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Pulsed Operating Ranges for AlInGaP LEDs vs. Projected Long Term Light Output Performance

Application Brief I-024

Introduction

There have been two significant questions related to pulsing AlInGaP LEDs in various applications. The first question is what is a safe maximum peak current and duty factor for AlInGaP LEDs? The second question is what long term performance can be projected for AlInGaP LEDs operated at various pulsed drive conditions?

This application brief presents data and accompanying discussion that addresses both of these questions.

The Need for Pulsed Drive Conditions

LEDs need to be strobed at some pulsed drive condition whenever high light output for a short duration is necessary, or when displaying variable and changing characters or images across the face of a matrix display. The selection of the pulse condition is usually based on the time average luminous intensity required for the application.

Primary considerations used to set pulsed drive conditions for LEDs include:

- Luminous intensity at the peak current, $I_{V\ PEAK}$ (mcd)
- Peak current, I_{PEAK} (mA)
- On-time duty factor, DF (%)
- Maximum allowed LED device junction temperature, T_J MAX (°C)
- Strobing rate, f (Hz)

For a simple square wave, the I_{PEAK} x DF determines the time average current, I_{AVG} (mA). The achieved time average luminous intensity is the light output at the peak current, $I_{V\ PEAK}$ (mcd) x DF.

The strobing rate (pulse rate), f (Hz), should be faster than 100 Hz to minimize observable flicker. The optimum strobing rate is 1000 Hz.

To summarize here, it is the necessary time average luminous intensity for a determined on-time duty factor that leads to selection of peak drive current.

Maximum Peak Current

Maximum peak current for an LED technology is based on the current density, in amperes per square centimeter, J (A/cm^2), the LED chips can withstand without damage, and the measured rate of light output degradation at that peak current. Light output degradation for AlInGaP LEDs is primarily a function of current density at the peak current over a collective period of on-time. It is not a function of I_{AVG}.

Basic Theory

The following theory lays the ground work for understanding the discussion on driving AlInGaP LEDs at various pulsed drive conditions. It is assumed that a rectangular current pulse train is used to drive the LEDs. Driving LEDs by rectified ac current gives a different result.

Light output degradation vs. on-time. Light output degradation of LEDs only occurs when forward current is flowing through the LED *p-n* junction. At any selected forward current, some amount of light output degradation will occur during the current pulse on-time period. The amount of light output degradation over an elapsed time period is the accumulated degradation of the collective on-time periods within an elapsed time period.

An example: A hypothetical example is shown in Figure 1. An LED driven at a 10% on-time duty factor will experience light output degradation for 10 on-time hours out of every 100 hours of elapsed time. If the light output degradation rate at the selected peak forward current is hypothetically -5% per decade on-time hours, then:

- After 100 hours of elapsed time, the LEDs will have degraded by approximately -5%,
- -10% after 1,000 hours elapsed time,
- -15% after 10,000 hours of elapsed time, and
- -20% after 100,000 hours of elapsed time.

This same LED driven under dc conditions, 100% on-time duty factor, at the same selected forward current, will experience light output degradation on an LED on-time basis (LED on-time = elapsed time).

- After 10 hours of LED on-time the light output degradation will be about -5% (equivalent to the above 100 elapsed time hours of 10% DF on-time pulsing),
- -10% after 100 hours (equivalent to the above 1,000 elapsed time hours of 10% DF on-time pulsing),
- -15% after 1,000 hours (equivalent to the above 10,000 elapsed time hours of 10% DF on-time pulsing), and
- -20% after 10,000 hours (equivalent to the above 100,000 elapsed time hours of 10% DF on-time pulsing).

Pulsed Drive Conditions for AlInGaP LEDs

Long term high temperature operating life (HTOL) data at 55°C have been evaluated by Agilent Technologies to determine the range of recommended pulsed and dc current operating conditions for AlInGaP LEDs. The drive current conditions used in these HTOL tests are listed in Table 1.

Using the results from the above HTOL testing, the absolute maximum drive current conditions, listed in Table 2, have been established for T-1$^3/_4$ AlInGaP LED lamps.

Designers should adhere to these maximum drive current conditions for both rectangular drive current pulses and rectified ac drive current.

The range for the recommended pulsed and dc drive current conditions for AlInGaP T-1$^3/_4$ LED lamps is shown in Figure 2. The boundary is from 100 mA peak and 30% DF to 50 mA dc. Operation anywhere within this range ensures operation without overdriving the LEDs.

Operation within the recommended range, shown in Figure 2, does not necessarily ensure a light output degradation that is acceptable in all kinds of applications. The long term light output degradation for a selected pulse drive

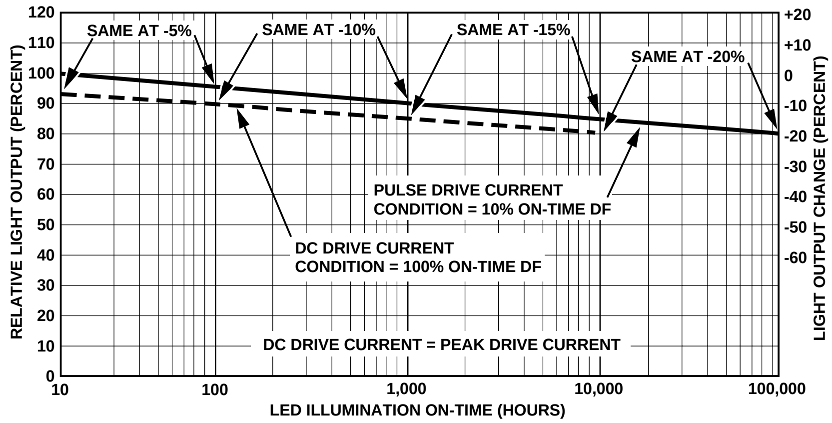

Figure 1. Comparison of Hypothetical LED Degradation of -5% per Decade On-Time Hours for 10% DF Pulsed Drive Condition vs. dc Drive Condition (100% DF), where dc Current Value = Peak Pulse Current Value.

Table 1. DC and Pulsed Drive Current Conditions Used for HTOL Testing

dc Drive Conditions	10%DF Conditions	I_{AVG} = 30 mA Conditions
20 mA dc	I_{PEAK} = 30 mA	I_{PEAK} = 50 mA, DF = 60%
30 mA dc	I_{PEAK} = 50 mA	I_{PEAK} = 75 mA, DF = 40%
50 mA dc	I_{PEAK} = 75 mA	I_{PEAK} = 100 mA, DF = 30%
	I_{PEAK} = 100 mA	

Table 2. Absolute Maximum Drive Currents

I_{DC} MAX	I_{PEAK} MAX	I_{AVG} MAX
50 mA	100 mA	30 mA

current condition must be evaluated to determine the acceptability for a given application.

AlInGaP T-1 3/4 LED lamps may be operated at peak drive currents less than 10 mA. However, attention to special considerations is required to ensure reliable operation. Designers are encouraged to contact Agilent Technologies before proceeding with a design that utilizes an LED drive current less than 10 mA.

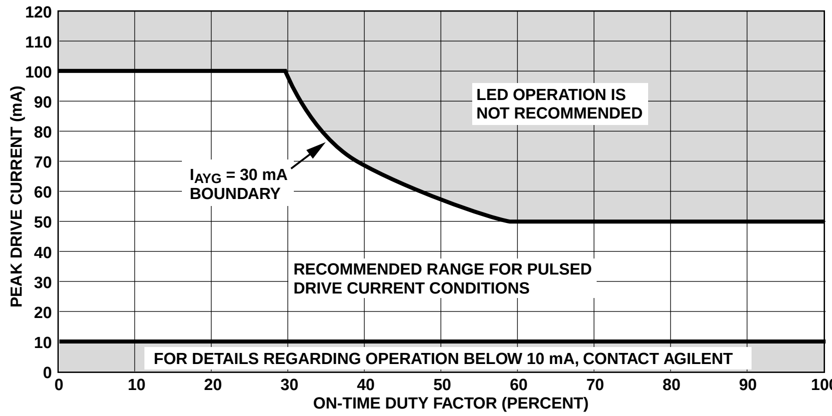

Figure 2. Recommended Range for Pulsed Drive Current Conditions for AlInGaP LEDs

Projected Long Term Performance for Various Drive Current Conditions

The projected light output degradation for each of the above listed drive current conditions is graphed as straight lines on semi-log plots for comparison purposes. These degradation graphs are projected typical performance, based on +55°C high temperature operating life (HTOL) test data out to 12,000 hours. For this reason, these graphs are only projections and the actual long term performance out to 100,000 hours cannot be guaranteed by Agilent Technologies.

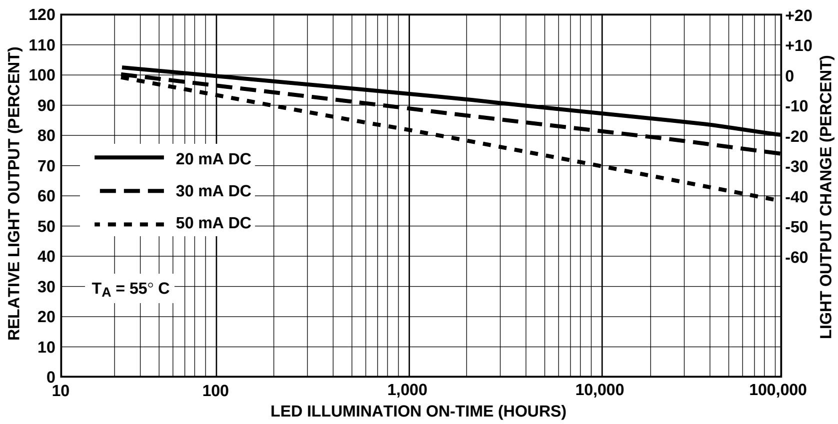

Figure 3. Projected Long Term Light Output Degradation for dc Drive Currents

Dc drive conditions. Figure 3 contains curves that project the long term light output performance for 20 mA dc, 30 mA dc, and 50 mA dc drive currents. DC drive currents between 20 mA and 30 mA exhibit long term degradation that is projected to be on average less than -30% after 100,000 hours of LED on-time.

Increasing the dc drive current above 30 mA results in additional degradation, as is exhibited by 50 mA dc. At 100,000 hours of LED on-time, the light output degradation for 50 mA dc is projected to be on average greater than -40%.

Pulsed operating conditions with 10% LED on-time duty factor. Figure 4 contains curves that project the long term light output performance for pulsed drive conditions where the LED on-time duty factor is 10%. At 100,000 hours of elapsed time, the cumulative LED on-time is 10,000 hours. For peak drive currents up to 50 mA, the long term degradation is projected to be on average about -30% after 100,000 hours of elapsed time. The light output degradation in Figure 4 for 30 mA and 50 mA peak currents at 10% DF, after 100,000 hours of elapsed time, can be compared to the degradation shown in Figure 3 for 30 mA dc and 50 mA dc, respectively, after 10,000 hours of LED on-time. At these respective time points, the light output degradations are approximately the same.

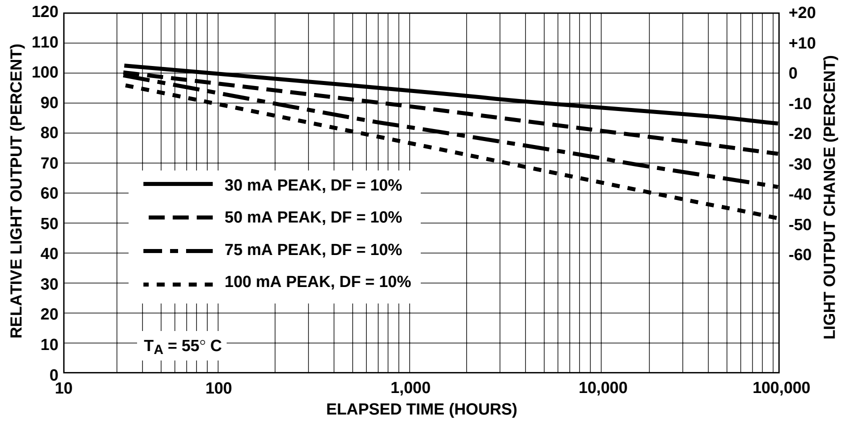

Figure 4. Projected Long Term Light Output Degradation for Pulsed Drive Conditions with an LED On-Time Duty Factor of 10%

Increasing the peak drive current above 50 mA results in a considerable increase in degradation. At 100,000 hours of elapsed time, the light output degradation for a peak current of 75 mA dc is projected to be on average near -40%, and with the peak drive current increased to 100 mA the degradation is projected to increase to an average near -50%.

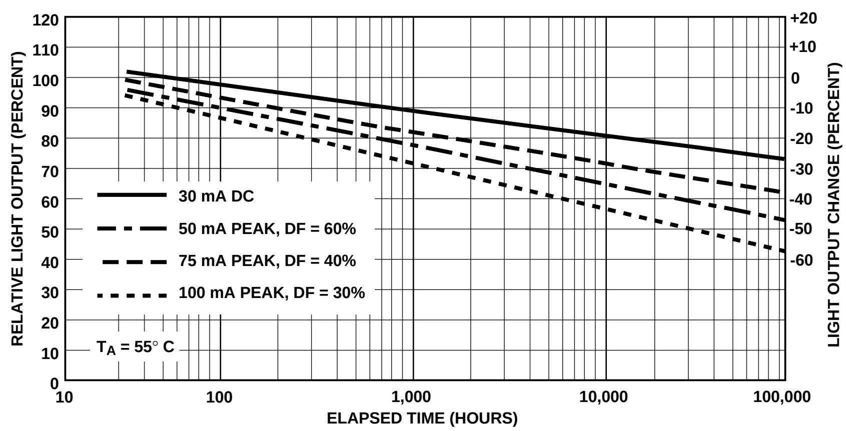

Figure 5. Projected Long Term Light Output Degradation for Pulsed Drive Conditions with the LED On-Time Duty Adjusted to Provide an I_{AVG} = 30 mA

Pulsed operating conditions with DF adjusted to provide I_{AVG} = 30 mA.
Figure 5 presents curves that project the long term light output performance for pulsed drive conditions where the DF is adjusted to provide a time average current of 30 mA. The curve of degradation for 30 mA dc drive current is included to provide a direct visual comparison with the pulsed drive conditions.

For a peak drive current of 50 mA, the DF is set at 60% and the cumulative LED on-time is 60,000 hours at 100,000 hours of elapsed time. The typical long term degradation is projected to be near -40% after 100,000 hours of elapsed time.

If a DF is set at 40% for the peak current of 75 mA, the long term degradation is projected to be typically about -47% after 100,000 hours of elapsed time.

If a DF of 30% is set for a peak drive current of 100 mA, the long term degradation is projected to be considerable, typically -58% after 100,000 hours of elapsed time.

The light output degradations in Figure 5 for the pulsed operating conditions can be compared to the 30 mA dc degradation curve. For all three pulse conditions, the light output degradation is greater than that for 30 mA dc.

The Agilent Technologies AlInGaP LED Extended Warranty

Agilent Technologies provides an Extended Warranty for AlInGaP T-1 3/4 plastic LED lamps that ensures sufficient light output for a period of 5 years, where sufficient light output is defined as less than -50% on average light output degradation during the 5 year period. The following drive current limits are defined within the text of the Extended Warranty:

1. For dc operation, the LED drive currents are maintained between 10 mA dc and 30 mA dc.
2. For pulsed operation, the LED drive peak current must be above 10 mA and must not exceed 70 mA.
3. Average currents must not exceed 30 mA (i.e. DF MAX = 50% at 60 mA $_{PEAK}$; DF MAX = 43% at 70 mA $_{PEAK}$). At DF greater than 50%, I_{PEAK} must not exceed 30 mA.

Failure to comply with these drive current conditions, and warranty specified environmental conditions, voids the Extended Warranty.

Figure 6 shows the pulsed current operation range for the Agilent Technologies AlInGaP LED Extended Warranty. The warranty pulsed current operating range is a subset of the larger recommended operating range shown in Figure 2. Pulsed current operation anywhere within this warranty drive current range ensures less than -50% on average light output degradation from AlInGaP T-1 3/4 LED lamps for a period of 5 years.

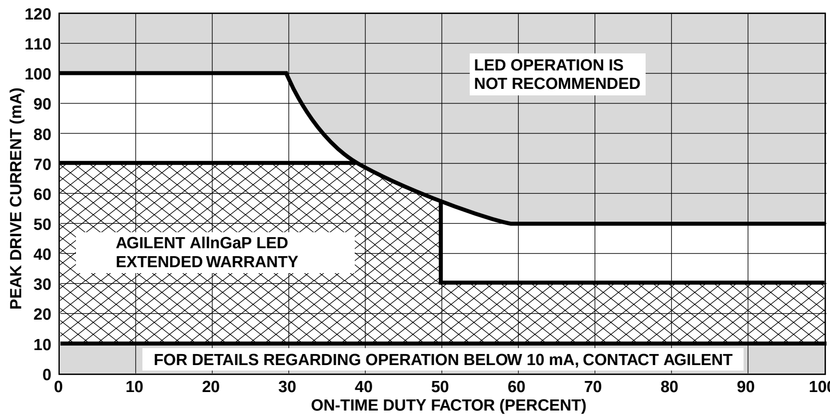

Figure 6. Agilent Technologies AlInGaP LED Extended Warranty Pulsed Current Operating Range

The Suitability of Various LED Drive Current Conditions

It is important for designers to understand the suitability of various drive current conditions as they apply to different applications. The necessary minimum light output at the end of operational life for a product using AlInGaP LEDs may be set by regulation or may be based on human factors data. In either case, the LED drive current condition should be chosen to ensure the LED long term light output degradation is compatible with the light output requirements of the application.

Some Suggested Maximum dc and Pulsed Current Operating Conditions

Table 3 offers suggested dc and pulsed drive current conditions for various applications. For purposes of this application brief, a long term average light output degradation of -40% is assumed for each application. This assumption, however, may not be an acceptable real world requirement for all applications. The actual drive condition selected for a particular application should be checked against the curves of Figures 3, 4, and 5 to ensure the projected long term average light output degradation of AlInGaP LEDs is in concert with the end product design and mission objectives.

Table 3. Suggested Maximum dc and Pulsed Drive Current Conditions for T-1$^3/_4$ AlInGaP LED Lamps in Various Applications

Application	Suggested Maximum Drive Current Conditions	Projected Degradation Information
Traffic Signal Modules and Railroad Signal Modules	I_{DC} MAX = 30 mA I_{PEAK} MAX = 50 mA with 10% DF	Figure 3, 30 mA dc curve. Figure 4, 50 mA PEAK curve.
Over Roadway and Trailer Mounted Variable Message Signs (VMS).	I_{PEAK} MAX = 30 mA	Figure 4, 30 mA PEAK curve.
Barricade Lights: Type A Type B Type C	I_{DC} MAX = 30 mA I_{DC} MAX = 30 mA I_{PEAK} MAX = 75 mA at 65 Flashes/Minute	Figure 3, 30 mA dc curve. Figure 3, 30 mA dc curve. Figure 4, 75 mA PEAK curve.
Beacon Flasher	I_{PEAK} MAX = 75 mA at 65 Flashes/Minute	Figure 4, 75 mA PEAK curve.
EXIT Signs	I_{DC} MAX = 30 mA	Figure 3, 30 mA dc curve.
Emergency Signs	I_{PEAK} MAX = 100 mA with 30% DF	Figure 5, 100 mA PEAK curve.
Commercial Advertising Signs	I_{PEAK} MAX = 50 mA with 60% DF	Figure 5, 50 mA PEAK curve.

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Data subject to change.

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