

## Challenges with Simple Series Regulation of High Power Array LEDs

### Overview

The LM80 specification spells out requirements for long term life tests for LEDs. This specification requires a constant (within 3%) DC bias current for the duration of the test. Though this is a simple specification, implementing it in a real-world stress system with simple components presents several challenges.

### High Power Dissipation in Regulation Resistor

The simplest regulation scheme is a series resistor to regulate the current. This resistor limits the current flow using Ohm's law:

$$(1) I = V/R$$

In a typical parallel regulation scheme, the resistor is placed between a bulk voltage supply and the Device Under Test (DUT). The current is then:

$$(2) I = (V_{bulk} - V_{fDUT})/R$$

The power dissipated in this resistor is equal to  $I^2R$ . For low power LEDs  $I$  is typically small, in the 10s of milliamps, and the power dissipation is negligible--even with a resistor in the 10s of ohms. For Bridgelux's high power LEDs running at 1.75A, even a 1 ohm resistor will dissipate 3W.

This high dissipation means a large (10W or more) power resistor must be used along with air cooling to remove the waste heat – up to 2700W of wasted heat in a 900 part system.

### Poor Current Regulation Due To Supply Voltage Changes

Since the current in the DUT is defined by equation 2, any changes in the  $V_{bulk}$  or the  $V_{fDUT}$  results in current changes. Ideally these values do not change; however, in real-world systems they do. For example,  $V_{bulk}$  is distributed via a series of cables, busbars, wires, and traces. Some of these components, like busbars and cables, conduct current that is used by more than one DUT. Since each has a finite resistance, there is a voltage drop on each conductor. When the current through that conductor changes, such as when a load board is removed, the voltage drop changes; this changes the DUT  $I_f$  for all the DUTs fed by that conductor.

This change need not be great in order to impact the current significantly. For the 1.75A case discussed above, a change of 52mV will cause a change in DUT  $I_f$  of 3% -- the limit allowed in LM80. Changes of this magnitude and more are common in parallel systems. The only way to combat this is to use very large conductors or eliminate the common conductors. One Vektrex client's system integrator had gone as far as running hundreds of parallel pairs of conductors back to the main supply – a trunk of cables roughly 1.5 feet in diameter. Even this did not solve their issues, and the client eventually scrapped their parallel system.

### No Ability to Adjust to DUT Vf Changes

Like changes in the bulk voltage DUT, Vf changes also change the current. There are two primary kinds of Vf changes: gradual and sudden. Gradual changes occur over hours or days. These can be accommodated with periodic adjustment of the resistance, though this is a tedious task with 900 resistors. It is also risky. If an operator inadvertently adjusts the resistor to an incorrect value, the current is outside the 3% specification. If the current spikes to too high a value, the DUT will be damaged.

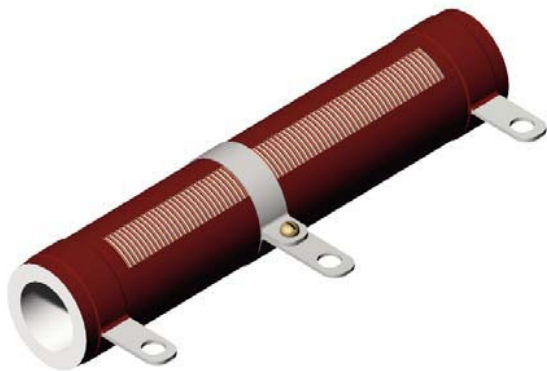
Sudden drops in Vf can occur when one of the LEDs in the array shorts. When this happens, the voltage across the resistor increases by the Vf of the failed LED. The voltage across the current regulation resistor is then:

$$(3) I = (V_{bulk} - V_{fDUT} - V_{fLED})/R$$

For the 1.75A case with a 1 ohm resistor,  $V_{bulk} - V_{fDUT} = 1.75V$ . When the LED fails, this increases the  $V_{fLED}$  (about 3V) to 4.75V. This results in a current surge to 4.75A through the device. The current surge will not be removed through regulation, so it will remain until the device fails catastrophically, the resistor burns up, or both. Failure analysis on the DUT will not be possible due to the extensive secondary damage caused by the current surge.

### Poor Current Resolution

The adjustment power resistor has a finite number of wire turns and a contact (usually a wiper or band) that reduces that number to the number required. A typical low-cost resistor is shown below.



In a typical application, the resistance is chosen to be in the middle of the range to allow for adjustment; with this scheme, the number of turns is reduced by half. The minimum increment of resistance is then:

$$(4) 1/(Turns/2)$$

For the typical resistor pictured above, this adjustment resolution is 1/30 or 3.3% -- more than that allowed by the LM80 specification. To combat this, a combination of a fixed resistor and an adjustment resistor can be used, but this increases cost and complexity.

**Need for High Voltage Data Acquisition System for Current Monitoring**

To monitor the current through each circuit, a data acquisition system must be assembled with 900 channels of capability. Current sense resistors (not the same as the current limiting resistor) must be added to each circuit and the voltage at each end of this resistor must be fed to the data acquisition system – a total of 1800 wires. Software must be developed to log each current. The software must support the manual adjustment needed.

Since the DUTs in question will be operating at voltage up to 25V, the data acquisition inputs must be able to withstand this without damage. This eliminates many common data acquisition systems, such as National Instruments systems, as they typically have +/- 10V input restrictions. Even if the resistor is placed on the ground side of the circuit, an open circuit would potentially deliver 25V to the data acquisition system, damaging or destroying it. To combat this, a high voltage data acquisition system must be used; these are typically more complex, costly and more difficult to program than the standard systems.

**Need for Numerous Safety Systems**

The power system driving the DUTs presents numerous safety risks; these must be handled with safety systems to prevent risk to DUTs, the building, and personnel. These risks require additional circuitry to be added to the system. Typical risks, along with common mitigation strategies, are listed below:

<b>Fault</b>	<b>Risk Of</b>	<b>Mitigation Strategy</b>
DUT cooling system failure	DUT damage, fire	Temperature monitoring system to shut off bulk power if temperature is out of limit
Driver cooling system failure	DUT damage, fire	Airflow monitoring system to shut off bulk power if temperature is out of limit
Inductive current surges at system power on	DUT damage	High quality power supplies with slow ramp up feature
Current regulation resistors burn up or catch fire when DUTs fail	DUT damage, fire	Current limiting devices such as fuses on individual circuits
High current short circuits – can cause fire and explosive melting of conductors – risk of burns, fires	Fire, burns, explosions	Place circuit breakers on main current distribution paths. Follow safe wiring practices. Install interlocks.
Abnormal current flows due to Rel board shorts	DUT damage	Individual circuit fuses will help but not eliminate all failures.

### **Summary – The Simple System is Risky**

LM80 seems to indicate that a simple regulation scheme can be used in a life test system. Simple schemes have been used effectively by many LED manufacturers in low power systems for LEDs in the millamp range. However, when these systems are scaled up to high power, manufacturers have consistently found that the complexity of the system grows quickly due to the difficulty of managing the power levels and the need to ensure safety.

Some manufacturers have turned to linear regulator approaches, often using the LM317 integrated circuit, to develop systems that operate up to 1.5A--the limit of the LM317. However, these systems require more sophisticated circuitry and a lot of cooling air or water to remove the waste heat. They are very expensive to operate and maintain.

Vektrex knows of no LED manufacturer that is operating above 1.5A with simple linear regulation.