
LED Thermal Testing

Application Brief A05

Introduction

An understanding of the thermal properties of an LED component in a customer-specific application is essential in order to achieve the highest optical performance without sacrificing reliability. The technical memo “LED Lamp Thermal Properties”, January 28, 1993, discusses the basic thermal modeling of an LED lamp. This memo describes the thermal test system used by Agilent Technologies to measure the junction temperature and pin temperature of an LED component mounted in a customer-specific application.

In general, the purpose of thermal testing of LED components is to measure the temperature rise, junction to ambient, so as to ensure that the maximum junction temperature is not exceeded. Temperature cycling of an LED component at temperatures higher than the maximum junction temperature tends to cause excessive thermal stresses of the gold wirebond, which leads to premature catastrophic failures. For most Agilent Technologies LED lamps, the maximum junction temperature is 110°C. The

maximum junction temperature can be found either in the *Maximum Absolute Ratings* of a product data sheet or extrapolated from the *Maximum Forward Current versus Temperature Curve*. The maximum junction temperature is the intercept of an extension of the sloping current derating curve with the ambient temperature axis of the curve at a forward current of zero.

The basic thermal test procedure is to thermocouple the pins of the LED components inside the customer-specific system, operate the system, and monitor the temperature rise at thermal equilibrium. Additionally, the junction temperature of selected LED components can be measured by measuring the change in forward voltage of the LED components. Care is taken in these measurements to ensure that the customer usage is duplicated as much as possible. This includes correct mechanical orientation of the system, mounting the system in its intended enclosure, and operating the system at voltages similar to normal operation.

A block diagram of the thermal

test system is shown in Figure 1. The thermal test system uses several pieces of test equipment that are controlled by a personal computer via the IEEE488 parallel bus. The portion of the test system that measures the pin temperatures of the LED components consists of an Agilent 3421A Data Acquisition System and a series of T-type thermocouples. The thermocouples consist of Omega TT-T-30 SLE thermocouple wire that is stripped, twisted together, and soldered to the pins under test. The Agilent 3421A converts the voltage developed across the thermocouple wires directly into a temperature measurement, which is sent to the computer controller via the IEEE488 bus.

The remaining pieces of equipment are used to monitor the junction temperature of an LED device under test by accurately monitoring the change in forward voltage. For best results, the device under test should be characterized for forward voltage over temperature at a constant current of 1.00 mA. Generally, the change is approximately -2.2 mV/°C and is very linear over the operating temperature range. After

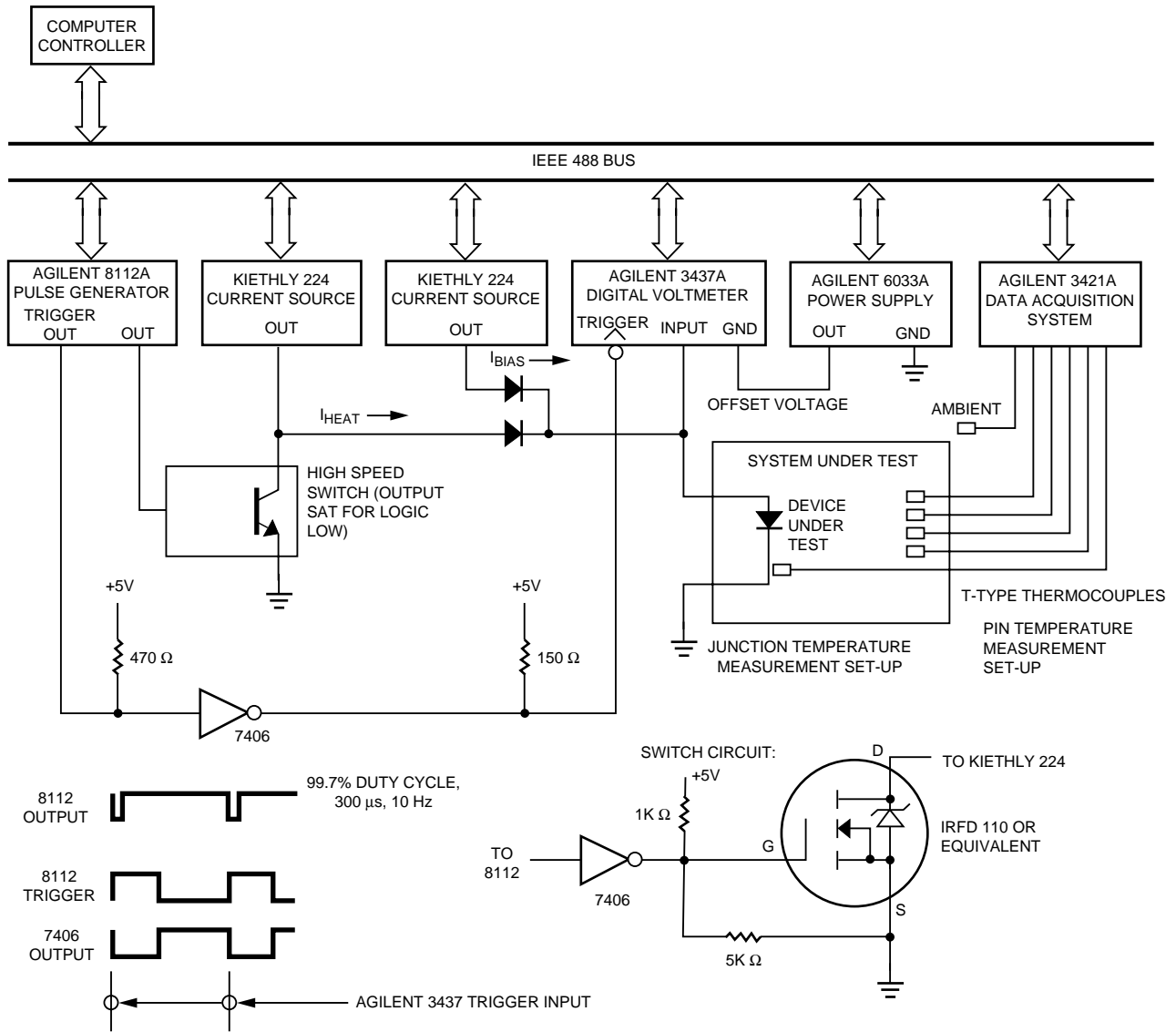


Figure 1. Thermal Test System.

characterization, the LED component can be soldered directly into the system under test. For best results, the device under test should be electrically isolated from the rest of the system under test.

The device under test is driven by two Keithly 224 Current Sources. One source is used to drive the device under test at the 1.00 mA bias current. The second source is used to drive the device under test at a programmable heating current. Note, that I_{BIAS} plus I_{HEAT} should equal the customer's intended drive current for the device under test. The Agilent 8112A Pulse Generator is programmed to produce a 99.7% duty cycle waveform. The output of the pulse generator is connected to a high speed digital switch that shunts the heating current source to ground during the 0.3% portion of the duty cycle. The trigger output of the pulse generator is used to trigger the sampling of an Agilent 3437A Digital Voltmeter. Note that the positive edge of the pulse generator trigger output is coincident with the 0.3% duty cycle waveform and that the digital voltmeter is negative edge triggered. To trigger the digital voltmeter on the correct edge, the trigger output of the pulse generator is inverted with a TTL level 7406 inverter. To get the highest resolution, the Agilent 3437A is configured to measure the voltage of the device under test on a 0.1000 volt range, using an Agilent 6033A Programmable Power Supply as an offset of about 1.6 volts. Since the LED

component begins to cool off fairly quickly, the Agilent 3437 is configured to measure the voltage of the device under test as soon as possible after the I_{HEAT} current source has been shunted off. Generally, this measurement should be made within 50 ms of the time that the I_{HEAT} source has been shunted off.

The operation of the system is as follows:

First, the forward voltage of the device under test is measured cold at 1.00 mA (I_{BIAS} only). This allows the HP6033A programmable power supply to be set to the proper offset voltage. All thermocouples are measured while the system under test is un-energized and the device under test is driven at the bias condition.

Next, the system under test and device under test are energized at the intended drive condition. The thermocouples are polled regularly, and the temperature rises are recorded at 10-second intervals. After thermal equilibrium has occurred, the forward voltage of the device under test is remeasured at the 1.00 mA (I_{BIAS}) condition. (In most cases, thermal equilibrium usually occurs within 30 minutes after the system has been energized.)

Then, the junction temperature rise is calculated as the change in forward voltage divided by the temperature coefficient of forward voltage. The junction temperature rise and pin temperature rises are corrected to

account for any change in ambient temperature.

Now that all the temperature rises are known, the thermal resistances can be calculated. In most applications, an approximation of the junction temperature rise can be calculated by measuring the pin temperature rises with a low thermal mass thermocouple and calculating the junction to pin temperature rise using the value of thermal resistance, junction to pin, published in the product data sheet or in the technical memo "LED Lamp Thermal Properties".

