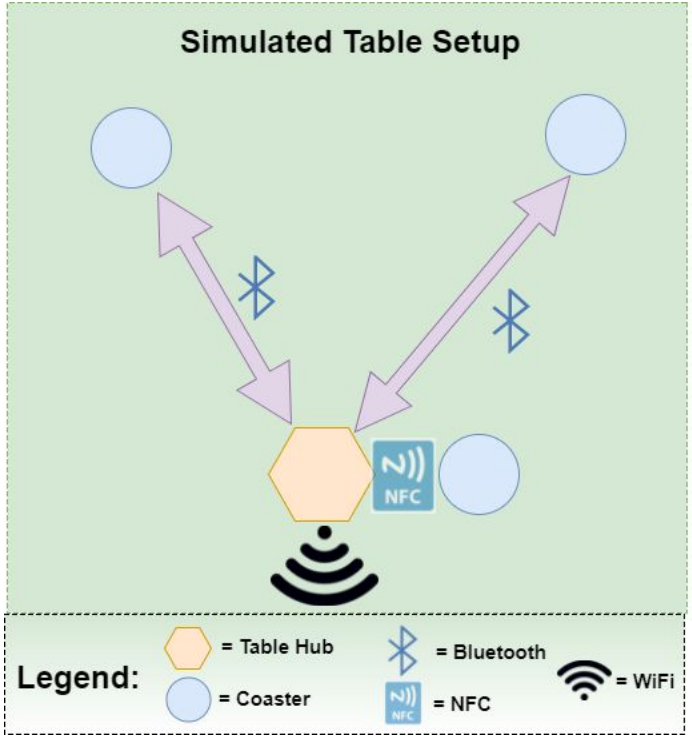
- Had to consider several design factors
  - Size of network: Table or Restaurant wide
  - Ease of moving coasters between areas
  - Usability
- Advantages and disadvantages to all options
  - Bluetooth LE: low power, but not enough range
  - WiFi: long range, but high power
  - RFID: Ultra low range

	Bluetooth LE	ZigBee	Wi-Fi	NFC
Cost per tag or module	~$10	~$18	~ $7-20	~$2
Range (meters)	50	up to 100	50 - 250	< .05
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



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)	Cycle Life	Charge Time (Hours)	Overcharge Tolerance	Cell Voltage	Maintenance Requirement
Alkaline	80	50	2-3	Moderate	1.5V	None
Lead-Acid	30-50	200-300	8-16	High	2V	3-6 Months
NiCd	45-80	1500	1	Moderate	1.25V	30-60 Days
NiMH	60-120	300-500	2-4	Low	1.25V	60-90 Days
LiPo	100-130	300-500	2-4	Low	3.6V	None

Device Power - Specific Battery Choice

800 mAh Capacity

$3.33 per Battery

25C Discharge Rate

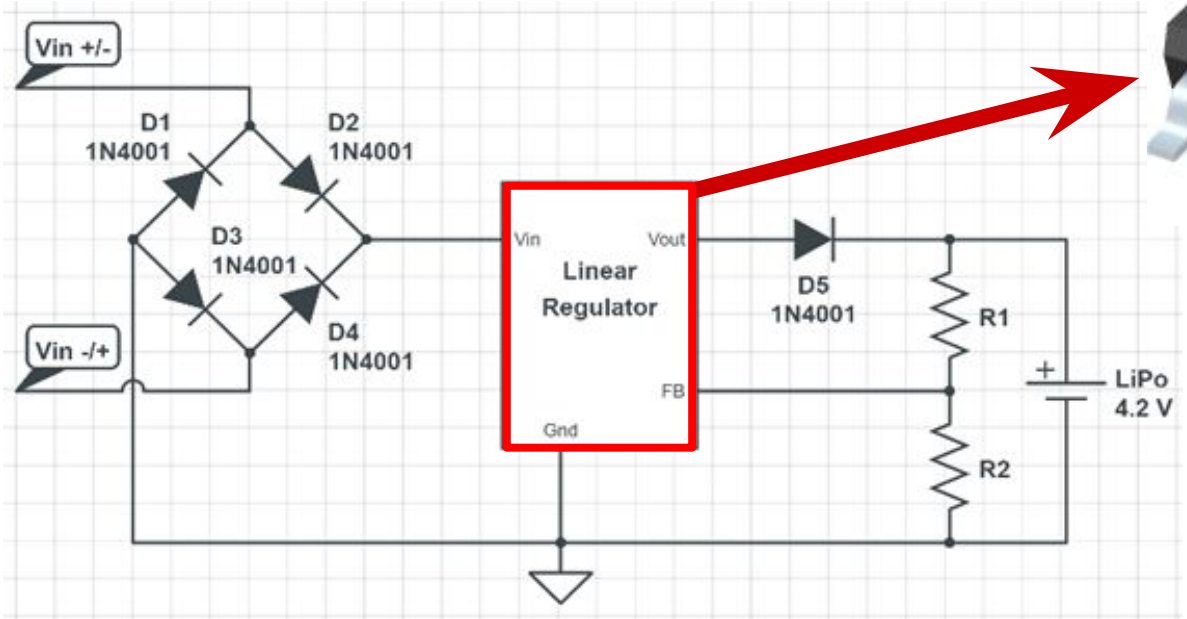
240 mAh/Dollar

44mm X 24mm X 9mm Dimensions

Device Power - Linear Regulator - Comparison

	Max Out Current (A)	Dropout Voltage (V)	Quiescent Current (mA)	Accuracy (%)	Feedback Resistance	Cost per Unit
LP38798	0.8	0.200	1.4	2	<250Ω	$3.25
TLV1117	0.8	1.200	5	1.6	<840Ω	$0.72
LP2951	0.1	0.380	0.075	2	<3MΩ	$0.68

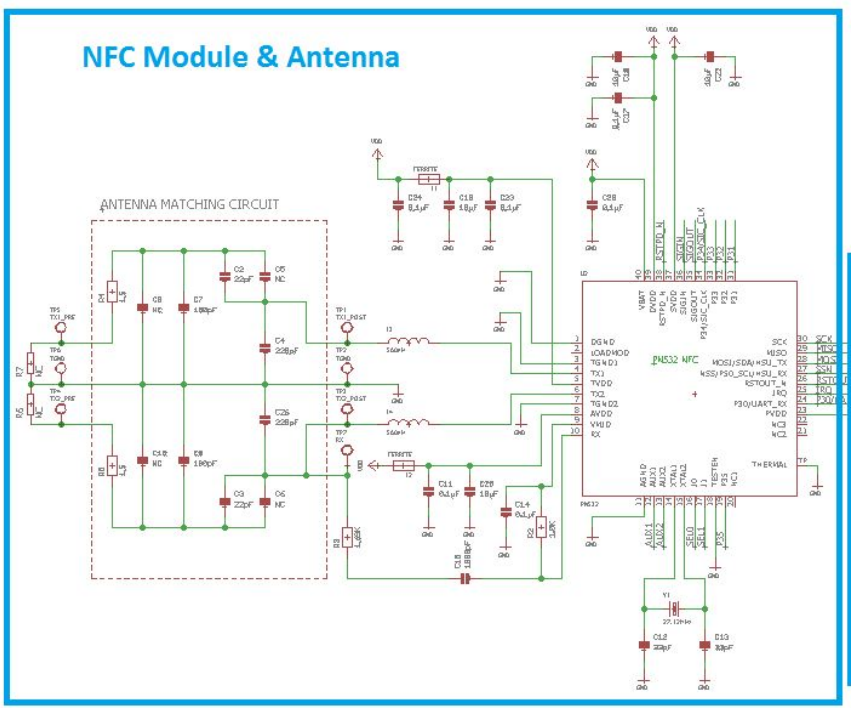
Device Power - Charging Circuit

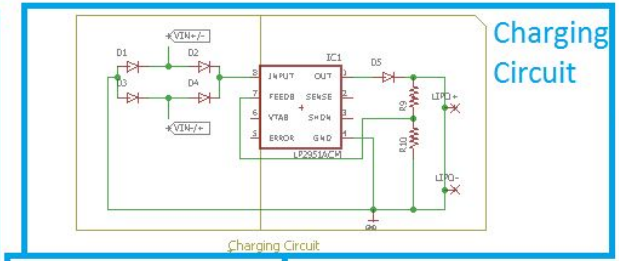


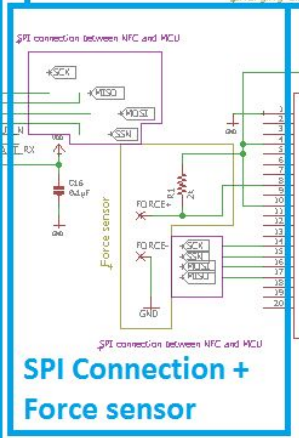
LP2951

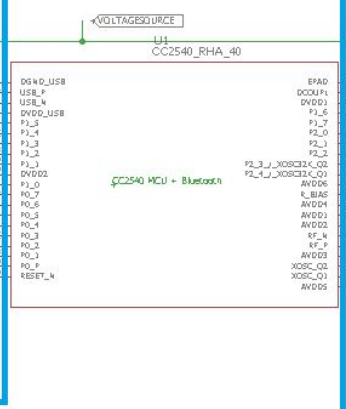
- Lowest Cost
- Low Dropout
- High Feedback Loop Resistance
- Good Accuracy

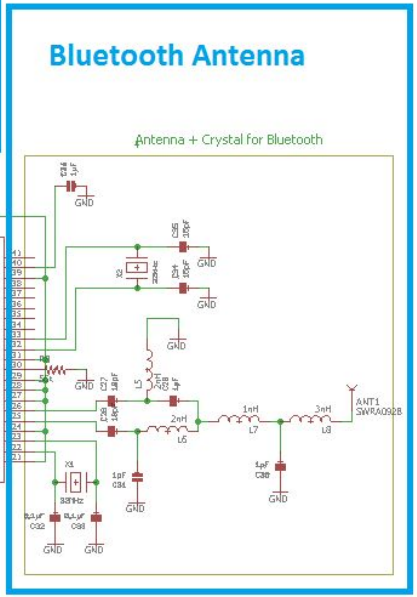
Initial System Schematic











Subsystems Eliminated from Design...

Bluetooth Antennas

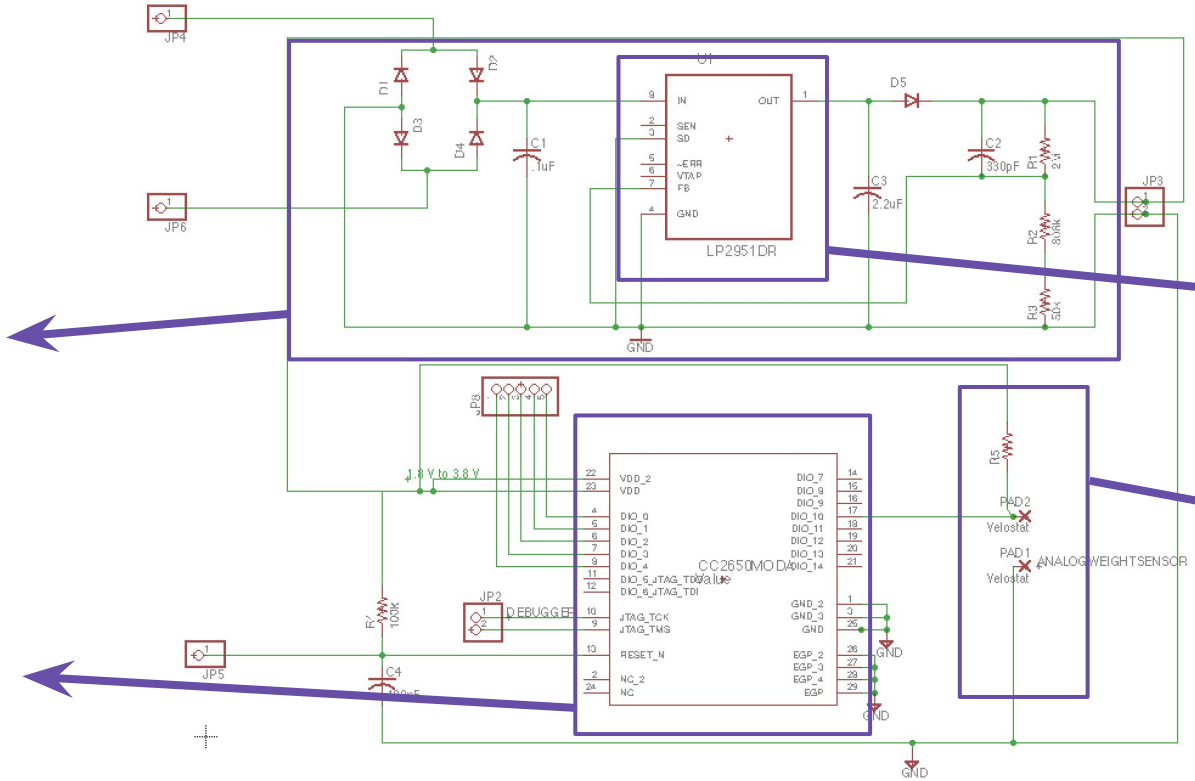
- Too many complex requirements in making our own bluetooth antenna
  - CC2650 MODA includes bluetooth antenna

NFC Module & Antenna

- NFC module only needs to be in the table hub (Mobile phone already has it)
  - Alternatively, individual NFC tags can be placed in each coaster to store its bluetooth address and other information

Optimize to save space on the PCB and reduce novice design error

Final Schematic Design



Charging Circuit

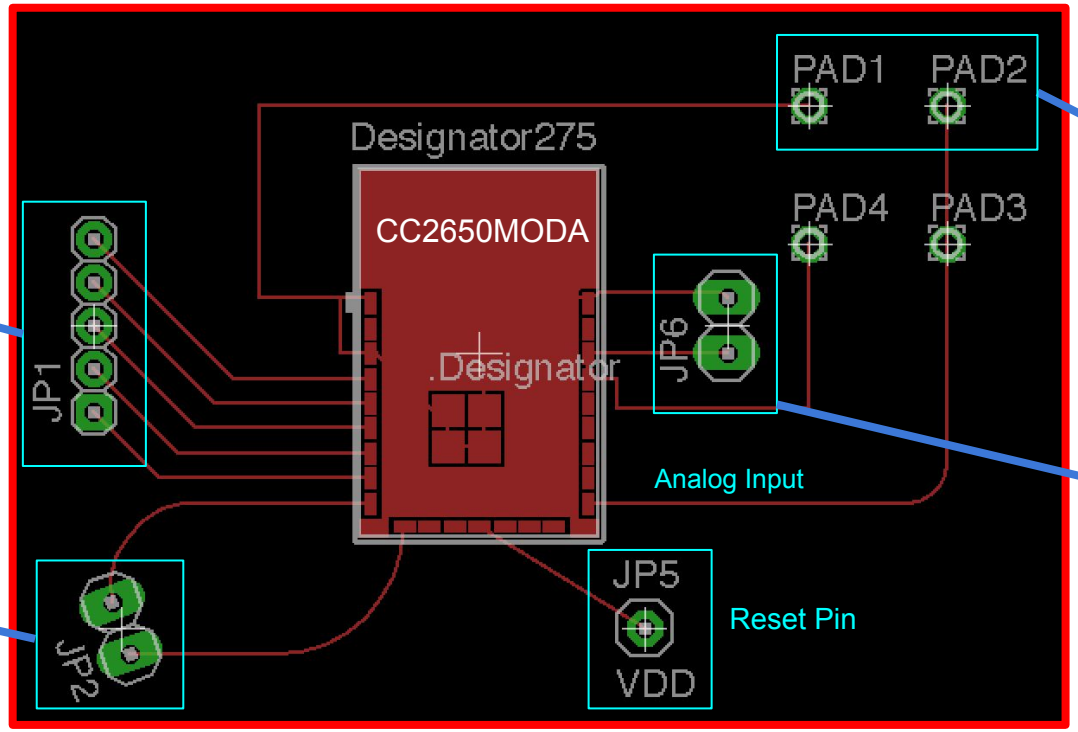
LP2591
Linear Regulator

Weight Sensor
Voltage Divider

CC2650MODA
Microcontroller

PCB Design - (In coaster)

1-Layer Board



GPIO Pins (unused)

LEDS & Buttons

JTAG Debugger (TMS/TCK)

For uploading code

Velostat

LiPo Battery

Software Design - Microcontroller

Sensor Controller

- Ultra Low Power
- 16-bit processor
- ADC controller
- Weight Sensor
- Active: 8.2 µA/MHz

Main CPU

- ARM Cortex M3
- Main Application
- 48-MHz Clock
- Flash Memory
- Active: 61 µA/MHz

RF Core

- 2.4 GHz Bluetooth
- BLE Communication
- Active TX: 6.1 mA
- Active RX: 5.9 mA

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Software Design - Sensor Controller

- Threshold Variables
  - noCupThreshold
  - emptyCupThreshold
  - halfCupThreshold
  - fullCupThreshold
- ADC Value
  - Compared to midpoints between known thresholds
  - State determined based on which threshold is passed
- State
  - Sent to main application as an interrupt

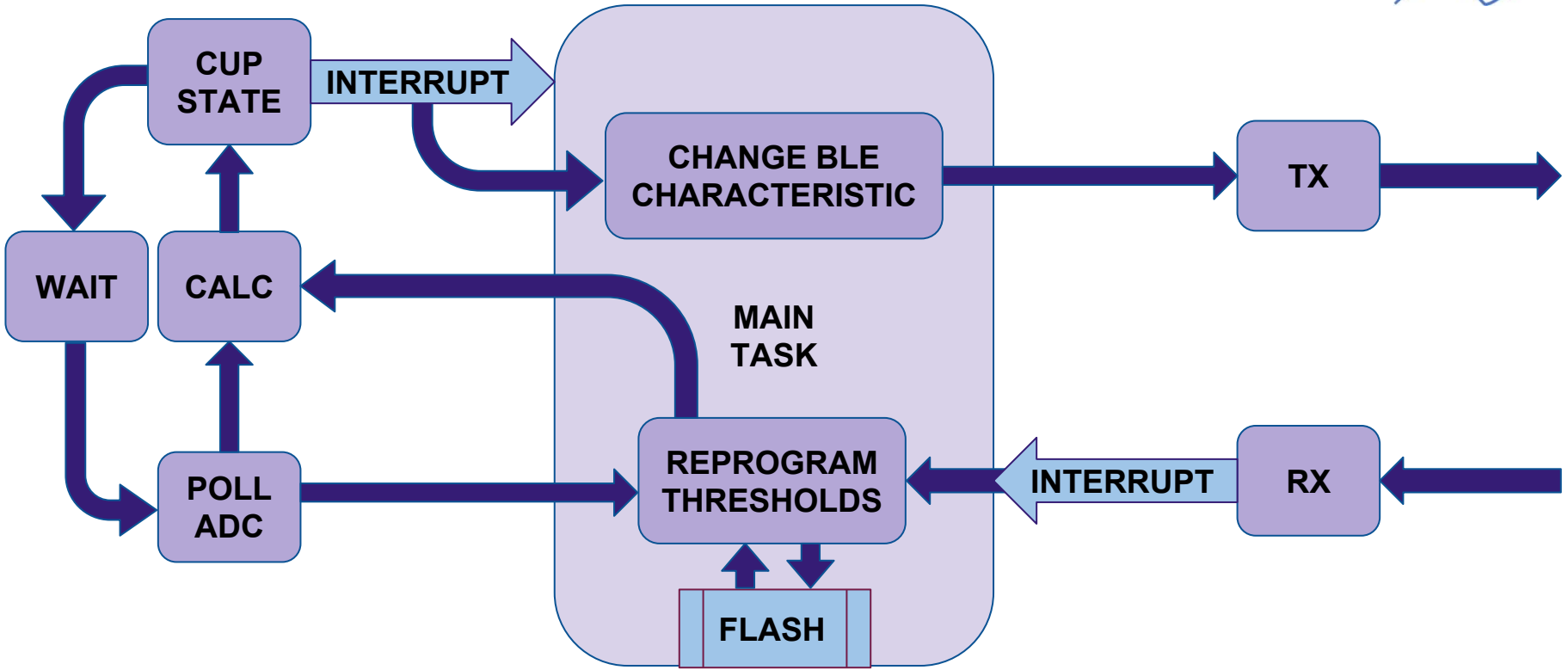
Software Design - Main CPU

- TI-RTOS
- Task Based Design
  - Tasks have different priorities and can be called with interrupts
- Interrupts
  - When something important happens, an interrupt is sent to the CPU
  - An interrupt launches a new, higher priority task
- Message Passing
  - A message is loaded into a buffer and an interrupt is sent
  - Message is read and appropriate actions happen in the task context

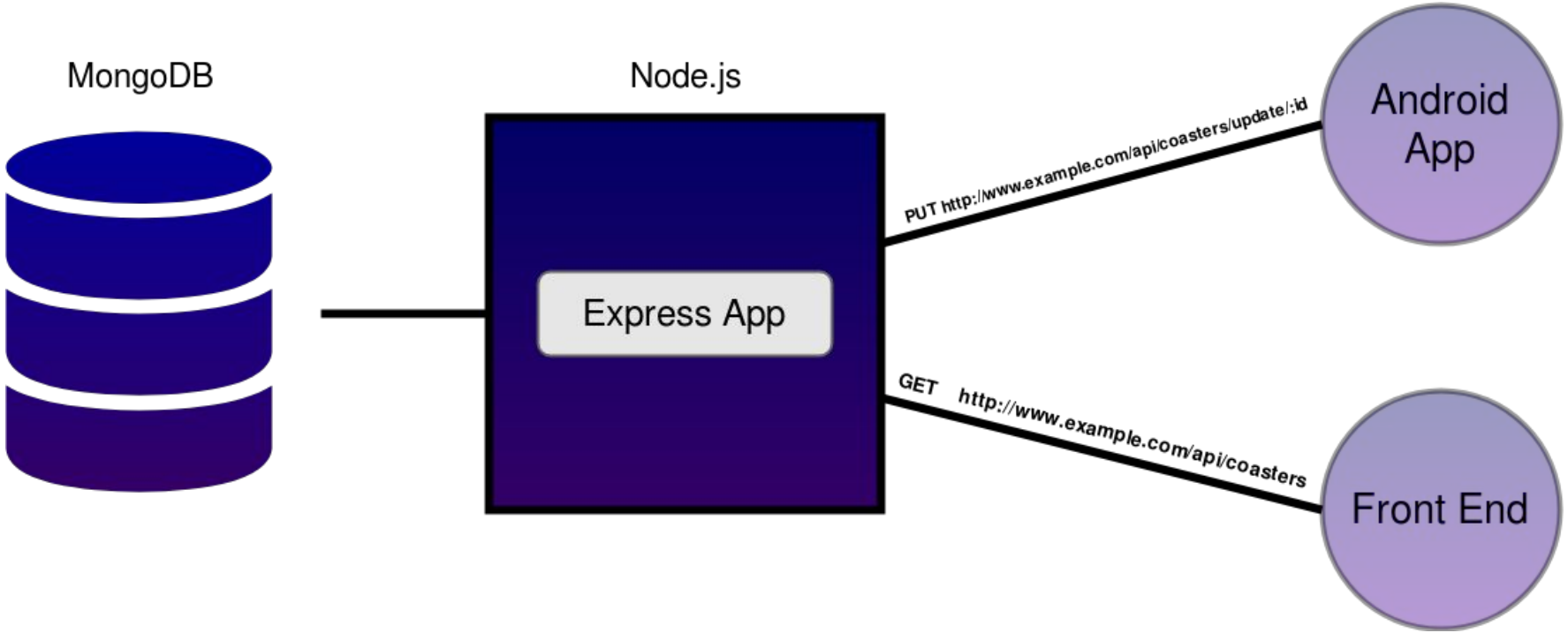
Software Design - Main CPU

- Advantages of task-based design
  - Pseudo-multithreaded
  - Periodic interrupts
  - Real-time operation
  - Non-blocking
- Disadvantages
  - Must be conscious of task priority when designing application
  - Can’t assume things will get done in an exact order

Software Design - Microcontroller

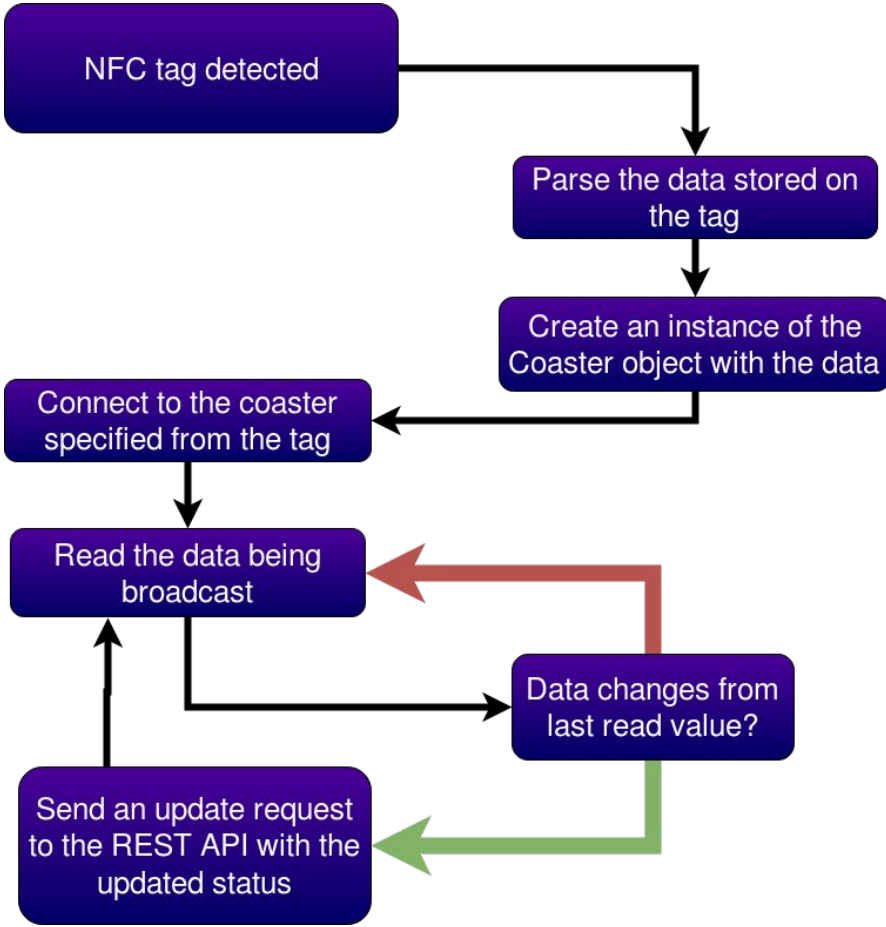


Software Design - REST API



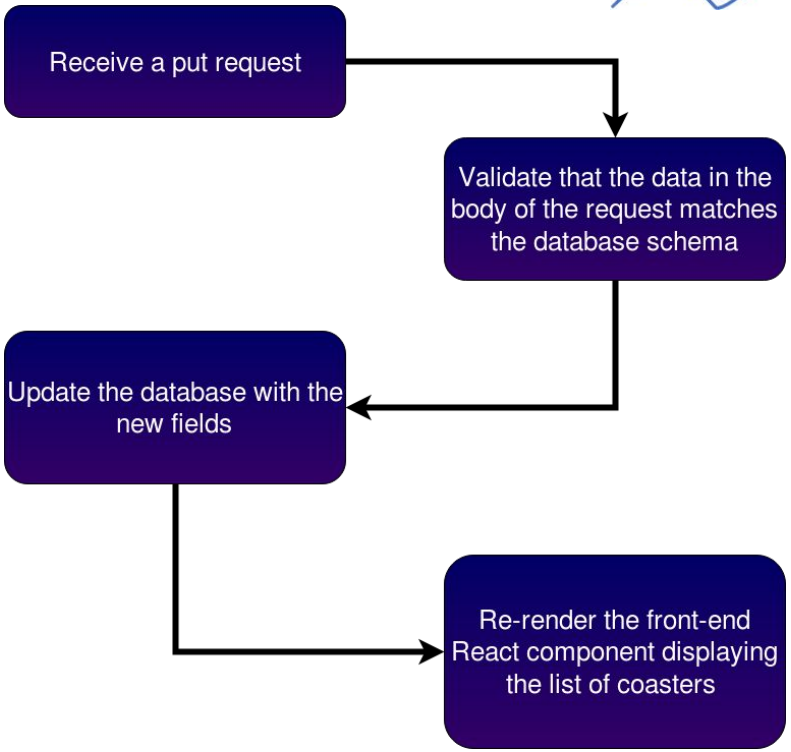
Software Design - Android

- Designed to function in the background- tap to connect and you're set
- Asynchronous - device won't slow down because of a thread being blocked



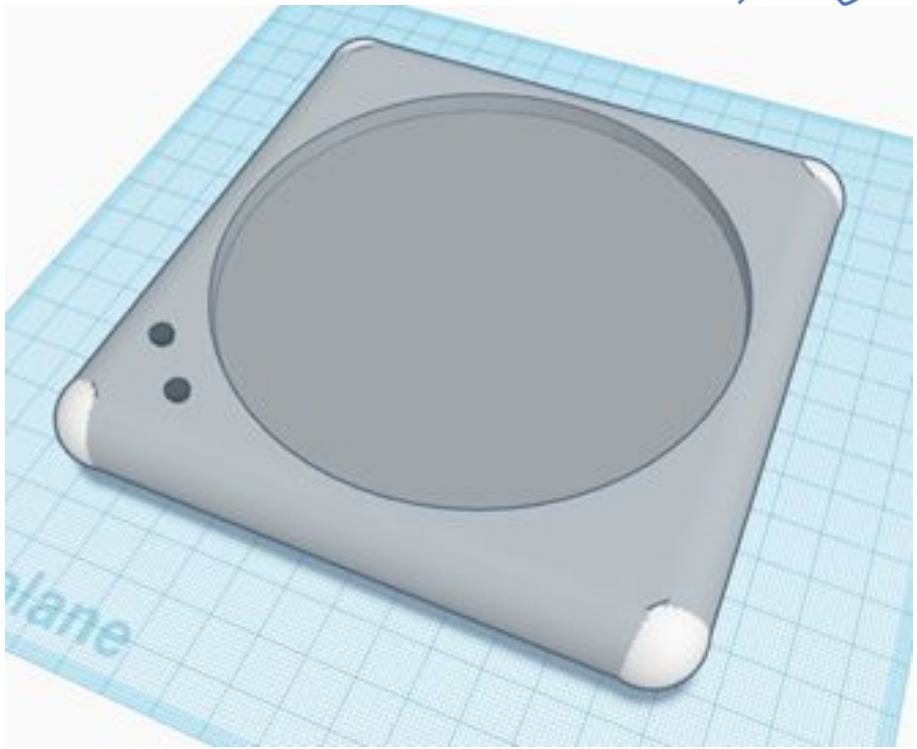
Software Design - Webpage

- Simple single page application that automatically updates whenever the database gets updated
- Made with React.js



Coaster Housing

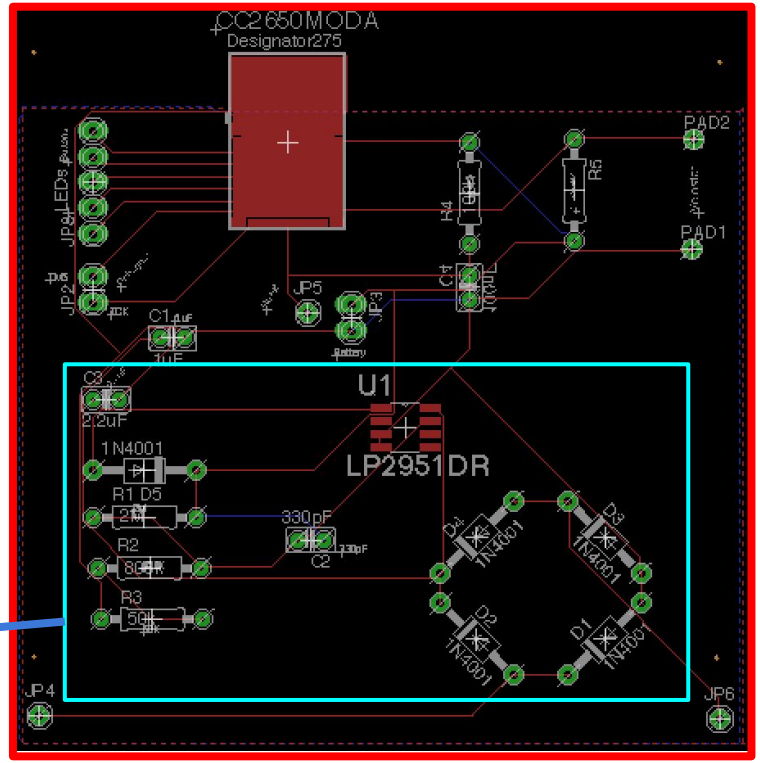
- 3D-Printed
- ABS
- Water Resistant
- Depressed Center



PCB Design - Not Working

Potential Reasons:

- Low-Quality Manufacturer
- Faulty Components
- Copper pour filling on both sides might be disturbing some wires
- Overall Novice at EagleCAD



Added the Charging Circuit

2 - Layer Board

Challenges

- Not sponsored project
  - Costs out of pocket
  - No PCB mentor
- Mechanical Issues
  - 3D printing delays
  - Novice soldering
  - Unable to finalize housing
- Time
  - Could not add the LEDs and button functionality (to be visible to user)
  - Did not have time or resources to make the charging dock
  - Could not troubleshoot charging circuit PCB

Responsibilities

	Rubba	Mitchell	Ted
PCB Design	Primary	Secondary	
Microcontroller	Secondary	Secondary	Primary
Waiter Hub	Secondary	Primary	
Power	Secondary		Primary
Table Hub		Primary	Secondary
Weight Sensor	Primary		Secondary
Housing		Secondary	Primary

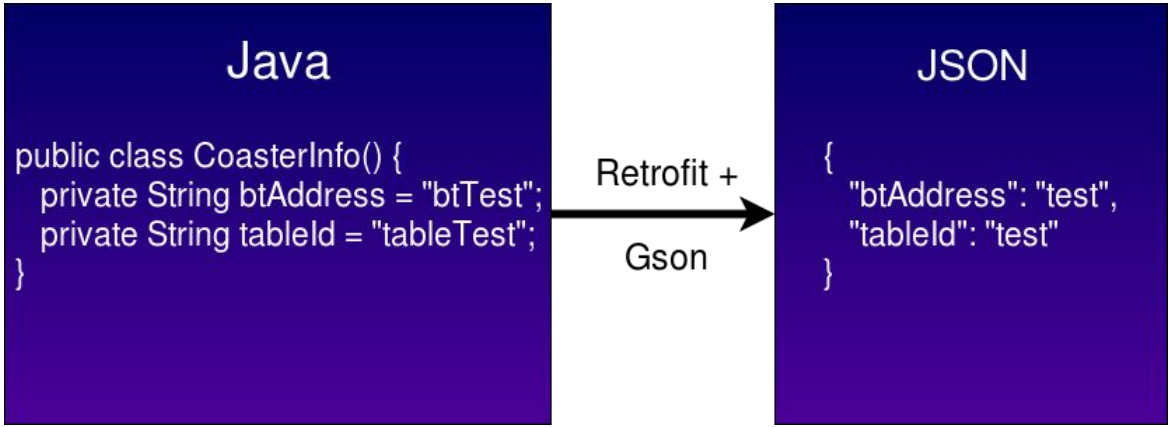
Questions?

DEMO TIME

(15 min)

Software Design - Android App

- Sends data to the webpage using RetroFit, a third party library designed to easily interact with REST API's
    - CoasterInfo class gets converted from a Java object to JSON, which our webpage can use to update the database



Device Power - Charging Solution - Comparison

	Ease of Use	Charging	Complexity	Cost	Scalability
Replaceable Batteries	Hard	Bad	Medium	High	Bad
Wired Charging	Medium	Good	Medium	Low	Average
Charging Dock	Easy	Good	Medium	Low	Good
Induction Charging	Easy	Average	High	High	Good

Device Power - Charging Method - Dock Design

AC-DC Switching PSU

Short Circuit Prevention

Over-(Voltage, Current, Temperature) Protection

Two Rails

9V DC