Data transfer with laser pointer

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1. Introduction

Which developper is not fascinated by laser beams? Laser devices have a touch of science fiction and are still a bit mysterious, and even not completely harmless. Furthermore, only a few years ago they were too expensive for experiments. With the appearance of laser pointers, which are actually more kind of a toy than serious instrument, the situation has changed fundamental. Now also the technically interested developper is able to build up his own small laser show and interesting measuring instruments, but also realize data transfer over larger distances with laser beams. This application note gives some suggests for it. It will show that a BASIC-Tiger with a laser pointer can be used more versatile as it first seems.

In the application note we are going to transfer data from BASIC-Tiger through a laser beam to a PC, that could e.g. be used for a distant datalogging system or a alarm system.

2. Danger reference

Before we take a laser pointer in operation, we should seriously deal with the danger sources coming from such a device. In all experiments these dangers have to be excluded for us, but also for uninvolved thirds (especially children !!).

What makes laser pointers so dangerous? Characteristic for lasers beams is their extreme beam focus, which is their main advantage (large range, low loss). Additional the diode laser’s conversion of electrical to optical radiation energy is very effective. The high radiation intensity at the point of impact is on the other hand a danger for the human eye’s retina. Here this radiation is transformed into warmth and might damage the retina.

Because of that lasers are - following an European norm - divided in laser classes depending on their radiation strength. For laser pointers the classes 1 and 2 are considered harmless. Using lasers of classes 3A, 3B and 4 can lead to irreversible eye damage. For the use of laser pointers as optical pointer and in the non-professional segment devices of class 1 or 2 are completely sufficient. Table 1 shows this classification:

<table>
<thead>
<tr>
<th>Laser class</th>
<th>Output power</th>
<th>Description of laser classes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&lt; 25 µW</td>
<td>No known biological hazard. The light is shielded from any possible viewing by a person and the laser system is interlocked to prevent the laser from being on when exposed.</td>
</tr>
<tr>
<td>2</td>
<td>&lt; = 1 mW</td>
<td>Power up to 1 milliwatt. These lasers are not considered a optically dangerous device as the eye reflex will prevent any ocular damage. Caution labels (yellow) should be placed on the laser equipment. No known skin exposure hazard exist and no fire hazard exist.</td>
</tr>
</tbody>
</table>
Power output between 1 milliwatt and 5 milliwatt. These lasers can produce spot blindness under the right conditions and other possible eye injuries. Products that have a Class IIIa laser should have a laser emission indicator to tell when the laser is in operation. They should also have a DANGER label and output aperture label attached to the laser and/or equipment. A key operated power switch SHOULD be used to prevent unauthorized use. No known skin hazard or fire hazard exist.

Power output from 5 milliwatts to 500 milliwatts. These lasers are considered a definite eye hazard, particularly at the higher power levels, which WILL cause eye damage. These lasers MUST have a key switch to prevent unauthorized use, a laser emission indicator, a 3 to 5 second time delay after power is applied to allow the operator to move away from the beam path and a mechanical shutter to turn the beam off during use. Skin may be burned at the higher levels of power output as well as the flash point of some materials which could catch fire. A red DANGER label and aperture label MUST be affixed to the laser.

Power output >500 milliwatts. These CAN and WILL cause eye damage. The Class IV range CAN and WILL cause materials to burn on contact as well as skin and clothing to burn. These laser systems MUST have:
- A key lockout switch to prevent unauthorized use.
- Inter-locks to prevent the system from being used with the protective covers off.
- Emission indicators to show that the laser is in use.
- Mechanical shutters to block the beam. Red DANGER labels and aperture labels affixed to the laser.
- The reflected beam should be considered as dangerous as the primary beam.

<table>
<thead>
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<th>Classes</th>
<th>Power Output</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>3A</td>
<td>&gt;1 - 5 mW and ≤ 25 W/m²</td>
<td>Product can produce spot blindness under the right conditions and other possible eye injuries. Products that have a Class IIIa laser should have a laser emission indicator.</td>
</tr>
<tr>
<td>3B</td>
<td>5 – 500 mW</td>
<td>These lasers are considered a definite eye hazard, particularly at the higher power levels, which WILL cause eye damage. These lasers MUST have a key switch to prevent unauthorized use, a laser emission indicator, a 3 to 5 second time delay after power is applied, a mechanical shutter to turn the beam off during use.</td>
</tr>
<tr>
<td>4</td>
<td>&gt; 500 mW</td>
<td>These lasers CAN and WILL cause eye damage. The Class IV range CAN and WILL cause materials to burn on contact as well as skin and clothing to burn. These laser systems MUST have: A key lockout switch, inter-locks to prevent the system from being used with the protective covers off, emission indicators to show that the laser is in use, mechanical shutters to block the beam, red DANGER labels and aperture labels affixed to the laser. The reflected beam should be considered as dangerous as the primary beam.</td>
</tr>
</tbody>
</table>

Tab. 1  Diversion of laser into their class of danger

3. The laser pointer

There are laser pointers in various forms, in different price classes and with different danger potential. For our experiments we should choose a form which at least fulfills our local safety requirements, for that the laser power must be below 1 mW (maximum laser class 2, better class 1). Cheap offers should be avoided, they often have evidently more laser power, what gives better “effect“, but is also more dangerous.

When we have the piece, it might look like shown in picture 1. For our experiments we don’t necessarily have to take it apart, nevertheless you can see in picture 2 how its inside looks. You’ll notice three button cells which supply the circuit with 4.5 V, a small printed circuit board with power switch and only few electronic components as well as the laser diode, mostly pressed in a piece of brass. This brass block is usually placed at
the plus pole of the battery, the negative voltage is supplied through a small spring at the end of the printed circuit board. Who wants and has the confidence to do it, can now take apart the laser pointer and use only the pure electronic for his experiments. But it is better to leave the laser pointer like it is (as you can use it as pointer again if needed). For our works we only have to do the following modifications:

- Power switch to “on” permanently.
- Voltage supply has to come from outside (so not through button cells)

In the version with completely dismantled laser pointer you can easily solder on the cables for power supply and bridge the power switch (Pictures 3 and 4). But both can also be done “from outside”. The switch can be clamped with a fitting ring around the laser pointer, so that it is always on. The voltage is mechanically supplied through the “battery cap”. The housing and with it the cap itself are usually the plus pole, the minus pole is, isolated in a suitable form, lead through this cap and in most simple case soldered to the spring on the circuit board. Who wants it more comfortable builds a plastic cylinder with the same dimensions as the three stacked button cells with lead through isolated minus contact (Picture 5). This will press on the end of the spring when screwing on the cap and thus supplying the power.

Pic. 1 A typical laser pointer...  Pic. 2 ...and its”inside life”
So far for the modifications on the laser pointer. We now have a module which can be externally supplied through two wires, the original laser pointer is operated with 4.5 V, the current is ca. 20 - 30 mA. Just a few words about the function of the internal control circuit. It has to supply an exactly defined current on different battery charges, which is absolutely necessary for secure operation of the laser diode. You should never change anything here. The control circuit also ensures an operation with 5 V, what comes in handy for connecting the BASIC-Tiger. For protection of the sensitive laser diodes there are usually some capacitors in the control circuit. These mainly determine the speed of switching the laser beam on and off, that is relevant for the experiments to come. The faster these switching operations run in the respective laser pointer model, the higher is the maximum reachable “modulation frequency” of our chip, maybe a playground for experienced engineers.
We want to use serial interface SER1 of the BASIC-Tiger for data transfer. This suggests itself, as the entire software background for communication is already present. In our case it is a unidirectional data transfer from BASIC-Tiger to PC, so not a dialog like in a real communication, but a “monolog” of the BASIC-Tiger, which is only listened to by the PC. Nevertheless such a data one-way street can be very useful.

Now the hardware has to be adapted to the conditions of laser data transfer. On the BASIC-Tiger side we need a circuit that switches the laser pointer on and off in cycle of the serial data transmission. On the PC side the laser light has to be converted into appropriate electrical signals. As a special challenge we will try to get along without external voltage source at the PC, what in practice simplifies the use of laser data transfer significantly.

4. The receiver circuit

At the receiver input there is a voltage divider, consisting of a phototransistor and a resistor. Depending upon optical conditions the resistor has to be adjusted, so that on starting point of the voltage divider a potential near 0 V is measured when the laser beam hits the chip and a potential near 5 V when the laser beam is switched off. That must still be working under influence of other light sources, meaning the phototransistor has to be shielded from daylight and lamplight (use a longer pipe if necessary). From this point on it goes further on the inputs of a CD4093 (CMOS-NAND gate with Schmitt-Trigger characteristics). This switching circuit always produces steel flanks from the „soft“ low-high and high-low transitions. A second gate negates the level again. The output signal now only has to be converted to RS232 level for directly connection to the PC, we already know that from the Plug & Play Lab. The RS232 interface doesn’t need 0 V resp. 5 V, but -3 to -15 V resp. +3 to +15 V as logical level. A MAX232 chip does this for us, it generates from a +5 V source the needed positive and negative operating voltage by itself.

Exactly here a problem occurs. For operation of our data transfer we should have another voltage source on PC side. A trick helps us – we get +5 V from the signals of the PC’s serial interface. Both pins 4 and 7 of the 9-ch. SUB-D connector carry in PC’s receive mode ca. +11 V each, loadable with some mA. Both diodes only let through positive voltage, which is limited to +5 V with a 5 V Zener diode. Together with the 22 µ electrolytic capacitor that works as a small power supply, sufficient for operating the frontend level, CD4093 and MAX232. This gets a little bit problematic using a laptop and a Plug & Play Lab, here the RS232 interface might supply much less voltage, meaning the circuit possibly won’t function anymore. In that case the receiver really has to get an external 5 V supply! Picture 7 shows the entire receiver circuit.
5. The transmitter circuit

On the transmitter side there is not so much to do. We need a simple circuit which, depending on transmitter signal TxD1, switches the laser pointer on and off. Now there are BASIC-Tigers with TTL levels (the more simple models) and others with RS232 levels (with integrated RS232 converters) on the serial interfaces. Picture 8 shows a simple transistor circuit for the more universal RS232 levels. With it both BASIC-Tiger with RS232 converter and Plug & Play Lab can swich the laser pointer. For BASIC-Tigers without RS232 converter a further transistor level has to be added, which then inverts the signal. Als this is directly installed on a 9-ch. SUB-D plug and connected to the Plug & Play Lab.

Pic. 8  Transmitter circuit
6. Operation

Once receiver and transmitter are built up, some tests are useful in the beginning.

- First on transmitter side it should be checked if the laser can be switched on and off. For this we use the program “LASER01.TIG”, where characters are slowly output through serial interface SER1. Here the laser beam should flicker visibly. In transmission breaks the laser pointer should be switched off.

- After that the receiver part is connected to the PC. The PC program TERMINAL.EXE is used to set the port parameters (COM1 to COM4, baudrate, data bits, start bits, stop bits etc.). The program is part of Windows 3.1 and can also be run under Windows 95/98. After starting the program you can set all relevant parameters with -> Settings -> Data transfer. Picture 9 shows a screen copy, 300 baud as data transmission rate are best suitable for first tests. With “OK“ the entered values are applied and the program waits for data on the choosen COM port of the PC. Next the “flickering” laser beam is pointed at the phototransistor of the receiver. If everything is working fine, the terminal program should now constantly give out text.

- Alternative to the test with TERMINAL.EXE on the PC you can also check the communication only with the Plug & Play Lab. Therefore the receiver circuit has to be connected to SER0. As hardware an adaptor is needed, because for PC operation our receiver is equiped with a 9-ch. SUB-D jack, but likewise is the Plug & Play Lab. The adaptor consists of two 9-ch. SUB-D plugs, which are wired through, except for pins 2 and 3, which are crossed. Additionally on operation with the Plug & Play Lab the supply voltage +5 V has to be connected externally to our receiver circuit! The above mentioned program LASER01.TIG not only controls the transmitter through SER1, but also receives data through SER0 und shows them on the display.

Pic. 9 Setting the serial port on PC
Pic. 10 ...it works, the text was transmitted
If the tests with 300 baud were successful, you can now step by step increase the data rate and approach the maximum transfer frequency (don’t forget, the baud rate has to be changed in both programs!).

In every-day operation transmitter and receiver have to be well aligned to each other and shielded from other light sources. Because of the good visibility of the laser point this is fairly easy even for larger distances, in contrast to e.g. infrared light barriers. Depending upon optical conditions it might make sense to use a collecting lens for an even better bundling on receiver side. For stable adjustment of the transmitter the spherical heads known from professional photographic have prooved to be worthwhile.

7. BASIC-Tiger software

For testing the transmission a modified form of the application program SER1_DEM.TIG, which comes with Tiger-BASIC 5.0, was used and renamed LASER01.TIG. The program source code comes as file with this application note.

Have fun with your experiments!