Free-Space Optical Communicator

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1 Objective

Our goal was to build an laser communication system (lasercomm) capable of transmitting (and receiving) high-speed data across a large distance.

2 System Overview

The lasercomm consists of four elements: an encoding computer; a transmitting circuit; a receiving circuit; and a decoding computer. The encoding computer generates a voltage wave used to power the laser transmitter. The receiver circuit consists of a number of "black box" components that isolate and clean the optical signal. The decoding computer read the output voltage from the receiver, parsed the processed signal, and read the encoded data. A block diagram of the system is given in Figure 1.

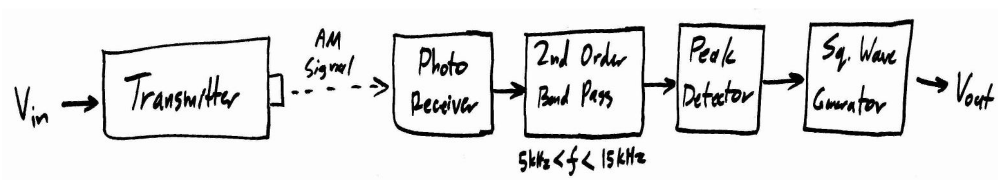

Figure 1: Block diagram of the lasercomm system. The dotted line represents a laser signal; V_{in} is supplied by a computer; V_{out} is read by a second computer.

Data was encoded as a square wave at a rate of 1kB/s into a 10kHz carrier wave whose amplitude varied between 3 and 4.5V (the laser would not turn on below 3V). High amplitudes represented a 1 and low amplitudes represented a 0. A sample test signal is shown in Figure 2.

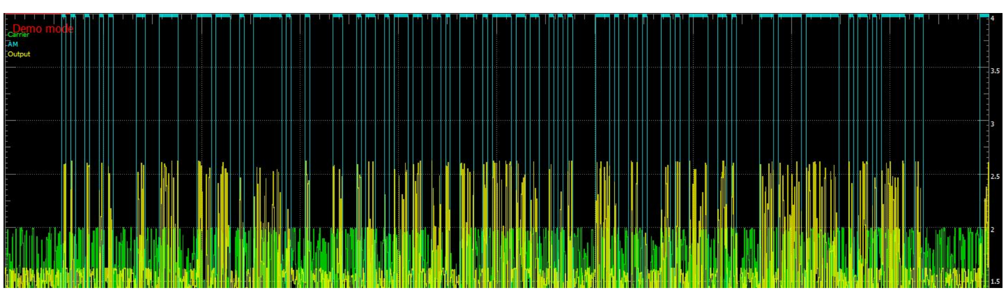

Figure 2: Data packet as a voltage signal generated by Digilent's Waveforms software. Bits are given in blue and the signal is given in yellow.

3 Circuit Diagrams

The transmitter was extremely simple, consisting only of a laser diode (a re-purposed cat toy from Petco) grounded at one end and driven at the other by a supplied voltage.

The receiver consisted of a photo-receiver, a 2nd order bandpass filter centered about 10kHz, a peak detector, and a square wave generator. The photo-receiver consisted of a photo-diode attached to an op-amp which converted its current into a voltage signal. This signal was passed through a 2nd order bandpass filter designed such that $5kHz < f_{pass} < 10kHz$. The resulting signal was a clean 10kHz sine wave with amplitudes corresponding to a square wave representing the data bits. A square-like wave was extracted from this sinusoidal wave by use of a peak detector which roughly followed the signal's regions of high and low amplitude. Finally, this rough square-like wave was passed through an op-amp referencing 2.5V without negative feedback to generate a clean square wave of magnitude 0 or 5V. This final signal was measured with respect to 2.5V, resulting in a V_{out} which consisted of a clean square wave of magnitude ±2.5V. A circuit diagram for the receiver is given in Figure 2.

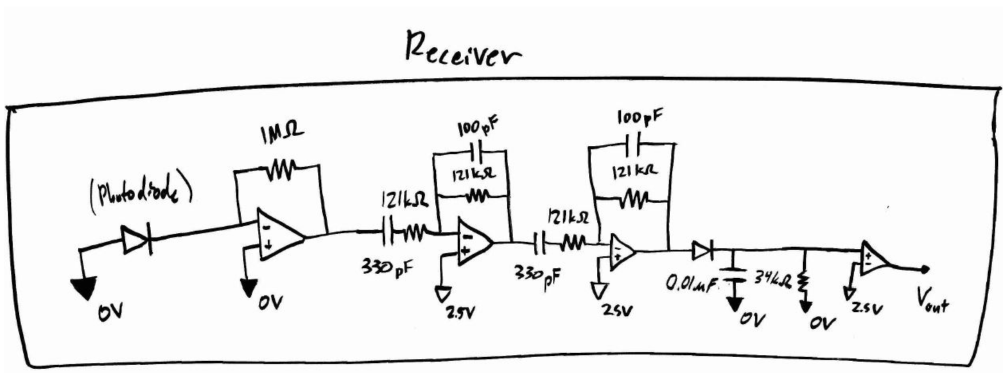

Figure 3: Circuit diagram for the optical receiver.

4 Data Handling

Python scripts were used to process raw text into a square wave (encoder) and parse a square wave to retrieve encoded bits (decoder) on either end of the lasercomm. The encoder converted raw text into ASCII integers and then into binary. It then attached a locking and unlocking sequence to bookend the message and form a data packet. The encoder returned a CSV compatible with Digilent Waveforms and the frequency at which the packet needed to be transmitted to achieve a bitrate of 1kHz.

The decoder received a waveform recorded by Waveforms as a CSV. The decoder would start at index 0 of the CSV and search for the first instance of a 1 bit (a positive voltage). Using this bit as a starting index, the decoder proceeded to capture 1ms time steps and averaged the points inside of that time step to determine if a 1 or a 0 was present. Finally, it would parse all the bits it had translated, find the lock/unlock sequences, and translate the bits between those sequences back into text.

5 Results

We encountered un-explainable erroneous bits appearing across large transmission distances until we drastically increased our sample rate. The increased sample rate made this error disappear, and we can reliably transmit text messages across distances of 100+ feet.