Dynamic Resistance

In a standard power supply that regulates output voltage the load resistance has a simple calculation:

\[ R_o = \frac{V_o}{I_o} \]

LEDs are PN junction diodes with a dynamic resistance that shifts as their forward current changes. When the load is an LED or string of LEDs, the load resistance is replaced with the dynamic resistance, \( r_D \). Simply dividing the LED forward voltage by forward current yields a value that is 5 to 10 times higher than the true dynamic resistance.

LED dynamic resistance is provided by some manufacturers, but in most cases must be calculated using I-V curves. (All LED manufacturers will provide at least one I-V curve.) To determine \( r_D \) at a certain forward current, draw a line tangent to the I-V slope as shown in Figure 1. Extend the line to the edges of the plot and record the change in forward voltage and forward current. Dividing \( \Delta V_F \) by \( \Delta I_F \) provides the \( r_D \) value at that point. Figure 1 also shows a plot of several \( r_D \) values plotted against forward current to demonstrate how much \( r_D \) shifts as the forward current changes.

One amp is a typical driving current for 3W LEDs, and the calculation below shows how the dynamic resistance of a 3W white InGaN was determined at 1A:

\[
\begin{align*}
\Delta V_F &= 4.0V - 3.45V \\
\Delta I_F &= 1.35A - 0A \\
r_D &= \frac{\Delta V_F}{\Delta I_F} = 0.55 / 1.35 = 0.4\Omega
\end{align*}
\]

Figure 1: \( V_F \) Vs. \( I_F \) and \( r_D \) Vs. \( I_F \) Curves

Dynamic resistances combine in series and parallel like linear resistors, hence for a string of ‘n’ series-connected LEDs the total dynamic resistance would be:

\[ r_{D\text{-TOTAL}} = n \times r_D + R_{SNS} \]

A curve-tracer capable of the 1A+ currents used by high power LEDs can be used to draw the I-V characteristic of an LED. If the curve tracer is capable of high current and high voltage, it can also be used to draw the complete I-V curve of the entire LED array. Total \( r_D \) can determined using the tangent-line method from that plot. In the absence of a high power curve tracer, a laboratory bench-top power supply can be substituted by driving the LED or LED array at several forward currents and measuring the resulting forward voltages. A plot is created from the measured points, and again the tangent line method is used to find \( r_D \).