Truck Smart Blind Spot Detection System Group #32

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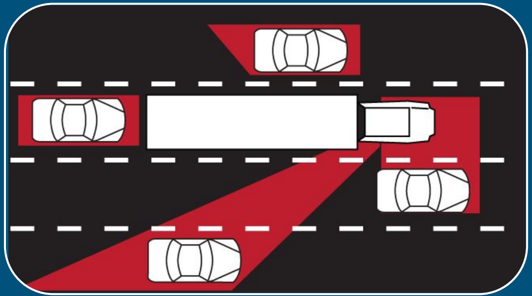


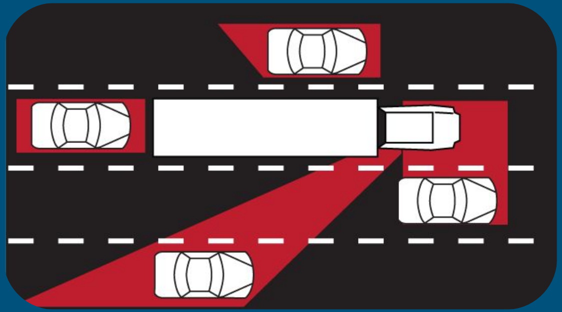
Motivation

- 15% of large truck collisions are caused by poor observations*
- 20,000 yearly incidents due to blind spots or driver failure*
- Extremely dangerous to anyone that has to share the road with trucks
- Some drivers are not aware of this issue
- This blind spot detection system will alert truck drivers on real time whether or not there is a vehicle in the truck's blind spot

* Data taken from study published by the Federal Motor Carrier Safety Administration in 2007

Goals and Objectives

- ➢ Three wireless sensors in key locations to detect any potential motorists
    - Front left trailer (facing backwards)
    - Front right trailer (facing backwards)
    - Back center trailer
- ➢ Wireless communication from sensors to hub unit
- ➢ Highly portable, easy to use and install
- ➢ Accurate, no false negatives
- ➢ Low power consumption

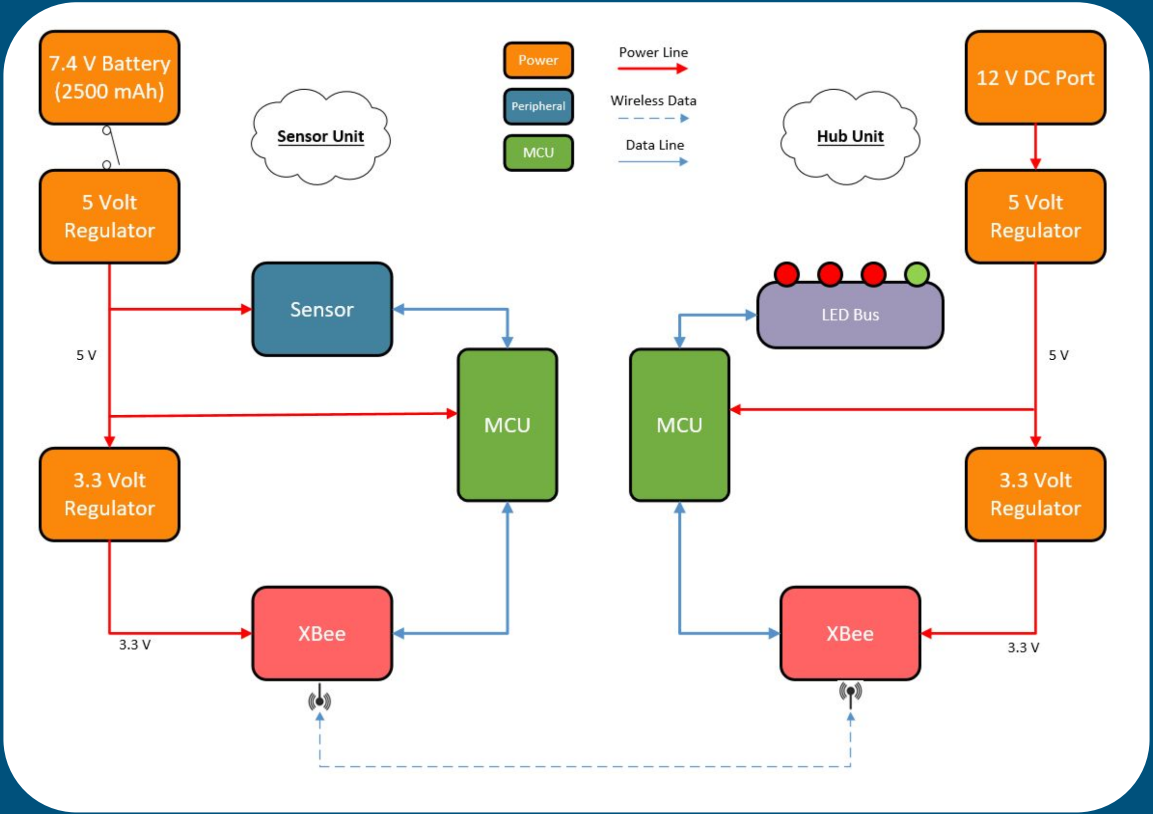


Requirements & Specifications

- Assist lane changes by warning the driver if there is a vehicle in the blind spot.
- Strategically placed sensors
- Wireless data transmission
- A hub unit in the truck cabin shall receive and display data to user
- Plug and play functionality

Design Attribute	Goal	Actual Value
System Installation Time	< 10 minutes	2 minutes
Sensor Unit Battery Life	> 18 hours	32.92 hours
Housing Durability	Weatherproof for 100,000 miles	Windproof Trauma-resistant
Sensor Unit Dimensions	115 x 115 x 50 mm; < 3 kg	101.6 x 142.75 x 38.86 0.30 kg
Hub Unit Dimensions	200 x 100 x 65 mm; < 2 kg	162.5 x 83.82 x 55.77 0.21 kg
System Cost	< $600	$797

Overall Block Diagram



Sensor Technology

- Different types of sensors include:
    - IR
    - Ultrasonic
    - Electromagnetic
- Sensor choice: Ultrasonic
- A signal is sent out and the return time is logged, distance is then derived.

Sensor Type	IR	Ultrasonic	Electromagnetic
Cost	Least expensive	Slightly more expensive than the IR	Significantly pricier
Environment	Not suitable for outdoor lighting condition	Lighting doesn't affect the accuracy	Lighting doesn't affect the accuracy
Power	Low power consumption	Low power consumption	High power consumption
Range	Relatively lower range	High range	Low range

Ultrasonic Sensor Selection

MB1000
LV-MaxSonar - EZ0

- ➢ Consistent and accurate performance
- ➢ Wider angle
- ➢ Lower power

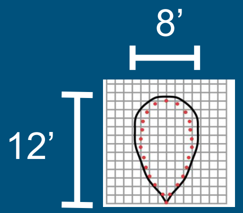
Sensor	HC-SR04	MB1000 LV-MaxSonar-EZ0
Max Range	4 m	6.45 m
Measuring Angle	15°	46.5°
Current Draw	15 mA	2 mA
Dimensions	45 x 20 x 15 mm	19.9 x 22.1 x 15.5 mm
Cost	$5.20	$29.99

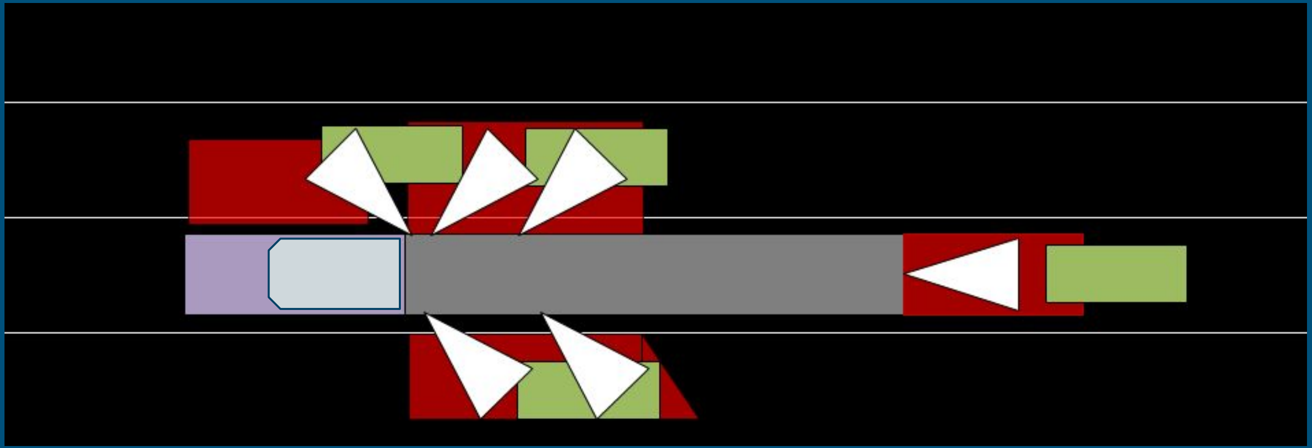
Sensor Range and Placement

Vehicle

Sensor field of detection

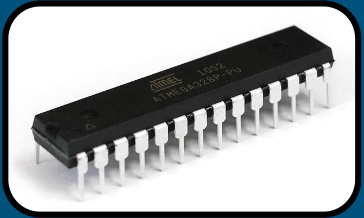
Blind spot regions





* All object representations are to scale

Microcontroller Selection



Selection of ATmega328P

- ➢ Compromise of power and performance
- ➢ Enough memory for project purpose
- ➢ Sufficient amount of pins
- ➢ Compatible with Arduino Uno
- ➢ Low cost

Microcontroller	**MSP430G2553**	**ATmega328P**	**MSP432P401R**
Frequency	16 MHz	20 MHz	48 MHz
Power Consumption	0.414 mW	0.360 mW	0.129 mW
Memory (Flash)	16 KB	32 KB	256 KB
Memory (RAM)	0.512 KB	2 KB	64 KB
I/O Pin Count / Rated Current	16 / 48 mA	23 / 100 mA	48 / 100 mA
Cost	$2.38	$3.30	$6.20

Wireless Communications Overview

- Advantages
  - Portability
  - Adaptability
  - Remote Configuration
  - Wires overstretching or getting loose is not a concern
- Disadvantages
  - Susceptible to hacking
  - Increases overall power consumption
  - Increases cost
  - Limited range
  - Packets can get lost during transmission

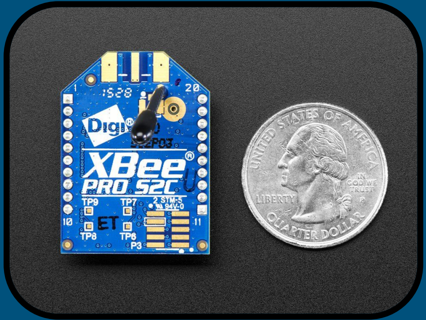
Wireless Technology Options

Wireless Attributes	WiFi	Bluetooth	Zigbee
Power Consumption	High	Medium	Low
Operating Channels	38 (2.4GHz & 5GHz)	40	15
Range	200 ft (real-environment)	32 ft	2 miles
Error Handling	Half Automated	Manual	Automated
Compatibility	Computers (big systems)	Embedded devices	Embedded devices
Data Rates	25 Mbps (minimum)	0.7 - 2.1 Mbps	250 kbps
Security	High	Low	Medium

➢ ZigBee protocol was chosen based on range and power consumption constraints

Network Setup using XBee Pro S2C

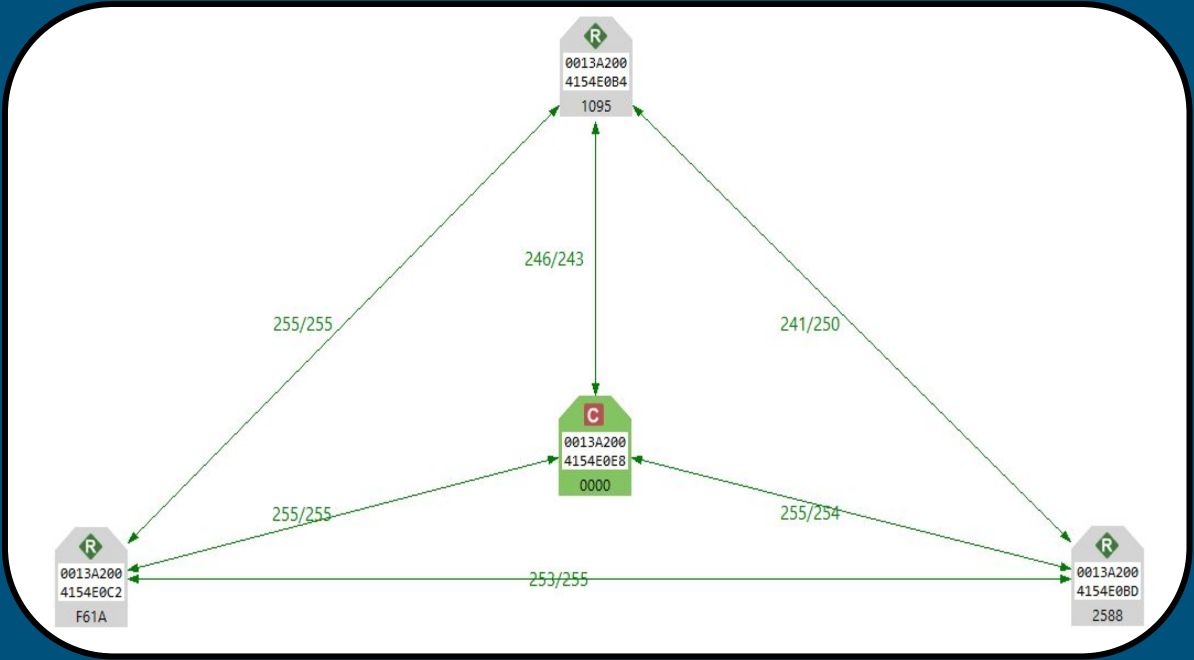
- Assign single coordinator parameters
  - PAN ID
  - Operating Channel
  - Switching to API Mode
  - Set Network Key (64-bit)
  - Enable Encryption (128-bit)
- Assign router devices (3)
  - PAN ID
  - Switching to API Mode
  - Destination Node
  - Enter network key



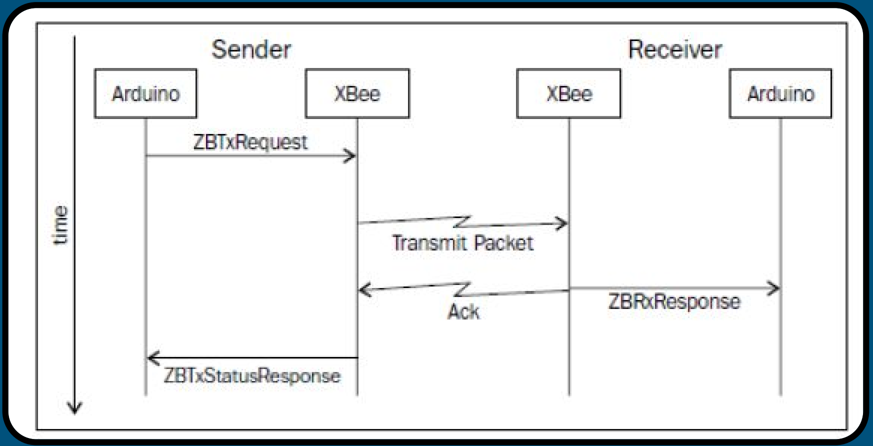
Range	2 miles (LOS)
Cost	$30
Power	3.3 V @ 29 mA
Encryption	128-bit
I/O Pins	8

Network Functionality

- Ability to configure nodes remotely
- Perform range test
- Easy integration of new sensors
- Multiple Access Collision Avoidance
- Packet Retrials if failures occur



Network Flow



Sender:

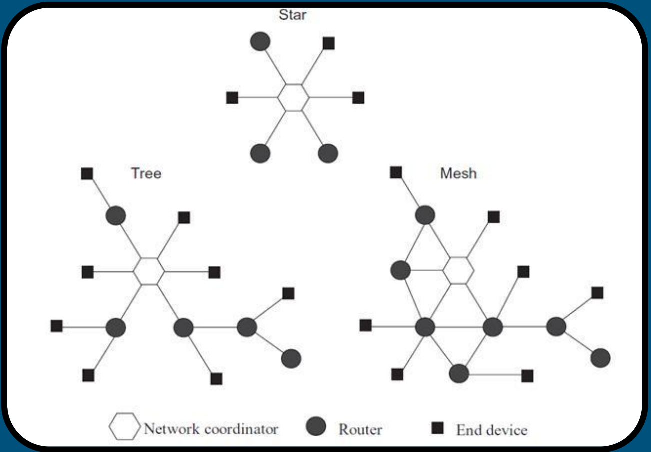
1. Get Data
2. Initiate TX Request
3. Transmit Packet/payload (wait for ackn.)
4. Inform MCU that data was/wasn't received and proceed accordingly

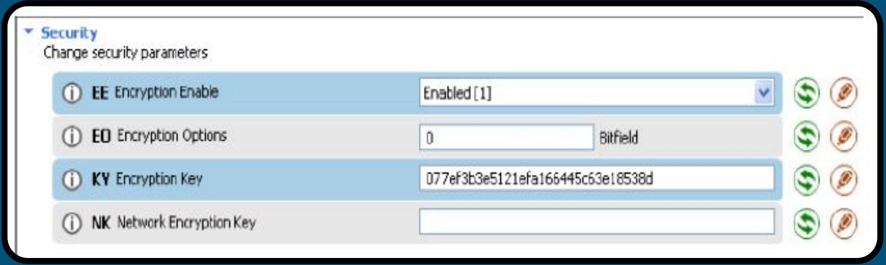
Receiver:

1. Receive payload
2. Send acknowledgement back to coordinator
3. Perform data manipulation

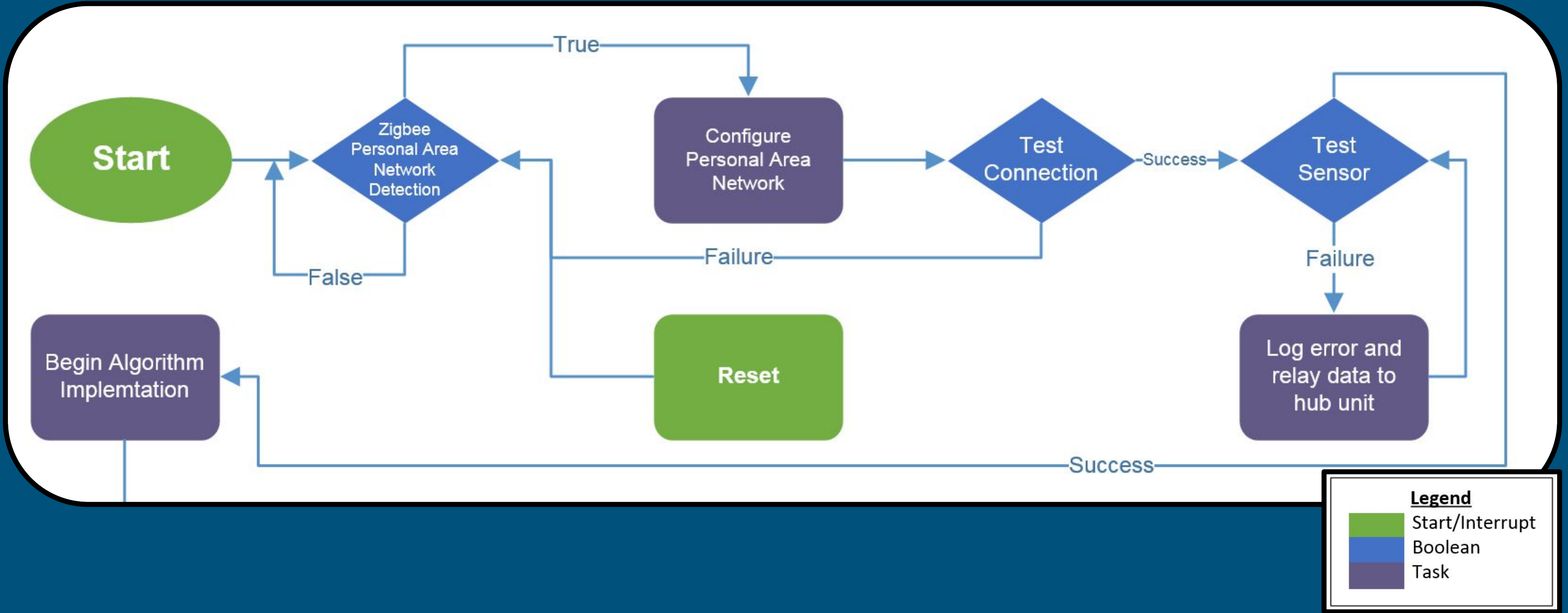
Security and Interference

- ➢ Global unique identifiers for each sensor
- ➢ Unique ID for each network
- ➢ 16-bit “short address”
- ➢ 128 - bit encryption key header
- ➢ Disable joining after setup has been completed



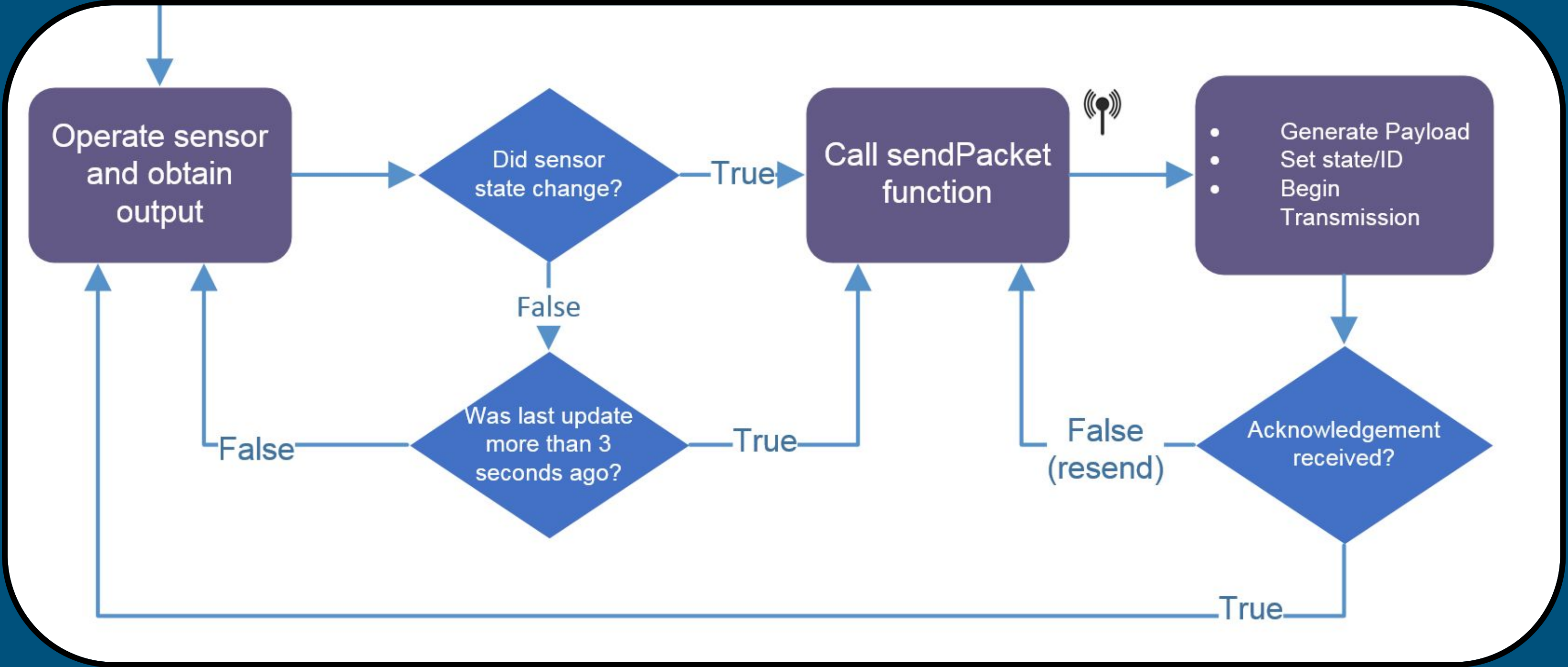


Wireless Setup Flow Diagram (Sensor Unit)

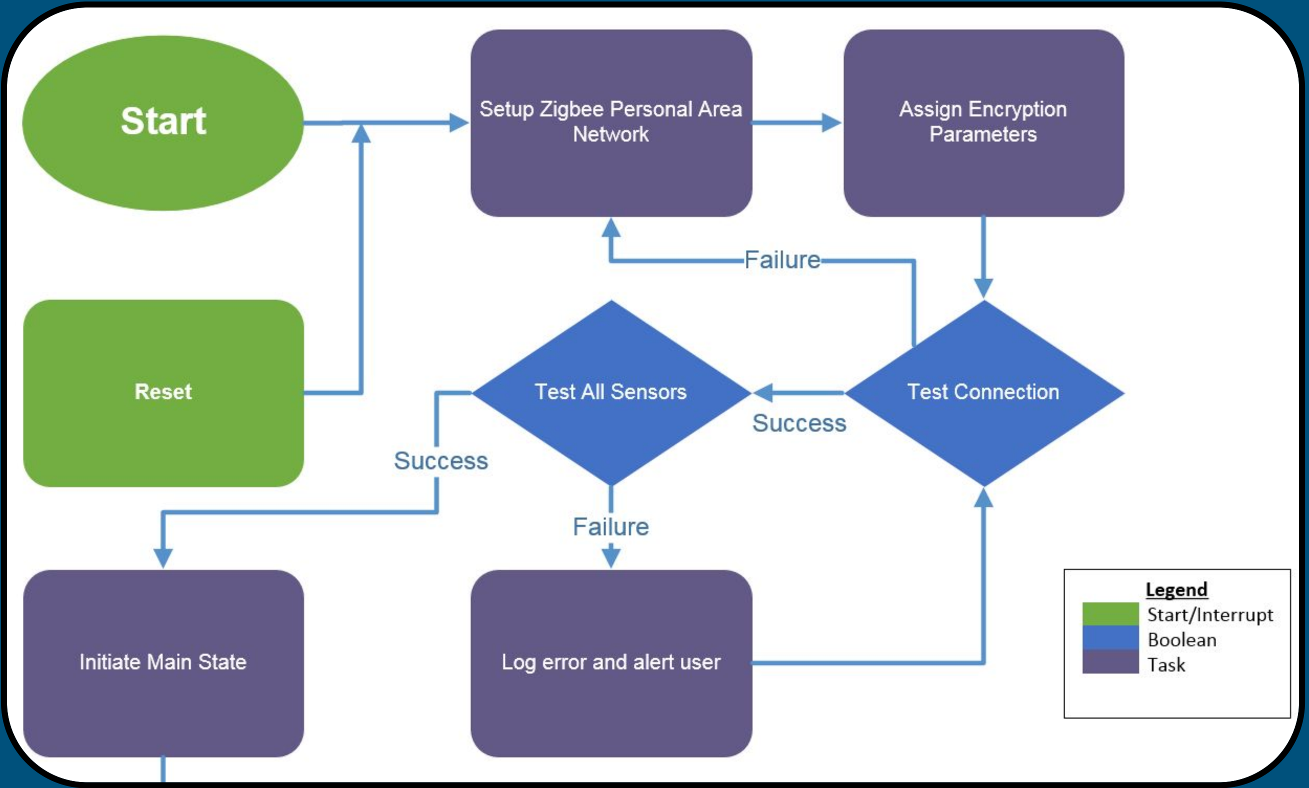


Software Flow Diagram (Sensor Unit)

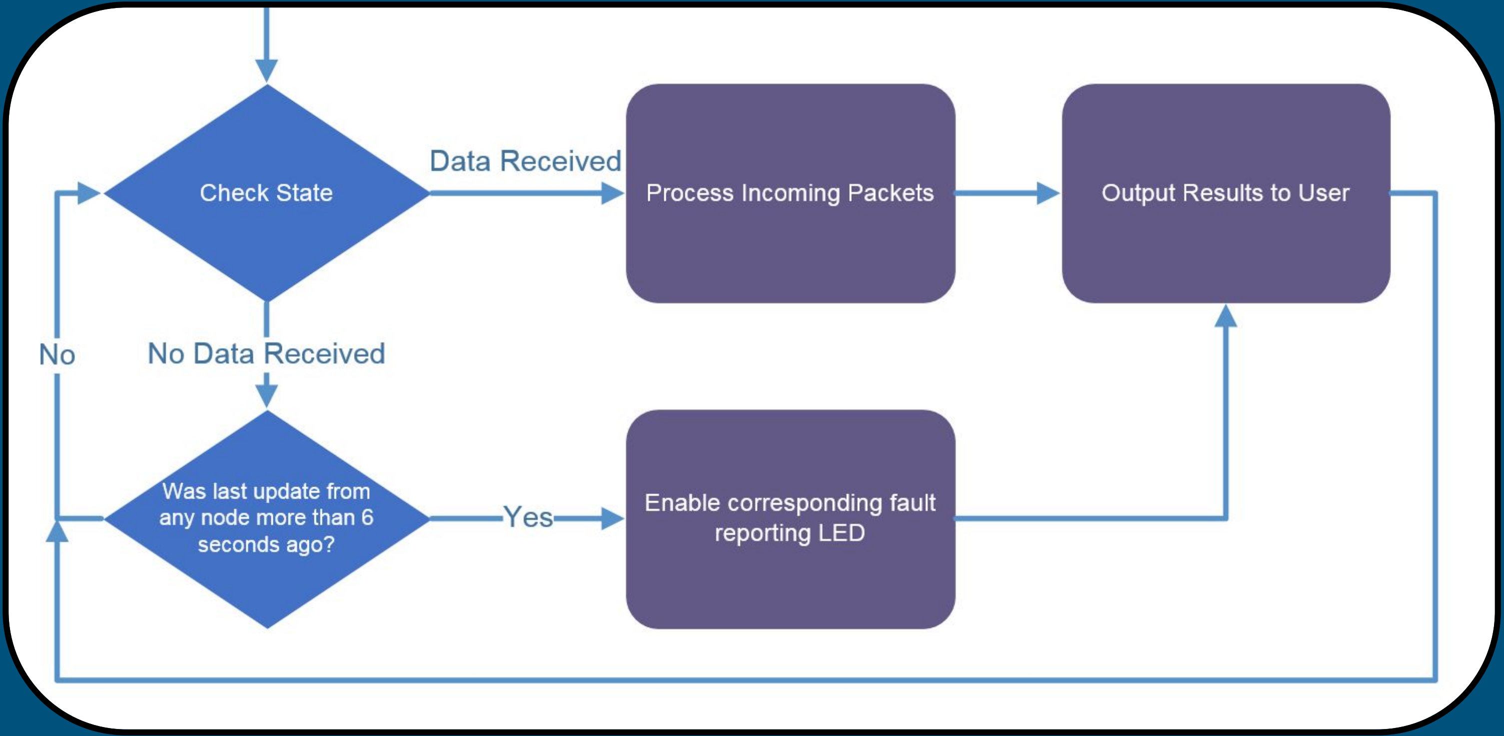
Legend
- Start/Interrupt
- Boolean
- Task



Wireless Setup Flow Diagram (Hub Unit)



Software Flow Diagram (Hub Unit)



Error Prevention, Detection, and Notification

- Sensor False Positives
  - Filter sensor data to prevent outliers from giving false positives
    - Sample size of 5 in 250 msec
- Timekeeping
  - Sensors log time of last sent packet
    - Forces a send every 3 seconds
  - Hub logs times of last received packet of each sensor
    - Checks for last received packets every 6 seconds
  - Check times periodically to ensure punctuality
    - Hub turns on red debug LED if poor response times are detected

Printed Circuit Board

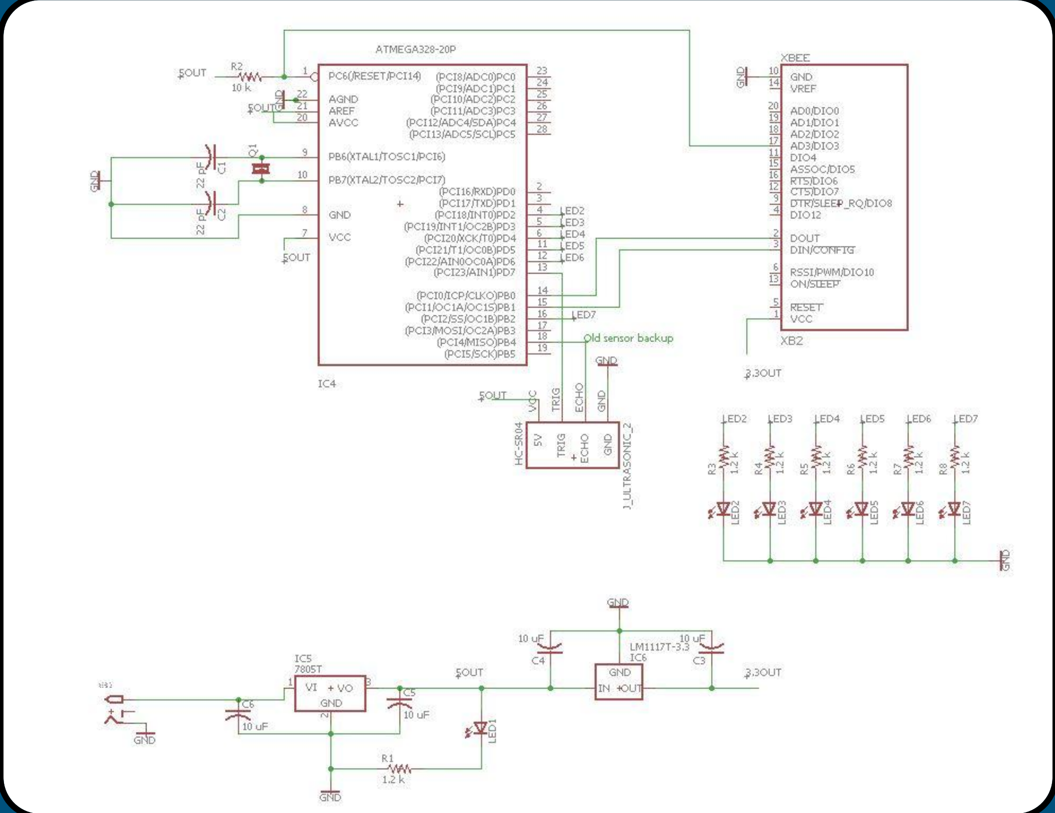
PCB Overview

- ➢ A total of four (4) PCBs are used in our project
- ➢ Three for sensors and one for the hub
- ➢ The board was designed so that the same generic board can be used for all four components of the system. This reduced the fabrication cost.
- ➢ CAD software used: Eagle
- ➢ Board size: 2.80” X 2.15”
- ➢ 2 layers
- ➢ Manufacturer: OSH Park

Table of Components Used in the Design

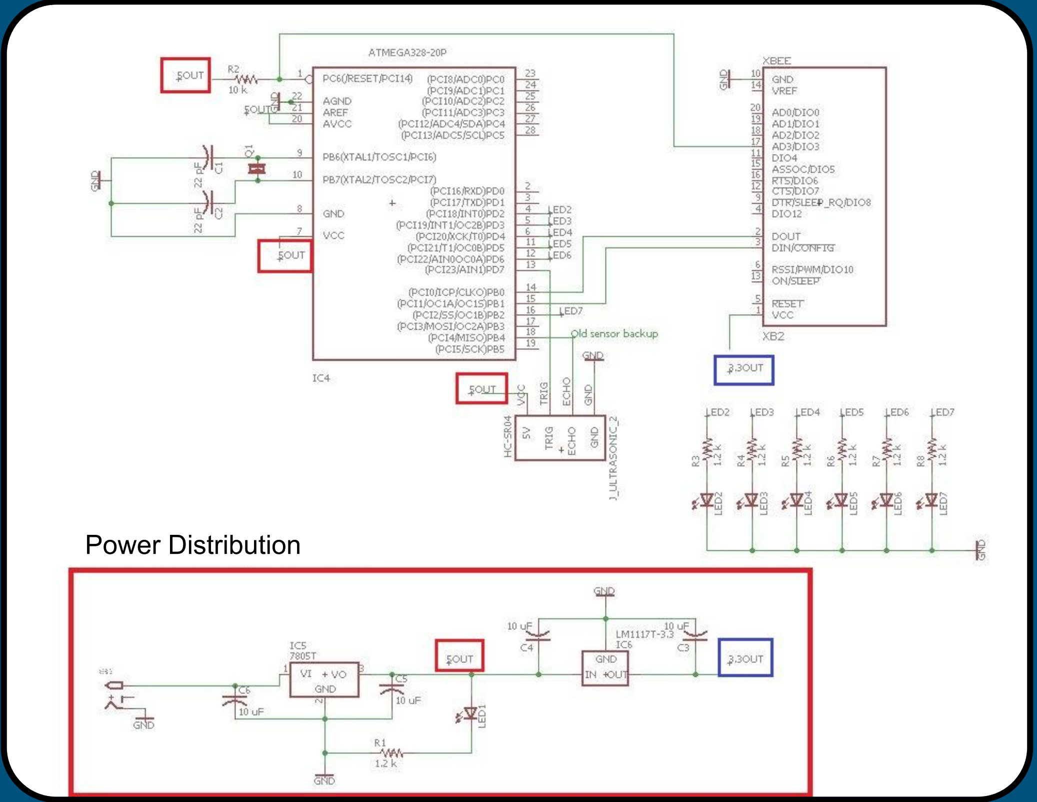
Item	Quantity (Per PCB)	Comments
ATMega 328P	1	
MB1000 LV Ultrasonic Sensor	1	Only for sensor PCBs
XBee Transceiver 2.4 GHz	1	
2.1 mm DC Barrel Jack	1	
7805T Voltage Regulator	1	
LM1117T - 3.3 Voltage Regulator	1	
16 MHz Clock Crystal	1	
22pF Capacitor	2	
10uF Capacitor	4	
10K Resistor	1	
1.2K Resistor	1/5	Sensor PCB/Hub PCB
LEDs	1/5	Sensor PCB/Hub PCB

Schematic

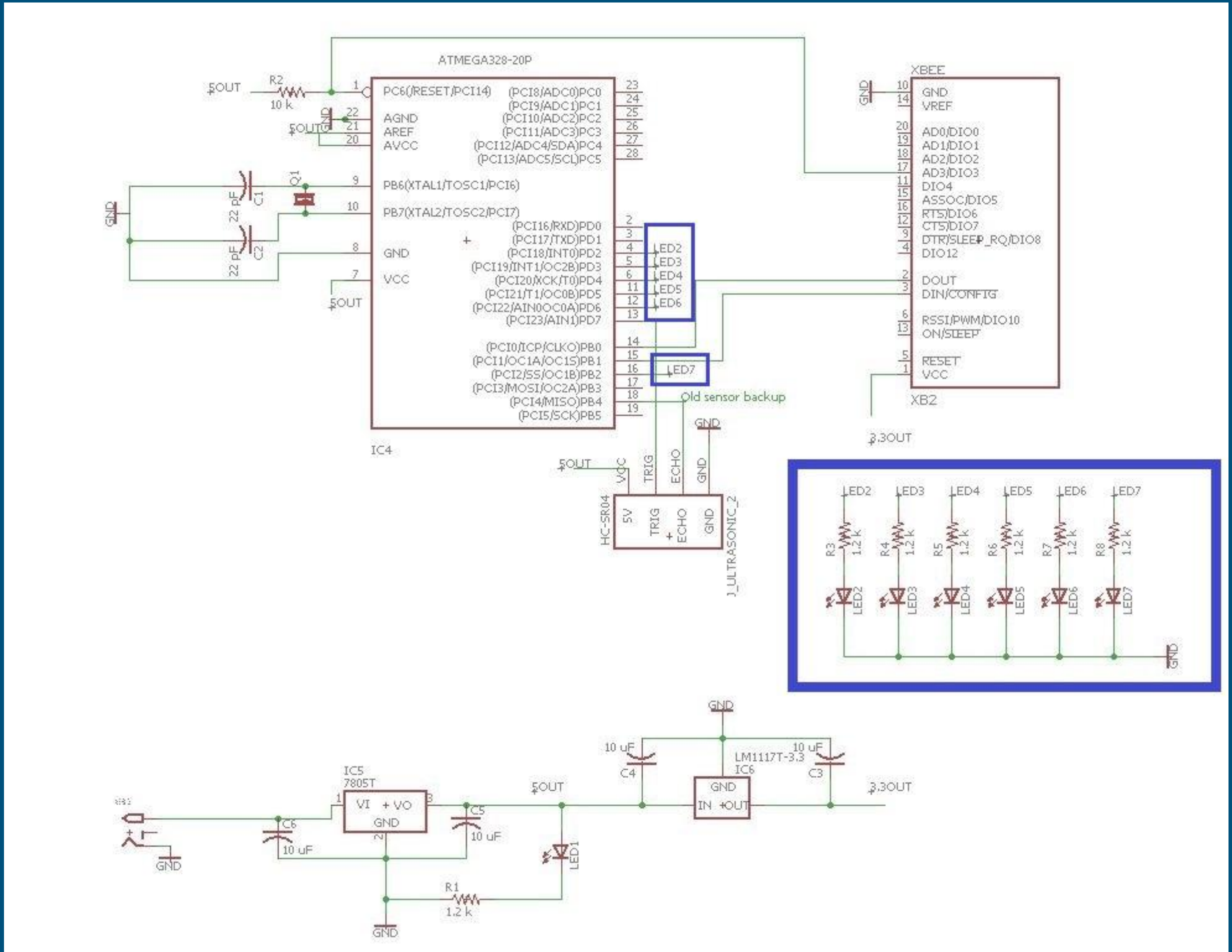


ATMEGA328-20P
IC4
XBEE
XB2
5OUT
3.3OUT
GND
R2
10 k
PC6(/RESET/PCI14)
AGND
AREF
AVCC
PB6(XTAL1/TOSC1/PCI6)
PB7(XTAL2/TOSC2/PCI7)
VCC
(PCI8/ADC0)PC0
(PCI9/ADC1)PC1
(PCI10/ADC2)PC2
(PCI11/ADC3)PC3
(PCI12/ADC4/SDA)PC4
(PCI13/ADC5/SCL)PC5
(PCI16/RXD)PD0
(PCI17/TXD)PD1
(PCI18/INT0)PD2
(PCI19/INT1/OC2B)PD3
(PCI20/XCK/T0)PD4
(PCI21/T1/OC0B)PD5
(PCI22/AIN0OC0A)PD6
(PCI23/AIN1)PD7
(PCI0/ICP/CLKO)PB0
(PCI1/OC1A/OC1S)PB1
(PCI2/SS/OC1B)PB2
(PCI3/MOSI/OC2A)PB3
(PCI4/MISO)PB4
(PCI5/SCK)PB5
Q1
C1
C2
22 pF
VREF
AD0/DIO0
AD1/DIO1
AD2/DIO2
AD3/DIO3
DIO4
ASSOC/DIO5
RTS/DIO6
CTS/DIO7
DTR/SLEEP_RQ/DIO8
DIO12
DOUT
DIN/CONFIG
RSSI/PWM/DIO10
ON/SLEEP
RESET
LED2
LED3
LED4
LED5
LED6
LED7
Old sensor backup
TRIG
ECHO
5V
HC-SR04
J_ULTRASONIC_2
R3
R4
R5
R6
R7
R8
1.2 k
IC5
7805T
VI
VO
10 uF
C3
C4
C5
C6
LM1117T-3.3
IC6
IN
OUT
LED1
R1

Power Distribution

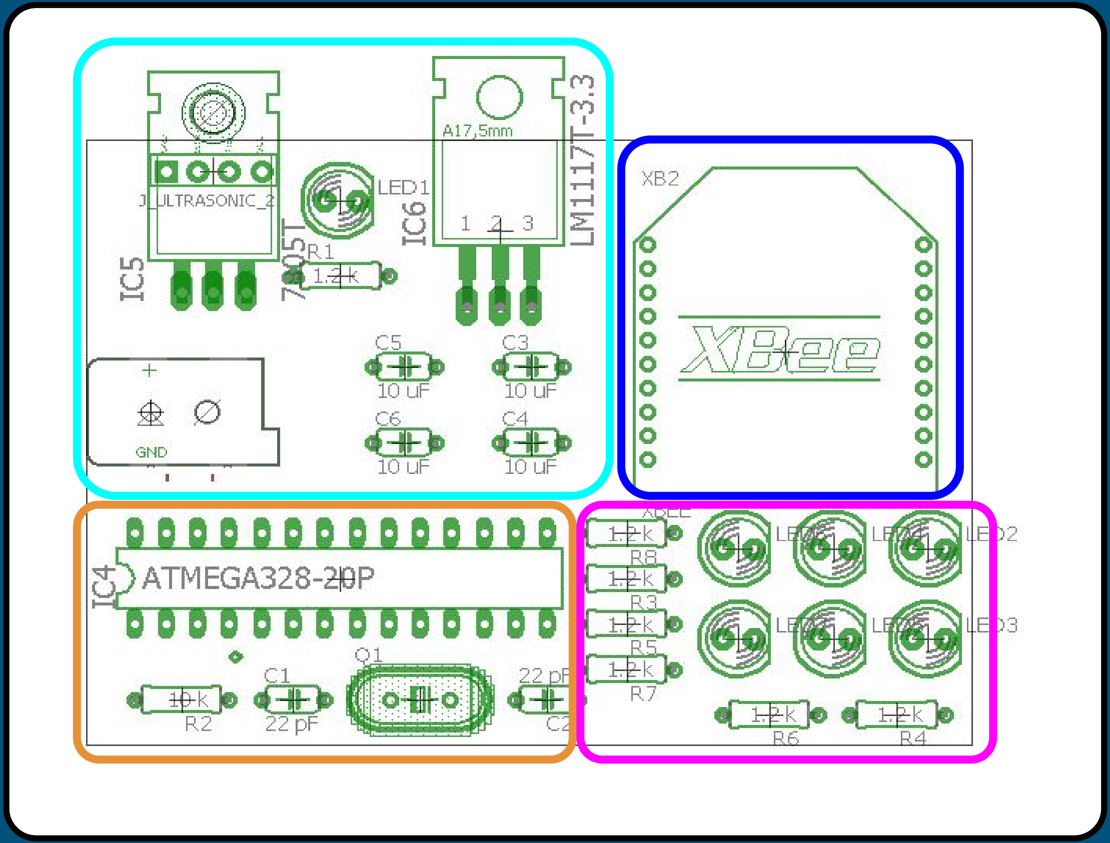


PCB Schematic - Cabin LED Display

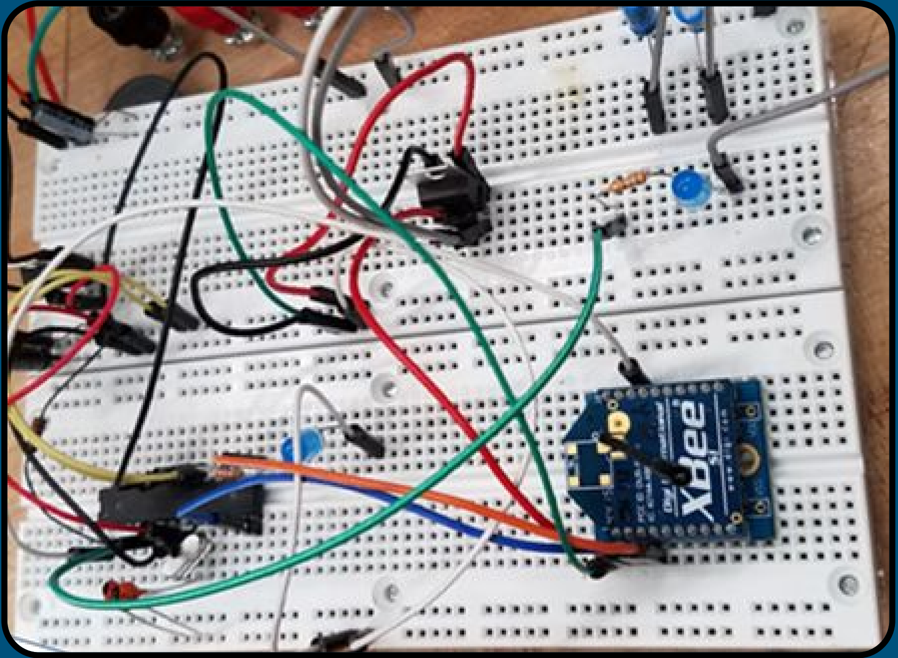


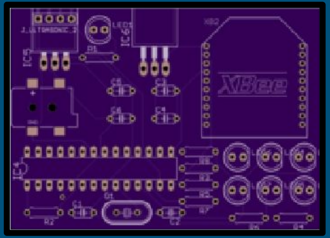
PCB Layout

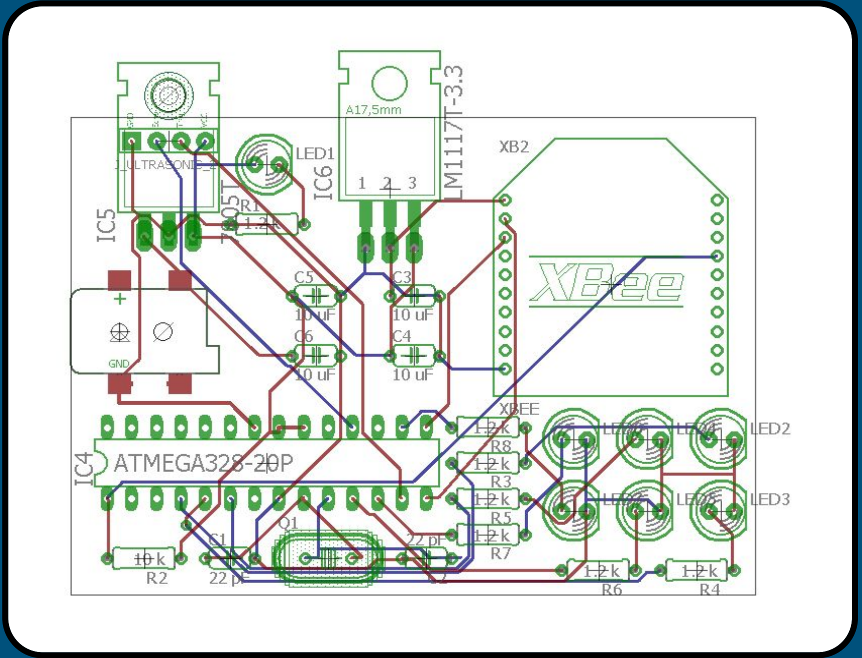
- Power Distribution
- Communications
- Notifications
- MCU



Breadboard & PCB Layout







System Testing

- Testing split into 2 phases
- **Phase 1** - Breadboard & Component Testing
  - Geared towards finding flaws in the design logic and the components
  - Aims to highlight component underestimations and unforeseen engineering challenges
  - Includes PCB testing
- **Phase 2** - System & Environment Testing
  - Aims to prove the practicality of the design under typical usage circumstances
  - Hopes to emphasize operational constraints and exploit defects
  - Includes weatherproofing testing

Test Cases for Verification

Phase 1 - Breadboard & Component Testing
Verify ATMega328P I/O does not exceed current limitations
Verify active secondary components are within operational ranges
Verify voltage regulators do not overheat in an enclosed capsule
Verify test LED code on breadboard circuit runs properly
Verify XBee packet receiving over UART hyperterminal
Verify XBee packet sending over UART hyperterminal
Verify relationship sync and local XBee network created
Verify multiple XBee networks can exist simultaneously w/o merging data.
Verify parallelized sensor activity
Verify Xbee network range requirements
Phase 2 - System & Environment Testing
Verify magnets can hold weight of sensor
Verify XBee sync/transmit/receive when out of line-of-sight
Verify object size sensing requirements
Verify sensor high-speed test (70 mph)

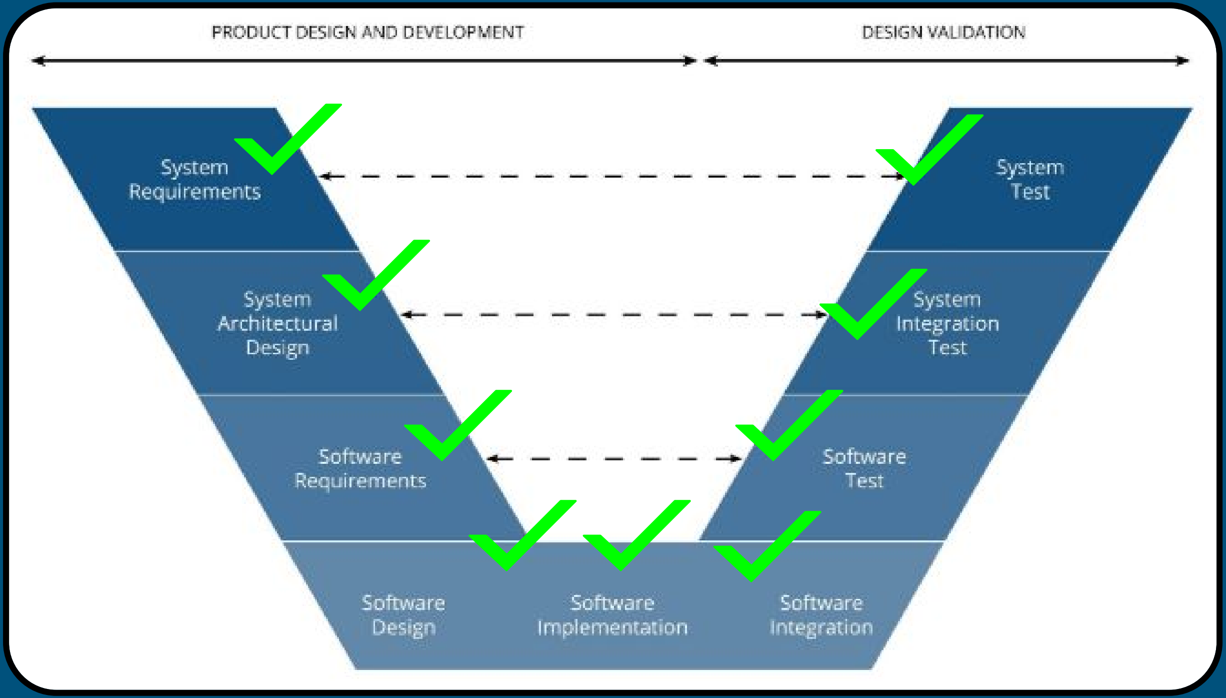
- Subset of test cases to be verified
- Phase 1 complete
- Phase 2 complete

Design Approach

> 90% Complete

In progress

Future tasks



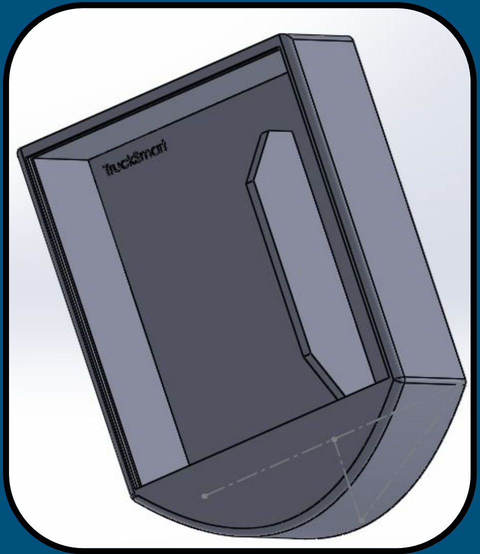
*Flow chart courtesy of pi-innovo.com

Housing Requirements

- ➢ Housing should enclose 2.8” x 2.15” PCB
- ➢ Material volume shall not exceed 100cm^3
- ➢ Sensor port shall provide 1mm (0.03”) tolerance around the sensor
- ➢ Housing shall have an inset to place a 3” x 0.5” x 0.125” neodymium magnet

Sensor Housing Model

- ➢ Housing dimensions: 101.6 x 142.75 x 38.86 mm
- ➢ Sensor port diameter: 0.723”
- ➢ $0.30/cm3 * 42.5 cm3 = $12.75



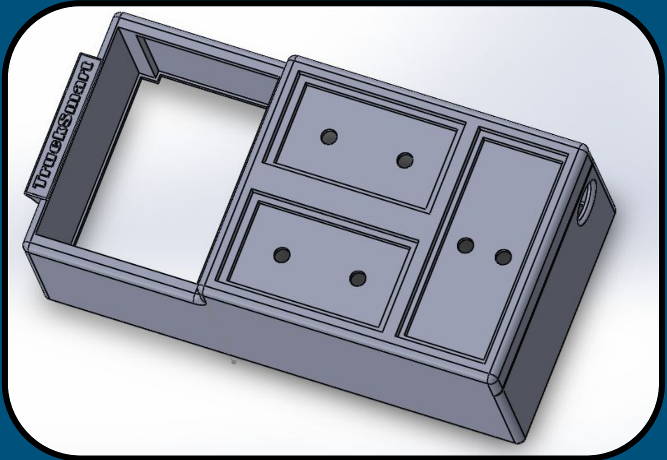
Density = 1.43 grams per cubic centimeter

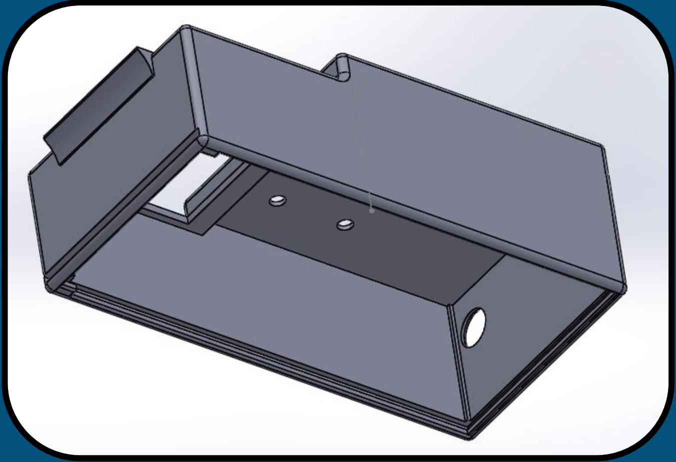
Mass = 60.76 grams

Volume = 42.49 cubic centimeters

Hub Housing Model (original design)

- ➢ The design has 3 alert zones, 3 warning LEDs and 3 fault LEDs
- ➢ Dimensions: 162.5 x 83.82 x 55.77 mm
- ➢ Accommodates screen and power cable



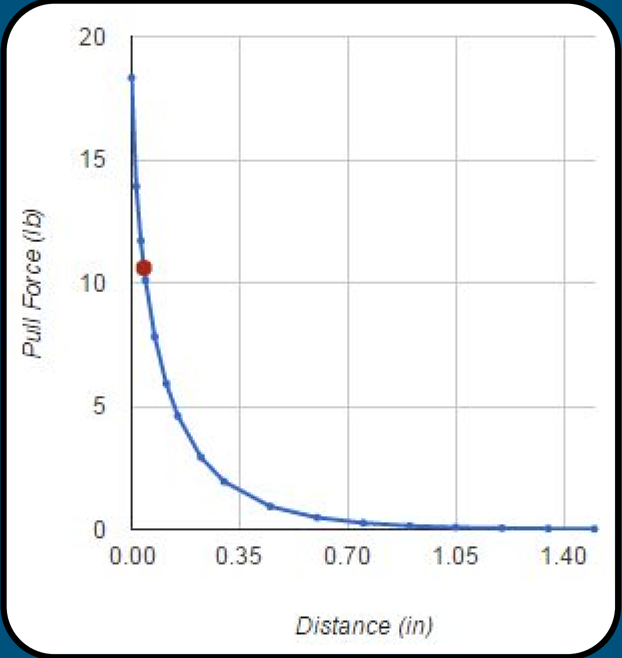


Magnet Attachment & Analysis

Grade = N42
Length = 3"
Width = 0.5"
Thickness = 0.125"
Distance = 0.04"
10.60 lb

- Magnet dimensions: 3” x 0.5” x 0.125”
- Pull force shall be greater than 6.61 lb (3 kg)
- Grade: Neodymium N42

	Magnet Distance (in.)	Pull Force (lb)
Min	0	18.33
Max	0.09	6.98
Avg. Dist	0.045	10.6



Power Consumption Analysis

TruckSmart Peripheral Sensor Component Power Consumption					
Active Components	Operating Voltage (V)	Operating (Idle) Current (mA)	Active Current (mA)	Average Current Draw (mA) @ 0% Idle	Power Consumption (mW)
EZ-MB1000 Sonar Sensor	5	2	2	2	10
Xbee RF Module	3.3	29	29	29	95.7
ATmega328P Chip @ 16Mhz	5	16.43	21.8	19.12	95.58
Total Load Draw	N/A	NA	NA	50.12	201.28

Regulator Efficiency (est.)*	75%
Battery Longevity (mAh)	2200
Lifetime est. (hours)	32.92

* Hub power consumption is estimated to peak at 860 mW and idle at 260mW.

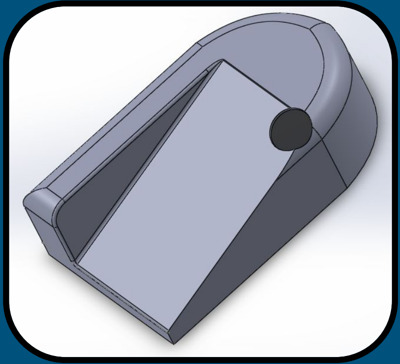
** Due to battery constraints, sensor consumption is deemed higher priority.

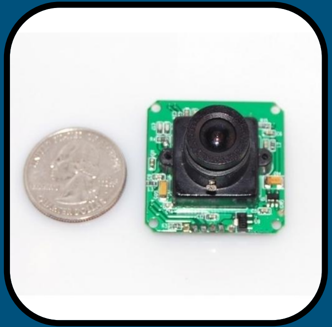
Battery Selection and Charging

- 7.4V output voltage
- 2200 mAh
- Lithium-Ion Polymer
- Connector: Banana-to-2.1mm Barrel Jack

Battery Recharge Time	
Battery Capacity	2200 mAh
Charger Current Output	800 mA
Charging Time for One Battery	2.75 Hours
Charging Time for Three Batteries in Parallel	8.25 Hours

Wireless Camera System (Stretch Goal)





- LinkSprite LS-Y201 Camera
- Embedded MCU
- Separate ZigBee Network
- Allows driver to see what's in the blind spot
- Peer to Peer direct communication
- Small delay of 2-3 seconds in between transmissions
- Option to get single or continuous shots
- Battery operated
- Simple Setup

Range	8 ft
Cost	$39
Power	5V @ 90 mA
Resolution	160x120
I/O Pins	5
Baud Rate	38.4 Kbps

Administrative Content

Work Distribution

Team Member	PCB	Power Distribution	System Housing	Wireless Setup & Camera	Sending & Receiving (MCU)	Sensor Readings
Aris				P	S	P
Abhijith				S	P	S
Neel	S	P	S			
David	P	S	P			

P = Primary S = Secondary

Estimated Budget

- Self-financed
- Legend:
  - System Development (green)
  - Base Product Cost (orange)

Estimated Costs			
Product	Quantity	Price	Total Order Cost
Wireless Transceiver	4	$40.00	$160.00
System Housing	4	$35.00	$140.00
PCB	4	$30.00	$120.00
Sensors	3	$25.00	$75.00
Arduino UNO R3	2	$25.00	$50.00
Base MCU/Dev Board	1	$50.00	$50.00
Power Supply	4	$10.00	$40.00
LCD/LED Display	1	$30.00	$30.00
ATMega328P Chip	3	$5.00	$15.00
R&D Total	1		$160.00
Final Product Total	8		$520.00
Overall Total	9		$680.00

Final Budget

Research and Development
Final Product
Administrative

Product	Quantity	Price	Total Order Cost
Sensor Housing	3	$59.85	$179.55
XBee 1mW Trans/Rec	5	$26.93	$134.65
XBee Pro S2C	4	$30.00	$120.00
MB1000 Range Sensor	3	$29.99	$89.97
U-Haul Rental	1	$86.00	$86.00
LED Hub Housing	1	$83.37	$83.37
Arduino UNO R3	2	$24.99	$49.98
Linksprite LS-Y201	1	$40.00	$40.00
Rechargable Batteries (3)	1	$36.99	$36.99
PCB (First Order) (3)	1	$35.00	$35.00
Hub Housing Concept	1	$33.95	$33.95
XBee Shield	2	$16.95	$33.90
PCB (Second Order) (3)	1	$30.00	$30.00
ATMega328P Chip (3)	2	$13.44	$26.88
XBee Networks Book	1	$24.99	$24.99
XBee Explorer Dongle	1	$24.95	$24.95
Floor Model	1	$18.29	$18.29
Shipping Costs	1	$25.83	$16.83
Touch Screen	1	$14.86	$14.86
DC Barrels (6)	1	$14.70	$14.70
Acryllic	1	$14.48	$14.48

Magnets (3)	1	$14.47	$14.47
Battery AA Packs (2)	2	$6.99	$13.98
XBee Book - PDF	1	$13.00	$13.00
HC-SR04 Sensor	2	$5.20	$10.40
Battery Charger	1	$10.00	$10.00
Mobile Phone Holder	1	$9.99	$9.99
Arduino Header Kit	2	$4.65	$9.30
Breadboard and Wires	1	$8.90	$8.90
AC/DC Converter Wall Plug	1	$7.58	$7.58
ArduCam 0.3 MP Camera	1	$7.09	$7.09
Barrel 2.1mm Sockets (10)	1	$6.99	$6.99
Power Switches (10)	1	$6.99	$6.99
Male Terminals (3)	1	$6.95	$6.95
Barrel Terminals (10)	1	$6.55	$6.55
LEDs	1	$6.50	$6.50
3.3V Voltage Regulator (5)	1	$6.45	$6.45
ATMega PCB Sockets (10)	1	$6.32	$6.32
5.5V Voltage Regulator (5)	1	$5.95	$5.95
XBee Headers (10)	1	$5.39	$5.39
16 MHz Oscillator (10)	1	$5.30	$5.30
USB Cable for Arduino	1	$4.99	$4.99
12V DC Car Plug	1	$4.95	$4.95
Administrative Total	4		$64.23
R&D Total	12		$365.45
Final Product Total	27		$857.70
Overall Total	42		$1,287.38

Issues/Constraints

- System had to be scaled down to 3 sensors due to budget constraints
- Initial sensor had to be upgraded due to range constraints
- Limited access to testing on a physical truck
- ZigBee’s low bandwidth limitations limits adding new features
- XBee S1 range
- Aluminum RF shielding

Future Potential

- Better UI
- Solar Powered
- Low Battery Warning
- Get a patent

Questions?