

Graphical, Numerical Techniques Size LED Array's Drive

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LED-BASED LIGHTING IS REPLACING incandescent and gas-discharge lamps in many situations. As practical lighting sources, and considering their directional nature, LED fixtures usually use multiple LEDs arranged in an array, with “m” LEDs in a serial string and “n” such strings in parallel (Fig. 1). For the array configuration and the exponential I-V characteristics model of a single LED,¹ it's additionally possible to have a similar model representing the loading of such an array.

Since the single LED is a diode with a nonlinear forward-voltage/current, driving it with a fixed voltage source is generally not recommended. Rather, a serial (current-limiting) resistor is needed to equalize the power source and the load (Fig. 2). However, sizing this resistor requires a significant analytical manipulation. Using the single-LED exponential model, a Kirchoff's voltage law (KVL) equation around the circuit loop gives:

$$R_x (ae^{bV_F} + c) + V_F = V_s \quad (1)$$

which can be rearranged to:

$$R_x = \frac{V_s - V_F}{ae^{bV_F} + c} \quad (2)$$

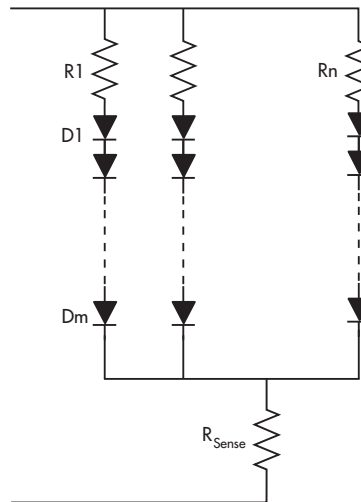
where a, b, and c are model parameters for a selected LED, as defined in the reference.

This is a challenge to solve symbolically, but it can be solved numerically with mathematical software tools. Alternatively, it can be solved graphically by

separating the two key I-V relationship equations, $v + R_x I_F = V_s$ and $I_F = ae^{bv} + c$.

For example, using a Lumileds Luxeon Rebel ES LED with a 3.2-V dc source and a desired drive current of 0.5 A, the horizontal current line intercepts the LED curve at 2.92 V (Fig. 3). Therefore, the series resistor will be $R_x = (3.2 - 2.92)/0.5 = 0.56 \Omega$.

However, the graphical approach would not handle an LED array effectively, and the numerical method works better. To represent the array current i_A , the exponential model for the (m × n) array is modified, since voltage drops across current-limiting resistor R_n and sense-resistor R_{Sense} are usually small compared with driving-source V_s :



1. Establishing the correct resistor size for each string of an array of n strings, where each strings has m LEDs, is challenging due to the nonlinear nature of the diodes.

$$i_A = n \left(ae^{\frac{bV_s}{m}} + c \right) \quad (3)$$

With the array model, the switch-mode buck-regulating current driver in a closed-loop configuration (Fig. 4) can be described by a set of equations starting at the feedback point, circling around the control loop, and ending at the driver output:

- Current sensing:

$$V_f = i_A \cdot R_{Sense} \quad (4)$$

- Error amplifier:

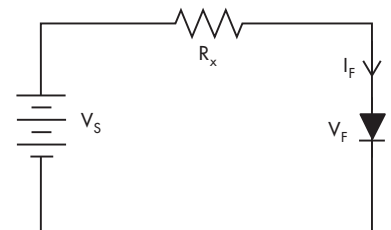
$$V_{er} = A(V_{Ref} - V_f) \quad (5)$$

- Effective error:

$$V_{ef} = \frac{V_{er} - V_F}{R_d} \cdot CTR \cdot R_e \quad (6)$$

- PWM ramp:

$$V_{Ramp}(t) = V_{Min} + \frac{V_{Max} - V_{Min}}{0.95 \cdot T_s} t \quad (7)$$



2. Even for a single LED driven by a voltage source, the exponential current-voltage relationship complicates selection of the series-resistor value.

