Visual Light Communication

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Problem Statement

Problem:

Cars currently lack proper real-time communication for safety and autonomous operations.

Solution:

Use the car's LED headlights to send important information between cars.

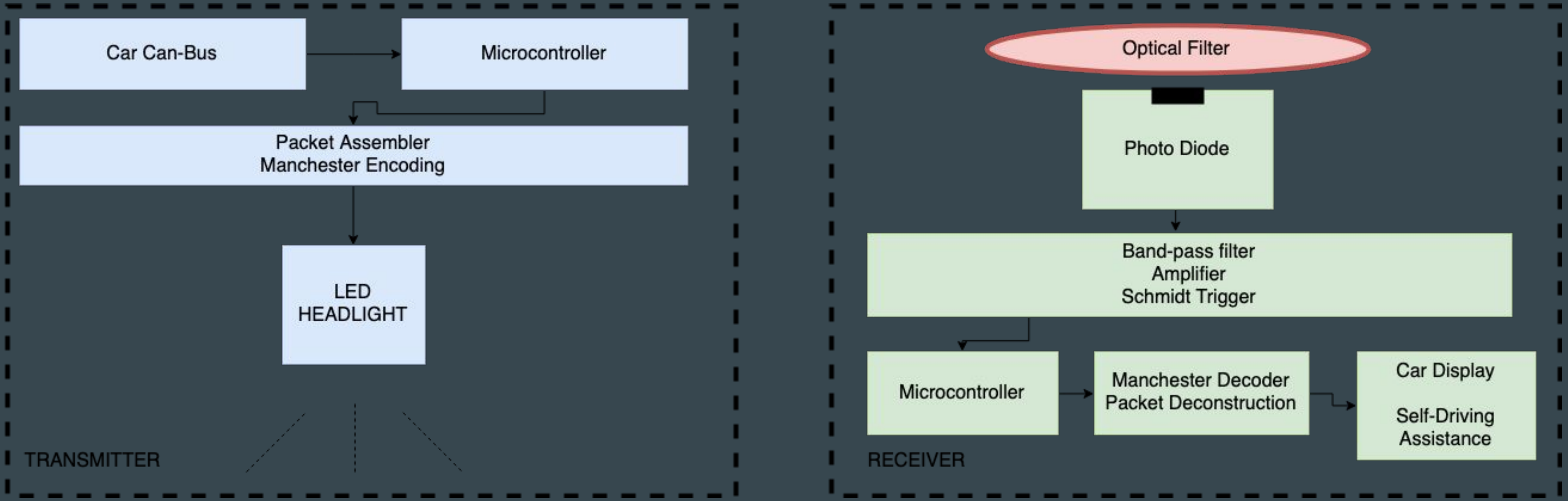
Methods

- 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
- Manchester Encoding is the IEEE standard VLC

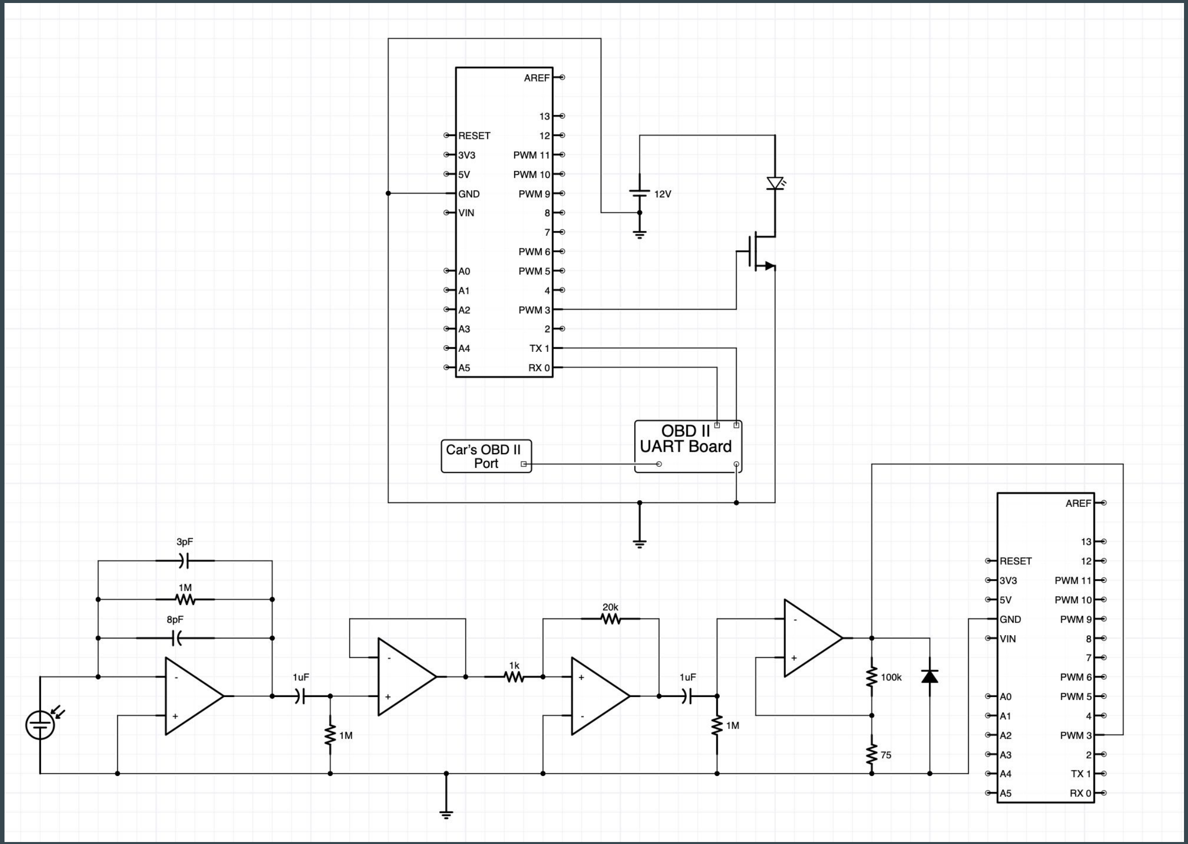
Why VLC?

- Can use existing hardware from the car
- Good for local communication
- Does not require any type of handshake
- Unused spectrum
- Relatively cheap and
- Simple compared to:
    - Radar
    - Wifi
    - Bluetooth

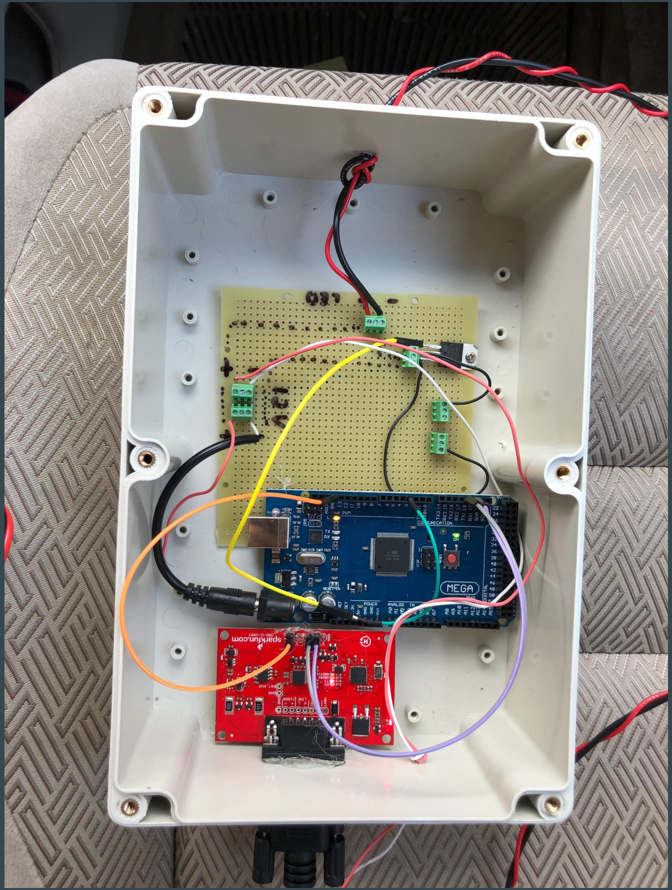
Block Diagram

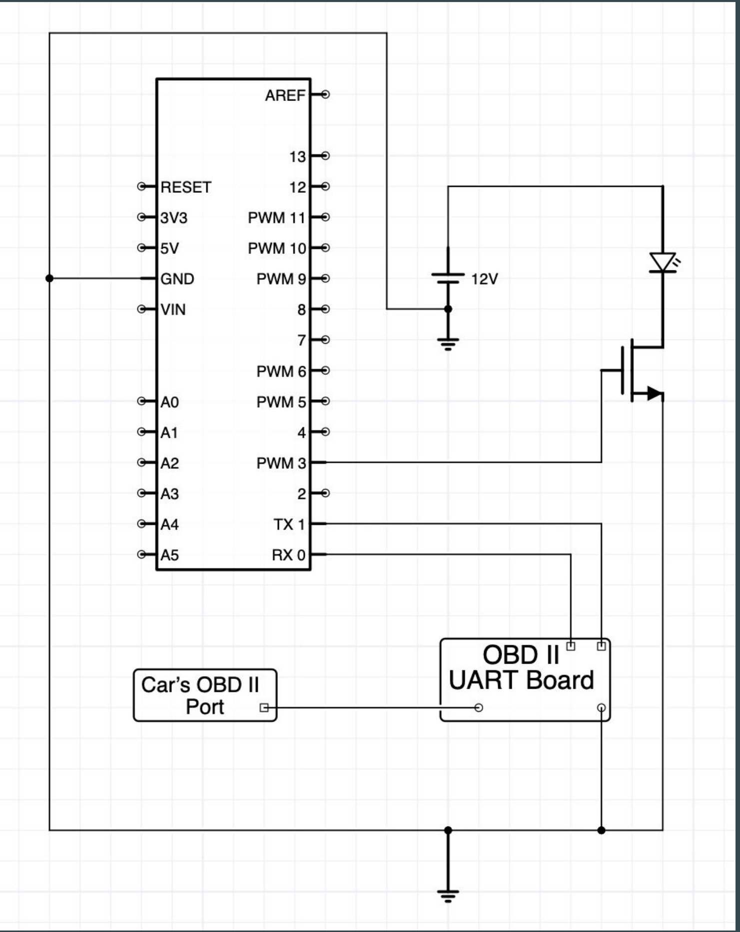


Hardware design

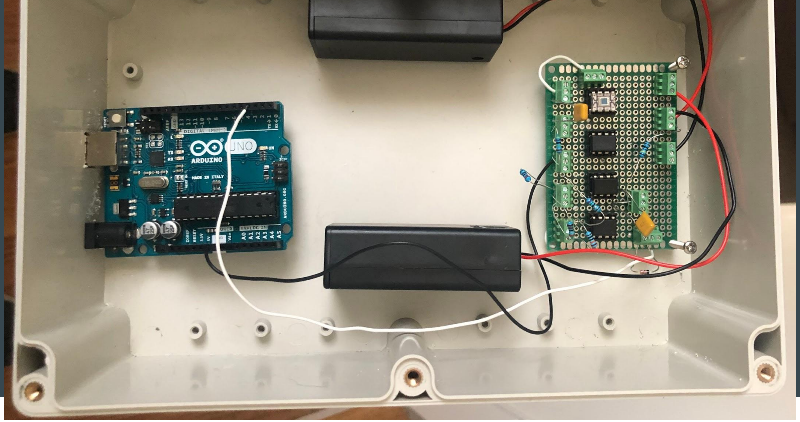


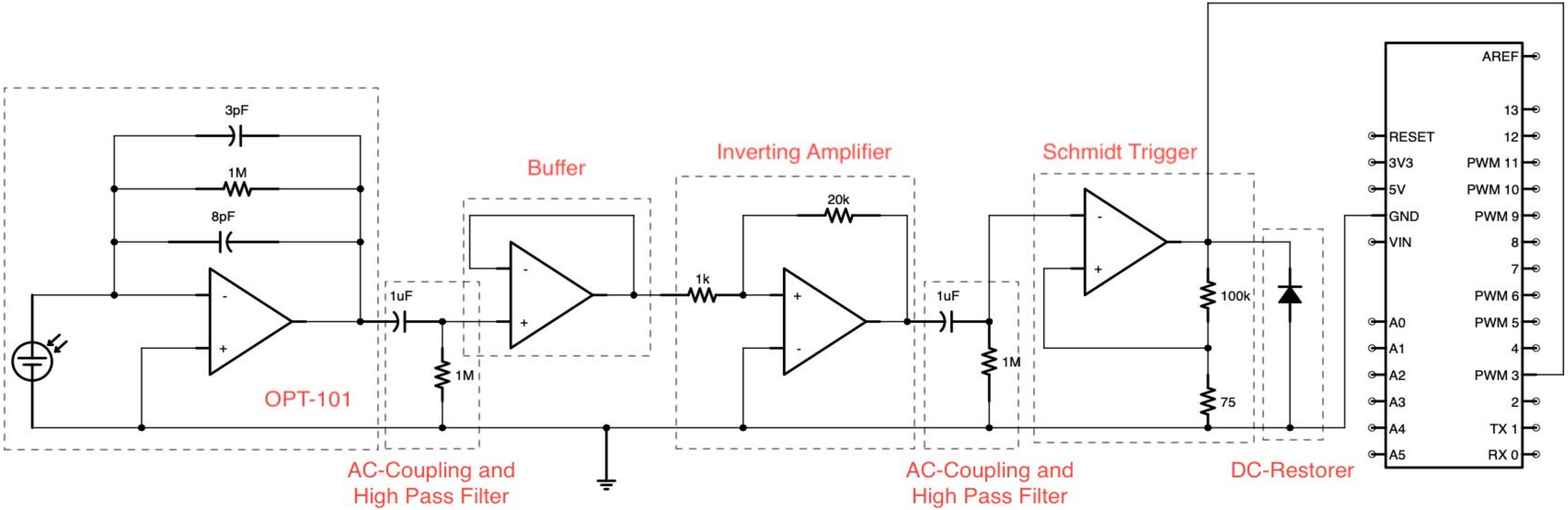
Transmitter





Receiver




3pF
1M
8pF
OPT-101
1uF
1M
AC-Coupling and
High Pass Filter
Buffer
Inverting Amplifier
20k
1k
1uF
1M
AC-Coupling and
High Pass Filter
Schmidt Trigger
100k
75
DC-Restorer
AREF
13
RESET
12
3V3
PWM 11
5V
PWM 10
GND
PWM 9
VIN
8
7
PWM 6
A0
PWM 5
A1
4
A2
PWM 3
A3
2
A4
TX 1
A5
RX 0

Receiver - Optical Filtering

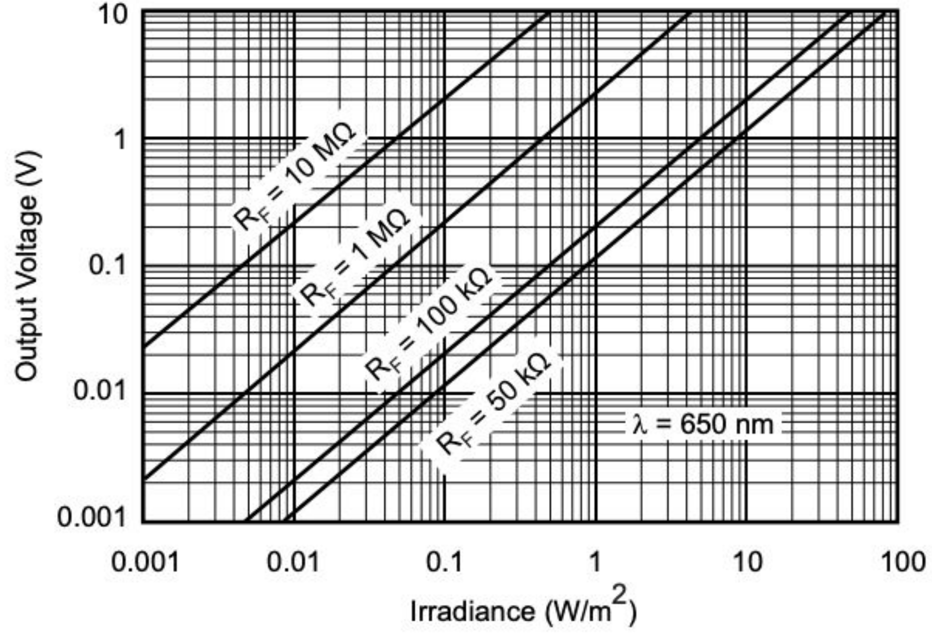
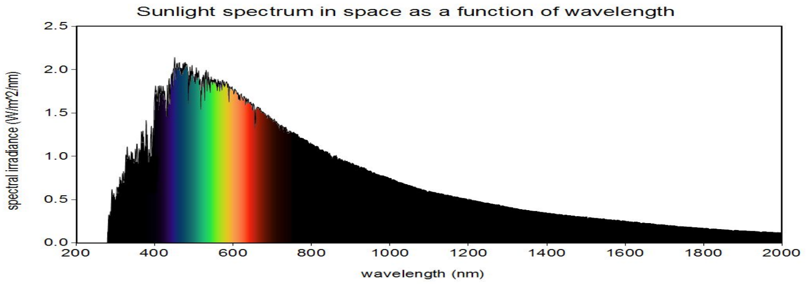
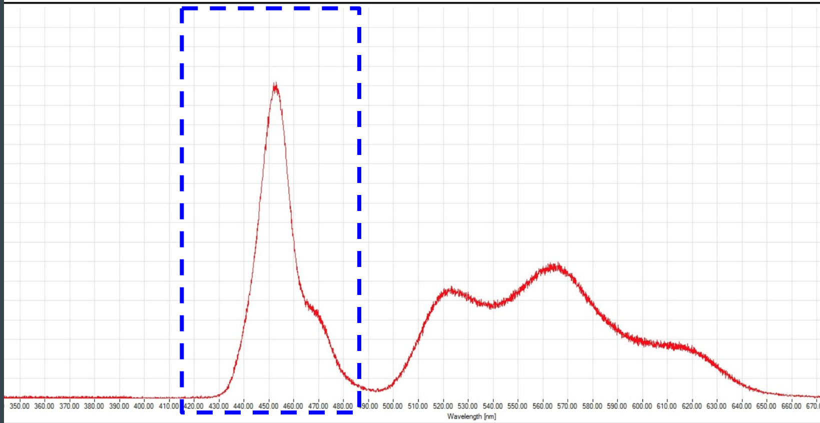


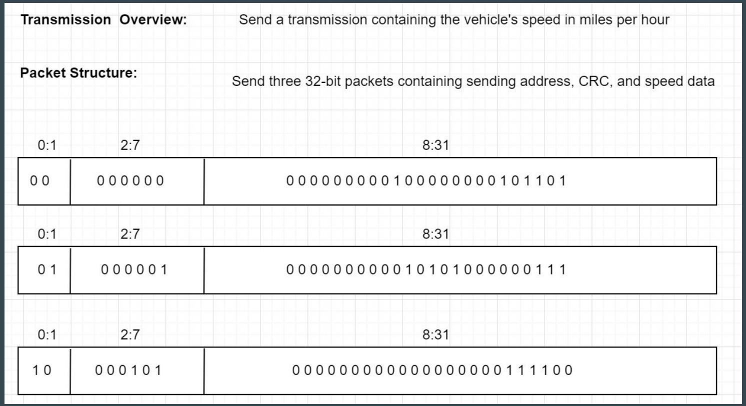
Figure 3. Voltage Responsivity vs Irradiance

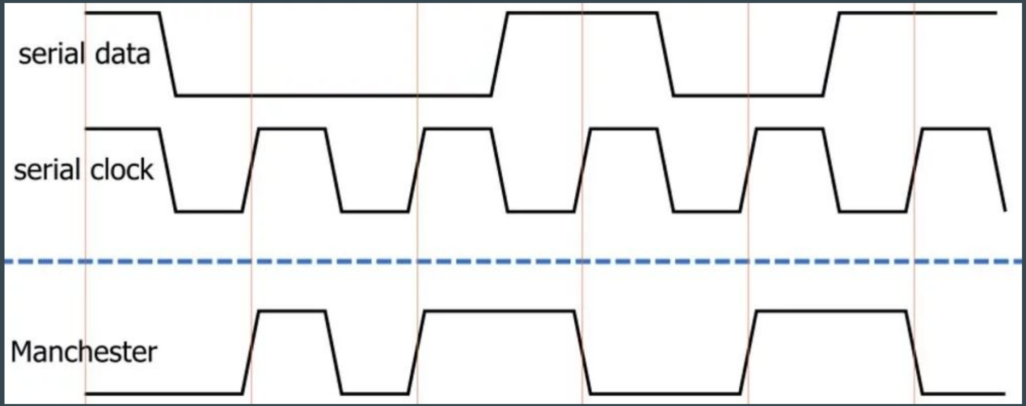




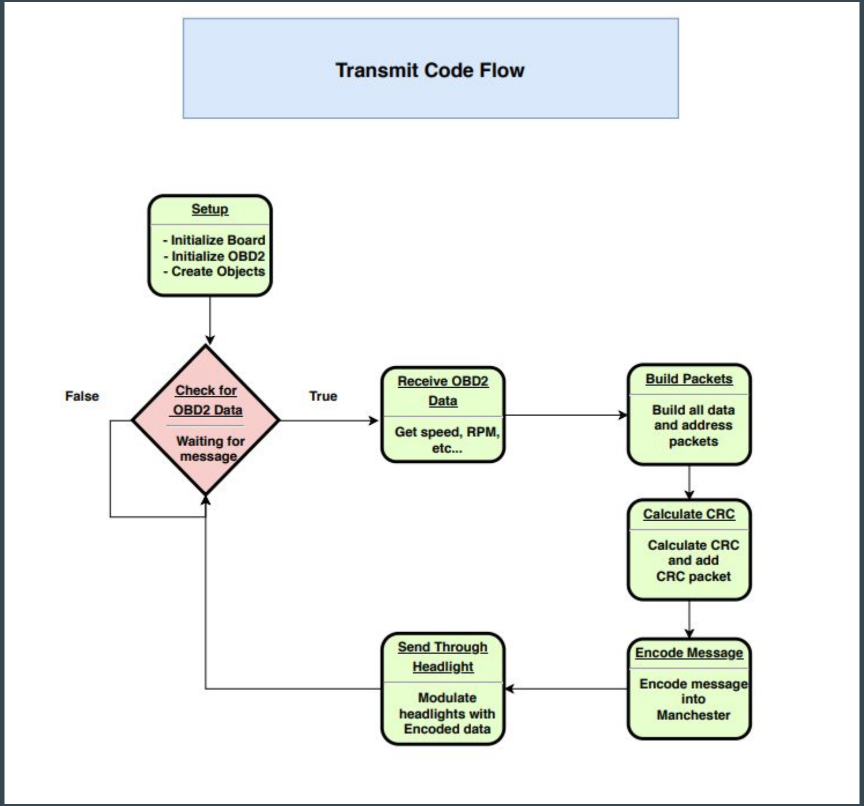
Signal Generation

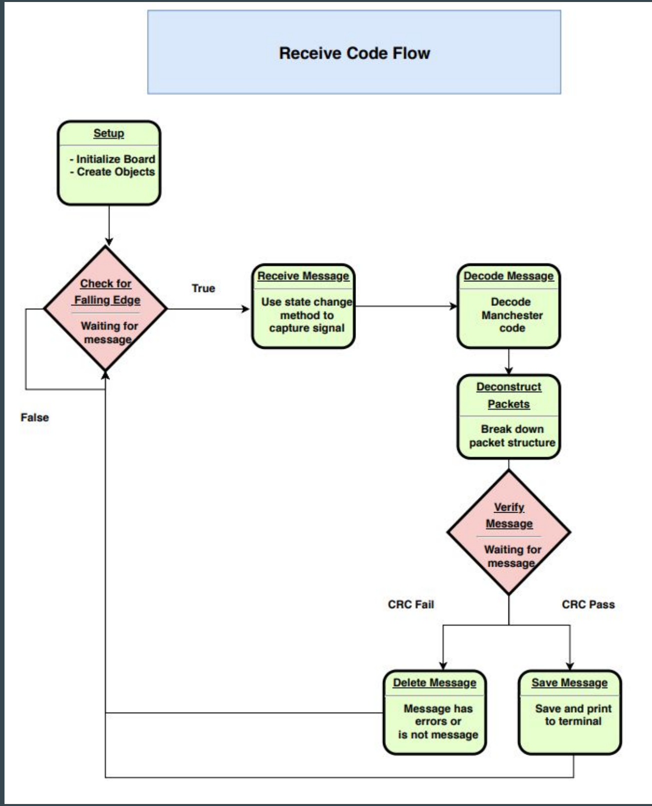
- A signal is passed from a car's on board diagnostic computer, through the OBD II port, to our microcontroller. The signal is then Manchester encoded, which keeps the duty cycle of the transmission at 50%. This helps avoid noticeable flicker due to a constant duty cycle. We match this 50% duty cycle during the times we are not sending messages.
- All transmissions are at least 3 packets: sending address, CRC, and the message.
- At most 8 full packets can be sent per transmission due of memory limitations with the arduino uno.





Software Flowchart





Unexpected Problems and Solutions

- With a more powerful LED we were unable to generate clean signals at high frequencies. We therefore had to adjust frequency from 9600 bits/sec to 2400 bits/sec.
- Originally flicker of LED was very noticeable even at high frequencies. Solution was to use Manchester and match the duty cycles of the sending transmissions and not sending transmissions.
- Due to the sensitivity of the Schmitt trigger, sampling once a cycle would often lead to misreads, therefore we switched to the state change and time approach discussed earlier.
- The photodiode saturated more easily than expected.
- Optical filter removed too much of our LED signal, decreased the range significantly.

Proposed Design Improvements

- Move away from Schmitt trigger and do all data analysis in software to allow for a more sensitive system. (Digital Signal Processing)
- Change PWM to match transmission frequency by changing pin timer/counter registers from their default settings to completely remove flicker.
- Create custom optical filter to better meet specific LED headlight spectrums
- Use a digital potentiometer to adjust feedback of photodiode dynamically dependant on outside light levels.

Demonstration

Thank you !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