Visible Light Communication Link

EE 344: Electronic Design Lab

Submitted by:
Group-18 (B. Tech)

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Abstract:

The aim of this project is to demonstrate a working model for communication and file transfer using Visible Light Communication Link. This link can be bidirectional or unidirectional (we are using unidirectional link here). It makes use of light waves instead of radio technology to deliver data. Using light to deliver wireless internet will also allow connectivity in environments that do not currently readily support Wi-Fi, such as aircraft cabins, hospitals and hazardous environments.

Aim/Objectives:

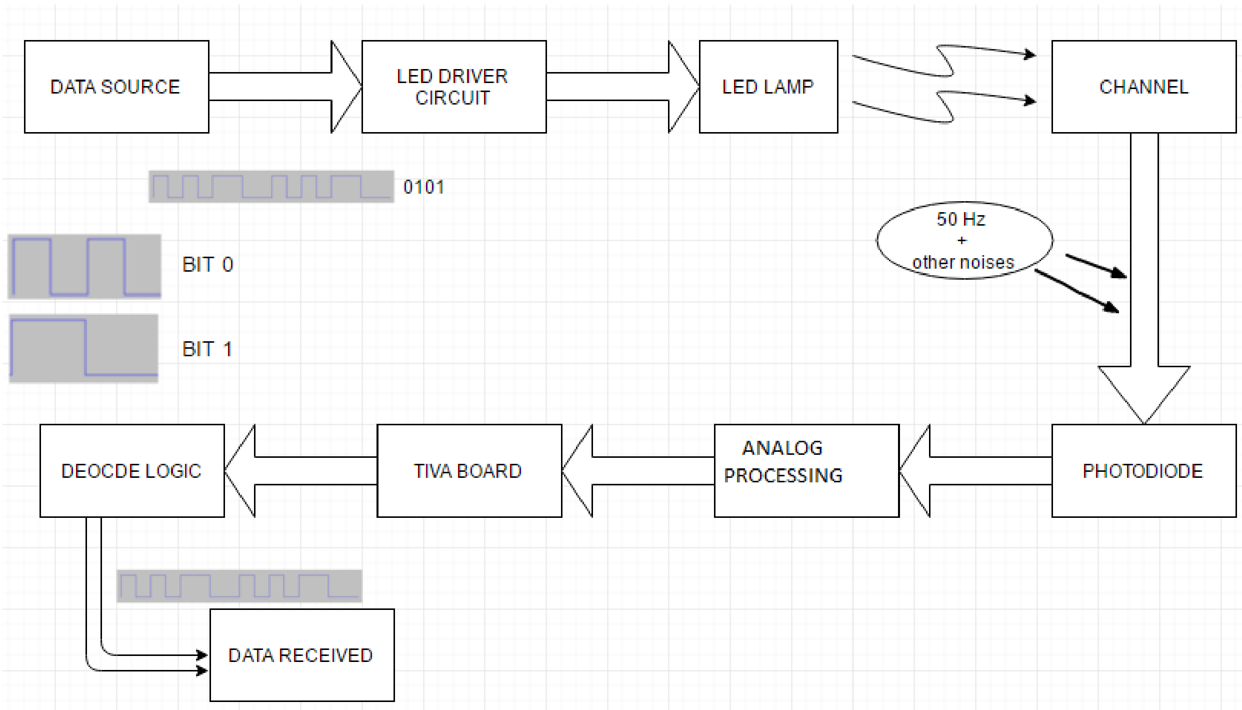
Our objective in this project is to transmit text via the visible light communication link at a speed close to 1 kbps.

Introduction:

Using light to deliver wireless internet has several advantages. Some of them are listed below:

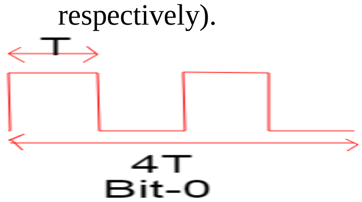
- Using light to deliver wireless internet allows connectivity in environments that do not currently readily support Wi-Fi, such as **aircraft cabins, hospitals, etc.**
- **Location Based Services (LBS)**
- **Vehicles & Transportation**
- This technology can also be used for effective wireless communication in "**Radio quiet zones**" (large area used for astronomical observations).
- **Security**: Li-Fi is confined to the illuminated area, providing a very controllable environment. essentially eliminating the threat of data being hacked remotely.
- **Safety:** Visible light wavelengths are harmless to humans.
- **RF Spectrum Relief:** Excess capacity demands of cellular networks can be off-loaded to Li-Fi networks where available.

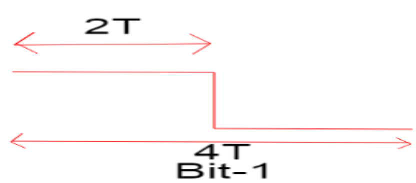
Block Diagram and description of blocks:



Data Source:

- Text message is stored in the internal memory of TIVA board.
- The encoding of the bits is such that the average energy of bits 1 and 0 is constant.
- We are sending text messages in ASCII characters. Therefore, we will need eight bits per character.
- The start 'wait' and stop 'wait' bits will be prepended and appended respectively to each ASCII byte.
- Each ASCII character is of 8 bits each. A parity bit is added. A wait symbol at the start and at the end of the 8 bit ASCII representation. This had been done to differentiate between start and stop bits.
- The start and stop signals will be 10-bit sequence (at present it is 10 bits of 1 and 10 bits of 0 respectively).





Led Driver Circuit:

- We are using a switching circuit to transmit the information. The switching happens through the power mosfet IRF840.
- The control input comes from the TIVA board and is fed to the gate of the mosfet (via optocoupler for safety reasons). The mosfet controls the current passing through the transmitter as shown in the circuit diagram.

- We planned to introduce an additional compensatory path to the led path so that the current passed through the filter remains the same in any part of the switching cycle. This arrangement however dissipated large amount of power. On experimenting we observed that there is no need to introduce the additional path.
- We isolated the power and control circuit using an optocoupler for safety.

Led Lamp:

- The output of the **LED Driver** circuit is fed into the Led Lamp and it drives the lamp to give the required transmission over the optical channel.

Photodetector:

- The photodetector circuit uses a photodiode and an amplifier.

Analog processing:

- Further processing is done using a high pass filter with a cut-off frequency of 0.25khz.
- This filter removes the Dc and 50Hz noise signals.
- After filtering Schmitt trigger is used to provide some threshold and convert the signal to high and low.
- The output of the Schmitt trigger is from -15 to +15 V, we use a positive clamper to clamp the voltage output to 0-30V.
- We then use a voltage divider to give an output of 0-3.3V which can be supplied to TIVA board.
- The output is given to TIVA board and voltage protected by a 4.7V zener diode.

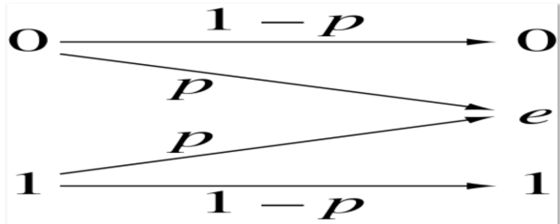
Received Data:

- The data is received by Tiva Board (using external interrupt).
- Received bits will be decoded and corrected for error.

Interrupt based Decoder

- The decoder detects the incoming bits by using the external pin interrupts.
- The interrupts get triggered when the state of the input changes from 1 to 0 or 0 to 1. It stores the input in 1 or 0 buffers.
- Time between two such interrupts is recorded and referenced to a 1-bit or a 0-bit or other special symbols.
- If the 1-buffer gets filled twice or the 0 buffer is filled 4 times, the bit detected is 1 or 0 respectively.
- Suppose time between two such interrupts come out to be less due to high frequency noise, the receiver will ignore the interrupt and calculate time till next interrupt. (This removes high frequency noise)
- Similar logic applies to a wait bit (except for erasure).
- If the interrupt is not triggered in the specified time intervals or the 1 or 0 buffers are not completely filled, the output will be declared as erasure.

Error Correction



- The channel can be estimated as a binary erasure channel; the output is of the form 1 or 0 or an erasure.
- We implemented parity check to correct an erasure.
- Parity bit is given by:

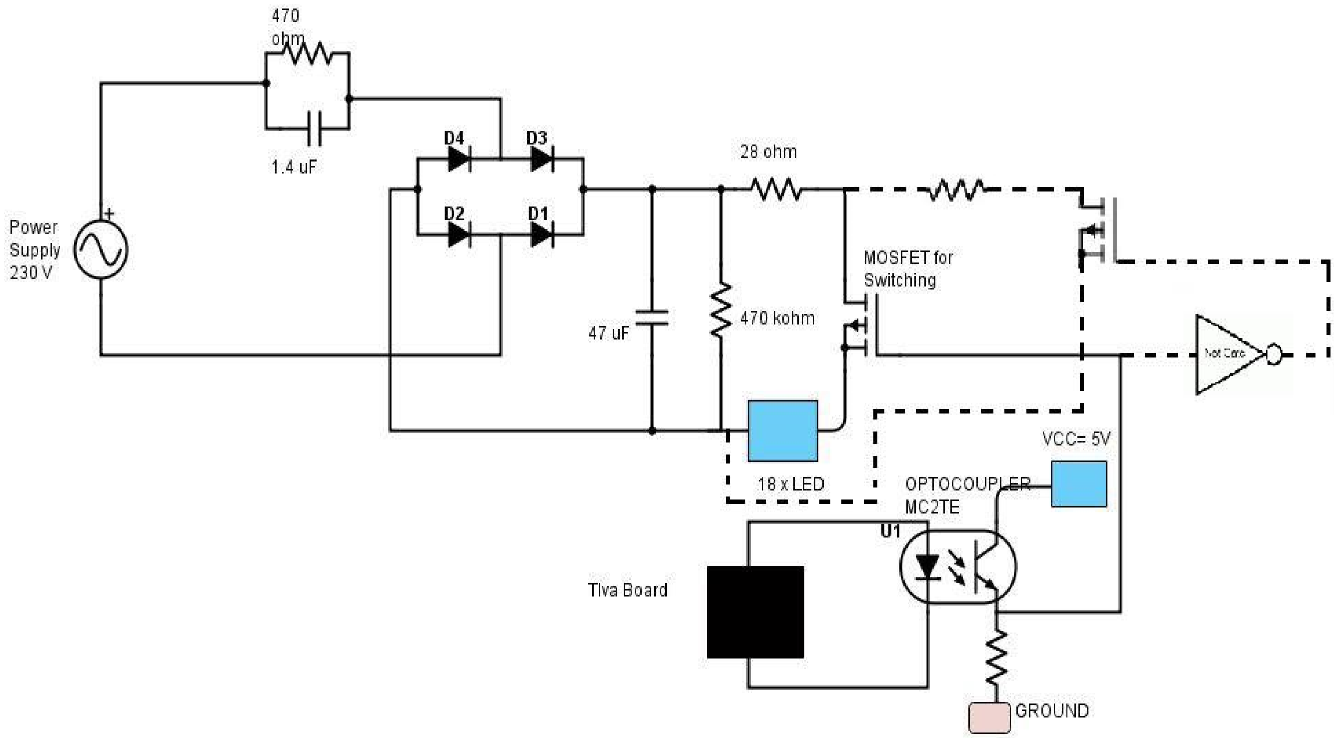
  $$v_{k+1} = -\sum_{i=1}^{k} v_i$$

  In binary case this is a XOR.
- We can recover original bit from parity bit using

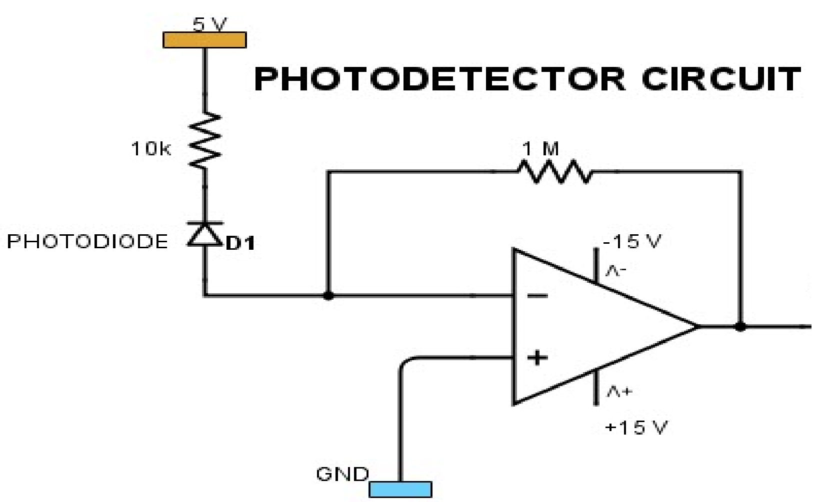
  $$v_e = -\sum_{i=1, i \neq e}^{k+1} v_i$$

Circuit Diagram for each block:

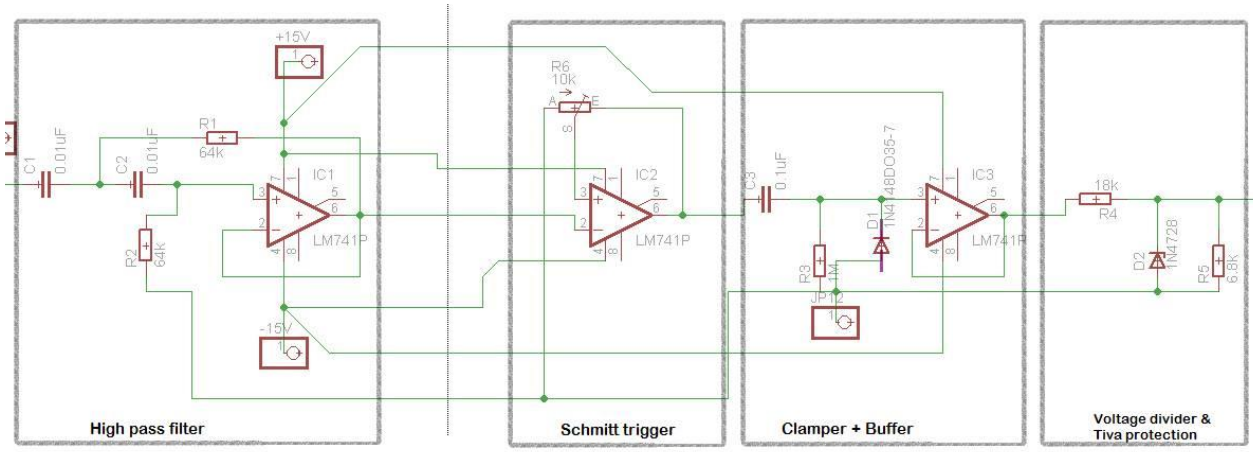
LED DRIVER CIRCUIT:

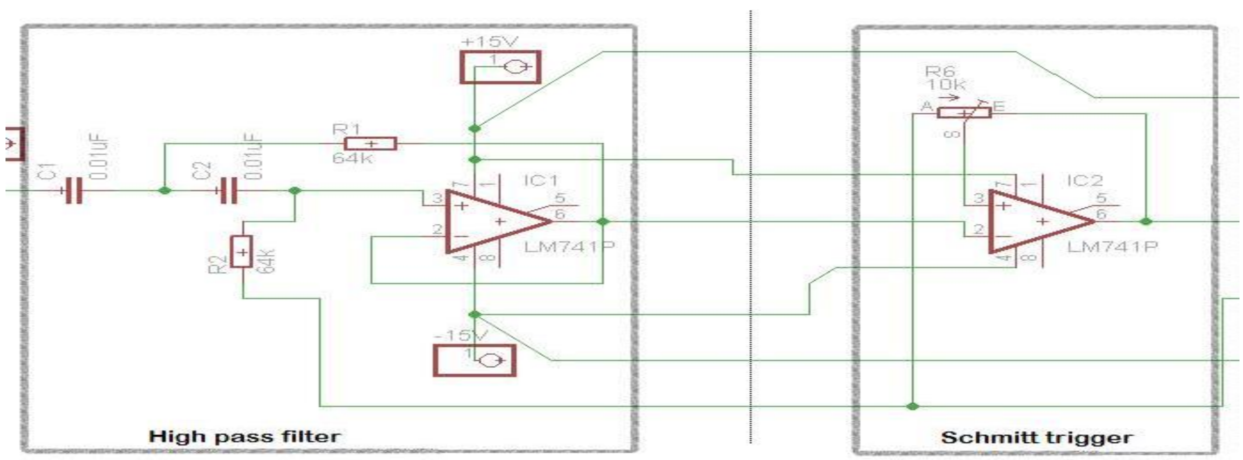


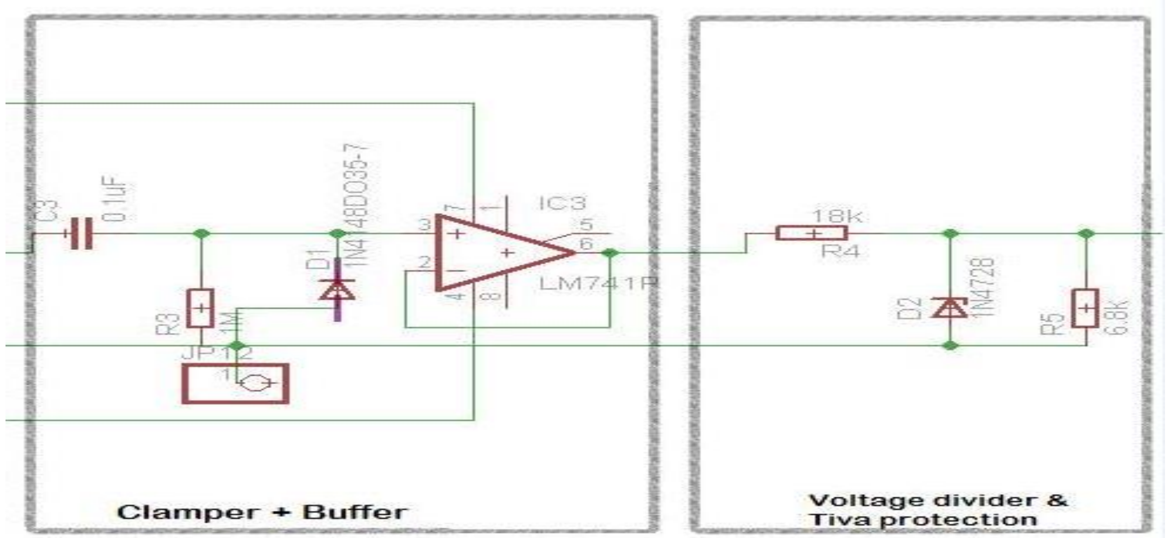
PHOTODETECTOR CIRCUIT:



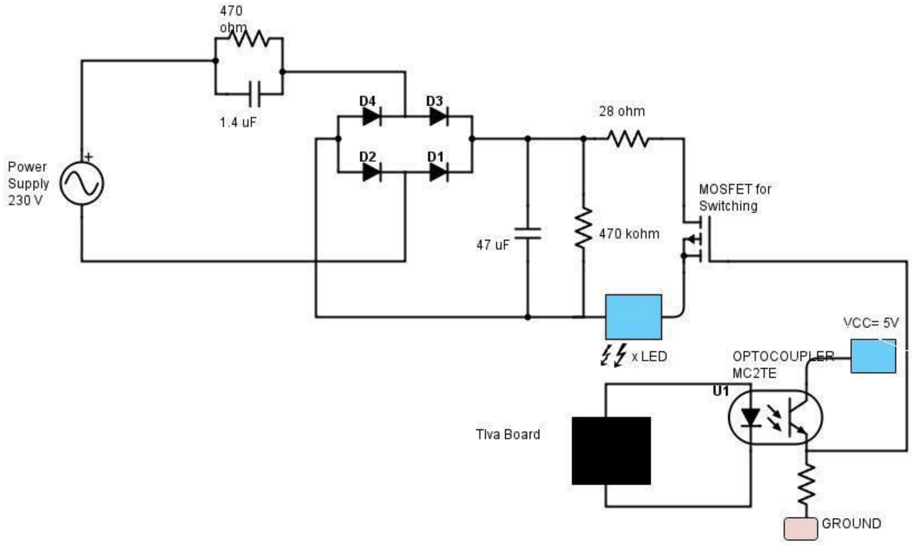
ANALOG PROCESSING:



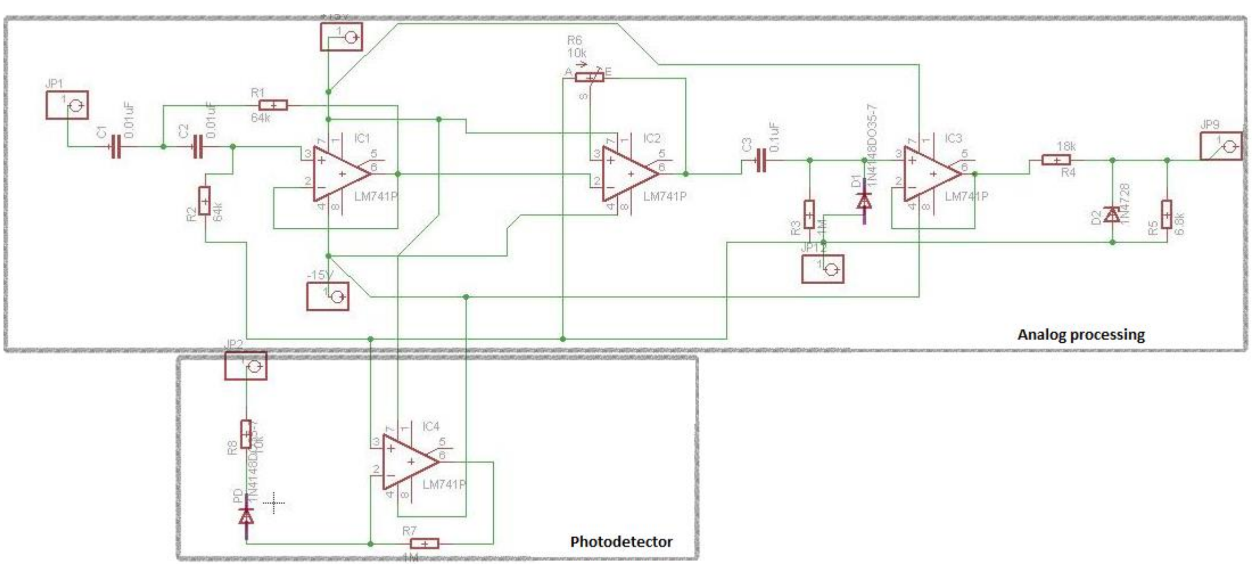




Complete Circuit Diagram:



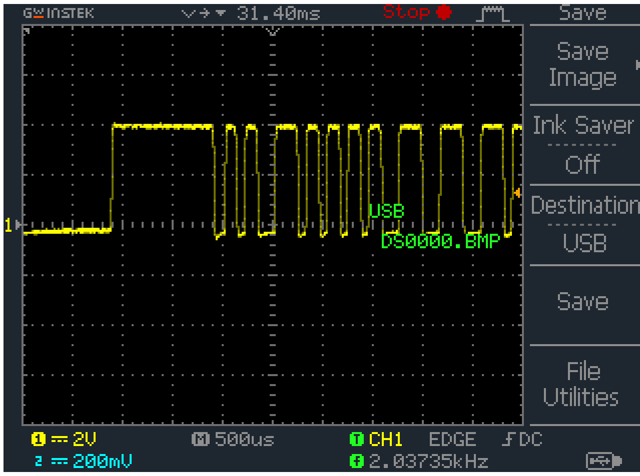
Transmitter

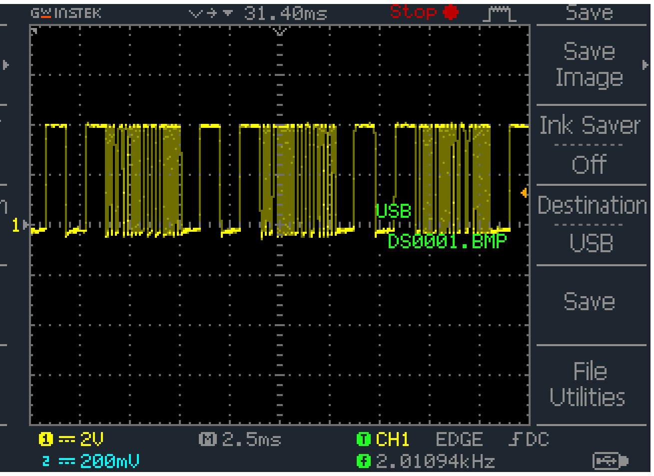


Receiver

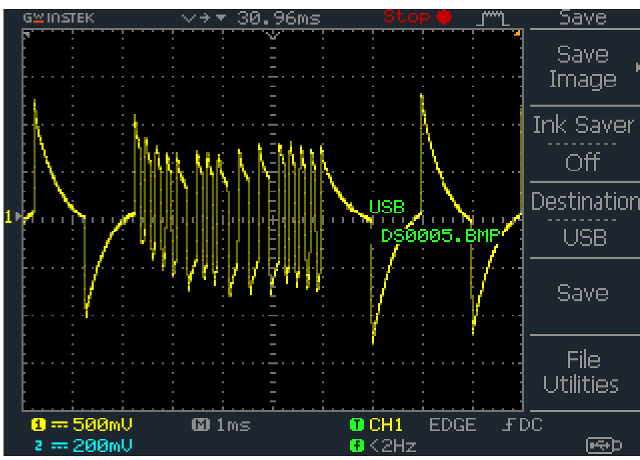
Photographs of the units/ waveform etc.:

Received Wave:

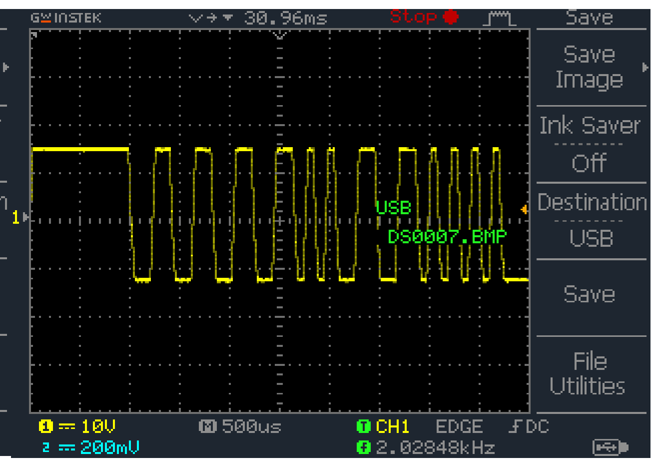




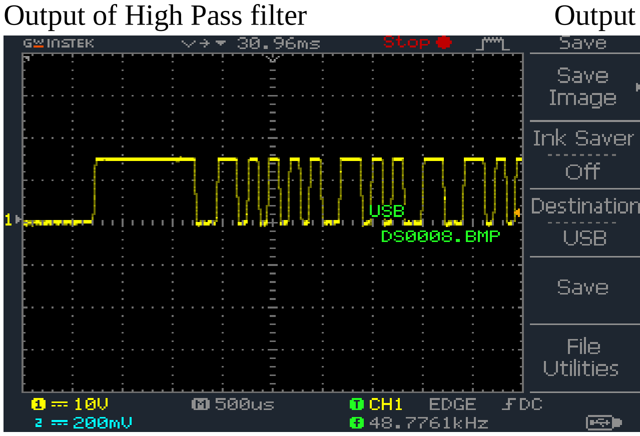
Outputs of various elements of Analog processing:



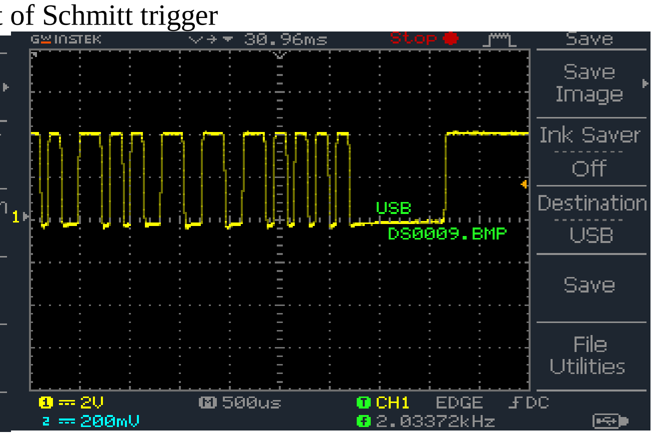
Output of High Pass filter



Output of Schmitt trigger



Output of positive clamper



Output of voltage divider

Sample sent and received messages:

Original message

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Received message(with one bit erasure error coding)

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Results/Objectives achieved:

- We have used analog filters to remove 50Hz noise received so that the processor is completely dedicated to data handling.
- We have encoded our message such that the brightness of the lamp isn't a function of the input data as bits 1 and 0 have equal brightness. Hence, it will not flicker too much when given an uneven data (data with unequal number of zeros and ones).
- Transmission Rate: 2.5 Kbits/s.
- Effective Data rate: 1.05Kbps.*
- Maximum distance of transmission: 0.75 to 1m.
- Bit Error Rate: 0.02**(after applying one-bit error correction). This is the error at bit level and can be decreased by using better error correction.
- There is a tradeoff between transmission rate and errors in data received and hence redundancy introduced due to ECC.

* Calculation of Effective data rate:
    - Bits per character:8(extended ASCII convention)
    - Error correcting bits:1
    - Wait bits effective length:10
    - Effective data rate = data bits per transmission/total bits per transmission*transmission rate
      = 8/ (10+9) *2.5Kbps = 1.05Kbps

** Calculation of BER: The above bit error rate is derived from the above mentioned sample Transmission (Received message). We get approximately 40 bit errors in the 4000 bits transmitted, giving an BER of 0.01. Thus we make a conservative estimate of 0.02.

Problems faced:

- At the start we introduced a compensatory path in the LED driver circuit so that the net current passing through the filter remains constant, this however causes a lot of power loss, thus as an alternate, we implemented the driver circuit without the compensatory circuit and it worked very well. There were spikes for small amount out of time, this time was very small and is not visible to naked eye and the moreover the power output doesn't change much as the spike runs for a short duration.
- To isolate the power circuit from the TIVA board we used an optocoupler.
- The PCB designed for the receiver didn't work well at first which was then corrected after debugging.
- We received erasure of a bit mostly at the start of the byte, this was caused due to processing costly decoding method, thus, we added a wait symbol at the start and end of the byte.

Conclusions:

- Visible light communication link has great applications and looks like the "Wi-Fi" of the future.
- However, the data rate achieved in our case was moderate, mostly because of processing limitations rather than the capacity of the channel.

Future work suggestions:

- Create an interface to send any file from one PC connected to a TIVA board to another PC. This would involve making of a GUI for the transfer mechanism and implementing some new encoding scheme.
- Using a microcontroller better suited to handle interrupts. TIVA board was not able to handle external interrupts that well even at speeds of 10kbps.

References:

- Okawa Filter Design: http://sim.okawa-denshi.jp/en/Fkeisan.htm
- Elements of Information Theory, Cover and Thomas.