Visual Light Communication

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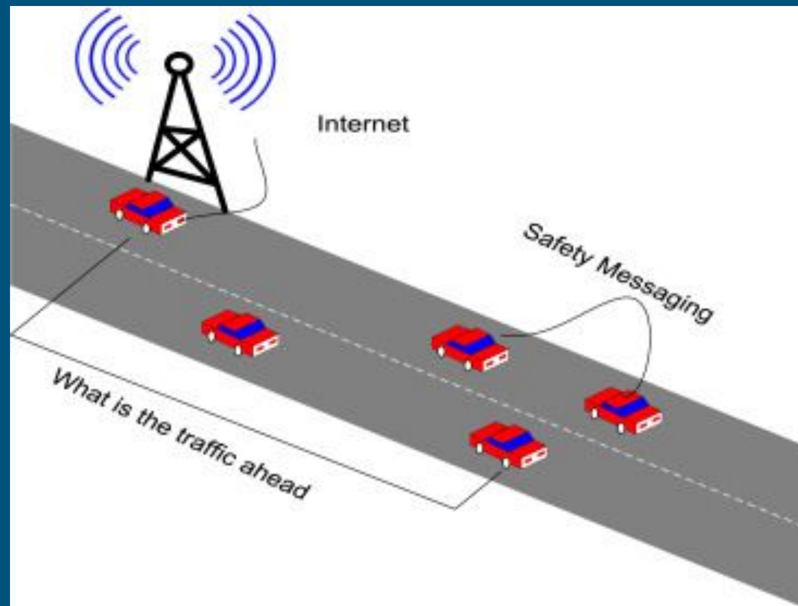
Problems

- There are 6 million accidents in the United States every year
- 90 people die in car accidents and 3 million others are injured everyday
- 75% of Americans do not want driverless cars because of safety and privacy concerns

With the help of Visual Light Communication (VLC), there is potential for cars to communicate with each other through their head and tail lights. Improving safety and improving the chance of fully autonomous vehicles in the future.



Methods

- Modern headlights use LEDs which can modulate at high rates

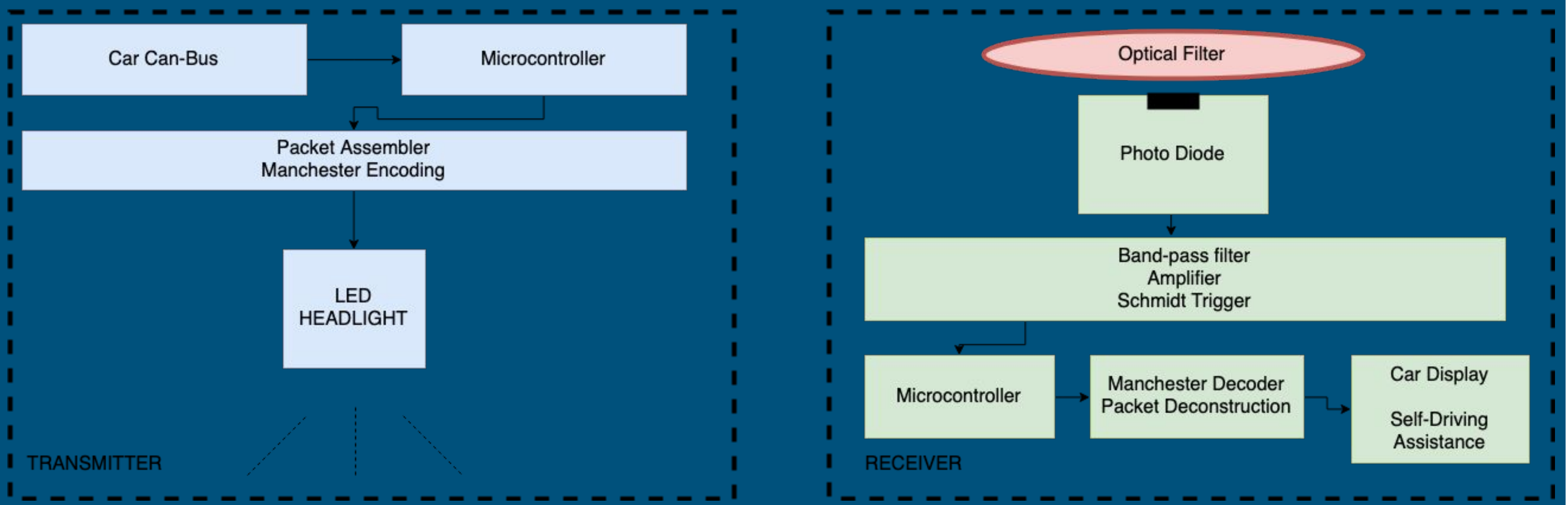
- The modulation of the LED is imperceptible to humans at anything over approximately 100 hertz
- Information can be encoded into the flicker of the LED
- This could be used to convey useful information, such as speed, acceleration, distance, etc.
- Could be used in self driving cars, giving them a means of local communication with minimal additional hardware

Why VLC?

- Can use existing hardware from the car
- Can use entire visual light frequency band (very large relative to BT/Wifi)
- Does not require any type of handshake
- Very low interference from others transmitting
- Highly secure
- Fast enough to not distract drivers / pedestrians
- Relatively cheap and simple compared to:
  - Radar
  - Wifi
  - Bluetooth

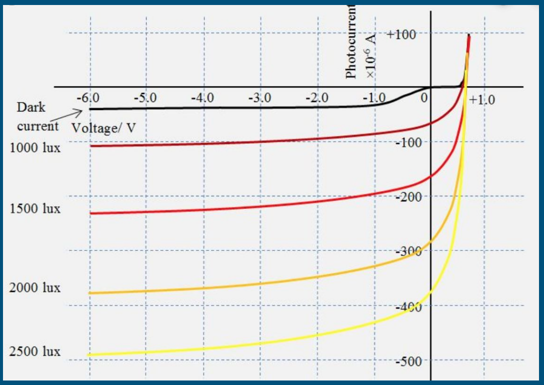
Block Diagram

- Successfully Tested TX / RX with photodiode using Arduino



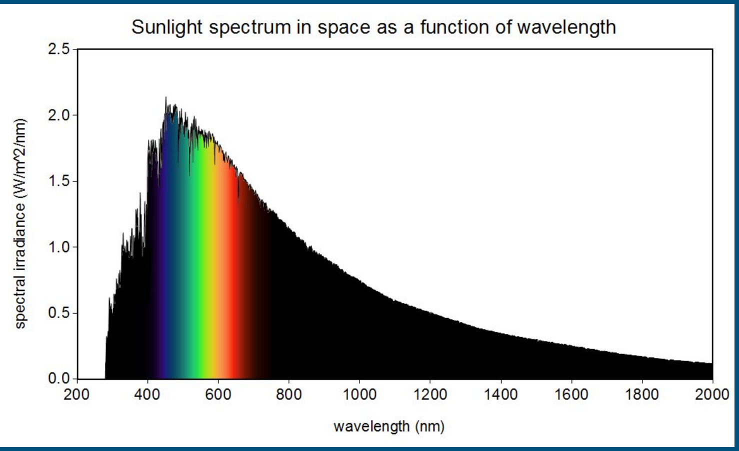
Light Detection - Photodiode

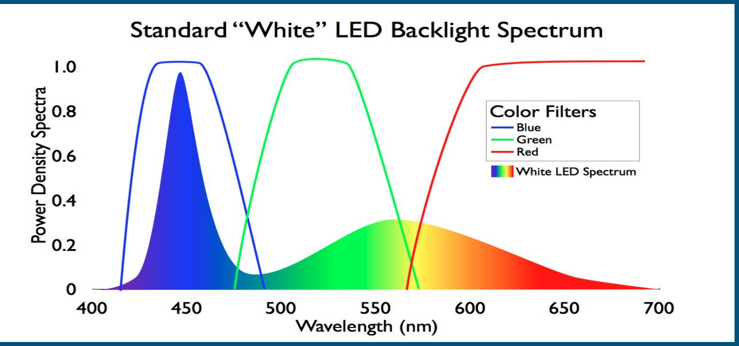
- A Photodiode converts changes in luminance to changes in current.
- In reverse bias, a photodiode produces a current based on the amount of light shined on it.
- A photodiode is preferable to other light detection components like a photoresistor, or camera because if its short rise and fall time (5-50ns).
- With a short rise and fall time, a photodiode can easily be used to detect PWM signals from an LED
- Photodiodes have a relatively high responsivity (roughly a mA per Watt of sunlight)



Optical Filtering

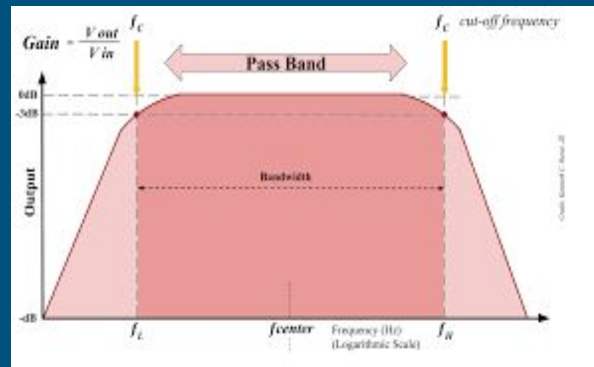
- All light is made up of a spectrum wavelengths. By using a spectrometer we can measure the exact spectrum of the LEDs
- Optical filters can be used to filter out light from sources other than the LED headlights.
- Two of the most common types include interference and colored glass.
- We will be using interference filters because they allow us to have a narrower bandpass range.
- This will help us deal with noise produced by sunlight. Since sunlight is made up of all spectrums we will still need to account for some noise.

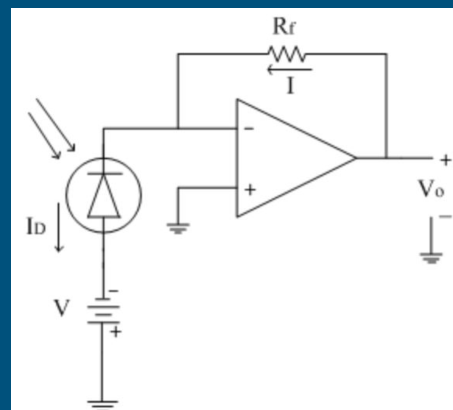




Amplification and Signal Filtering

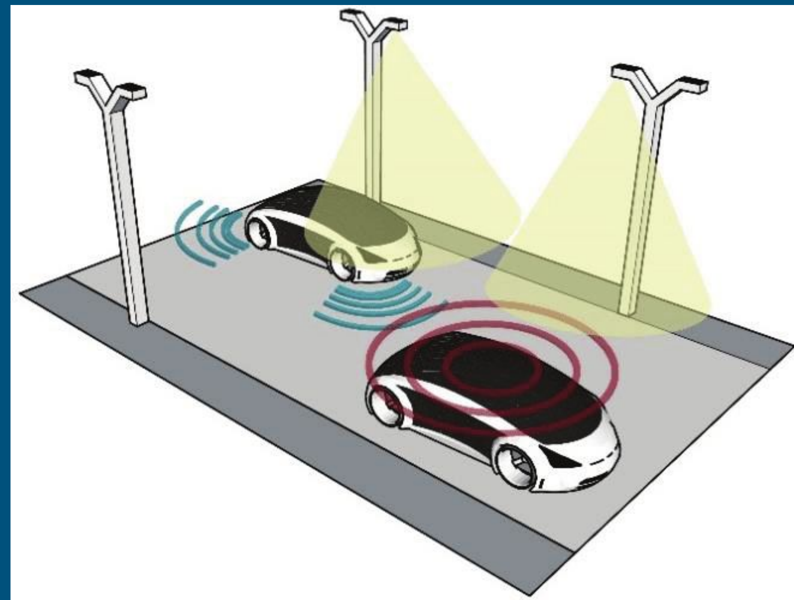
- A simple operational amplifier should provide sufficient gain
- A schmitt trigger can be used to square off the analog signal from the photodiode
- Capacitor to remove direct current caused by sunlight
- A filtering step will contain a band pass filter, only allowing signals, at our chosen rate to reach the input pin





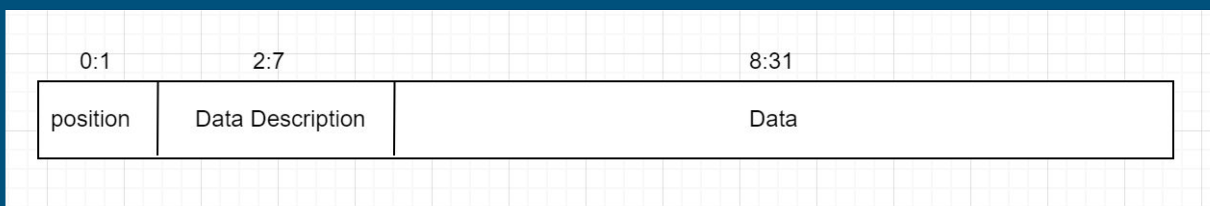
Communication - Overview

- Communication control handled by Arduinos.
- 32-bit packets with custom packet structure designed for broadcast-like communication.
- Manchester Encoded.
- Data error checking using CRC.



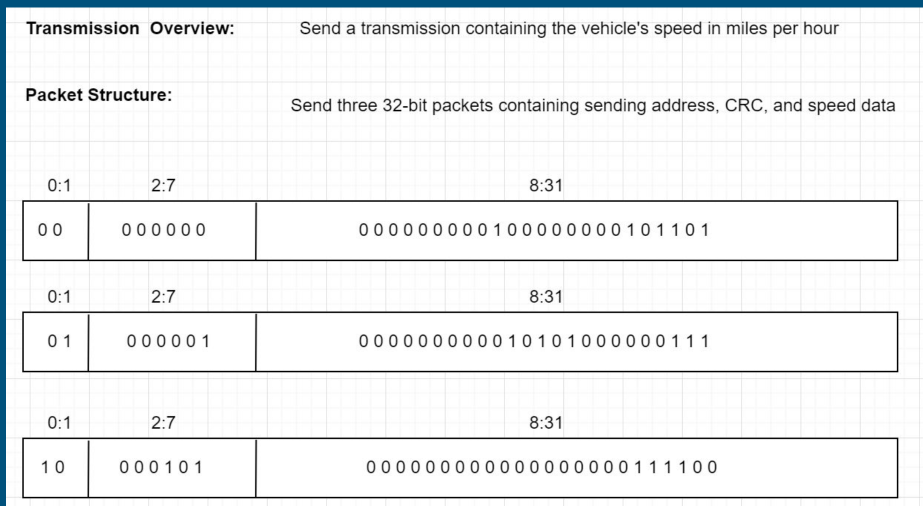
Communication - Packet Structure

- 32-bit packets
- First 2 bits represent the position of the packet within one transmission: 00 for packet 0, 01 for packets 1 to n-1, and 10 for the last packet,
- Next 6 bits describes the data with in the particular packet ie. address, speed, turn signals, ect...
- Last 24 bits contain packet data.



Communication - Packet Structure

- All transmissions are at least 3 packets: sending address, CRC, message

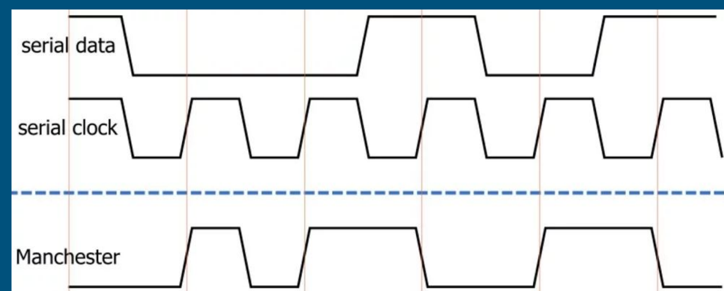


Manchester Encoding

Benefits

1. AC coupling problem is eliminated: every bit requires a transition and therefore the data signal will never remain at a logic low or high state for an extended period of time

2. Synchronization of transmitter and receiver on separate vehicles. The transitions provided by Manchester provide information about when the signal should be sampled. This means that no separate clock signal is needed.



Applications

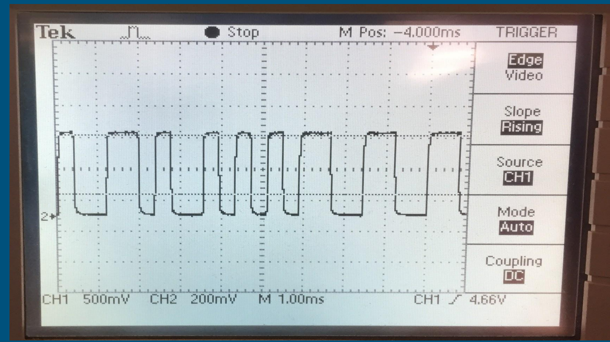
Current:

- Driver Assist - VLC as a method for sending safety messages to driver to avert accidents, and automatic braking in case of imminent crash

Future:

- Traffic Lights/Signs - Their inclusion could serve as another avenue for communication
- Self Driving Cars - A network of communicating vehicles could improve overall autonomy and safety

Possible Roadblocks



Roadblock

- Can an LED headlight modulate at the necessary rates?
- Can a photodiode detect headlight/taillights in sunlight?
- Can a photodiode detect headlights/taillights at the necessary range?

Solutions

- Tested using power FET to switch the headlight, easily modulates at 9600 bps. Trace shown.
- Filter out sunlight using optical filters, has not been tested
- Provide significant amplification of the received signal, has not been tested greater than 3 feet.

Planned Budget

Part	Quantity	Price	Purpose
Power MOSFET	5	$2.27	Modulate headlight
LED headlight	2	$19.99	Transmit light messages
PhotoTransistors + Photodiodes	~	$200	Receive Light Messages
Arduino	4	$71.48	Interpret messages received and control of headlight modulation
Thorlabs bandpass optical filters	~	$300	Filter out sunlight and other excess noise
Draper Labs Car	1	Borrow	Easily obtain and send messages from car such as a person stepping on the brakes

Total : $587.74
Remaining: $486.26

***The remaining budget will be used if replacement parts need to be purchased or if unforeseen circumstances arise that require us to buy different components \

Calendar

Milestones	**Objectives**
End of September - Milestone 1	Have completed circuitry for photodiode biasing and signal filtering. Confirm that the photodiode circuit is capable of accepting data at a speed of at least 2.4kb/s. Also use spectrometer to determine our headlights' light spectrum. After completing these steps we can order optical filters and our final more expensive photodiodes.
End of October - Milestone 2	Complete software implementation of communication framework outlined in this report. Ensure that a computer can send and receive understandable messages. Ensure that with use of optical filters transmit distance is at least 10 feet.
Mid November - Milestone 3	Apply project to real world applications to obtain videos and supporting documentation to show capstone success
December - Milestone 4	Finish all necessary documentation and participate in competition

Thank you!

Questions?