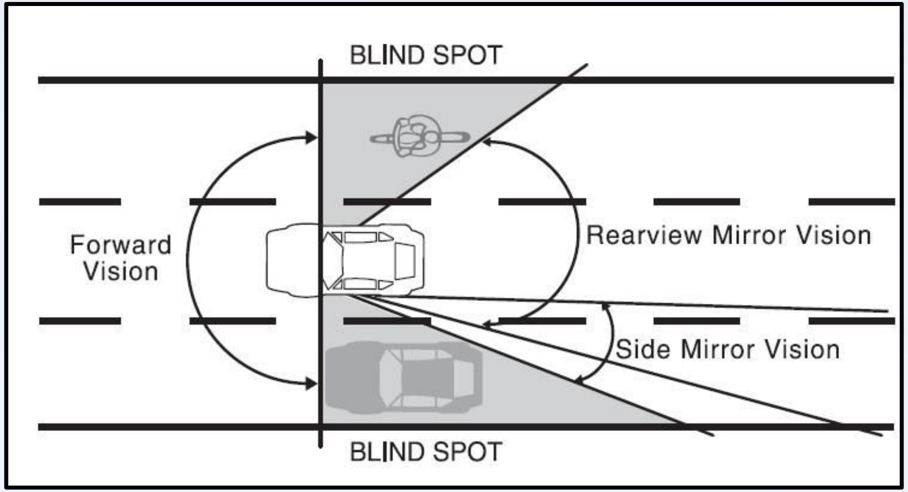
Blind Spot Detector

Travis Pow
Raghad Boulos
Sepehr Laal
Madeleine Roche

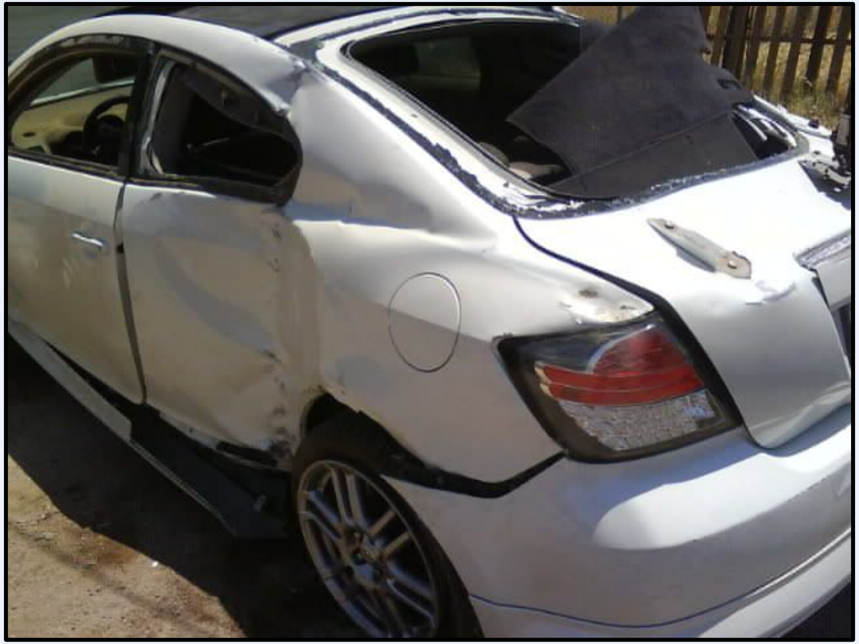
Problem

- What is the problem?
  - Blind spots pose a potential hazard
- When is it a problem?
  - Anytime anyone drives a vehicle
- What is being solved?
  - Object detection in the blind spot where the driver can't see



Motivation

- Improve driving safety
  - Prevent injuries
  - Save lives
  - Prevent costly repairs from accidents

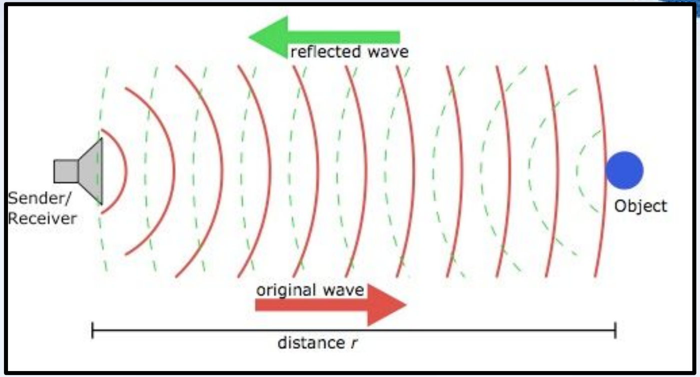


Objective

- A device that visually alerts user when an object is present in the blind spot
  - **Must** have a lower response time than human eye’s response time
  - **Must** work off of vehicle’s battery power
  - **Should** have low power footprint
  - **Should** be controllable by the turn signal

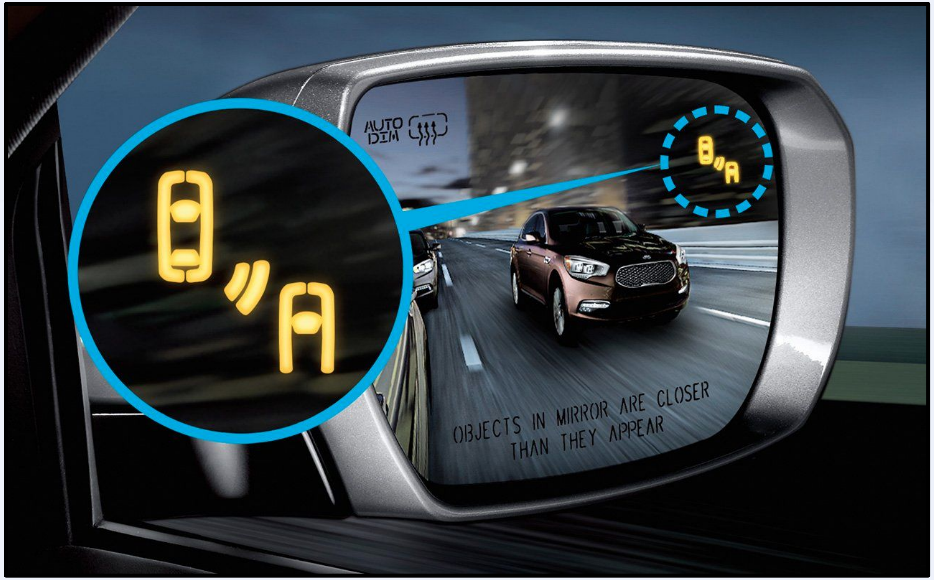
How It’s Currently Done

- Ultrasonic Sensors
  - Pros
    - Object detection when stationary/moving
    - Cheap
  - Cons
    - May miss smaller objects
    - Holes drilled in bumper
- Electromagnetic Sensors
  - Pros
    - Better object detection when in motion
    - Typically mounted in bumper
  - Cons
    - Expensive
    - Can’t detect objects when stationary



How It's Currently Done

- Light located on side mirrors
  - Always on when object in blind spot
  - Noise/vibration warning when turn signal is on
- Power source
  - Most utilize car battery
  - Very few use separate battery



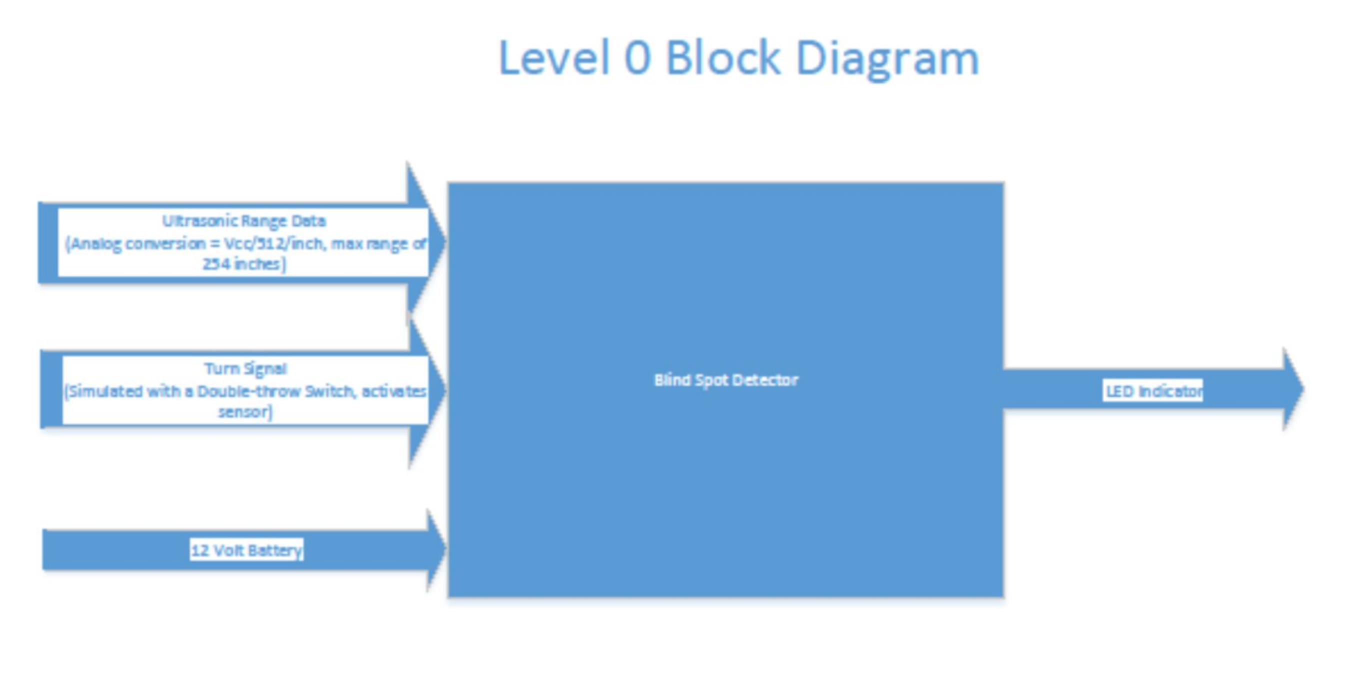
Our Approach

- Object Detection
  - Ultrasonic Sensor
  - 42 kHz sound waves
- User Alert
  - LED located on side mirror
  - Only alert when turn signal is on
- Powered via car battery
- Controlled via turn signal (activated only when turning)

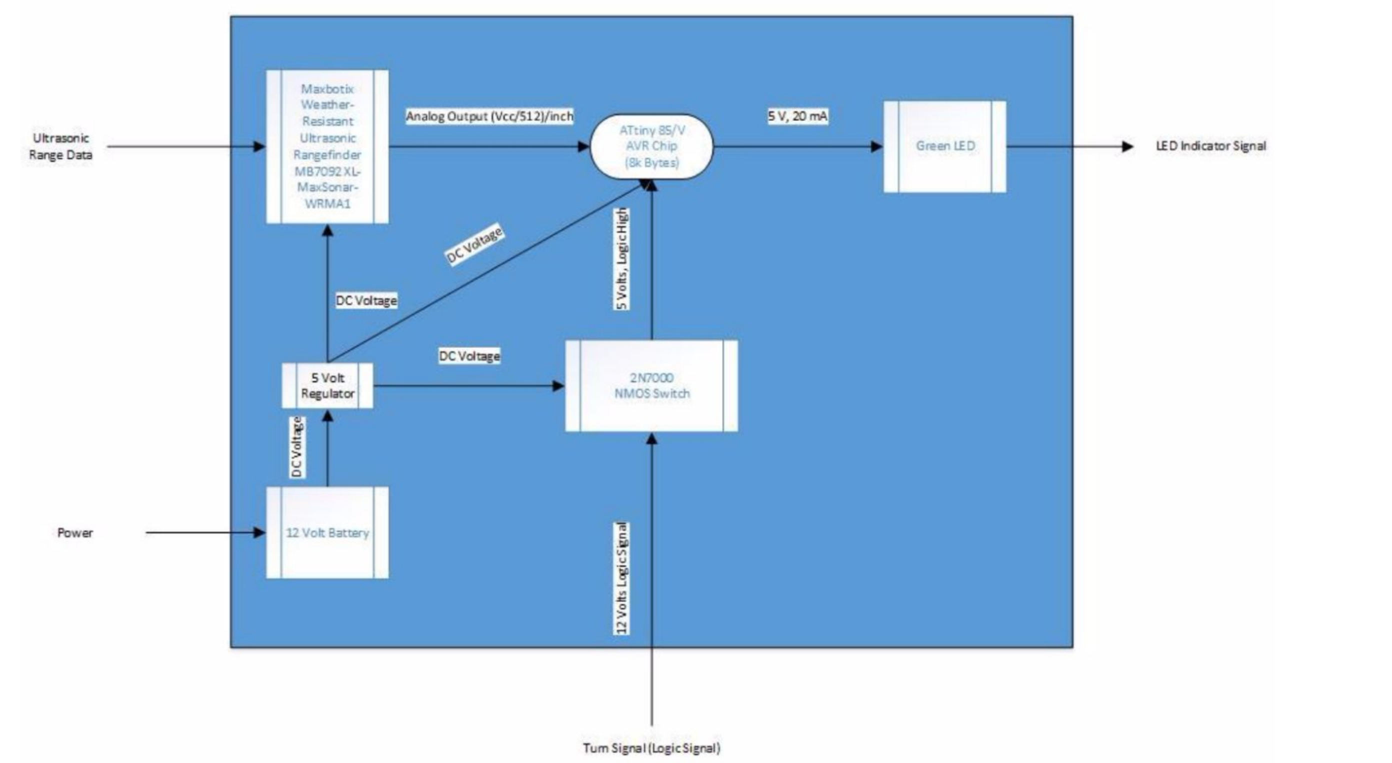
Requirements

- Alert user within a fifth of a second
- The product should be self-operable
- No maintenance needed
- Climate proof
- Low cost, less than $200

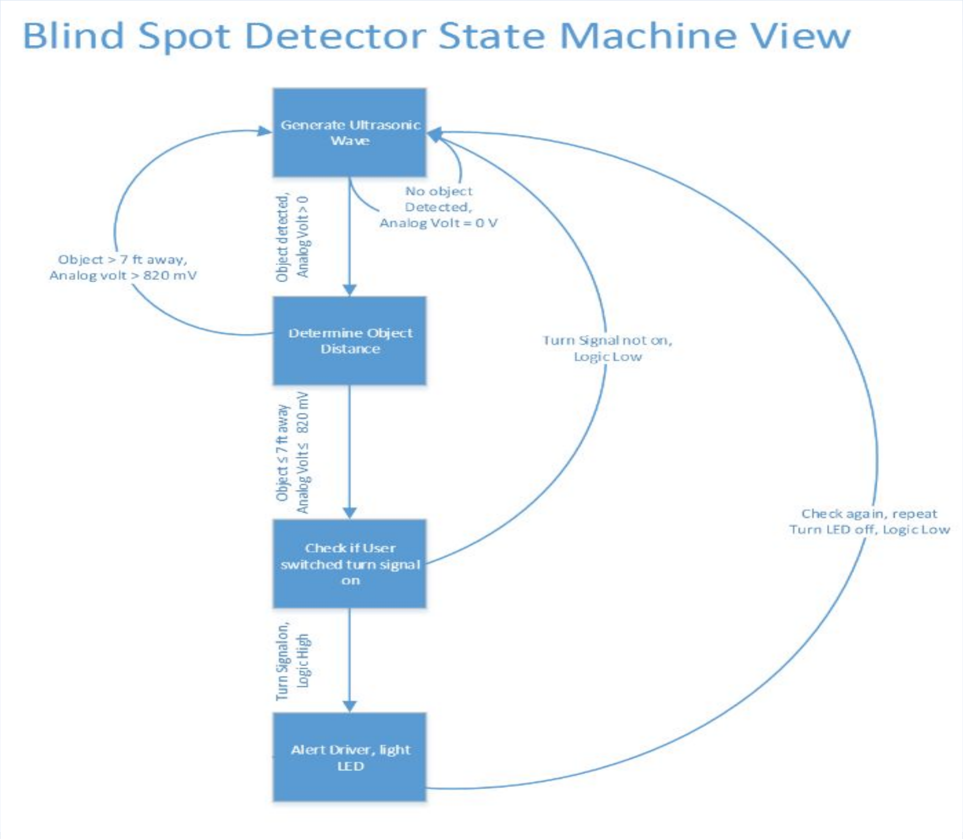
Hardware Design Level 0



Hardware Design Level 1



UML

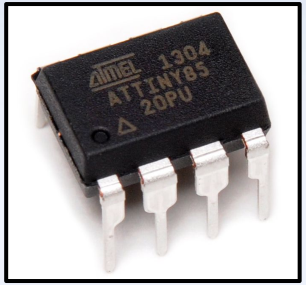

Blind Spot Detector State Machine View
Generate Ultrasonic Wave
No object Detected, Analog Volt = 0 V
Object detected, Analog Volt > 0
Object > 7 ft away, Analog volt > 820 mV
Determine Object Distance
Turn Signal not on, Logic Low
Object ≤ 7 ft away Analog Volt ≤ 820 mV
Check if User switched turn signal on
Check again, repeat Turn LED off, Logic Low
Turn Signal on, Logic High
Alert Driver, light LED

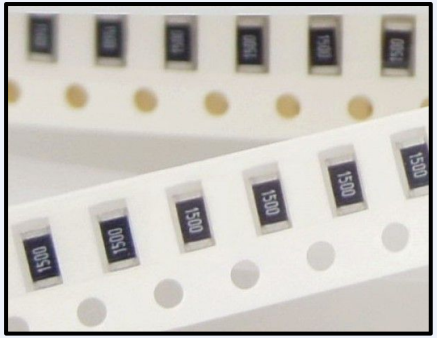
Tools Employed

- EagleCAD
  - Schematic
  - PCB layout
- Git (+Github client)
- Android Studio on Ubuntu VM
- Pivotal Tracker (software only)

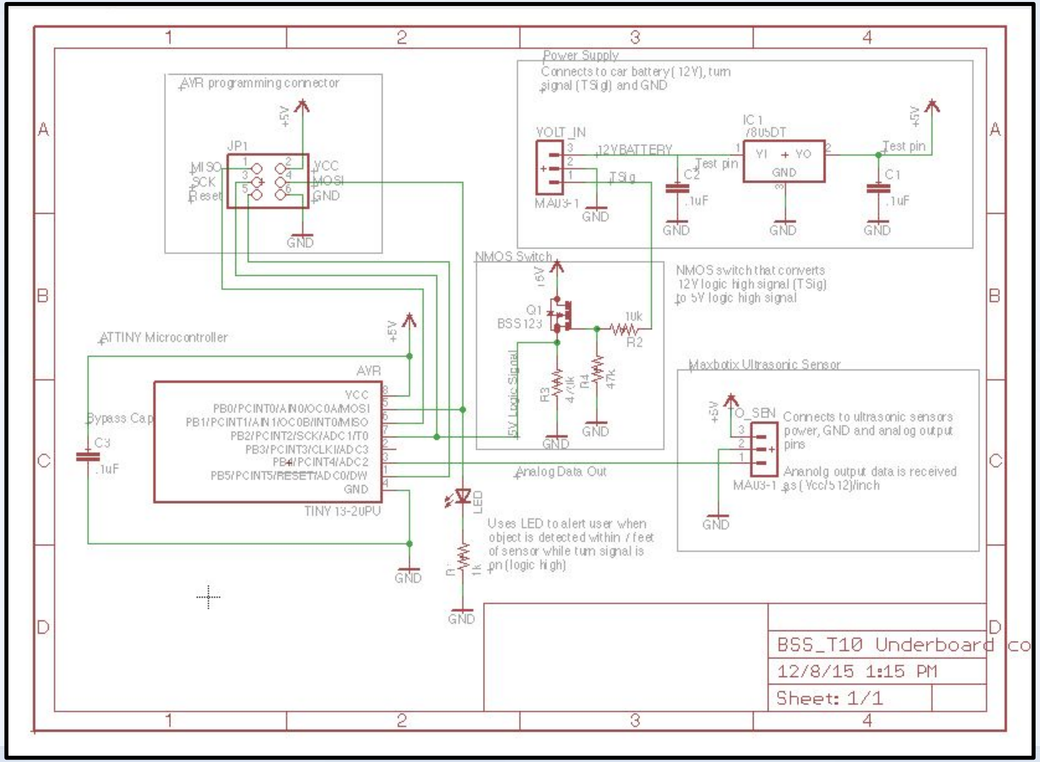
Bill of Materials

- Maxbotix Ultrasonic Sensor
- Atmel AVR 8-Bit Microcontroller
- 2 layer PCB board
- Header pins: males (12x), females (7x)
- 22 AWG Stranded wire
- LM7805 5-Volt Regulator
- 2N7000 NMOS transistor
- Double-throw mechanical switch
- 9 Volt Battery and connector
- 82 Ω, 10K Ω, 47K Ω, 470K Ω resistors
- 0.1 uF capacitors (3x)
- LED
- Tiny AVR Programmer





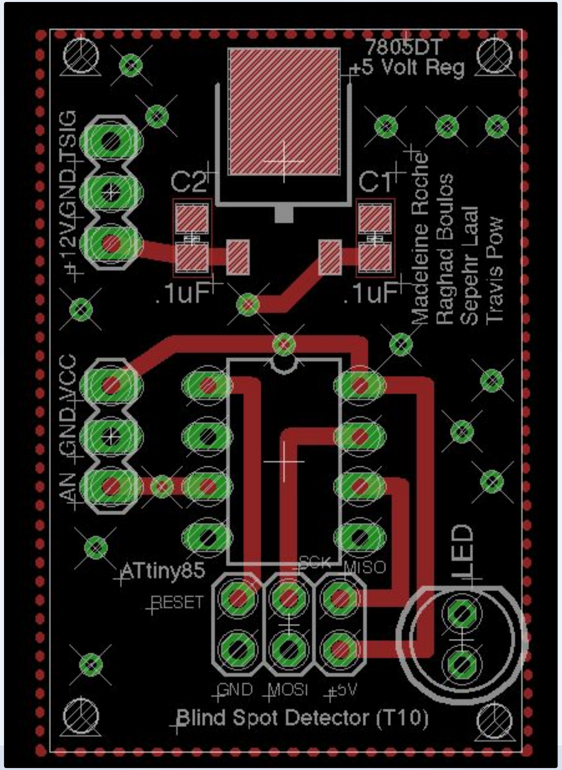
Schematic

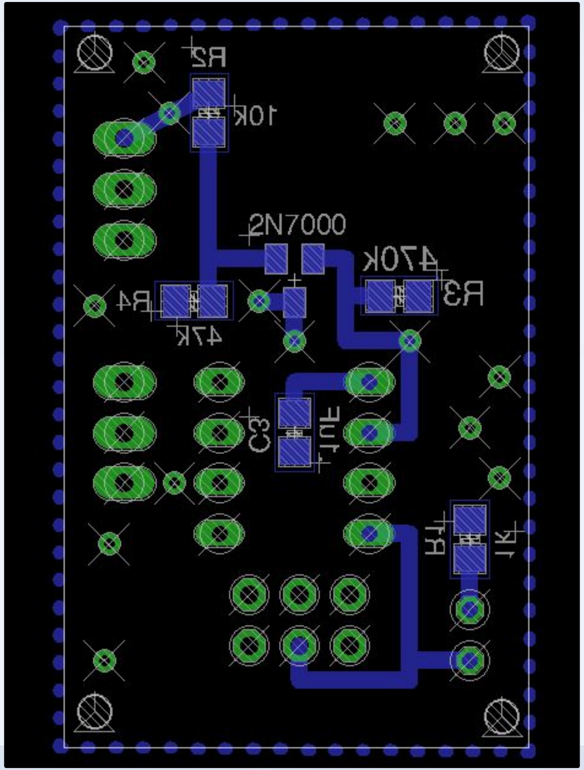


AVR programming connector
JP1
MISO
SCK
Reset
VCC
MOSI
GND
Power Supply
Connects to car battery (12V), turn signal (TSig) and GND
VOLT_IN
12V BATTERY
TSig
IC1
7805DT
Test pin
NMOS Switch
BSS123
NMOS switch that converts 12V logic high signal (TSig) to 5V logic high signal
ATTINY Microcontroller
Bypass Cap
TINY 13-20PU
PB0/PCINT0/AIN0/OC0A/MOSI
PB1/PCINT1/AIN1/OC0B/INT0/MISO
PB2/PCINT2/SCK/ADC1/T0
PB3/PCINT3/CLKI/ADC3
PB4/PCINT4/ADC2
PB5/PCINT5/RESET/ADC0/DW
Analog Data Out
Maxbotix Ultrasonic Sensor
Connects to ultrasonic sensors power, GND and analog output pins
Ananolg output data is received as (Vcc/512)/inch
Uses LED to alert user when object is detected within 7 feet of sensor while turn signal is on (logic high)
BSS_T10 Underboard co
12/8/15 1:15 PM
Sheet: 1/1

Board Layout

Top

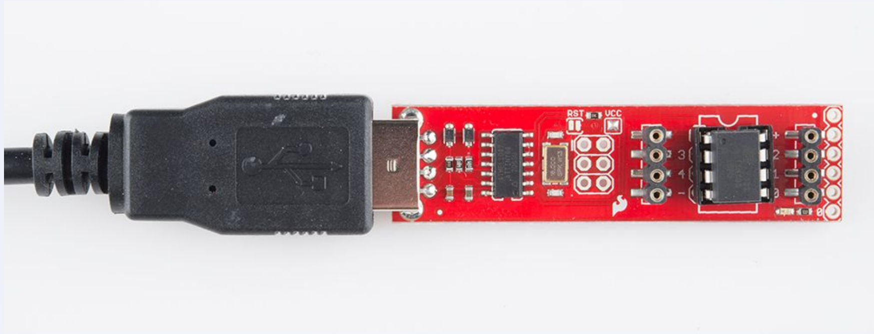




Bottom

Software Development

- The source code is written in what is commonly referred to as “Arduino C”
- Algorithm is straightforward, simply comparing distance read with a value
- Source code is compiled by Arduino Studio and GCC underneath
- Compiled code is transferred to Attiny85 via its special programmer
- For ease of development, Arduino Studio on Ubuntu was used



Software Development (Psuedo Code)

- Simplest pseudo code ever!
-
```
if (turn_signal_on AND object_in_range)
{
    Turn LED ON;
}
else
{
    Turn LED OFF;
}
sleep 50ms;
```
- Sensor outputs analog value relative to distance. (10 mV / inch)

Software Development (Life Cycle)

- Development was done in an Agile fashion
- Scope too small, but still helped to keep everything on track
- Pivotal Tracker used to track tasks and required future steps

- Git was used to track project files and revisions
- Git also helped in managing various versions of the source code
- Github’s WIKI was used to store documentation

Software Development (Safety Hazards)

- We needed a system with relatively low response time
- Human eye is known to have a response time of 100ms
- We have to have a sleep time in our code’s update loop
    - Lower power consumption
    - Relaxed LED toggle action
- By trial and error we set it to 50ms to balance among response time, power consumption and a relaxed LED toggle action

IP and prior work

- Research as to what's currently on market
  - Type of sensors
  - Location of sensors
  - Method of user alert
  - Connection setup
- No prior hardware/software was utilized

Test Plan

Blind Spot Detector Test Plan

Authors: Travis Boos, Madeleine Roche,
Raghad Boulos, Sepehr Laal
Revision History: BSD Test Plan 1.1
Revision Date: 12/8/2015

1. Blind Spot Detector (BSD)
   1.1. Design Documentation
      1.1.1. BSD System Specifications
      1.1.2. BSD System Requirements
      1.1.3. BSD Block Level Diagram
      1.1.4. BSD Schematic
      1.1.5. BSD PCB Layout
      1.1.6. BSD Software
2. Equipment and materials required
   2.1. Blind Spot Detector
   2.2. Vehicle
   2.3. Person
   2.4. Bicycle
   2.5. Multimeter
   2.6. Environmental chamber
   2.7. Measuring tape
   2.8. Protractor
   2.9. Thermometer
   2.10. Oscilloscope
   2.11. Mechanic to Install Blind Spot Detector
3. Installation Test
   3.1. Mechanic required for installation
4. Environmental Test
   4.1. Temperature
   4.2. Humidity
   4.3. Rain
   4.4. Snow
   4.5. Hail
   4.6. Altitude
5. Use Test
   5.1. Object detection while stationary
      5.1.1. Vehicle
      5.1.2. Biker
      5.1.3. Pedestrian
   5.2. Object detection while moving
      5.2.1. Vehicle
      5.2.2. Biker
      5.2.3. Pedestrian
6. Stress Testing
   6.1. Accuracy in extreme weather conditions
      6.1.1. Heat
      6.1.2. Cold
      6.1.3. Rain
      6.1.4. Snow
      6.1.5. Hail
   6.2. Accuracy at freeway speeds

   6.3. Accuracy in a noisy environment
7. Module Tests
   7.1. Maxbotix Ultrasonic Sensor
   7.2. BSD Processor
8. Parametric Test
   8.1. Detection time
   8.2. Power Consumption
9. Exhaustive Testing
   9.1. With turn signal off
      9.1.1. Object within 7 feet of sensor
      9.1.2. No object within 7 feet of sensor
   9.2. With turn signal on
      9.2.1. Object within 7 feet of sensor
      9.2.2. No object within 7 feet of sensor
10. Object Detection Tests
   10.1. Range of Detection
      10.1.1. Maxbotix Ultrasonic Sensor: Max/min distance object can be detected
         10.1.1.1. Various size of object at room temperature in ideal condition
            10.1.1.1.1. Vehicle
            10.1.1.1.2. Biker
            10.1.1.1.3. Person
         10.1.1.2. Various outdoor temperatures
            10.1.1.2.1. 35 degrees Celsius
            10.1.1.2.2. -40 degrees Celsius
         10.1.1.3. Various levels of humidity
            10.1.1.3.1. High humidity
            10.1.1.3.2. Low humidity
         10.1.1.4. During rain
            10.1.1.4.1. Light rain
            10.1.1.4.2. Heavy rain
         10.1.1.5. Snowy conditions
            10.1.1.5.1. Snowing
               10.1.1.5.1.1. With snow on ground
               10.1.1.5.1.2. Without snow on ground
            10.1.1.5.2. Not snowing with snow on ground
      10.1.2. Maxbotix Ultrasonic Sensor: Width of beam width
         10.1.2.1. Various outdoor temperatures
            10.1.2.1.1. 35 degrees Celsius
            10.1.2.1.2. -20 degrees Celsius
         10.1.2.2. Various levels of humidity
            10.1.2.2.1. High humidity
            10.1.2.2.2. Low humidity
         10.1.2.3. During rain
            10.1.2.3.1. Light rain
            10.1.2.3.2. Heavy rain
         10.1.2.4. Snowing

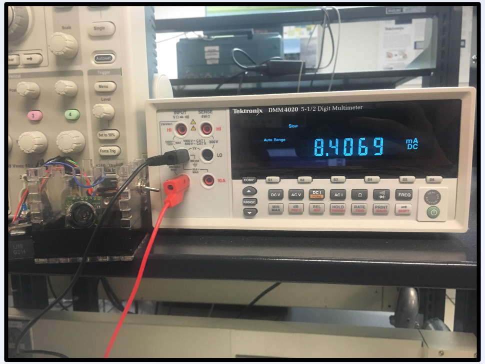
Test Plan

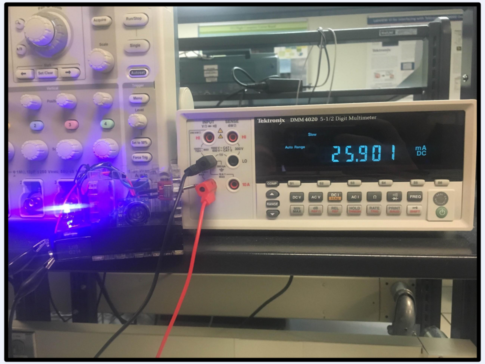
10.1.3. Software (AVR ATtiny85): Determine accuracy of distance measurement with set distance on ATtiny 85)
10.1.3.1. Various size of object at room temperature in ideal condition
10.1.3.1.1. Vehicle
10.1.3.1.2. Biker
10.1.3.1.3. Person
10.1.3.2. Various outdoor temperatures
10.1.3.2.1. 35 degrees Celsius
10.1.3.2.2. -40 degrees Celsius
10.1.3.3. Various levels of humidity
10.1.3.3.1. High humidity
10.1.3.3.2. Low humidity
10.1.3.4. During rain
10.1.3.4.1. Light rain
10.1.3.4.2. Heavy rain
10.1.3.5. Snowy conditions
10.1.3.5.1. Snowing
10.1.3.5.1.1. With snow on ground
10.1.3.5.1.2. Without snow on ground
10.1.3.5.2. Not snowing with snow on ground
10.1.3.6. Software (AVR ATtiny85): Stability of detection indication
10.1.3.6.1. Object near max detection
10.1.3.6.2. Object near min detection
10.1.4. Detection time of Blind Spot Detector (whole system)
10.1.4.1. When turn signal is on
10.1.4.2. When turn signal is off
11. Durability Tests
11.1. Operating temperature
11.1.1. Max temperature
11.1.1.1. 85 degrees Celsius
11.1.2. Min temperature
11.1.2.1. -40 degrees Celsius
11.1.3. Degree of humidity
11.1.3.1. High humidity
11.1.3.2. Low humidity
11.1.4. Rain
11.1.5. Snow
11.1.6. Hail
11.1.7. Collisions
11.1.7.1. Small object projectiles/collisions
11.1.7.2. Larger object projectiles/collisions
11.1.8. Input voltage variations due to car battery inconsistencies
11.1.8.1. Test functional range of 14V < Voltage In < 6V
12. System power requirements measurements
12.1. Power consumption
12.1.1. Sensor

12.1.2. AVR ATtiny
12.1.3. LED
12.1.4. Voltage regulator
12.1.5. NMOS switch
12.1.6. Resistors
12.1.7. Capacitors
12.1.8. System as a whole
12.2. Current consumption
12.2.1. No object detected
12.2.2. Object detected
12.2.2.1. Outside of set max distance (no user alert)
12.2.2.2. Within set max distance (user alert)

Test Case 1

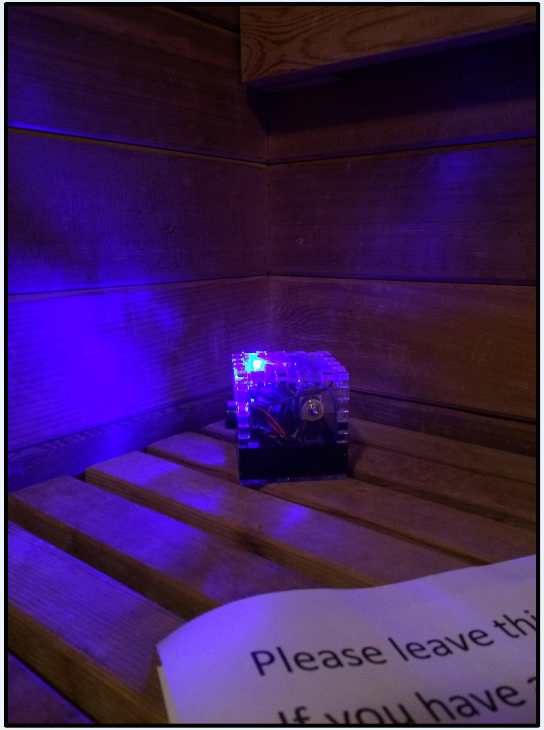
Test Writer: Travis Pow						
Test Case Name:		BSD Current Consumption Parametric Test#1	Test ID:			BSD-PT-01
Description:		Measures the power consumption of the whole device with 0V on the TSIG input and no object within detectable range	Type:			Black Box
Test Information						
Name of Tester:		Travis, Madeleine, Sepehr , Raghad	Date: 12/09/2015			
Hardware Ver:		BSD 1.0	Time: 08:30 pm			
Setup:		Apply power to VCC pin on the Blind Spot Detector and connect a multimeter to between the input voltage and the VCC pin of the Blind Spot Detector				
Step	Action	Expected Result	Pass	Fail	N/A	Comments
1	Connect multimeter to the 12V voltage source and VCC of BSD	Should read approximately zero amps until voltage source is turned on	x			
2	Turn on 12V voltage supply	BSD will start up and begin taking measurements	x			
3	Read multimeter current measurement	Current consumption should be approximately 12mA	x			Less than expected with current draw of approximately 8.5-9mA
Overall test results			x			Current draw was better than expected





Test Case 2

Test Writer: Travis Pow						
Test Case Name:		Blind Spot Detector Stress Test #1	Test ID:			BSD-ST-01
Description:		Checks if the Blind Spot Detector will operate correctly at a max temperature of 85 degrees Celsius	Type:			White box Black box
Test Information						
Name of Tester:		Travis Pow	Date:			12/10/2015
Hardware Ver:		Blind Spot Detector 1.0	Time:			7:00AM
Setup:		The Blind Spot Detector should powered and placed in a weathered chamber set to 85 degrees Celsius with an object set exactly 6 feet away.				
Step	Action	Expected Result	Pass	Fail	N/A	Comments
1	Apply 12 volts to both VCC and TSIG pins	Blind Spot Detector will start up and begin detecting objects within its detectable range	X			
2	Insert device into weathered chamber	Temperature of room should be approximately 85 degrees Celsius and leave for 1 hour	X			
3	Connect a voltmeter to the AN pin of the Blind Spot Detector	Depending on the distance of object detection, voltmeter should have a voltage reading between 2.5V – 0V	X			
4	Place a person sized object 6 feet away from device	Voltmeter should read a voltage of ~(voltage value for 6 feet)	X			
5	Leave device in chamber for 2 hours and check voltmeter reading	Voltmeter should have approximately same reading from step 4	X			
6	Move device further then 7 feet away	LED should turn off		X		LED remained on at all times, even when no object is within detection range
Overall test results				X		Identify location of failing component/module



Test Case 3

Test Writer: Travis Pow			
Test Case Name:	AVR Distance Measurement Unit (non-water proof) test #2	Test ID:	AVR-UT-02
Description:	Checks the accuracy of the max detectable distance set on the ATtiny85	Type:	White box Black box
Test Information			
Name of Tester:	Sepehr, Madeleine , Travis, Raghad	Date:	12/09/2015
Hardware Ver:	BSD Processor Module – Processor version 1.1	Time:	7:00 pm
Setup:	Blind Spot Detector should be connected to power, including the TSIG input and an using a tape measure, an object approximately the size of a person will be placed 7 feet in front of the device's sensor.		

Step	Action	Expected Result	Pass	Fail	N/A	Comments
1	Apply power to board and TSIG input	Board should start up and begin detecting objects within detectable range	x			Board turned ON
2	Using a tape measure, a human sized object will be placed 7 feet from the device's sensor	If object is exactly 7 feet away, LED should be on	x			LED turned ON
3	Move object forward if LED is off or move object backwards if LED is on	When moved further from sensor, LED should turn off	x			LED turned OFF
4	Measure distance of object again	Measurement should be approximately 7 feet	x			
Overall test results			x			

Test Case 4

Test Writer: Raghad Boulos						
Test Case Name:		Ultrasonic sensor Distance and delay Measurement Unit (water proof) test #1	Test ID:			UltraS-UT-01
Description:		Checks the maximum detection range and response sensitivity	Type:			White box Black box
Test Information						
Name of Tester:		Raghad, Madeleine, Sepehr, Travis	Date:12/09/2015			
Hardware Ver:		Ultrasonic Module – Ultrasonic version 1.1	Time: 08:45 pm			
Setup:		Blind Spot Detector should be connected to power, including the TSIG input and an using a tape measure, an object approximately the size of a person will be placed 7 feet in front of the device's sensor.				
Step	Action	Expected Result	Pass	Fail	N/A	Comments
1	Apply power to board and TSIG input	Board should start up and begin detecting objects within detectable range		x		Sensor detected objects within 5.5 ft only
2	Using a tape measure, a human sized object will be placed 7 feet from the device's sensor	If object is exactly 7 feet away, LED should be on		x		LED is OFF
3	Move object forward if LED is off or move object backwards if LED is on	When moved further from sensor, LED should turn off	x			
4	Measure distance of object again	Measurement should be approximately 7 feet				Measurements were ~ 5 ft
5	Response measurement	Object must be detected within 15th of second		x		Response is delayed by a sec
Overall test results				x		

Results

- 2/4 test cases passed
- non Weather-Resistant sensor met all but 1 requirement - not climate proof
- Weather-Resistant sensor did not meet range detection requirement or necessary response time to ensure safety of user and car
- Power consumption performed better than expected

Contributions

Development Process	**Team Member**
Hardware Development and Debugging	**Travis**, Madeleine, Raghad
CAD Schematic, PCB Layout	**Travis**
Software Development	**Sepehr**
Technical Documentation	**Madeleine**, Travis, Raghad, Sepehr
3D Modeling and Printing	**Raghad**
Packaging	**Raghad**, Travis, Madeleine
Testing	**Travis**, Sepehr, Madeleine, Raghad

Lessons learned

- New Tools!
  - Arduino IDE
  - EagleCAD
  - Git Hub and Wiki
  - InkScape
  - Maker Case
- Project Management
  - How to have an effective meeting
  - How to deal with team members' conflicting schedules and ideas
  - Concurrent Engineering
- If we had another go…
  - Allow more time for packaging and testing
  - More time for document reviews

Thank You!