# Thermal derating of LEDs

In the last few years, the high-brightness LEDs have developed enormously from a niche existence as a high-priced designer spotlight to a useful general purpose illumination source with efficiencies of up to 160 Lumens/Watt and lifetimes measured in decades. As high power LEDs have become more popular as an alternative to wasteful incandescent bulbs or toxic CFL lamps , the economies of scale have caused the price of LEDs to fall to a level where they can now compete in mass markets rather than just the cutting edge applications.

However, the introduction of high power LED Technology has pushed the issue of thermal management back to the forefront of lighting design. Like all semiconductors, LEDs must not overheat otherwise their celebrated long lifetimes will be adversely affected. Although the efficiency of a standard high power LED is around six times better than a standard incandescent light bulb and around twice as good as a fluorescent, a significant amount of the electrical energy flowing through the device is still converted into heat. Therefore, it is essential that thermal management and the consideration of the effects of high environmental temperatures are addressed right at the start of the design phase.

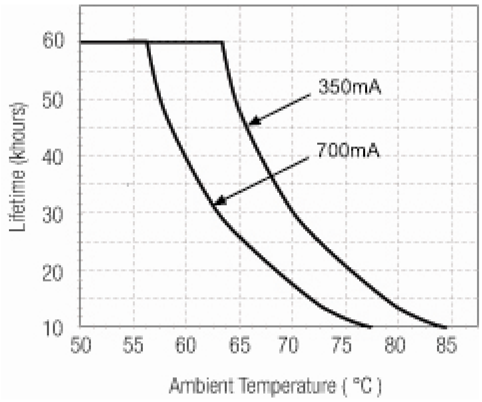



**Figure 1a: Effect of ambient temperature on lifetime derating curve**

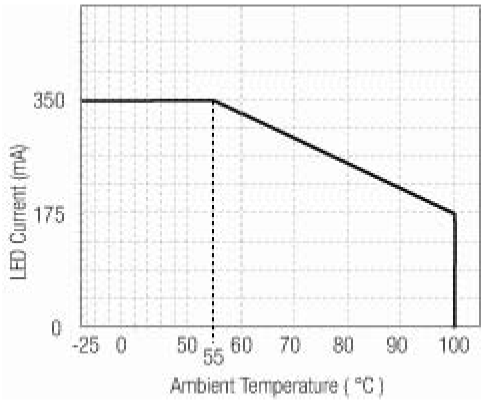



**Figure 1b: Typical LED temperature**

Figure 1a shows how the lifetime of power LEDs drops rapidly once the high ambient temperature causes the internal junction temperature to exceed 130°C. The maximum ambient operating temperature is dependent on the internal thermal design of the LED, its efficiency and its power dissipation, so it varies from manufacturer to manufacturer. However, setting the derating point to 55°C ambient is a reasonable compromise.

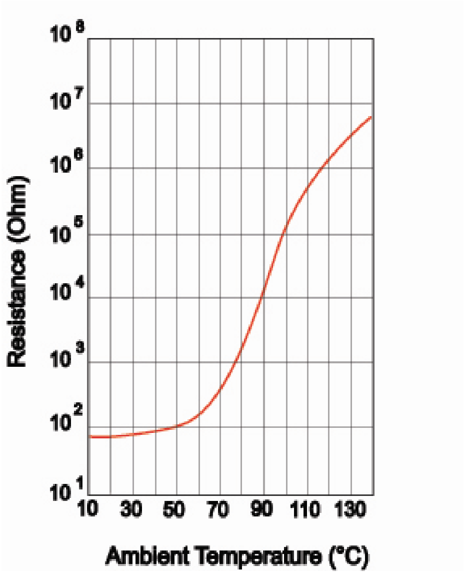
Figure 1b therefore shows an ideal LED current verses temperature relationship. Up to the maximum operating temperature, the LED current remains constant. As the LED temperature exceeds the limit, the current is reduced and the LED dimmed to protect it from overheating. This curve is called a “Derating Curve” and keeps the LED working within its safe power dissipation limits.

## Adding automatic thermal derating to an LED driver.

LED constant current drivers are circuits that maintain a constant output current even if the input voltage changes or the LED characteristics change over time or from production batch to production batch. An accurate constant current control  is required as the light output of an LED is directly proportional to the current flowing through it.

If the LED driver has a dimming input, then we can easily add an external temperature sensor and some external circuitry to recreate the desired derating characteristic as shown in Figure 1b. The RCD-24B series LED driver from RECOM has three different dimming inputs and so is an ideal candidate to explain the three different ways in which over-temperature protection can be added to an LED driver circuit. In addition, it also has a useful 3.3V Vref output that can deliver up to 5mA to power external circuits. Of course, these circuit suggestions can be used with other LED drivers from the RECOM range if an external regulated power supply is used.

## 1: Over-temperature Protection using a PTC Thermistor




A thermistor is a resistor that changes its value with temperature. If the resistance increases with increasing temperature, it has a positive temperature coefficient (PTC). It is possible to obtain PTC thermistors with very non-linear characteristics (Figure 2).

As long as the temperature stays below a given threshold, in this case 70°C, the PTC thermistor has a relatively stable low resistance in the order of a few hundred ohms. Above this threshold, the resistance increases very rapidly: at 80°C the resistance is 1kOhm; at 90°C it is 10kOhm and at 100°C, it is 100kOhm.

Conveniently, PTC thermistors are also available pre-assembled to a mounting lug that can be very easily attached to the heat-sink casing of a LED lamp fixture.

**Figure 2: Typical PTC thermistor resistance / temperature curve**

We can use this response to make a very simple, low cost and reliable over-temperature protection circuit using the resistive analogue dimming input of the RCD-24B series LED drivers (Figure 3). This dimming input is controlled by a variable external resistance and so a PTC thermistor plus bias resistors are the only additional components required. If different derating temperature points are required, PTC thermistors are available with different threshold temperatures in 10°C steps from 60°C to 130°C, so it is simply a matter of selecting the right part to match the specification of the LED.

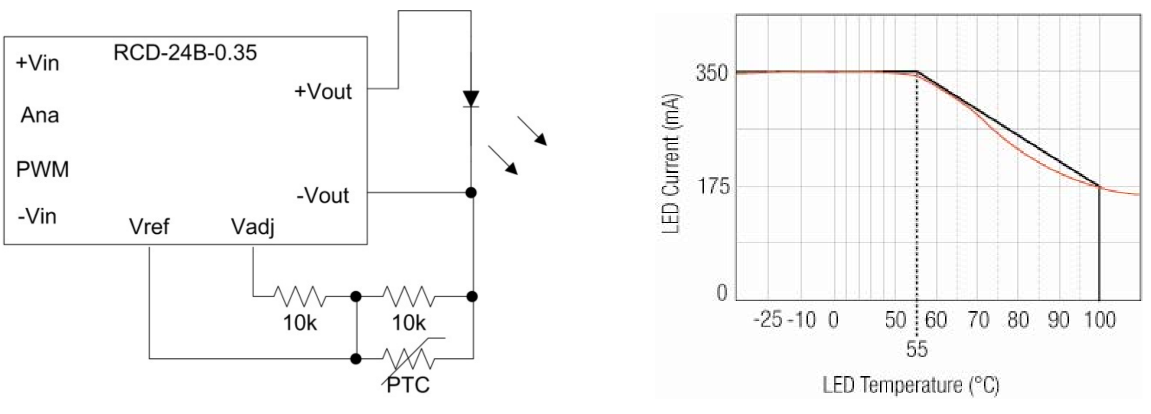



**Figure 3: PTC Thermistor circuit and resulting LED derating curve (red line)**

## 2: Over-temperature protection using an analogue temperature sensor IC

There are many IC temperature sensors available that provide a linear output with temperature. They do not cost much more than PTC thermistors and have the advantage that the linearity and offsets are very accurate, so temperature monitoring with 1°C resolution is possible. The output needs to be amplified in order to generate a useful control signal voltage, so they are most often used in conjunction with an operational amplifier.

The circuit suggestion below (figure 4) uses a common temperature sensor IC and dual operation amplifier. Similar products are available from a wide range of manufacturers. The output of the temperature sensing circuit is fed into the analogue voltage dimming input of the RSD-24B series. This control input linearly dims the LED brightness according to the voltage present on the pin.

In the circuit below, the LM61 temperature sensor delivers a linear output voltage depending on its temperature.  The output is pre-calibrated to give 10mV/°C + 600mV, so at 55°C the output voltage will be 1.15V. The LM10 device contains two low power op-amps and a precision 200mV voltage reference. The 10kOhm offset adjustment preset adjusts the offset to 1.15V and the gain is set so that at 100°C, the LED is running at 50% nominal current.

The advantage of this circuit is that only one design is needed to compensate for different LED characteristics from different manufacturers as the corner point of the derating curve is adjustable.

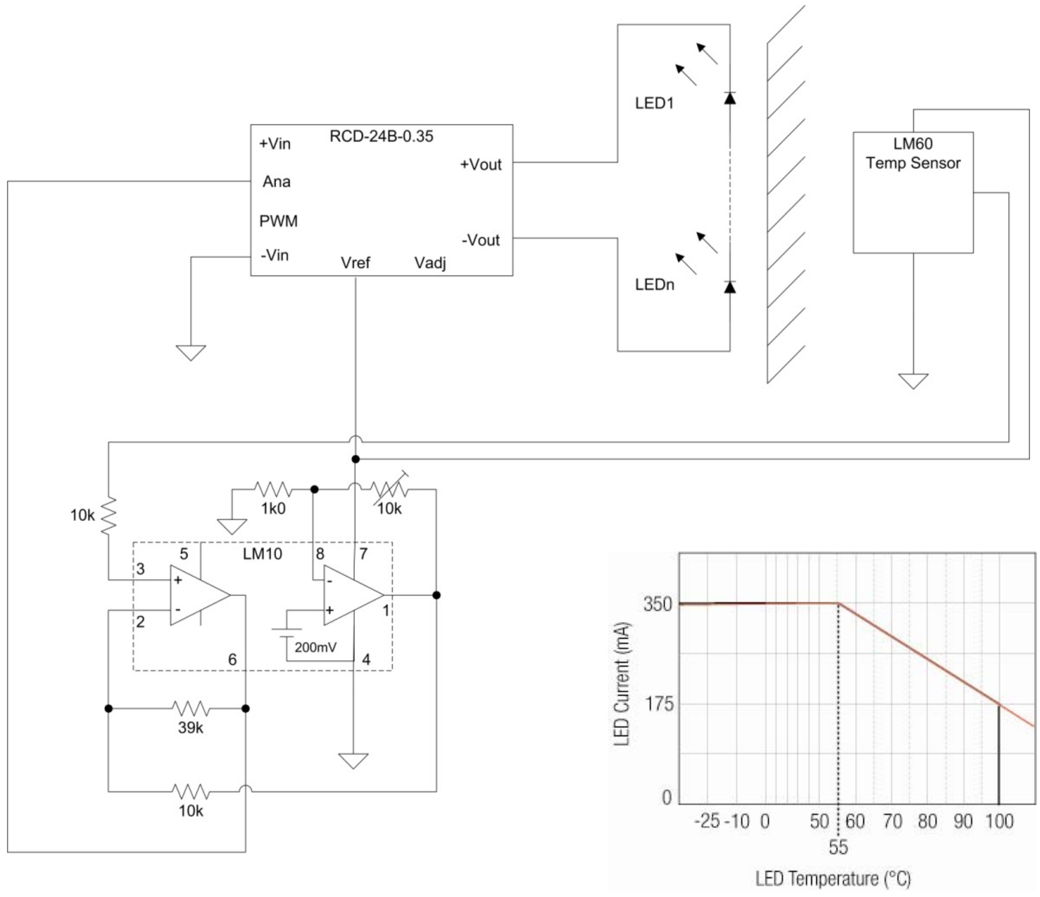



**Figure 4: Analogue over-temperature circuit and resulting LED derating curve (red line)**

### 3: Over-temperature protection using a PWM controller

The third dimming input possibility of the RCD-24B series is the PWM input. Pulse width modulation uses a digital control signal to alter the brightness of the LED by switching it on and off too rapidly for the eye to see. If the LED spends more time off than on, it will appear dim. If the LED spends more time on than off, it will appear bright. The PWM input responds to logic level signals, so is ideal for interfacing to digital controllers.

The circuit suggestion below (figure 5) uses a microprocessor to monitor and control up to eight LED drivers. As only 5 I/O pins are used, the circuit could be easily expanded to control more LED drivers or an additional remote over-temperature alert could be added.

Temperature sensing is realized via MAX6575L/H devices which are low cost, low current temperature sensors. There are other manufacturers offering equivalent temperature sensors with digital interfaces, but these parts have the advantage that up to eight temperature sensors can share a single control line. Temperatures are sensed by measuring the time delay between the microprocessor initiated trigger pulse and the falling edge of the subsequent pulses reported from the devices. On the output side, a low power addressable latch is reset with each trigger pulse, so turning all LED drivers on. The microprocessor then can individually set each output after an appropriate time delay to generate eight PWM signals to independently control each LED driver.

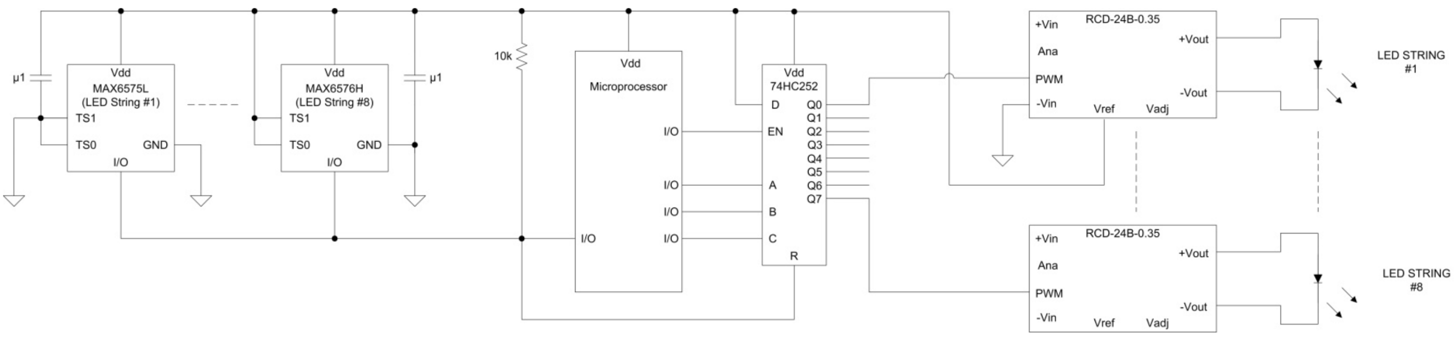



**Figure 5: Microprocessor-based PWM controller for up to eight LED drivers**

All electronic components become less reliable at high temperatures, so such over-temperature feedback circuits as suggested above are vital for a long-life LED solution. The same also applies to the LED driver, so although the RECOM RCD series can be safely used in ambient temperatures of up to 85°C, it is recommended that the LED driver is not placed too close to the LED to avoid unduly thermally stressing it.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