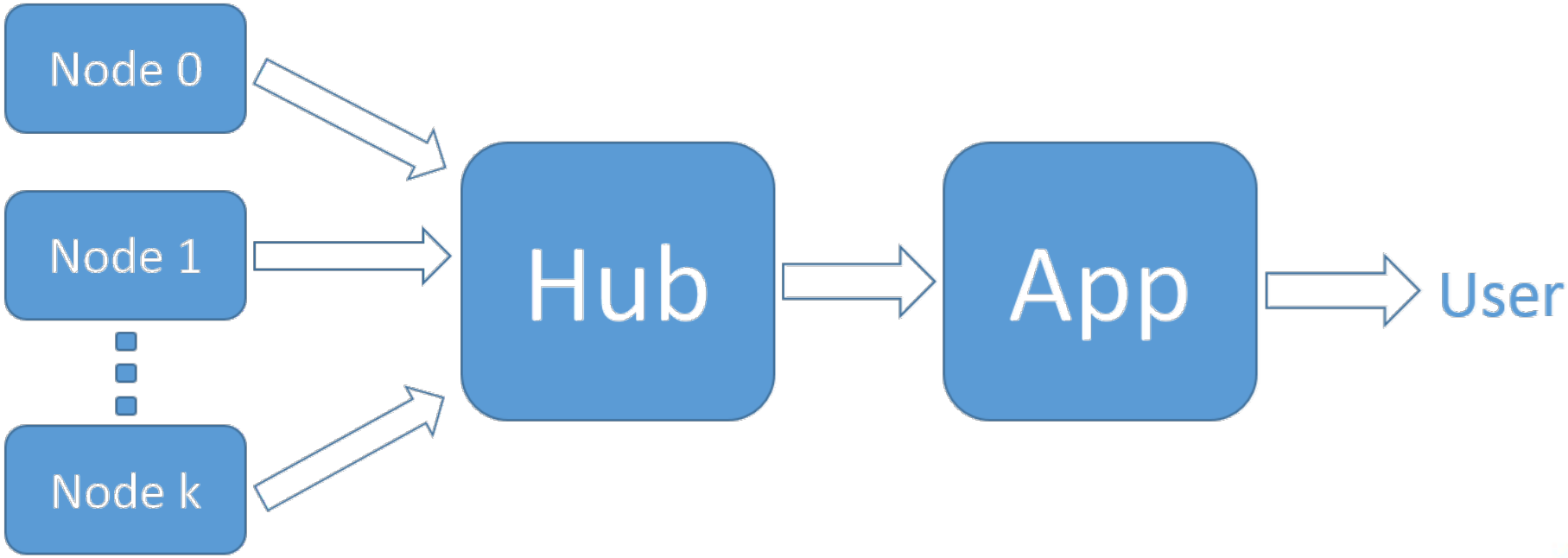
Ryan Dufrene, Matthew Kreider, Jason Smith, Bao Doan

Problem Finding a Spot?

Our Project


Detection Method
Transmit Data
Compute and Transform Data
User

Our Project



Engineering Requirements

- The sensor device should consume no more than 3W.
- The system should use a non-AC grid power source.
- The system should operate in the FCC unlicensed spectrum.
- The sensor signal should have a usable range of at least 240’ – enough to travel over 30 traditional parking spaces.
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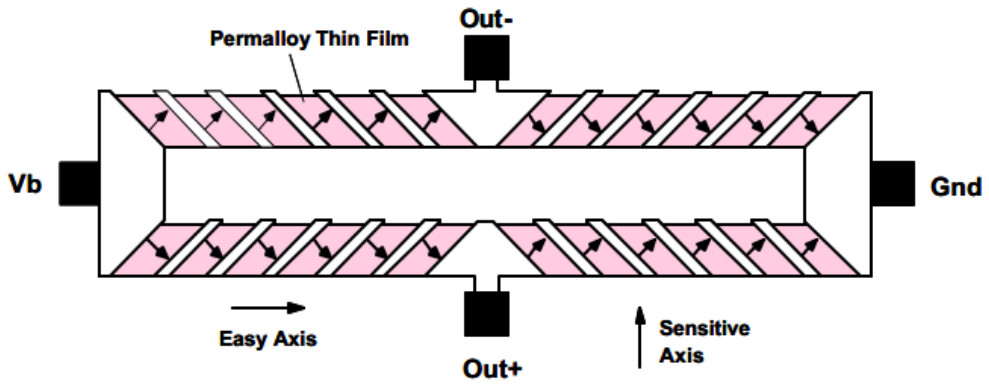
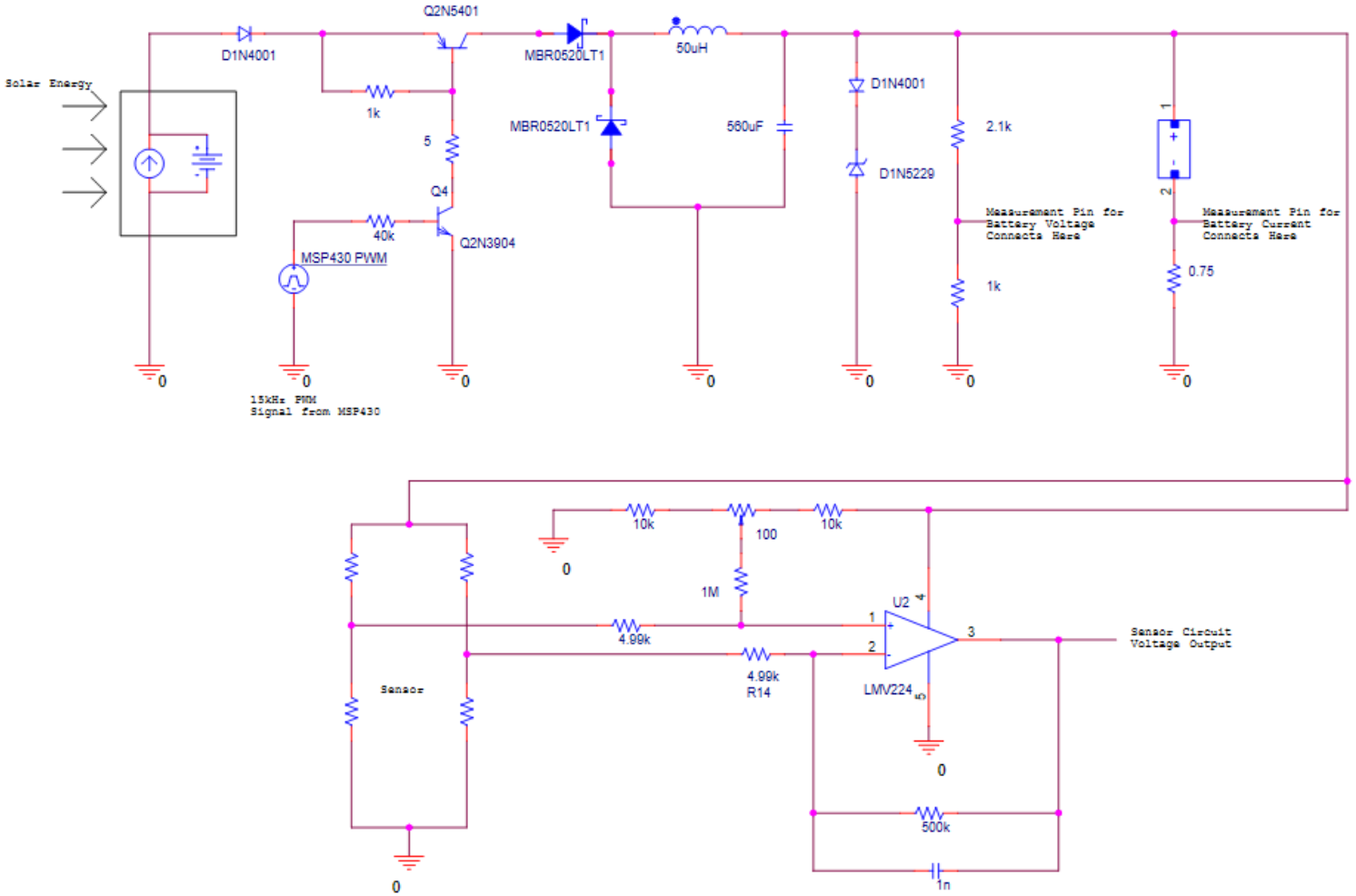
Sensor Device

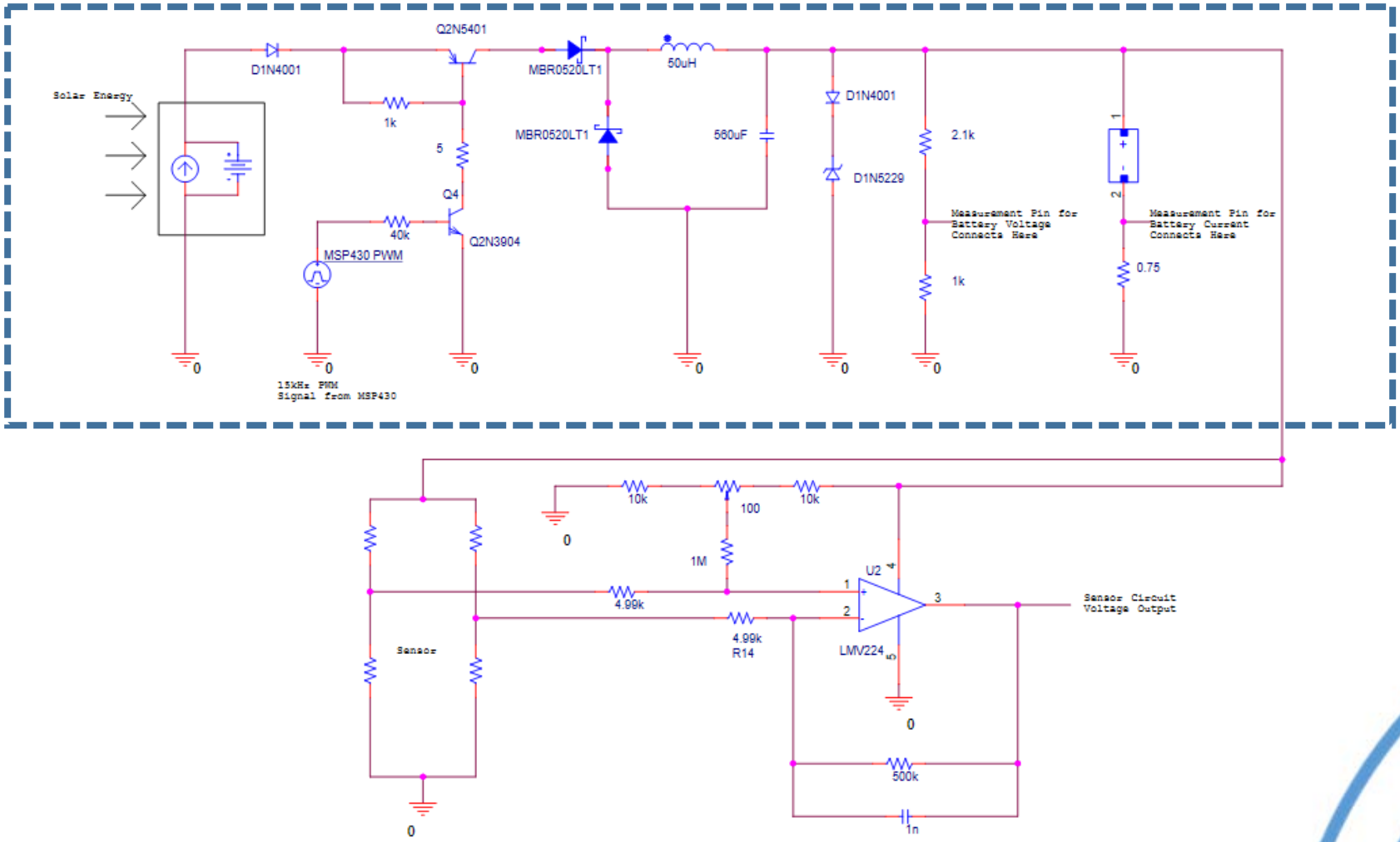


- Honeywell HMC-1021z
- Anisotropic Magneto-Resistive (AMR)

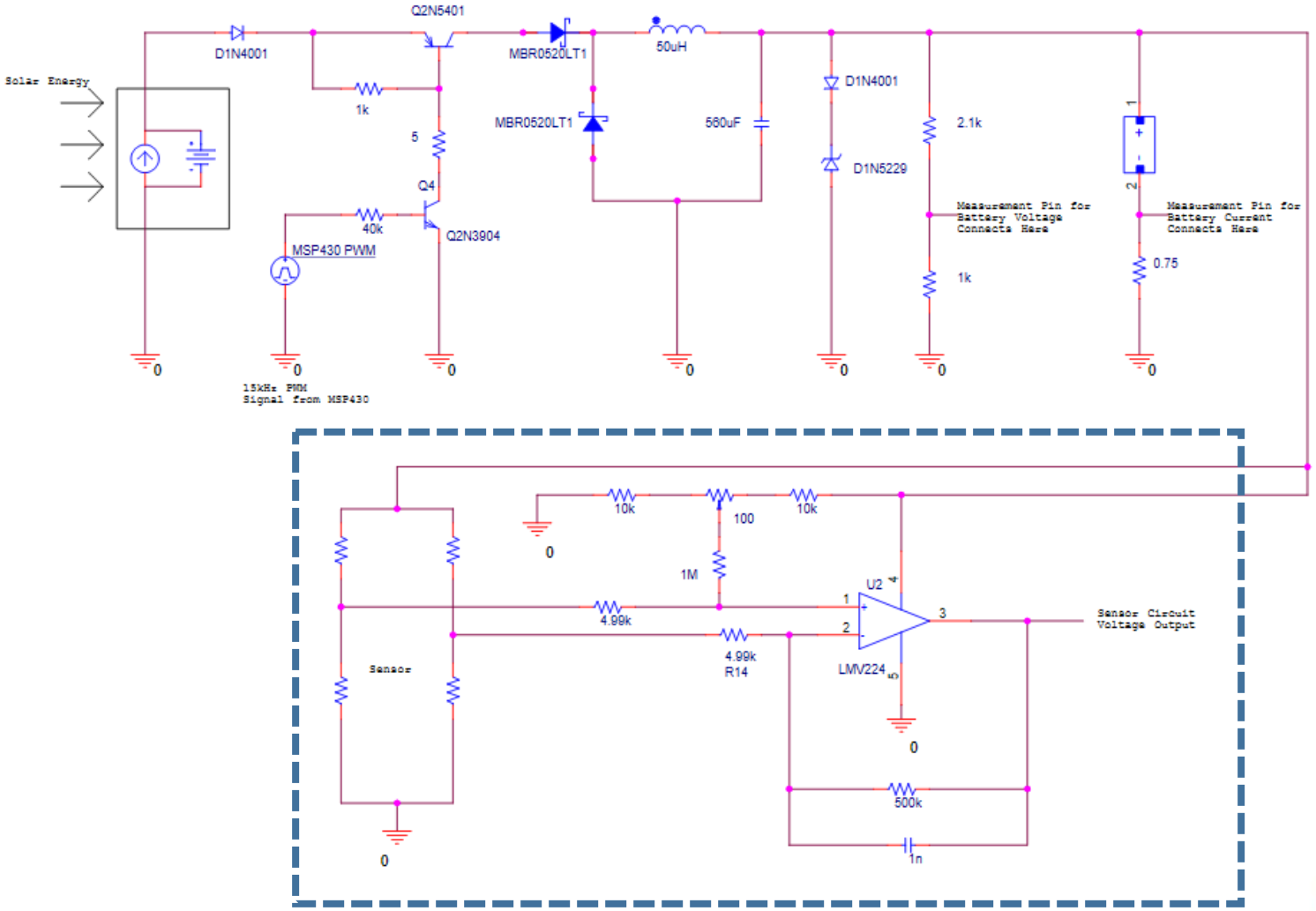
Sensor Device



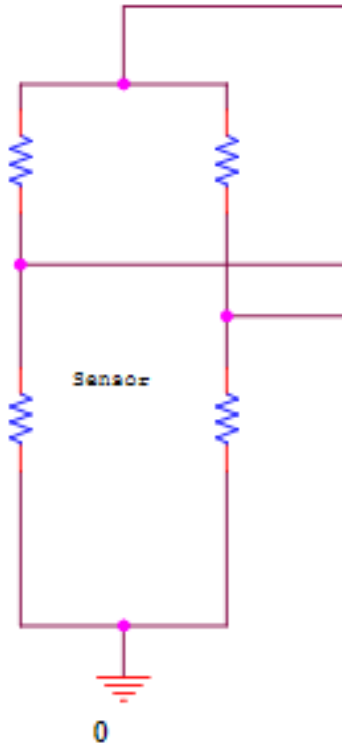
Sensor Device – Battery Charger

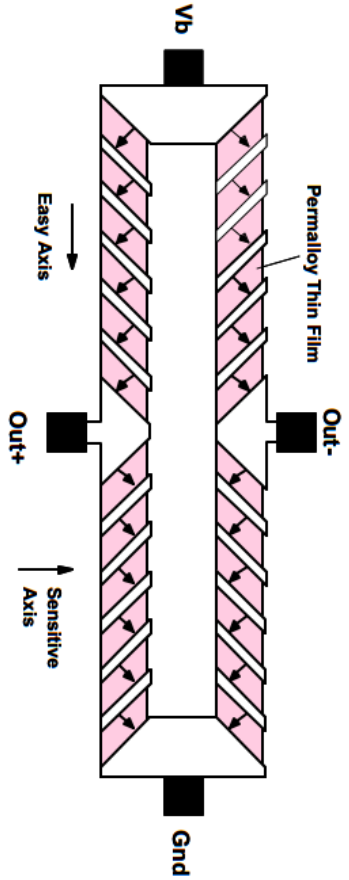


Sensor Device – Sensor and Amplifier



Sensor Device – Sensor





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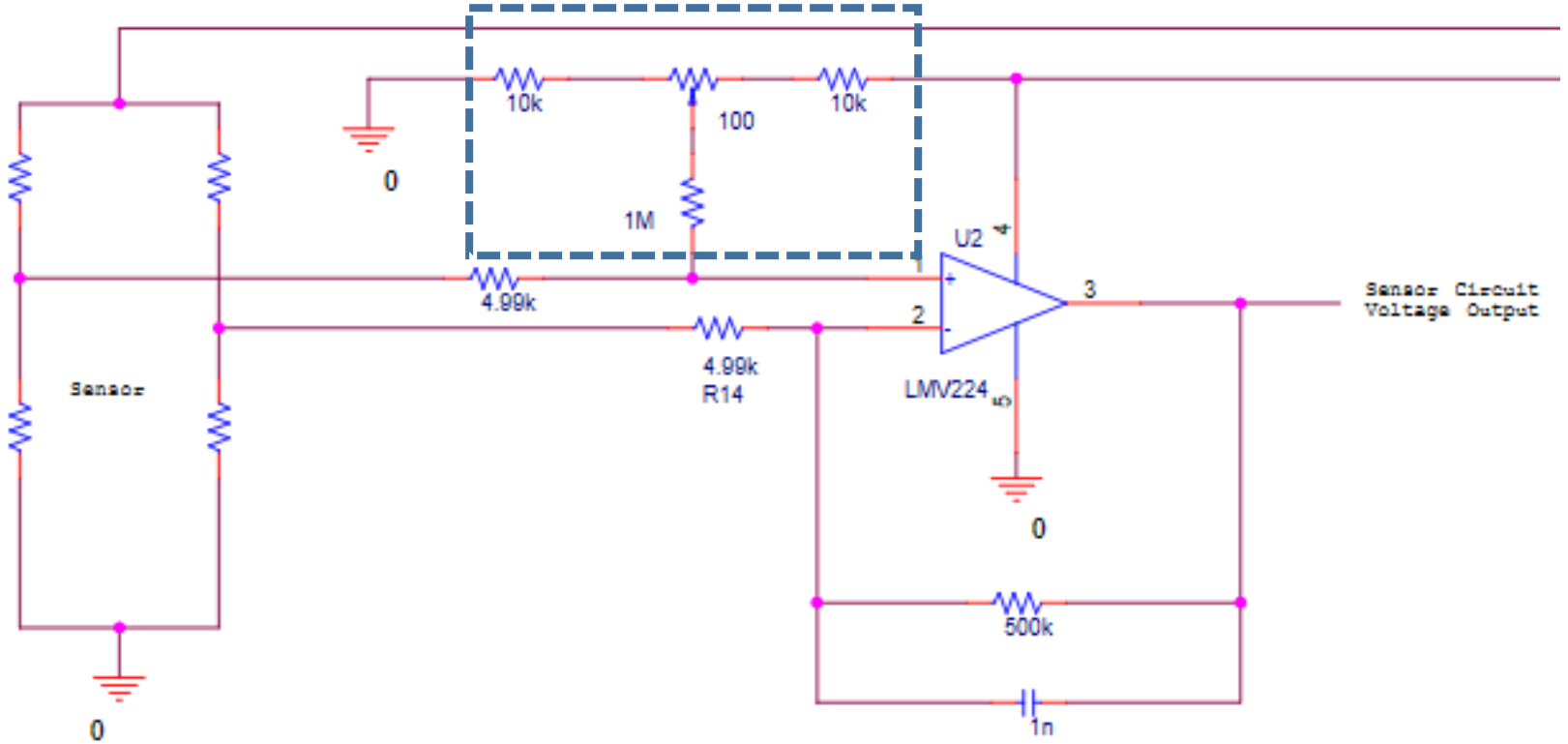
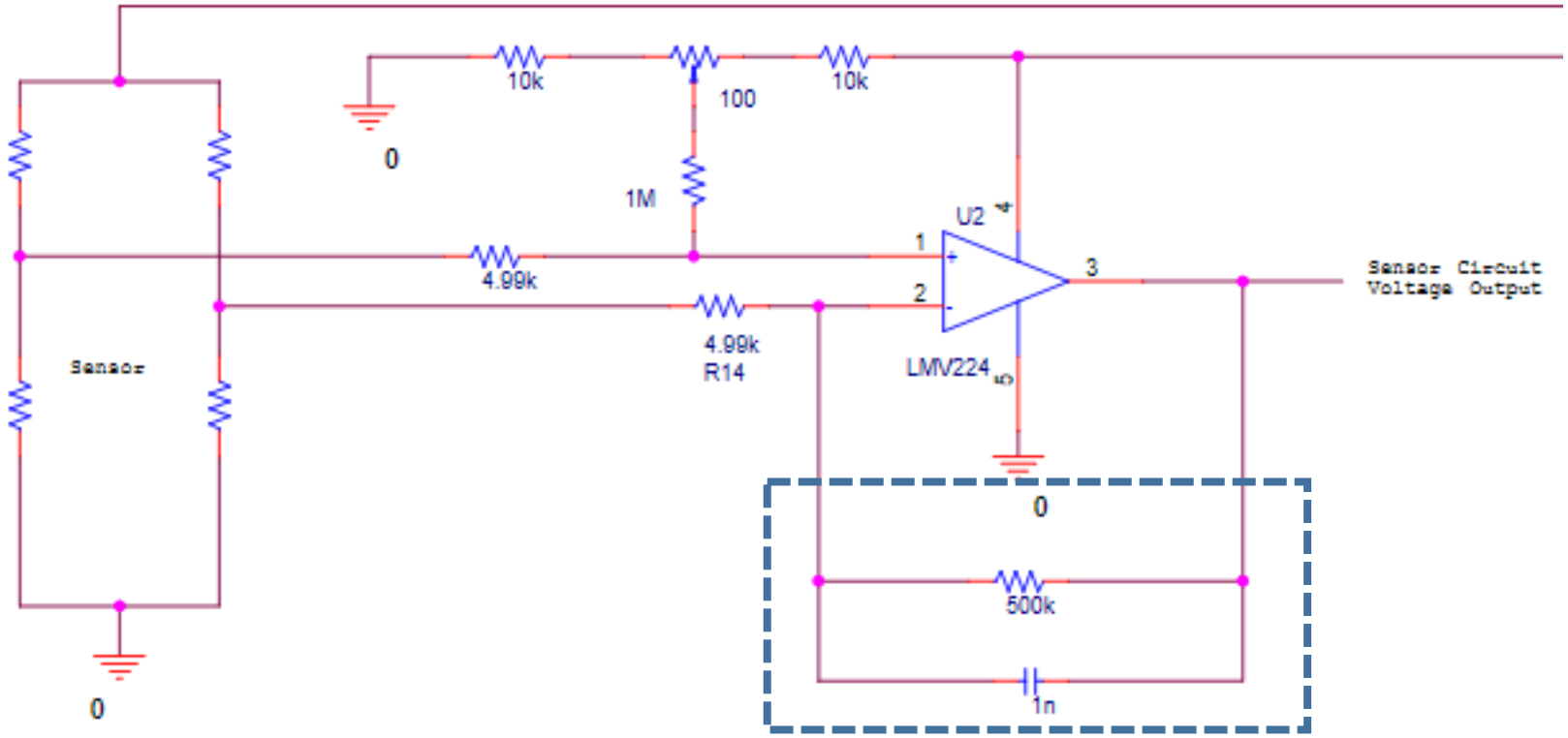


- Bias Network Holds Guaranteed Output
- Anisotropic Magneto-Resistive (AMR)

Sensor Device – Sensor and Amplifier

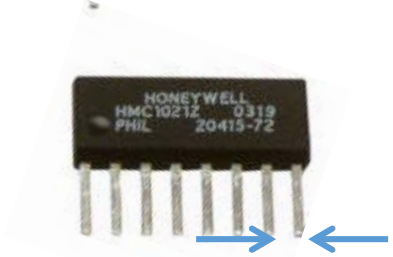


- Feedback Network Sets Gain of Amplifier
- Supply Voltage Affects Selection of resistance

Sensor Device – Challenges Faced

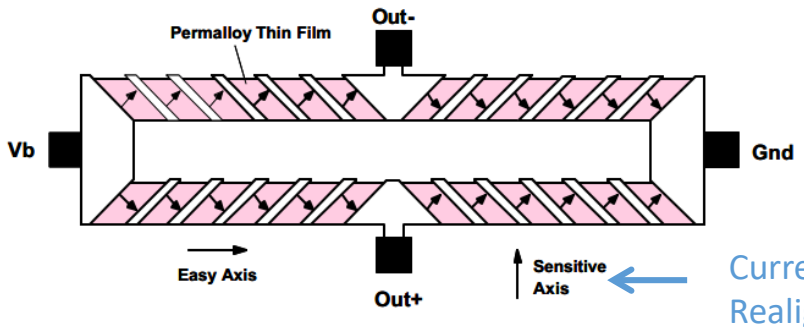
- Output Biasing
- Sensor Pin Pitch

Bridge Offset	Offset = (OUT+) – (OUT-) Field = 0 gauss after Set pulse, Vb = 5V	-10	±2.5	+11.25	mV



1.27mm

- Set/Reset for Sensitivity Realignment



Current Can Realign Axis

Sensor Device – Challenges Faced

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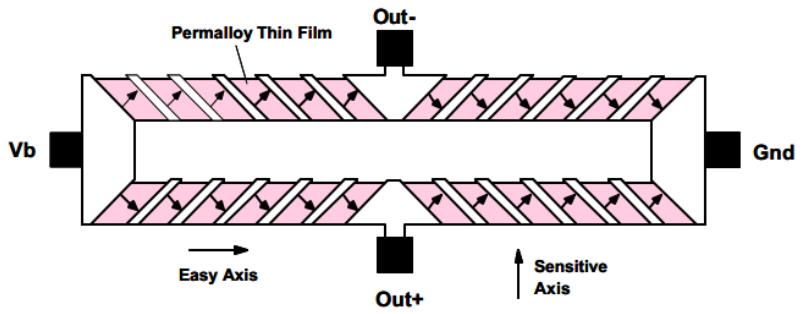
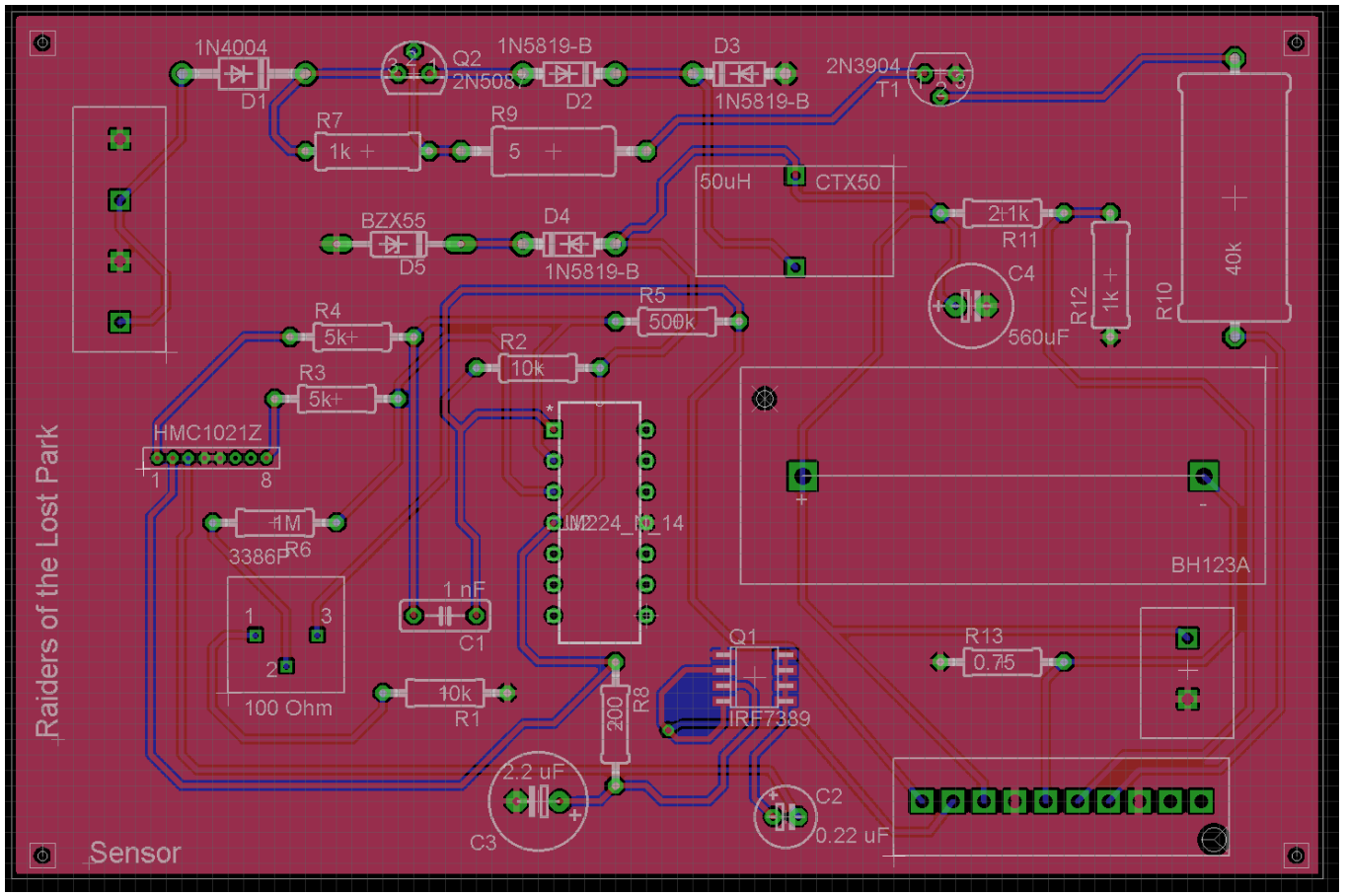
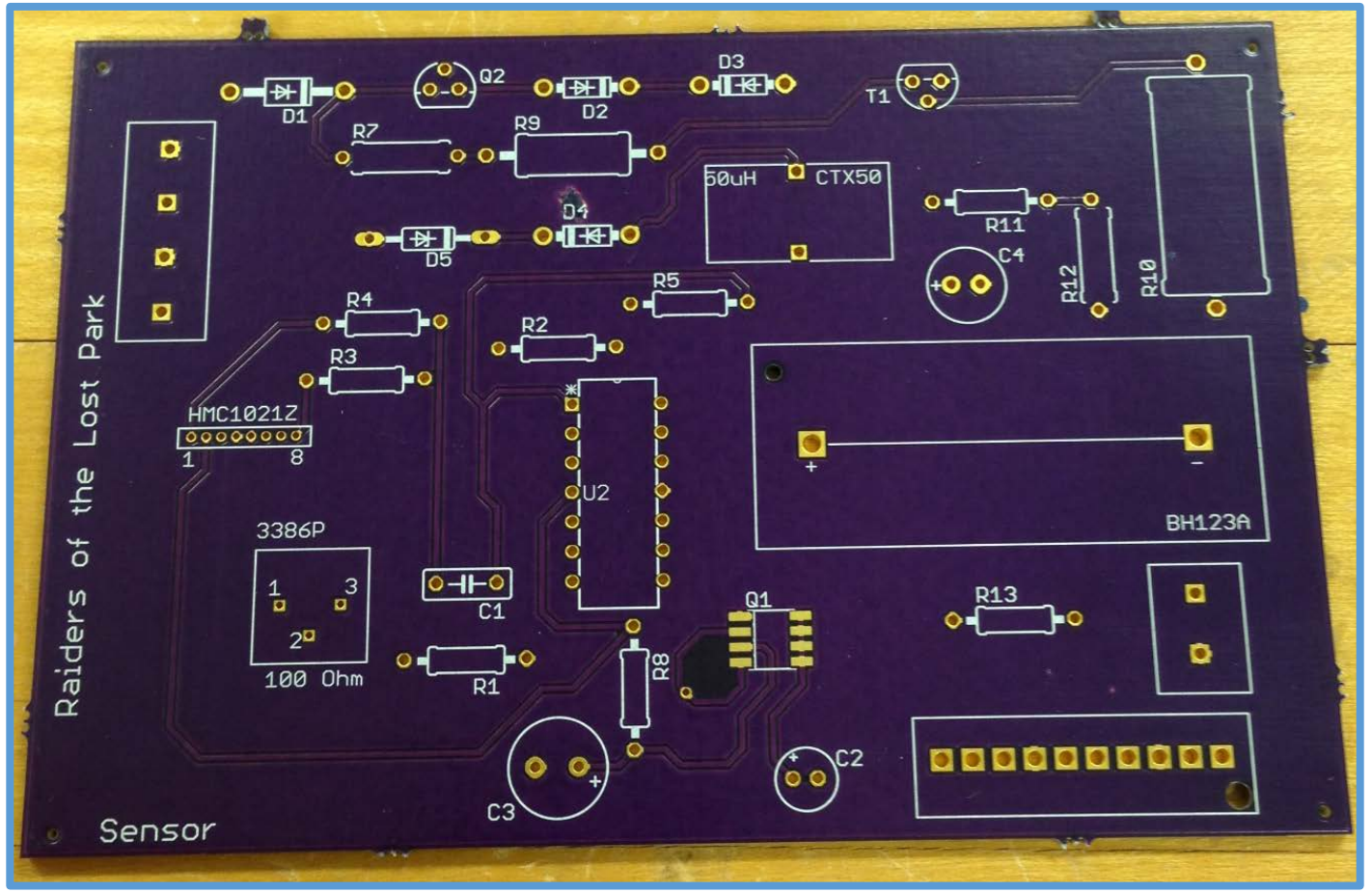


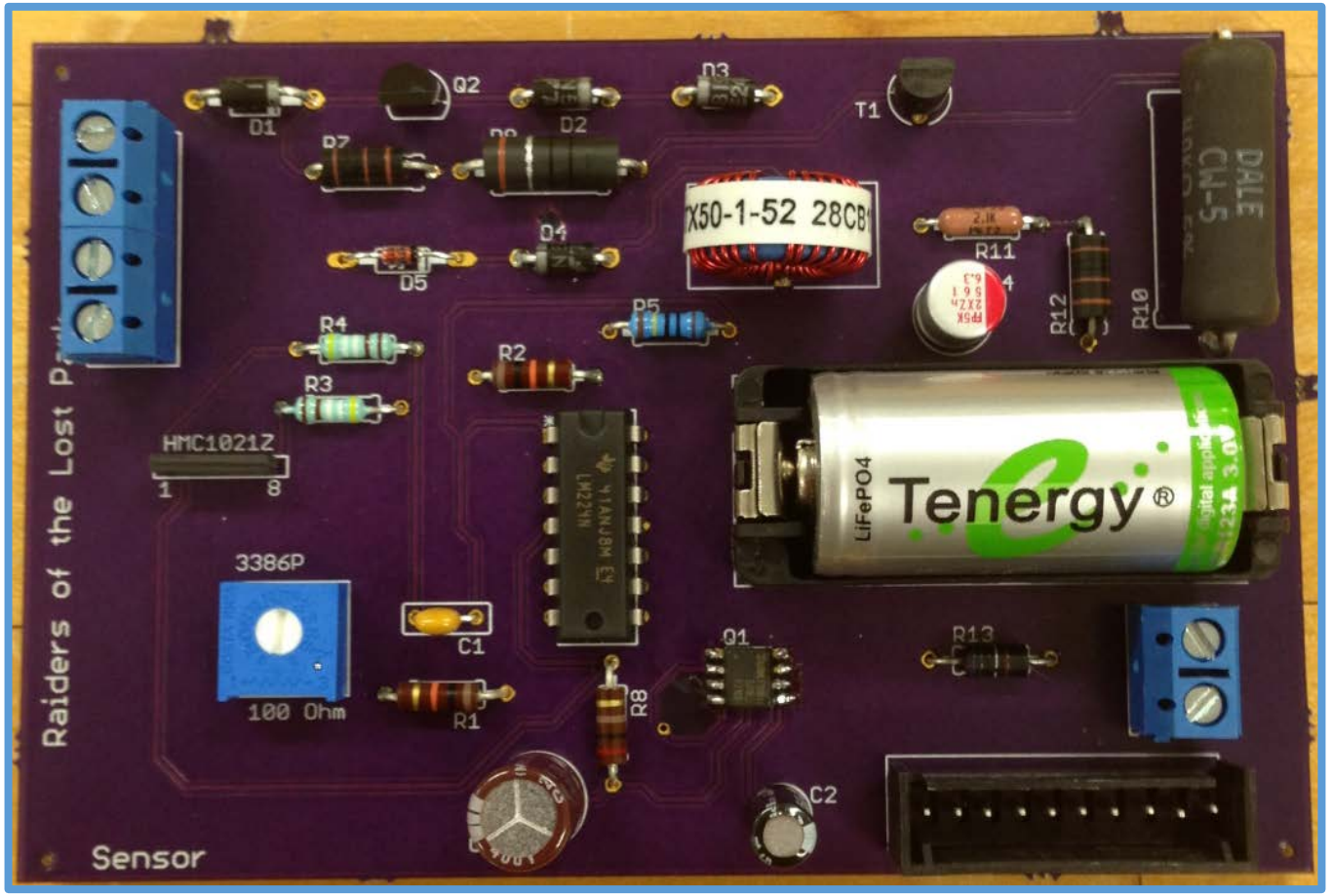
PCB


1N4004
D1
Q2
2N5087
1N5819-B
D2
D3
1N5819-B
2N3904
T1
R7
1k
R9
5
50uH
CTX50
BZX55
D5
D4
1N5819-B
2.1k
R11
C4
560uF
R12
1k
R10
40k
R5
500k
R4
5k
R2
10k
R3
5k
HMC1021Z
1
8
1M
3386P
R6
LM224_NC_14
1 nF
C1
100 Ohm
10k
R1
200
R8
Q1
IRF7389
R13
0.75
BH123A
2.2 uF
C3
C2
0.22 uF
Raiders of the Lost Park
Sensor

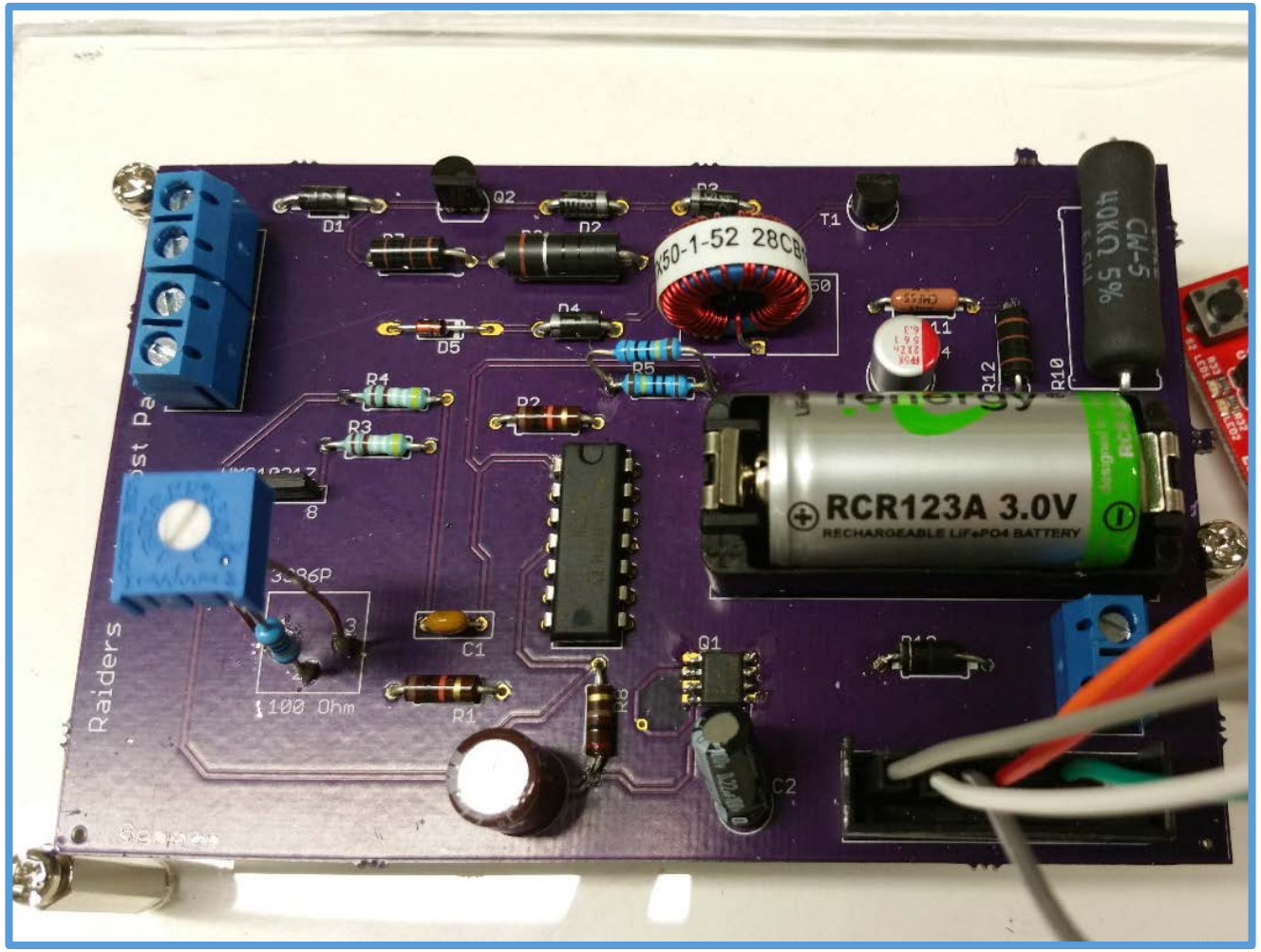
PCB


Raiders of the Lost Park
Sensor
D1
Q2
D2
D3
T1
R7
R9
50uH
CTX50
D4
D5
R11
C4
R12
R10
R5
R4
R2
R3
HMC1021Z
1
8
U2
BH123A
3386P
1
3
2
100 Ohm
C1
Q1
R13
R1
R8
C3
C2

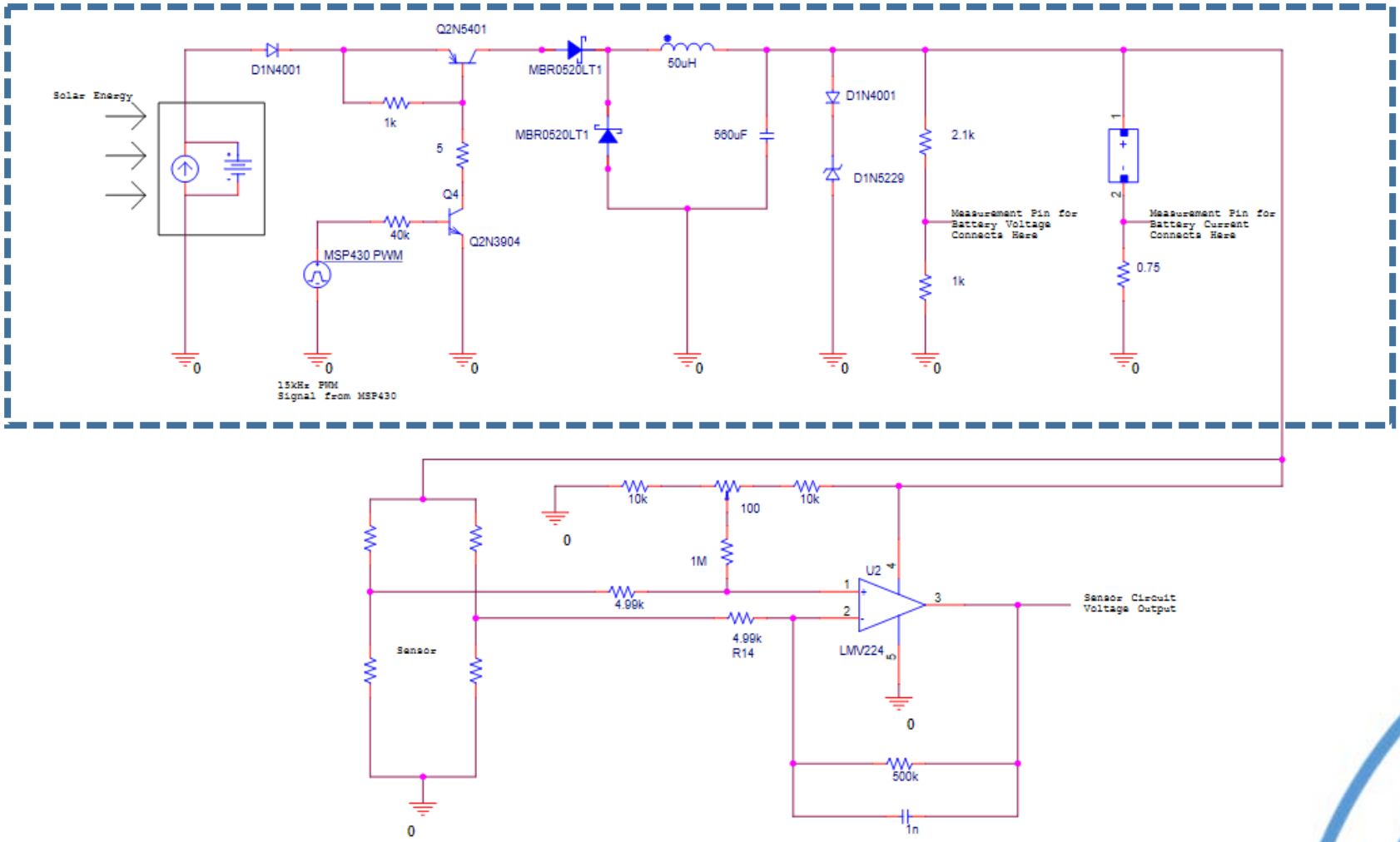
PCB


Raiders of the Lost P
Sensor
D1
Q2
D2
D3
T1
D5
D4
R11
R12
R10
R4
R2
R3
HMC1021Z
1
8
3386P
100 Ohm
C1
R1
R8
Q1
R13
C2
DALE
CW-5
LiFePO4
Tenergy®

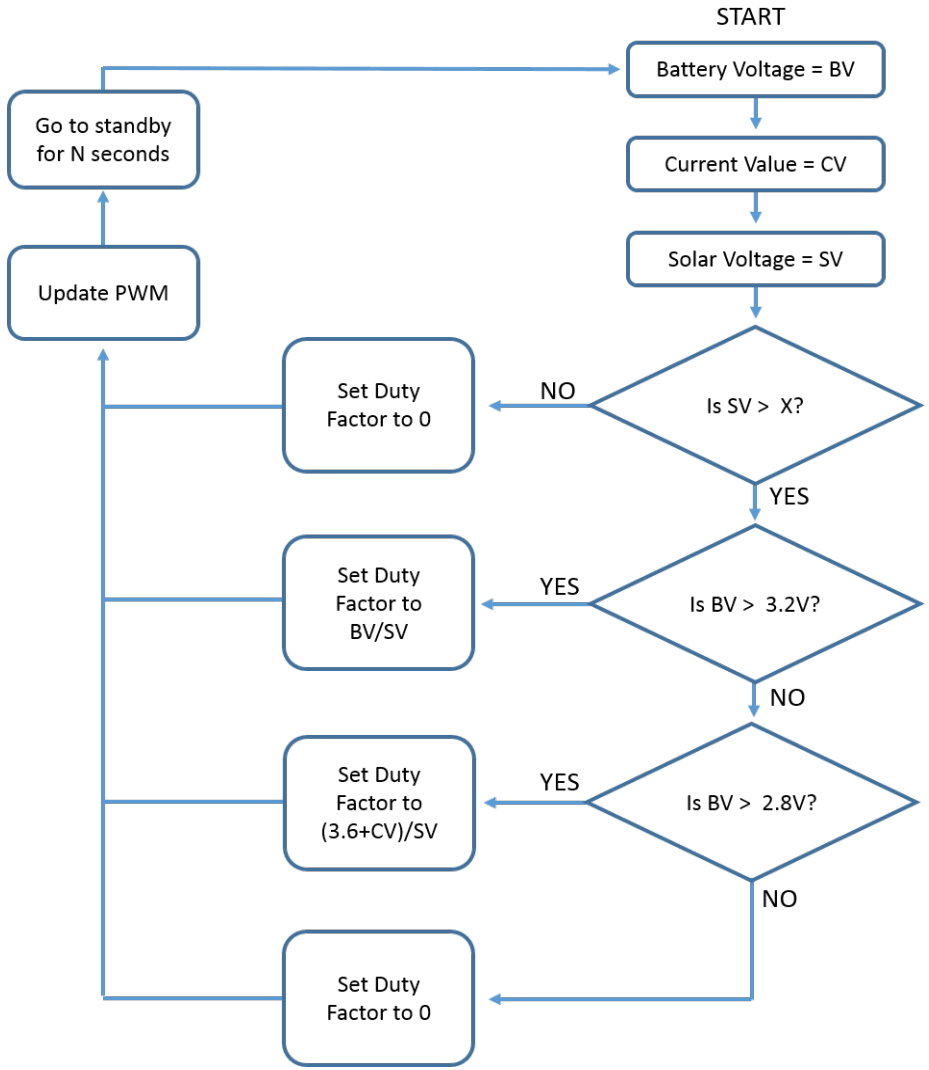
PCB


RCR123A 3.0V
RECHARGEABLE LiFePO4 BATTERY
Raiders
100 Ohm
D1
D2
D3
D4
D5
Q1
Q2
T1
R1
R2
R3
R4
R5
R10
R12
C1
C2

Sensor Device – Battery Charger



Pulse Width Modulation



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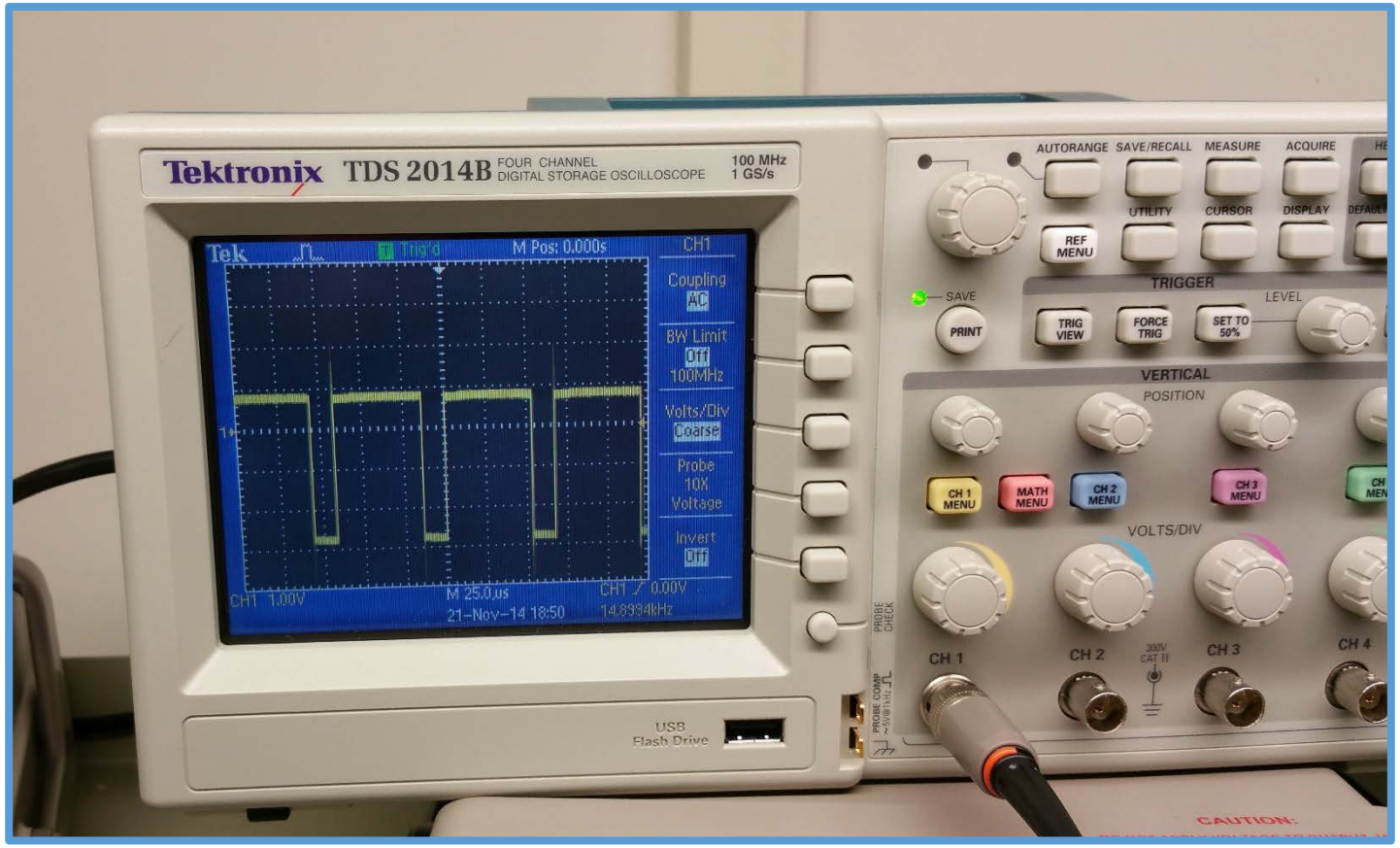
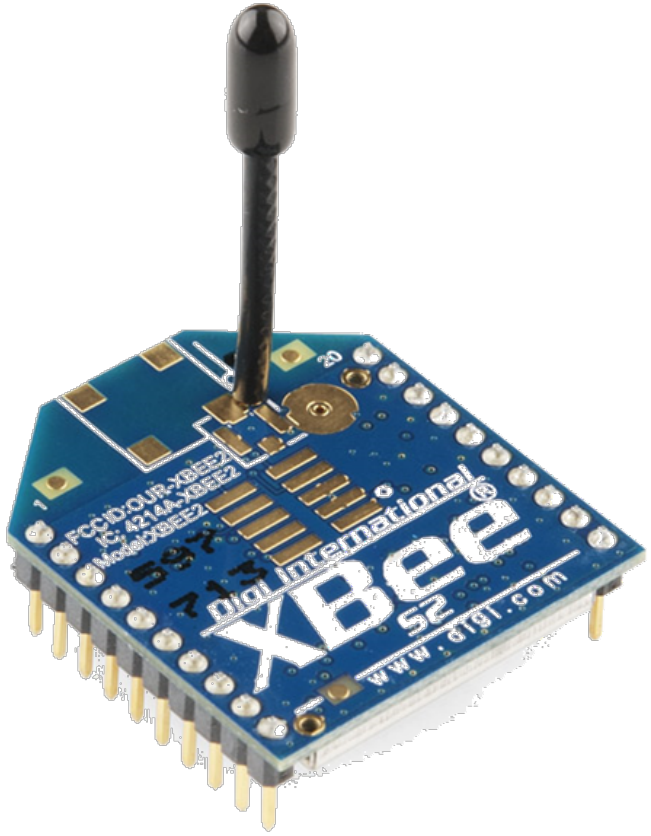


Communication



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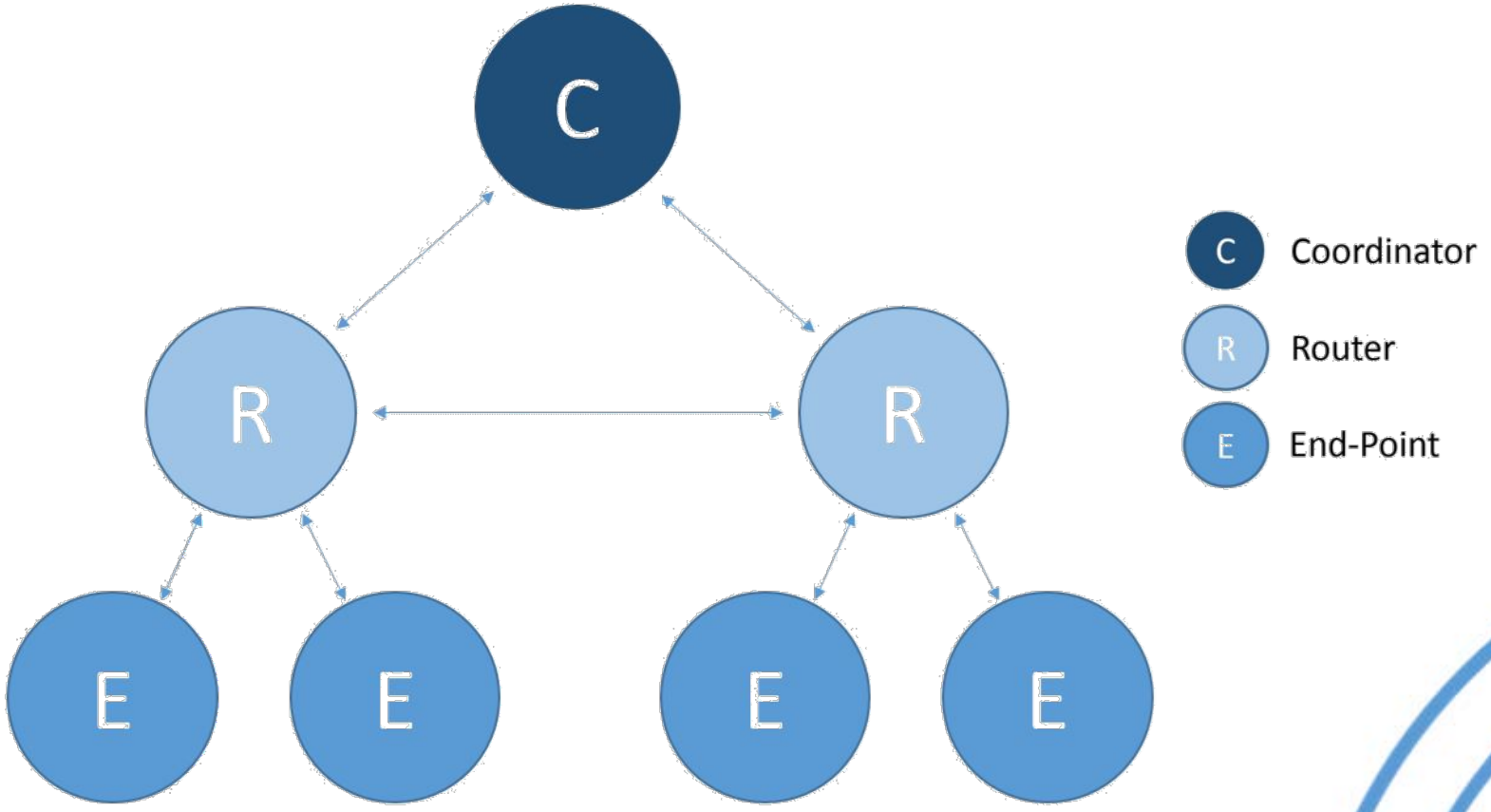

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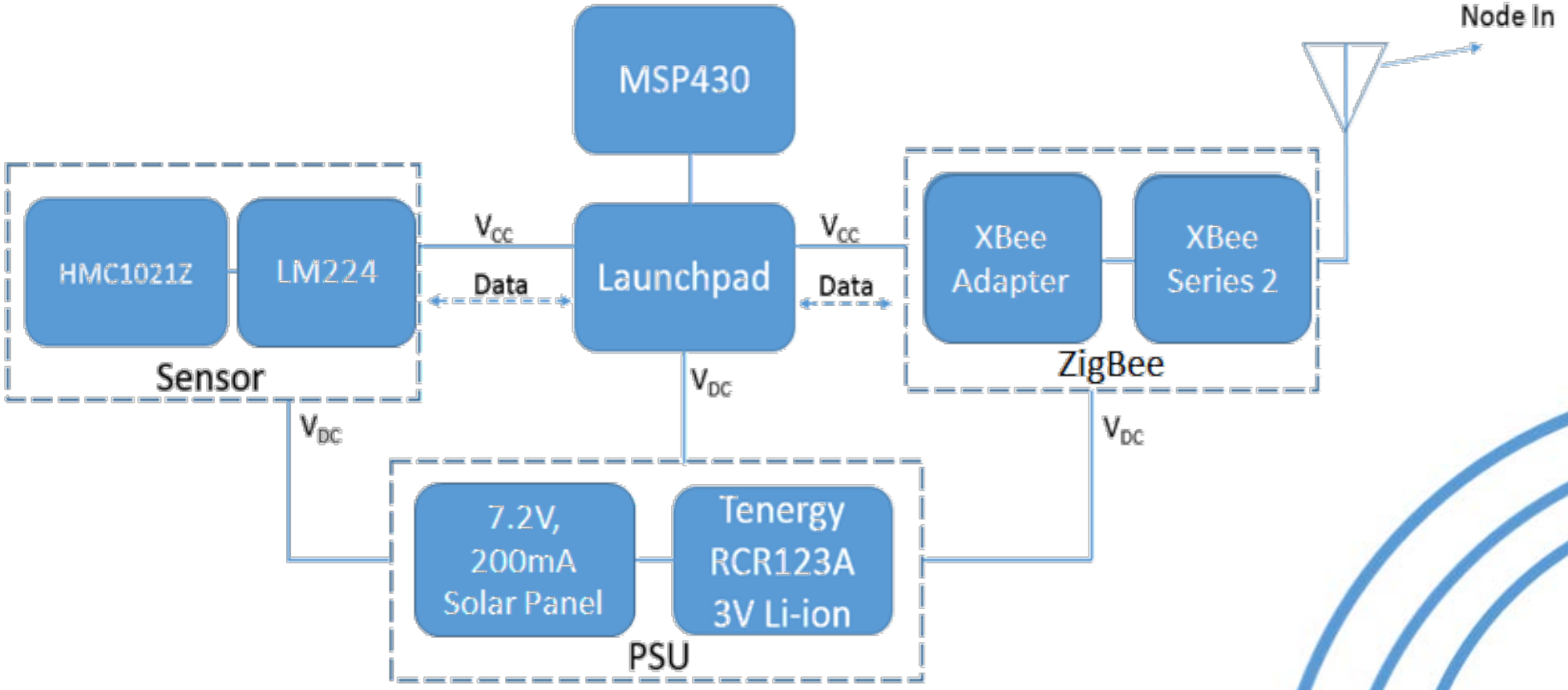
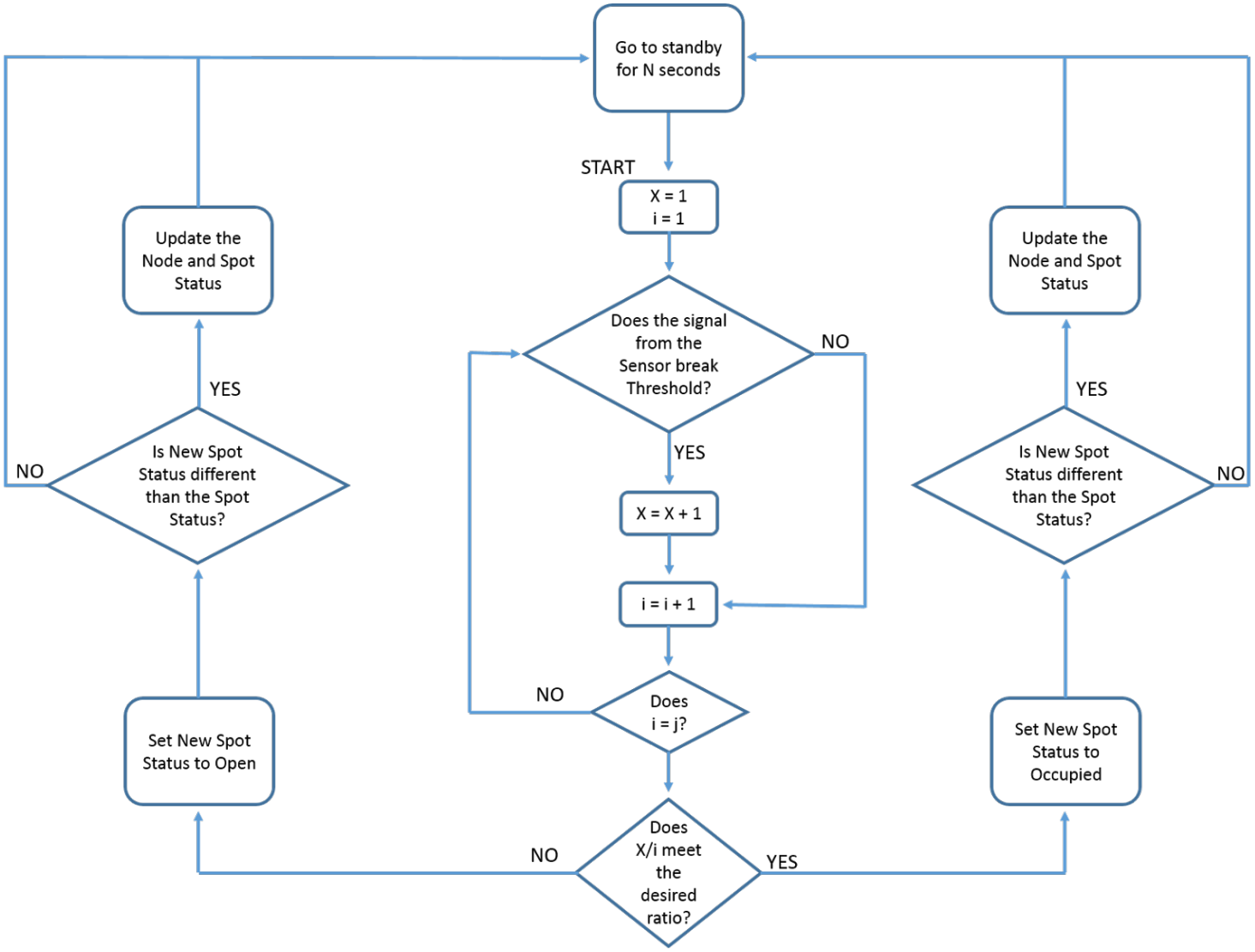
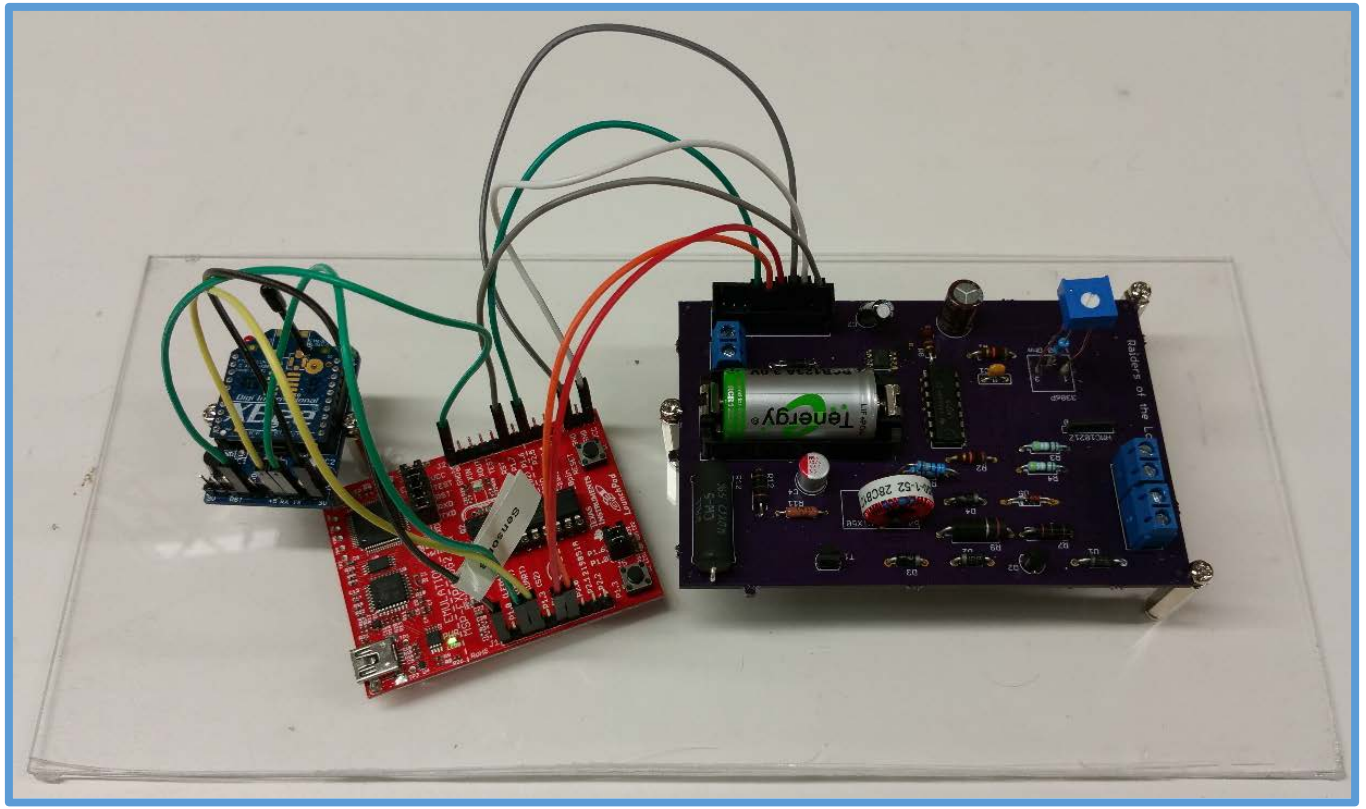


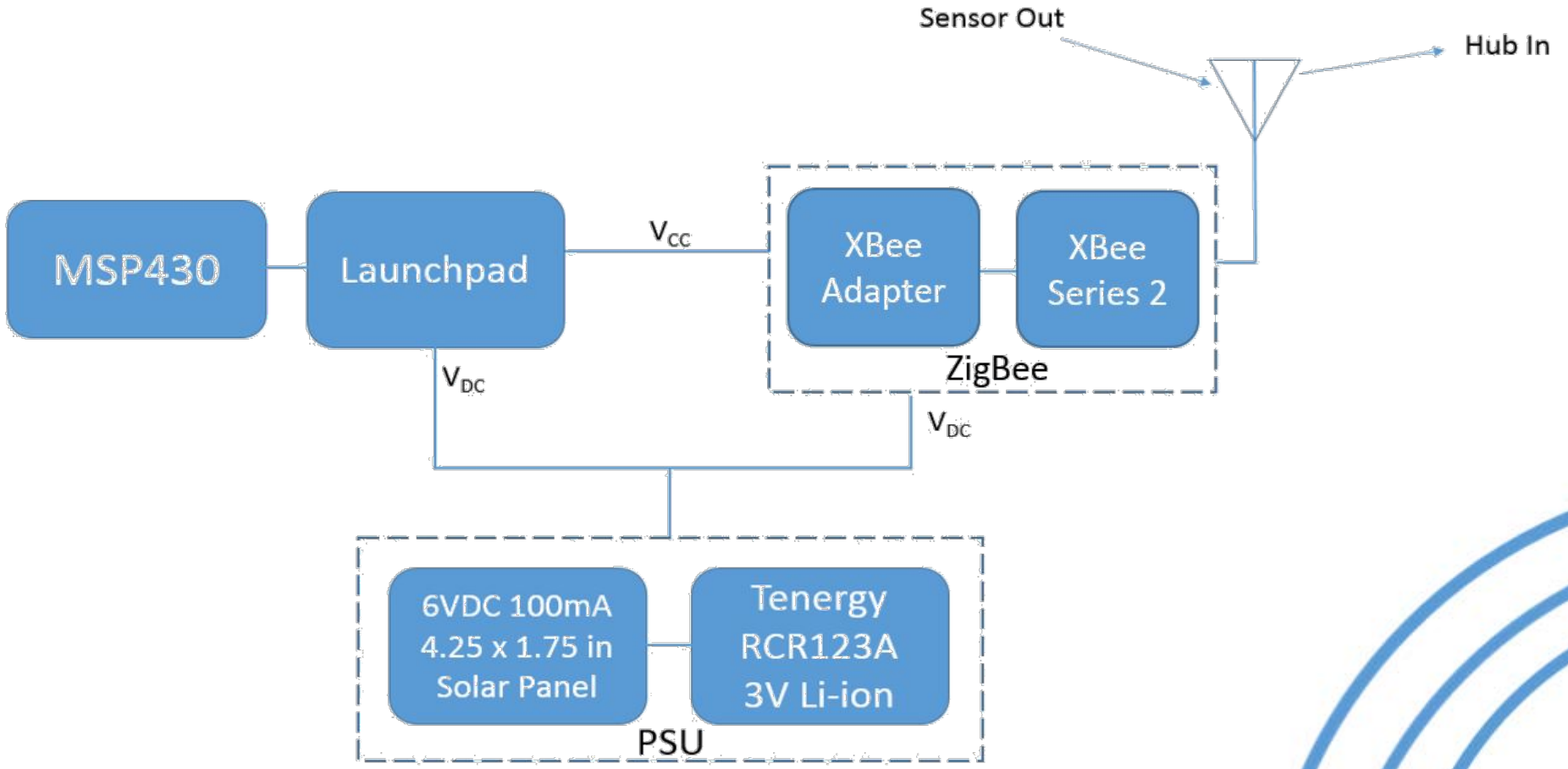
Sensor Device



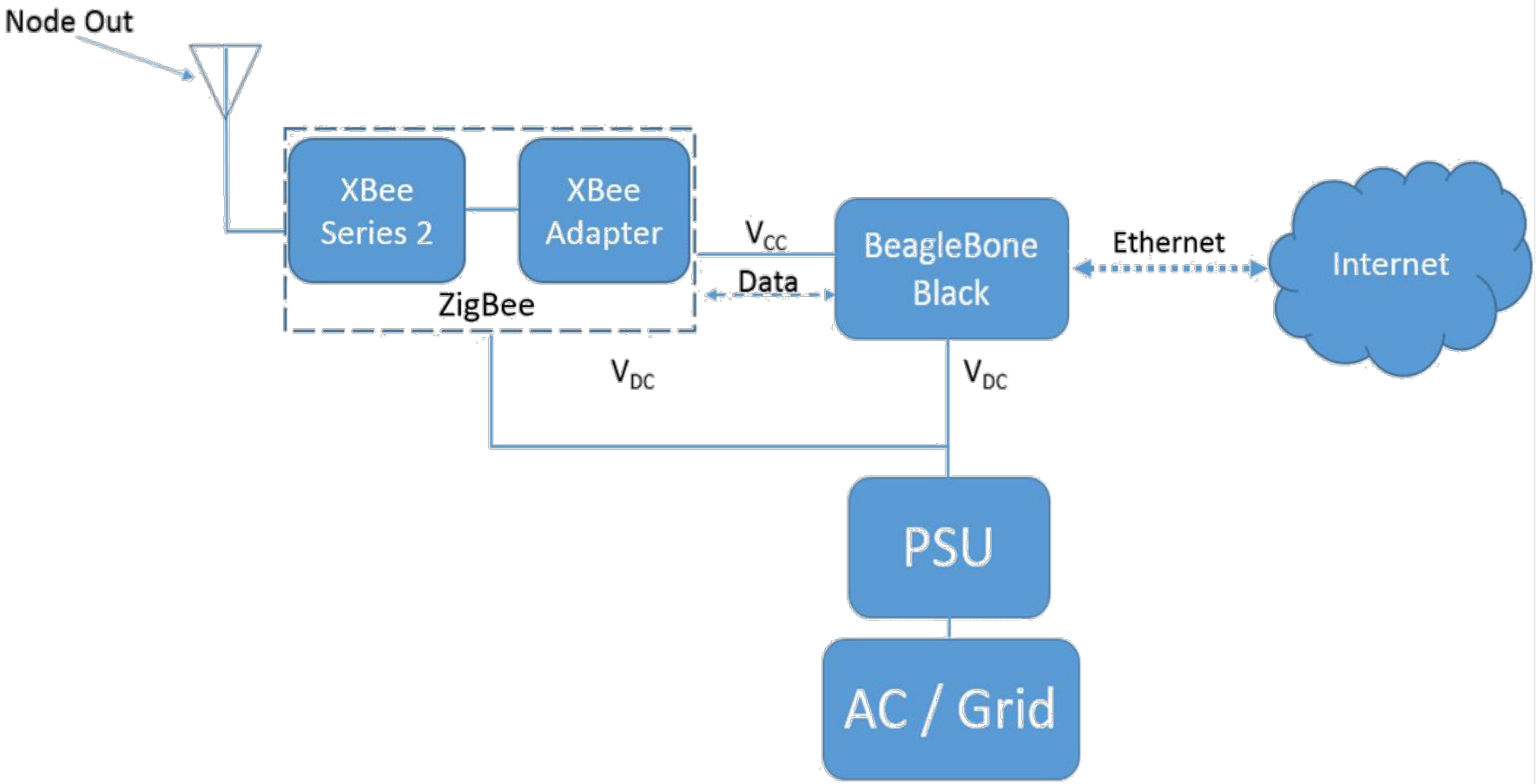
Sensor Device



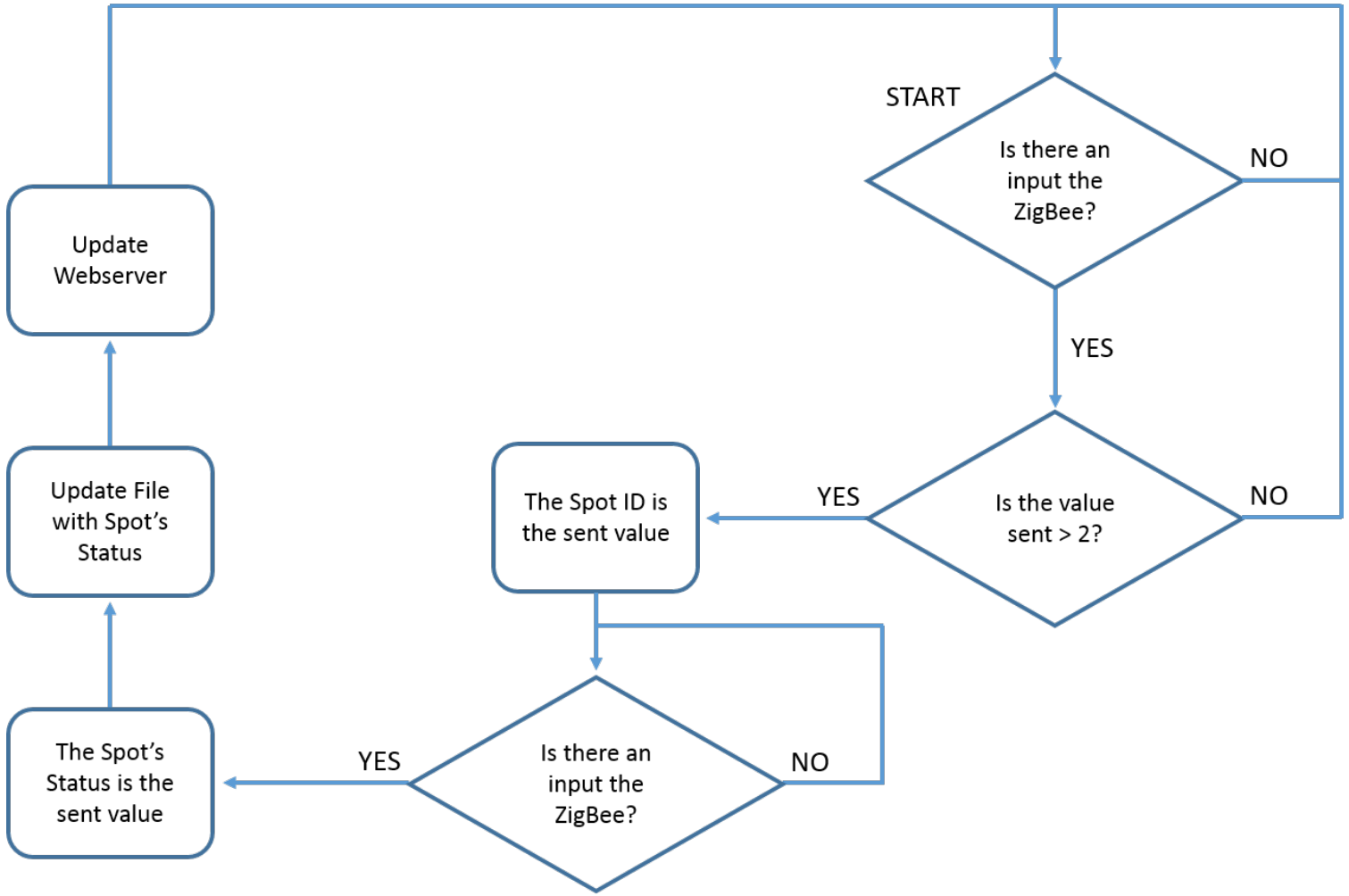
Node


Sensor Out
Hub In
MSP430
Launchpad
V_{CC}
XBee Adapter
XBee Series 2
ZigBee
V_{DC}
V_{DC}
6VDC 100mA 4.25 x 1.75 in Solar Panel
Tenergy RCR123A 3V Li-ion
PSU

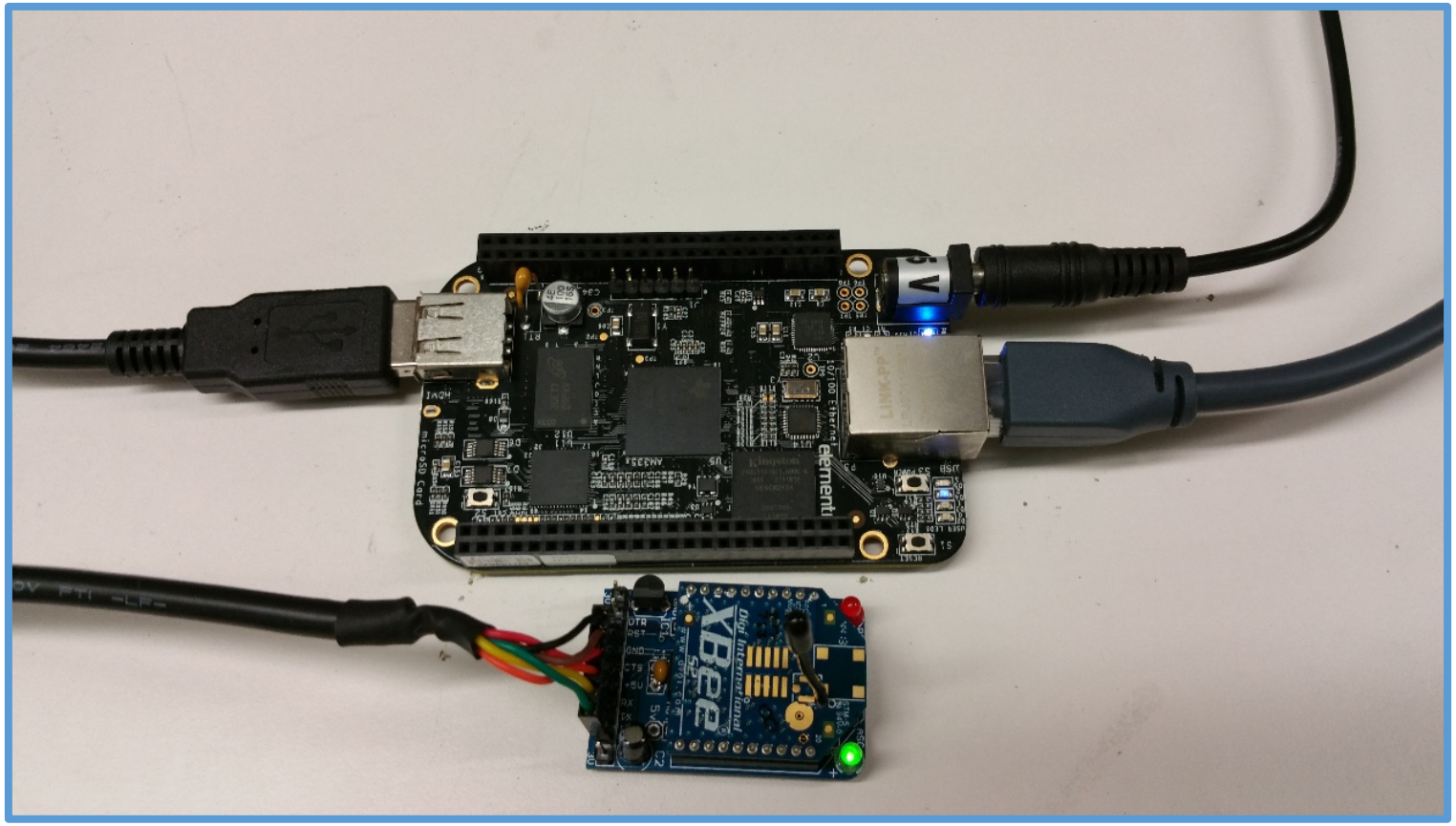
Hub


Node Out
XBee Series 2
XBee Adapter
ZigBee
V_{CC}
Data
BeagleBone Black
Ethernet
Internet
V_{DC}
V_{DC}
PSU
AC / Grid

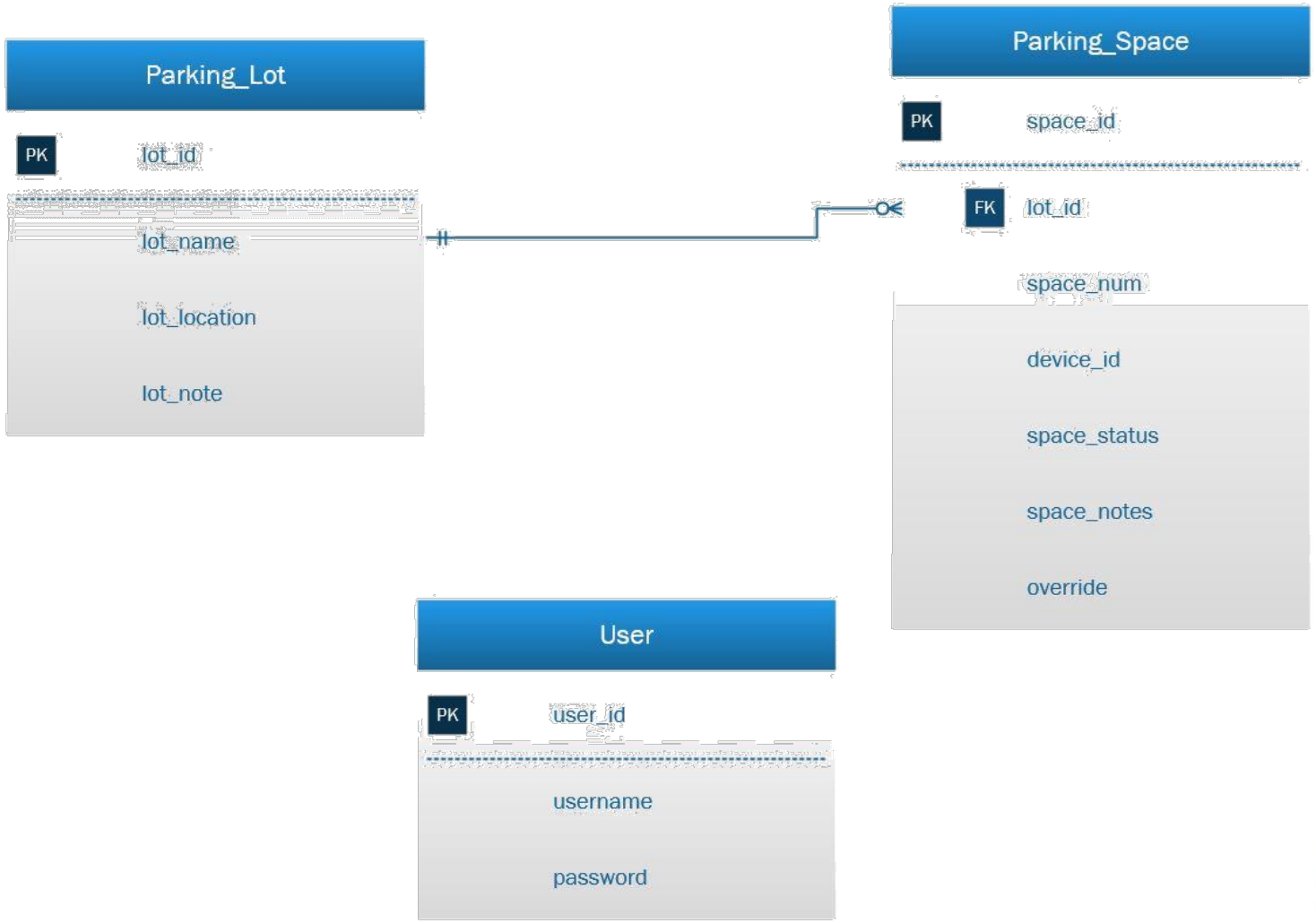
Hub


START
Is there an input the ZigBee?
NO
YES
Is the value sent > 2?
YES
NO
The Spot ID is the sent value
Is there an input the ZigBee?
YES
NO
The Spot's Status is the sent value
Update File with Spot's Status
Update Webserver

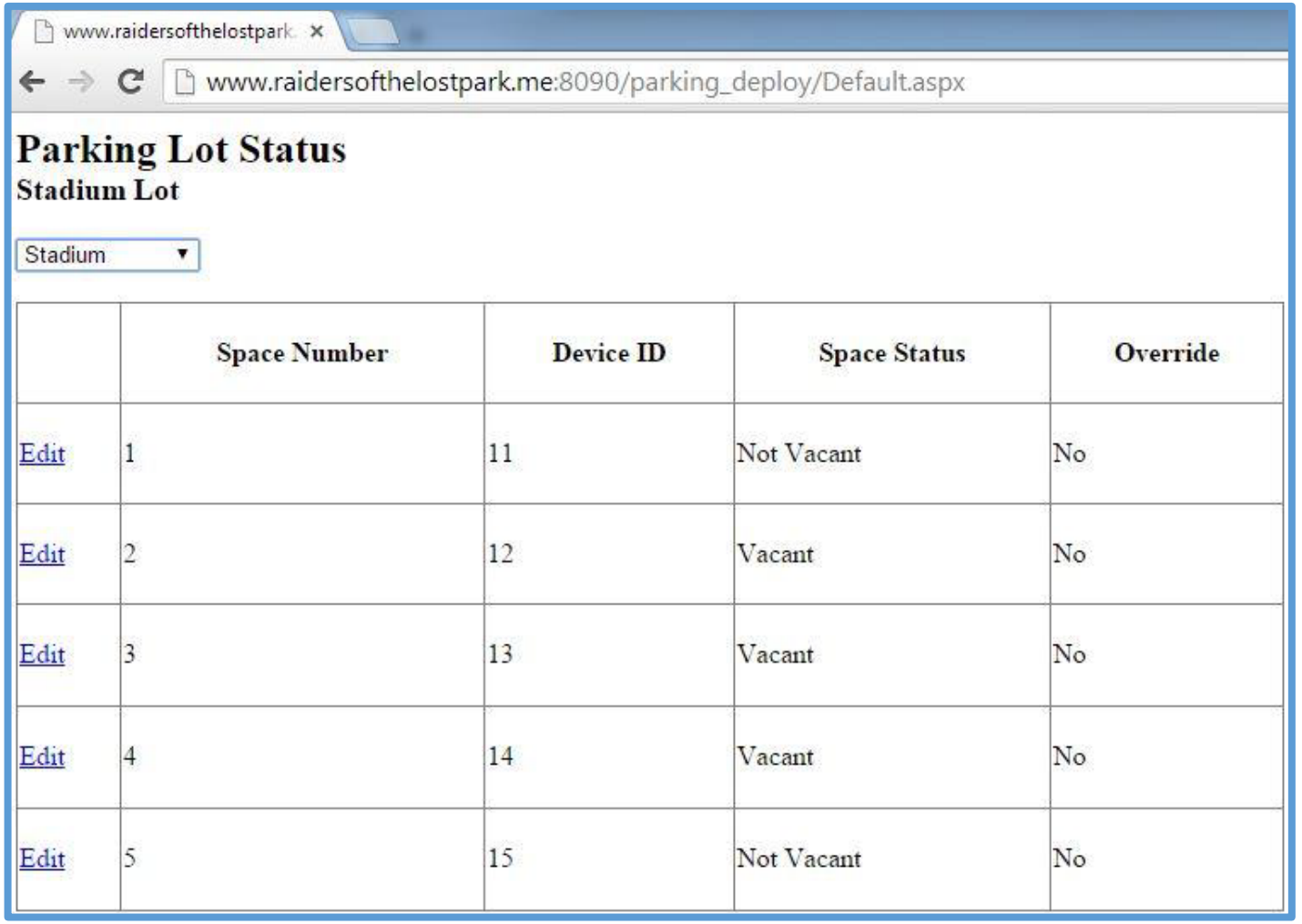
Hub



Database


Parking_Lot
PK
lot_id
lot_name
lot_location
lot_note
Parking_Space
PK
space_id
FK
lot_id
space_num
device_id
space_status
space_notes
override
User
PK
user_id
username
password

Web Server



	Space Number	Device ID	Space Status	Override
Edit	1	11	Not Vacant	No
Edit	2	12	Vacant	No
Edit	3	13	Vacant	No
Edit	4	14	Vacant	No
Edit	5	15	Not Vacant	No

Web App

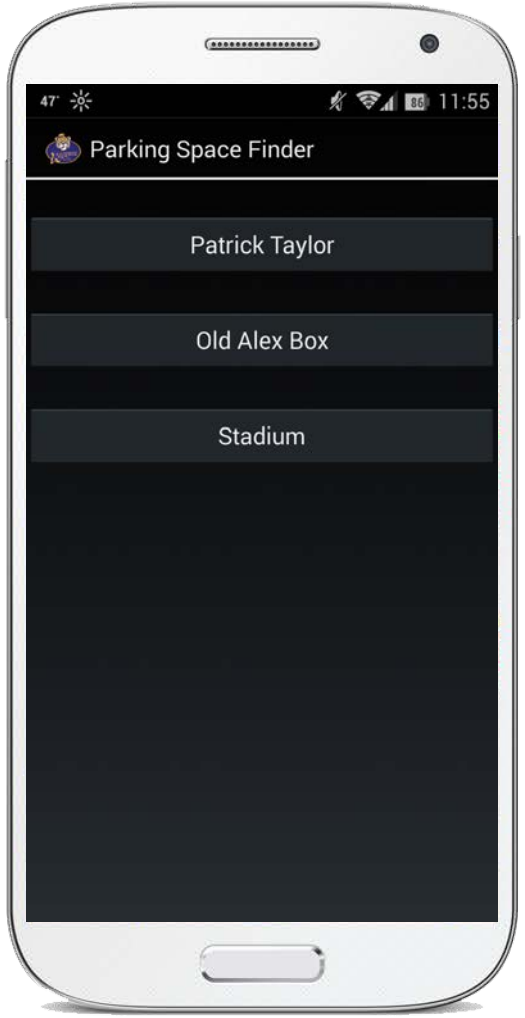
Parking Lot Status

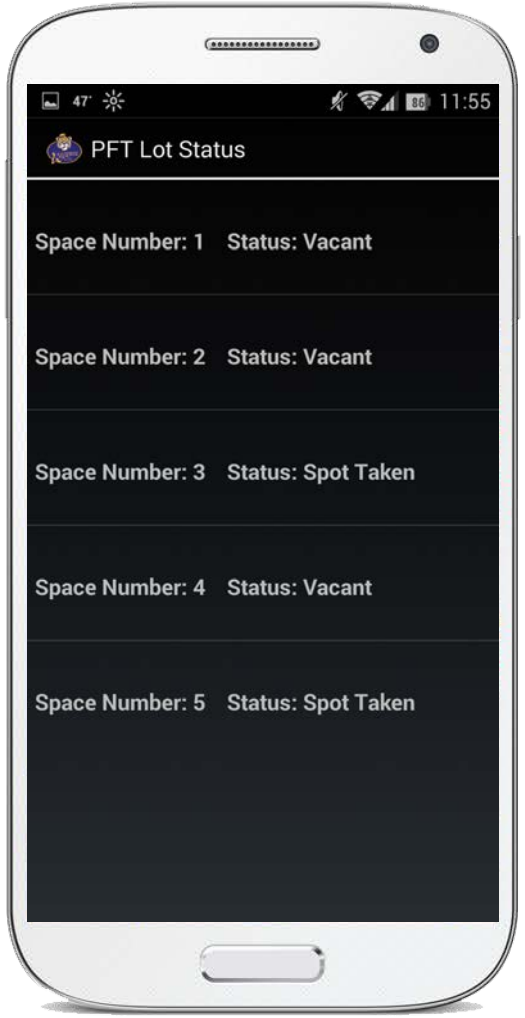
Lot	Status	Vacant Spaces
Patrick Taylor	0.4000	3
Alex Box	0.8000	1
Stadium	0.4000	3

Patrick Taylor Lot

Available Spot Spot Taken

Android App


11:55
Parking Space Finder
Patrick Taylor
Old Alex Box
Stadium


11:55
PFT Lot Status
Space Number: 1 Status: Vacant
Space Number: 2 Status: Vacant
Space Number: 3 Status: Spot Taken
Space Number: 4 Status: Vacant
Space Number: 5 Status: Spot Taken

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Our Costs

Solar	$64.70
Charger	$104.71
PCB	$59.30
Sensor	$88.70
Xbee	$139.75
Xbee Adaptor	$50.00
MSP430	$41.48
BeagleBone	$55.00
Total	**$603.64**

Our Costs

Solar	$16.18
Charger	$26.18
PCB	$19.77
Sensor	$29.57
Xbee	$27.95
Xbee Adaptor	$10.00
MSP430	$10.37
BeagleBone	$0.00
Total	**$140.01**

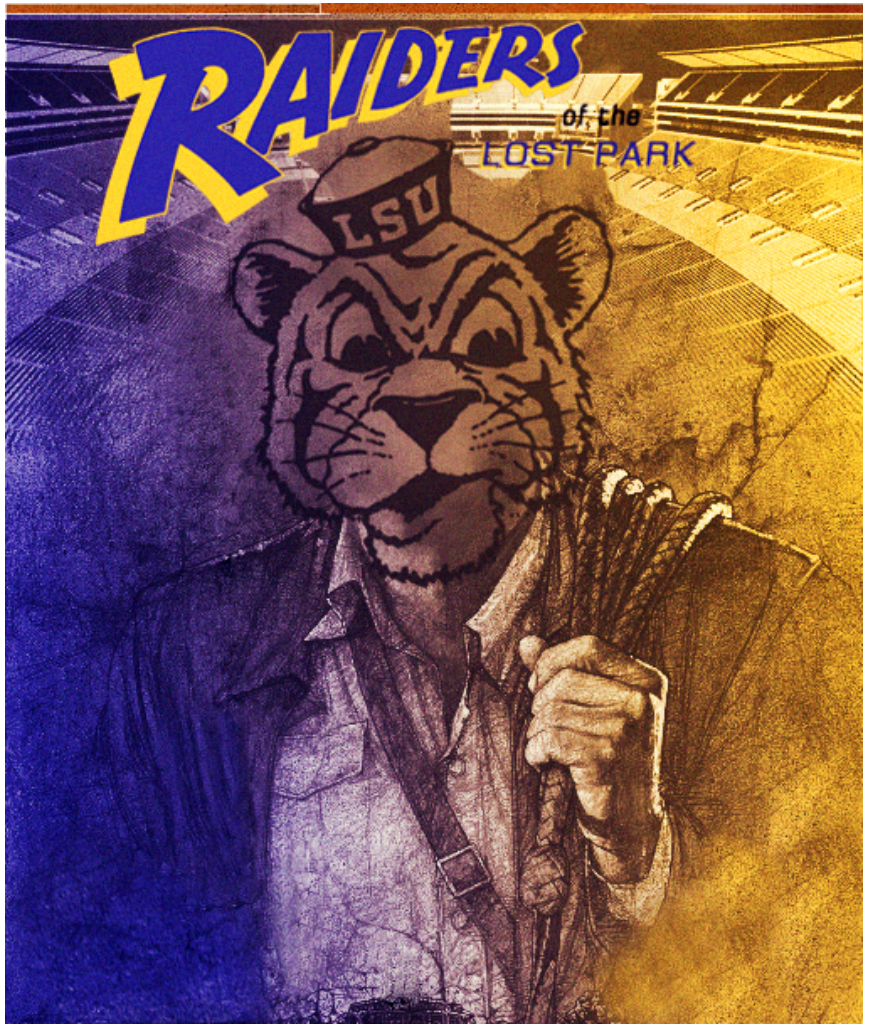
Commercialization

Car Demonstration

System Demonstration

www.raidersofthelostpark.me:8080/status.php

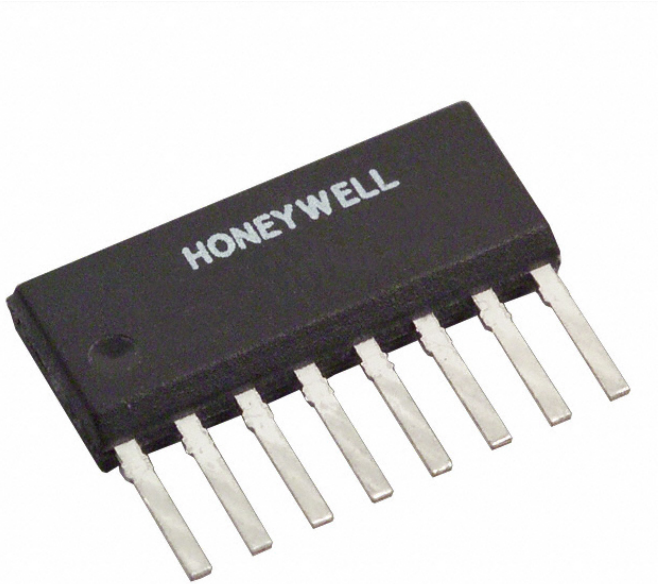
Find Your Lost Spot



Appendix

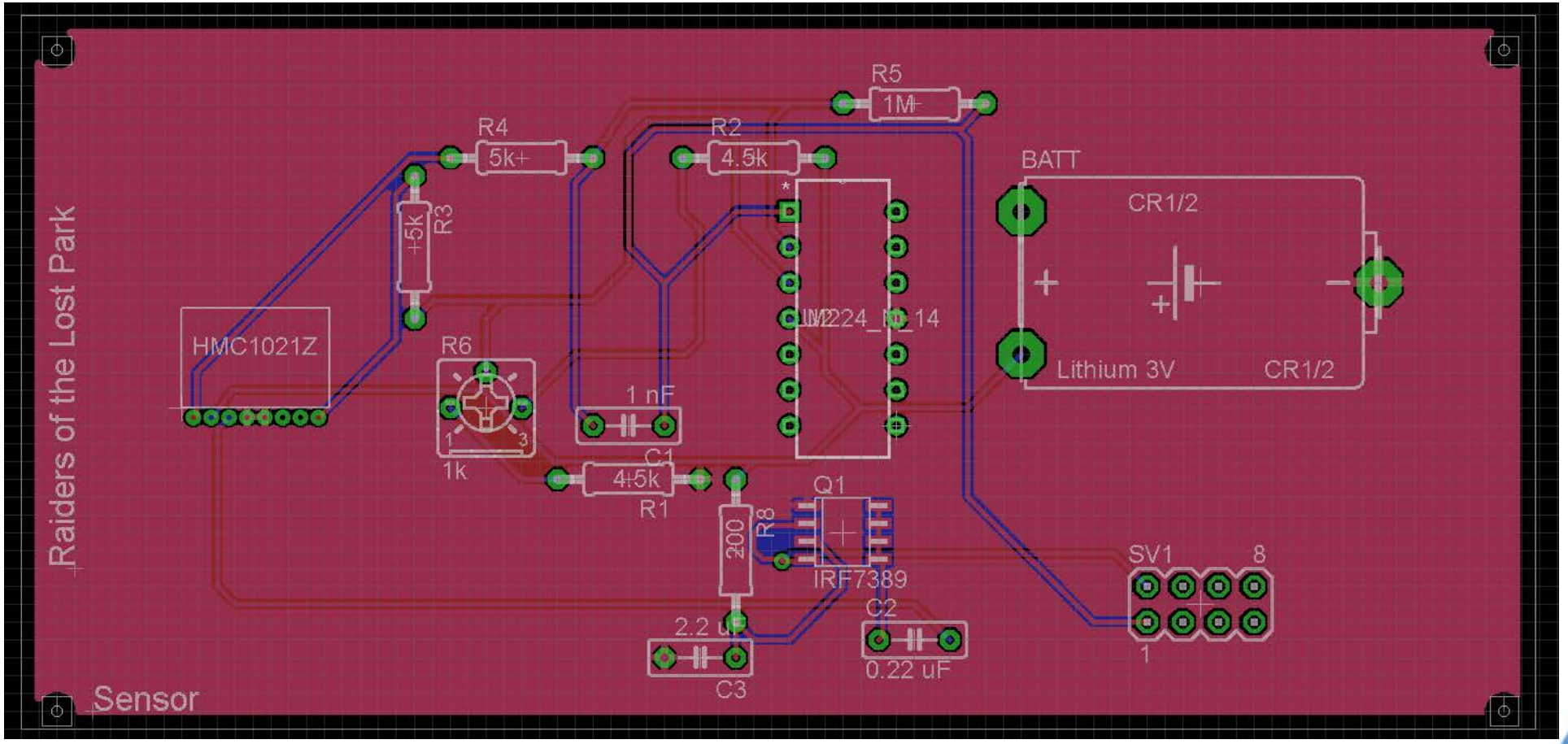
Sensor

- Honeywell HMC1021

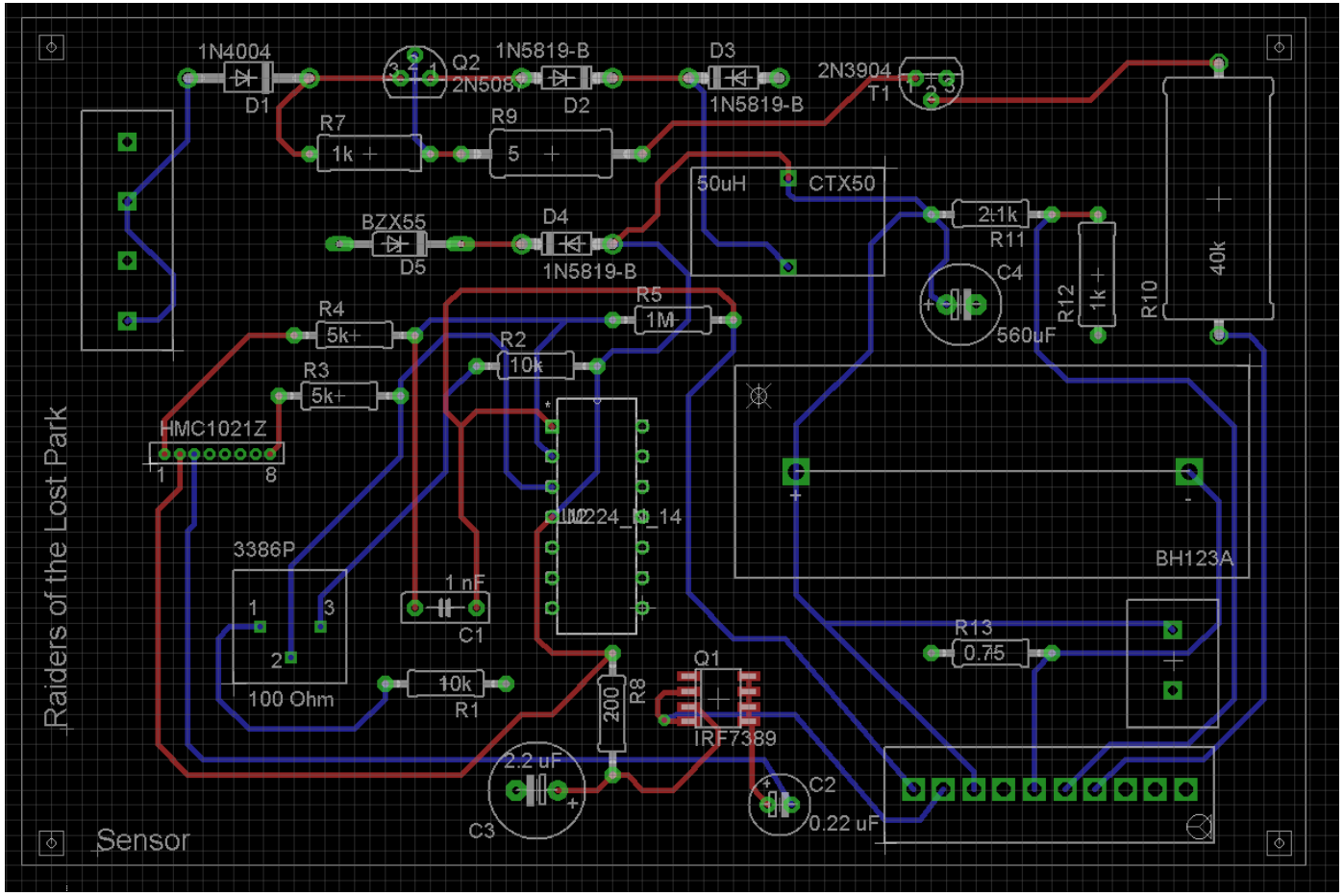


Standoff Distance	Flux Density Shift
1 foot	270 milligauss
3 foot	75 milligauss
5 foot	10 milligauss
10 foot	2 milligauss
12 foot	<1 milligauss

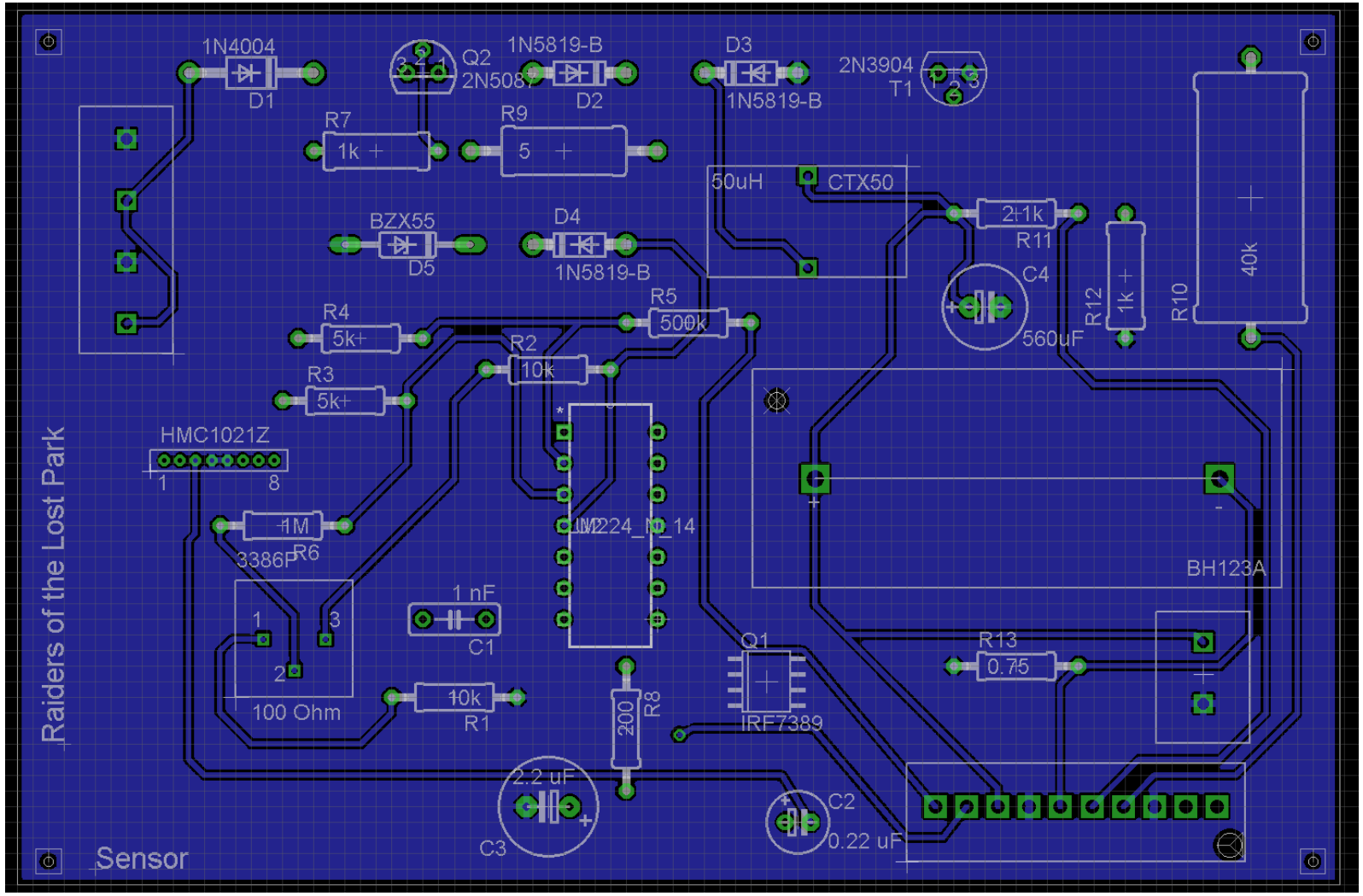
PCB


Raiders of the Lost Park
Sensor
HMC1021Z
R4
5k
R3
5k
R5
1M
R2
4.5k
R6
1k
1 nF
C1
4.5k
R1
R8
200
Q1
IRF7389
C2
0.22 uF
C3
2.2 uF
BATT
CR1/2
Lithium 3V
CR1/2
SV1
8
1

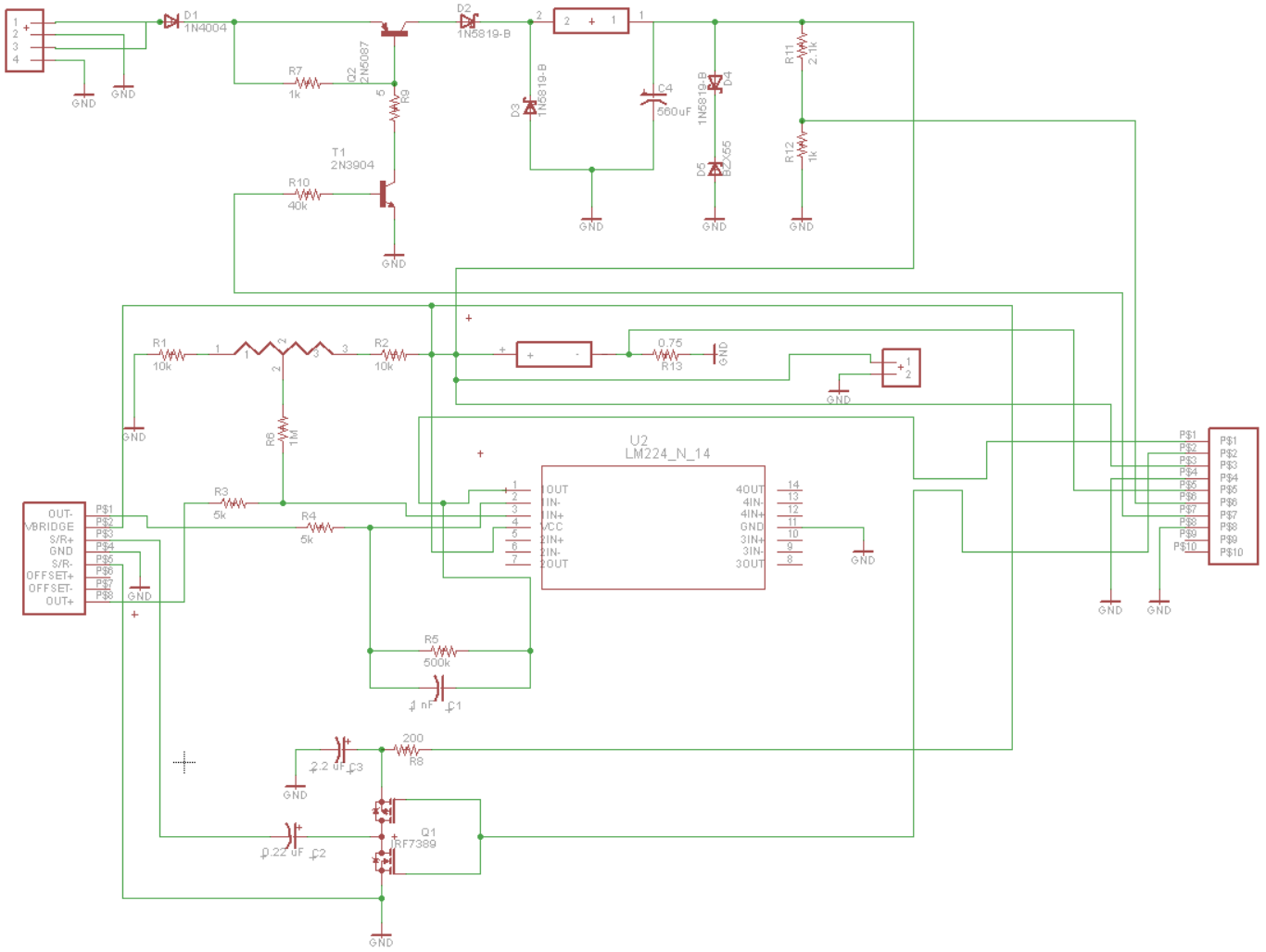
PCB


1N4004
D1
Q2
2N5087
1N5819-B
D2
D3
1N5819-B
2N3904
T1
R7
1k
R9
5
50uH
CTX50
BZX55
D5
D4
1N5819-B
2.1k
R11
C4
560uF
R12
1k
R10
40k
R5
1M
R4
5k
R2
10k
R3
5k
HMC1021Z
1
8
LM224_D_14
3386P
100 Ohm
1 nF
C1
BH123A
R13
0.75
Q1
IRF7389
10k
R1
200
R8
2.2 uF
C3
C2
0.22 uF
Raiders of the Lost Park
Sensor

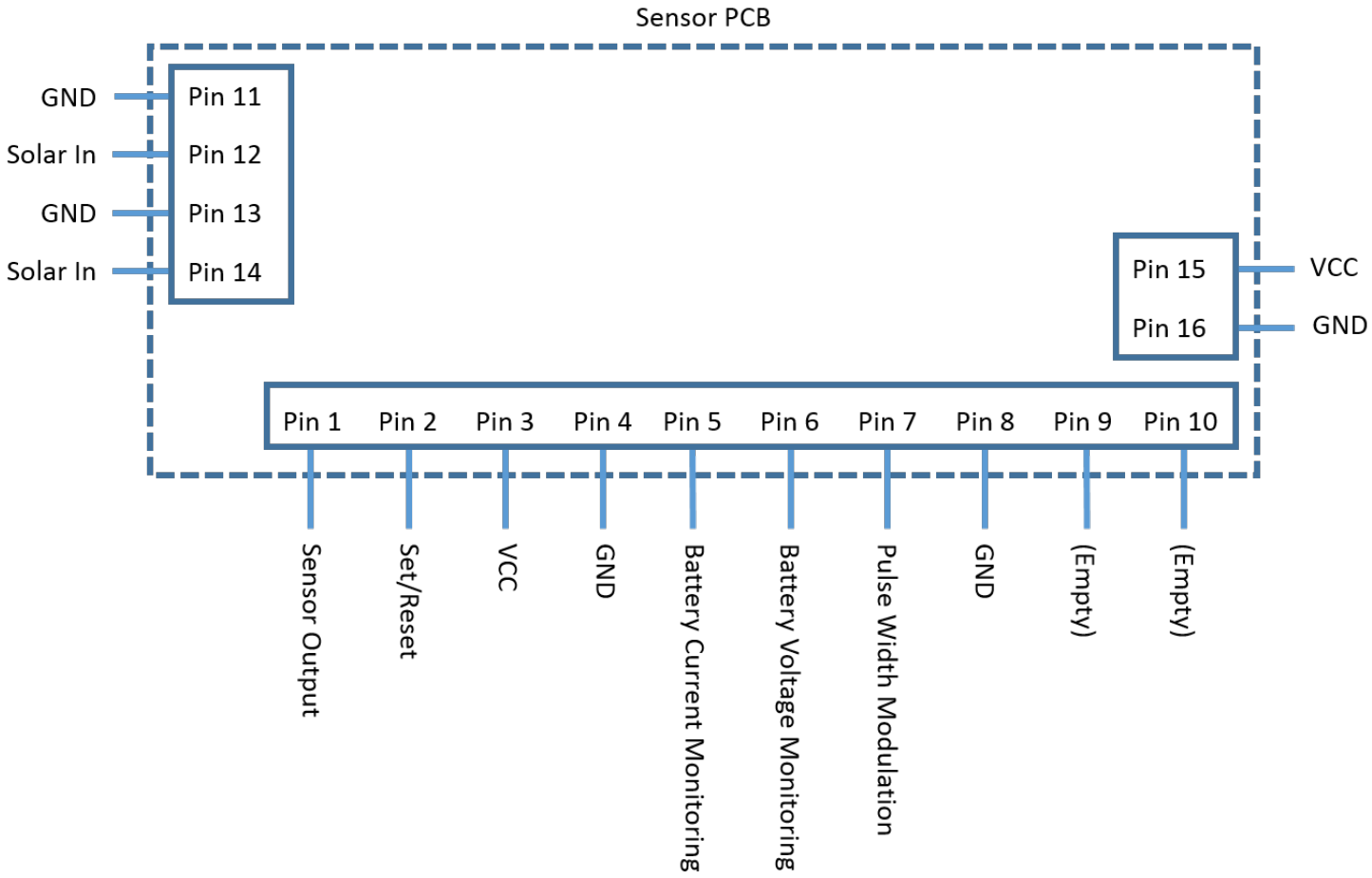
PCB


1N4004
D1
Q2
2N5087
1N5819-B
D2
D3
1N5819-B
2N3904
T1
R7
1k
R9
5
50uH
CTX50
BZX55
D5
D4
1N5819-B
2.1k
R11
C4
560uF
R12
1k
R10
40k
R5
500k
R4
5k
R2
10k
R3
5k
HMC1021Z
1
8
1M
3386P
R6
LM224_14
1 nF
C1
1
2
3
100 Ohm
10k
R1
200
R8
Q1
IRF7389
R13
0.75
BH123A
2.2 uF
C3
C2
0.22 uF
Raiders of the Lost Park
Sensor

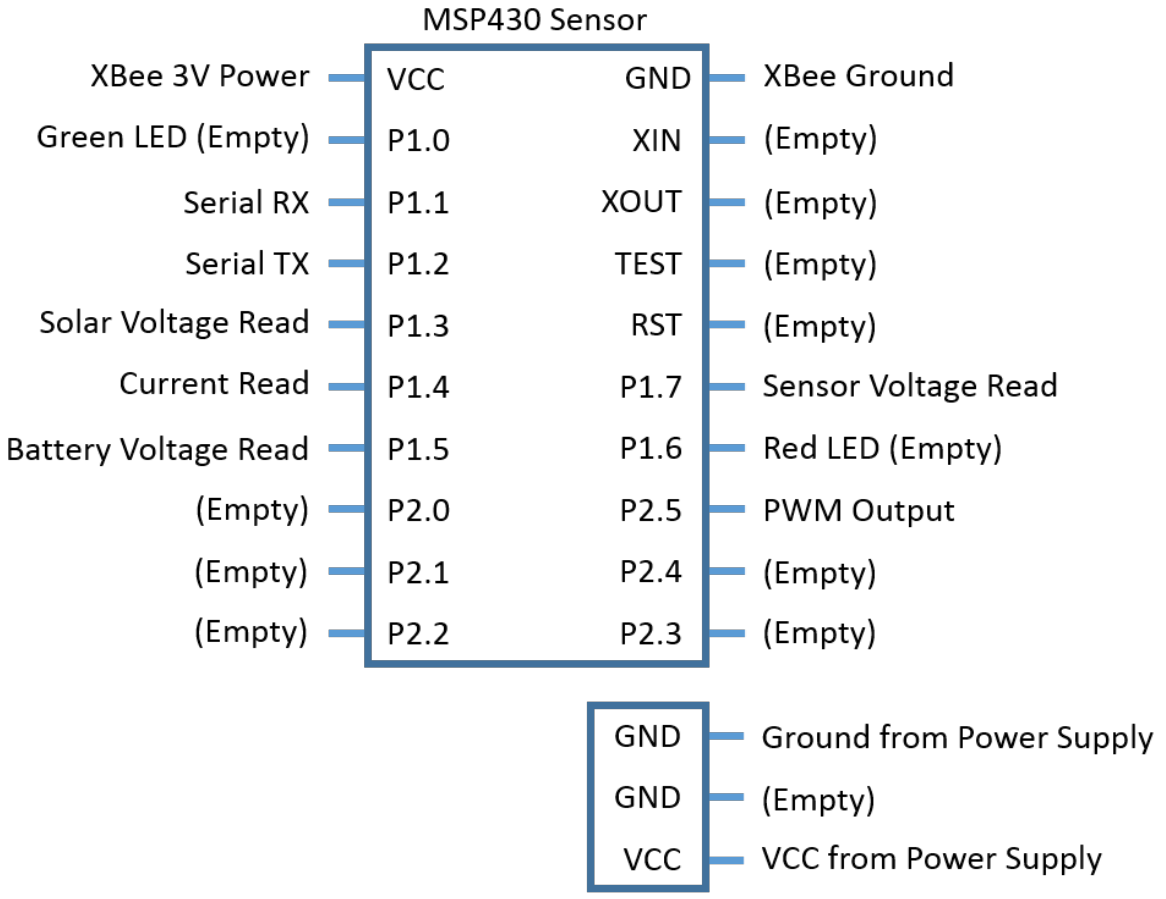
PCB Circuit Schematic



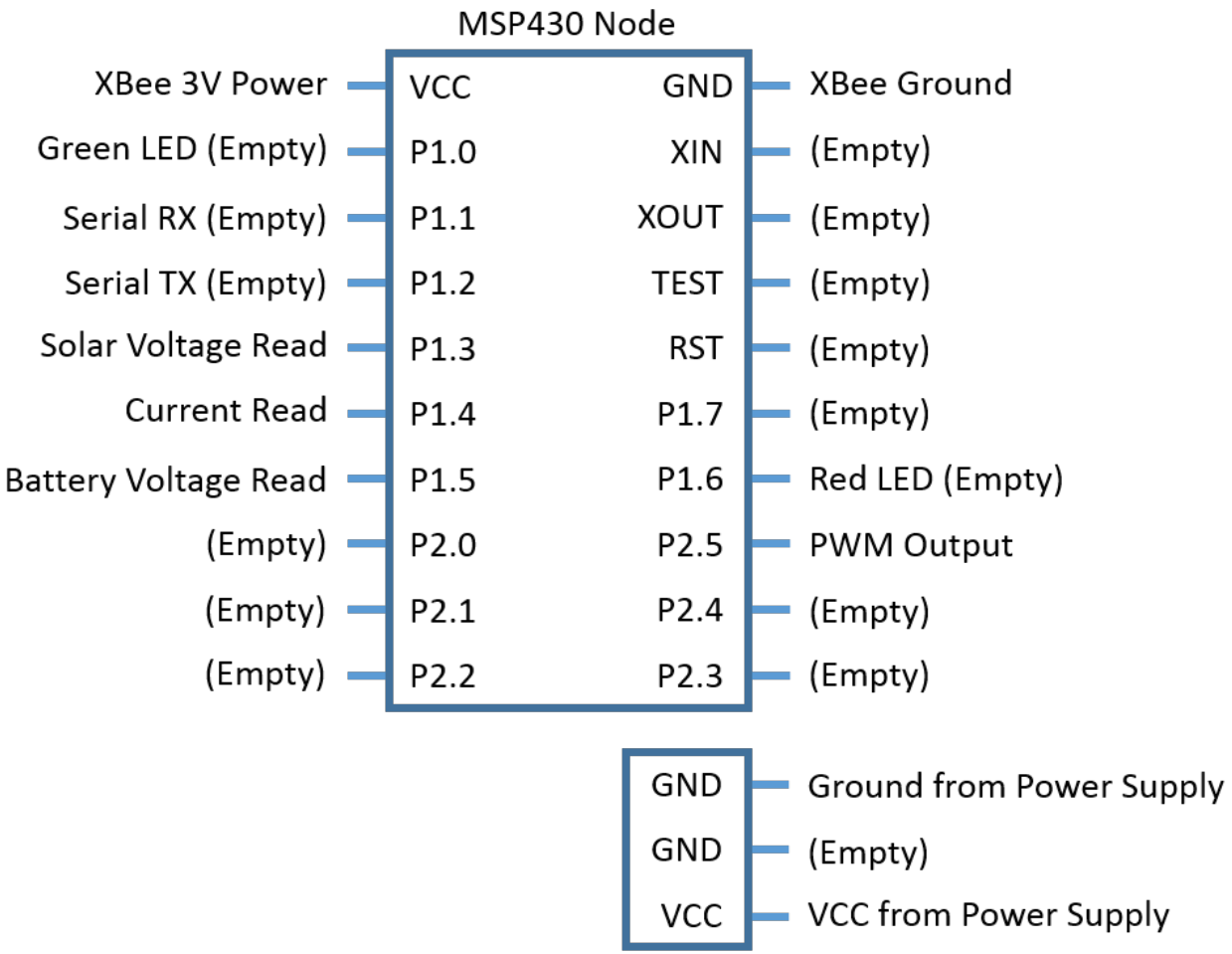
Sensor PCB Pin Assignment



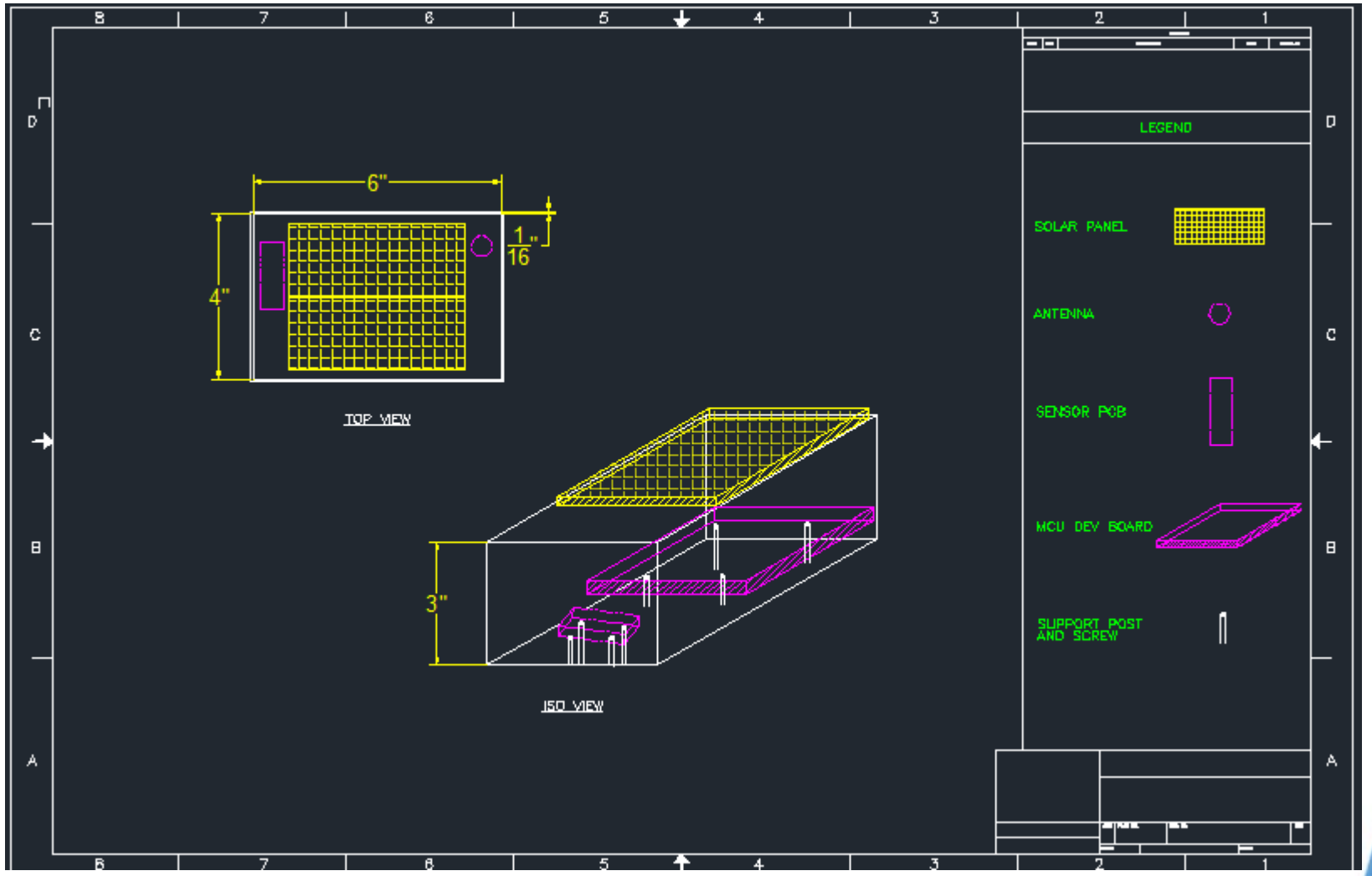
Sensor Pin Assignment



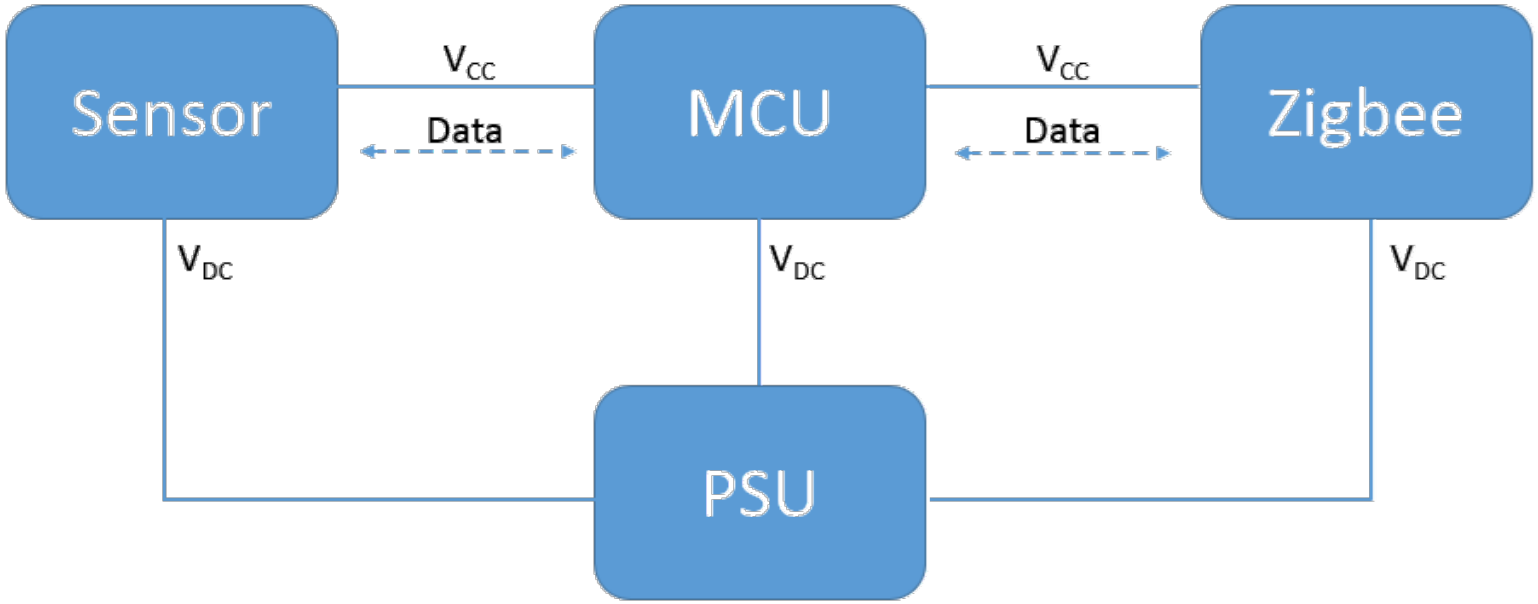
Node Pin Assignment



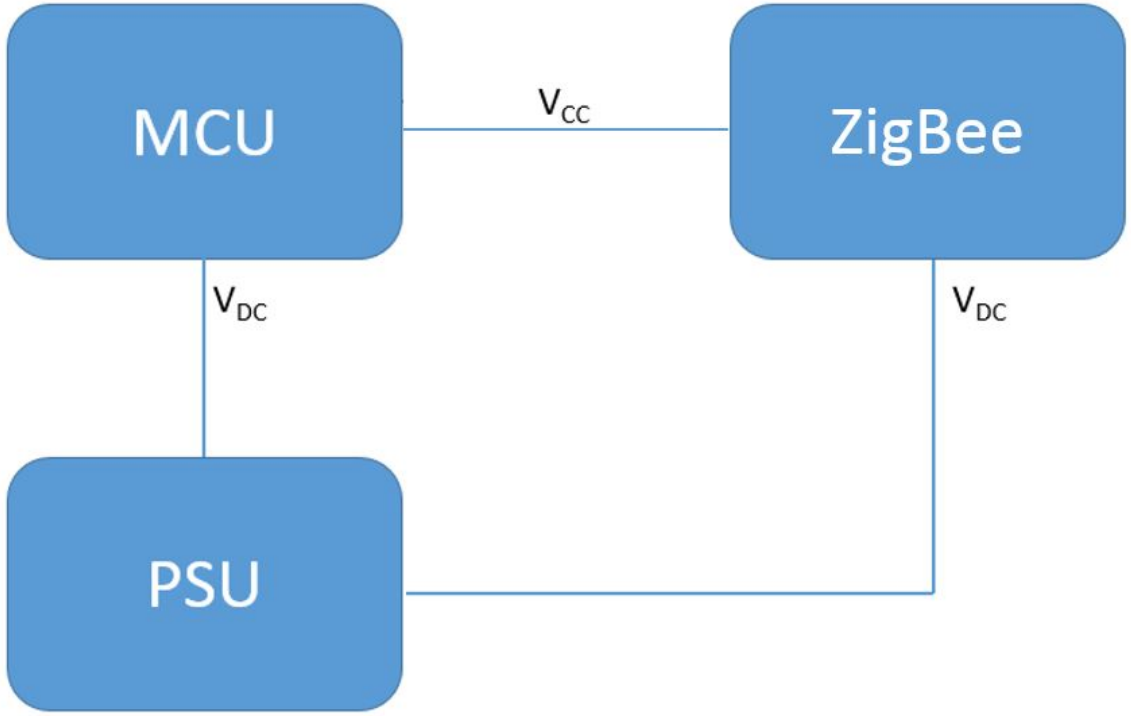
Housing


6"
4"
1"
16
TOP VIEW
3"
ISO VIEW
LEGEND
SOLAR PANEL
ANTENNA
SENSOR PCB
MCU DEV BOARD
SUPPORT POST
AND SCREW

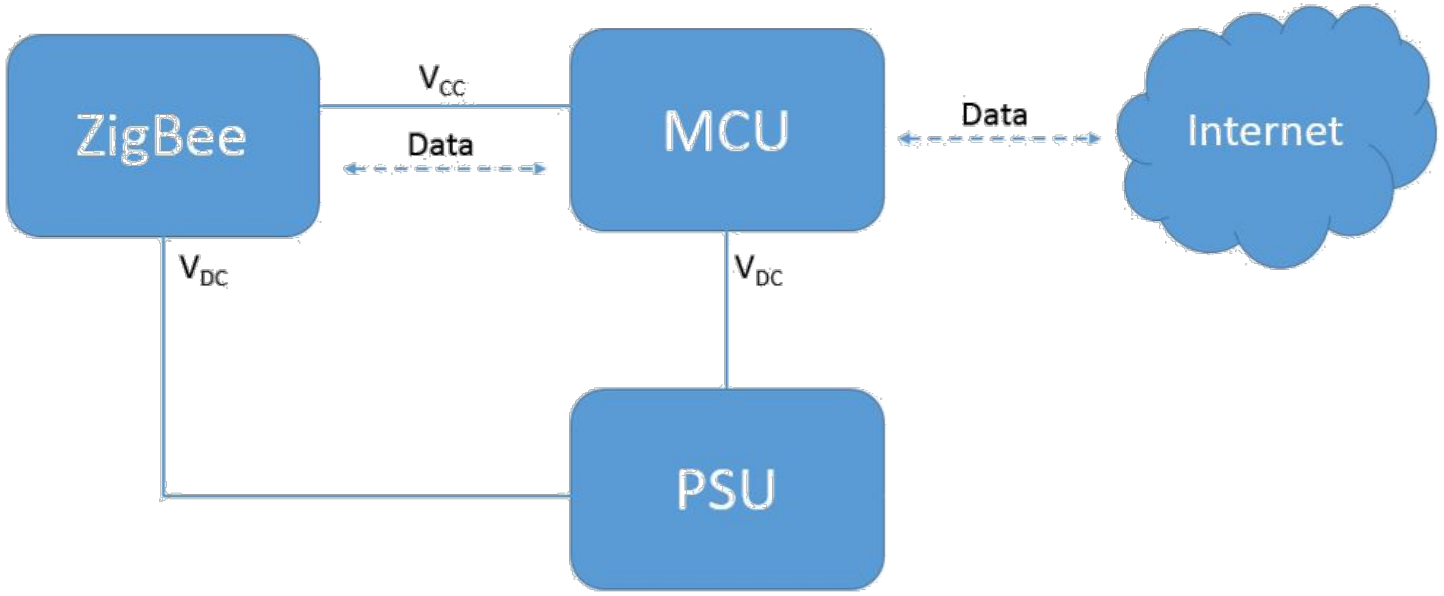
Sensor Design



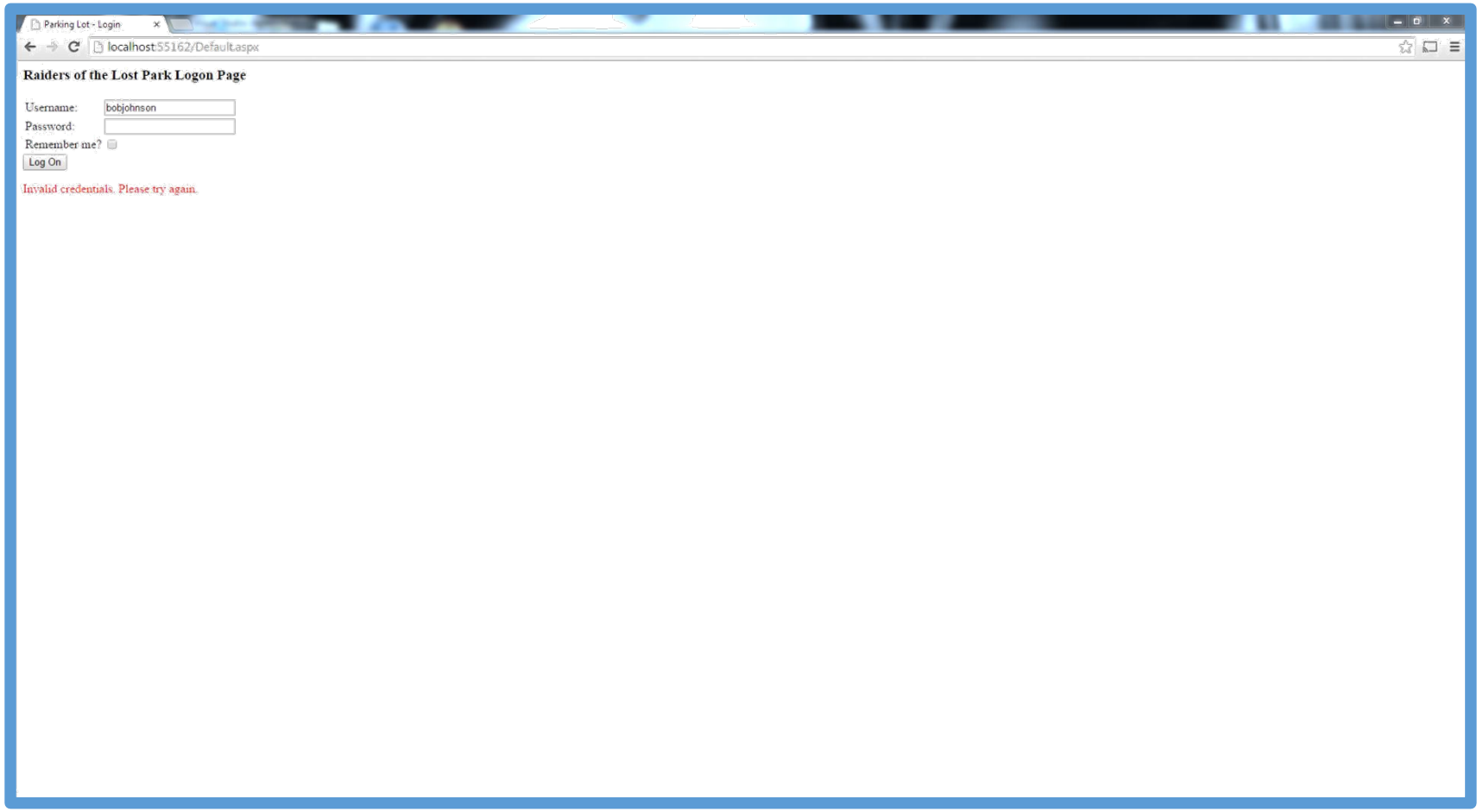
Node Design



Hub Design



Web App

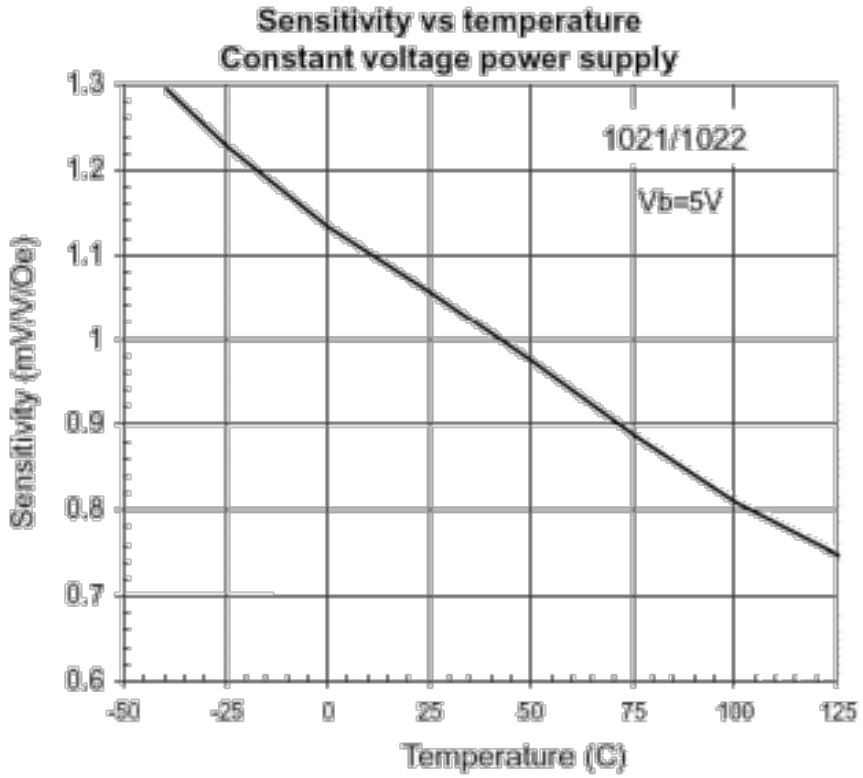

Parking Lot - Login
localhost:55162/Default.aspx
Raiders of the Lost Park Logon Page
Username:
bobjohnson
Password:
Remember me?
Log On
Invalid credentials. Please try again.

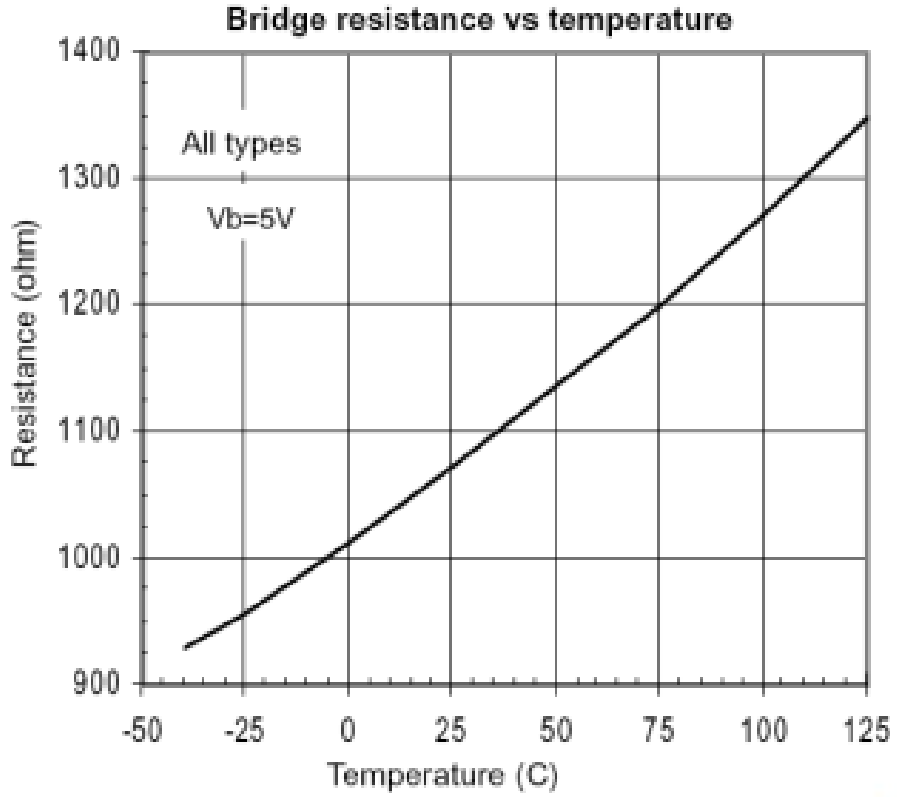
Demo

- Video of testing the system
  - SUV
  - Truck
  - Sedan

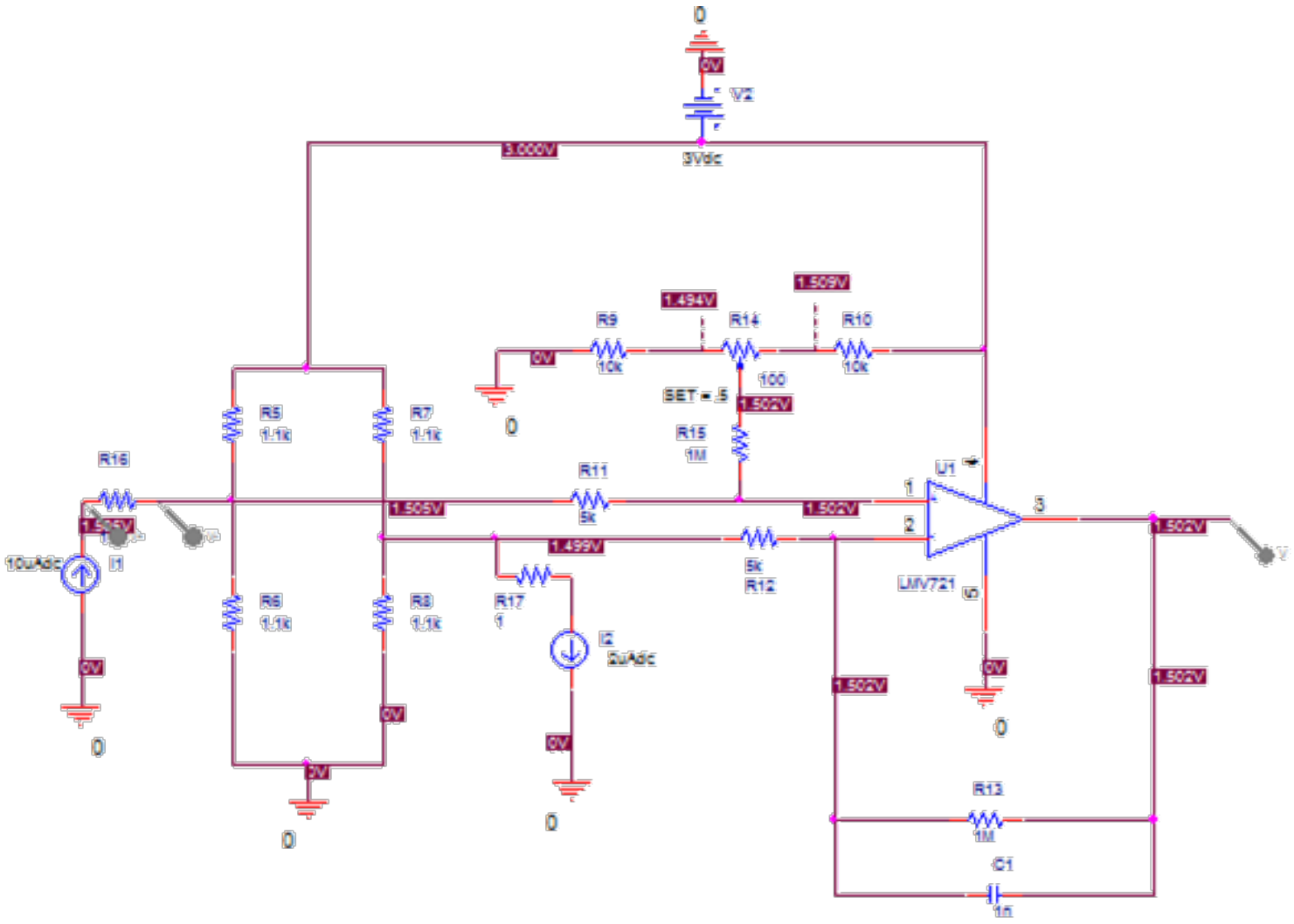
- Live Demo
  - Sensor detecting steel

Sensor

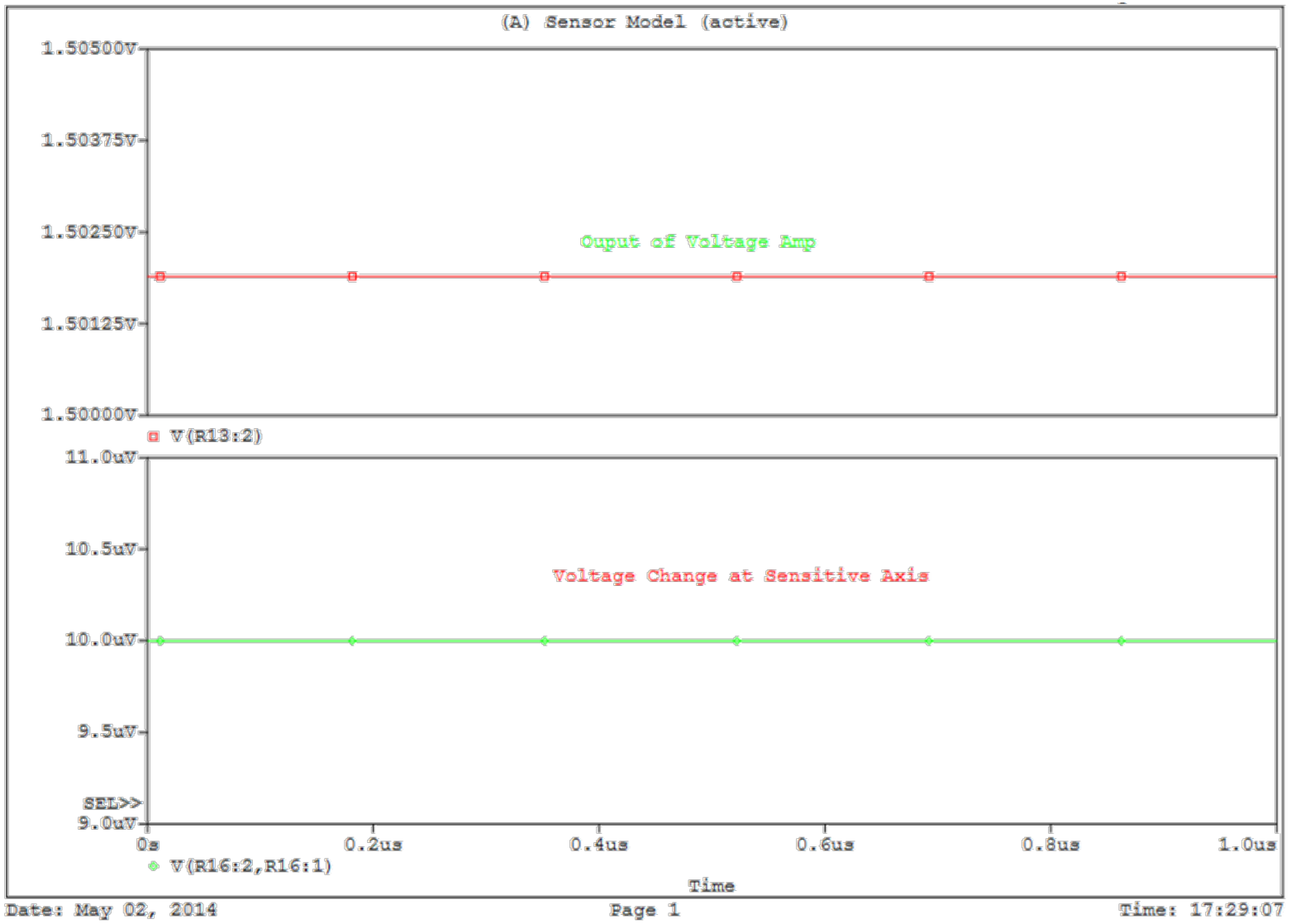

Sensitivity vs temperature
Constant voltage power supply
1021/1022
Vb=5V
Sensitivity (mV/V/Oe)
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
-50
-25
0
25
50
75
100
125
Temperature (C)


Bridge resistance vs temperature
All types
Vb=5V
Resistance (ohm)
1400
1300
1200
1100
1000
900
-50
-25
0
25
50
75
100
125
Temperature (C)

Sensor

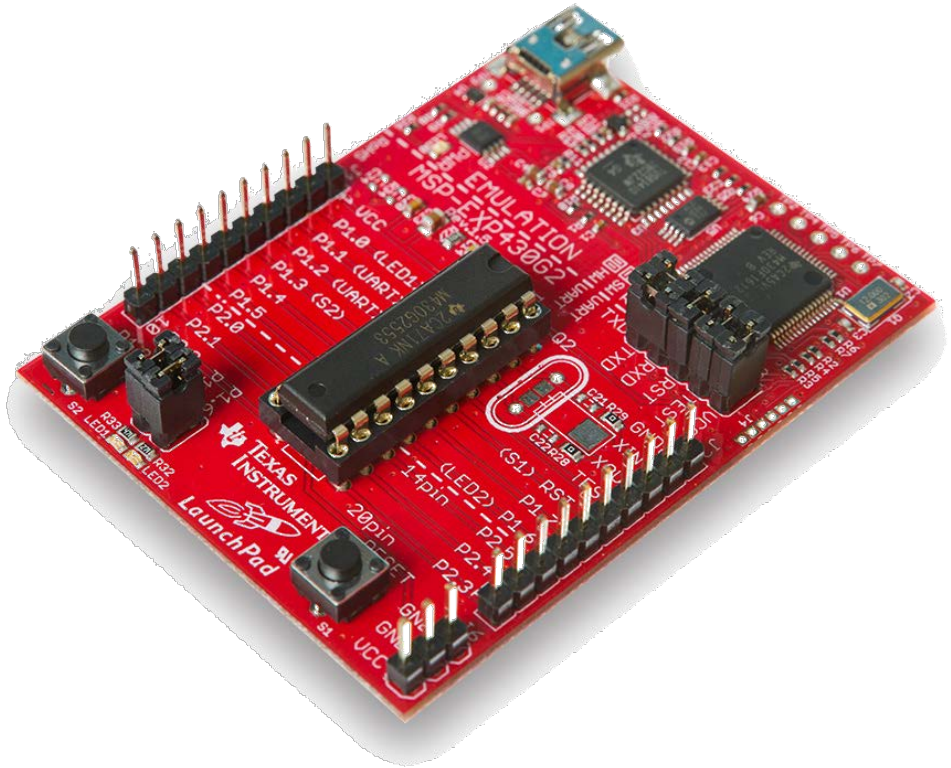

0
0V
V2
3Vdc
3.000V
1.509V
1.494V
R9
10k
R14
100
SET = .5
R10
10k
1.502V
R15
1M
R5
1.1k
R7
1.1k
R16
R11
5k
U1
1.505V
1.502V
1.499V
R12
5k
LMV721
10uAdc
I1
R17
1
I2
5uAdc
R6
1.1k
R8
1.1k
R13
1M
C1
1n

Sensor


(A) Sensor Model (active)
1.50500V
1.50375V
1.50250V
1.50125V
1.50000V
Ouput of Voltage Amp
V(R13:2)
11.0uV
10.5uV
10.0uV
9.5uV
SEL>>
9.0uV
Voltage Change at Sensitive Axis
0s
0.2us
0.4us
0.6us
0.8us
1.0us
V(R16:2,R16:1)
Time
Date: May 02, 2014
Page 1
Time: 17:29:07

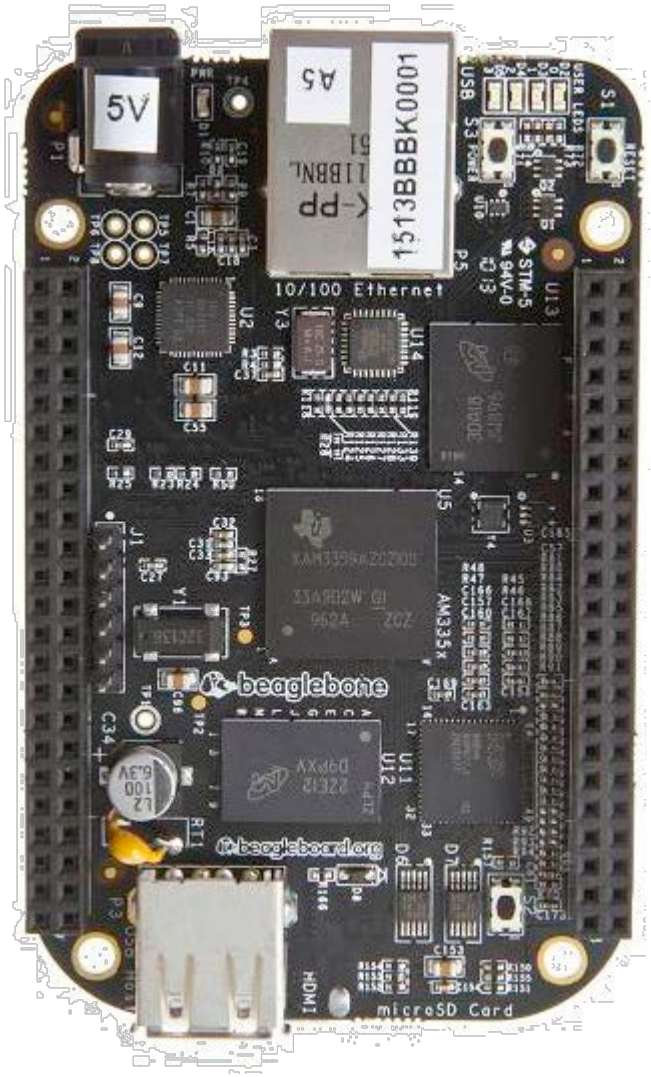
Sensor and Node Microcontrollers

- MSP430 Launchpad
  - MSP430G2553IN20
  - 16kB Flash
  - 512B RAM
  - 16MHz Clock Cycle



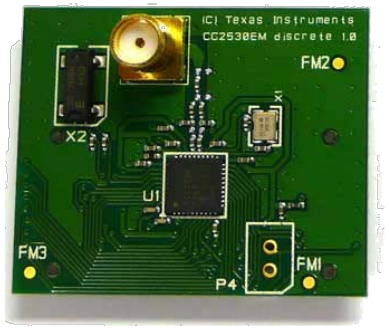
Hub Microcontroller

- BeagleBone Black
  - AM3358
  - 2GB Flash
  - 512MB DDR3 RAM
  - 1GHz Clock Cycle
  - Linux



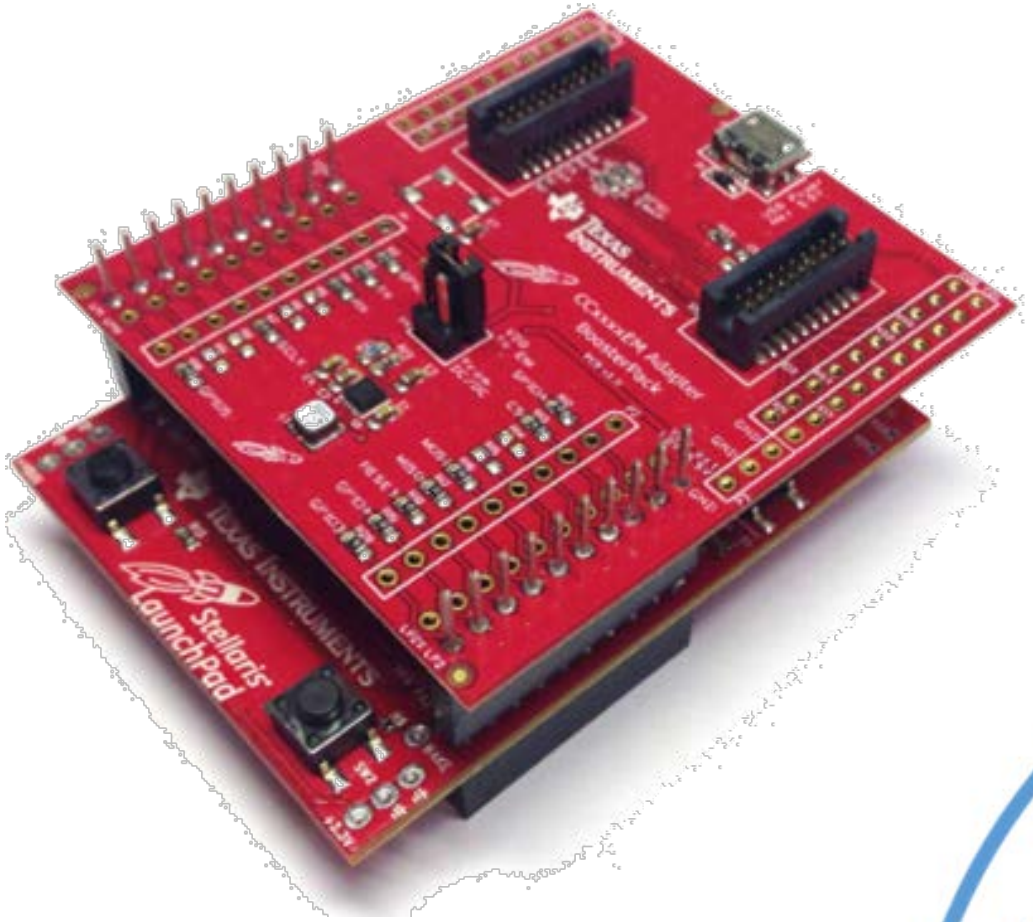
Zigbee Selection

- CC2530EM



Zigbee Selection

- LaunchPad EM Adapter BoosterPack



Battery Selection

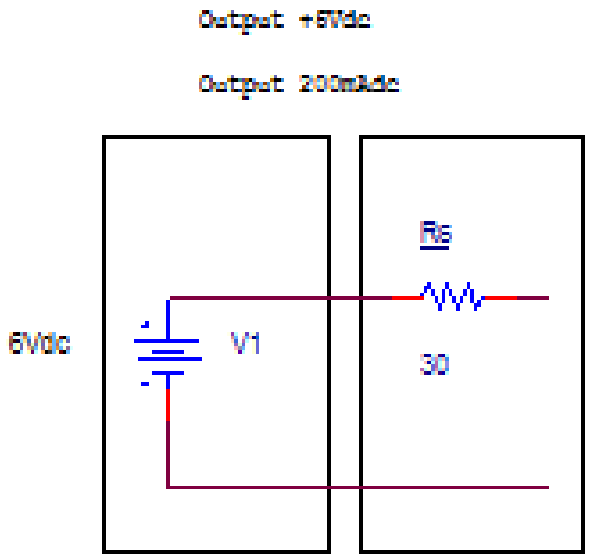
- Tenergy RCR 123A
  - 3.2V
  - 450mAh
  - 1000 Cycles

Solar Cell Selection

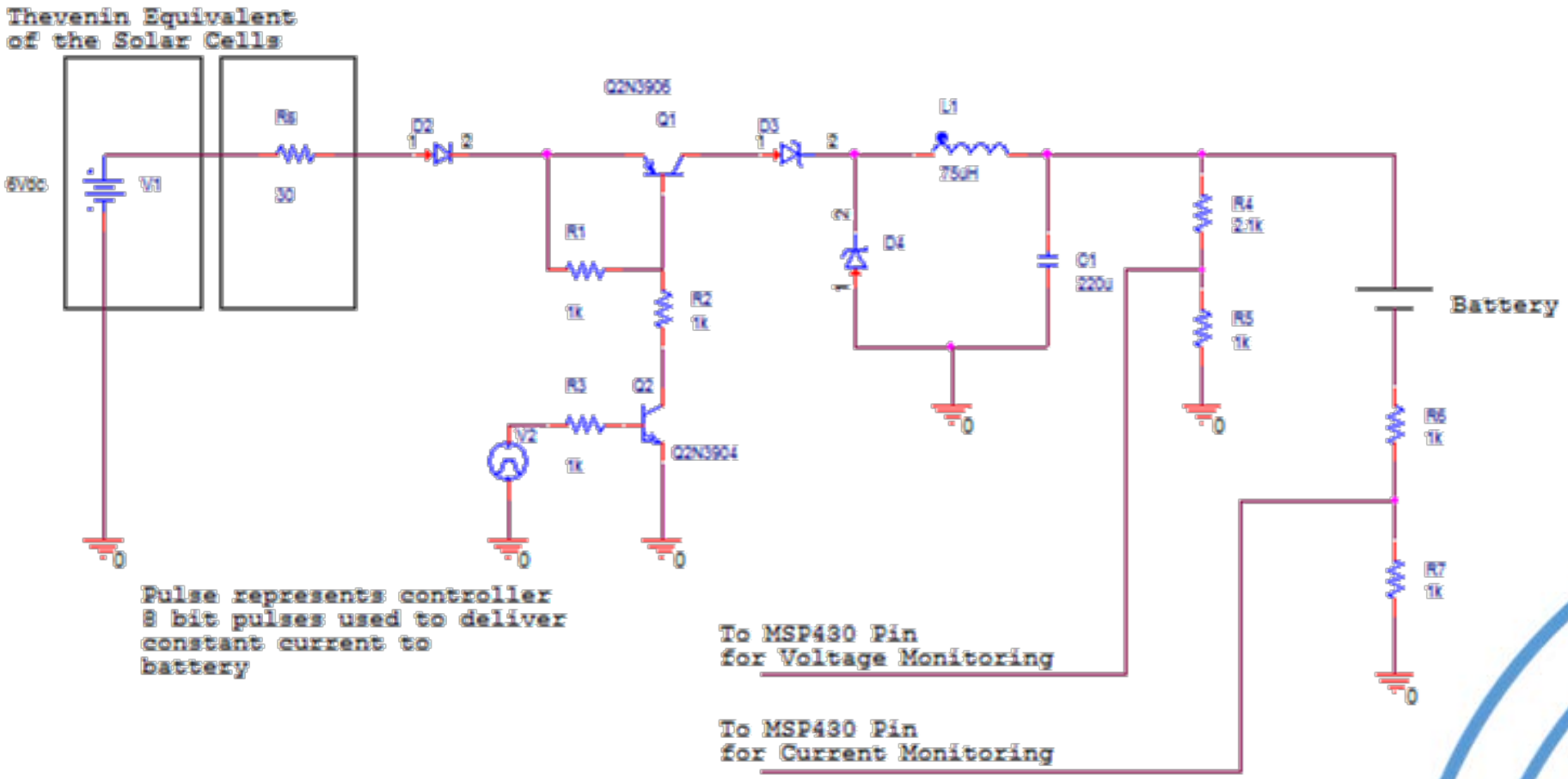
- 6V DC
- 100mA

Solar Cell Selection

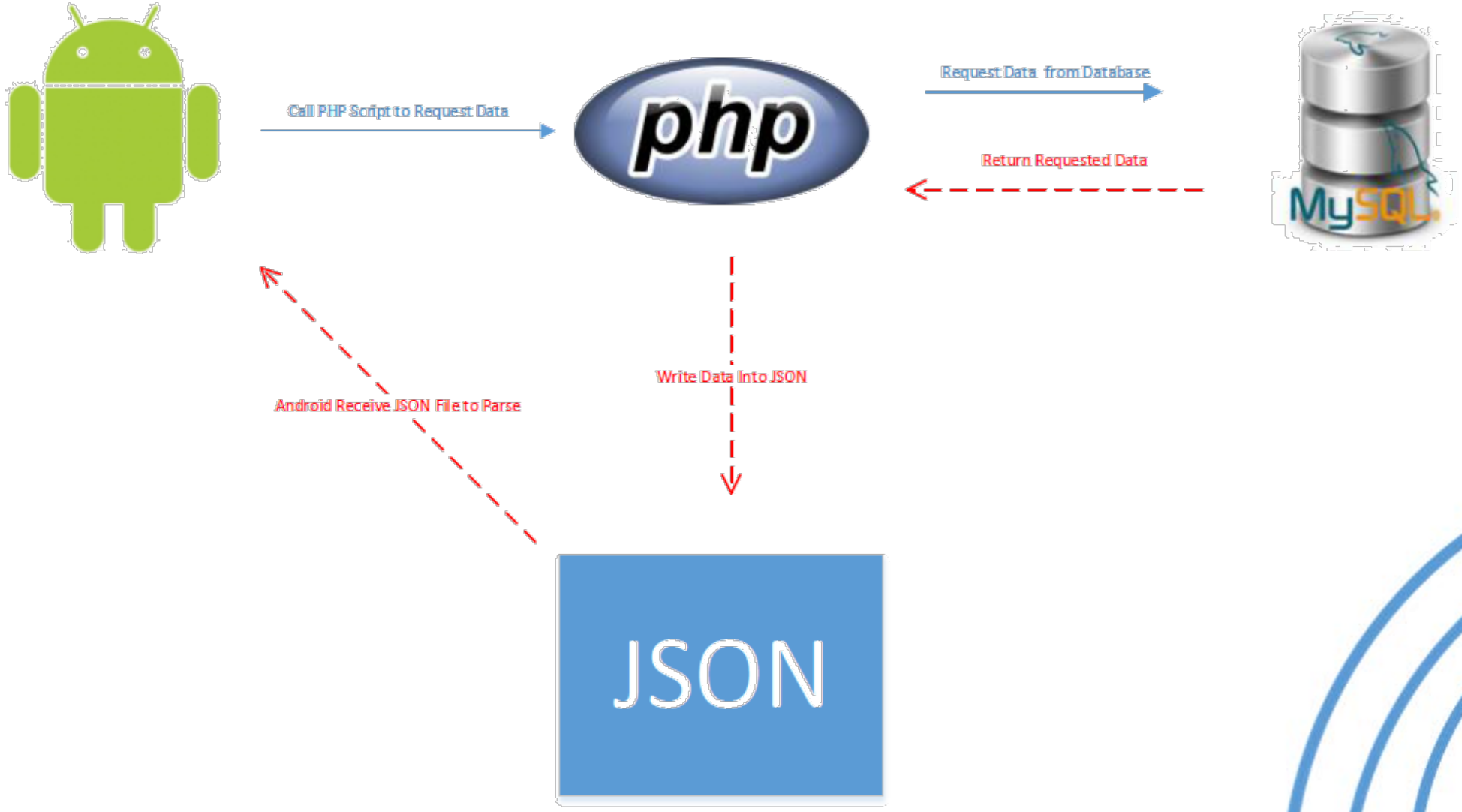
Two Total
4.25" x 1.75"
Solar Cell
6Vdc Open Circuit
100mA Short Circuit
Wired in parallel to achieve 6Vdc, 200mA



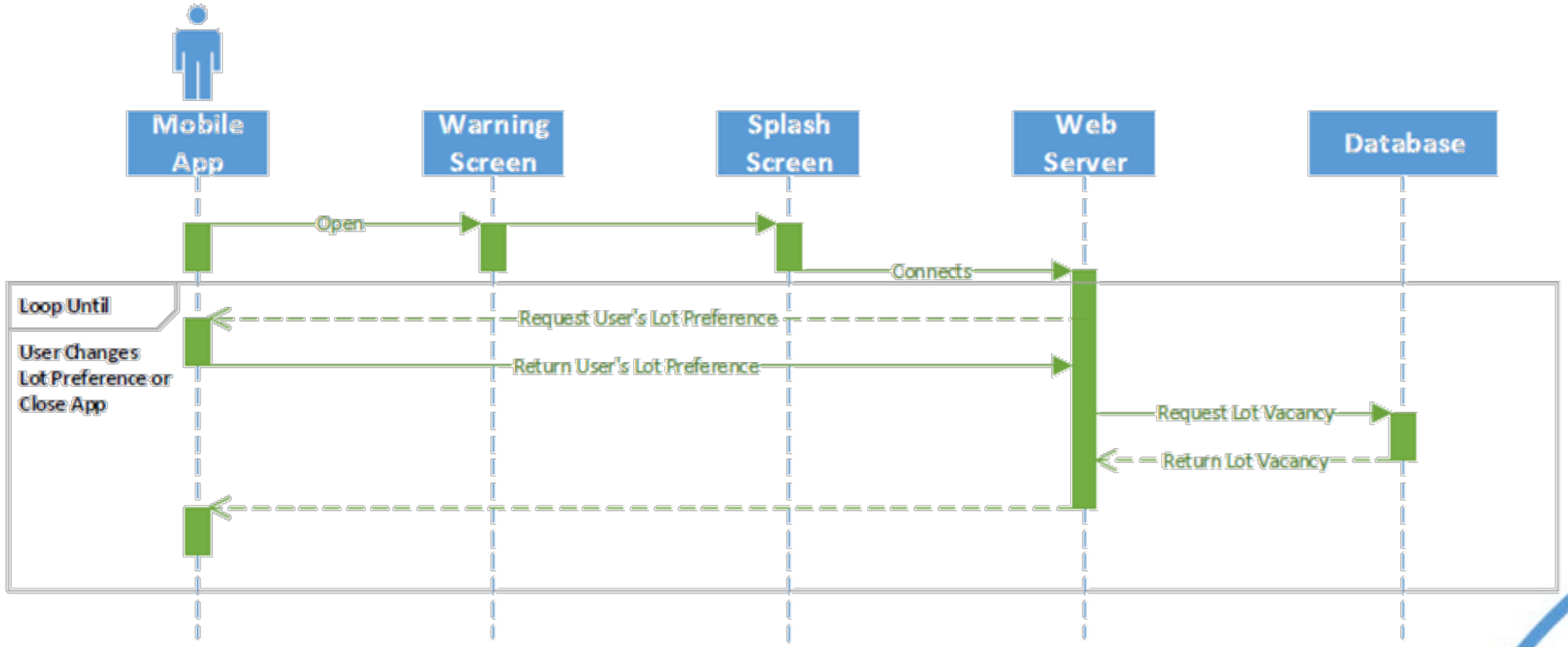
Power Design



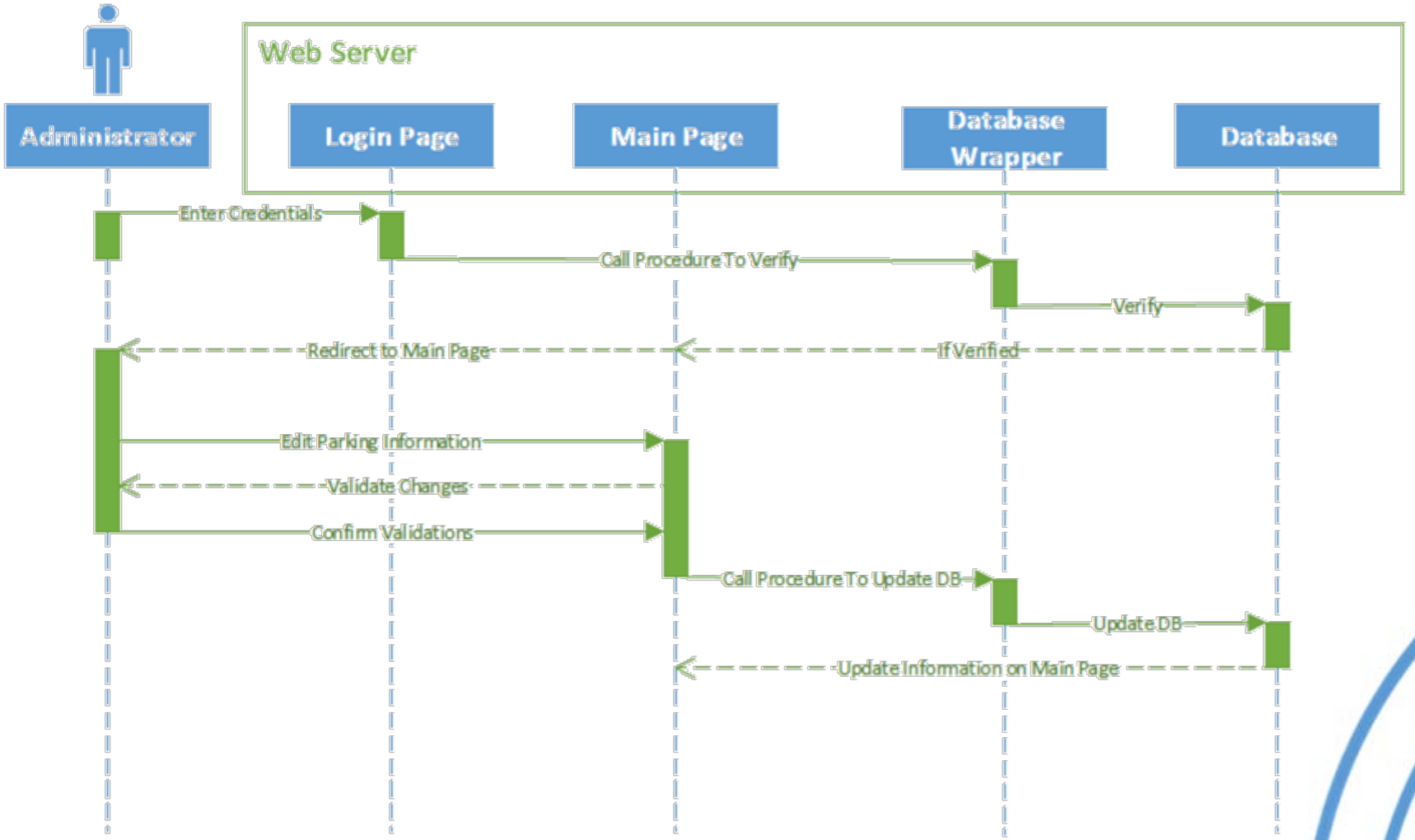
App Design


Call PHP Script to Request Data
Request Data from Database
Return Requested Data
Write Data into JSON
Android Receive JSON File to Parse
JSON

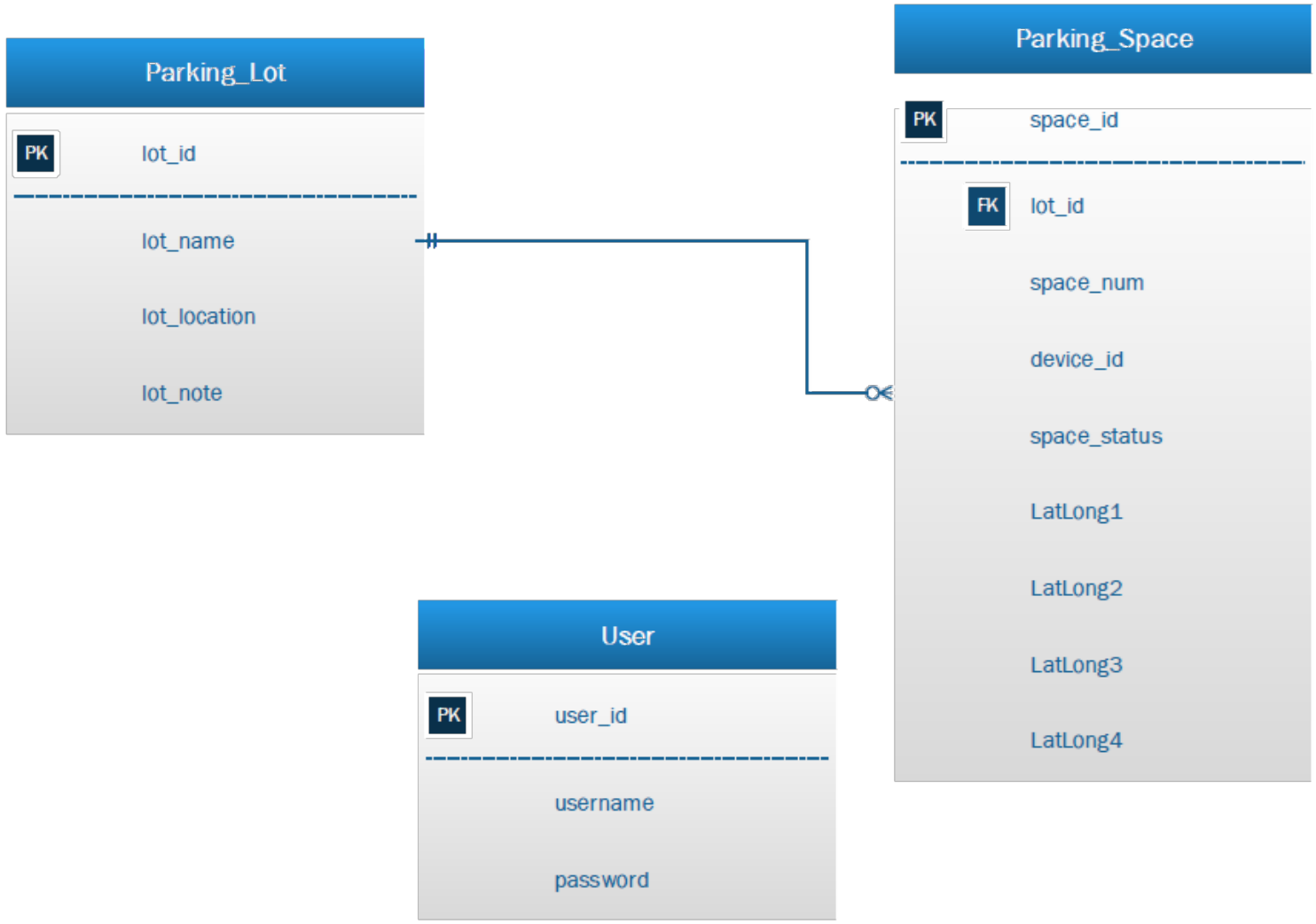
Retrieving Vacancy Data



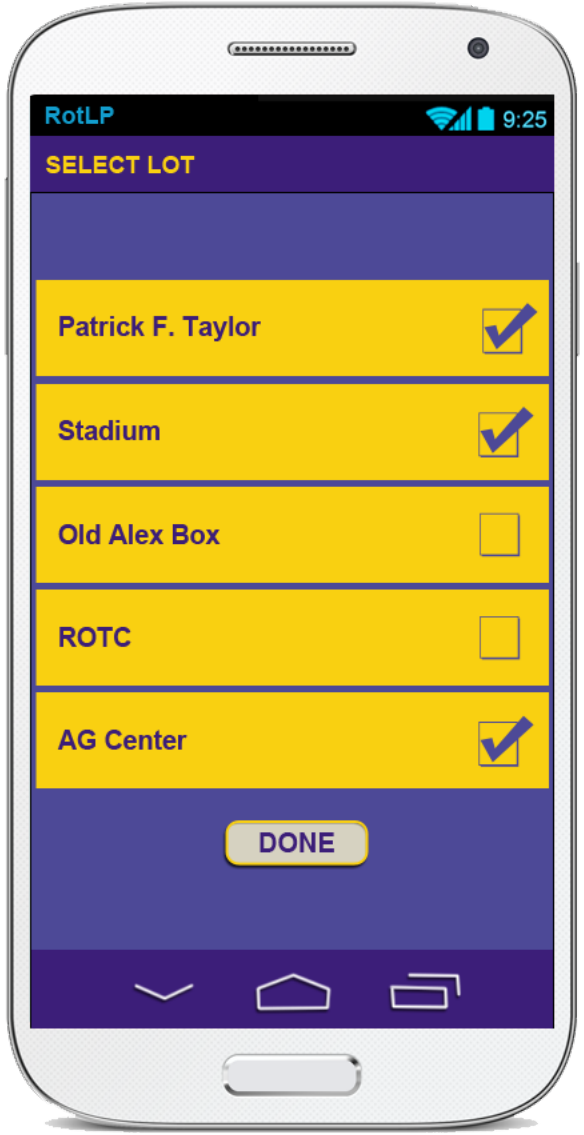
Administrator Sequence Diagram

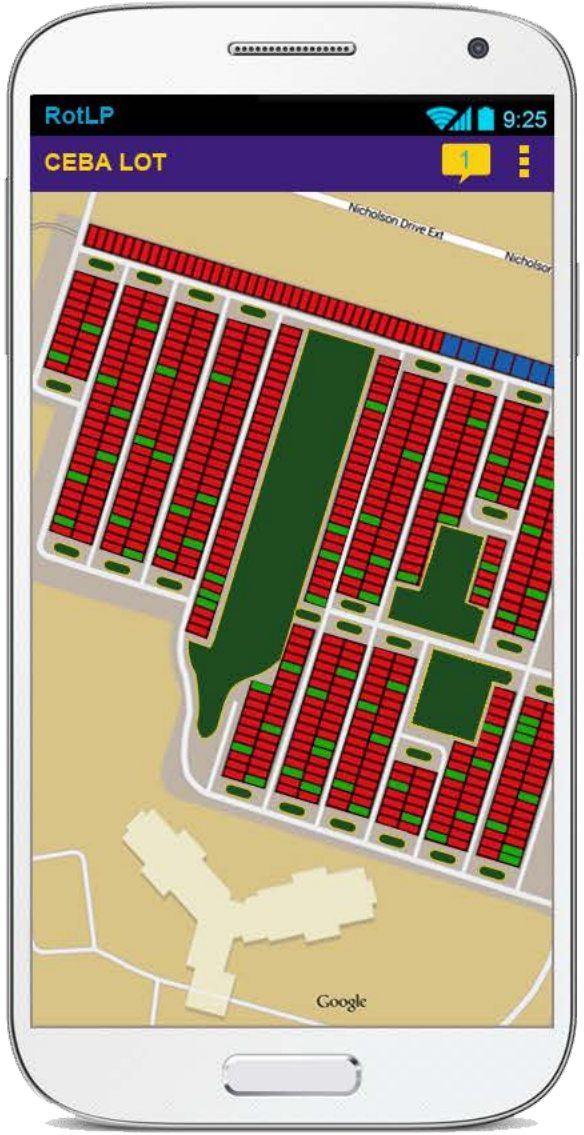


Database Design

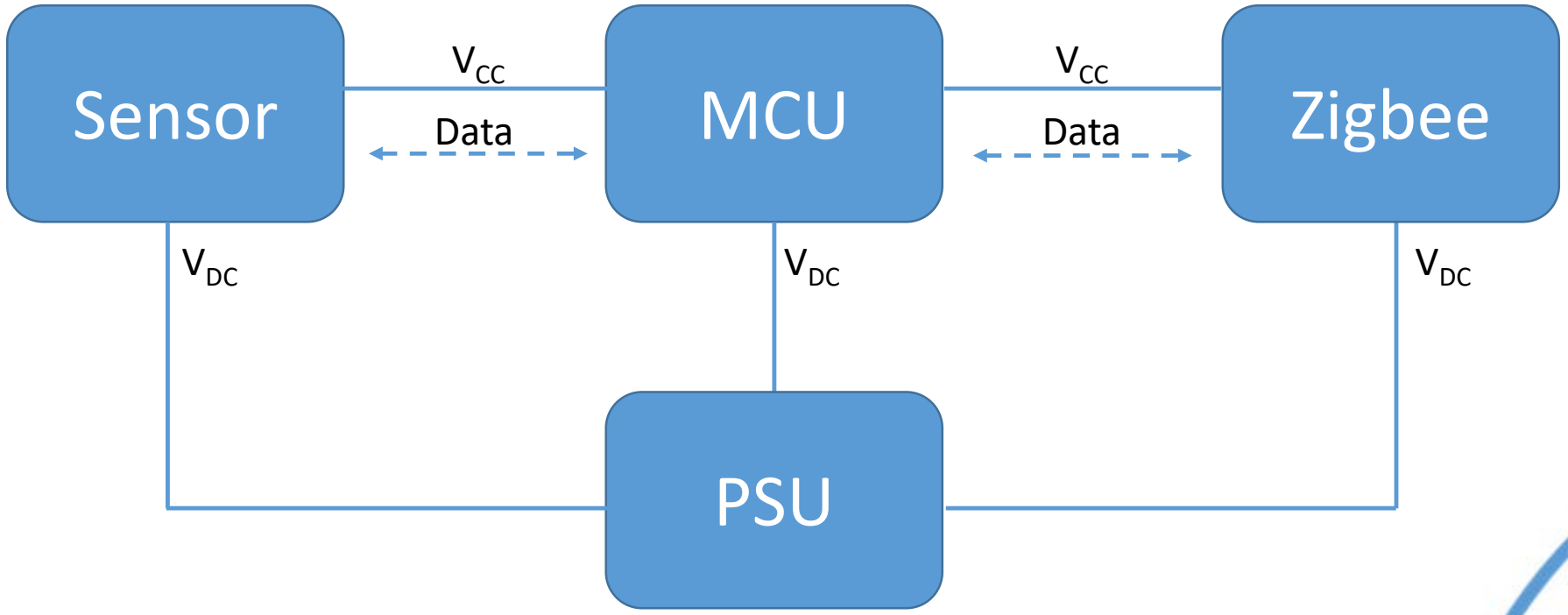


App UI Design

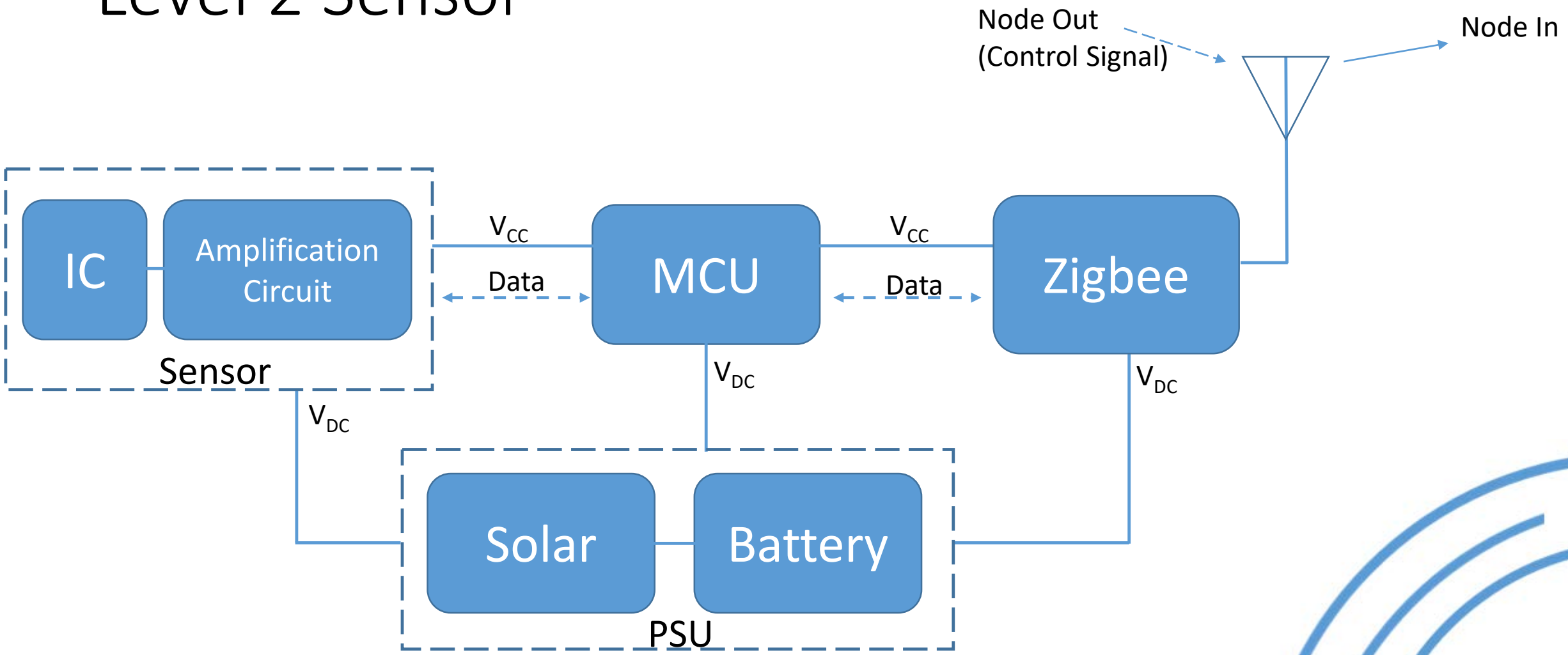




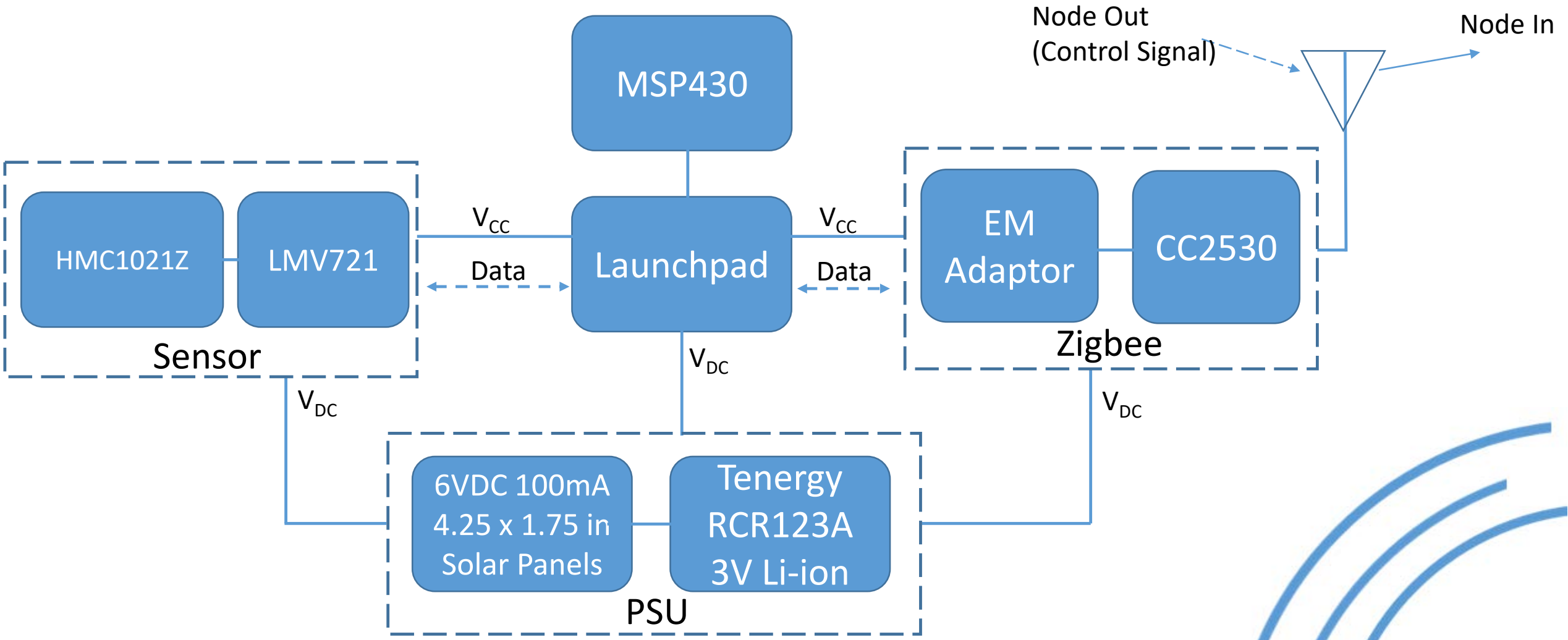
Level 1 Sensor



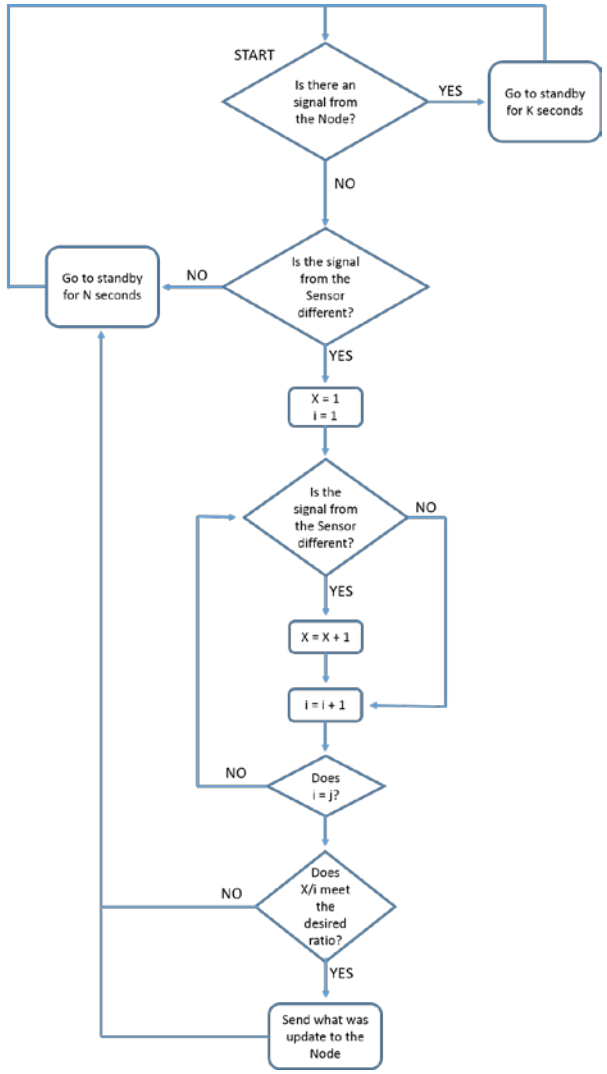
Level 2 Sensor



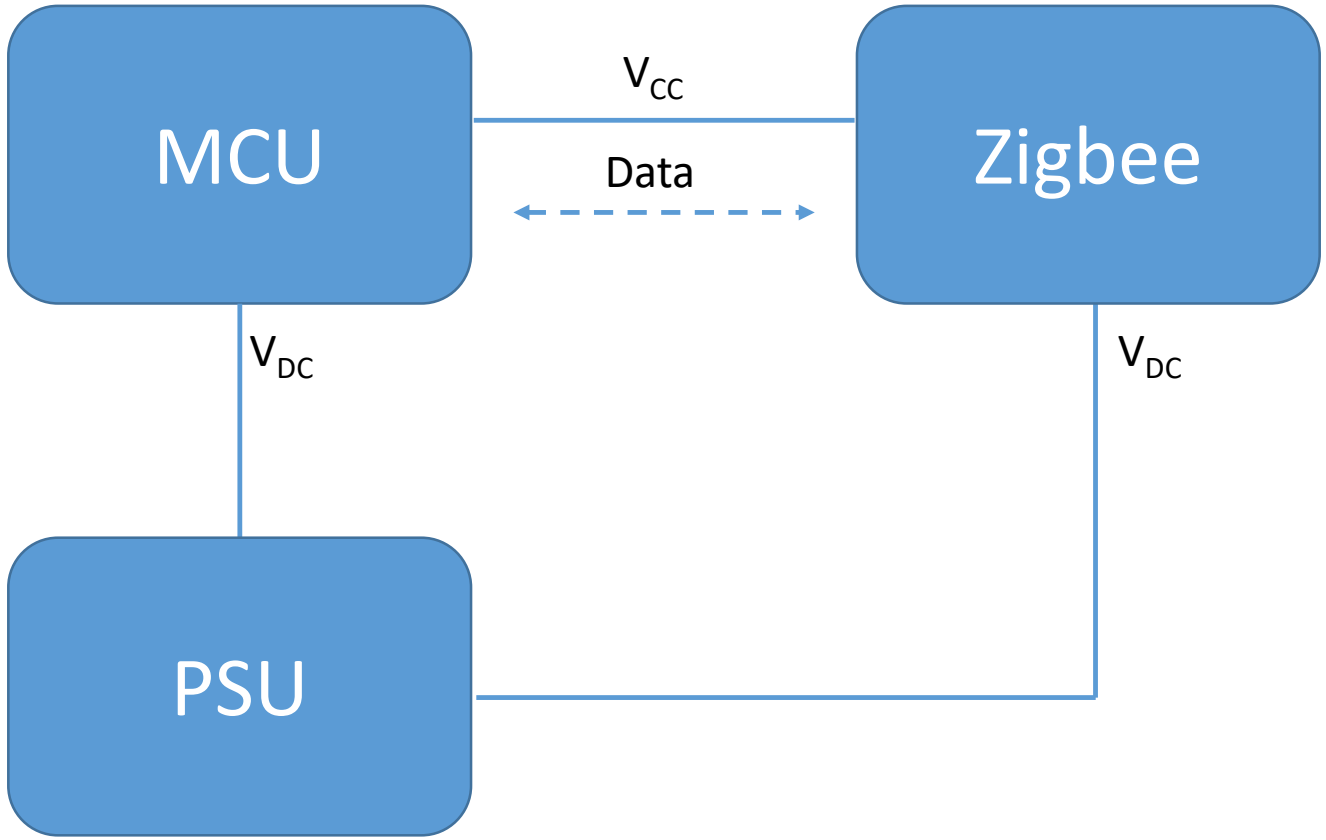
Level 3 Sensor



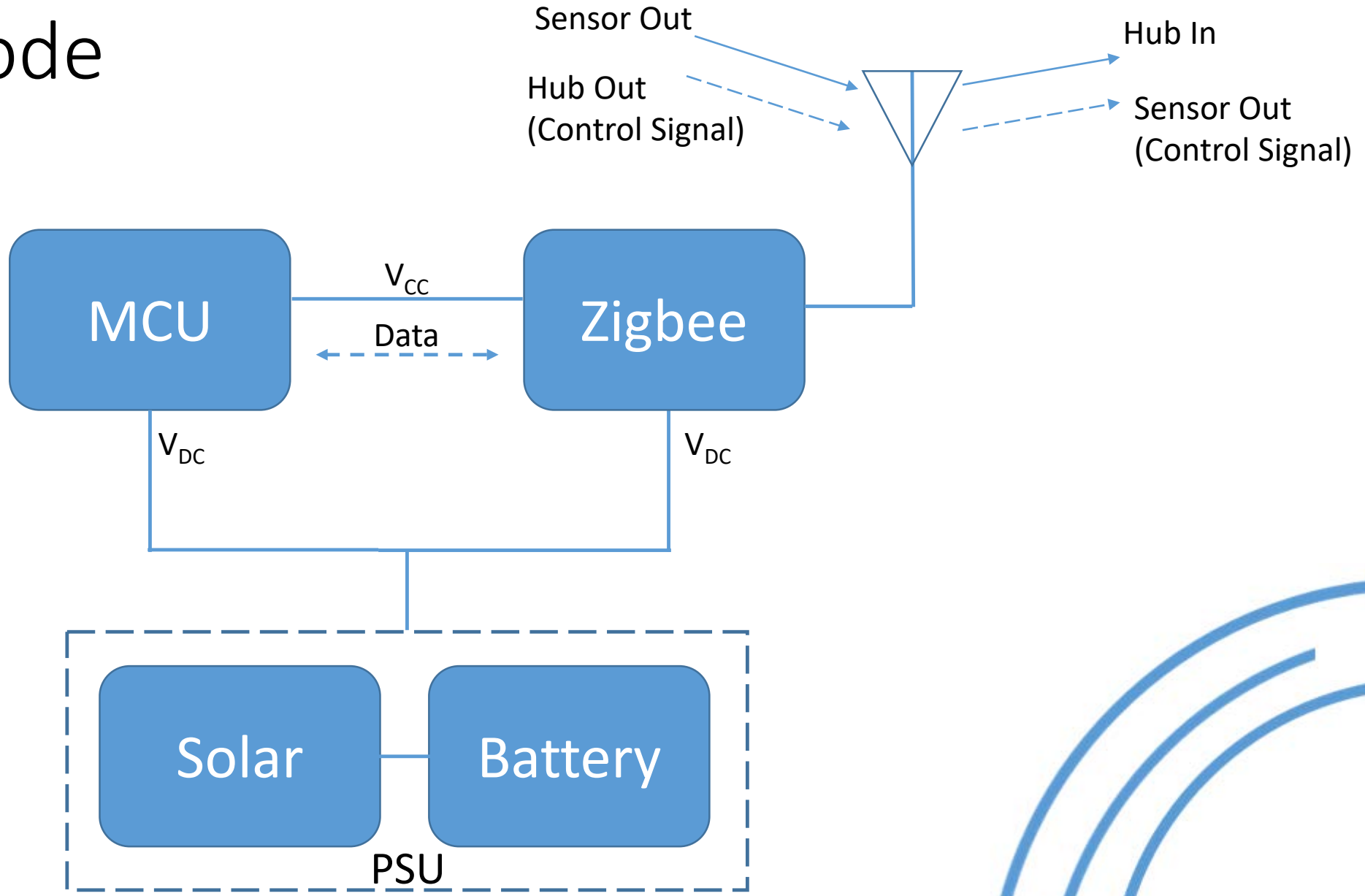
Sensor Software Behavior



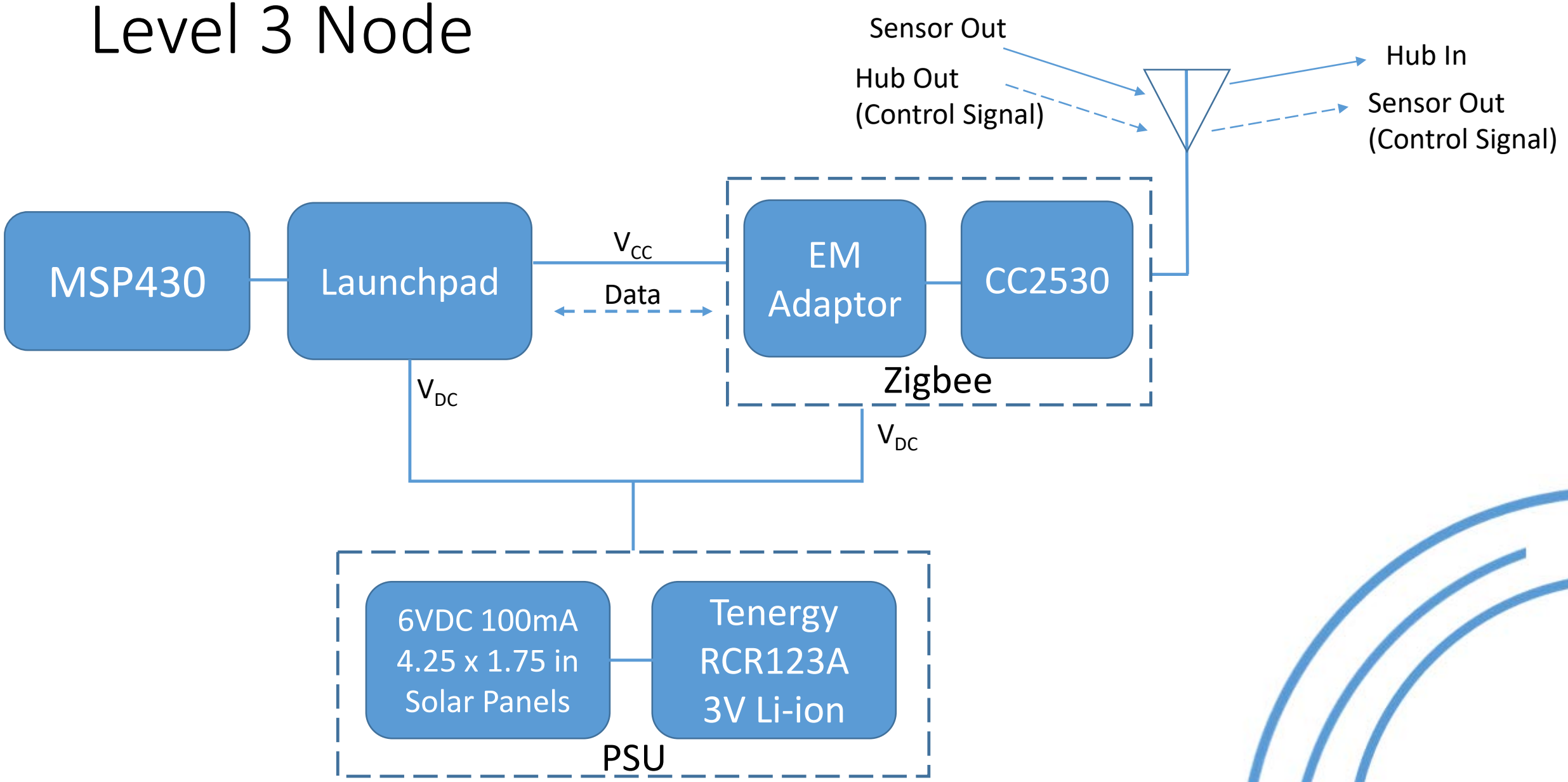
Level 1 Node



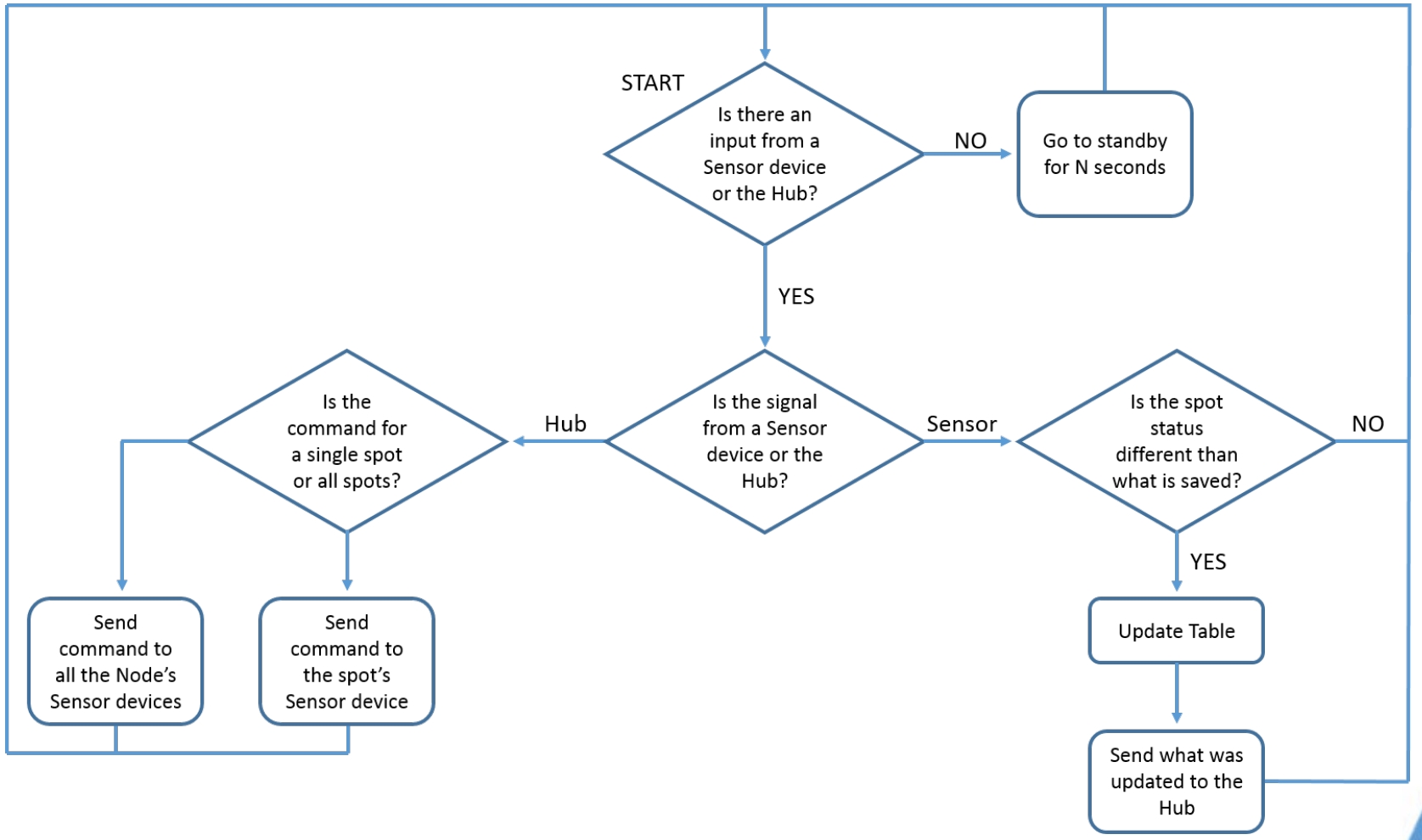
Level 2 Node


Sensor Out
Hub Out
(Control Signal)
Hub In
Sensor Out
(Control Signal)
MCU
V_{CC}
Data
Zigbee
V_{DC}
V_{DC}
Solar
Battery
PSU

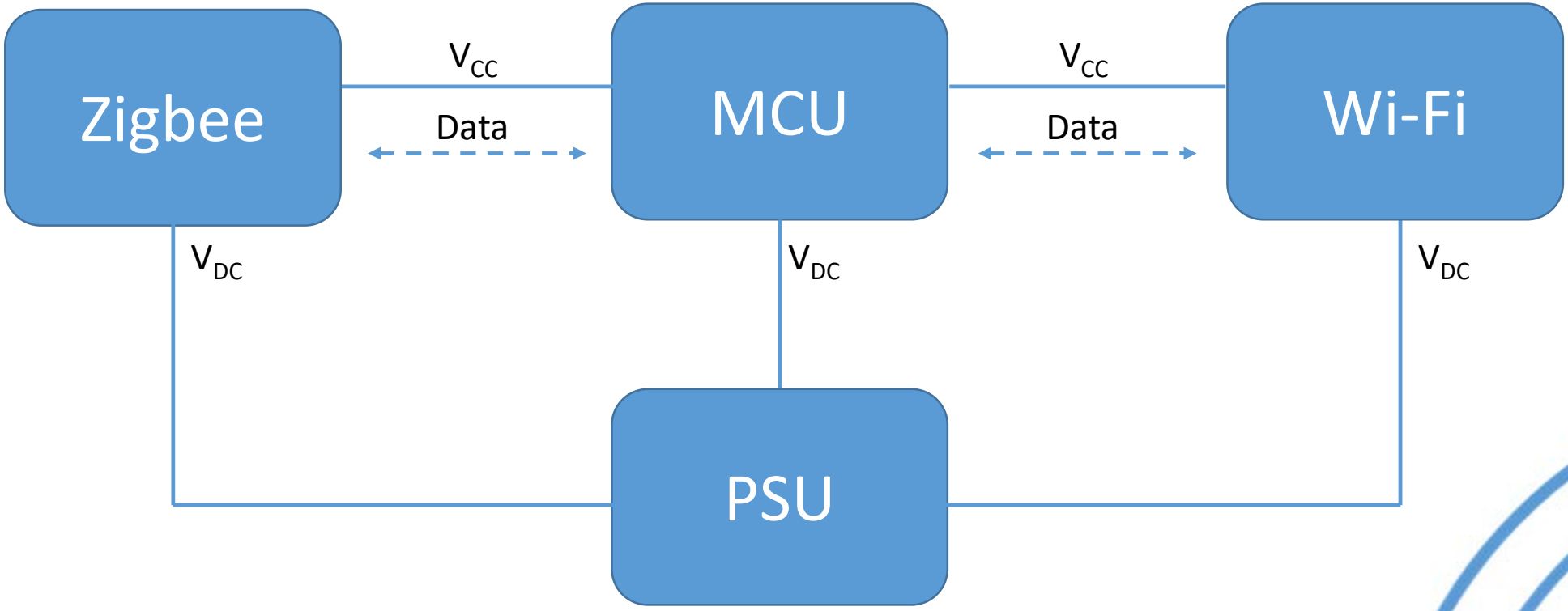
Level 3 Node


Sensor Out
Hub Out
(Control Signal)
Hub In
Sensor Out
(Control Signal)
MSP430
Launchpad
V_{CC}
Data
EM
Adaptor
CC2530
Zigbee
V_{DC}
V_{DC}
6VDC 100mA
4.25 x 1.75 in
Solar Panels
Tenergy
RCR123A
3V Li-ion
PSU

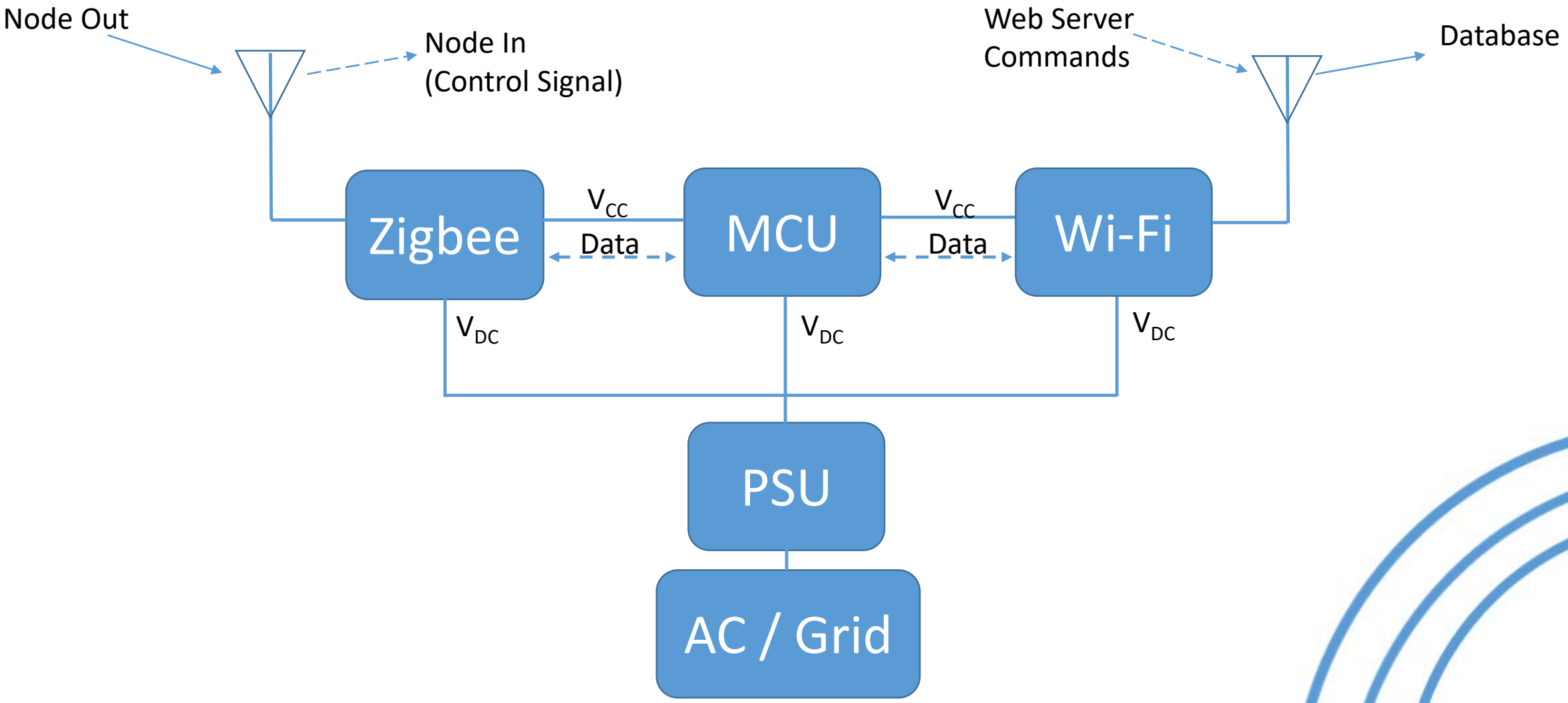
Node Software Behavior



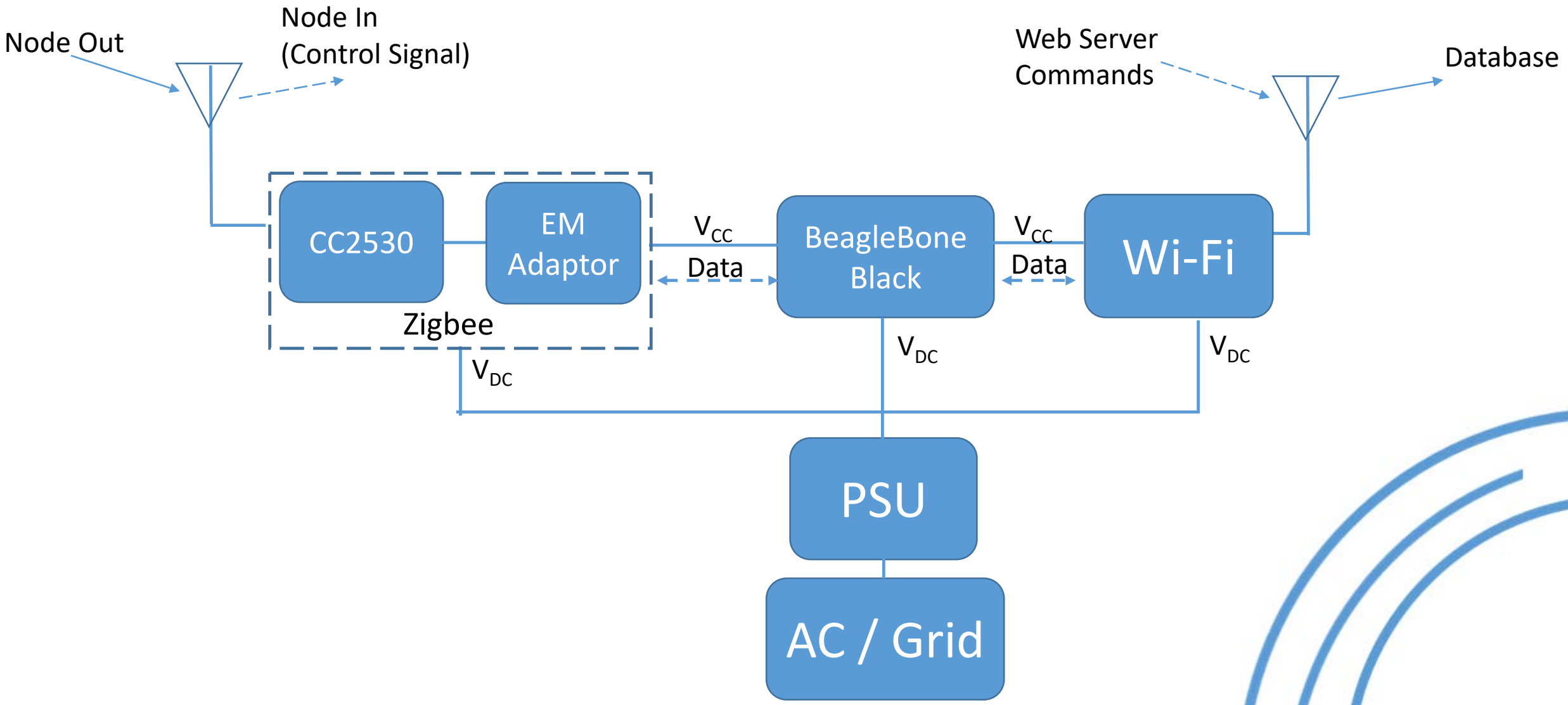
Level 1 Hub



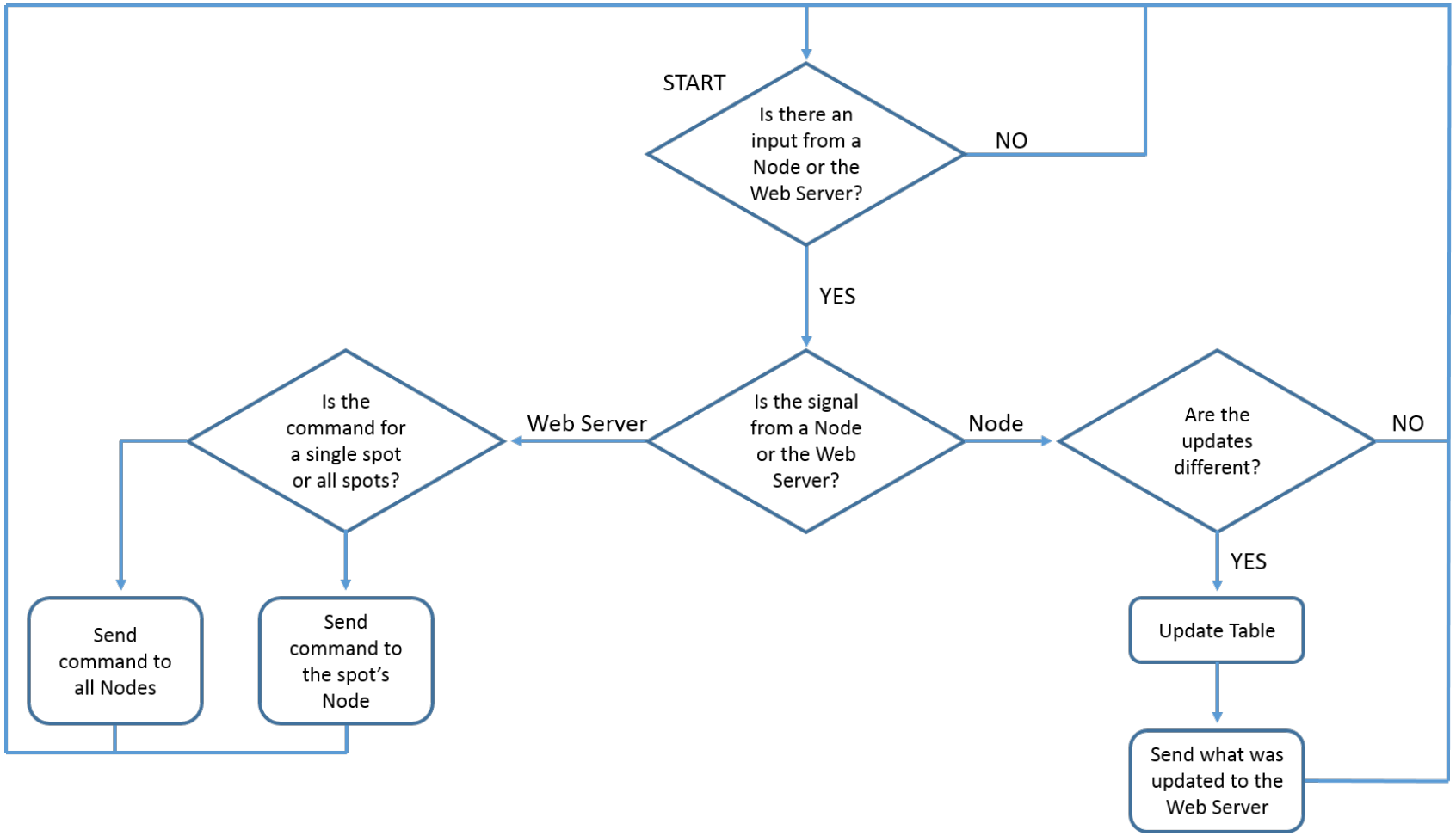
Level 2 Hub


Node Out
Node In
(Control Signal)
Web Server
Commands
Database
Zigbee
MCU
Wi-Fi
V_{CC}
Data
V_{CC}
Data
V_{DC}
V_{DC}
V_{DC}
PSU
AC / Grid

Level 3 Hub

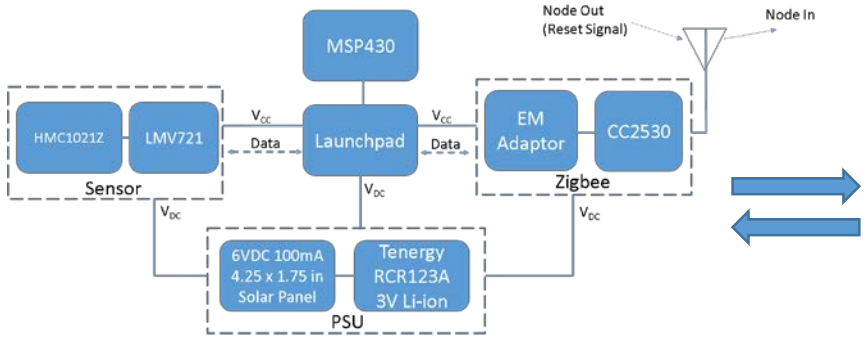

Node Out
Node In
(Control Signal)
Web Server
Commands
Database
CC2530
EM
Adaptor
Zigbee
V_{CC}
Data
BeagleBone
Black
V_{CC}
Data
Wi-Fi
V_{DC}
V_{DC}
V_{DC}
PSU
AC / Grid

Hub Software Behavior

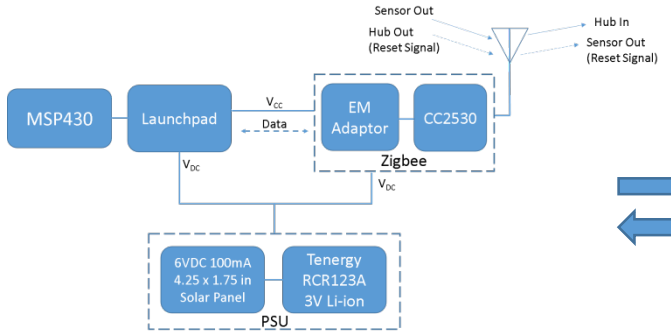


Level 3 all Hardware

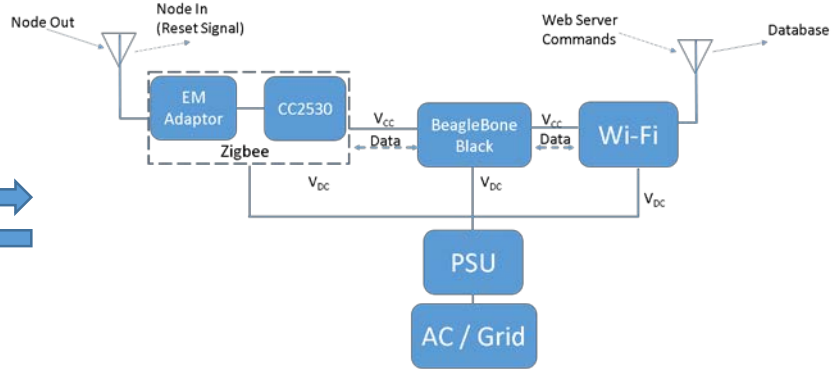
Sensor



Node



Hub



Detection Method → Transmit Data → Compute and Transform Data → User

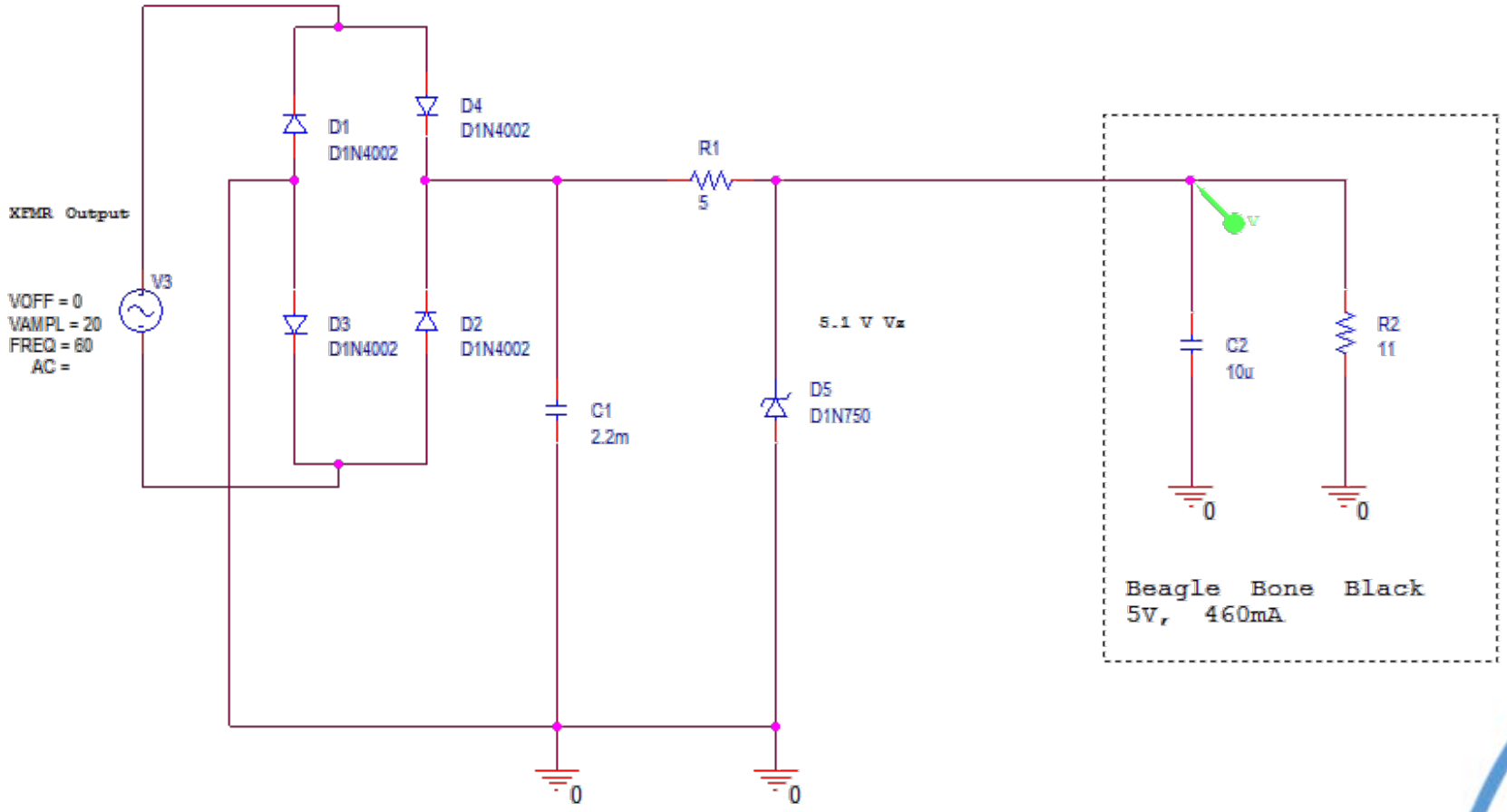
Ethics and Safety

- App While Driving
- Battery Malfunction
- Tripping
- Standards
- Privacy

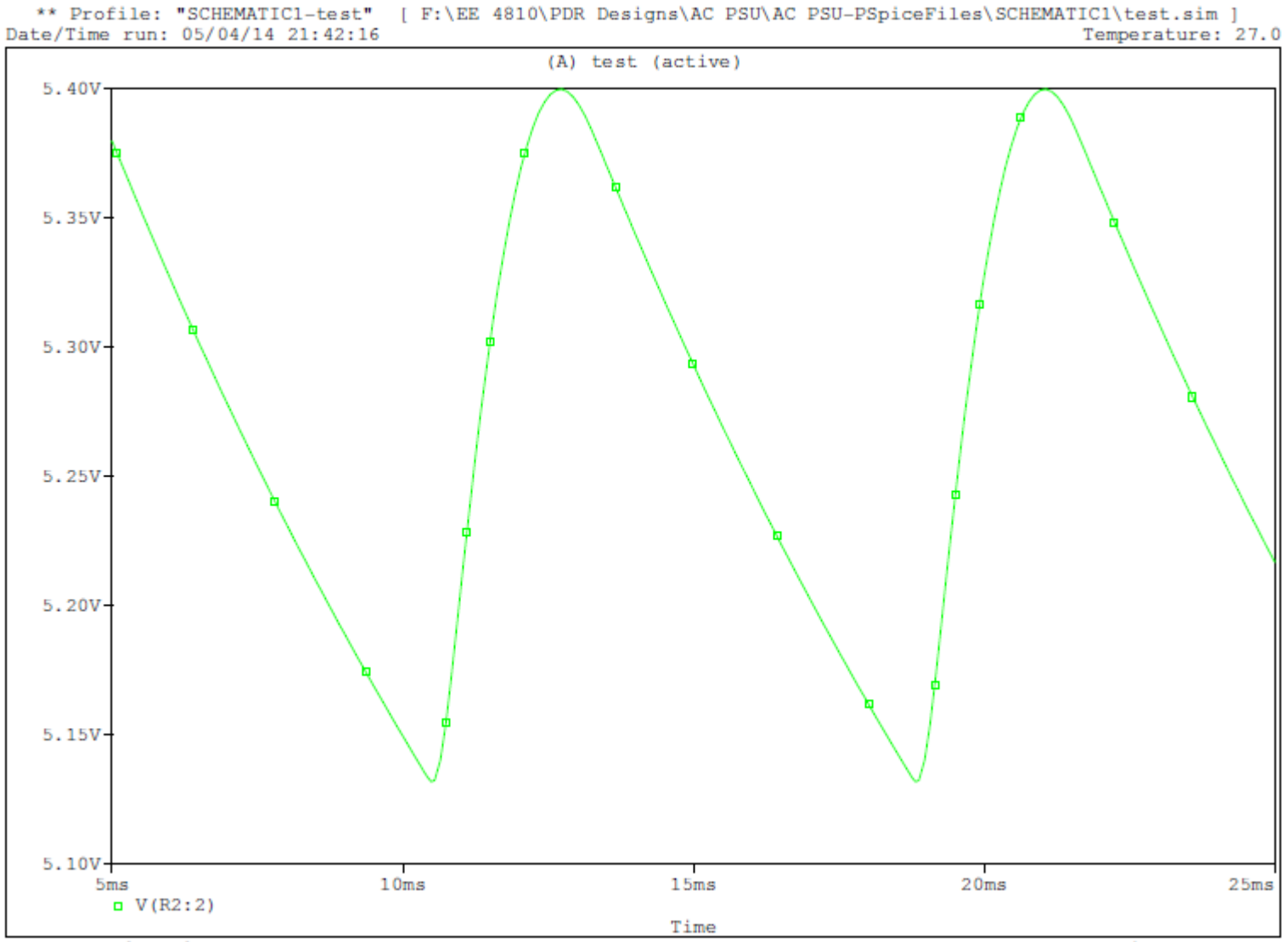
Budget

Budget						
	Qty	Ea		Shipping		Total
Sensor						
Sensor	2	$	6.57	$	10.00	$ 23.14
CC 25xx	2	$	70.00	$	10.00	$ 150.00
MCU	2	$	2.00	$	-	$ 4.00
Dev Boards	2	$	10.00	$	-	$ 20.00
Electronics	1	$	30.00	$	10.00	$ 40.00
Power Supply	1	$	50.00	$	-	$ 50.00
					Subtotal	$ 287.14
Node						
CC25xx	1	$	70.00	$	10.00	$ 80.00
MCU	1	$	2.00	$	-	$ 2.00
Dev Boards	2	$	10.00	$	-	$ 20.00
Electronics	1	$	30.00	$	10.00	$ 40.00
Power Supply	1	$	50.00	$	-	$ 50.00
					Subtotal	$ 192.00
Hub						
Beagle Bone	1	$	50.00	$	10.00	$ 60.00
MCU	1	$	75.00	$	10.00	$ 85.00
Electronincs	1	$	30.00	$	10.00	$ 40.00
Power Supply	1	$	-	$	-	$ -
					Subtotal	$ 185.00
Housings						
Sheet Acrylic	1	$	30.00	$	15.00	$ 45.00
Hardware	1	$	25.00	$	-	$ 25.00
Enclosure for Hub	1	$	60.00	$	10.00	$ 70.00
					Subtotal	$ 140.00
Misc.						
Batteries	1	$	40.00	$	10.00	$ 50.00
					Subtotal	$ 50.00
					Total	$ 854.14
				Minus TI		$ 473.14
				Minus Hub		$ 403.14

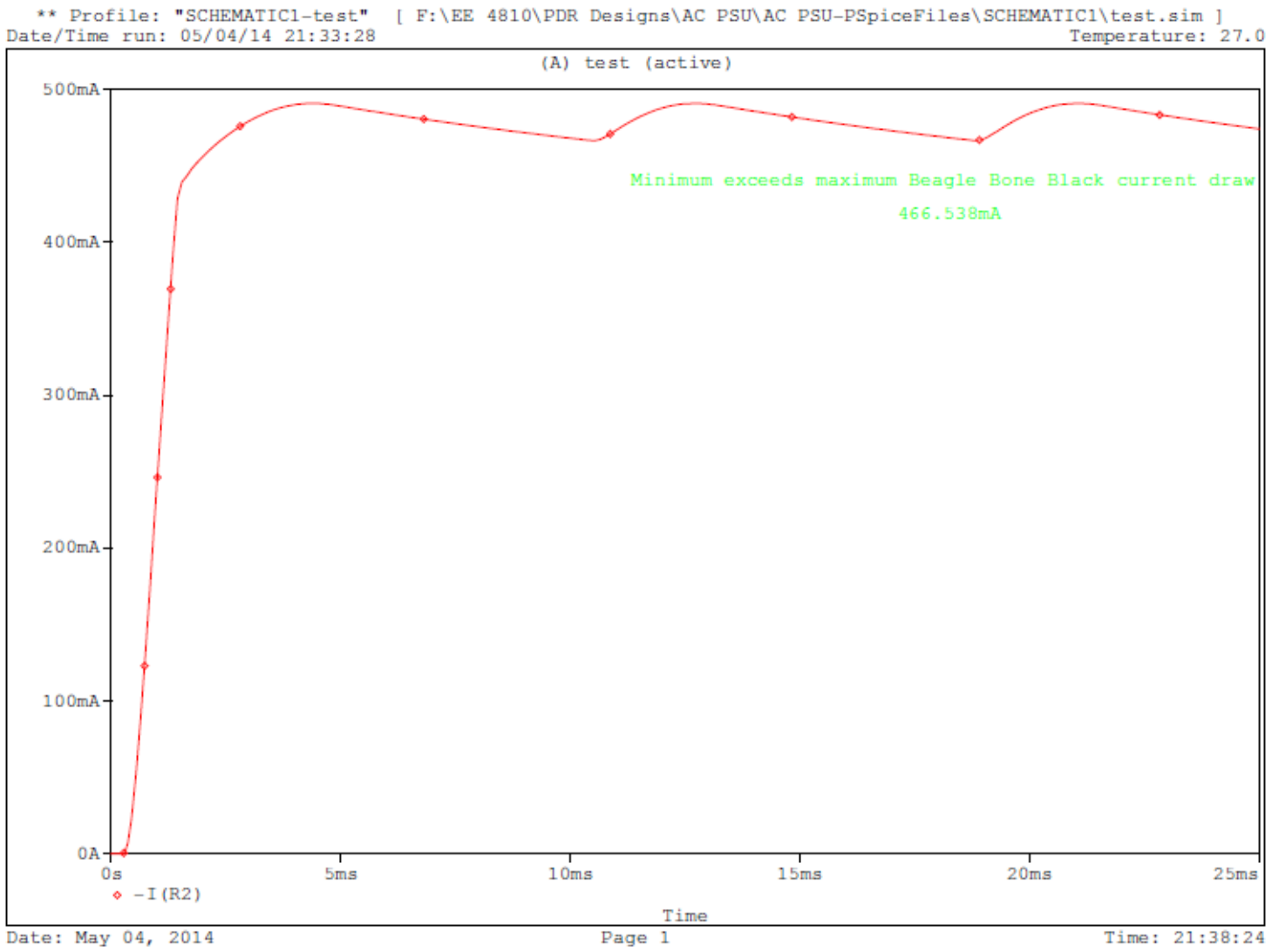
A/C Power for BeagleBone Black



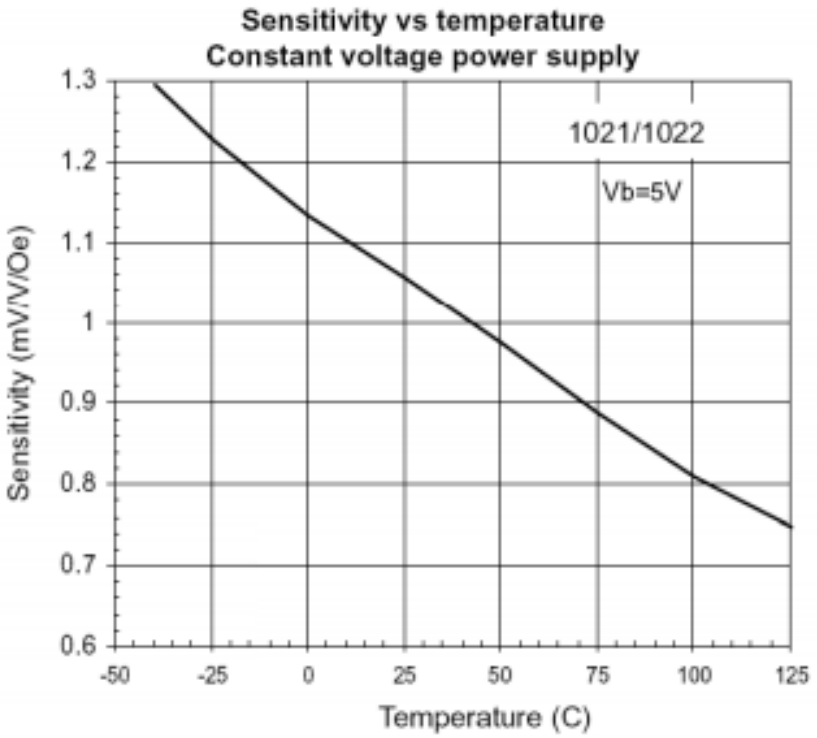
A/C Power for BeagleBone Black

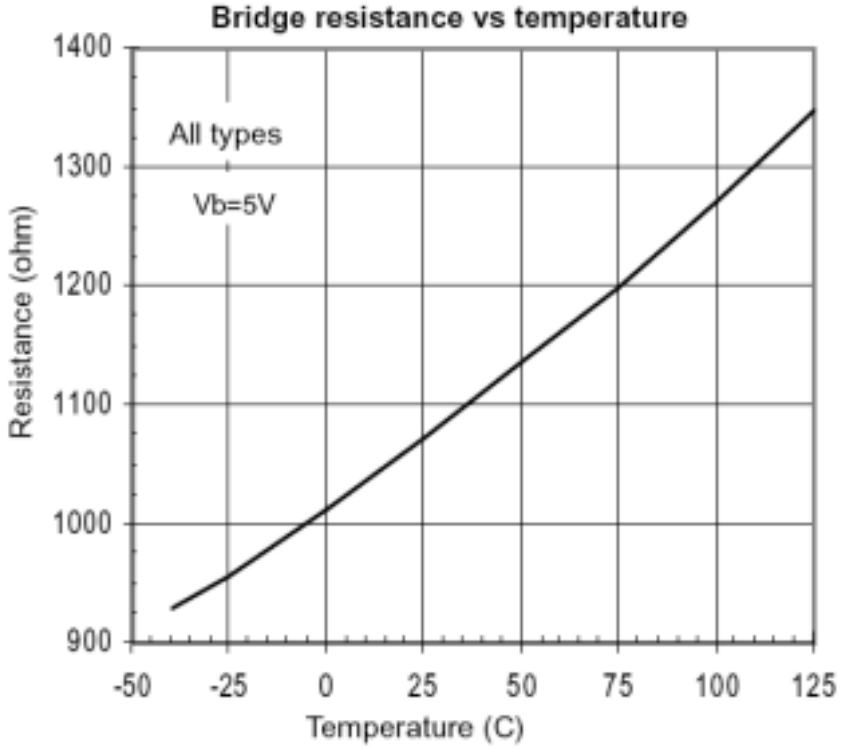


A/C Power for BeagleBone Black



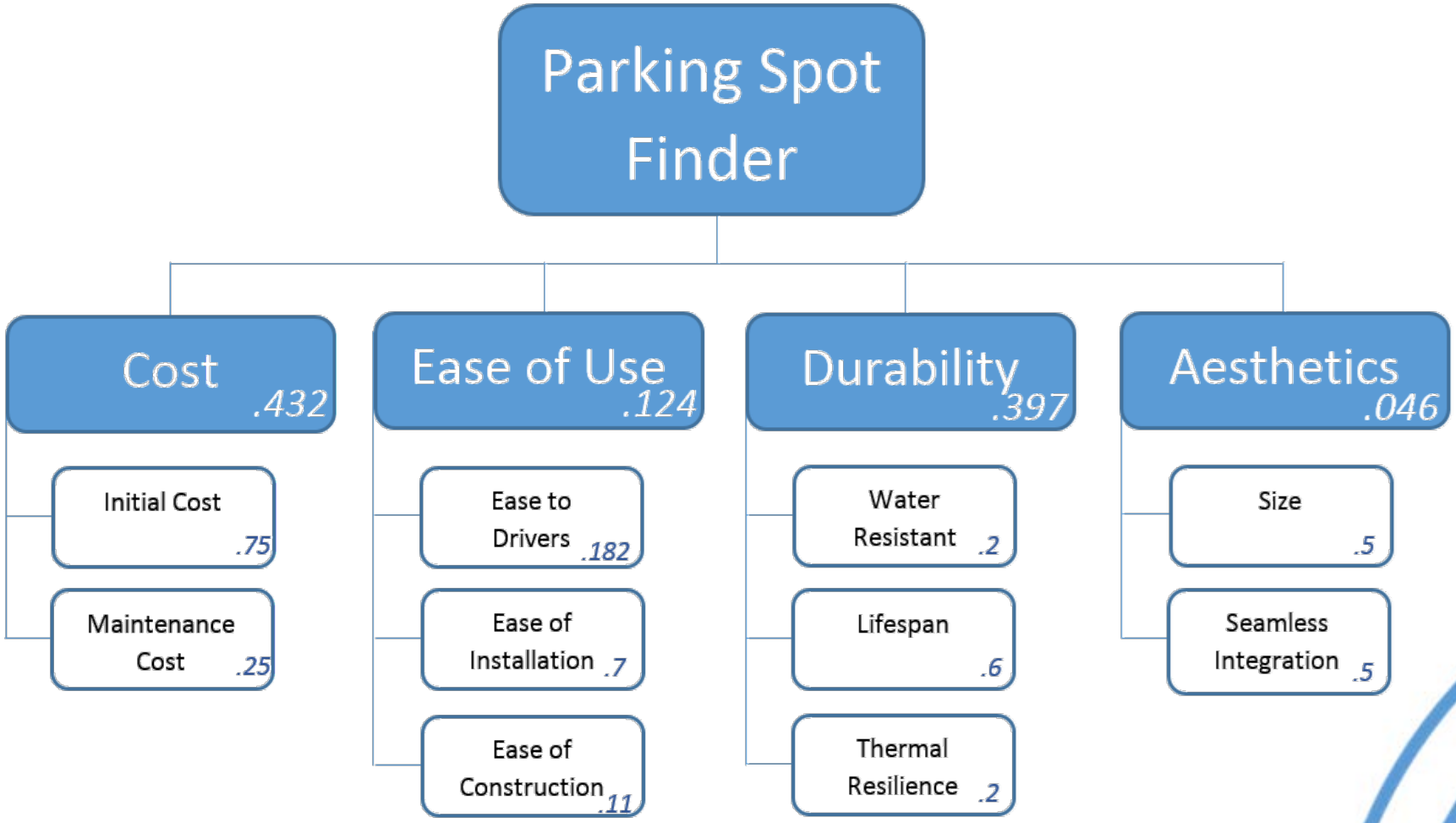
Sensor





Standoff Distance	Flux Density Shift
1 foot	270 milligauss
3 foot	75 milligauss
5 foot	10 milligauss
10 foot	2 milligauss
12 foot	<1 milligauss

Objective


Parking Spot Finder
Cost .432
Initial Cost .75
Maintenance Cost .25
Ease of Use .124
Ease to Drivers .182
Ease of Installation .7
Ease of Construction .11
Durability .397
Water Resistant .2
Lifespan .6
Thermal Resilience .2
Aesthetics .046
Size .5
Seamless Integration .5

Pressure Plate

- Pros
  - Accurate
  - Very little interference
- Cons
  - Installation
  - Size
  - Price
  - Awkward

http://2.bp.blogspot.com/-4oJXiS8xn4w/UNSsSLwNWvI/AAAAAAAAACw/xIxoizjVhtM/s1600/Safety+mats.JPG

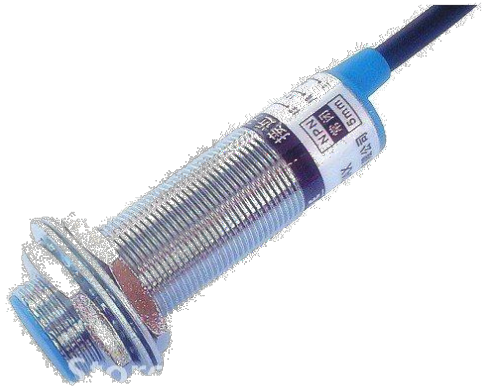
Cameras

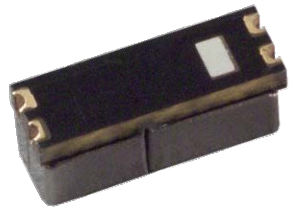
- Pros
  - Don’t need one per spot
- Cons
  - Line of sight
  - Expensive
  - Lots of computing
  - Bandwidth

Image of Cars: http://cvlab.epfl.ch/files/content/sites/cvlab2/files/data/multiclass/c3.png
Image of Camera: http://www.2mcctv.com/images/SecurityCamera_PTZ_VEZ-221_2.JPG

Proximity Sensors

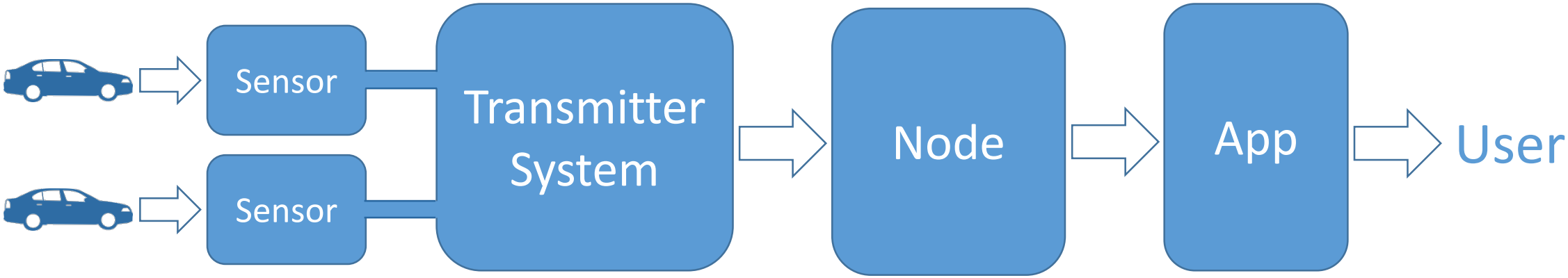
- Pros
  - Small
  - Cheap
- Cons
  - Interference
  - Operating range



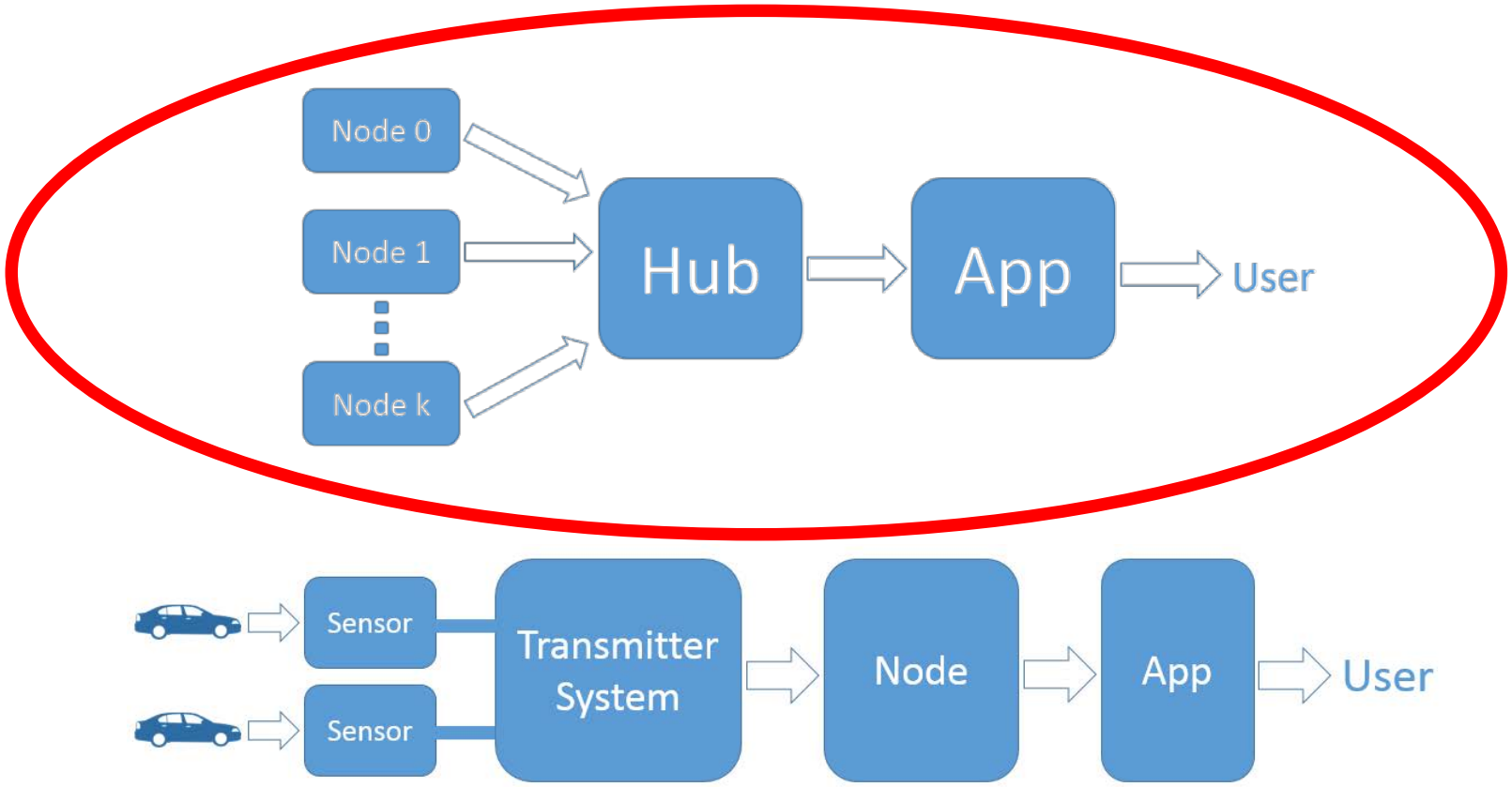


http://i00.i.aliimg.com/wsphoto/v0/475168710/Inductive-font-b-Proximity-b-font-Sensor-LJ18A3-5-Z-BX-NPN-3-wire-NO-font.jpg

Wired Sensor



Our Choice


Node 0
Node 1
Node k
Hub
App
User
Sensor
Sensor
Transmitter System
Node
App
User

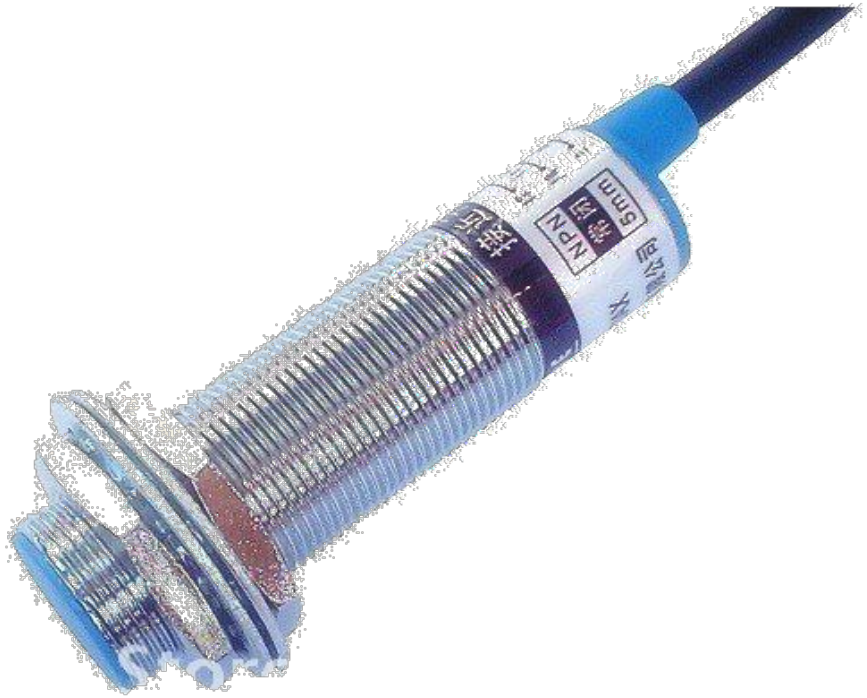
Our Decision

Design Options

Factors		Options								Weights	
Category	Sub-Category	Initial		Hub		Super Sensor		Wired Sensor		Sub Weight	Category Weight
		Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score		
Cost	Initial Cost	0.3	0.0972	0.7	0.2268	0.25	0.081	0.8	0.2592	0.75	0.432
	Maintenance Cost	0.5	0.054	0.5	0.054	0.4	0.0432	0.2	0.0216	0.25	
Ease of Use	Ease to Drives	0	0	0	0	0	0	0	0	0.182	0.124
	Ease of Installation	0.4	0.03472	0.4	0.03472	0.7	0.06076	0.2	0.01736	0.7	
	Ease of Construction	0.75	0.010509	0.7	0.0098084	0.25	0.003503	0.3	0.0042036	0.113	
Durability	Water Resistance	0	0	0	0	0	0	0	0	0.2	0.397
	Lifespan	0	0	0	0	0	0	0	0	0.6	
	Termal Resistance	0	0	0	0	0	0	0	0	0.2	
Aesthetics	Size	0.5	0.0115	0.55	0.01265	0.6	0.0138	0.45	0.01035	0.5	0.046
	Seamless Integration	0.35	0.00805	0.4	[illegible]	0.8	0.0184	0.05	0.00115	0.5	
	Total	2.8	**0.215979**	3.25	**0.3471784**	3	**0.220663**	2	**0.3138636**		

Proximity Sensors

- Electromagnetic
- Optical
- Ultrasonic



http://i00.i.aliimg.com/wsphoto/v0/475168710/Inductive-font-b-Proximity-b-font-Sensor-LJ18A3-5-Z-BX-NPN-3-wire-NO-font.jpg

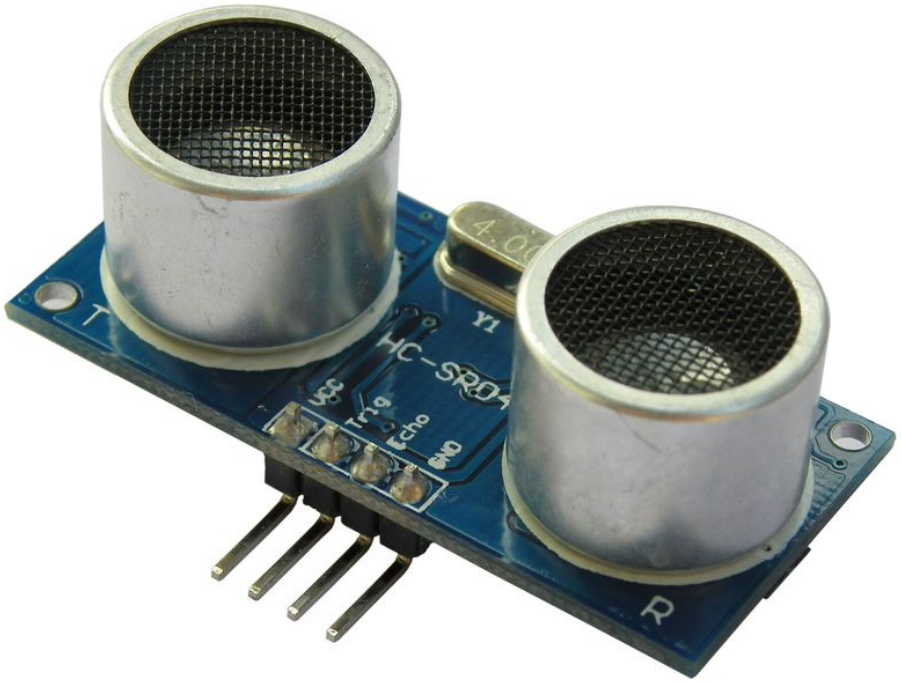
Proximity Sensors

- Electromagnetic
- Optical
- Ultrasonic

http://media.digikey.com/photos/Avago%20Tech%20Photos/HSDL-9100-021%20MINISMD.jpg

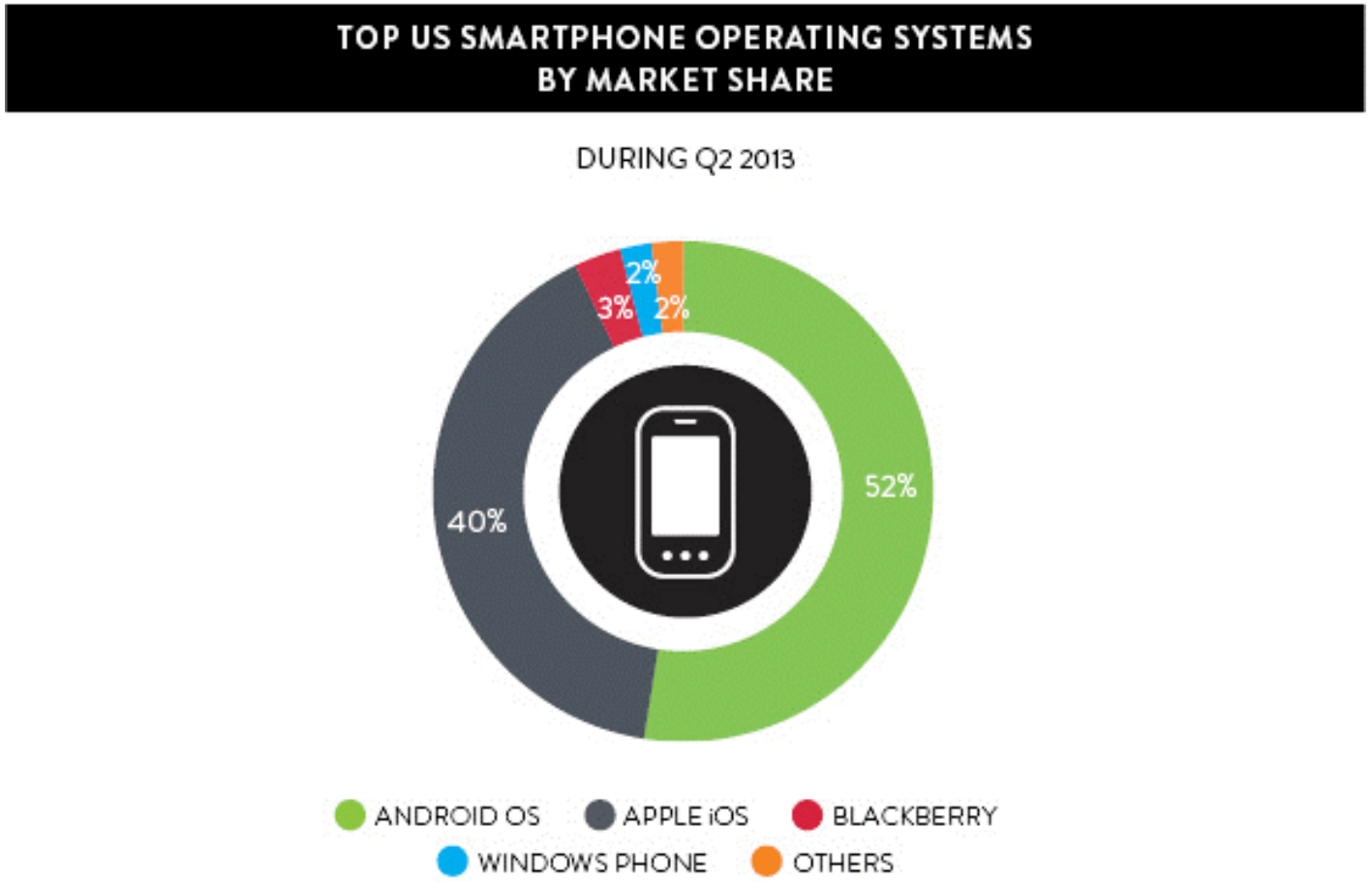
Proximity Sensors

- Electromagnetic
- Optical
- Ultrasonic



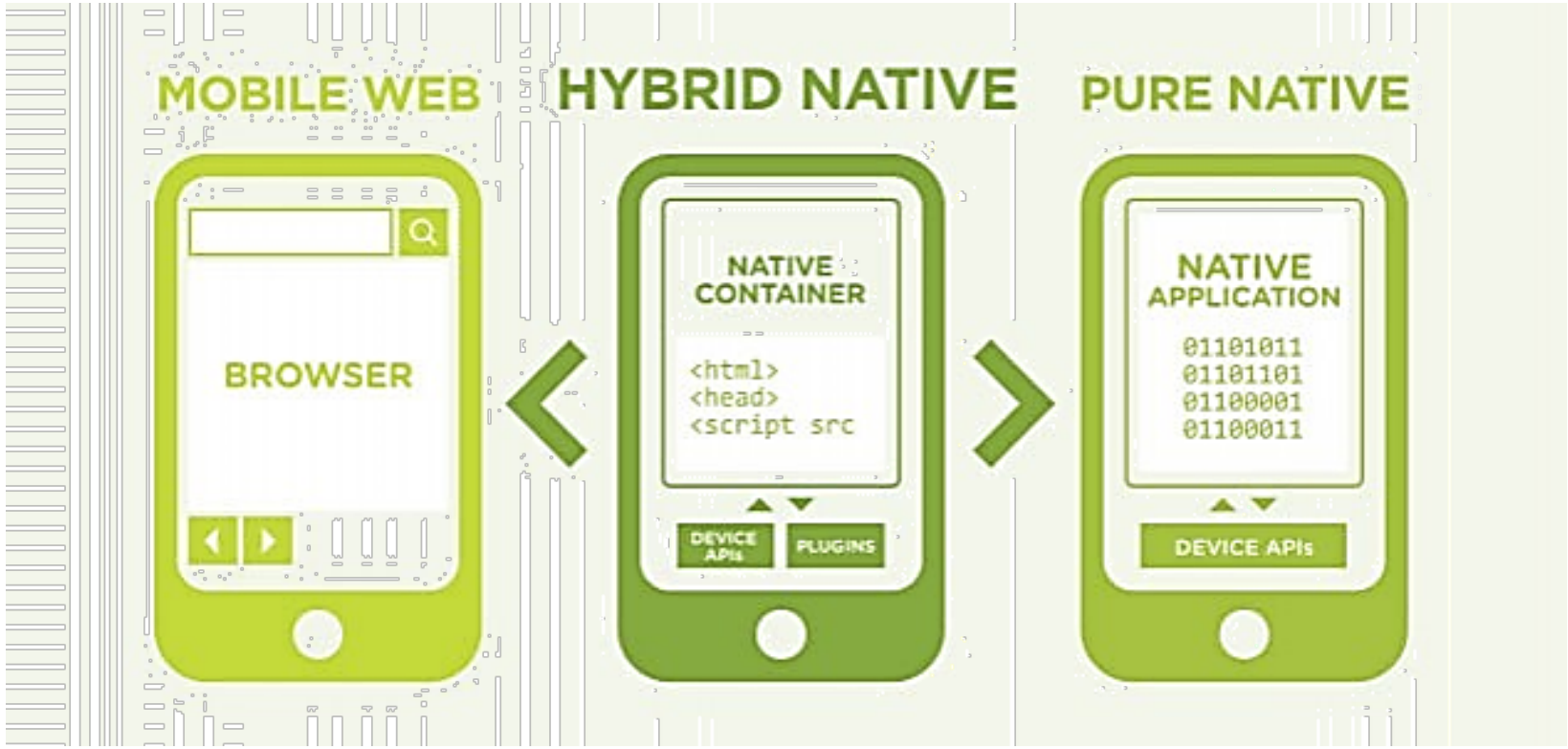
http://www.robosoftsystems.co.in/wikidocs/images/archive/8/84/20130108065629!HC-SR04.jpg

Native Apps Options



http://www.nielsen.com/us/en/newswire/2013/mobile-majority--u-s--smartphone-ownership-tops-60-.html

Mobile Application Options

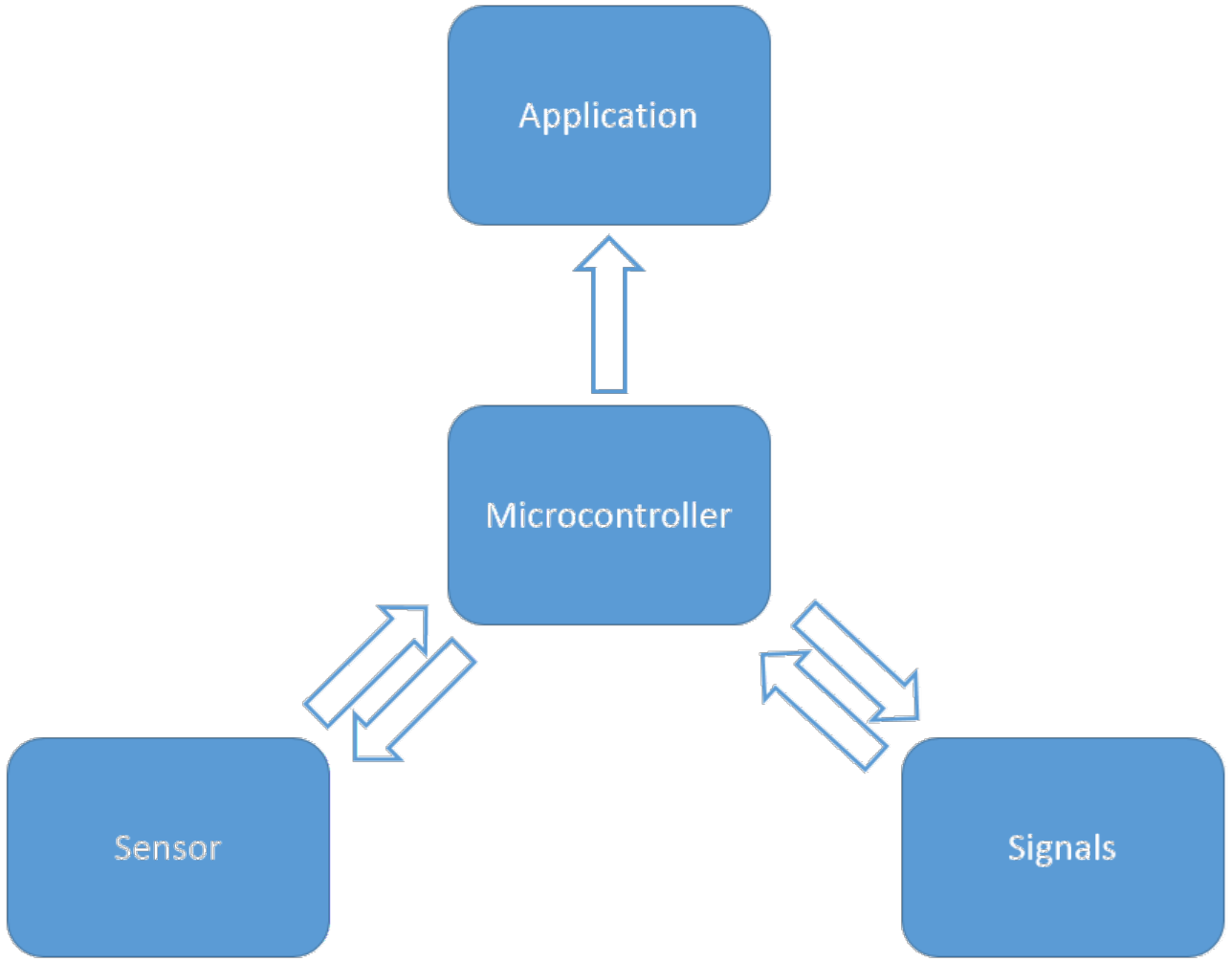


http://blogs-images.forbes.com/anthonykosner/files/2013/01/blog-header-rev2.jpg

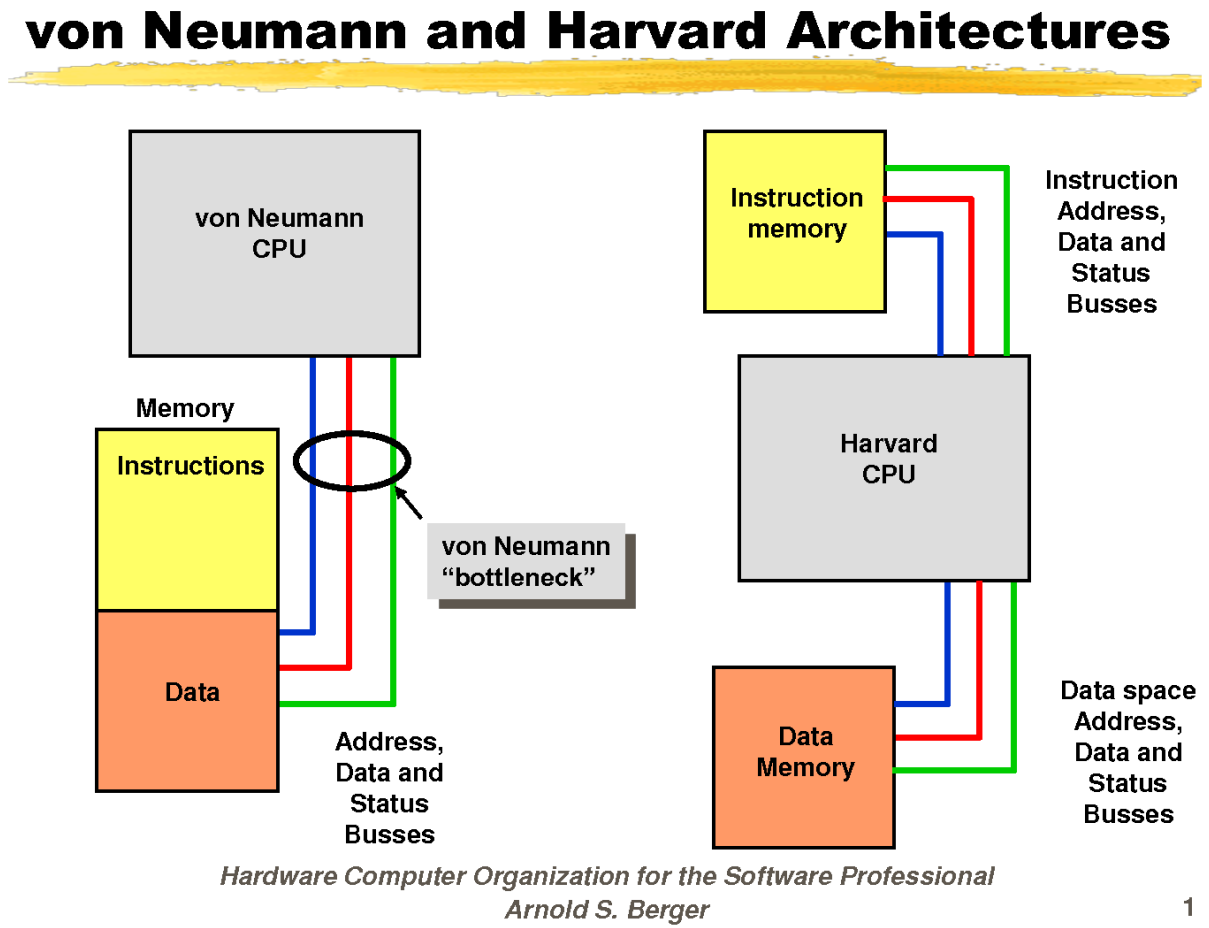
Application Safety

http://www.team-bhp.com/forum/attachments/modifications-accessories/933410d1338258704-garmin-nuvi-50lm-review-gps-navigation-garmin-nuvi50lm-review-9.jpg

Microcontroller Use



Microcontroller Architecture



http://img.docstoccdn.com/thumb/orig/115624566.png

Microcontroller Instruction Set

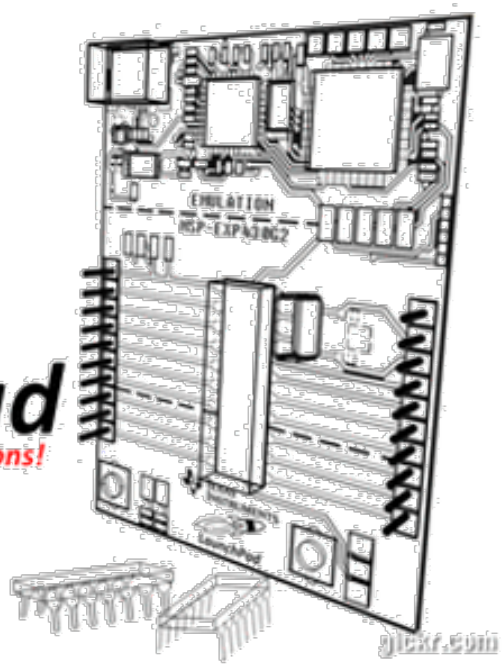
CISC  **vs**  **RISC**

http://www.marclimon.com/wp-content/uploads/2012/04/boxing-gloves.gif

Microcontroller Options

MSP430™ LaunchPad

Everything you need to Launch your applications!



http://www.mouser.com/new/Texas-Instruments/tilaunchpad/

Power

- Non-AC Source
  - Avoids hardwired system
  - Reduces installation cost
- Battery Powered
- Solar Cell for Charging

Image of Battery: http://blog.batteryheads.com/wp-content/uploads/2012/10/Lithium-Ion-battery.jpg
Image of Solar Cell: http://www.kissolar.com/images/WB-66.jpg

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Image of Solar Cell: http://www.kissolar.com/images/WB-66.jpg

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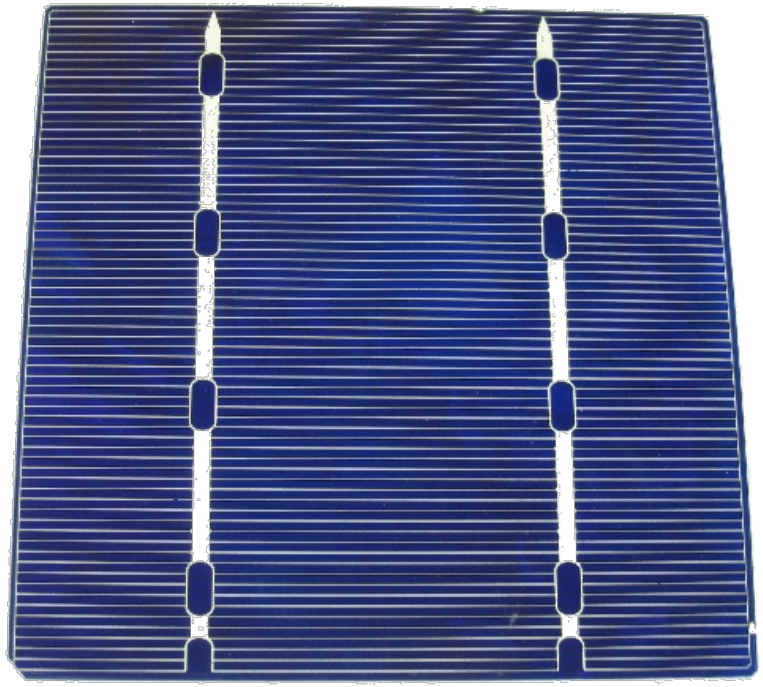


Image of Battery: http://blog.batteryheads.com/wp-content/uploads/2012/10/Lithium-Ion-battery.jpg
Image of Solar Cell: http://www.kissolar.com/images/WB-66.jpg

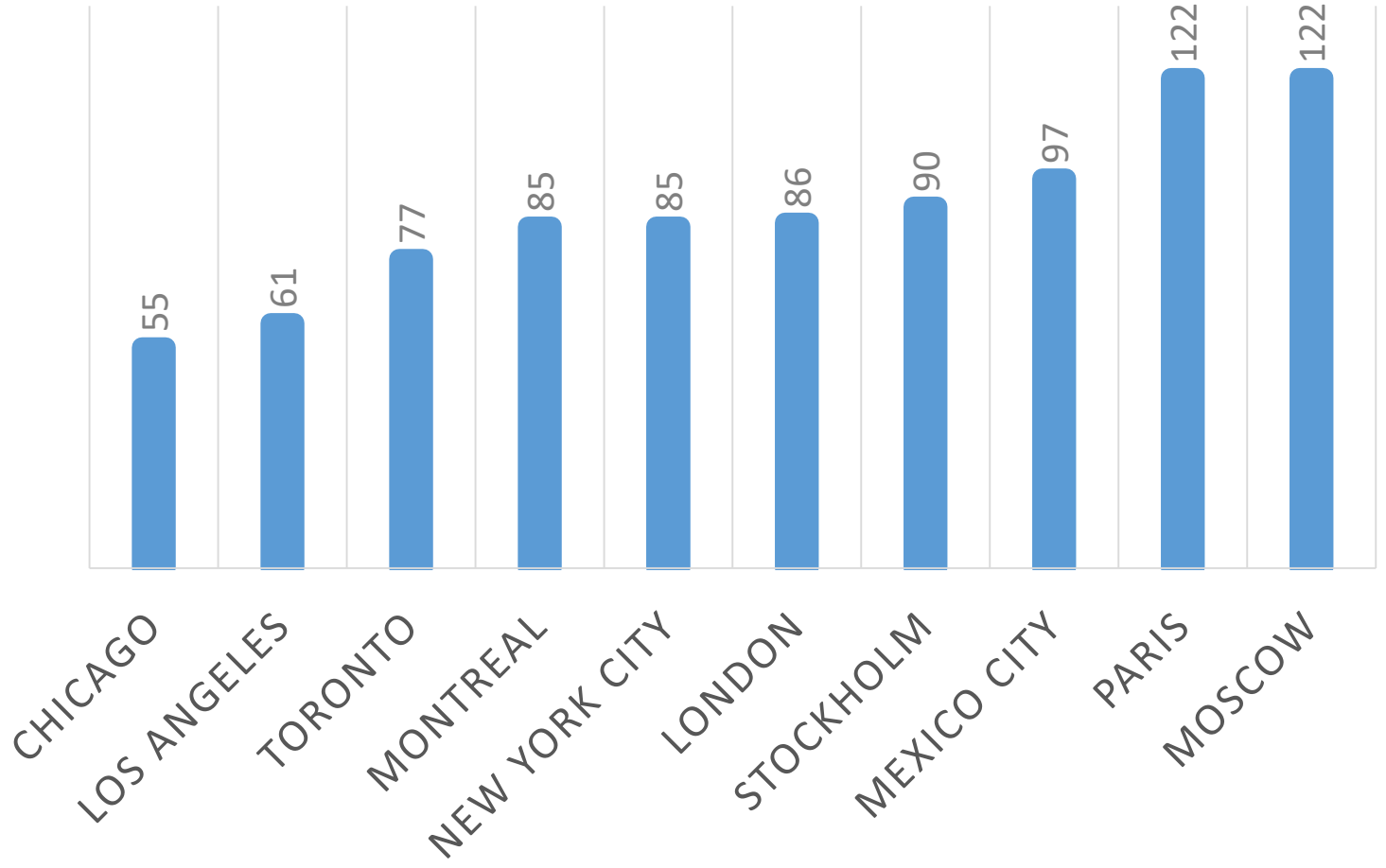
Objective Statement

- The objective of this project is to design and prototype a system that will provide information as to the location of available parking spots. In order to be considered successful, the system must be able to detect a motorized vehicle occupying a parking space with a high-degree of accuracy. The method of detecting the motorized vehicle must be cost-efficient enough to be scaled for large numbers of parking spots. The finished system should consist of a device used to detect motorized vehicles, a method of manipulating the information received from the devices, and an end-user interface.

IBM Pain Index

- Parking Index that ranks the emotional and economic toll of parking in a cross-section of 20 international cities with the highest number being the most onerous.
- *The IBM Parking Index is comprised of the following key issues:*
  1. *Longest amount of time looking for a parking place*
  2. *Inability to find a parking place*
  3. *Disagreement over parking spots*
  4. *Received a parking ticket for illegal parking*
  5. *Number of parking tickets received*

Parking Pain



Need Statement

- People need a better, more efficient, way to find available parking spaces in parking lots. “More than half drivers of 8,000 commuters in 20 cities worldwide say they gave up looking for parking more than once” (“*Smart Parking Tech Might Be Paying Off in US Cities*”, *http://www.govtech.com/transportation/Smart-Parking-Tech-US-Cities.html*). In addition, according to a report on EDF.org, “frequent restarts are no longer hard on a car’s engine and battery. The added wear (which amounts to no more than $10 a year) is much less costly than the cost of fuel saved (which can add up to $70-650 a year, depending on fuel prices, idling habits and vehicle type).”

What Exists?

Standards & Constraints

- Standards: FCC Part 15, IEEE 802.11 specifically, all applicable IEEE and NEC standards, NEMA enclosure standards,
- Constraints: Non-AC Power technologies, limiting to TI processors to save money, Android to save costs, outdoor operations conditions, vehicle weight-bearing materials that are inexpensive

Table 3.1

Marketing Requirements	Engineering Requirements	Justification
6	The sensor should consume no more than 3W.	Non-AC grid sources of energy do not always output constant levels, therefore power conservation is important.
3	The system should use a non-AC grid power source.	Remote instatllations are easier if the device has self-generated power.
3,4	The system should operate in the FCC unlicensed spectrum.	FCC liscensing requires certification and has associated fees.
7,8,9	The sensor signal should have a usable range of at least 240' – enough to travel over 30 traditional parking spaces.	Parking lots are large and often are designed to maximally utilize free space, so placement of nodes may be difficult if the node placement is not flexible and blends into the usable parking spaces.
1,3	The nodes should contain a microcontroller to process signals.	Modern microcontrollers are simple to use and offer great economies of scale in production.
1	The microcontrollers should be sourced from TI to reduce the cost of the prototype.	Mr. Scalzo notified us that TI is interested in providing microcontrollers to our groups.
2, 10	The microcontrollers must have enough storage to hold both system data and code.	Lag delays will cause dissatisfaction in the use of the system by the end-user.
2, 10	The microcontrollers must process the code using only memory and not storage.	Lag delays will cause dissatisfaction in the use of the system by the end-user.
1	The end-user interface must be designed for the Android operating system.	Apple development costs exceed Android costs.
2,7, 10	The system must update the current parking availability to the end-user interface efficiently and error-free in a real time environment.	Drivers shouldn't be able to enter the parking lot and drive to a reasonbaly distant spot without their interface updating.
7,9,10	Each sensor in a parking space must have an effective operating range to accurately detect a vehicle in that space only.	Verifiable vacancy is crucial to performance as a life-improvement device.
5,7, 10	The sensor device must work in both light and dark environments, as well as in inclement weather.	Power sources, sensors, and housings can all affect the operation with respect to time of day. The device must take those shortfalls into account.
7	The sensor device must be a proximity detection device.	The requirement of having multiple sensor devices in each space is not univeral enough to be practical for generic parking layouts.
10	The sensor must accurately detect each of the design group's individual vehicles.	We have a variety of vehicles, this is a reliable test for a successful system.

Marketing:
1. The device must have a low initial cost and maintenance cost.
2. The end-user interface must be simple to use.
3. Installation of the system must be inexpensive and take as little time as possible.
4. The construction of the system should be simple enough to require no specialty training.
5. The device should withstand reasonable weather conditions.
6. The device should have a long lifespan.
7. The device should operate in typical parking lot conditions.
8. The device should be small.
9. The device should integrate into the existing aesthetics of the typical parking lot surface.
10. The system must be reliable.

Table 3.5

		Power Consumption < 3mW	Non-AC Grid Power Source	Carrier Frequency is in ISM Band	Range > 240'	Microcontroller Signal Processing (from TI)	Microcontroller has > 1Kb storage	Microcontroller processes code without overflow from memory	Efficient and error free, only validating at most one space per sensor	Independently operates from weather and time-of-day changes	Employs a proximity sensor to succesfully detect group members' cars
		-	-	+	+	+	+	+	+	+	+
Cost	-	↑	↑↑	↑	↓	↑↑	↓↓			↓	
Ease of Use	+			↑	↑			↑	↑↑		
Durability	+									↑↑	
Aesthetics	+									↑	

Table 3.6

		Power Consumption < 3mW	Non-AC Grid Power Source	Carrier Frequency is in ISM Band	Range > 240'	Microcontroller Signal Processing (from TI)	Microcontroller has > 1Kb storage	Microcontroller processes code without overflow from memory	Efficient and error free, only validating at most one space per sensor	Independently operates from weather and time-of-day changes	Employs a proximity sensor to succesfully detect group members' cars
	-	-	-	+	+	+	+	+	+	+	+
Power Consumption < 3mW	-		↑↑	↓	↓				↑	↓	↓
Non-AC Grid Power Source	+				↓					↓	
Carrier Frequency is in ISM Band	+				↑					↑	↑
Range > 240'	+										
Microcontroller Signal Processing (from TI)	+										
Microcontroller has > 1Kb storage	+										
Microcontroller processes code without overflow from memory	+										
Efficient and error free, only validating at most one space per sensor	+									↑	
Independently operates from weather and time-of-day changes	+										↑
Employs a proximity sensor to succesfully detect group members' cars	+										

Table 3.8

EOC 3.12 : Table 3.8

Engineering Requirements	Score
Each engineering requirement is abstract.	4.5
Each engineering requirement is verifiable.	5
Each engineering requirement is unambiguous and written as a concise statement.	5
Each engineering requirement can be traced to a user or need.	5
Each enginnering requirement is realistic and has a justification provided.	5
Standards and constraints applicable to the project have been identified and included.	3
The Requirements Specification	
The requiements are normalized, with minimal redundancy and overlap.	4
The engineering requirements are organized by similarity.	5
The requirements are complete, addressing all needs.	4
The requirements are bounded (not overspecified).	4.5
The requirements have been validated and agreed upon by all stakeholders.	5

Table 9.1

EOC 9.6 : Table 9.1

Team Formation	Score
The team's objectives are clearly defined	5
There is a consensus among all team members that the objectives are the correct ones	5
The team members' complementary skills (technical, functional, interpersonal) have been identified.	4
There are enough members on the team to cover all of the necessary competencies.	5
Team Processes	
The team has developed effective guidelines for holding all members of the team mutually accountable for achieving the objectives.	3
The team has developed a strategy for holding effective meetings.	5
The team has agreed upon a mutual meeting place and time.	5
The team members trust each other.	4
The team members demonstrate respect for each others ideas.	5

Pairwise Matrix

Objective						
	Cost	Ease of Use	Durability	Asthetics	Geometric Mean	Weight
Cost	1.00	5.00	1.00	7.00	2.432299279	0.43194914
Ease of Use	0.20	1.00	0.20	6.00	0.699927102	0.124299223
Durability	1.00	5.00	1.00	5.00	2.236067977	0.397100656
Asthetics	0.14	0.17	0.20	1.00	0.262690989	0.046650981

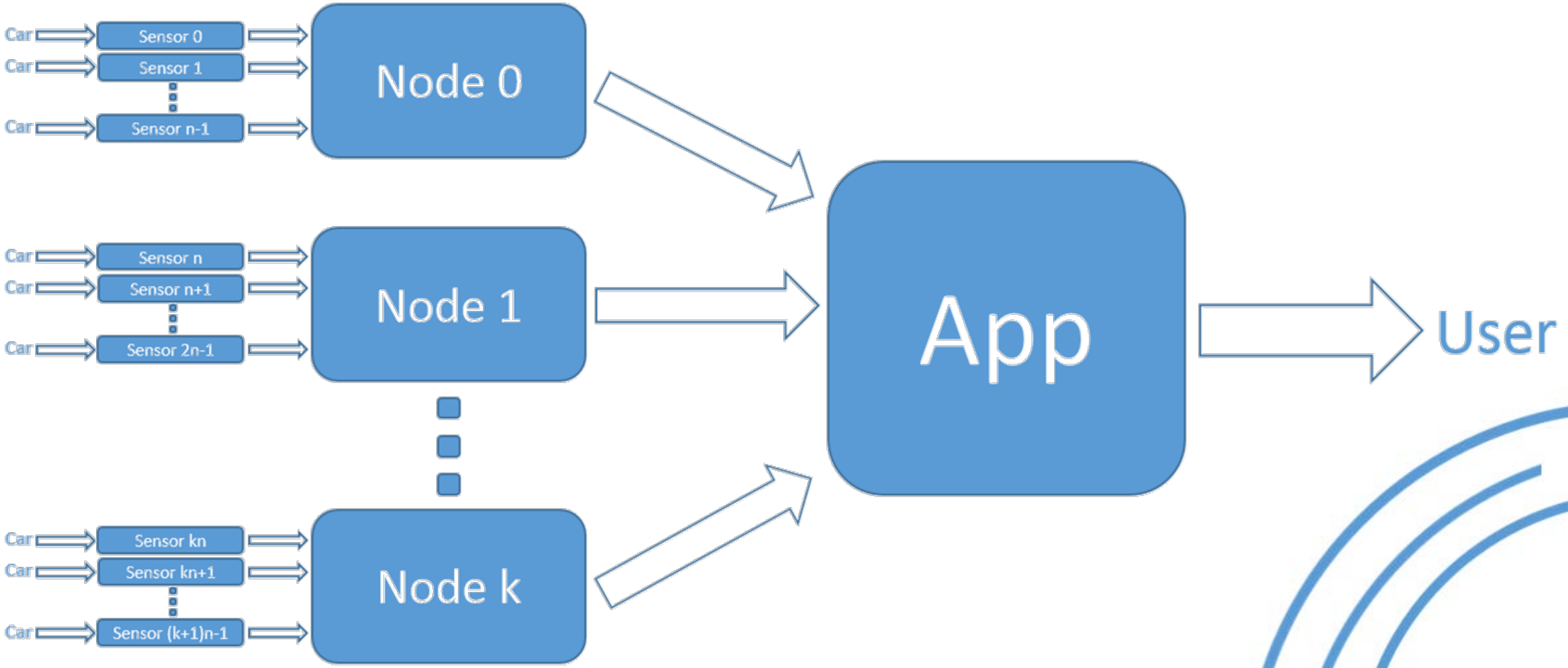
Cost				
	Installation Cost	Maintenance Cost	Geometric Mean	Weight
Installation Cost	1.00	3.00	1.732050808	0.75
Maintenance Cost	0.33	1.00	0.577350269	0.25

Ease of Use					
	Ease to Drivers	Ease of Installation	Ease of Construction	Geometric Mean	Weight
Ease to Drivers	1.00	0.20	3.00	0.843432665	0.181881806
Ease of Installation	5.00	1.00	7.00	3.27106631	0.705388198
Ease of Construction	1.00	0.14	1.00	0.522757959	0.112729997

Durability					
	Water Resistance	Lifespan	Thermal Resistance	Geometric Mean	Weight
Water Resistance	1.00	0.33	1.00	0.693361274	0.2
Lifespan	3.00	1.00	3.00	2.080083823	0.6
Thermal Resistance	1.00	0.33	1.00	0.693361274	0.2

Asthetics				
	Size	Seamless Integration	Geometric Mean	Weight
Size	1.00	1.00	1	0.5
Seamless Integration	1.00	1.00	1	0.5

Initial Concept



Super Sensor