Effects of Proto 2000 Constant Intensity Lighting On Engine Speed And Modification Procedures To Improve Performance

By Stuart Dom (1/18/11)

Background

When the first Proto 2000 (Life-Like) engines came onto the scene, I raced out to buy everything I could in my preferred railroad (PRR), and there was plenty from which to choose. The engines were extremely detailed, looked better than almost anything I'd seen before, and ran well. However, this delight soon subsided when I found that the engines ran much more slowly (perhaps prototypical) than the breed of engines most club members had (Atlas, Athearn & some Stewart).

That didn't stop me from buying, as it appears to be a major part of the hobby to want to own one of everything. However, many times these engines were not put on the mainline, because they would get overtaken by the majority of the trains. There were many words from other club members about these obstacles on the track, more than a handful of rear-enders, and I would reluctantly take these beautiful "beasts" off of the track and run my other engines.

Then one day - I believe it was at the Springfield show two years ago - we decided to have a "Proto 2000 Only" time slot. This was prompted by the unbelievable sale price of these engines by one of the dealers. I believe club members bought 40 or 50 much needed engines. This renewed my interest in these wonderful engines, but it soon became apparent, that few of the club members wanted to put up with these sluggish engines. We tried to remedy this situation with a "Proto 2000 Only" operating session. But this, again, ran its' course and the engines (most) went back in their boxes. For some mystical reason, a few of the off-the-shelf engines actually ran faster than others and fit right in with the MPRR club members' rosters. To this day, I don't know why.

I really wanted to run these engines, and began to look into the cause for this uncommon behavior. The first thing I noticed was that these engines came equipped with constant intensity directional lighting – which appeared to be relatively new to the off-the-shelf stable of engines. My original Stewart F units had very bright lights but I don't believe they were "Constant Intensity" lights. Having some electrical background, I decided to take a further look into these engines to determine if this could be the cause of this phenomena, understand why this was the case, and to develop a corrective fix. I initiated my first efforts on a pair of SD-9 engines that I had, and later moved onto SD-7, GP-7 & GP-9 engines.

Constant Intensity Lighting Circuit Effects

In all cases, I found that the constant intensity lighting circuit introduces a resistance or voltage drop in series with the motor. This means that for a given track voltage, the actual voltage getting to the motor was up to about 2.5 to 2.8 volts less, which translates to about a 20% reduction at full power. The power that a motor is able to produce is directly dependent on the current in the motor, and Ohms Law would indicate that this current is also directly related to the voltage across the motor, so the motor was receiving less current than other engines.

In these 4 engine types I found three different circuit boards. However, each of these boards has the simplified circuit relating to the constant intensity lighting and the power to the motor as shown in Figure 1. This circuit serves to illustrate both the method of achieving constant intensity lighting and the reasons why this circuit limits the current to the motor for a specific track voltage.

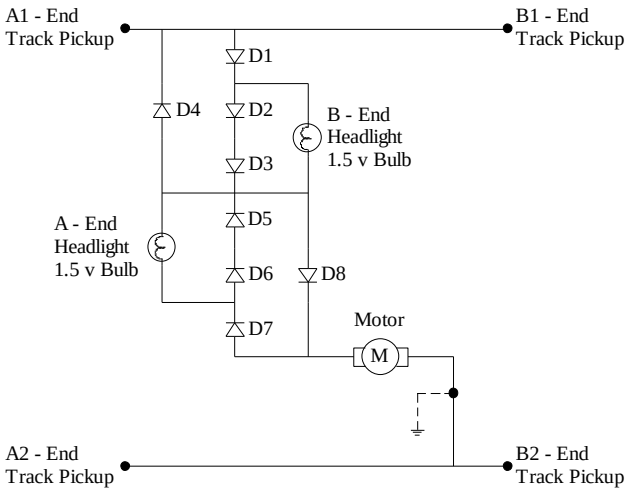

Figure 1 - Simplified Circuit for Constant Intensity Lighting of Proto 2000 Engines

First, track power is picked up by all wheels. On one side of the engine (we'll call it side 1) the power from the wheels is fed to the above circuit by wires connected to a standoff over the wheels (silver colored metal bracket similar to those found on Athearn Engines). On the other side (Side 2) the track power is either tied directly to the chassis, or ground as shown in Figure 1. It is between these two power pick-off points where all of the interesting stuff happens.

Obviously the engine has two ends which we'll call A & B, rather than front and rear, since the true front and rear of the engines varied by specific railroad operational conventions. The motor and the lighting must get power somewhere between the two sides of the engine, and that is where the circuit above comes into play. In looking at Figure 1, you'll note that there are 8 diodes (D1-D8), a motor (M) and two headlights (A & B end headlights). At the risk of boring most of you with basic electrical theory, I would like to identify the attributes and characteristics of these components.

- **Diodes** - Diodes are basically one way check valves. Current will only flow in one direction through a diode - with the arrow. Thus if the voltage is of positive polarity on the arrow end, current will flow. If the voltage is of opposite polarity, current will not flow. The characteristic of the diode is that the typical voltage drop across a conducting diode is around 0.7 volts over a large range of current, and that not much current flows though a diode until the voltage drop is realized. Diodes are rated for the maximum rated continuous current and maximum voltage that they can take in the reverse direction. For this application, diodes with a current rating of 1 amp or more and a voltage rating of 15 volts or more are required.
- **Headlights (Lamps)** - The headlight can be thought of as a resistance in the circuit, and these lamps have a maximum current and voltage rating. The lamps used in the Proto 2000 engines have a maximum voltage capability of about 1.5 volts at a current of about 30 ma (milliamps).
- **Motor** – This is the working part of the engine. Current is required to produce torque in a motor and, therefore speed, and current is proportional to voltage. Thus, the higher the voltage, the higher the current and speed of the engine.

Again referring to the circuit of Figure 1, let's follow the current flow through the system assuming the Side 1 track (that's at the top of the circuit) is positive. In this case motor current will flow from top to bottom through diodes D1, the parallel combination of series diodes D2/D3 and the B-End Headlights, through diode D8 and then through the motor. However, before any significant current can even flow through the circuit, the track voltage must increase to around 1.4 volts, dictated by the need for diodes D1 and D8 to have that voltage impressed upon them to get them to conduct electricity.

Once a voltage of 1.4 volts is achieved, current will flow through the B-End Headlight and motor. In this case the headlight is in series with the motor so it helps to limit current to the motor. This continues until about 30 ma is going through the circuit, when the voltage drop across the lamp has reached 1.4 volts, and diodes D2 & D3, now seeing forward voltage across them start to conduct current. At this stage the headlight has reached its near maximum brightness and this is where the headlight is truly at a "Constant Intensity. This is also the point in time that any change of track voltage causes a direct change in the motor current, related only to the motor parameters. However, diodes D1/D2/D3/D8 have a total drop of around 2.8 volts across them, which takes away from the voltage available to the motor. A highly simplified speed versus input voltage curve showing this behavior is graphically depicted in Figure 2. There is more to this picture than shown, but for illustrative purposes, this picture will do (John Waller has explained back-EMF, and torque/speed in previous tutorials).

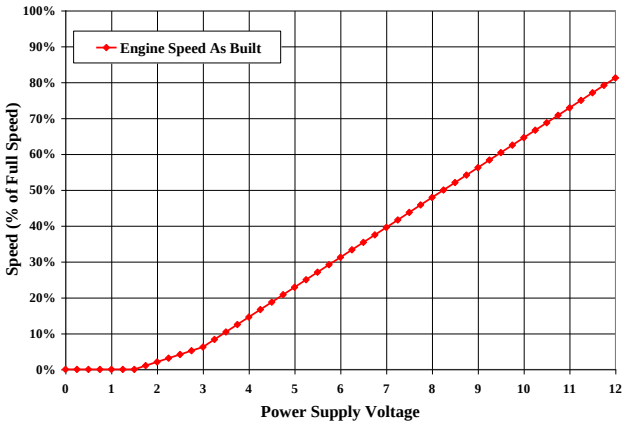

Figure 2 - Speed vs. Input Power Supply Voltage for Stock Proto 2000 Engine

A similar scenario could be made if track voltage polarity were reversed and the Side 1 was made more negative than Side 2. In this case diodes D4/D5/D6/D7 and the A-End Headlight are now in the circuit.

It is not at first apparent why all of these diodes are needed for the circuit. However, this is a short explanation of the need. First the manufacturer does not want the engine to move until the headlights are at near maximum brightness, which is around 1.5 volts. Diodes D2/D3/D5/D6 serve to limit the voltage drop across the headlight to near 1.4 volts and retain the brightness for track voltages above that. Secondly, diodes D1/D4/D7D8 are needed in the circuit to obtain directional light capability. All in all, the circuit represents a pretty good effort at achieving constant intensity lighting with a minimal number of low-tech components.

For comparison purposes, the most maximum speed of an engine would occur if the motor were to be place directly across the power pick-up leads. In this case, the engine performance would look something like shown in Figure 3. Except in some special cases, this would definitely create a rocket-like performance similar to some unnamed club members equipment. In truth, what we need to do is to

develop a speed vs. input voltage engine performance somewhere between the two curves.

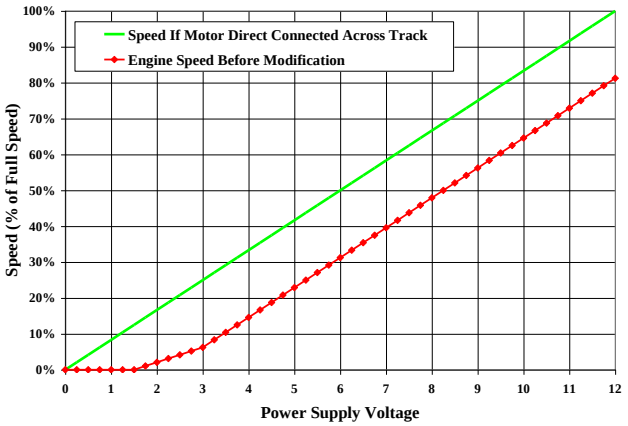

Figure 3 - Maximum Performance Relative to As Built Proto 2000 Engines

Modifications To Increase Speed

There are several objectives I placed on making modifications to change the performance of the engine.

- The engine had to be able to be returned to its' original condition with little effort. This eliminated my making changes to the circuit boards. I did remove them from the engine and store them in the original engine box after noting the location and color of each wire leading to the circuit board.
- Direction lighting was a condition that should be preserved.
- The lighting had to be bright enough at typical MPRR operational settings to be seen.
- I wanted to match the speed of other engines being run as close as possible.
- The costs should be held to a minimum

With all of these conditions, I found the easiest way of accomplishing this was to use the scheme most commonly found on other engines, with some slight modifications. The circuit I came up with is depicted in Figure 4, which consists of 4 (or possibly 6) new diodes and 2 new lights.

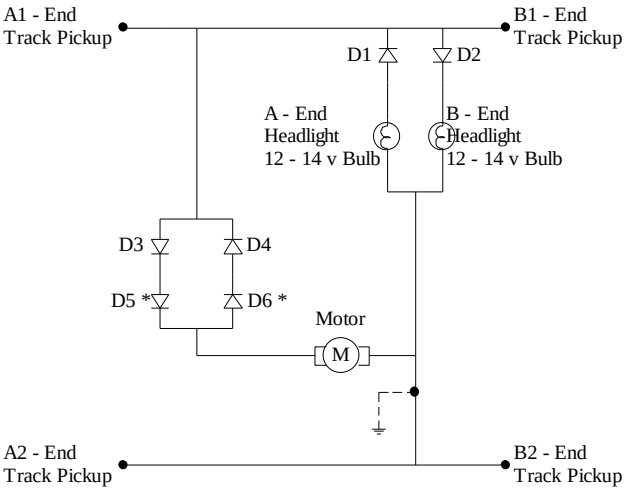

Figure 4 - Revised Proto 2000 Engine Directional Lighting Circuit To Improve Speed Performance

The diodes can be almost any type as long as they have a minimum current rating of 1 Amp and a maximum reverse voltage rating of at least 15 volts. I found a pack of 25 diodes at Radio Shack for about $2.50 which yielded 20 or more diodes suitable for this use (the ones that appear similar to the ones in the original circuit boards). The new lamps needed to be of the 12 volt variety, although 14 v lights will also work, and I prefer a 50 ma current rating to get the brightness up. Light bulbs found through Minatronics have these qualities, although Radio Shack sells a 30 ma version which I have also used successfully.

This is how the new circuit works. First, the lighting circuit is not in series with the motor so there is no drop in voltage for the motor to support the lighting. The purpose of diodes D1 and D2 is simply to provide directional lighting control. The motor could simply be connected across the track pickup points A1/B1 & A2/B2 directly, but I have found that the speed of the engine would be too great – a good rocket ship. Therefore, I have installed two diodes (D3 & D4) in series with the motor to drop the voltage – remember a diode is simply a check valve, so two are needed to allow current to flow in either direction. On several motors I have found that the engine runs too fast with installation of only diodes D3 & D4, so I've included an option of adding an additional set of diodes (D5 & D6) if needed. You could continue to add sets of diodes to further reduce the voltage, but the circuit would begin to look more and more like the initial circuit of Figure 1, so why modify the engine at all.

The resulting speed versus input voltage curve becomes more like shown in Figure 5, which you can see, causes increased speed for any specific voltage setting.

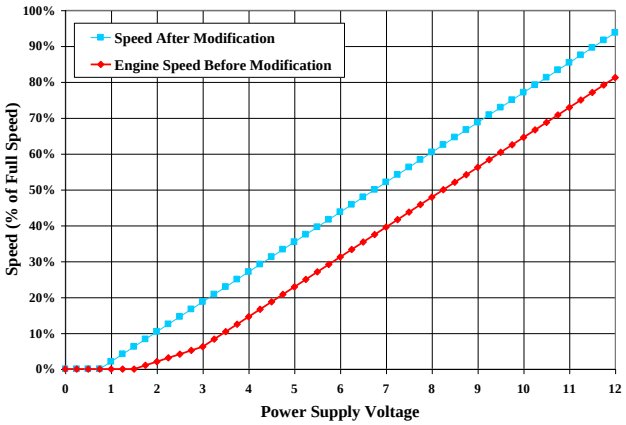

Figure 5 - Speed vs. Input Power Supply Voltage For Modified Proto 2000 Engine

Modification Check List

First, the leads connected to the circuit board should be carefully removed from the board by prying off the little plastic caps. With the caps removed, the leads will simply pull out of the holes in the circuit board. Label the leads so that you don't get confused later. Put the circuit board and both headlights aside (you won't be using them again for this modification), but be sure to keep them in a safe place as you may want to install it later. The following pictures are of an SD-7 or SD-9 (I never know which is which) with wires attached:

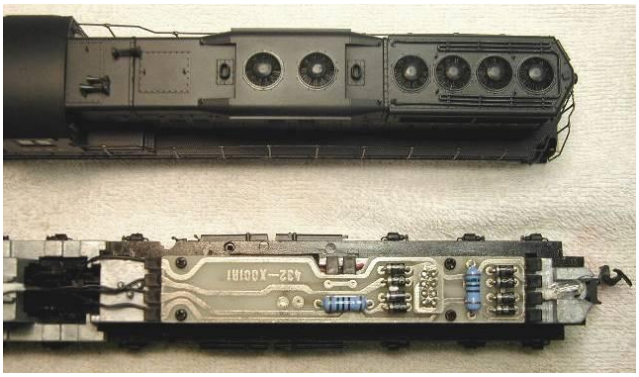

Figure 6 - SD-7/SD-9 Circuit Board Connection

In Figure 6, the upper terminals of each end are attached to wires connected to the upper wheel sets which I have labeled as A1 and B1 in Figure 3. The lower terminals of each end are attached to the lower wheel sets (A2 & B2). The middle leads on each end are leads to the headlights. And, the leads to the motor are attached at the center of the circuit board (top – middle).

After removing and labeling the leads, connect the A1 & B1 leads together by soldering a wire between them, and attach a lead to this connection. Make a similar connection to the A2 & B2 leads.

> **NOTE: You don't need very large wire for any of this work as the motor draws very little current (You can easily get by with 22 Gauge stranded wire, although heavier wire is OK if you can cram all of this wire into the shell). Furthermore, keep leads a short as possible to reduce bulk in the installation.**

There are really two tricky parts to this modification. First, and foremost, is the need to connect the motor properly, as all engines must run in the same direction for a given input. (I guess this may not be too important if you like to have cornfield meets all the time). The key to this is to connect the motor wires to the proper pickup leads. Trial and error is the only way that I know to do accommodate this for all installations. Here's my tried and true approach.

- Temporarily connect one motor lead to the A1/B1 lead and the other to the A2/B2 lead. You can do this by firmly twisting the leads together, clamping each connection or soldering.
- Place the engine on a test track with a known good engine and apply power. Three things could occur at this point.
  1. The engines could travel in the same direction indicating that the wires are properly attached. Murphy's Law (I don't think Bob Murphy had anything to do with this) would suggest that this will not likely happen, although there is a 50% probability of getting it right on the first try.
  2. The engines would move, but in opposite directions. This indicates that the motor wires are not correctly connected. Repeat the first step after reversing the motor connections and try again.
  3. The engine does not run at all. Recheck you temporary connections and try again.
- Once you have correct movement of the engine, permanently attach one of the motor leads to the appropriate power pickup lead. Take the other motor lead and attach it diodes (D3 & D4) and connect the other end of the diodes to the other power pickup lead. At this point the engine can be run with no additional modifications, but the headlights will not work.
- You may wish at this time to check the speed of the engine against one that you know to run at an appropriate speed for your taste, or that of other club members if you care. If the engine runs too slow, not likely to be the case, remove diodes D3 & D4 and try again. If the engine runs too fast, install diodes D5 & D6 and try again. I doubt that the engine would still run too fast, but if it does, you can add another set of diodes.

Once that is done, you're ready for the next challenge – getting the headlights operating properly. Again, this is done by trial and error, but it is likely to be no big deal.

1. Connect a diode in series with each new lamp.
2. Attach one of the lamp sets across the track pick-up leads A1/B1 and A2/B2. Attach the second set, if it has one - most FA and PA units have only one light, across the pickup leads with the diode facing the opposite direction from the first.
3. Place the engine on the track and energize, noting which light lights. At this point it is a simple matter to install the proper headlight in the proper end of the engine.
4. If you have only one headlight for the engine, make sure that this light is lit for the proper direction of the engine. If it operates opposite the direction that is desired, simply reverse the leads to the track pick-up.

You're almost done now, but this part may give you the most problem. Carefully tape or wrap all bare leads using electrical tape or shrink tubing. Take this entire bundle and squeeze it into the smallest package possible. Tape this bundle to the frame, making sure there is no bare wire contact with the motor frame, and install the shell. My guess is that you'll have to do this several times before the shell can be installed properly.

Final Thoughts

As noted before, not all Proto 2000 engines have the same circuit boards, but nearly all have the same pickups. On several engines, one side of the engine has the pickup grounded to the frame and the motor is also grounded to the frame. Just be observant. This may be a problem upon conversion to DCC but does not affect the modifications noted herein.

I believe that 14 volt lamps are preferred for use in a DCC engine, so you may wish to use 14 volt lamps instead of 12 volt, in case you might consider DCC later. For the same current rating of the lamps, the 14 volt lamps will not be as bright as the 12 volt lamps for the same input voltage. Make sure that you buy bulbs that fit into the existing holder for the headlights. Smaller bulbs always are easier to fit.

As noted before, I have modified several of these engines and have been extremely happy with the performance. These engines pull very well, and I'll pull them out to run my trains just as quickly as an Atlas or Stewart engine. If you see the results yourself, you will likely buy more of them for your use. Of course, there is always the Proto 1000 engines which run well right out of the box. These engines do not have the heavy flywheels nor look as good as the Proto 2000 engines, but they are a great buy – if you replace those couplers.

GOOD LUCK – You'll be happy with the results.

Stu Dom