

**LEDset
Power Interface Specification**

Edition 1.0
February, 2016

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CONTENTS

COPYRIGHT	2
DISCLAIMER	2
CONTENTS	3
INTRODUCTION.....	4
1 Scope	4
2 Normative references	4
3 Terms and definitions	4
4 General notes on tests	6
5 General description	6
6 LED driver requirements	7
6.1 Fixed-current driver.....	7
6.1.1 Single fixed current	7
6.1.2 Multiple fixed currents	8
6.2 Window driver.....	8
7 LED module requirements.....	8
8 LED driver documentation requirements	8
8.1 Fixed-current driver	8
8.1.1 Single fixed current	8
8.1.2 Multiple fixed currents.....	9
8.2 Window driver.....	9
9 LED driver verification methods.....	10
9.1 Fixed-current driver	10
9.1.1 Single fixed current	10
9.1.2 Multiple fixed currents.....	10
9.2 Window driver.....	10
9.3 LED driver operation and differential resistance	10
9.4 Current ripple.....	11
9.5 Tolerances	11
10 LED module documentation requirements.....	12
11 LED module verification methods	12
Annex A	13
Test circuit for LED driver verification	13
Annex B.....	15
Differential resistance values	15
Annex C	18
Example LED driver data	18
Annex D.....	19
Example LED module data	19
Annex E	20
LED driver and LED module matching.....	20
E.1 Fixed-current driver	20
E.1.1 Single-fixed current	20
E.1.2 Multiple-fixed currents	20
E.2 Window driver.....	20

INTRODUCTION

The LEDset specifications consist of several documents describing LED driver interfaces . The first of the LEDset specifications (LEDset1) describes an analog programming method that uses a resistor to set a desired output current. The second of the LEDset specifications (this document) describes the electrical interface between a LED driver and a LED module in terms of the output current and voltage.

1 Scope

This specification describes the requirements for the information that the data sheets of a LED driver and a LED module have to provide with respect to their electrical interface. In addition, this specification describes the operating conditions and measurement methods that should be used to verify the provided information. LED drivers that provide a pulse-width modulated output current are not in the scope of this specification.

2 Normative references

LEDset1 Information Interface Specification, downloadable from md-sig.org.

3 Terms and definitions

3.1

LED driver

A device that converts mains power to a combination of current and voltage that is suitable to power one or more LED modules.

NOTE: In other specifications and in international standards, a LED driver is usually referred to as a LED controlgear.

3.2

Constant-current driver

A LED driver that acts as a current source.

3.3

Fixed-current driver

A constant-current LED driver that enables a user to select the output current from one or more nominal values.

NOTE: The separation between adjacent nominal current values is much larger than the tolerance margin associated with each nominal current value.

3.4

Window driver

A constant-current LED driver that enables a user to select any output current from a continuous range of possible operating points.

NOTE: The output current range typically consists of a large number of closely spaced operating points with overlapping tolerance margins.

NOTE: The output current of a window driver supporting the LEDset1 specification varies in response to the current drawn from its LEDset terminal (and is therefore not necessarily constant).

3.5

Ripple

A periodic variation superimposed on a nominally constant current or voltage.

NOTE: The ripple does not include aperiodic variations due to transients or noise.

3.6

Rated output current, I_{rated}

The output current of a fixed-current driver as provided in its data sheet.

3.7

Minimum output current, I_{\min}

The rated minimum average output current of a window driver.

3.8

Maximum output current, I_{\max}

The rated maximum average output current of a window driver.

3.9

Operating current, I_{out}

The output current of a constant-current driver during operation.

3.10

Minimum output voltage, U_{\min}

The rated minimum average voltage that a constant-current driver can handle across its outputs without shutting down or malfunctioning otherwise.

3.11

Maximum output voltage, U_{\max}

The rated maximum average voltage that a constant-current driver can handle across its outputs without shutting down or malfunctioning otherwise.

3.12

Operating voltage, U_{out}

The voltage across the outputs of a constant current driver during operation.

3.13

Minimum output power, P_{\min}

The rated minimum output power that a window driver can handle without shutting down or malfunctioning otherwise.

3.14

Maximum output power, P_{\max}

The rated maximum output power that a window driver can handle without shutting down or malfunctioning otherwise.

3.15

Current ripple, I_{ripple}

The maximum excursion of the output current from its average value due to the ripple.

NOTE: The current ripple is expressed as a percentage of the average current $I_{\text{out,avg}}$, i.e.

$I_{\text{ripple}} = 100\% \cdot (I_{\text{out,peak}} - I_{\text{out,avg}}) / I_{\text{out,avg}}$, where $I_{\text{out,peak}}$ is the maximum output current. The window for averaging is at least 100 ms wide. To exclude noise and glitches, it is recommended to apply a 20 MHz low-pass filter before averaging.

3.16

Operating Window

The set of operating points (i.e. combinations of output current and output voltage) of a window driver that is bounded by the minimum and maximum output currents I_{\min} and I_{\max} , the minimum and maximum output voltages U_{\min} and U_{\max} , and the minimum and maximum output powers P_{\min} and P_{\max} .

3.17

Differential resistance, R_{diff}

The mathematical derivative of a component's voltage versus current function.

NOTE: The differential resistance is relevant for an ac signal that is superimposed on a constant dc operating current.

3.18

Minimum differential resistance, $R_{\text{diff,min}}$

The minimum differential resistance that a constant current driver can handle without shutting down or malfunctioning otherwise.

3.19

Maximum differential resistance, $R_{\text{diff,max}}$

The maximum differential resistance that a constant current driver can handle without shutting down or malfunctioning otherwise.

3.20

Rated LED current, I_{LED}

The rated supply current of a LED module.

NOTE: If the LED module is operated at its rated supply current, typically one or more of its photometric parameters have a value that as specified in its data sheet.

3.21

Maximum LED current, $I_{max,LED}$

The maximum driving current of a LED module.

NOTE: The LED module can be operated at this current level, without any ripple being present, for a prolonged period of time without being damaged and without impact on its rated lifetime.

3.22

Minimum LED voltage, $U_{min,LED}$

The minimum voltage that can result across the LED module's power terminals in response to it being supplied with its rated current.

3.23

Maximum LED voltage, $U_{max,LED}$

The maximum voltage that can result across the LED module's power terminals in response to it being supplied with its rated current.

3.24

LED+

The designation of LED driver and LED module terminals for the positive power supply wire connection.

3.25

LED-

The designation of LED driver and LED module terminals for the negative power supply wire connection.

3.26

LED differential resistance, $R_{diff,LED}$

The differential resistance of a LED module at its rated current.

NOTE: The differential resistance depends on the value of the dc operating current, and typically decreases with increasing current.

4 General notes on tests

The following conditions apply for performing all tests defined in this specification:

- The ambient temperature shall be in the range of 20 °C to 27 °C.
- The constant current LED driver shall be supplied with an input signal (voltage, current, frequency) that is within its rated operating range.

NOTE: All tests defined in this specification are type tests. This means that in order to determine the compliance of a particular product design, it is only required to subject a single product sample to these tests.

5 General description

Most LED modules cannot be driven directly from the mains power grid. They need a LED driver to convert the mains current and voltage to a suitable level. A typical LED module requires a constant current at a voltage that adapts itself to the needs of the LED module. Together, this current and voltage constitute the power interface between the LED module and the LED driver. The schematic diagram in figure 1 shows the two connections, labelled LED+ and LED-, that are associated with this interface.

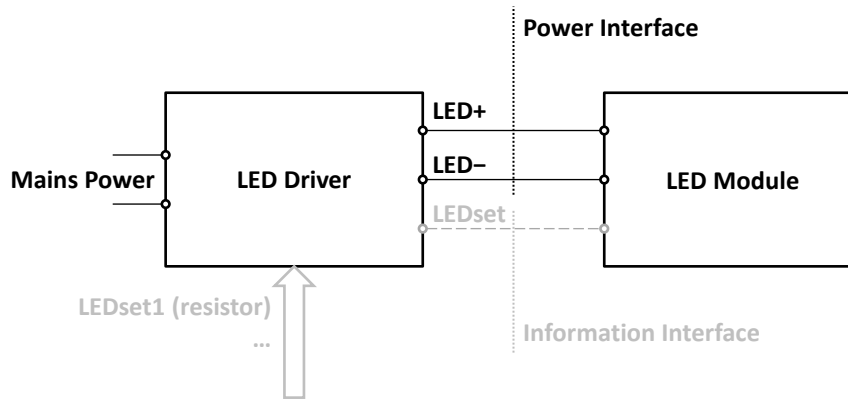


Figure 1: Schematic representation of the module-driver interface

This specification distinguishes between three varieties of constant-current LED drivers:

- Single-fixed-current drivers. These drivers are designed to provide an output current at a single value only. Typically, they are optimized to serve a limited subset of LED modules at the lowest cost possible.
- Multiple-fixed-current drivers. The functionality of these drivers is similar to single-fixed-current drivers, but as an added feature they enable a user to select the desired output current from a limited number of operating points. Accordingly, these drivers can serve a larger subset of LED modules.
- Window drivers. These drivers offer even greater flexibility with respect to their output current by enabling the user to select the latter from a continuous range. This flexibility enables fine-tuning of the output current to the specifics of the application.

Whereas multiple-fixed-current drivers typically use jumpers to select the output current, window drivers offer more advanced methods. The LEDset1 specification provides an example of such a method. This method is a special case, because it may employ an additional connection between the LED driver and the LED module (see the dashed line in figure 1). For clarity, this additional connection is not part of the power interface. Instead it is part of the so-called information interface between the LED driver and the LED module. See the LEDset1 specification for details.

LED drivers can provide dimming functionality in which the output current can be driven below its rated value. The specifications in the remainder of this document apply only in the case that such dimming functionality is not active, which means that the output current is not reduced below its rated value.

This edition of the LEDset Power Interface Specification does not limit the current, voltage and power levels that can be present on the LED+ and LED- connections between the LED driver and the LED module. Instead, it provides requirements with respect to the documentation of these levels in the data sheets of the associated products. In particular, it requires these levels to be listed for a well-defined set of operating conditions. This makes it more straightforward to compare the numbers in the data sheets and to determine the compatibility of a particular LED driver and LED module. Finally, to enable verification of the documented values this edition also defines the associated measurement procedures.

Section 6 provides the requirements that apply to a LED driver. Sections 7 and 9 list the information about the power interface that a user needs for matching a LED driver and a LED module. The data sheets of LED drivers and LED modules may provide additional information. Sections 8 and 10 define measurement methods to generate and verify the information of the power interface. Finally, annex E explains the matching criteria.

6 LED driver requirements

A LED driver shall have a terminal labeled LED+ for its output current, and a terminal labeled LED- for its return current.

6.1 Fixed-current driver

6.1.1 Single-fixed current

At each operating point defined by its rated current I_{rated} and voltage range U_{min} to U_{max} , the fixed-current driver shall be able to handle the range of differential resistances between the $R_{diff,min}$ and $R_{diff,max}$ values listed in Annex B, without shutting down or malfunctioning otherwise.

6.1.2 Multiple-fixed currents

At each operating point defined by its rated current I_{rated1} , I_{rated2} , etc., and voltage range U_{min1} to U_{max1} , U_{min2} to U_{max2} , etc., the fixed-current driver shall be able to handle the range of differential resistances between the $R_{diff,min}$ and $R_{diff,max}$ values listed in Annex B, without shutting down or malfunctioning otherwise.

6.2 Window driver

Figure 2 illustrates the operating window of a window driver. At each point in this range, the window driver shall be able to handle the range of differential resistances between the $R_{diff,min}$ and $R_{diff,max}$ values listed in Annex B, without shutting down or malfunctioning otherwise. The detail illustrates the effect of the differential resistance on the current and voltage ripple of the window driver.

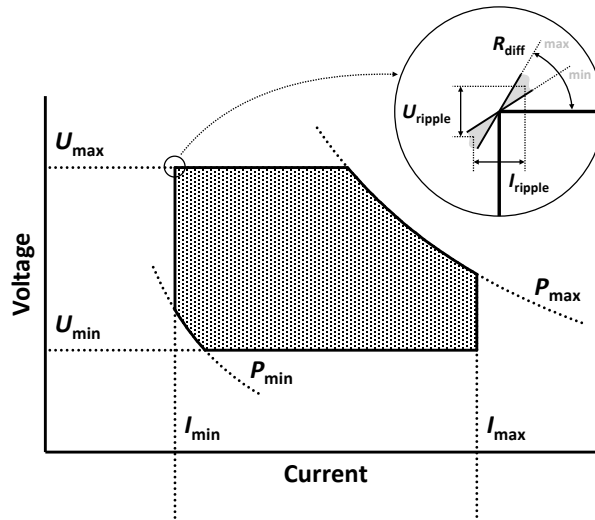


Figure 2: Output range of a window driver (shaded)

7 LED module requirements

A LED module shall have a terminal labeled LED+ for its input current, and a terminal labeled LED- for its return current. If the module does not have space for this labeling, alternative shorter labels may be used.

The differential resistance $R_{diff,LED}$ of a LED module at its rated current, i.e. $I_{out} = I_{LED}$ and $U_{min,LED} < U_{out} < U_{max,LED}$, shall be between the minimum and maximum $R_{diff,min}$ and $R_{diff,max}$ values listed in Annex B.

8 LED driver documentation requirements

8.1 Fixed-current driver

8.1.1 Single fixed current

The data sheet of a single-fixed-current driver shall provide at least the following information:

- The rated output current I_{rated} .
- The voltage range that the fixed-current driver can handle without shutting down or malfunctioning otherwise; in terms of the minimum and maximum values U_{min} and U_{max} .
- The maximum current ripple I_{ripple} that can be observed at the rated output current.

See figure 3.

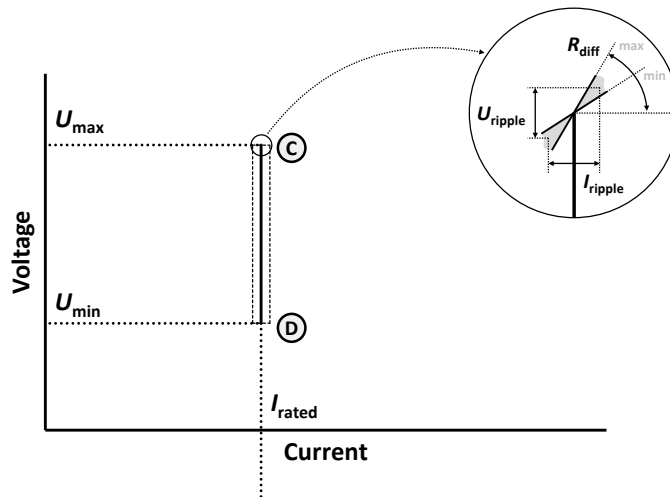


Figure 3: Output range of a single-fixed-current driver

8.1.2 Multiple fixed currents

The data sheet of a multiple-fixed-current driver shall provide at least the following information:

- The rated output currents I_{rated1} , I_{rated2} , etc.
- The voltage range that the fixed-current driver can handle without shutting down or malfunctioning otherwise; in terms of the minimum and maximum values U_{min1} and U_{max1} , U_{min2} , and U_{max2} , etc.
- The maximum current ripple I_{ripple} that can be observed at each of its rated output currents.

See figure 4.

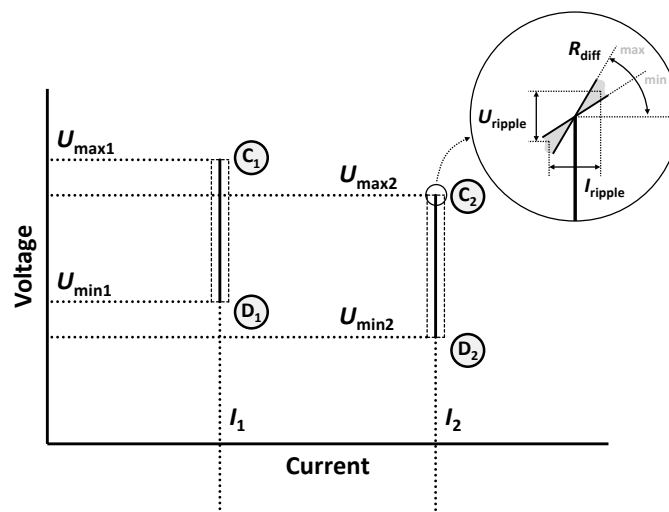


Figure 4: Output ranges of a multiple-fixed-current driver

8.2 Window driver

The data sheet of a window driver shall provide at least the following information:

- The boundaries of its operating window in terms of its minimum and maximum output currents I_{min} and I_{max} , its minimum and maximum output voltages U_{min} and U_{max} , and its minimum and maximum output powers P_{min} and P_{max} .
- The maximum current ripple I_{ripple} that can be observed at the maximum output current I_{max} of its operating window (i.e. at the right-hand side boundary between corners C and D).

See figure 5.

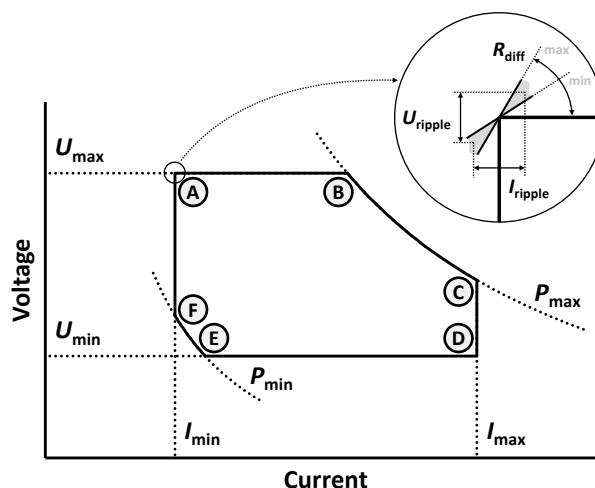


Figure 5: Output range of a window driver

9 LED driver verification methods

The information provided in the data sheet of a LED driver shall be verified by connecting the LED+ and LED- terminals of the LED driver under test to the test circuit that is provided in Annex A and applying the procedures defined in the following sub sections.

9.1 Fixed-current driver

9.1.1 Single fixed current

Proper operation of a single-fixed-current driver shall be verified by executing the test defined in section 9.4 at the corners C and D of the rated operating range (see Figure 3).

The rated current ripple of a single-fixed-current driver shall be verified by executing the test defined in section 9.5 at corners C and D of the rated operating range.

9.1.2 Multiple fixed currents

Proper operation of a multiple-fixed-current driver shall be verified by executing the test defined in section 9.3 at the corners C₁, C₂, etc., and at corners D₁, D₂, etc. of the rated operating range (see Figure 4).

The rated current ripple of a multiple-fixed-current driver shall be verified by executing the test defined in section 9.4 at corners C and D of the operating range of the highest rated operating current.

9.2 Window driver

Proper operation of a window driver shall be verified by executing the test defined in section 9.3 at the corners A, B, C, D, E, and F of the rated operating window (see Figure 5).

The rated current ripple of a window driver shall be verified by executing the test defined in section 9.4 at corners C and D of the rated operating window.

9.3 LED driver operation and differential resistance

The following steps shall be executed using the specified operating point (see sections 9.1.1, 9.1.2, and 9.2):

1. Set resistance R1 to the minimum differential resistance $R_{diff,min}$ as specified in Annex B, with I_{out} and U_{out} corresponding to the rated current and voltage of the specified operating point.
2. Program the LED driver under test to provide an output current I_{out} corresponding to the rated current at the specified operating point.

NOTE: Consult the documentation of the driver under test for information on how to set its operating current I_{out} to the rated value.

3. Use voltage source U1 of the test circuit to drive the output voltage U_{out} of the LED driver under test, measured across its LED+ and LED- terminals, to the rated voltage at the specified operating point.

NOTE: It is recommended to first drive the output voltage to the far end of the tolerance range (i.e. the largest deviation from the rated value). If the step 5 below cannot be completed successfully at this operating point, the output voltage should be driven closer to the rated value.

4. Verify that the setting of R1 and the measured values of I_{out} and U_{out} comply with the tolerances provided in section 9.5.
5. Verify that the LED driver under test operates as intended for at least 10 seconds without shutting down or malfunctioning otherwise.

NOTE: An example of malfunctioning is a flickering behavior of the LED driver under test when no changes are being made to the test setup (some flickering may occur when the resistor R1 is being changed).

6. Repeat steps 2 to 5, setting resistance R1 to the maximum differential resistance $R_{diff,max}$ as specified in Annex B for I_{out} and U_{out} according to the rated current at the specified operating point.

9.4 Current ripple

The following steps shall be executed using the specified operating point (see Sections 9.1.1, 9.1.2, and 9.2):

1. Set resistor R1 to the value $R_{diff} = R_{diff,min} + 0,3 \cdot (R_{diff,max} - R_{diff,min})$, where $R_{diff,min}$ and $R_{diff,max}$ are the rated minimum and maximum differential resistances at the specified operating point.
2. Program the LED driver under test to provide an output current I_{out} corresponding to the rated current at the specified operating point.

NOTE: Consult the documentation of the LED driver under test for information on how to set its output current to a desired value.

3. Use voltage U1 to drive the output voltage U_{out} of the LED driver under test, measured across its LED+ and LED- terminals, to the rated voltage at the specified operating point.
4. Verify that the setting of R1 and the measured values of I_{out} and U_{out} comply with the tolerances provided in section 9.5.
5. Measure the current ripple I_{ripple} as a percentage of the average operating current $I_{out,avg}$, i.e. $I_{ripple} = 100\% \cdot (I_{out,peak} - I_{out,avg}) / I_{out,avg}$, where $I_{out,peak}$ is the maximum measured output current. The window for averaging shall be at least 100 ms wide. To exclude noise and glitches, a 20 MHz low-pass filter shall be applied to the signal before averaging.
6. Verify that the measured ripple currents I_{ripple} does not exceed the rated value in the documentation of the LED driver under test.

9.5 Tolerances

Settings and measurements made during the test shall be within the tolerance range provided in Table 1.

Table 1: Tolerance ranges for parameters in the tests

	Operating point	Source of target value	Positive tolerance	Negative tolerance
$R1 = R_{diff,min}$	A, B, C, D, E, F	See Annex B	0%	50%
$R1 = R_{diff,max}$	A, B, C, D, E, F	See Annex B	50%	0%
R1 (ripple)	C, D	See Section 9.4	0%	50%
I_{out}	A, B, C, D, E, F	LED driver documentation	(1)	(1)
U_{out}	A, B, C	LED driver documentation	10%	0%
U_{out}	D, E, F	LED driver documentation	0%	10%

- (1) Tolerance as specified in the LED driver documentation.
- (2) The value of R1 shall be in the specified range. In case that test fails with the R1 value used, the test may be repeated with another value of R1, closer to the nominal value.

10 LED module documentation requirements

The data sheet of a LED module shall provide the following information for at least one operating point:

- The rated supply current I_{LED} .
- The minimum and maximum LED voltages $U_{min,LED}$ and $U_{max,LED}$ at the rated supply current. These voltages shall be applicable over the full rated operating temperature range.
- The minimum and maximum operating temperature.
- The maximum operating current $I_{max,LED}$.

The above information shall be applicable over the full rated lifetime of the LED module.

The data sheet of the LED module should provide the following information:

- The luminous flux and operating voltage at the rated supply current and rated temperature.

11 LED module verification methods

This specification does not provide verification methods for the data set provided with a LED module.

Annex A

(normative)

Test circuit for LED driver verification

Figure 6 shows the test circuit that shall be used to verify the documented values of a LED driver.

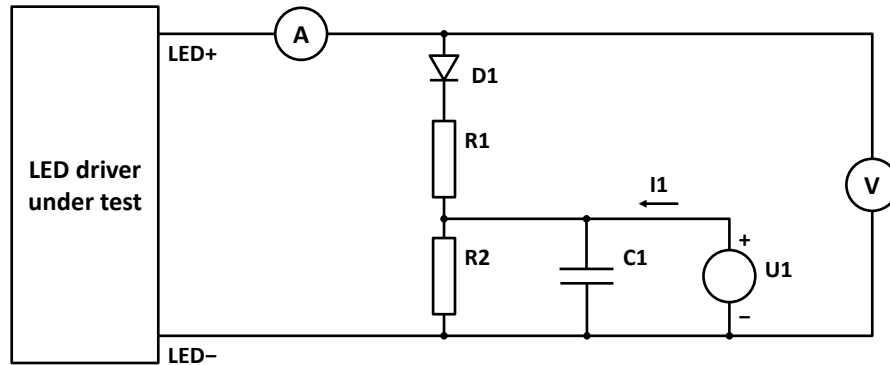


Figure 6: Test circuit 1

The components in this test circuit listed in Table 2. The wiring of the circuit that is attached between the LED+ and LED- terminals of the LED driver under test, shall have

- an inductance L_s that is less than the minimum of $1,5\mu\text{H} \cdot \left(\frac{R_{1\text{min}}}{6\Omega} + 1\right)$ and $5\mu\text{H}$, where $R_{1\text{min}}$ represents the lowest value of $R_{\text{diff, min}}$ that is being used in the tests; and
- a resistance R_s that is less than the maximum of 10% of the lowest value of $R_{\text{diff, min}}$ that is being used in the test and $0,1\Omega$.

NOTE: The inductance L_s shall be verified by disconnecting the voltage source U1 and replacing the LED driver under test with a vector network analyzer.

Table 2: Components of test circuit 1

Component	Rating	Comment
C1	$C > 100 \mu\text{F} \cdot \hat{I}_{\text{max}}$	Buffer capacitance. \hat{I}_{max} represents the maximum output current of the LED driver under test in amperes. To guarantee a low ESR for the high frequency ripple currents, at least 10% of C1 shall be implemented by means of a parallel foil capacitor in MKP technology.
D1	$I_f > 2 \cdot \hat{I}_{\text{max}}$	The forward current of D1. D1 shall be implemented by means of a mains rectifier power diode.
	$U_f < 1 \text{ V}$	The forward voltage of D1.
	$U_r > 2 \cdot U_{\text{max}}$	The reverse voltage of D1. U_{max} represents the maximum output voltage of the LED driver under test.
R1	$R_{\text{diff,min}} \leq R \leq R_{\text{diff,max}}$	Variable resistance. $R_{\text{diff,min}}$ and $R_{\text{diff,max}}$ represent the lowest and highest differential resistance value that the LED driver under test can handle. See also Annex B
	$P > 30\% \cdot P_{\text{max}}$	The power rating of R1. P_{max} represents the maximum output power of the LED driver under test.
R2	$R2 < 0,4 \cdot U1 / I_{\text{out}}$	Variable resistor. The R2 resistance is chosen such that the current I1 from the variable DC voltage source is positive throughout the test.
	$P > U1^2 / R2$	The power rating of R2.
U1	$U > U_{\text{max}}$	Variable DC voltage source. U_{max} represents the maximum output voltage of the LED driver under test.
	$I > U1 / R2_{\text{max}}$	The current rating of the DC voltage source.

Annex B

(normative)

Differential resistance values

The minimum and maximum differential resistances $R_{diff,min}$ and $R_{diff,max}$ that a constant-current driver can handle without shutting down or malfunctioning otherwise, depend on the operating point.

Table 3 provides a set of $R_{diff,max}$ values and table 4 provides a set of $R_{diff,min}$ values. Each table divides the current-voltage plane in a set of rectangles, with a rectangle defining a set of possible operating points. The lower and right-hand side rectangle boundaries are part of the set and the upper and left-hand side boundaries are not. Each rectangle—and thus each set of possible operating points—has an associated R_{diff} value.

NOTE: The values in table 3 and table 4 are calculated from the following equation:

$$R_{diff} = \frac{U_{out}}{3V} \cdot \frac{0,2A}{I_{out}} \cdot R_{diff,LED}$$

In this equation, U_{out} represents the lower boundary of a rectangle; I_{out} represents the right-hand-side boundary of a rectangle; and $R_{diff,LED}$ is a constant. The values in table 3 are calculated using $R_{diff,LED} = R_{diff,LED,max} = 4,2 \Omega$, and the values in table 4 are calculated using $R_{diff,LED} = R_{diff,LED,min} = 0,48 \Omega$.

At each of its operating points, the window driver shall be able to handle the minimum and maximum differential resistances $R_{diff,min}$ and $R_{diff,max}$ that are associated with the rectangle that contains the operating point. For example:

- At an operating point of (0,6 A; 48 V), $R_{diff,max} = 22,4 \Omega$ and $R_{diff,min} = 2,56 \Omega$.
- At an operating point of (1,1 A; 72 V), $R_{diff,max} = 16,8 \Omega$ and $R_{diff,min} = 1,92 \Omega$.
- At an operating point of (1,4 A; 130 V), $R_{diff,max} = 27,0 \Omega$ and $R_{diff,min} = 3,09 \Omega$.
- At an operating point of (2,5 A; 200 V), $R_{diff,max} = 19,6 \Omega$ and $R_{diff,min} = 2,24 \Omega$.

Table 3: Maximum differential resistance $R_{diff,max}$

I_{out} (A)	0,2	0,4	0,6	0,8	1	1,2	1,4	1,6	1,8	2	3	4	8
U_{out} 3	4,2	2,1	1,4	1,05	0,84	0,70	0,60	0,53	0,47	0,42	0,28	0,21	0,11
(V) 6	8,4	4,2	2,8	2,10	1,68	1,40	1,20	1,05	0,93	0,84	0,56	0,42	0,21
9	12,6	6,3	4,2	3,15	2,52	2,10	1,80	1,58	1,40	1,26	0,84	0,63	0,32
12	16,8	8,4	5,6	4,20	3,36	2,80	2,40	2,10	1,87	1,68	1,12	0,84	0,42
15	21,0	10,5	7,0	5,3	4,2	3,5	3,0	2,6	2,3	2,1	1,4	1,1	0,5
18	25,2	12,6	8,4	6,3	5,0	4,2	3,6	3,2	2,8	2,5	1,7	1,3	0,6
21	29,4	14,7	9,8	7,4	5,9	4,9	4,2	3,7	3,3	2,9	2,0	1,5	0,7
24	33,6	16,8	11,2	8,4	6,7	5,6	4,8	4,2	3,7	3,4	2,2	1,7	0,8
27	37,8	18,9	12,6	9,5	7,6	6,3	5,4	4,7	4,2	3,8	2,5	1,9	0,9
30	42,0	21,0	14,0	10,5	8,4	7,0	6,0	5,3	4,7	4,2	2,8	2,1	1,1
33	46,2	23,1	15,4	11,6	9,2	7,7	6,6	5,8	5,1	4,6	3,1	2,3	1,2
36	50,4	25,2	16,8	12,6	10,1	8,4	7,2	6,3	5,6	5,0	3,4	2,5	1,3
39	54,6	27,3	18,2	13,7	10,9	9,1	7,8	6,8	6,1	5,5	3,6	2,7	1,4
42	58,8	29,4	19,6	14,7	11,8	9,8	8,4	7,4	6,5	5,9	3,9	2,9	1,5
45	63,0	31,5	21,0	15,8	12,6	10,5	9,0	7,9	7,0	6,3	4,2	3,2	1,6
48	67,2	33,6	22,4	16,8	13,4	11,2	9,6	8,4	7,5	6,7	4,5	3,4	1,7
51	71,4	35,7	23,8	17,9	14,3	11,9	10,2	8,9	7,9	7,1	4,8	3,6	1,8
54	75,6	37,8	25,2	18,9	15,1	12,6	10,8	9,5	8,4	7,6	5,0	3,8	1,9
57	79,8	39,9	26,6	20,0	16,0	13,3	11,4	10,0	8,9	8,0	5,3	4,0	2,0

I_{out} (A)	0,2	0,4	0,6	0,8	1	1,2	1,4	1,6	1,8	2	3	4	8
60	84,0	42,0	28,0	21,0	16,8	14,0	12,0	10,5	9,3	8,4	5,6	4,2	2,1
63	88,2	44,1	29,4	22,1	17,6	14,7	12,6	11,0	9,8	8,8	5,9	4,4	2,2
66	92,4	46,2	30,8	23,1	18,5	15,4	13,2	11,6	10,3	9,2	6,2	4,6	2,3
69	96,6	48,3	32,2	24,2	19,3	16,1	13,8	12,1	10,7	9,7	6,4	4,8	2,4
72	100,8	50,4	33,6	25,2	20,2	16,8	14,4	12,6	11,2	10,1	6,7	5,0	2,5
75	105,0	52,5	35,0	26,3	21,0	17,5	15,0	13,1	11,7	10,5	7,0	5,3	2,6
78	109,2	54,6	36,4	27,3	21,8	18,2	15,6	13,7	12,1	10,9	7,3	5,5	2,7
81	113,4	56,7	37,8	28,4	22,7	18,9	16,2	14,2	12,6	11,3	7,6	5,7	2,8
84	117,6	58,8	39,2	29,4	23,5	19,6	16,8	14,7	13,1	11,8	7,8	5,9	2,9
87	121,8	60,9	40,6	30,5	24,4	20,3	17,4	15,2	13,5	12,2	8,1	6,1	3,0
90	126,0	63,0	42,0	31,5	25,2	21,0	18,0	15,8	14,0	12,6	8,4	6,3	3,2
105	147,0	73,5	49,0	36,8	29,4	24,5	21,0	18,4	16,3	14,7	9,8	7,4	3,7
120	168,0	84,0	56,0	42,0	33,6	28,0	24,0	21,0	18,7	16,8	11,2	8,4	4,2
135	189,0	94,5	63,0	47,3	37,8	31,5	27,0	23,6	21,0	18,9	12,6	9,5	4,7
150	210,0	105,0	70,0	52,5	42,0	35,0	30,0	26,3	23,3	21,0	14,0	10,5	5,3
165	231,0	115,5	77,0	57,8	46,2	38,5	33,0	28,9	25,7	23,1	15,4	11,6	5,8
180	252,0	126,0	84,0	63,0	50,4	42,0	36,0	31,5	28,0	25,2	16,8	12,6	6,3
195	273,0	136,5	91,0	68,3	54,6	45,5	39,0	34,1	30,3	27,3	18,2	13,7	6,8
210	294,0	147,0	98,0	73,5	58,8	49,0	42,0	36,8	32,7	29,4	19,6	14,7	7,4
225	315,0	157,5	105,0	78,8	63,0	52,5	45,0	39,4	35,0	31,5	21,0	15,8	7,9
240	336,0	168,0	112,0	84,0	67,2	56,0	48,0	42,0	37,3	33,6	22,4	16,8	8,4
255	357,0	178,5	119,0	89,3	71,4	59,5	51,0	44,6	39,7	35,7	23,8	17,9	8,9
270	378,0	189,0	126,0	94,5	75,6	63,0	54,0	47,3	42,0	37,8	25,2	18,9	9,5
285	399,0	199,5	133,0	99,8	79,8	66,5	57,0	49,9	44,3	39,9	26,6	20,0	10,0
300	420,0	210,0	140,0	105,0	84,0	70,0	60,0	52,5	46,7	42,0	28,0	21,0	10,5

Table 4: Minimum differential resistance $R_{diff,min}$

I_{out} (A)	0,2	0,4	0,6	0,8	1	1,2	1,4	1,6	1,8	2	3	4	8
U_{out} 3	0,48	0,24	0,16	0,120	0,096	0,080	0,069	0,060	0,053	0,048	0,032	0,024	0,012
(V) 6	0,96	0,48	0,32	0,240	0,192	0,160	0,137	0,120	0,107	0,096	0,064	0,048	0,024
9	1,44	0,72	0,48	0,360	0,288	0,240	0,206	0,180	0,160	0,144	0,096	0,072	0,036
12	1,92	0,96	0,64	0,480	0,384	0,320	0,274	0,240	0,213	0,192	0,128	0,096	0,048
15	2,40	1,20	0,80	0,60	0,48	0,40	0,34	0,30	0,27	0,24	0,16	0,12	0,06
18	2,88	1,44	0,96	0,72	0,58	0,48	0,41	0,36	0,32	0,29	0,19	0,14	0,07
21	3,36	1,68	1,12	0,84	0,67	0,56	0,48	0,42	0,37	0,34	0,22	0,17	0,08
24	3,84	1,92	1,28	0,96	0,77	0,64	0,55	0,48	0,43	0,38	0,26	0,19	0,10
27	4,32	2,16	1,44	1,08	0,86	0,72	0,62	0,54	0,48	0,43	0,29	0,22	0,11
30	4,80	2,40	1,60	1,20	0,96	0,80	0,69	0,60	0,53	0,48	0,32	0,24	0,12
33	5,28	2,64	1,76	1,32	1,06	0,88	0,75	0,66	0,59	0,53	0,35	0,26	0,13
36	5,76	2,88	1,92	1,44	1,15	0,96	0,82	0,72	0,64	0,58	0,38	0,29	0,14
39	6,24	3,12	2,08	1,56	1,25	1,04	0,89	0,78	0,69	0,62	0,42	0,31	0,16

I_{out} (A)	0,2	0,4	0,6	0,8	1	1,2	1,4	1,6	1,8	2	3	4	8
42	6,72	3,36	2,24	1,68	1,34	1,12	0,96	0,84	0,75	0,67	0,45	0,34	0,17
45	7,20	3,60	2,40	1,80	1,44	1,20	1,03	0,90	0,80	0,72	0,48	0,36	0,18
48	7,68	3,84	2,56	1,92	1,54	1,28	1,10	0,96	0,85	0,77	0,51	0,38	0,19
51	8,16	4,08	2,72	2,04	1,63	1,36	1,17	1,02	0,91	0,82	0,54	0,41	0,20
54	8,64	4,32	2,88	2,16	1,73	1,44	1,23	1,08	0,96	0,86	0,58	0,43	0,22
57	9,12	4,56	3,04	2,28	1,82	1,52	1,30	1,14	1,01	0,91	0,61	0,46	0,23
60	9,60	4,80	3,20	2,40	1,92	1,60	1,37	1,20	1,07	0,96	0,64	0,48	0,24
63	10,08	5,04	3,36	2,52	2,02	1,68	1,44	1,26	1,12	1,01	0,67	0,50	0,25
66	10,56	5,28	3,52	2,64	2,11	1,76	1,51	1,32	1,17	1,06	0,70	0,53	0,26
69	11,04	5,52	3,68	2,76	2,21	1,84	1,58	1,38	1,23	1,10	0,74	0,55	0,28
72	11,52	5,76	3,84	2,88	2,30	1,92	1,65	1,44	1,28	1,15	0,77	0,58	0,29
75	12,00	6,00	4,00	3,00	2,40	2,00	1,71	1,50	1,33	1,20	0,80	0,60	0,30
78	12,48	6,24	4,16	3,12	2,50	2,08	1,78	1,56	1,39	1,25	0,83	0,62	0,31
81	12,96	6,48	4,32	3,24	2,59	2,16	1,85	1,62	1,44	1,30	0,86	0,65	0,32
84	13,44	6,72	4,48	3,36	2,69	2,24	1,92	1,68	1,49	1,34	0,90	0,67	0,34
87	13,92	6,96	4,64	3,48	2,78	2,32	1,99	1,74	1,55	1,39	0,93	0,70	0,35
90	14,40	7,20	4,80	3,60	2,88	2,40	2,06	1,80	1,60	1,44	0,96	0,72	0,36
105	16,80	8,40	5,60	4,20	3,36	2,80	2,40	2,10	1,87	1,68	1,12	0,84	0,42
120	19,20	9,60	6,40	4,80	3,84	3,20	2,74	2,40	2,13	1,92	1,28	0,96	0,48
135	21,60	10,80	7,20	5,40	4,32	3,60	3,09	2,70	2,40	2,16	1,44	1,08	0,54
150	24,00	12,00	8,00	6,00	4,80	4,00	3,43	3,00	2,67	2,40	1,60	1,20	0,60
165	26,40	13,20	8,80	6,60	5,28	4,40	3,77	3,30	2,93	2,64	1,76	1,32	0,66
180	28,80	14,40	9,60	7,20	5,76	4,80	4,11	3,60	3,20	2,88	1,92	1,44	0,72
195	31,20	15,60	10,40	7,80	6,24	5,20	4,46	3,90	3,47	3,12	2,08	1,56	0,78
210	33,60	16,80	11,20	8,40	6,72	5,60	4,80	4,20	3,73	3,36	2,24	1,68	0,84
225	36,00	18,00	12,00	9,00	7,20	6,00	5,14	4,50	4,00	3,60	2,40	1,80	0,90
240	38,40	19,20	12,80	9,60	7,68	6,40	5,49	4,80	4,27	3,84	2,56	1,92	0,96
255	40,80	20,40	13,60	10,20	8,16	6,80	5,83	5,10	4,53	4,08	2,72	2,04	1,02
270	43,20	21,60	14,40	10,80	8,64	7,20	6,17	5,40	4,80	4,32	2,88	2,16	1,08
285	45,60	22,80	15,20	11,40	9,12	7,60	6,51	5,70	5,07	4,56	3,04	2,28	1,14
300	48,00	24,00	16,00	12,00	9,60	8,00	6,86	6,00	5,33	4,80	3,20	2,40	1,20

Annex C

(informative)

Example LED driver data

Table 5 lists an example of the documentation that is provided with a fixed-current driver having a single operating point.

Table 5: Example LED driver data set

	Minimum	Rated	Maximum
Current [mA]		600	
Voltage [V]	15		54
Ripple current			6%

Table 6 lists an example of the documentation that is provided with a fixed-current driver having two operating points.

Table 6: Example LED driver data set

	Minimum	Rated	Maximum
Current [mA]		600	
Voltage [V]	15		54
Ripple current			6%
Current [mA]		1400	
Voltage [V]	15		54
Ripple current			6%

Table 7 lists an example of the documentation that is provided with a window driver.

Table 7: Example LED driver data set

	Minimum	Rated	Maximum
Current [mA]	600		1400
Voltage [V]	15		54
Power [W]	10		50
Ripple current			6%

Annex D

(informative)

Example LED module data

Table 8 lists an example of the documentation that is provided with a LED module having a single rated operating point.

Table 8: Example LED module data set

Rated current: 380 mA	Minimum	Rated	Maximum
Voltage [V]	44,2	46	50,2
Operating temperature [°C]	0	65	90
Luminous flux [lm]		2000	

Maximum current: 450 mA

Table 9 lists an example of the documentation that is provided with a LED module having two rated operating points.

Table 9: Example LED module data set

Rated current-1: 380 mA	Minimum	Rated	Maximum
Voltage [V]	44,2	46	50,2
Operating temperature [°C]	0	65	90
Luminous flux [lm]		2000	
CCT [K]		3000	

Rated current-2: 450 mA	Minimum	Rated	Maximum
Voltage [V]	45,0	48	51,0
Operating temperature [°C]	0	65	90
Luminous flux [lm]		2250	
CCT [K]		-	

Maximum current: 500 mA

Annex E

(informative)

LED driver and LED module matching

This section is a guideline for luminaire design.

E.1 Fixed-current driver

E.1.1 Single-fixed current

A single-fixed current driver and a LED module match if the following criteria are satisfied:

- The rated LED module current I_{LED} matches the rated output current I_{rated} of the LED driver.
- The minimum and maximum LED voltages $U_{min,LED}$ and $U_{max,LED}$ are contained within the boundaries of the output range of the LED driver.

E.1.2 Multiple-fixed currents

A multiple-fixed current driver and a LED module match if the following criteria are satisfied:

- The rated LED module current I_{LED} matches one of the rated output currents I_{rated} of the LED driver.
- The minimum and maximum LED voltages $U_{min,LED}$ and $U_{max,LED}$ are contained within the boundaries of the output range of the LED driver at the selected rated output current.

E.2 Window driver

A window driver and a LED module match if the following criterion is satisfied:

- The rated LED module current I_{LED} as well as the minimum and maximum LED voltages $U_{min,LED}$ and $U_{max,LED}$ are contained within the boundaries of the output range of the window driver.