Design and Implementation of Laser Transceiver for Free Space Optical Communication.

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ABSTRACT

Free-space optical communication systems can provide high-speed, improved capacity, cost effectiveness, and ease of deployment for wireless networks. This paper addresses the design and construction of a laser transceiver. This laser transceiver can be used for data communications between two computers via free space optical link.

In this project, the serial ports of the computers are used which are defined by C programming. A laser pointer is used as the optical source for electrical to optical signal conversion at the transmitter section. Optoelectronic conversion is performed by a phototransistor at the receiver section. A set of magnifying glass is used for proper alignment and transmission of the laser beam. We use MAX 232 to convert RS 232 logic to TTL logic and then an optical transmitter circuit to transmit data via free space optical link. At the receiver we have an optical receiver circuit which receives data using a photo transistor and a MAX 232 again to convert TTL logic to RS 232 for the serial port at the receiving end computer. The desired baud rate can be set using the program.

For transmitting data the program is executed once and whatever is present at the serial port is sent to the other computer via the free space optical link. At the receiver, the program is executed to receive data on the serial port. The laser transceiver allows any two computers with serial (RS-232) communication capability to communicate over 200 meters using a laser beam.

(Keywords: FSO, Laser, Transceiver, and data communication.)

INTRODUCTION

Current wireless technologies such as Bluetooth, WiFi, or WiMax have low data transmission rates compared to those of wired local-area network (LAN) systems. These networks require licensing and pose security risks [1]. Many efforts over the last decade have been undertaken to develop an alternative for wireless networks. Free space optic (FSO) networks can be set up within a day with absolute security because the transmission is based on line-of-sight [2-6]. The data rate for optical systems is in the Gbps range [5]. A laser is used as the light source in order to lower the cost while maintaining the high-speed data rate and the security features that FSO offers [2-4]. FSO laser links will provide an alternative to traditional RF wireless communication that is currently nearing its bandwidth limitations [4].

Laser as a communications medium has some unique properties compared to other forms of media. A line-of-sight laser beam is useful where wires cannot be physically connected to a remote location. A laser beam, unlike wires, also does not require special shielding over longer distances. Lasers offer at least an order of magnitude longer distances compared to infrared LEDs. Although RF transmitters may offer longer distances than line-of-sight lasers, they are subject to interference from other transmitters.

Since the laser medium is line-of-sight and the beam being only several millimeters in diameter it is very difficult for the data stream to be tapped. This offers secure communications since any attempts to intercept the laser beam would be detected at the receiver as a loss in data. A laser medium also allows for the sender and receiver to be galvanically isolated from each other.

A transceiver is a device that both transmits and receives analog or digital signals. The term is used most frequently to describe the component in LAN that actually applies signals onto the network wire and detects signals passing through the wire. For many LANs, the transceiver is built into the network interface card. Some types of networks, however, require an external transceiver.

In this project, a laser transceiver is designed for FSO communication over a certain distance. The laser transceiver allows any two computers with serial (RS-232) communications capability to communicate over 200 meters using a laser beam. In that case, MAX 232 is used to convert RS 232 logic to TTL logic. A laser pointer is used as the optical source of the transceiver and a photo transistor as a receiver of incoming light signals for the transceiver. A computer program is developed on C to interface the laser transceiver with computer. First we have implemented and tested the laser transceiver on the project board. Finally, we have implemented and tested the laser transceiver on the printed circuit board (PCB).

SYSTEM DESCRIPTION

The complete system consists of two transceivers, each capable of simultaneously transmitting and receiving data. Figure 1 shows the data communication between two computers using laser transceiver.

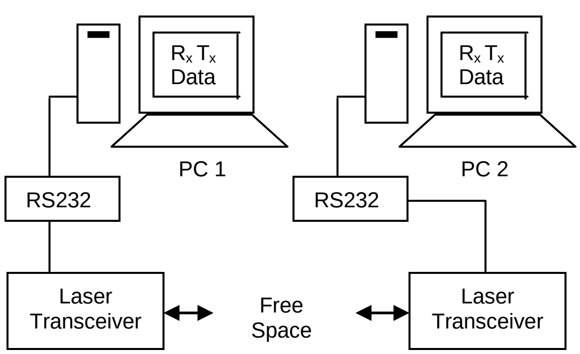


Figure 1: PC to PC Free Space Optical Communication.

The circuit diagram of laser transceiver shown in Figure 2. The laser transceiver is based on the MAX232A IC for generating and receiving RS-232 compatible voltage signals. The receiving sensor is an NPN photo-transistor (OP505A). Although the laser wavelength is in the visible spectrum (~670nm) the photo-transistor's broad response band (550nm to 1050nm) is wide enough to sense the intense laser beam. The signal from the photo-transistor is buffered via a pair of Schmitt trigger buffers to clean up and square the signal. The output of the second buffer is then directly converted to a RS-232 standard signal via the MAX232A.

The MAX232A generates +10V and -10V voltage swings using a dual charge-pump voltage converter from a single +5VDC rail. Several different versions of the MAX232 chip exist. The A version requires only 0.1 uF capacitors for the charge-pump and inverter, whereas the MAX232 requires 1uF capacitors. The advantage of the A version is that it has faster response times, and allows for faster data rates. MAX232A IC provides the interface to the PC, and the 74LS05 is used to drive the laser diode inside the laser pointer.

The laser diode driver consists of a 7405 open-collector hex inverter IC. All the outputs of the inverters are coupled together to provide enough drive current for the laser diode which draws around 35mA @ 3V. A 7805 voltage regulator is used to provide the IC and laser diode with a stable 5V voltage source. The two 1N4001 diodes, in series with the laser diode, step down the voltage from +5VDC to around 3.6VDC which is close to the nominal voltage for the laser diode.

The transceiver is designed in such a way that when no signal is present, the laser is on. This helps to see where the laser is pointing during the laser-detector alignment. The transceiver is powered by a 9V battery and draws approximately 80mA (laser on) and 40mA (laser off).

HARDWARE IMPLEMENTATION

First we started by checking the printed circuit board (PCB) to make sure it was clean and free from dirt and dust. We have designed a PCB layout with the help of a computer program named PSPICE which is shown in Figure 3. We draw the PCB pattern on the PCB board with the help of a permanent marker.

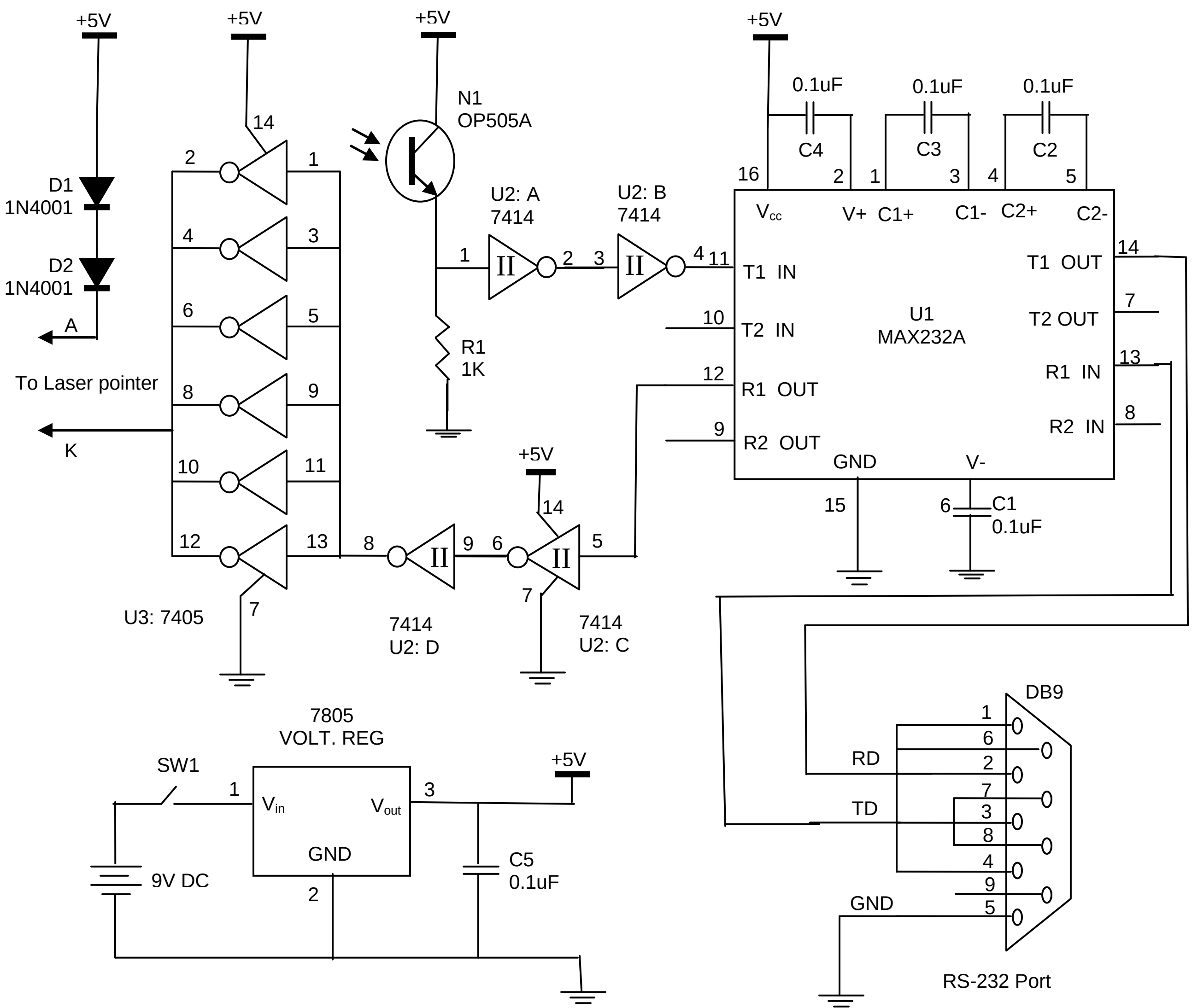


Figure 2: Circuit Diagram for Laser Transceiver.

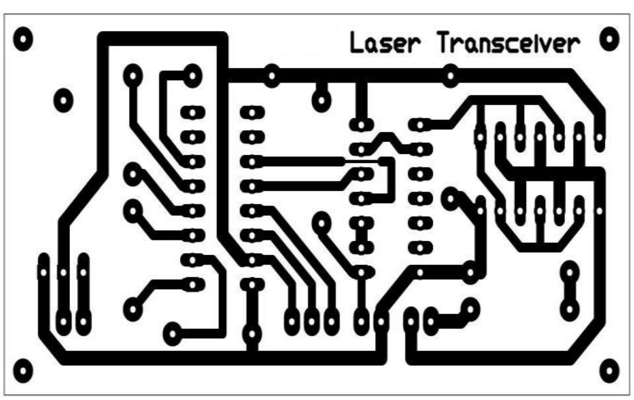


Figure 3: PCB Patterns for the Laser Transceiver.

We were careful about drawing the layout on the PCB. Next the board was placed in the Ferric Sulphate solution for 20 minutes. It cleared the un-shaded portion on the plate. The board was cleaned with a soft piece of cloth. Then it was ready for component implementation.

Next we mounted all the passive components; this included the resistors and capacitors. Then we mounted the diodes taking note of their polarity. Next we fitted the active components; this included all the ICs and the voltage regulator. The voltage regulator does not require a heat sink, so it was placed flush against the PCB. The

ICs were soldered with the help of IC bases to the PCB. We fitted the pin-headers to the appropriate holes on the PCB.

Now we started to attach the external components. These included the laser pointer, photo-transistor, battery connector, switch, and the DB-9 connector. To mount the photo-transistor, we simply drilled a snug hole in the side of the PCB. Particular care was taken with the orientation of the photo-transistor when clipping the pins and soldering wires to it.

Then we started to prepare the serial connector. We used a standard (female) DB-9 connector which is shown in Figure 4. DB-9 connectors are found on most IBM-PCs. The IBM PC serial port contains several data and handshake lines. We only used the Transmit Data (TD), Receive Data (RD) and common ground (GND) lines.

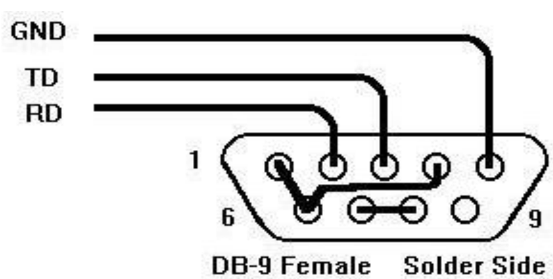


Figure 4: Connection Diagram of DB-9 (female) Connector for an IBM PC Compatible Computer.

Handshaking was done via software. In order to make the serial port active, we connected the Data Terminal Ready (DTR) line to the Data Set Ready (DSR) and Data Carrier Detect (DCD) lines. We also connected the Request To Send (RTS) line to the Clear To Send (CTS) line. This has the effect of tricking the serial port into thinking that it is always ready to receive and send data. These links were soldered inside the connector itself. Only 3 wires were required for the connection to the transceiver. We connected the three wires to the RD (pin 2), TD (pin 3) and GND (pin 5) lines of the connector. For the transmitter, we wired only the TD (pin 3) and GND (pin 5) lines.

Next we connected the black wire of the 9V battery clip to the PCB and the red wire to one contact on the switch. The other switch contact should then be wired to the PCB.

The last and most important component needed to be wired to the circuit is laser. We prepared the laser pointer since almost none have wires already hanging from them. The laser pointer requires 3 button cell batteries. First we removed the batteries carefully noting the polarity of the contacts.

For the laser pointer used in this design, in order to reach the negative contact deep inside the case, a thin wire was cut to the length of both batteries and a wire was soldered to the end of it. The wire was wrapped in electrical tape to insulate it from the aluminum case which formed the other contact. An exposed wire was taped to the insulation of the wire so that it made contact with the case when the rod was inserted. This made the positive contact. Figure 5 shows the orientation for correct wiring.

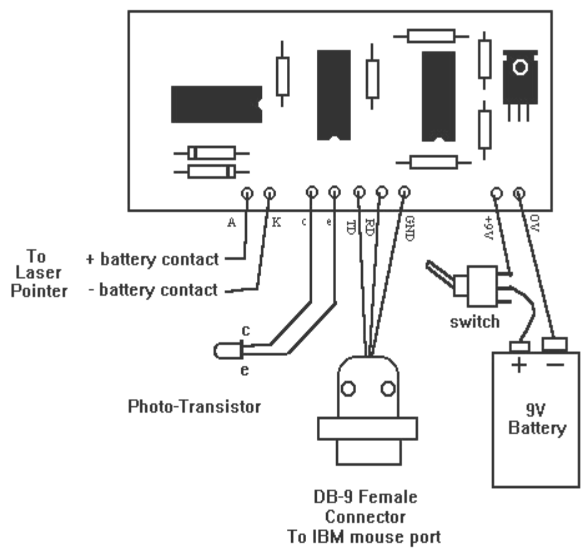
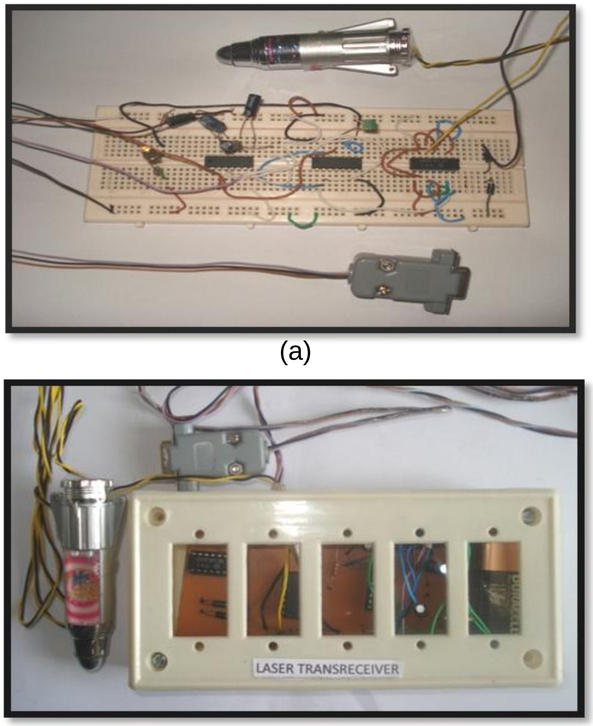


Figure 5: Connections to the External Components are shown here for Laser Transceiver.

Usually most laser pointers have a push- on switch to turn on the laser. This switch was simply taped down with electrical tape to hold it closed. Laser pointer was ready for use then. Again it is very important that the correct orientation of the wires from the laser pointer when connecting them to the PCB. Figure 6 shows the final implemented laser transceiver on bread board and PCB.



(a)

(b)

Figure 6: Implemented Laser Transceiver on: (a) Bread Board and (b) PCB.

RS-232 STANDARDS

RS-232 is a standard for transferring data in serial format. Information is sent in small packets of data called data frames. A data frame consists of the following sequence: a start bit, the actual data word, an optional parity bit and ends with one or two stop bits. The data word can be 7 or 8 bits long. RS-232 offers asynchronous communication with the combination of start and stop bits of being used to synchronize each data frame. The parity bit is used by the receiver to determine if an odd number of bits were corrupted during transmission.

There are two types of parity, odd and even. For example, if even parity is used the transmitter makes the parity bit a 1 anytime there is an odd number of 1's in the data word. This makes a total even number of bits in the data frame. If an odd number of bits arrive at the receiver then the data frame was corrupted.

The standard not only specifies the order of bits but also specifies the voltage levels used to send the data. Bipolar signaling is used in the RS-232 protocol to support long cabling with minimum noise. A logic 0 is represented by a positive voltage between +3VDC and +15VDC and a logic 1 is represented by a negative voltage between -3VDC and -15VDC.

COMPUTER PROGRAM

```
/***********************************
**
** Laser Pointer RS-232 Transceiver
** Data Transmitted @ 9600 bps
**
***********************************/

#include <dos.h>
#include <stdlib.h>
#include <conio.h>
#include <bios.h>
#include <stdio.h>

#define COM1       0
#define COM2       1
#define DATA_READY 0x100
#define TRUE       1
#define FALSE      0
#define ESC_KEY    '\x1b'

#define SETTINGS (_COM_9600 |
_COM_CHR8 | _COM_NOPARITY |
_COM_STOP1)

void clear_line(int line)

{
    int i;

    gotoxy(1,line);  // clear a
whole line
    for(i=0;i<80;i++)
        printf(" ");
}

int main(int argc, char *argv[])
{
 int in, out, status, done = FALSE;
int curs_rx=0,curs_ry=15,curs_tx=0,
curs_ty=4;
   int com_port=COM1;

   if (!(argc == 2 && (argv[1][0] ==
'2' || argv[1][0] == '1')))
   {
      printf("Usage: LASER
[1|2]\nwhere 1 = Com port 1\n
2 = Com port 2\n");
```

```
      exit(-1);
   }

   if (argv[1][0]=='2') // select
com port
      com_port = COM2;
else
      com_port = COM1;

   bioscom(_COM_INIT, SETTINGS,
com_port);    // Initialize serial
port
   clrscr();
   printf("       Laser Transceiver
Communicator \n");
clear_line(curs_ty);
          }
          gotoxy(curs_tx,curs_ty);
// goto correct screen location
          putch(in);
// print the character
          bioscom(_COM_SEND, in,
com_port); // output data
      }
   }
   clrscr();
   return (0);
printf("                Press [ESC]
to exit program\n");
printf("____________________________
Sent Data_______________________");
   gotoxy(1,13);

printf("____________________________
Recieved Data ___________________");

   while (!done) {
      status = bioscom(_COM_STATUS,
0, com_port);   // recieved data?
      if (status & DATA_READY)
         if ((out =
bioscom(_COM_RECEIVE, 0, com_port) &
0x7F) != 0)   {  // get data
            if (curs_rx < 78)
// move cursor
               curs_rx++;
            else {

                curs_rx = 1;
// at end of line
                if (curs_ry < 23)
                    curs_ry++;
                else
                    curs_ry = 15;

                clear_line(curs_ry);
            }
            gotoxy(curs_rx,curs_ry);
// goto correct screen location
            putch(out);
// print the character
         }

      if (kbhit())  {
          if ((in = getch()) ==
ESC_KEY) // check for ESC key
             done = TRUE;

          if(!in)
// read an extended character
              in = getch();

          if (curs_tx < 78)
// position cursor
              curs_tx++;
          else   {
              curs_tx = 1;
// at end of line
              if (curs_ty < 12)
                  curs_ty++;
              else
                  curs_ty = 4;

}
```

PERFORMANCE TEST

A PC is needed to test the circuit. A C compiler is also needed to compile it. The code was compiled using Turbo C3.1. To test the circuit, the DB-9 connector was plugged into the mouse port. Power to the circuit and the laser were switched on. Then we turned on the PC and made sure a mouse driver is not loaded. A TSR (Terminate and Stay Resident) mouse driver will interfere with the operation of the circuit. Now the pointer was pointed directly at the photo-transistor. Next we run the test program from a DOS prompt by typing LASER 1 and pressing the key. Where 1 represents the COM port number the circuit is connected to. Anything we typed on the keyboard appeared at the top of the screen as well as the bottom. The top part the screen displays the data sent out over the laser pointer while the bottom part shows the received data. To end the program the ESC key should be pressed.

To test communications between two computers simply we had to repeat the steps above for each computer except that the lasers are pointed towards the other transceiver. Over longer distances it was found that it was much easier to fix the laser and move the receiver in order to align them properly. Also depending on the laser pointer, beam intensity and beam spread vary which affect the distance over which reliable communication can be achieved. The laser transceiver is allowing any two computers with serial (RS-232) communication capability to communicate over 200 meters using a laser beam. No noise was detected in that range.

Computer Response

```
Laser Transceiver Communicator
Press [ESC] to exit program
Sent Data
---------------------------------------------
Khulna University of Engineering and
Technology


Received Data
---------------------------------------------
Khulna University of Engineering and
Technology
```

CONCLUSION

In this project, we designed and implemented a laser transceiver for data communication between two computers via free space optical link. In this design, MAX232 IC is used which posses a mean to convert the RS232 signal into TTL signal. A laser pointer is used as optical source for electrical to optical signal conversion at the transmitter section.

Optoelectronic conversion is performed by phototransistor at the receiver section. A set of magnifying glass is used for proper alignment and transmission of laser beam. A computer program is developed using Turbo C3.1 to interface the laser transceiver with computer. The laser transceiver allows any two computers with serial (RS-232) communication capability to communicate over 200 meters using a laser beam. In the future we have the intention to extend its application on different sectors of free space optical communication based technology.

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