Optical Sensor Interface for AFX Digital LED Timer/Counter

by George Warner, Jan. 2003
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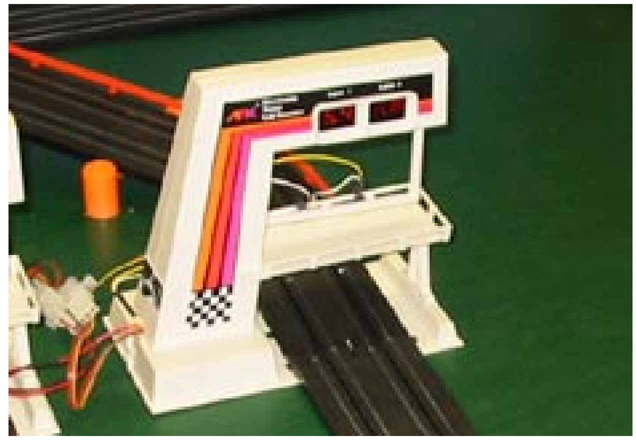


Abstract
This paper presents a design for an optical sensor interface to an AFX Digital LED Timer/Counter. The goal of the design is to create a highly reliable circuit which can be made from readily available parts and run off of a single wall power adapter ("wall wart"). All the circuitry must fit inside the base of the timer/counter where the batteries are normally housed. While this circuit is being designed specifically for the Aurora LED Timer/Counter, the design is generic by nature such that it can be adapted for use with other lap counter systems.

Introduction
In the late 1970's, Aurora produced an AFX Electronic Lap Counter/Timer. The device featured two sets of LED displays to display lap time from 0.1 to 99 seconds or lap counts from 0 to 99. The counter/timer appeared in two different colors: white for AFX and blue for Ultra 5. The elegant and compact system makes an attractive and useful addition to virtually any home track.

Many of these AFX LED counter/timers can still be found today. They were even available from REH, a distributor of Aurora new old stock, as recently as a couple years ago until their supply was exhausted. The counter/timer utilized a "trip track," a dead section of Aurora AFX track which detected cars when they passed over it. Many of the lap counters found today are missing the trip track. Plus, many slot enthusiasts no longer use the Aurora AFX track. Furthermore, there is a better way to detect cars now -- optical sensors.

Design Philosophy
The goal was to make a virtually fool-proof circuit with the highest possible reliability and from readily available parts.

There is nothing more frustrating than an unreliable lap counter. By some standards, this circuit may appear overdesigned. For some applications, you could probably omit some of the circuitry and still have a decent optical interface. But, to meet the requirements of the AFX LED counter/timer and to meet the desired high reliability requirements, this design goes the full distance. The added circuitry doesn't add much extra cost or effort to the circuit construction.

The circuits being referred to, specifically, are the voltage regulator and the "one shot" "pulse stretcher."

Others have described experiences of "cross talk" or false detections when operating two of these lap counter/timers off of a single wall supply. One solution could have been simply to use two wall supplies. Instead, this design provides a voltage regulator for each lap counter. These regulators provide a solid 9 volts for the optical interface circuit as well at the lap counter/timer.

Through testing of the AFX timers, it has been determined that they are only about 95% reliable in detecting today's fastest cars which create an extremely short pulse when passing over the optical sensor. Therefore, a "one shot" was added to the circuit design. The device employed is a 556 (contains dual 555's) timer. This device can detect the smallest pulses and then output a pulse of fixed width. You could think of this circuit as a "pulse stretcher." A narrow pulse goes in; a wide pulse comes out. Not only does it stretch the pulse; it cleans it up. Glitches and noise on the signal are eliminated.

Other circuit considerations will be described throughout the text.

Parts

All of the parts utilized are available from Radio Shack. One of the design goals was to use readily available parts.

Qty.	RS Part No.	Description	Cost each
		Voltage Regulator Circuit	
1	276-1778	LM317T Adj. Voltage Regulator	
1		0.047 uF / 25 V Ceramic Capacitor	
1		1 uF / 50 V Electrolytic Capacitor	
1		240 Ω Resistor	
1		1500 Ω Resistor	
		Comparator Circuits	
1	276-038	1458 Dual Op-Amp	0.99
2		10 kΩ Resistor	
2		47 kΩ Resistor	
4		100 kΩ Resistor	
2		10 uF / 50 V Electrolytic Capacitor	
		One Shot Circuits	
1	276-1728	556 Dual Timer	1.59
2		0.01 uF / 25 V Ceramic Capacitor	
2		100 kΩ Resistor	
2		1 uF / 50 V Electrolytic Capacitor	
		Driver Circuits	
2		2N2222 Transistor	
2		1500 Ω Resistor	
		Overhead LED Supply Circuit	
1	271-152A	100 Ω / 1 watt Resistor	0.49
		Miscellaneous Parts	
1	276-150A	General-Purpose IC PC Board	
1	273-1612A	Power Adapter, 9 Volts DC, 1200 mA	
		Wire for leads and jumpers	
2	276-145A	NPN Silicon Infrared Phototransistor	0.99
2	276-143C	High-Output Infrared LED	1.69

Bill of Material

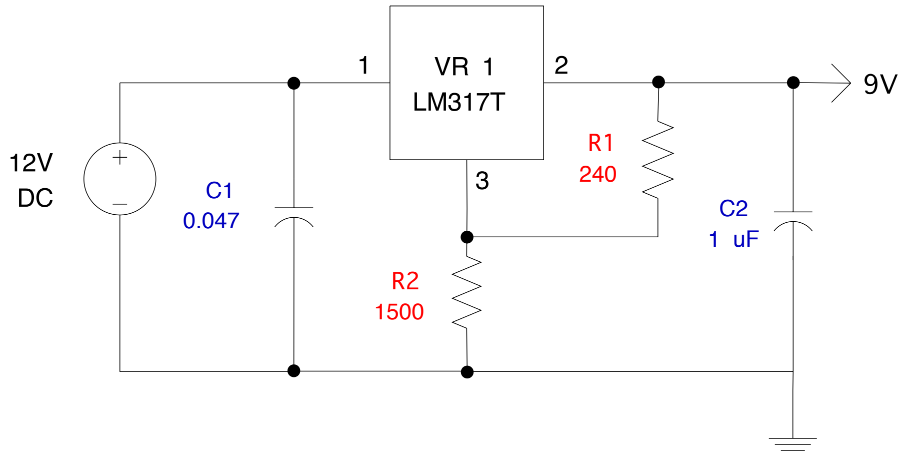
The interface circuit is designed for 9 volt operation. Thus, some higher voltage must be regulated down to the required 9 volts. To minimize the heat that will be dissipated by the voltage regulator, an input voltage that is not much greater than 9 volts must be chosen. The Radio Shack 9 volt supply listed actually supplies about 11 to 12 volts. It only needs to be regulated down by 2 or 3 volts. This helps keep the regulator from getting excessively hot. Thus, it is perfect for this application. If some other supply is used, care should be taken to avoid overheating the voltage regulator. After all, this regulator will ultimately be housed in the base of the timer/counter where there is no ventilation to facilitate heat dissipation.

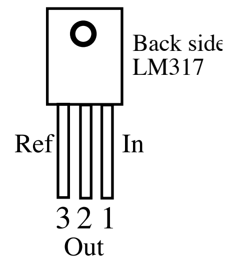
Components used for the interface

Construction of the interface

This document will proceed with the construction of the circuit stage by stage.

1) The Regulator Circuit

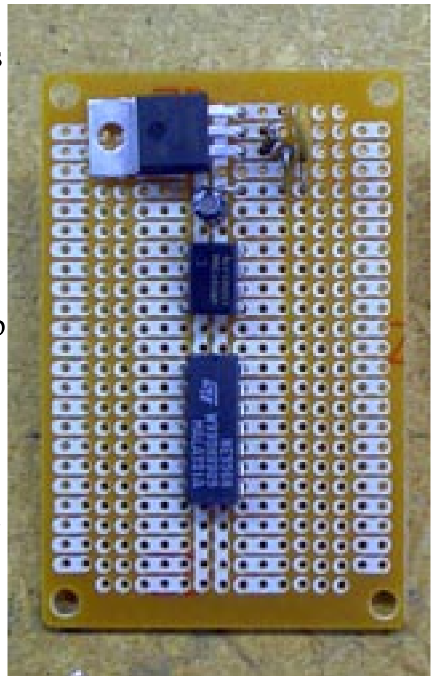


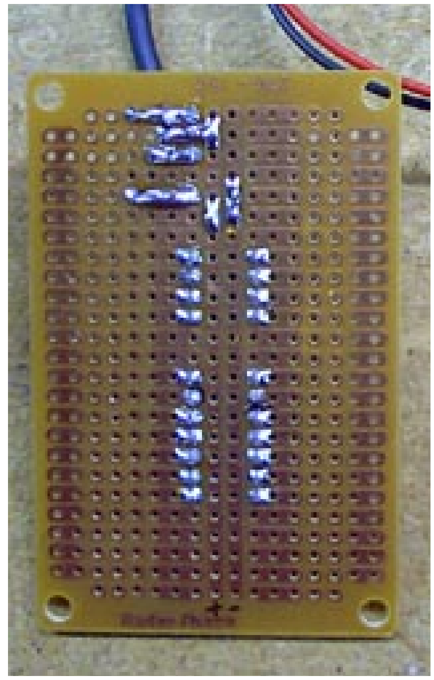


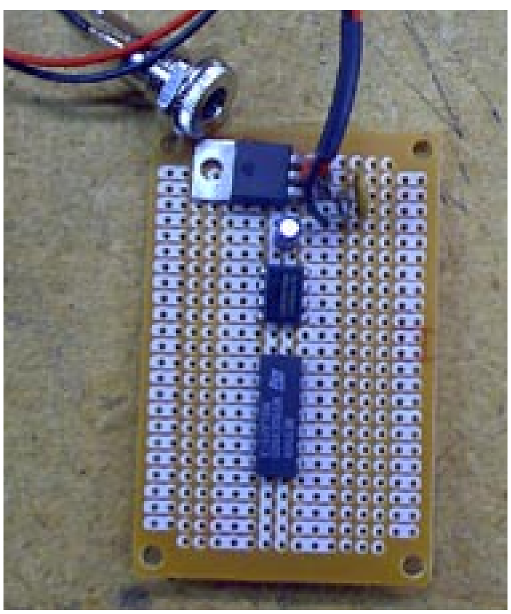
1.1) Populate the board with the voltage regulator circuit and other integrated circuits (ICs).

Note that the backside of the PC board has two vertical printed circuit strips that run the full length of the printed circuitry. Use these two traces to carry the regulated 9 volt signal (output from regulator) and ground up and down the full length of the board such that they are easily accessible by all of the circuitry.

Position the comparator (1458) and one shot (556) ICs such that they straddle the +9V and Ground signal traces.

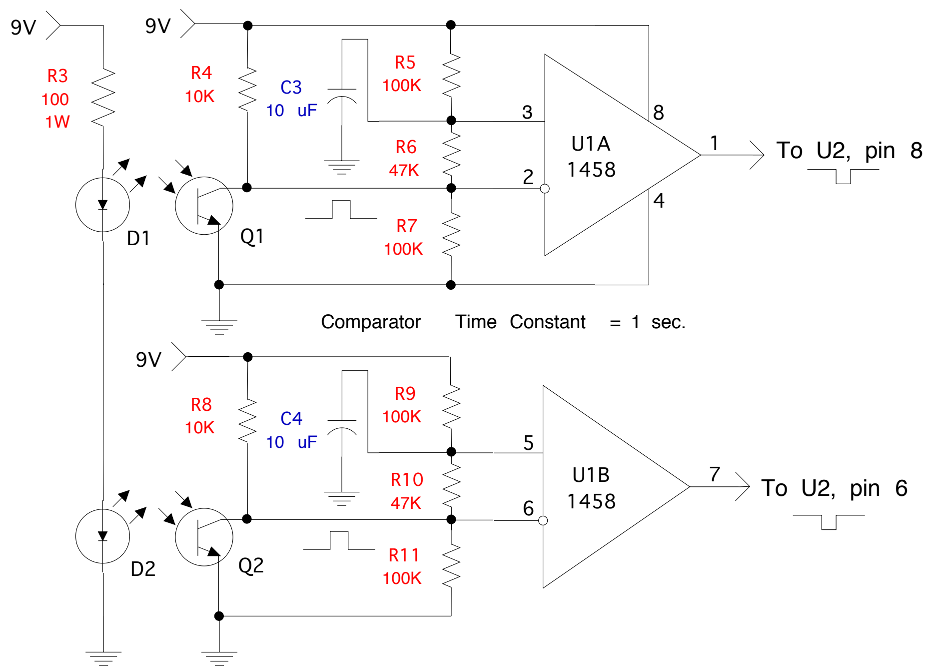




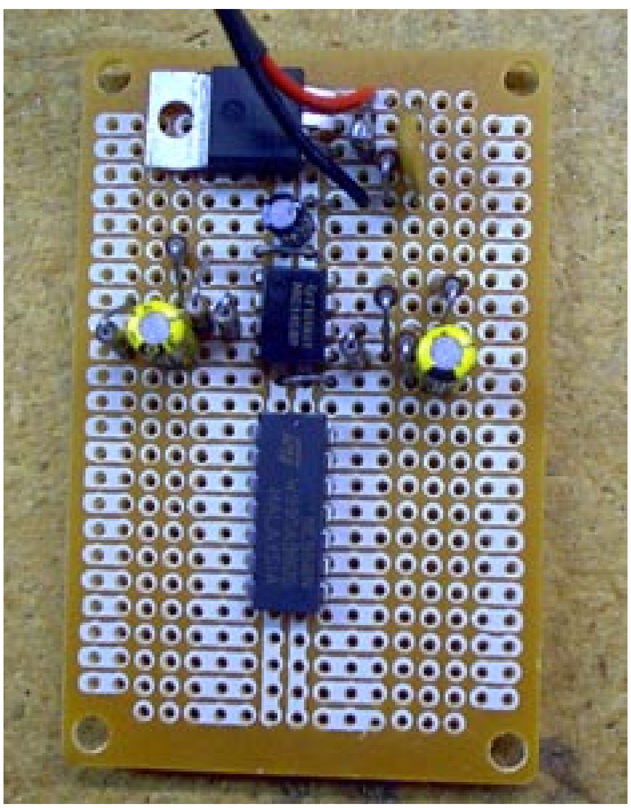


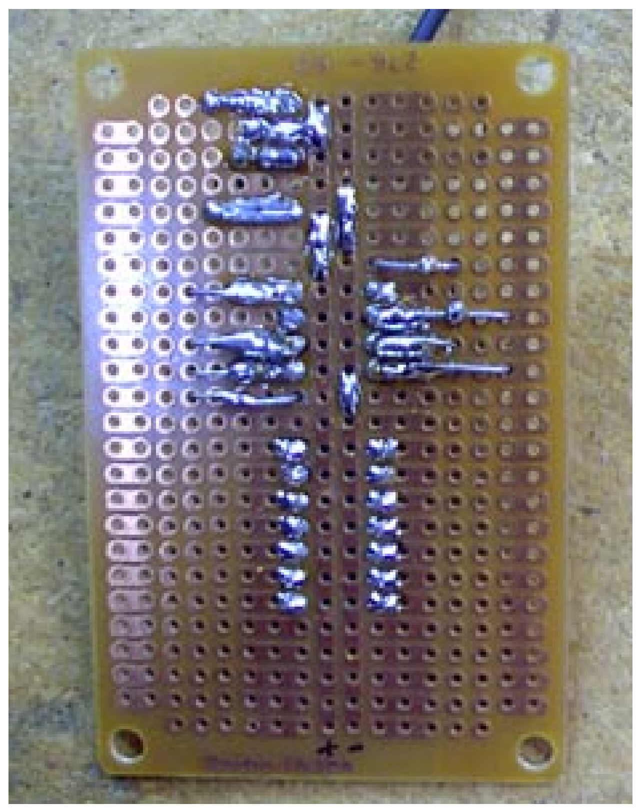
1.2) Attach power leads and, optionally, a power jack. Now, is your opportunity to test the regulator circuit. Plug in the power supply and measure the regulator output. It should read 9±0.5 Volts.

The Comparator Circuit

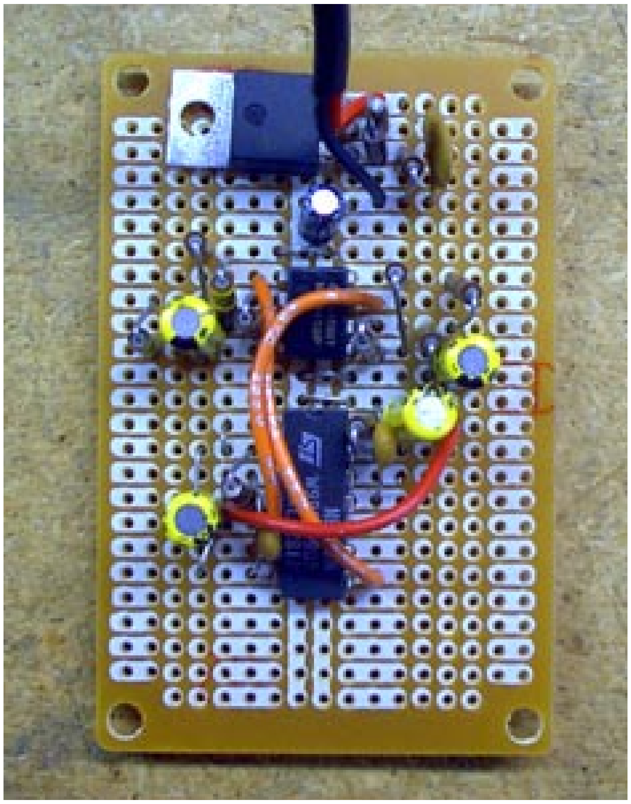


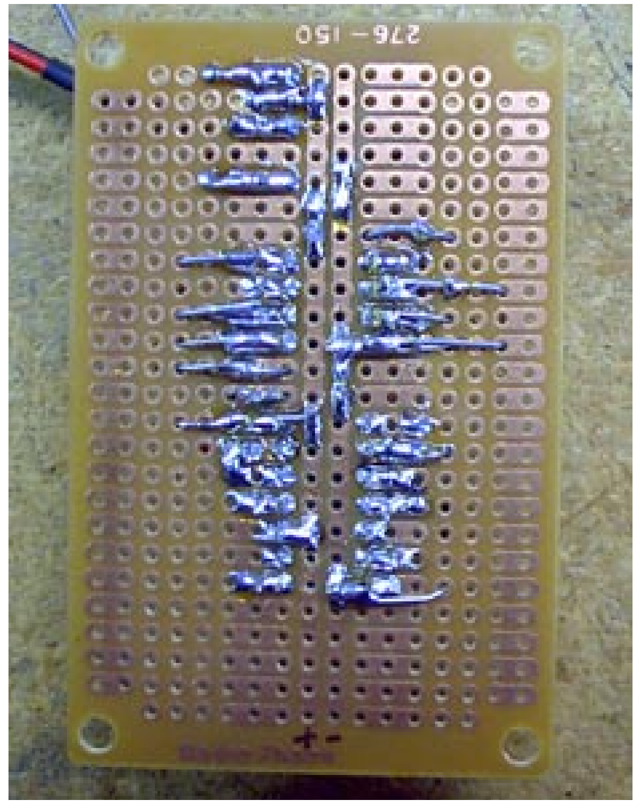
The comparator circuit uses voltage dividers (R5/6 and R9/10) with time averaging (C3 and C4) to automatically adjust sensitivity to ambient light conditions. No adjustments are required.



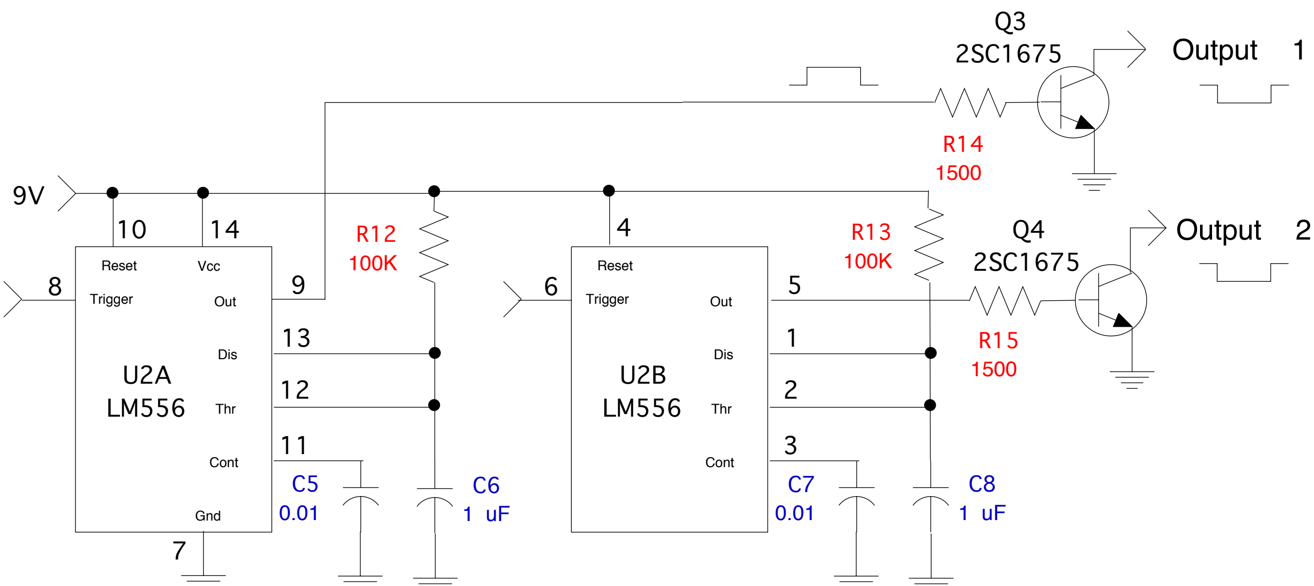


3) Populate the comparator circuit with resistors and capacitors.





3) Populate the one shot circuit with resistors and capacitors. Jumper comparator outputs to one shot inputs. This circuit also uses the red jumper to connect pin 4 to 9 volts.

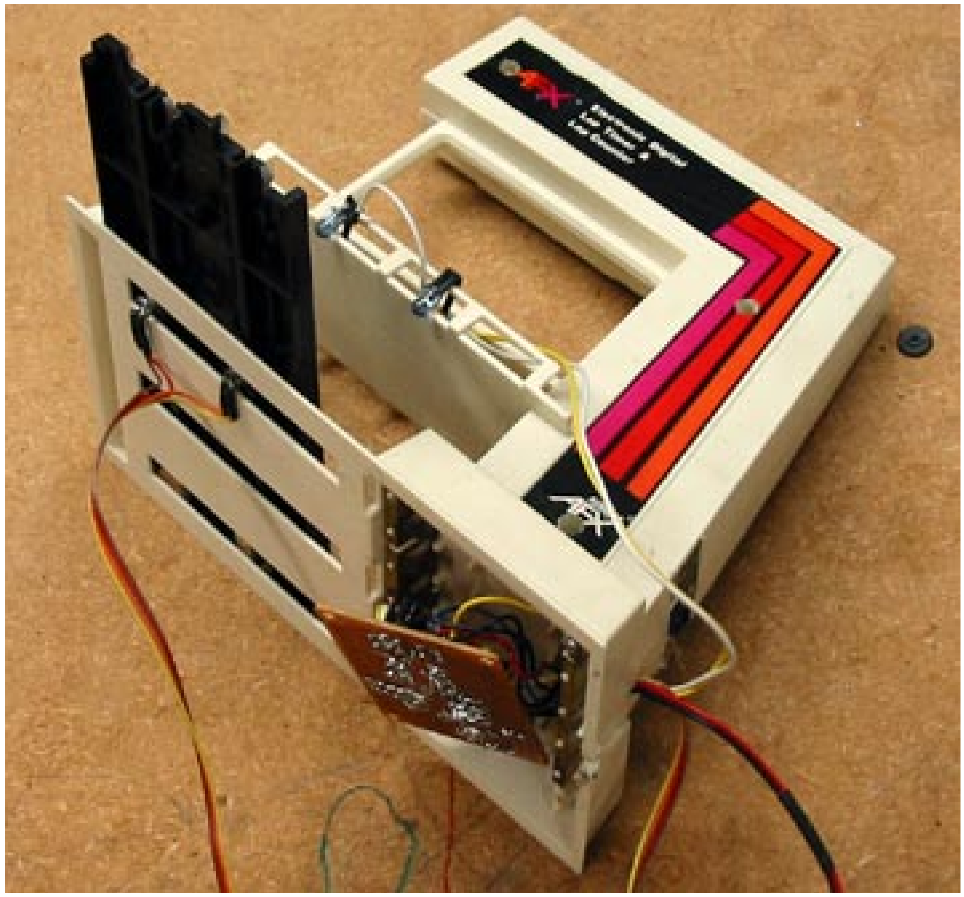


It was desired to have a pulse width long enough to be detected by slow circuitry or hardware, yet short enough to avoid a missed detection on a short, fast track. The output pulse is held for a period of 1.1 $R_{12}C_6$ or about 0.11 seconds. This output pulse width is independent of the input pulse width. Thus, the very fastest magnet cars provide the same strong pulse to the counter as do slow cars.

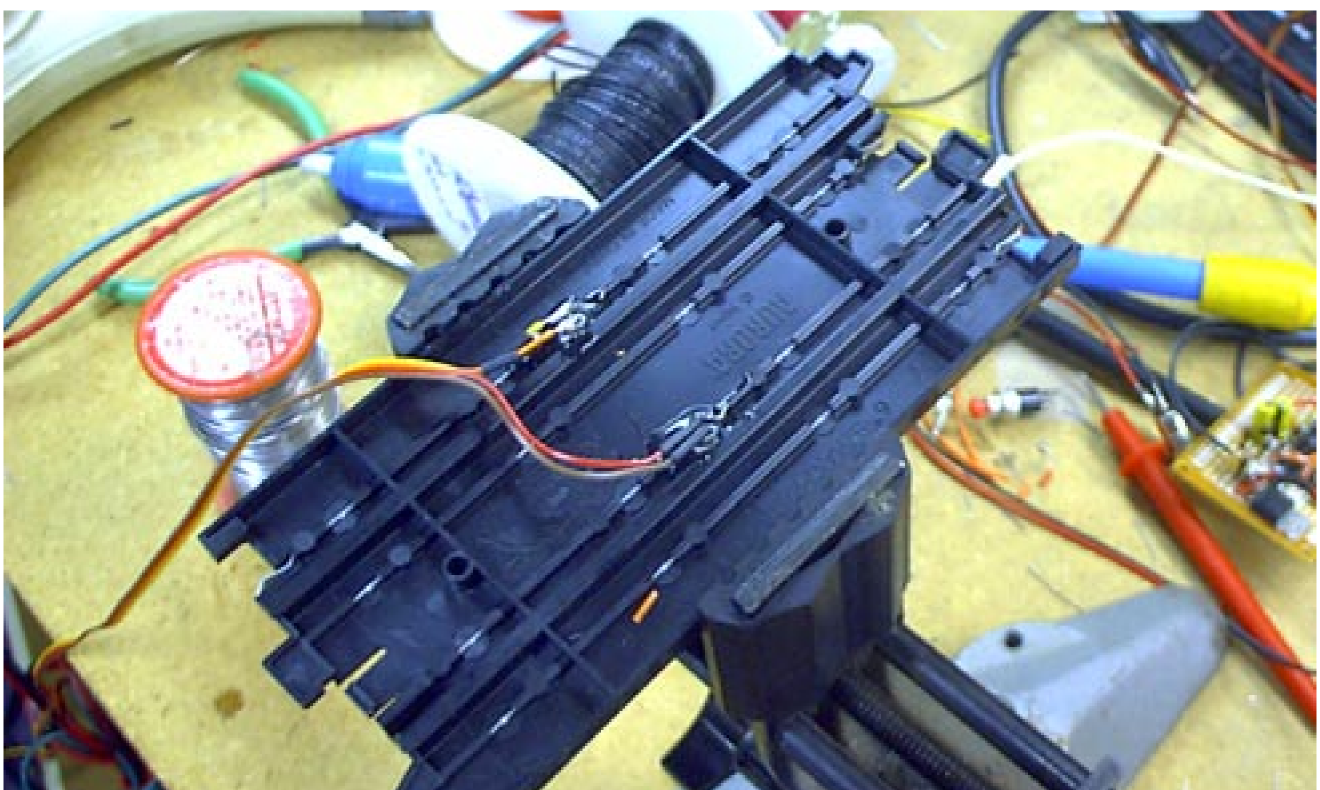
The open collector output transistors ground the output when a car is detected by the optical sensor. This output is a fixed length regardless of the speed at which the cars passes through the sensor.

Once constructed, you are ready to install your interface circuit. “Output 1” and Output 2” go to the lap counter wires that originally went to the trip track. For this project, the IR LED’s and phototransistors are mounted externally above and below the track. Timer power is obtained from the output of the circuit board 9 V voltage regulator.

The board is mounted in the base of the counter. The Infrared LED’s are mounted on the lap counter platform.

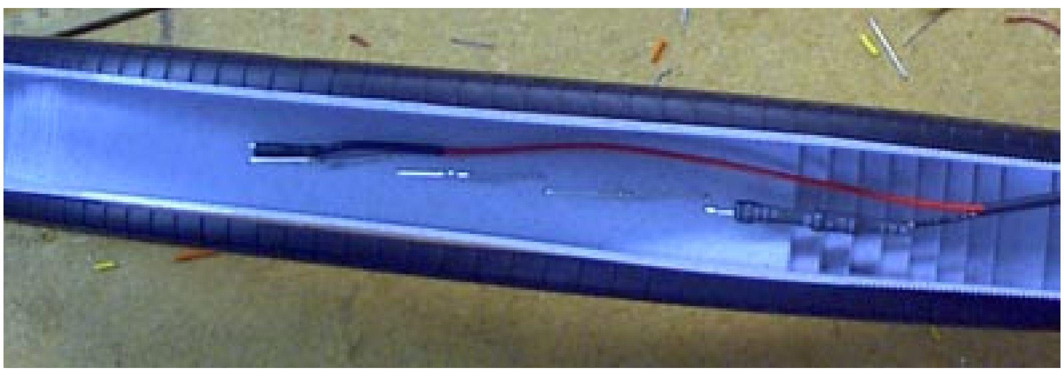


In the photo below, the phototransistors are epoxied into tapered holes drilled into the bottom of a track section. To glue these in, the tops of the holes were sealed with Scotch tape. Then, the phototransistors were placed in the bottom of the upside-down track piece and glued with 5-minute epoxy. After the epoxy has dried, the top-side Scotch tape is removed revealing a flat, smooth surface.
Once installed, wires are soldered to the phototransistor leads and insulated with heat-shrinkable tubing.



For a four lane application, IR LED's were mounted in a pedestrian bridge as shown below.

The LED's were wired in series such that only two power wires were required.

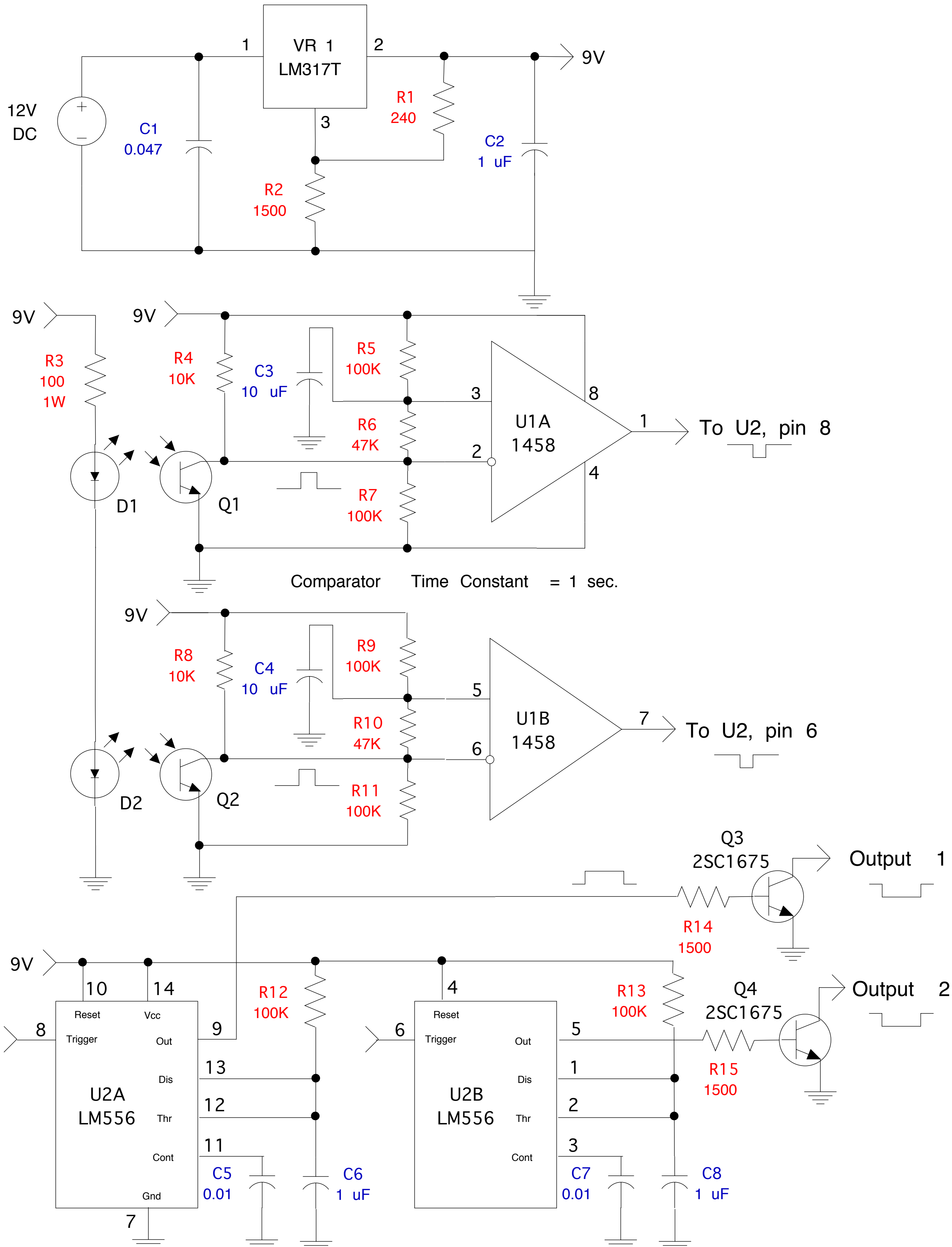


Here are four-lane sensors being tested.

Here’s a bare-bones overhead LED solution.

Here’s a setup using two AFX lap counters for a four lane track.

Full schematic.



Conclusion
An interface to couple optical sensors to an Aurora AFX Electronic Lap Counter/Timer has been presented. The generic design of the interface provides it with a much greater potential for interfacing to other devices. It could be used for utilizing 1960's-era Aurora electromechanical lap counters. Or it could be used for an interface to a computer where a more reliable detection method is desired.

Ideally, a printed circuit board (PCB) could be laid out and manufactured. Many service houses now provide low cost PCB production. This would provide a solution for easily constructing the interface.

About the author
George Warner is an electrical engineer in Lititz, Pennsylvania, USA who collects and races HO slot cars -- predominantly Aurora. He can be reached by email at warnergt@ptd.net.