WIRELESS TRANSMISSION OF TELEMETRY DATA VIA LASER BEAM

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Introduction

Interfacing diagnostics and monitoring equipment with computers plays a vital role when huge amounts of measurement data must be processed. One of the mostly widely spread interface is RS-232 (serial-port). However this interface has some limitations, like for example: the distance between terminals is limited to approximately 10 m, it has high sensitivity to electromagnetic noise, etc.
In order to overcome some of these limitations the device, laser transceiver, was developed together with Daumantas Ciplys (Vilnius University, Laboratory of Physical Acoustics, Lithuania) and Derek Weston (Realtime Control, Australia). The main reason of developing this device was that, to our knowledge, there're no similar devices available on the market.
The basic idea behind laser transceiver is to empower the user by making available an open system capable of solving real world data acquisition problems at very low cost. By documenting the design, anyone may build laser transceiver and write software for it. The entire design is open and available free of charge for non-profit use.

Wireless solution

Connecting measuring equipment to computer may present a great challenge when the wire must pass near equipment which generates strong electromagnetic fields or when there is a need of big distance between place of measurements and computer (for example when connecting anemometer) and/or when wiring is simply impossible due natural obstacles (for example when observer and object of study are separated by the river).
Here wireless technologies become handy. Until now only radio transceivers could do this kind of job. However radio transceivers are susceptible to electromagnetic noise and can interfere with delicate measurement equipment. Also radio FCC licensing presents a problem.
But recent advent of cheap laser diodes introduces radical changes to whole picture. Laser beam with its direct point-to-point-only connection opens new horizons. Open-air laser beam technology advantages over radio are following:

- Data channel is resistant to electromagnetic and radio noise;
- It does not interfere with other equipment and thus requires no FCC licensing.

Optimal laser light properties

In order the equipment could be easily mounted and adjusted the laser beam should be visible. Human eye's sensitivity depends on the light wavelength, as shown in figure 1 [1].

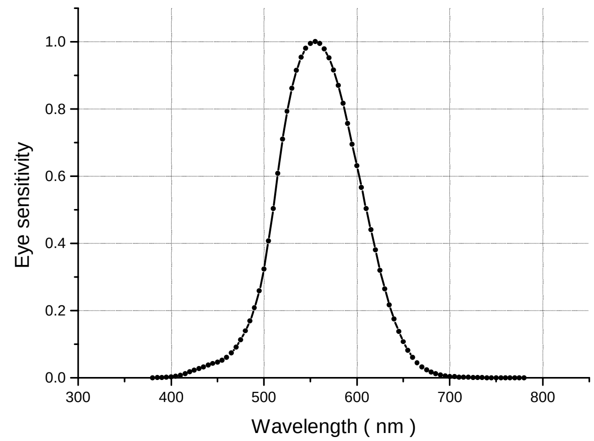

Figure 1. C.I.E. photopic luminous efficiency function

The second factor is that the beam should not be bright (and thus psychologically distractive), but still visible in order the equipment could be aligned. Thus, as seen from figure 1, the possible laser wavelength ranges are: 410-500 nm and 640-700 nm. The question is which one is better. Here the following points come into consideration:

- The atmosphere's light absorption in ultraviolet region is much greater than in infrared region;
- The shorter wavelength light has more injurious effect to biological objects;
- The availability and cost of coherent light sources in both regions – near UV laser technologies pose much more problems than near IR ones.

Unambiguously 640-700 nm region is a better choice.
The maximum laser power level is defined in IEC 825-1, International standard for the safe use of lasers [2]: "Class 3a lasers and laser systems are normally not hazardous when viewed momentarily with the naked eye, but they pose severe eye hazards when viewed through optical instruments (e.g., microscopes and binoculars). Class 3a lasers have power levels of 1-5 mW."
Thus we conclude that 640-700 nm 5 mW laser is the optimal choice. And most importantly, the price of laser diodes with needed characteristics has dropped dramatically in recent several years, making them easily affordable even for hobby enthusiasts.

Building laser transceiver

Unlike light emitting diodes (LEDs), laser diodes require much greater care in their drive electronics or else they will die – instantly. There is a maximum current, which must not be exceeded for even a microsecond - and this depends on the particular device as well as junction temperature. In other words, it is not sufficient in most cases to look up the specifications in a data book and just use a constant current power supply. This sensitivity to overcurrent is due to the very large amount of positive feedback, which is present when the laser diode is lasing. Note that the damage from improper drive is not only due to thermal effects (though overheating is also possible) but due to exceeding the maximum optical power density (E/M field gradients) at one of the end facets (mirrors) – and thus the nearly instantaneous nature of the risk. Closed loop regulation using optical feedback to stabilize beam power is usually implemented to compensate for device and temperature variations.

The following must be achieved to properly drive a laser diode and not ruin it in short order:

- Absolute current limiting. This includes immunity to power line transients as well as those that may occur during power-on and power-off cycling. The parameters of many electronic components like ICs are rarely specified during periods of changing input power. Special laser diode drive chips are available which meet these requirements but a common op-amp may not be suitable without extreme care in circuit design - if at all;
- Current regulation. Efficiency and optical power output of a laser diode goes up with decreasing temperature. This means that without optical feedback, a laser diode switched on and adjusted at room temperature will have reduced output once it warms up. Conversely, if the current is set up after the laser diode has warmed up, it will likely blow out the next time it is switched on at room temperature if there is no optical feedback based regulation.

The optical output of a laser diode also declines as it heats up. This is reversible as long as no actual thermal damage has taken place. However, facet damage due to exceeding the optical output specifications is permanent. The result may be an expensive LED or (possibly greatly) reduced laser emission.

Thus we see that special laser diode driving circuit must be implemented into laser transceiver.

For infrared data transmission across open space at ultrashort ranges (up to one meter) The Infrared Data Association (IrDA) has developed specifications [3]. For encoding RS-232 signals into optical impulses IrDA SIR modulation is used because it is mostly closely related to RS-232.

The encoding of up to 115.2 kbps (due to UART limitation) is such that '0' is represented by a optical pulse and '1' is represented by no pulse. The pulse is defined as occupying a nominal of 3/16th of a bit period to minimize power dissipation. The pulse width is inversely proportional to the rate of the data.

IrDA SIR modulation has a number of advantages over other modulation schemes:

- It is an established and well supported standard;
- The low (<20%) duty cycle of the modulated light minimizes power consumption, and results in lower operating temperature and longer component (in our case laser diode) life;
- It has high noise immunity to both sunlight and artificial light sources.

Laser transceiver basic function blocks, as outlined above, are shown in figure 2.

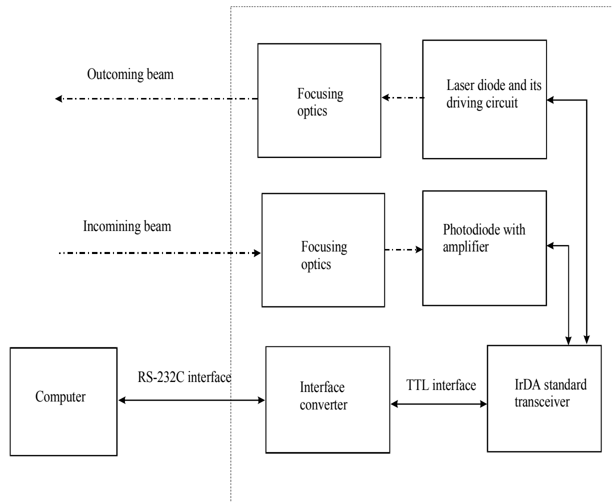

Figure 2. Laser transceiver basic function blocks

Laser transceiver circuit

Laser transceiver consists of two parts: laser diode driver subsection (figure 3) and IrDA transceiver subsection (figure 4).

The laser diode driver limits the current flow through the laser diode to an absolute maximum value, and also regulates it on the basis of the signal from the monitor photodiode integrated into the laser diode package. R8 limits the average current through the laser diode, which reduces laser output if the duty cycle is greater than 20%, the maximum required for IrDA SIR.

Key parts and their functions:

U1 – +5V voltage regulator;

U2 – Crystal Semiconductor’s multi-standard transceiver chip. This IC performs most of the complex, sensitive and critical functions required for an optical data link. It is a multi-standard device, and for the laser transceiver is configured to provide IrDA SIR modulation and demodulation.

In the receive path the CS8130-CP provides a high-gain PIN diode amplifier with compensation for ambient DC light, high and low pass filters, threshold detection and demodulation. Bit timing is regenerated. In the transmit path it provides modulation and an LED driver. Again, bit timing is regenerated.

U3 – RS-232 to TTL interface converter;

U4 – logical inverter;

CON2 – RS-232 port;

D2 – receiving photodiode;

D4…D8 – indicating LEDs;

L1 – transmitting laser diode.

Because CS8130-CP chip is multi-standard, it must be set to IrDA SIR standard before using the device. The software for configuring device can be written according to CS8130 data sheets or get from the author by email (mp@takas.lt) or can be downloaded at http://www.geocities.com/Athens/Cyprus/1288/ltransc.zip. Printed circuit board (PCB) Gerber RS-274D photo-plotter files also available.

One such device can be built for approximately 80 USD or less. For one data channel link two devices are needed. Laser transceiver could be used not only for connecting measurement equipment with computer, but also for connecting two computers as well (direct comm link).

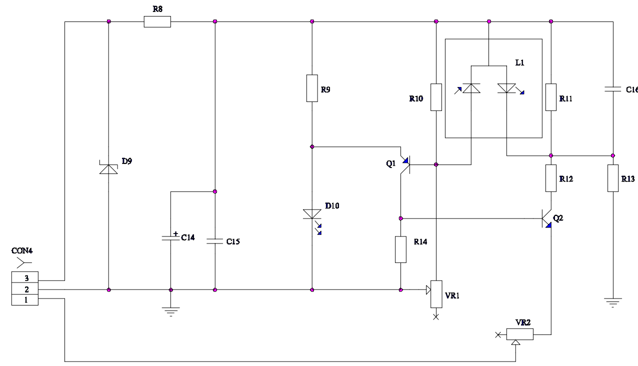

Figure 3. Laser diode driver subsection

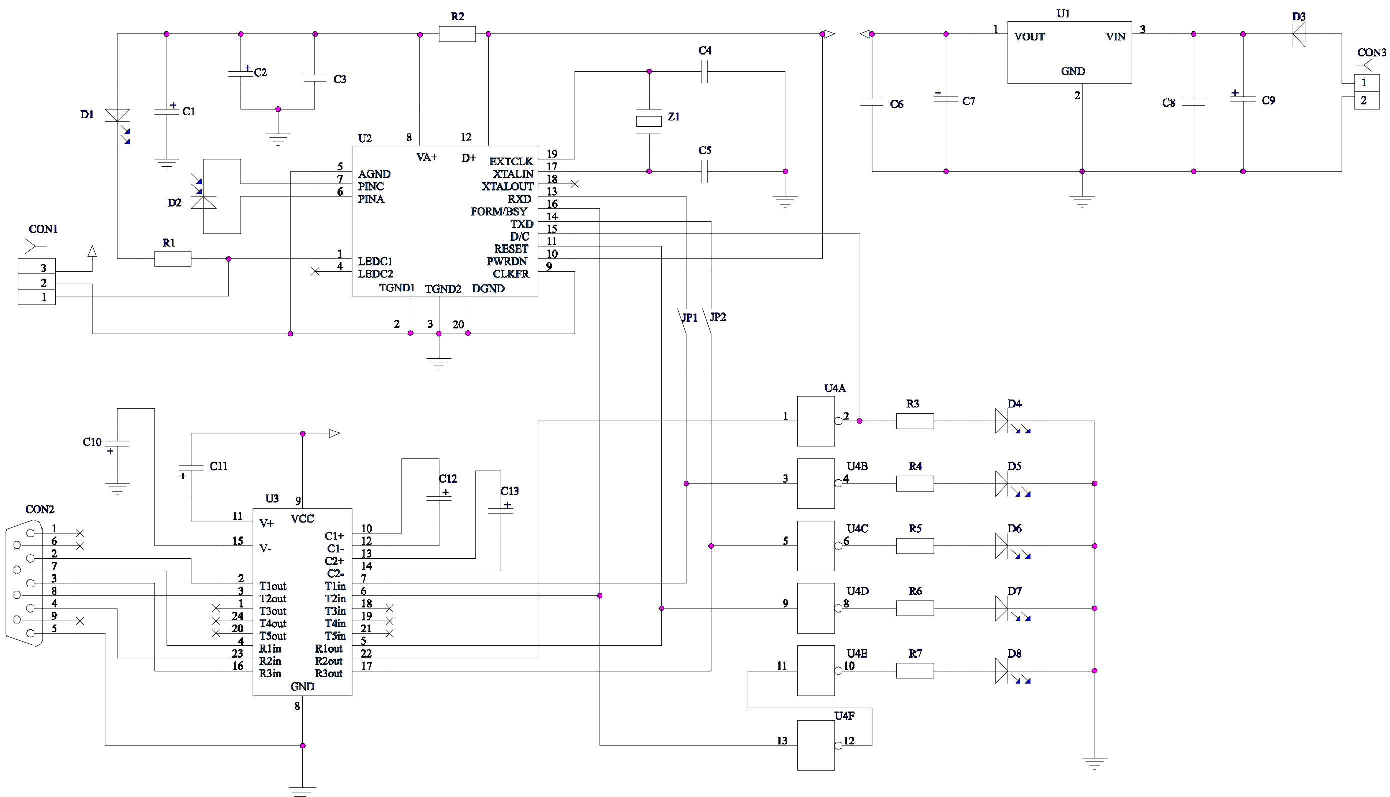

Figure 4. IrDA transceiver subsection

Table 1. Laser transceiver parts list

Part	Value	Quantity
C1	47 µF	1
C2, C7, C9	10 µF tantalum	3
C3, C6, C8	0,1 µF	3
C4, C5	18 pF	2
C10..C13	1 µF	4
C14	0,47 µF	1
C15	0,1 µF	1
C16	0,01 µF	1
D1	АЛ107Б	1
D2	SFH213 or ФД-256	1
D3	N4004	1
D4..D8	Red 3 mm	4
D9	5V1 250 mW	1
D10	Red 3 mm	1
L1	Sanyo DL-3149-053 670 nm 5 mW or Hitachi HL6720G 670 nm 5 mW	1
Q1	BC327	1
Q2	BC337	1
R1	5,5 Ω	1
R2	10 Ω	1
R3..R7	360 Ω	4
R8	180 Ω	1
R9, R14	1kΩ	1
R10	47 kΩ	1
R11	47 Ω	1
R12	1,5 Ω	1
R13	4,7 kΩ	1
U1	MC78L05ACP or L7805CV	1
U2	CS8130-CP EP	1
U3	HIN237 CP	1
U4	7404 or 155ЛН1	1
VR1	47 kΩ	1
VR2	100 Ω	1
Z1	3,6564 MHz	1

Conclusions

Laser transceiver, the device for wireless transfer of data has been developed. Laser beam technology has following advantages:

1. Increases the distance of RS-232 interface from approx. 10 m up to 500 m, so monitoring equipment can be placed at a significant distance and without wiring to computer;
2. Data channel is resistant to electromagnetic and radio noise;
3. It does not interfere with other equipment;
4. Requires no FCC licensing.

This low cost device is capable of 115,2 kb/s speed and distance of 500 m and is ideal for applications where round the clock monitoring is necessary.

References

1. Photopic Luminous Efficiency Function, C.I.E., 1988.
2. IEC 825-1, International standard for the safe use of lasers
3. IrDA Data Protocols, http://www.irda.org.
4. Crystal Semiconductor Corporation, CS8130 data sheet, June 1994.
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7. Gerald L. Ginsberg, Printed Circuits Design Featuring Computer-Aided Technologies, McGraw-Hill, Inc., 1991