RECOMMENDATIONS FOR USING WHITE LEDs

CURRENT LIMITING

For ALL LEDs, some form of current limiting should **always** be provided. Typically a resistor is used, but a constant-current circuit is also an option. To determine the ideal resistor value, use OHM's LAW:

$$V = I * R \quad \text{or} \quad R = V / I$$

where V is the resistor voltage in Volts, I is the current in Amps, and R is the resistance in Ohms
(Don't forget: A milliamp is 1/1000 Amp)

The LED will use up part of any applied voltage, and the resistor must use up the rest when they are connected in series. A typical white LED uses up 3.5 volts, while a typical red LED only consumes 1.8 volts. If excessive forward voltage is forced on any LED, it will generally draw excessive current and burn out. The series resistor prevents this.

> Example: Assume the applied voltage across a white LED and a resistor in series is 8 volts, and you want a current of 3 milliamps (mA) through the LED. Since the resistor and LED are connected in series, they will have the same current but divide the voltage. The LED gets the first 3.5 volts, so the resistor gets the other 4.5 volts. The appropriate ideal resistor for 3 mA in this example is R = V / I = 4.5 / .003 = 1500 ohms.

REVERSE VOLTAGE PROTECTION

All LEDs have a limited ability to withstand reverse voltage polarity. For white LEDs, the limitation is more critical than for familiar colored LEDs. White LEDs are generally easily destroyed by static electricity. When handling white LEDs, simple precautions include grounding the person handling the LED and keeping the two LED leads touching each other during handling.

When a white LED is installed in a locomotive headlight circuit, great care must be taken to prevent inductive voltage spikes from the motor from reaching and destroying the LED. For an LED in a DCC decoder circuit, the decoder circuit will serve to isolate the LED from the motor, and no further precautions are needed. In a normal DC motor circuit, protection should be provided in the form of a diode reverse connected across the LED. In this connection, a reverse voltage will essentially be shorted out by the reverse diode, preventing the high reverse voltage from reaching the LED. If the locomotive lighting circuit has two LEDs, for forward and reverse headlights, generally one LED will serve as the reverse protection for the other if the LEDs are directly connected together back-to-back and share a common resistor. If they don't share a single resistor, each needs a protective diode.

If a locomotive has two separate lighting circuits, or if one LED is removed, the LEDs are probably unprotected. Protection should be added in the form of a silicon diode. Tiny surface mount rectifier diodes are ideal for this protection. Their small size allows them to be mounted directly to the LED's leads near its epoxy package.

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FLICKER PREVENTION

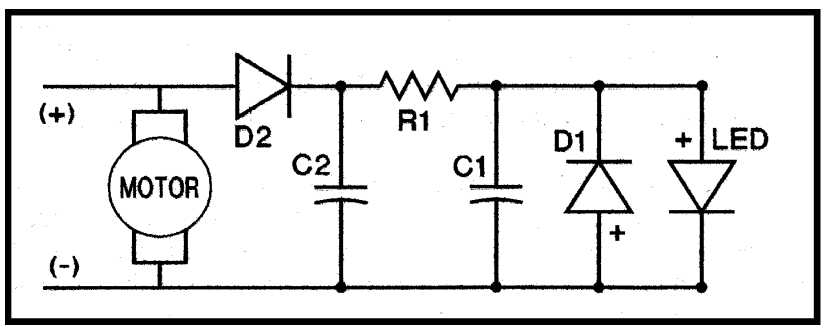
When a model railroad locomotive's motor briefly loses contact with the track while it is being driven, it will emit a voltage pulse. When the polarity of this pulse *reverse biases* the LED, the situation described in the previous section occurs, and the protective diode (rectifier or LED) will prevent the pulse from reaching the LED. When the polarity of this pulse *forward biases* a headlight LED, that LED will flash unless provisions are made to prevent the pulse from reaching the LED. These flashes can be observed in a dark environment if the flashing has not been prevented. Generally, the rear light will emit brief flashes when the locomotive is moving forward. A small ceramic capacitor connected directly across the LED will short circuit these high frequency pulses.

OPERATION WITH ARISTOCRAFT / CREST CONTROLLERS

The Aristocraft / Crest controller chops its input at about 15 kHz to create its high frequency square wave output voltage which is applied to the track. Motor speed is controlled by controlling the width of these square waves. The small ceramic capacitor discussed in the previous section will tend to short circuit the square wave voltage applied to the LED, greatly diminishing its brightness. This effect can be eliminated by supplying the square wave voltage through a rectifier and capacitor connected before the current limiting resistor. The diode and capacitor form a *peak-hold* circuit that actually improves the lighting. Even with very narrow square wave pulses too narrow to turn the motor, the peak hold circuit will charge to the peak voltage, and the peak hold circuit will release this stored power to the LED during the intervals when the track voltage is zero. Thus, lights can remain on at full brightness even when the motor is not turning, if the Aristocraft throttle setting is very low but not off.

RECOMMENDED CONNECTIONS AND COMPONENTS

R1 = Current Limiting Resistor
C1 = Antiflicker Capacitor
D1 = Reverse Protection Diode
D2 & C2 = Peak Hold



Recommended Digi-Key Part Numbers:

R1 (for 3 mA @ 8 volts the track) = 1500 ohms, 1/8 W, 5%, axial leads, 1.5KEBK-ND
C1 = 3.3 µF, 6.3 V, ceramic, PCC1925CT-ND
C2 = 1.0 µF, 25 V, ceramic, PCC1893CT-ND
D1, D2 = 20 Volts (reverse), 300 mA, MA2Z720CT-ND

If you prefer, Richmond Controls can provide small quantities of these parts or do conversions.

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