INVENTRONICS

DALI, DALI-2 and D4i, a Technical Primer

DALI

The Digital Addressable Lighting Interface (DALI), was first released in the early 1990's and has been a leading lighting control protocol ever since. Developed as a digital successor to analog dimming, DALI allows for networked control of individual luminaires, groups of luminaires, or all luminaires via a connection to the DALI bus. This provides versatility by allowing the creation and reconfiguration of lighting groups and scenes through software instead of having to modify the control wiring. DALI, DALI-2, and D4i are governed by the Digital Illumination Interface Alliance (DiiA). DALI and DALI-2 standards reside within IEC-62386.

DALI-2

DALI-2 is the second generation of DALI and builds upon the first generation of DALI in the following ways: increased interoperability, more stringent test protocols and extended commands. While the first generation of DALI is self-certified by the manufacturer, DALI-2 test certificates must be uploaded to the DiiA's website. The more stringent test protocols and requiring the test certificates to be verified by the DiiA, have greatly increased the interoperability within DALI-2 devices and the first generation of DALI. Table 1 shows the minimum standards the LED driver must be tested to become DALI-2 compliant.

Minimum Requirements for DALI-2 LED Drivers		
IEC 62386 Standard	**Correlated DALI Standard**	**Description**
IEC 62386-101	DALI Part 101	General DALI Requirements
IEC 63286-102	DALI Part 102	General Control Gear Requirements
IEC 62386-207	DALI Part 207	DALI for LED Modules

Table 1: Minimum Requirements for DALI-2 LED Drivers

D4i

While the first generation of DALI targeted traditional DALI applications, D4i is targeting Intra-Luminaire applications. Traditional applications feature a DALI bus distributed through a room or building and connecting to many DALI devices. In Intra-Luminaire applications, the DALI-2 bus does not leave the fixture and instead is utilized as a standardized data bus between the driver and a wireless radio or sensor. The minimum requirements for a D4i certified driver are shown in Table 2. It is important to note that DALI-2 can exist without D4i, but D4i cannot exist without DALI-2.

DALI-2 is the communication standard and D4i is the feature set. The rest of this article will expand on the required feature set for D4i.

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IEC-62386-101	DALI Part 101	General DALI Requirements
IEC-62386-102	DALI Part 102	General Control Gear Requirements
IEC-62386-207	DALI Part 207	DALI for LED Modules
-	DALI Part 250	Integrated DALI Bus Supply
-	DALI Part 251	Memory Bank 1 Extension
-	DALI Part 252	Energy Reporting
-	DALI Part 253	Diagnostics and Maintenance

Table 2: Minimum Requirements for DALI-2 D4i LED Drivers

Diagnostics and Maintenance

DALI Part 253 standardizes the collection and storage of diagnostic and maintenance data. The following methods are used for the collection and storage of this data:

- Performance Data
- Failure Flags
- Failure Flag Counters
- Lifetime Counters
- Timers
- Luminaire Operation Information

Performance Data

Performance data allows for real-time driver operation information to be read back to a centralized controller. This information is useful for diagnostic information. A list of information is shown in Table 3 with definitions to follow.

Performance Data
Driver External Supply Voltage
Driver External Supply Frequency
Driver Power Factor
Driver Temperature
Driver Output Current Percentage
Light Source Voltage
Light Source Current
Light Source Temperature

Table 3: List of Performance Data

Performance Data Defined

Driver External Supply Voltage: RMS value of external supply voltage, in VAC.

Driver External Supply Frequency: Frequency of external supply voltage. If the external supply voltage is DC, the frequency is equal to zero.

Driver Power Factor: Real-time power factor of driver.

Driver Temperature: Internal temperature of the driver, in degrees Celsius.

Driver Output Current Percentage: Output current percentage in relation to the nominal output current setting of the control gear. It only shows output current reductions in relation to failure conditions. For normal operation, DALI Part 102 provisions for reading the current driver dimming percentage.

Light Source Voltage: Output voltage to the driver, in Vdc.

Light Source Current: Output current to the driver, in mA.

Light Source Temperature: Temperature of external NTC in degrees Celsius.

Failure Flags and Counters

DALI Part 253 also defines a set of failure flags and failure flag counters for the light source and driver.

Failure flags are raised when a defined threshold is passed for a defined parameter. DALI Part 253 does not standardize the setting of these thresholds. Each failure flag threshold is set either by the driver manufacturer or programmed by the luminaire manufacturer through programming software provided by the driver manufacturer. Failure flags will be reset after a power cycle, or after a hysteretic period in which the driver resumes normal operation within the set threshold.

Each failure flag has a correlated failure flag counter and will increment each time the failure flag is raised. As defined by DALI part 253, each failure flag counter can count 0 to 253 occurrences of an event. Other than knowing the thresholds and number of events, no other event data is stored. Failure Counters are non-volatile, read-only memory and will retain values after power is removed.

Driver and Light Source Failure Flags and Counters

DALI Part 253 breaks down failure flags and counters into two categories: Driver Failure Flags and Light Source failure flags. It is important to note that all this information resides inside the D4i certified driver. Driver failure flags revolve around things happening internally to the driver, whereas light source failure flags revolve around the output of the driver. Failure flags are listed in Table 4 and failure flag counters are listed in Table 5 with the definitions to follow.

Driver Failure Flags	Light Source Failure Flags
Overall Failure	Light Source Overall Failure
External Supply Under Voltage	Light Source Open Circuit
External Supply Over Voltage	Light Source Short Circuit
Output Power Limitation	-
Thermal Derating	Light Source Thermal Derating
Thermal Shutdown	Light Source Thermal Shutdown

Table 4: Driver and Light Source Failure Flags

Driver Failure Counters	Light Source Failure Counters
Overall Failure Counter	Light Source Overall Failure Counter
External Supply Under Voltage Counter	Light Source Open Circuit Counter
External Supply Over Voltage Counter	Light Source Short Circuit Counter
Output Power Limitation Counter	-
Thermal Derating Counter	Light Source Thermal Derating Counter
Thermal Shutdown Counter	Light Source Thermal Shutdown Counter

Table 5: Driver and Light Source Failure Counters

Failure Flags Defined

Driver Overall Failure: Any event where the control gear cannot operate as intended.

Driver External Supply Under Voltage: Event when the external supply voltage is less than the minimum threshold. Two different thresholds can be implemented for AC or DC operation.

Driver External Supply Over Voltage: Event when the external supply voltage is more than the maximum threshold. Two different thresholds can be implemented for AC or DC operation.

Driver Output Power Limitation: Event when the control gear limits the output current due to an internal power limitation. This is the case if the LED voltage multiplied with the control gear output current is higher than the output power threshold of the control gear.

Driver Thermal Derating: Event flag is set when the thermal derating temperature threshold is passed. The thermal derating threshold is always less than the thermal shutdown threshold.

Driver Thermal Shutdown: Event flag is set when the thermal shutdown temperature threshold is passed. The Thermal Shutdown threshold is always less than the thermal derating threshold.

Light Source Overall Failure: Any event where the lamp cannot operate as normal.

Light Source Open Circuit: Flag is set if an open circuit is detected on the driver output.

Light Source Short Circuit: Flag is set if an short circuit is detected on the driver output.

Light Source Thermal Derating: Event flag is set when the light source thermal derating temperature threshold is passed. The thermal derating threshold is always less than the thermal shutdown threshold (ex. Driver external NTC).

Light Source Thermal Shutdown: Event flag is set when the light source thermal derating temperature threshold is passed. The thermal derating threshold is always less than the thermal shutdown threshold (ex. Driver external NTC).

Timers

DALI Part 253 defines three timers: Driver Operating Time, Light Source On-Time and Light Source On-Time Resettable. Timers use a one second time base and will increment every second that a criterion is met. DALI Part 253 reserves four bytes of data for each timer, allowing each timer to count past 136 years. While 136 years is much longer than the estimated lifetime for any luminaire, three bytes of data would only allow for approximately six months of recording time. The timer definitions are listed below.

Timers Defined

Driver Operating Time: Time that power has been applied to the driver. This timer cannot be reset and is stored in non-volatile memory. The operating-time timer will return its value after power is removed.

Light Source On-Time: Total time that the light source has been on in the lifetime of the fixture. This timer cannot be reset and is stored in non-volatile memory. The light source on-timer will retain its value after power is removed.

Light Source On-Time Resettable: Same as the light source on-time listed above. However, this timer can be reset and is useful for creating custom timing schemes.

Lifetime Counters

Lifetime counters are very similar to failure flag counters but can count much higher; in fact, lifetime counters can count to 16 million events. There are three lifetime counters defined in DALI part 253: Driver Start Counter, Light Source Start Counter and a Resettable Light Source Start Counter. The definitions are listed below.

Lifetime Counter Definitions

Driver Start Counter: This counter will increment each time AC is removed and applied to the driver and cannot be reset. Driver start counter values are stored in non-volatile memory and will retain value after power is removed from the driver.

Light Source Start Counter: This will increment each time the light source is turned on. This counter cannot be reset, is stored in non-volatile memory and will retain its value after power is removed from the driver.

Resettable Light Source Start Counter: Same as the light source start counter but allows the values to be reset. This is useful for creating custom timing schemes.

Luminaire Operation Information

DALI Part 253 also implements data locations for luminaire operation information. This information is populated by the luminaire manufacturer and is useful for determining the remaining life of the luminaire. DALI Part 253 lists three points of luminaire operation information: Rated Median Useful Luminaire Life, Internal Driver Reference Temperature and Rated Median Useful Light Starts. The definitions are listed below.

Luminaire Operation Information Defined

Rated Median Useful Luminaire Life: Useful life of luminaire, including LEDs and other components.

Internal Driver Reference Temperature: Value is derived by the luminaire manufacturer by measuring the driver temperature at an ambient temperature of 25°C at 100% rated luminaire power within the luminaire.

Related Median Useful Light Starts: Rated light starts of luminaire- transitions of Lamp Off to Lamp On.

Energy Reporting

The Energy Reporting aspect of D4i is governed by DALI Part 252. Table 6 highlights what data can be recorded and monitored with definitions to follow. For quick reference, the Power Triangle can be reviewed in Figure 1.

Required	Optional
Active Energy	Apparent Energy
Active Power	Apparent Power
	Apparent Energy Load-Side
	Apparent Power Load-Side

Table 6: Required and Optional Measurements for DALI Part 252

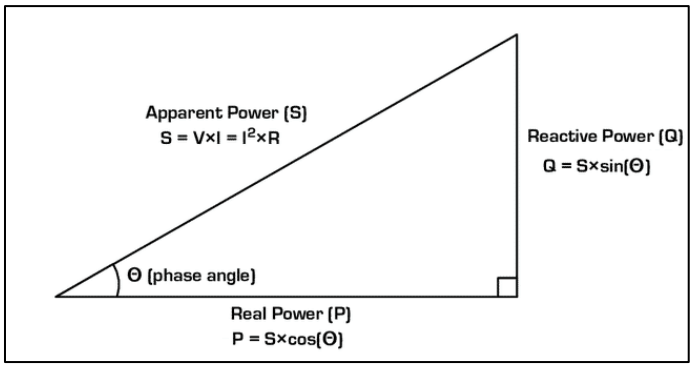

Figure 1: The Power Triangle

Energy Reporting Defined

Active Energy: The integral of the instantaneous power over a time interval, measured in units of watt hour.

Active Power: Under periodic conditions, mean value, taken over one period of the instantaneous power, measured in watts.

Apparent Power: The product of the RMS voltage between the RMS electric current, measure in VA.

Apparent Energy: The integral of apparent power over a time interval, measures in units of watt hour.

Load-Side Power: The input power minus the sum of power used for the DALI bus power supply (if present) and the power used for the AUX power supply (if present).

Load-Side Energy: The integral of load-side power over a time interval, measured in units of watt hour.

Energy Reporting Notes

According to DALI Part 252, the accuracy of these measurements is to be defined by the driver manufacturer. Inventronics utilizes 1% power monitoring accuracy.

In many areas, certain laws will restrict the usage of these devices as a power meter (a device used to track and bill for power used). The recommended use for this feature is to track and verify energy savings, as well as checking the health of the luminaire.

Memory Bank 1 Extension

The Memory Bank 1 Extension is required by D4i and defined by DALI Part 251. DALI Part 102 defines two memory banks for luminaire and driver information, Memory Bank 1 and Memory Bank 0. Memory Bank 1 is reserved for luminaire data, while Memory Bank 0 is reserved for driver information. DALI Part 251 builds upon the luminaire data available to the fixture manufacturer. Listed in Table 7 are the requirements for Memory Bank 1 Extension and in Table 8 are the requirements for Memory Bank 0.

Memory Bank 1 Extension: Luminaire Information
Luminaire GTIN*
Luminaire Identification Number*
Luminaire Manufacturer Date Code
Nominal Input Power
Power at Minimum Dimming Level
Nominal Minimum AC Mains Voltage
Nominal Maximum AC Input
Nominal Light Output
CRI of Luminaire
CCT (K)
Light Distribution Type (IES 901.11)
Luminaire Color (60 ASCII Characters)
**Also Required by DALI Part 102*

Table 7: Memory Bank 1 Extension, Luminaire Information

Memory Bank 0: Driver Information
Driver Firmware Version
Hardware Version
Driver Serial Number
DALI Versions for 101, 102, 103
Number of Control Devices Inside

Table 8: Memory Bank 0, Driver Information

Why is the Memory Bank 1 Extension Important?

The Memory Bank 1 extension allows for the luminaire manufacturer to store pertinent fixture information into the driver. This information can be written to the driver on the luminaire manufacturers production line or by using the DALI-2 compliant control system. The information can be read by the DALI-2 control system, stored in a database and is useful for asset tracking and informed maintenance.

Integrated DALI Bus Supply

D4i requires a driver integrated DALI Bus Supply and is governed by DALI Part 250. Each DALI network requires a DALI Bus Supply to operate and is specified by DALI Part 101 at 16Vdc, with a maximum of 250mA. DALI Bus Supplies can be combined in parallel if the total current

does not exceed 250mA. The benefit of DALI Part 251 is that it standardizes the ability to enable and disable the DALI Bus Supply. Inventronics DALI drivers supply a maximum of 60mA on the DALI bus, so when connecting more than four drivers to one DALI bus, you will need to use this feature. According to DALI Part 251, the default status of the DALI bus is left up to the driver manufacturer. Inventronics D4i drivers ship with the DALI Bus Supply enabled.

DALI Bus Supplies can also be used to control lower power sensors and switches. These devices must be specially designed to run on DALI Bus Power.

Auxiliary Power Supply

While not required to be D4i certified, DALI Part 150 standardizes driver auxiliary supplies. DALI Part 150 requires a 24vdc, 125mA auxiliary supply with a 3W average and a 6W peak. While some lower power devices may be able to be powered directly off the Integrated DALI Bus Supply, other devices, such as wireless radios, require more power. The inclusion of an auxiliary power supply removes the need for AC Power Packs and allows for the sensor or wireless control module to be powered directly from the driver. This helps to increase reliability, and remove costs pertaining to wiring and extra components.

It is important to note that the Auxiliary Supply is separate from the DALI Bus Supply. Also, if an Auxiliary Supply is present, a DALI Bus Supply is still required for a DALI network to work properly.

Summary

D4i allows for the standardization of smart data capabilities by standardizing what information is monitored by the driver and where it is stored. This allows for plug and play compatibility with a wide variety of control solutions, while using the same driver. D4i allows for luminaire manufacturers to keep customers lights on, save money on maintenance, verify energy savings, and track lighting assets, by answering the following questions:

Who: Which luminaire is malfunctioning?

What: What is the luminaire and driver part number?

When: When does the luminaire need to be replaced and has it already failed?

Where: Where is the exact location of the failed luminaire? This is especially helpful for streetlights or large warehouses.

Why: Why did the luminaire malfunction or fail? Thermal stress, over voltage, over power, age? Are there other drivers that can be replaced now that are showing these same signs of wear?

Inventronics sees the tremendous advantages to having the D4i certification and will continue to develop products needed to have access to this valuable solution in various applications and projects. To learn more about Inventronics DALI-2 D4i LED drivers, visit https://www.inventronics-co.com/dali-2-d4i-led-drivers/.

Disclaimer

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Inventronics (Hangzhou), Inc
+86-571-56565800
sales@inventronics-co.com

Inventronics USA
+1-405-600-7480
usa-sales@inventronics-co.com

Inventronics Europe
+31-857-470-061
eu-sales@inventronics-intl.com

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