Building an IR Lap Counter

Once I had my layout where I wanted it, complete w/ custom power base and driver stations I next turned my attention to a computerized lap counter. I did not want a light bridge; I did not want dead strips. IR sensors are the only option for me. I was waiting until I was ready to go ahead and purchase an IR sensor track from for Brent Carlson, and now I see he is on a hiatus. I am very disappointed; it looks like a very nice product. In response to my desire to get this taken care of, I decided to build my own IR hardware. I view this as an opportunity to learn a bit more about electronics. My most ambitious "electronics" project to date was my 15V/5A variable power supply and the extent of the electronics was the regulating circuit.

Now that I've decided to build an IR lap counter, I want to document the process. My goal is to make this clear enough so that anyone can be successful, even as a first electronics project.

What I hope to document is the process of understanding basic schematics downloaded from a web site. Reading this you should have the details clarified and the construction simplified. You will be prepared with the necessary information to build an IR lap-timing device, with the confidence that it will work because you will understand how it works.

Basics Needs

- Basic soldering skills and equipment (iron, rosin core solder, wet sponge, 3rd hand etc..).
- 5v power for testing. I got myself a D-link 5v 2.5a wall wart for $4.
- A multi-meter is always helpful.
- -Ability to read basic schematics.
- OPTIONAL – A device capable of measuring frequency. This is the one thing that is not cheap if you do not have any access to one. I felt I needed it because I was uncertain of my translations of the schematics, you should not have this same uncertainty but it will help in tuning the emitter and output signal.

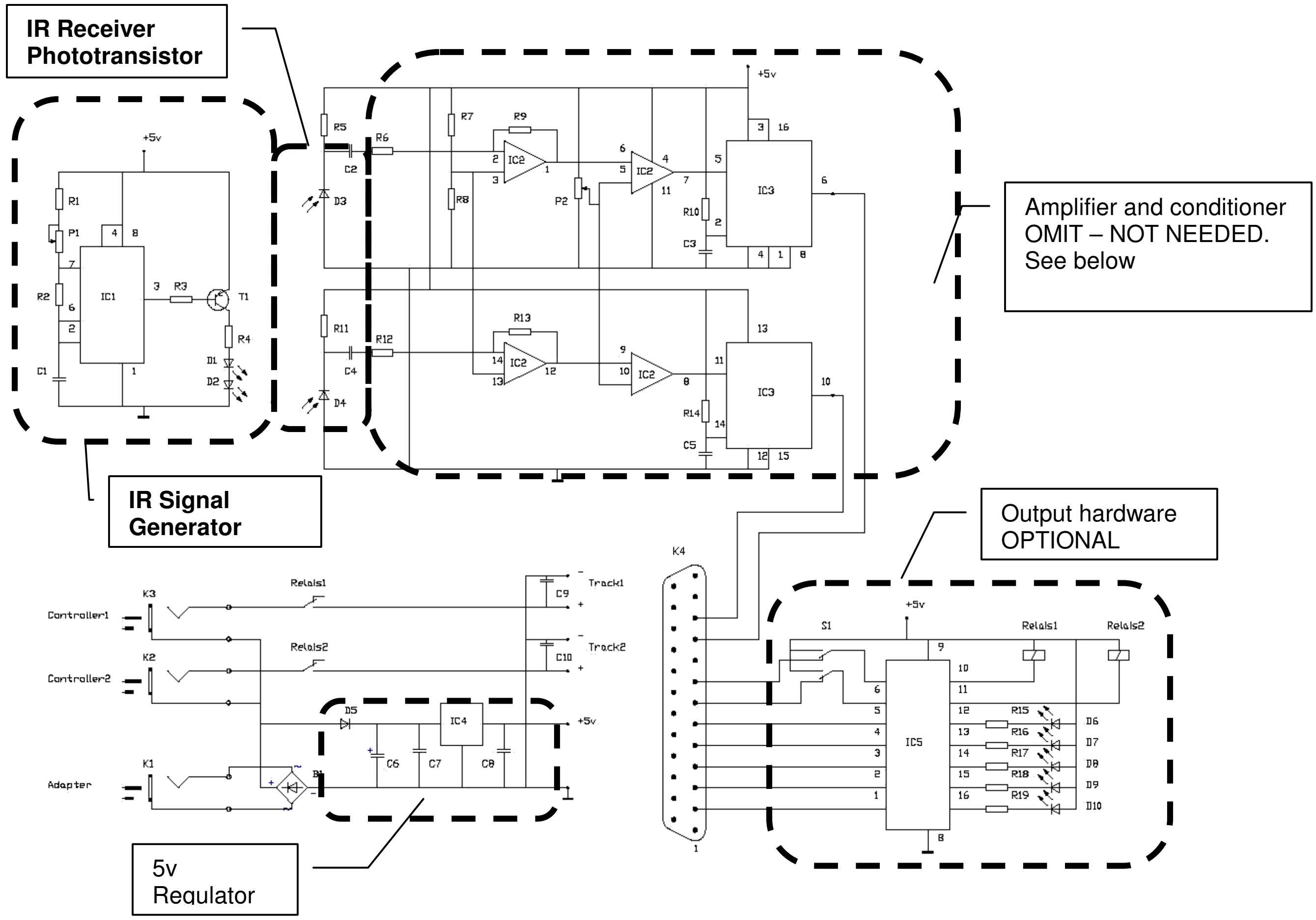
- Lets take a moment and mention at some items in the schematic that we will ignore and why.
  - Controller jacks these are assumed to be in place
  - Bridge rectifier (that diamond in the lower left hand corner). The assumption is that you have at least 1 spare amp of 7-30 V DC available from your track.

The Source Schematic

I based the hardware on NiVaRo's timing hardware as described on Mario's Slot Race Manager site. While it likely makes sense to an electronics specialist, I started out with this schematic looking foreign to me (even the Dutch "manual" link is busted), but it comes with a comprehensive part list (more on that later) and the pins are numbered on the schematic, so I was confident that it can be figured out.

Also, the focus on this effort is on the practical, I am taking a black box approach. To keep it simple we just need to know enough about the function of and interface to each component. Understanding the details of what goes on inside them is not necessarily needed in order build from these instructions. I encourage anyone interested in the specifics to research these components and look up their datasheets. It really isn't too complicated

Conceptually, I broke the electronics into 4 sub systems; here is the schematic for reference:



Knowing the function of resistors, capacitors, pots and diodes, relays and switches, it was clear that I needed to focus the effort on understanding the purpose of all those pesky ICs. The place to start is the documentation that does exist. I downloaded the spec datasheets for all five ICs and this is what I have determined from them:

5V Regulator (IC4):

IC 4 is a 5V regulator; and will supply a steady 5v to the electronics regardless of the track voltage (7v DC min). This is a small and simple circuit intended to deliver regulated 5V power to all the electronics. Where the schematics note +5, it is a connection to the output of this regulating circuit. The ground symbol is also connected to the regulator ground/common (-). This setup is wired to run off of the track's power. The electronics should draw less than 1A; I do not anticipate any power supply issues as I have a 5 Amp supply for my 2-lane setup.

This particular circuit was (and can be) assembled without question or issue, but as you can see I need to work on my board layout skills. I am mounting this system, on the track power distribution board; connections to the electronics are made through barrier terminal blocks.

IR Signal generator (IC1):

This device uses IC1, an LM555 timer to drive a PNP transistor (T1). The effect of this is that the circuit generates a pulse signal powerful enough to drive a couple of IR emitters (D1 and D2). They pulse at a frequency settable by the 10Kohm multi-turn trim pot (P1). As I got into this project, I assumed, that this trim pot would be used to tune the signal to the receiver. Additional information will be added, as it is determined to be useful.

IR Signal Receiver Amplifier (IC2) and Conditioner (IC3):

The IR receivers (D3 and D4) pick up the IR signal and respond by sending a signal through a series of Op amps and oscillators. I would go ahead and sound ignorant as I attempt to explain more, but it us not necessary. In my experiments, I found a way to remove all of this, except the IR receivers (phototransistors).

I took some input that I received to heart and looked for a way of simplifying and reducing the cost of the system. Phototransistors react to IR by converting it to voltage. I found that this minute voltage generated by the IT phototransistor did the following:

1. It did not adversely affect my LPT port.
2. The change in the induced voltage states (blocked/unblocked by guide) was sufficient for SRM to interpret it as a resistance change thus trigger the software very reliably.

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<u>Recap:</u>
Whew… that's a lot so far. Let us recap what we have.

We use a simple 5v voltage regulator (IC4) to create power for our electronics. The IR Signal generator transmits a high frequency IR signal through the IR emitter to the IR phototransistors. The LPT port reads this directly. This schematic uses pins 10 and 11 of a parallel port interface to trigger the software. That's all that is needed for reliable and functioning timing hardware. The rest of the circuitry is bells and whistles.

<u>Output Hardware (IC5):</u>
IC5 is a device that provides 7 Darlington Arrays (ULN2003). Who is Darlington, I do not know. What I have learned is that this curiously named bit of silicon is that it is used to drive loads. This unit has seven load drivers. The schematic we have based this design on is configured accept 7 inputs from the software to light up 4 red LEDs and one green simultaneously tripping the two relays providing power to the track. This appears to be the simplest to understand and most user configurable circuit in this project. I am entering into the effort with the least clarity on how I want it to work for me.

I am in the process of pulling together the complete output package. I bit of a little more than I can chew right now, this part will be discussed in another revision.

Design

Now that we understand the basic functioning of the sub-systems, we can begin to figure out how to put it together and have it work on our first attempt. I am not an expert so I want to avoid mistakes and chances. There are two key functions in design of this nature, one is layout and the other is procurement. Layout deals with how the components lay out on the board, how the board looks in regards to the etched conductors. Layout is really about the fit of all the components while being properly connected. Procurement is about obtaining the component parts. Anyone who has built electronics can attest to the fact that it sometimes turns into a treasure hunt. For this project I had to go to 3 different suppliers (Radio Shack, BG Micro and Surplus Gizmos) to obtain the right components. Shop around for price and availability.

<u>Procurement</u>
First things first, lets get the things that we need in order to build our device. This is the procurement part. Overall you could do this project for about $30. It might cost a little more if you need a few of the basics. $30 will cover it for most of us. A frugal shopper can probably do it for less than $20. Watch out for those shipping charges. Remember multiple shipments drive the project cost up. Also, Radio Shack is expensive I try to shop to minimize my purchases there. The electronics are great and they often have things I can't find anywhere else (in my timeframe). They always get my business, but the price is high.

This is a good time to look at the Bill of Materials, AKA the parts list.

Below is a modified BOM, with additional clarity added.
I spent some time translating some of the values.
Remember (.001m=1u=1000n=1000000p)

ITEM	Value	Notes	Est Cost (USD)
R1	1k Ohm		Purchased in a 500-resistor variety pack for $14. Prices for these this can be found as low as $10. Else assume 10 cents each.
R2	470 Ohm		
R3	330 Ohm		
R4	15 Ohm		
P1	10k multi-turn resistor	Board-mount trim pot.	$2.00
C1	10n (0.01 uF)		$1.30
C7,8	100n (0.1 uF)	5V regulator	$2.60
C6	1000uF/35v	5V regulator	$1.50
D1,2	IR LED	Emitter (radio shack tinted)	$3.00
D3,4	IR Phototransistor	Receiver (radio shack clear)	$3.00
D5	1N4001	Regulator protection diode	0.75
T1	BD138	Emitter Driver, PNP transistor	$1.50
IC1	LM555	Emitter timer, Buy a board mount socket	$1.00
IC4	7805	5V Voltage regulator	$0.75
K4	Sub-D 25 male	This will be connected to a parallel printer extension cable.	1.20

Additional Items;

Printed Circuit Board		Radio Shack	$4.00
Project Box		Radio Shack	5.00

All the parts cost $28 ($35 with shipping). A careful and smart shopper can easily do this for less than $20. If I would do this again, I would look for different IR transistor sets. I am finding them for $0.50 each now that I am looking deeper. I paid 6 bucks for my haste…. Hmmm no I am not a smart shopper. Not the first time around. The parts for the regulator cost about $4-5. If you can get a 5V wall wart for $4, it pays to do that.

Layout

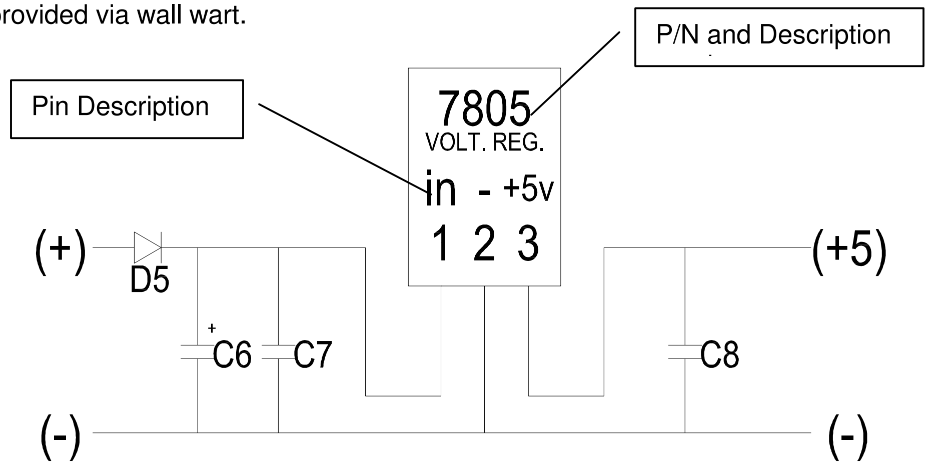
Now that we have the components defined. Let us look closer at the “layout.” I do not feel that the source schematic has been simplified enough to build to. For me to build the device, I needed to understand how it went together. I needed to come up with my own set of schematics. Below are three schematics that I felt I needed to understand and successfully build the timing device. I tried to represent the relative pin locations on the chips and labeled them for easier reference.

These schematics begin to approach an appearance of something you can build. For me, these are just a step in my understanding and building process. I used these to assemble the breadboard (pictures below) to figure out if I understand the electrical connections correctly and test a prototype circuit. I will use information garnered from this experience to layout the components on an etched circuit board.

Additional detail and instructions on building the timer is below. This section mostly provides the “engineering/build” schematics

Legend	
C=Capacitor R=Resistor D=Diode	IC=Integrated Circuit P=Trim Pot (Variable resistor) T=Transistor

The regulating circuit can almost be translated literally with components and wire. There was no need for me to breadboard this. Also this component was finished before I decided to document this process. There is very little build information and for the most part it is assumed you will have this part covered or have the 5v provided via wall wart.

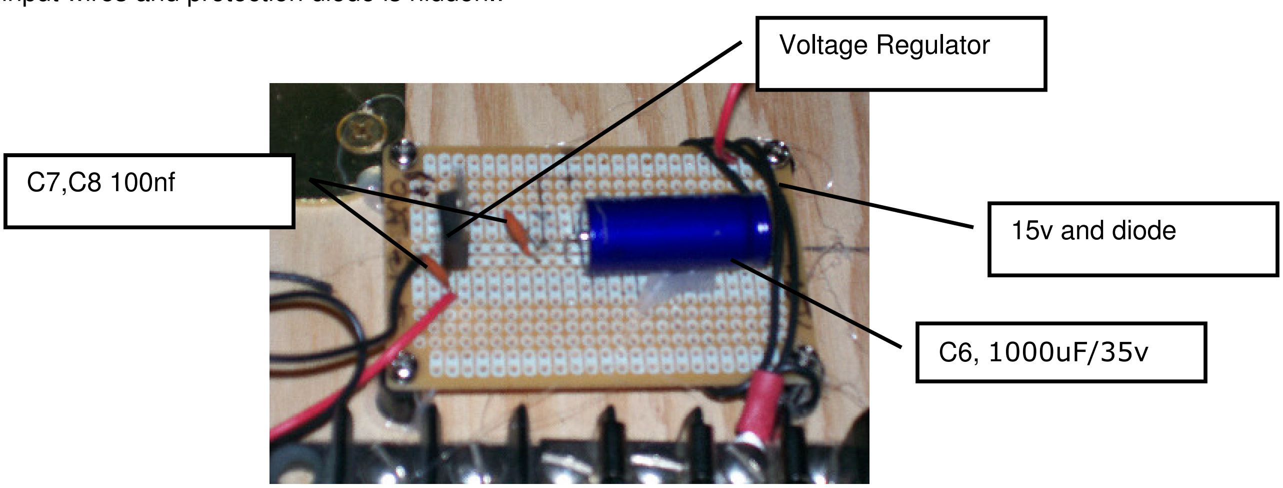


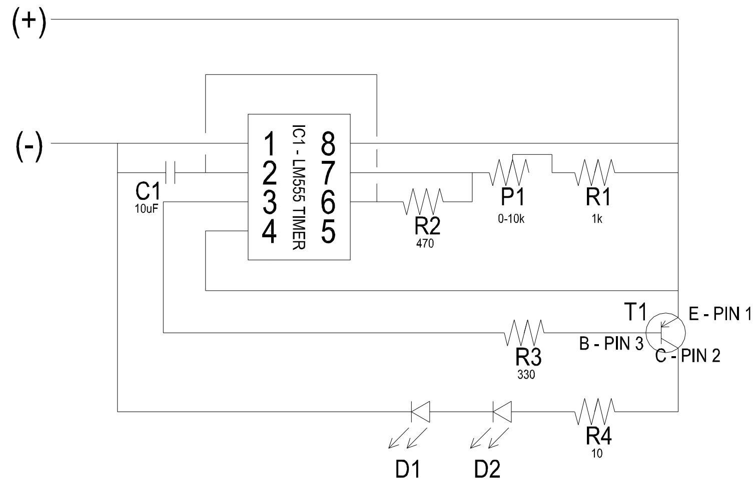
VOLTAGE REGULATING CIRCUIT (IC-4)

BOM

IC4	7805
C6	1000uF/35v, polarized capacitor (electrolytic)
C7,8	100nf (0.1 uF)
D5	1N4001

Here is a picture of a completed regulator, I wrapped wire around the board for my wire management, so the input wires and protection diode is hidden.:





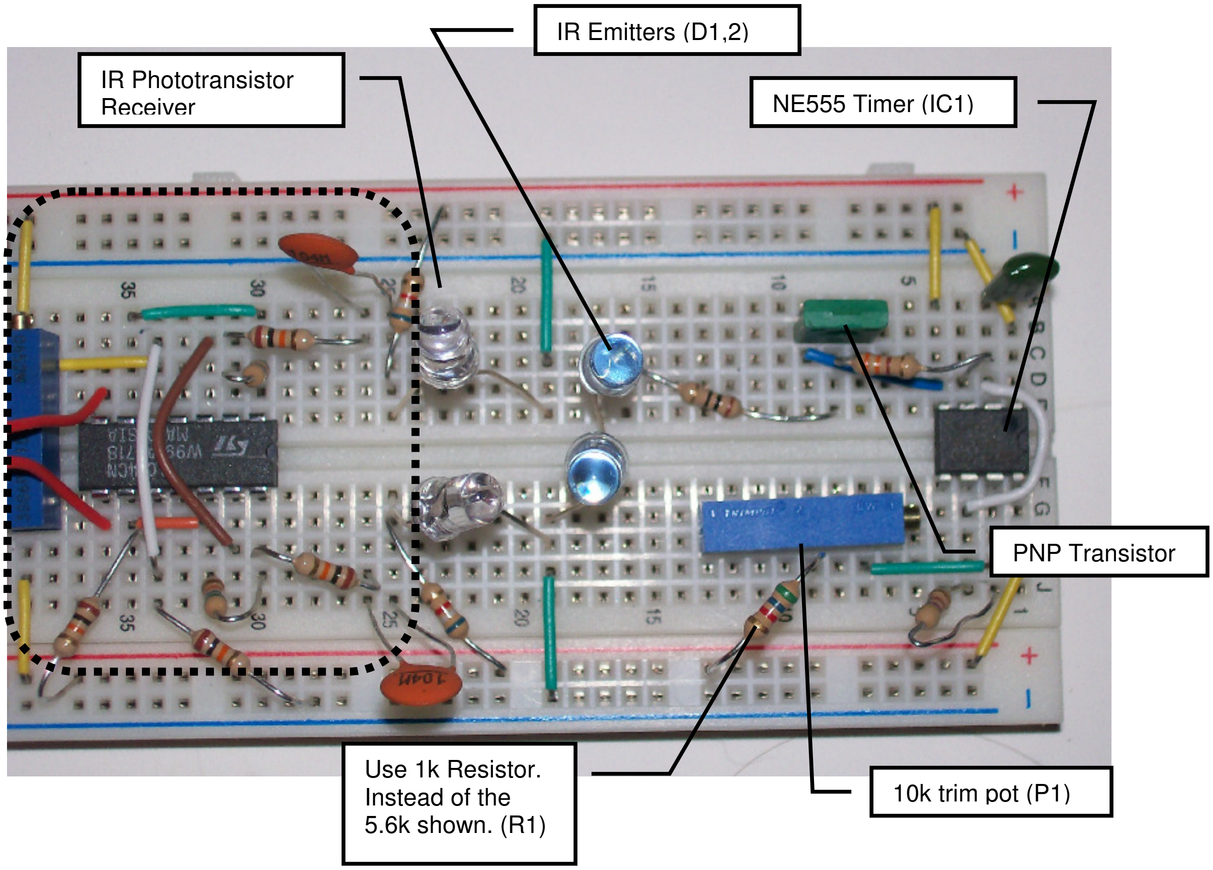
IR TRANSMITTER

BOM

IC1	LM555
C1	.01uF
R1	1k Ohm
R2	470 Ohm
R3	330 Ohm
R4	12 Ohm
P1	10K Ohm Multi Turn Trim Pot
T1	PNP Transistor, BD138
D1,2	IR Emitters (LCD)

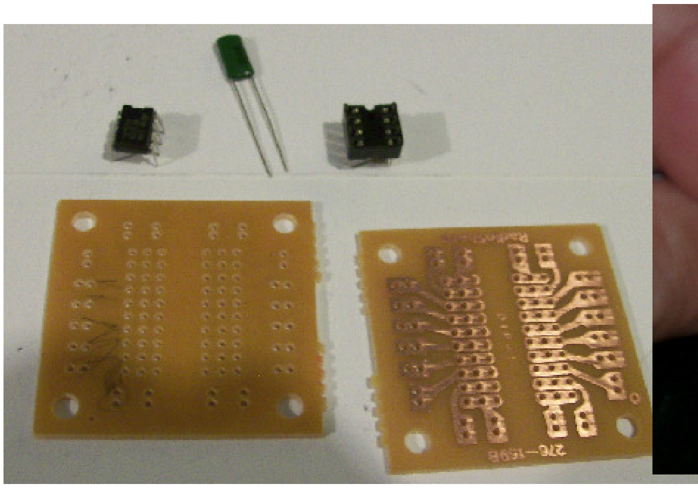
I would like to explain my thoughts about this piece of circuitry. When I discovered that the receivers required only to be plugged into the computer's parallel port I wondered about the necessity of this piece of the hardware.

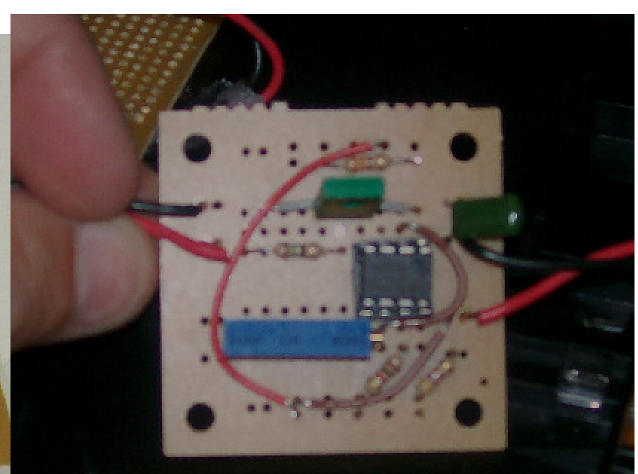
1. This component is a very accurate high frequency pulse generator.
2. Diodes are limited by what is called forward voltage. Exceeding this will get more brightness out of the LED, but it will burn it out. In practice you do not want to exceed the forward voltage. However pulsed LEDs can withstand a greater voltage with out damage thus is brighter.
3. While I haven't tried it, I have is no reason to believe that a LED emitter with a resistor wouldn't suffice.
4. I currently believe that he pulsed signal is superior to a lower intensity continuous one.



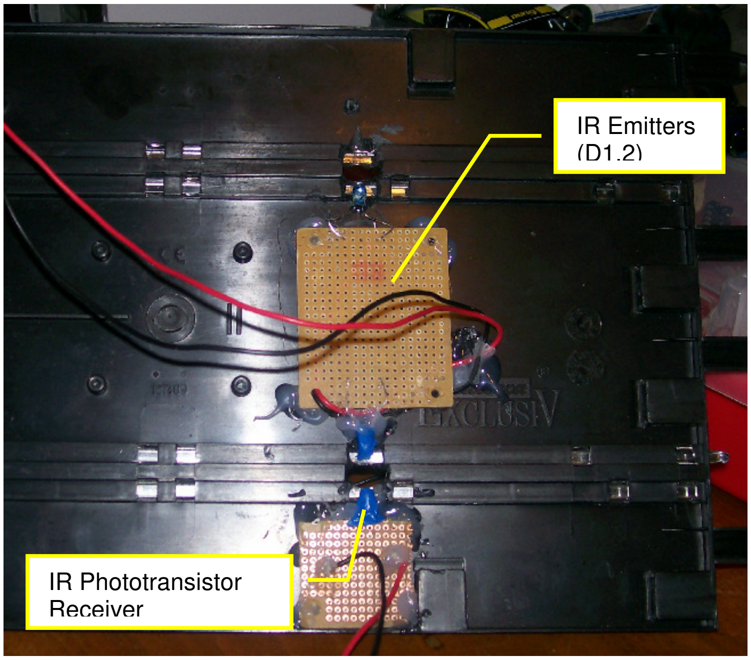
Above is a picture of the breadboard that I created. I was able to get this working fairly easily in the mock-up. I initially used LEDs to see if the circuit was working. Then I found out that the CCD in electronic cameras is sensitive to the wavelength of the IR emitter. Use real-time viewing to see the bluish glow emitted from the IR sensor. What we see in the picture is the reflection of the camera flash.

Below is a picture of the finished circuit board. I butchered my first attempt to solder the emitter circuit together. I decided the straight patterned printed board I was using did not work, layout wise. I needed one tailored to chip layout





I also learned that it would be better to attach the LEDs remotely, instead of on the board with the other components of the circuit. Lastly do yourself a favor and use board-mounted sockets for your ICs. The heat from the soldering iron could damage the chip.



Below you can see the remotely mounted emitter diodes. I use circuit boards to mount the LEDs, It creates a means for mounting and securing the diodes to the track without damaging the diodes themselves.

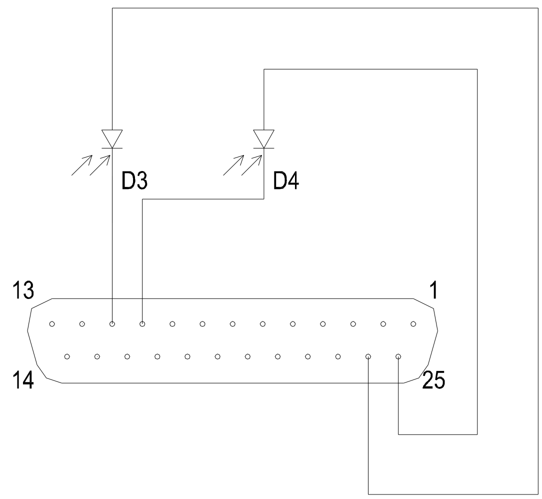
The blue is duct tape, I discovered that the Scaley guides are very shallow and poses problems with sensors not mounted sufficiently close to the track surface.

Polarity

One thing to remember is that LEDs have polarity. The short leg of an emitter must be connected (closest) to the COM/GND/(-).

Also keep in mind that that he phototransistor is the OPPOSITE of a emitter and the short leg gets attached to the + side of things.

During my testing I discovered a way keep the receiving circuit simple. I found that by directly connecting the receivers to the LPT port SRM reads everything without issue.



IR RECEIVER