Cab Lighting Fixtures Using Light Emitting Diodes (LEDs)

Part 1
(LED Basic Parameters and Application)

By

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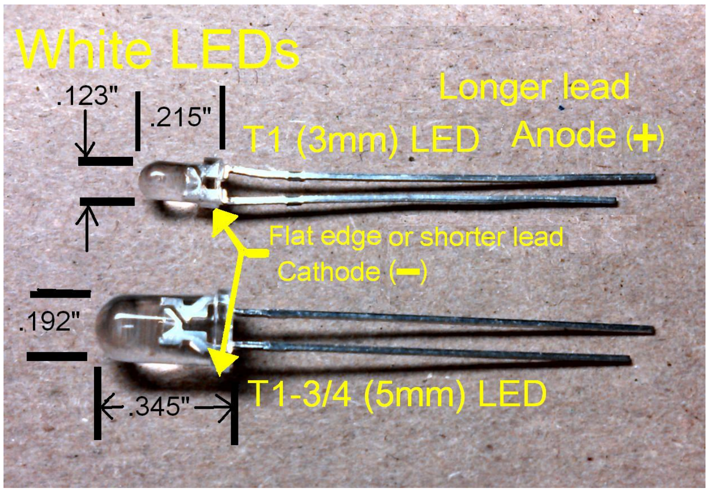
For some of us running our engines at night, especially in the warm summer evenings, is another enjoyable aspect of the live steam experience. At night, track signals, train lights and even the glow from the engine's firebox take on a visual relief from the norm of daylight running. The engineer's ability to run a live steam locomotive at night becomes more challenging especially if there is a lack of ambient light allowing them to effectively see into their cab interior. The use of cab lighting has now become an integral part of running trains at night. Light emitting diodes usually called LEDs are ideal sources of illumination for small light fixtures that can be easily installed inside the cab. This two part article about cab lighting covers basic parameters and application of light emitting diodes in Part 1, while the Part 2 provides details for layout and fabrication of lighting fixtures for use in smaller scale live steam engine cabs.

Advances in LED technology now allow a more practical way to either illuminate the whole cab interior of live steam locomotives, a specific area or just a single component such as a water glass, gauge, etc. LEDs have been steadily replacing traditional light bulbs and have several advantages since they have no filament to break which causes a shorter operating life or produce an in rush of current (aka surge) when first energized. LEDs also have a more efficient light output that uses a much smaller amount of power while producing minimal heat. Finally there are no glass housings to break, they are very compact, durable and not subject to physical vibration.

Figure 1



The most common and practical LEDs for cab lighting in this project are the white T1 (3mm) and the T1-3/4 (5mm) LEDs shown in **Figure 1** which are sometimes mounted at the end of a small two conductor cable of a fixture or a lens. Some LEDs have a clear lens for a higher light output that produces a narrow beam. Other LEDs have a diffused housing which reduces the light output but provides a wider viewing angle. All LEDs must operate within their specific current and voltage limits to prevent destruction of the device. The easiest way to ensure a LED's longevity is to operate it at 75% to 80% of its absolute maximum current. For the majority of these type of LEDs this is .02 amperes or in another accepted notation is 20 milliamperes (20mA) and LED polarity must be followed since it is a direct current device. In some cases with proper current limiting values, LEDs will work with alternating current (AC voltage).

In **Figure 2** the recommended operating value would be .015 to .016 amperes and the values for current limiting resistors **R1**, **R2** is calculated using Ohms Law with the voltage developed across either **LED1** or **LED2** which is about 3.3 volts. In **Figure 2, LEDs 1** and **2** have safe operating current via limiting resistors **R1, R2**, sometimes called "ballast resistors". **S1** connects or interrupts the + side of the 12 volt power source. **F1** protects the circuit from excessive current draw when **S1** closes if an overload should occur in the circuit. When **S2** is open additional series resistance is added to the circuit which reduces the amount of current flowing through **LED1** and **LED 2** decreasing their light output. When **S2** is closed **R3** is shunted (bypassed) and full operating current flows in the circuit.

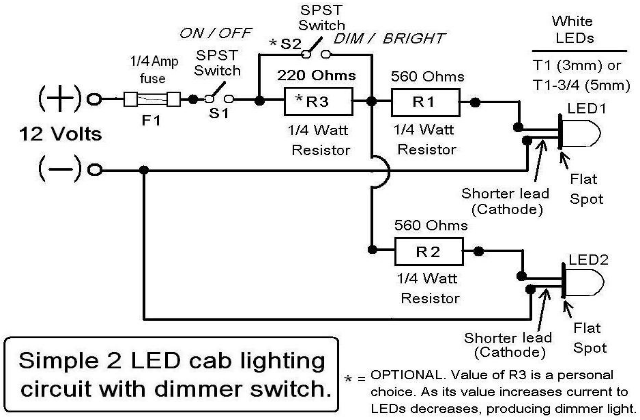


Figure 2

*For those interested in the calculations of R1, R2 in detail, they are shown in **Figure 4** at the end of this article. Additional resistor information is also included along with upper and lower values for R3.*

White and blue LEDs usually develop an operating voltage of approximately 3 to 3.6 volts across their leads depending on their operating current at the time, where as red, yellow, green LEDs typically develop 1.05 to 2.1 voltage reading also dependent on operating current. In some cases bluish/green LEDs will develop a 3.3 voltage measured across their leads. It should be noted the T1 (3mm) and T1-3/4 (5mm) LEDs have the same current limitations and operating characteristics. Depending on the type of LED manufactured the light output can vary greatly and the operating current can be as small as a few milliamperes of current to several hundred. Typically the higher current LED devices require mounting on a suitable heat sink to dissipate the internally developed heat.

There are multiple ways to configure LEDs for cab lighting as shown by 4 simplified **Examples A, B, C, D** in **Figure 3**. In **Examples A** and **B** there are two current limit resistors, one for each LED. In **Example A** the resistors are located in the tender and require three wires to supply power to the LEDs in the cab. This configuration may be necessary only if some condition exists inside the cab to prevent their installation. In **Example A** it may be inconvenient to run an additional third wire, however there is an advantage when one of the LEDs needs a different amount of current for a brighter or dimmer application. Another advantage also exists if one of these LEDs is a different color which requires a different resistor value. In **Example B** resistors can be of different values as well and be installed in line with the wiring next to the fixture or at the point where the wiring from the tender enters the cab. When all of the cab LEDs are the same type and expected to produce approximately the same illumination, then a single resistor can be used in the cab as shown in **Examples C** and **D** which will help keep the circuit simple by connecting multiple LEDs in series with the resistor (this resistor can also be located in the tender). LEDs of different colors may also be used in **Examples C** and **D** <u>providing</u> all of the LED voltages have been taken into account for determining the value of the series resistor. The resistors used in **Examples C** and **D** have been selected for various combinations of 3mm and 5mm <u>white</u> LEDs only.

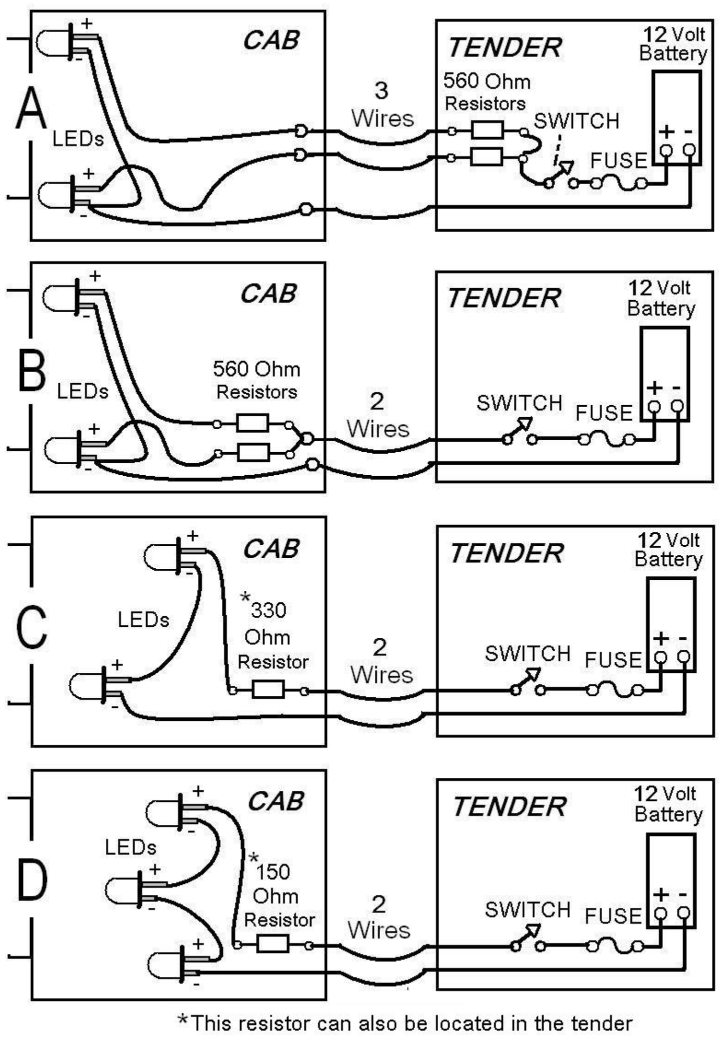
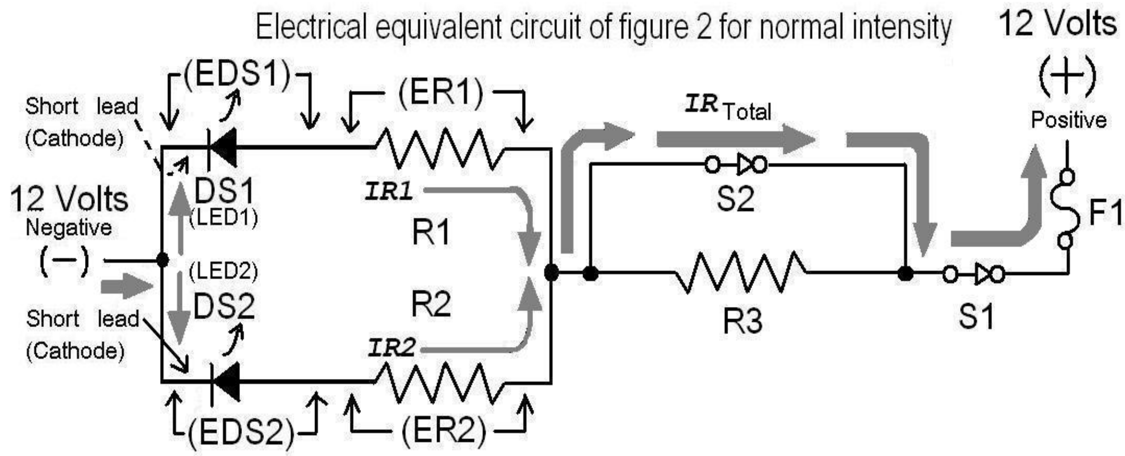


Figure 3

Here are a few important tips for T1 (3mm) and T1-3/4 (5mm) LED usage:

- The operating current must never exceed .02 amperes for most LEDs used in this article.
- Maximum operating temperature is +45 degrees C (+85degrees C for some military/industrial grade devices).
- Soldering time for per lead is no more than 3 seconds maximum at 750 degrees F.
- LED connection polarity must be observed when connected to direct current circuitry.
- Care must be taken when bending or forming LED leads to prevent damage to the epoxy body and internal connections which renders the device inoperable.



Calculating values of R1, R2

As discussed resistors R1, R2 safely limit operating current to DS1, DS2 while allowing normal intensity. As current flows in a resistor a voltage drop develops. The amount of voltage dropped is proportional to the amount of current as expressed in Ohms law which is Er (voltage dropped) = Ir (current flow in amperes) X R (resistor value in Ohms). To determine the values of R1, R2. An operating current of 75% of the maximum .02 amperes or 20 milliamperes = .015 amperes (A) or 15 millamperes. The necessary voltage drop needed is obtained by subtracting the power source voltage of 12V (E1) minus LED1 voltage of 3.3 volts (EDS1) = 8.7 volts. The value of R1 can now be calculated by using Ohms of R = E / I (R = 8.7V / .015A = 580 ohms). A resistor value of 580 ohms is non standard and harder to obtain where as the standard value of 560 ohms is easy to find and only very slightly increases the R1 current to .01553 amperes or .0155 (15.5mA). The value of R1 should be used for R2 as well.

Finding the resistance value of R1, R2 is only one factor in determining parameters of the 2 LED lighting circuit in figure 2. Another consideration involves the power handling capacity of the resistor. Resistors come in different resistive values,power ratings and tolerences. The combination of current flowing in a resistor along with the voltage developed across it produces power (P) which generates heat and is expressed in watts. Using Ohms law by multiplying the current flowing in R1 (IR1) X the voltage drop across R1 (ER1) the power dissipation of R1 can be obtained. P = ER1 (8.7V) X IR1 (.0155 A) = .1348W (135mW, mW = milliwatts). Typical wattage increments range from 1/8W(watt) 1/4W, 1/2W, 1W, 2W, 5W,10W, 20W and so forth. The calculated power value of 135mW exceeds the 1/8W (.125 watt) rating and the next increment of 1/4W (.250 watt) is more than sufficent to handle the power developed by R1.

Another factor for resistors is tolorence rating. Usually +/- 5% or +/- 10% can be used in figure 2. However given worst case values for 10% tolerences is 110% X 560 = 616 ohms high value, 90% X 560 = 504 ohms which will allow a minimum operating current of .014A or 14.4 mA and maximum current of .0173A or 17.3mA respectively. The lower minimum tolerence rating of -10% for the 560 ohm resistor places the operating current of LED1 at 86.5% which is beyond the desired limit. With an average rating of 50,000 hours of operation and a 86.5% operating current LED1, LED2 should still provide many years of service.

R3 Can vary from 390 to 100 Ohms and it is a personal choice depending on the level of dimming desired.

Figure 4

With several types of LEDs and light fixture styles to choose from, a practical lighting scheme will ensure years of trouble free cab illumination and improve running at night.