THE TRAIN SAVER

Digital Electronic Train Controller

DRAFT

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Created: July 26th 2005
Updated: Oct 21st 2005

It All Started With A Hankerin' For Bar-B-Que...

A BBQ restaurant that my fellow workers and I frequent here in Austin has a nifty electric train that circumnavigates the entire restaurant. One afternoon, as we entered the establishment, we noticed the train was missing! A short chat with the manager revealed the train would break down from continuous use and had to be sent to a repair shop. Moreover, the cost of repairing the train engines had gotten high enough that the management had canceled plans to add trains to any of their other locations and was even considering "retiring" the existing train from our favorite restaurant!

I began to mull over the problem and decided I should be able to rescue the train from abandonment while maybe at the same time enhancing it's value to restaurant. A few inquiries with a local hobby shop showed their might also be other applications for such a solution in enhancing the life of other "toy" trains used in commercial environments. It seems that the motor and gear train in many "consumer" grade trains are not designed for the continuous use to which they are put when placed in a commercial venue. Since there are a limited number of hours their gearboxes and motors could provide, we needed to find a way to get the most out of them.

Is It Train Time Yet?

Initially, my design revolved around various timer circuits to reduce the total amount of time the train spent in a "powered" condition (presumption being "less run time" = "longer life"). I built a simple 555 timer circuit to start and stop the train on intervals, but on testing I discovered this approach was less than adequate. With no positioning feedback, the train would stop at random points around the track when power was removed by the timer. It was also not very "realistic" as it seemed as if the train had malfunctioned when it would stop or start for no apparent reason in "mid lap" around the track. Some patrons actually approached the cashier to point out that the train had "broken down". Worse yet, my simple timer approach would not allow the staff to start the train "on demand" for folks that would ask to see it run (as a treat for someones birthday for example).

Having the train run and stop in a predictable manner, combined with the ability to start the train on command, would dictate something more sophisticated than a simple timer. In fact it seemed to call for a microcontroller. Coincidently, it would also give me an excellent opportunity to create a project around the new Prop-1 I had received (see figure 1) from ParallaxEFX, a new division of Parallax that specializes in controllers for animatronics and entertainment devices. The Prop-1 microcontroller seemed to be a good match for this project for the following reasons:

- It is low cost at only $35.00 for the entire unit
- It has an on board ULN2803 high current Darlington driver capable of driving inductive loads.
- The ULN2803 is socketed so this critical part would be field replaceable.
- It has a built-in 5v power regulator so it may be run it directly off the train transformer unit.
- With 8 I/O pins, it has plenty of device control available.

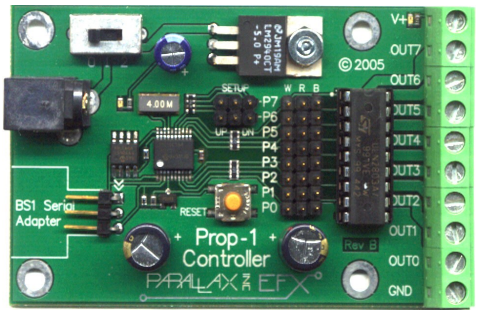

Figure 1: ParallaxEFX Prop-1

Of course, once we have a microcontroller at our command, we have a slew of new capabilities that can add fun and value to the project. For example, we could utilize Pulse Width Modulation (PWM) to gently start/stop the motor. This should enhance the life of the motor and the gear train since it would reduce the torque exerted on the gear box when power was applied/removed. It would also make it trivial to allow direct control of the train so the restaurant staff could trigger it to perform "on command".

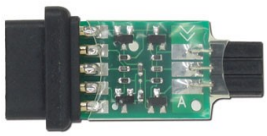
Figure 2: Serial Programmer Key

With a microcontroller, I could add a position sensor to have predictable stop and start points and also "count the laps" the train had run. At first, I imagined using hall effect sensors or some other physical method to sense the train's position, but I decided I would get a more reliable operation with a "touch free" sensor, so I decided that an IR LED/IR Phototransistor arranged in a "beam break" style would provide a good way to determine the train position without requiring any modifications to the train or the track.

Also, most train track setups have a station, trestle, tunnel or some other feature where the LED and sensor could be hidden, so this seemed the best approach. In my case, there was an obvious section of the track where the train should "stop", so the optimal position of the sensor obvious (there was a tunnel that would hide the train from view).

Since the train would be integral to the "ambiance" of the establishment, we could have a "self start" mode that would cause the train to run one or more laps if it was left "idle" for a software configurable period of time (i.e. not manually triggered by the cashier in, lets say, a 5 minute period). Since the idea was to have the train operate without attention from the staff, the user interface should be as simple as possible consisting entirely of a single button and a single indicator LED. So I had my list of requirements... or did I?

What's A Train Without A Whistle?

I tried out my prototype design at the restaurant, and I was able to have the train run on command, run on "unattended" intervals and to stop and start from a consistent location. I even had a small PWM routine in the code that would "ramp" the power up on "start" and down on "stop" to ease the strain on the motor/drive train. However, as I observed my prototype design in action, I noticed that in many cases people would not notice the train had started, or were puzzled when the train would just "disappear" without apparent reason.

It occurred to me that having some sort of sound effects would add to the realism of the train and bring peoples attention to it when it was about to "perform". I could use specific sounds to let people know when the train was "stopping" or just passing through the station. Since the Prop-1 had some unused outputs in my existing design, I decided to look for a sound module.

Sound Sound, Everywhere The Sound

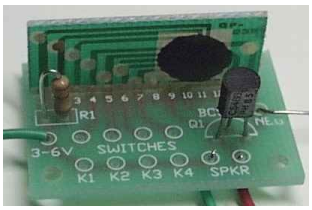

Figure 3: Sound Module Kit

A quick web search turned up a very inexpensive COB (Chip On a Board) digital sound generator. This little sound module kit is widely available from various manufacturers online, including one of my favorite sources, Jameco. The Train Sound Module Kit comes with the sound generator itself, four N.O. pushbutton switches, a small "motherboard" on which the chip is mounted, and a 3", 8 ohm, 1 watt speaker.

This neat little module plays back digital samples of various train sound effects including a crossing bell, the clickety-clack of the train wheels on a trestle and a steam train whistle. Due to the nature of the switch inputs, it would be trivial to trigger the sounds using pins on the Prop-1. Since I can establish the position of the train using the IR Sensor, I would be able to trigger the various sound effects to occur when the train was near the speaker, thus enhancing the illusion the sounds were emanating from the train itself.

Whistle with Laryngitis?

When I assembled the unit COB sound module, I noticed it came with a rudimentary audio amp in the form of a single transistor output. On my bench the sound was audible, but certainly didn't play with much "authority". When I put the prototype in place at the restaurant, you couldn't hear the module at all! Though the speaker was capable of handling up to 1 watt at 8 ohms, the single output transistor on the module just wasn't putting out enough power.

I decided to "beef it up" by ordering an LM386 based audio amplifier kit (figure 3). This little circuit puts out up to 1 watt of power into 8 ohms. A perfect match for the speaker included with the sound module kit. It gave me the "punch" I needed so the train sounds could be heard throughout the restaurant.


Figure 4: LM386 Audio Amp Kit

Putting it all together

So, now that I had all my parts, it was time to break out the soldering iron. The Prop-1 comes pre-assembled with the ULN2803, the 2904 voltage regulator and the .100 spacing headers for each of the I/O pins. It would be the "heart" of this project. I allocated the Prop-1 pins in this way (see figure 3):

- Pin 0- Sound Module (Crossing Bell sound)
- Pin 1- Sound Module (Clickety/Clack sound)
- Pin 2- Sound Module (Whistle sound)
- Pin 3- LED Indicator Light
- Pin 4- Power to Train Motor
- Pin 5- Future Expansion
- Pin 6- IR Phototransister
- Pin 7- N.O. Pushbutton

The assembly of the components into a small finished box is fairly straight forward. I started bysoldering together the COB Sound Module kit, then the LM386 amplifier kit. With the two kits assembled, I now needed to fabricate the IR transmitter and receiver.

The pin spacing on the Prop-1 is .100” and is a perfect match for extra CD-AUDIO cables I happen to have laying around, so I decided to “salvage” them for their connectors. Since the Prop-1 has +5v (labeled “R”), Gnd (labeled “B”) and IO (labeled “W”) arranged for servo connection, I would have an easy source for power and ground for the sensor and for the source IR LED.

I found some 3 conductor wire from an old mic cable in my junk box and added the .100 spacing header to one end. I then created two pigtails for the IR LED and the IR phototransistor. I used an old pen cap as the ambient light shield for the phototransistor. I placed a current limiting resistor in-line near the LED and then wrapped it all up nicely with heat shrink tubing.

Now, with the sensors squared away, I needed to mount all the parts in the case. I mounted the Prop-1 board on the case bottom using four screws and then cut a hole in the side of the cabinet big enough to accommodate the Serial Programmer (Figure 4). Next, I mounted the sound module (Figure 2) using a dab of hot melt glue since there are no mounting holes on the board, and it is rather lightweight.

I connected the sound module's power to the Prop-1 P0 “R” and “B” power connectors. I then connected the sound module's K1, K2 & K3 pins to the Prop-1 P0, P1 and P2 “W” connectors (Figure 1). The LM386 amp kit (Figure 5) was easily mounted in the box in the same manner as the sound module (again, a dab of hot melt glue) right next to the sound module and I soldered the output from the LM386 to the speaker on the inside of the box. I mounted a N.O. Pushbutton (that was included with the COB sound module kit) to the inside cover of the box, and then soldered another salvaged CD-AUDIO cable to it as a “pigtail” and connected that to Pin7 of the Prop-1. I added a panel mount LED and then drilled holes in the box to allow the sound to escape for from the 3” speaker. Now that I had the hardware all assembled, all I needed to do was write some code!

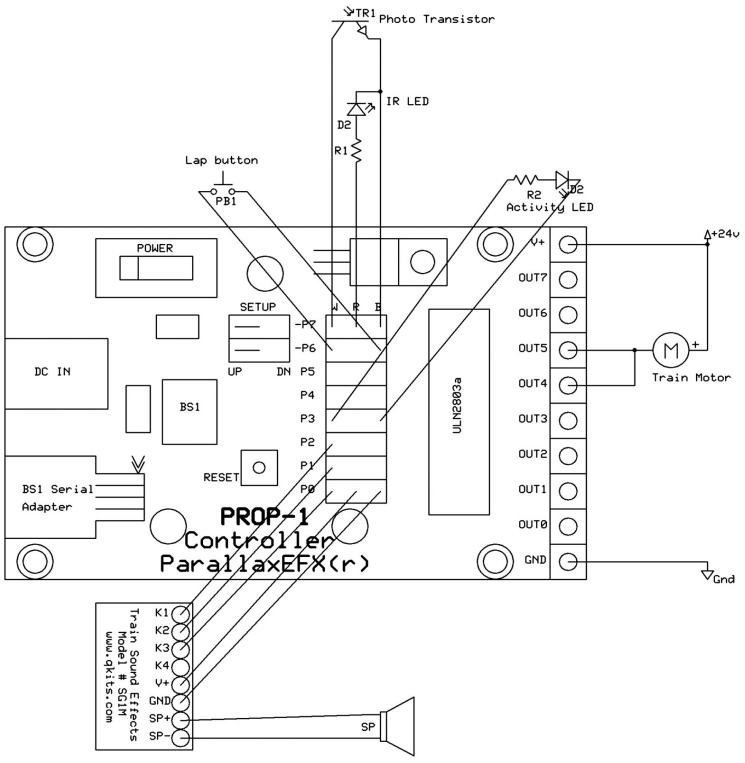

Figure 5: Schematic

Go with the Flow

The software would need to control the train, the sound, read the button and sense the train position. As the function list got longer, the coding concepts became more complex. If you are ever faced with this situation, I highly recommend that you spend some time building a flow chart for your program as it will really help you to segment your concept and then write code to handle each section. I built a basic concept flowchart (figure 6) before attempting to actually write code for this project. The program breaks down into these functions:

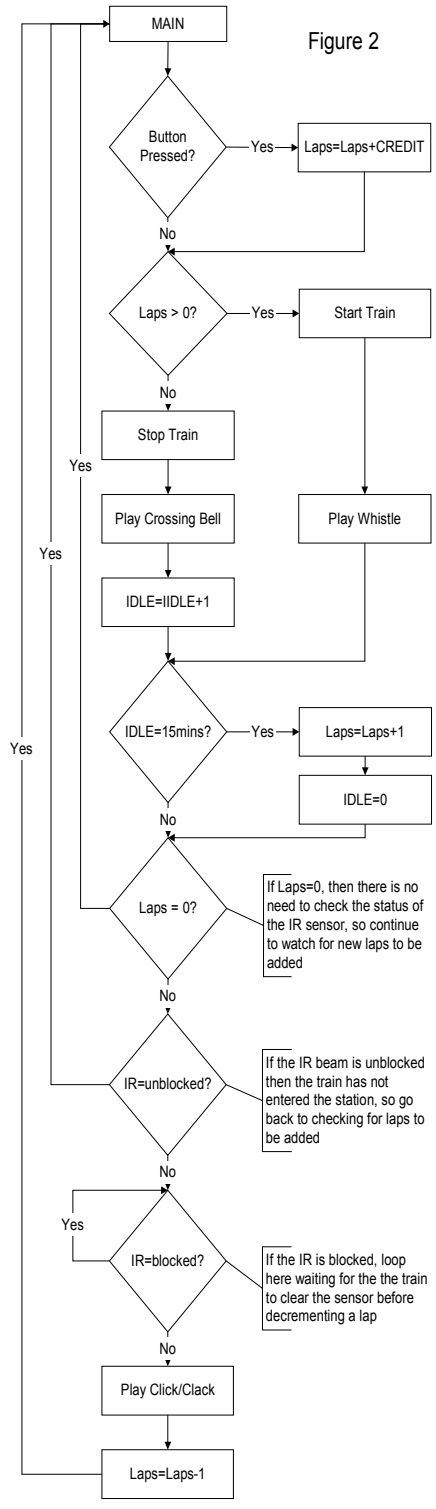

Figure 2

- Check if the button has been pressed
- Check value of the "laps" variable and stop/start the train
- Check if the "idle time" has expired and if so add a "lap"
- Check if the IR beam is broken, is so decrement a "lap"
- Loop back to the begining

The program takes quite a bit of space in the Prop-1's memory, but I managed to get all the functions in that I was seeking and still had enough room for some expansion. The finished program provides the following operations:

1) Provide a Test/Calibrate mode for the IR LED beam
2) Read the button and add a number of "laps" when pressed
3) Decrement laps whenever the train passes through the IR beam
4) If the train is idle for a preset time, then the train runs a single lap
5) Plays a sound when the train starts up (Train Whistle)
6) Plays a sound when the train stops (Crossing Bell)
7) Plays a sound when the train is "passing" the IR sensor (Click/Clack)
8) Blinks the LED to indicate the # of laps remaining

Testing.. Testing.. is this thing on?

Now that the code was written, it was time to set up the system and test it out. The first thing we need for testing is power. In my situation, I was able to run the Prop-1, the Train Sound Module, the LM386 audio amplifier and the train itself, all from the train transformer included with the train***.

***WARNING: You will have to make sure the voltage output from the train transformer does not exceed the power specifications of the Prop-1's power rating of between 6 and 30 volts DC!

Make sure the switch on the Prop-1 is set to the "0" position, then connect the positive output from the train transformer to the V+ screw terminal of the Prop-1. The train transformer's negative connection will be connected to the GND screw terminal of the Prop-1. Now, connect the negative lead for the train track itself to the GND screw of the Prop-1 and the positive track lead to the "OUT 5" screw terminal of the Prop-1. Turn on the train transformer on set the speed to approximately 50%. Now, turn the switch on the Prop-1 to the "2" position. Two power LEDs should illuminate on the Prop-1. If they do not, then double check all your connections (including making sure the train transformer is actually plugged in!). Once you have the Prop-1 showing power, it's time to download the program.

Open the Parallax Basic Stamp Editor and load the source code (available for download from the website shown at the end of this article) and download the code to the Prop-1. If the download is

successful, then hold down the “lap” button and download the code again (or you can hold the “lap” button down and press the RESET button on the Prop-1).

The reason for holding down the “lap” button is that, on startup, the program checks to see if the button is down and if so it will enter a “calibrate” mode where it simply illuminates the indicator LED when the IR beam is intact, and then extinguishes the LED when the beam is broken. This allows those of us who cannot see into the IR spectrum to align the LED IR source with the phototransistor sensor across the track.

Now that you can “see” the alignment of the IR sensor, pick an appropriate position on the track where the train will reliably interrupt the beam when it passes. The mouth of a tunnel or the start of a bridge span are good locations. If possible, I recommend placing the sensor at a height that will keep the beam continuously interrupted between the train cars. You can accomplish this by placing the sensor at the level of the *coupler* between cars. If this is not possible, you may need to adjust the “mask” value in the program to allow for all the train cars to pass the sensor before you decrement a lap, otherwise each train car that passes the sensor would decrement a lap!

Once you have the beam aligned, it's time to test out the system. Press the “lap” button one time to exit the “calibrate” mode. Once out of “calibrate mode”, the system is waiting for either a) the lap button to be pressed or b) enough “idle” time to pass to cause a lap to be added to the lap counter.

To have the train start, simply press the lap button one time. This will add five laps to the train (the number of “laps” added by a single button press is adjustable in the software). A single “blink” of the indicator LED will acknowledge the 5-lap “credit” has been added. The train whistle sound should play and the train should slowly startup and begin to move around the track.

When the train gets to the point where it interrupts the IR beam, the indicator LED on the Train Saver box should “blink” the number of laps remaining before the train will stop and the “click/clack” sound should play. When “laps” value has reduced to 1, and the train breaks the IR Beam, the train will slow to a stop and the “crossing bell” sound should play.

If no one presses the “laps” button for 5 minutes (the number of minutes of idle time is adjustable) the train saver will add one lap to the lap counter and the train will play the whistle, describe one lap, and the halt to to accompaniment of the crossing bell sound. If everything operates as described, then you have a working Train Saver! Congratulations!

Future Expansion

Though I'm happy with the current incarnation of the Train Saver, I've already been brainstorming about future improvements to this device. For example, the pushbutton switch could be replaced with a a “coin box” that would allow patrons to drop a coin to receive a preset number of “laps” from the train. This would allow the owner of the train system to recoup some of the inevitable cost of repairing or replacing a train engine when it wears out. An external speaker could be placed inside a tunnel or in a fake building near the “station” where the train stops so the sounds would appear to come from the vicinity of the train. Pin 4 on the Prop-1 could be used to control a relay that would “direct” the sound to different parts of the track. It could be used to add a motion sensor to the unit so the train won't run if the dining room is empty, enhancing the train life even further. Since that pin is already set up for one, a servo could be attached and code added to control a automatic crossing gate (lift and lower the barrier as the train passes). It's amazing that with such a small and inexpensive controller, there's still so much room for exploration!

Parts List:

All the parts are available from the sources listed here. If you shop carefully and/or have a well stocked junk parts bin, you should be able to keep the total cost of this project below $100.00

Microcontroller

Desc: Prop-1
Mfg P/N: 31101
Price: $35.00
Link: http://www.parallax.com/detail.asp?product_id=31101

Serial Programmer

Desc: BASIC Stamp 1 Serial Adapter
Mfg P/N: 27111
Price: $4.95
Link: http://www.parallax.com/detail.asp?product_id=27111

Sound Module:

Desc: Train Sound Generator Kit
Jameco P/N: 125170
Mfg P/N: 6101-KT
Price: $9.49
Link: http://www.jameco.com/webapp/wcs/stores/servlet/ProductDisplay?langId=-1&storeId=10001&catalogId=10001&productId=125170

Amp

Desc: 1 watt audio amp kit:
Jameco P/N: 125111
Mfg P/N: 6027-KT
Price: $6.29
link: http://www.jameco.com/webapp/wcs/stores/servlet/ProductDisplay?langId=-1&storeId=10001&catalogId=10001&productId=125111

IR LED and Sensor:

Desc: Matched Infrared Emitter and Phototransistor Detector
Radio Shack P/N: 276-142
Price $3.29
link:http://www.radioshack.com/product.asp?catalog%5Fname=CTLG&category%5Fname=CTLG%5F011%5F002%5F017%5F000&product%5Fid=276%2D142

Project Case:

Desc: 8x6x3" Project Enclosure
Radio Shack P/N: 270-1809
Price: $6.99
Link: http://www.radioshack.com/product.asp?catalog%5Fname=CTLG&product%5Fid=270-1809

Case mount LED

Desc: Red LED with Holder

Radio Shack P/N: 276-068
Price: $2.39
Link:http://www.radioshack.com/product.asp?catalog%5Fname=CTLG&category%5Fname=CTLG%5F011%5F006%5F001%5F000&product%5Fid=276%2D068

Misc Parts:

(1) N.O. Pushbutton	(Included with the Train Sound Generator)
(1) 3" 8ohm 1w Speaker	(Included with the Train Sound Generator)
(1) 50 ohm 1/4w resistor	(IR xmitter LED)
(1) 10k ohm 1/4w resistor	(Pull up resistor for Phototransistor)
(1) 180 ohm 1/4w resistor	(Current limit resistor for case LED)