LEDset1
Information Interface Specification

Edition 1.3
April, 2017

DISCLAIMER

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CONTENTS

INTRODUCTION

This edition of the LEDset1 Information Interface Specification describes an analogue interface allowing basic communication between a window driver and one or more LED modules.

The interface can support the following functions:

- Output current setting of a constant current window driver to a single LED module
- Window driver output current setting for LED modules with parallel or series connection
- Thermal de-rating of the LED module(s)

1 Scope

This international standard describes the general requirements of an analogue interface for the communication between a window driver and one or more LED modules.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 62717, *LED modules for general lighting – Performance requirements*

LEDset Power Interface Specification, downloadable from md-sig.org

3 Terms and definitions

For the purpose of this document the following terms and definitions apply. The definitions provided in the LEDset Power Interface Specification apply as well.

3.1
Setting current, I_{set}
Setting current that determines the output current of a window driver.

3.2
Setting voltage, U_{set}
Setting voltage applied to the control wire connection by a window driver.

3.3
LED$_{set}$
Window driver and LED module terminals for the control wire connection.

3.4
GND$_{set}$
Optional low current GND-terminal: window driver and LED module terminal at equipotential with the LED− terminal.

3.5
Setting resistor, R_{set}
Setting resistor mounted on the LED module or alternative setting resistor that is plugged into a window driver.

3.6
Test circuit 1
Test circuit 1 provides a reference LED load for testing a window driver. It is defined in Annex A of the LEDset Power Interface Specification.

4 General notes on tests

Unless otherwise specified, the tests shall be carried out at an ambient temperature of 20 °C to 27 °C.

Unless otherwise specified, window driver tests shall be carried out using its rated (mains) supply voltage and frequency.

Tests dealt with in this standard are type tests.

5 General description

Different LED modules typically have different supply current requirements. The interface defined in this document enables a window driver to adapt its output current as necessary. Moreover, this interface enables the window driver to dynamically adapt its output current depending on changes in the operating conditions. For example, the LED module(s) may have to be operated at a lower current to prevent overheating at increased ambient temperatures—a feature that is known as thermal de-rating.

As shown in Figure 1, the operating principle for adapting the output current of the window driver is that this output current is a scaled version of a setting current I_{set}, which is drawn from a 5 V reference voltage source within the window driver. The output current I_{out} of the window driver is:

$$I_{out} = 1000 \times I_{set} .$$

Optional dimming or other control functionality may reduce the output current below the above value. However, such current reduction is outside the scope of this standard. Note that the scaling of the output current with the value of I_{set} should not be used as an alternative to a proper dimming interface to the window driver. The reason is that the LED driver may respond to changes in the setting current at a low rate such as 0,1 Hz. Accordingly, the scaled output current may lag the setting current by many seconds. Also note that the window driver may implement the optional dimming functionality by means of pulse-width modulation (PWM) of its output current.

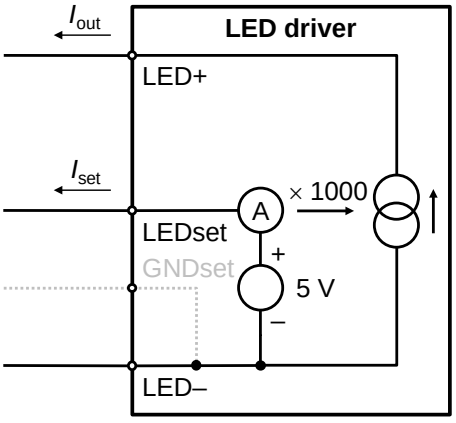

Figure 1: Basic operation of a LEDset window driver

To implement the interface, the window driver provides three terminals, namely a LED+ terminal to provide the output current I_{out} to one or more LED modules; a LEDset terminal to measure the setting current I_{set}; and a LED–

terminal to serve as a return path for the currents. In addition, implementations may provide an optional fourth terminal (GNDset), which is at the same potential as the LED– terminal. Figure 2 illustrates the current and voltage characteristics at the LED+ and LEDset terminals.

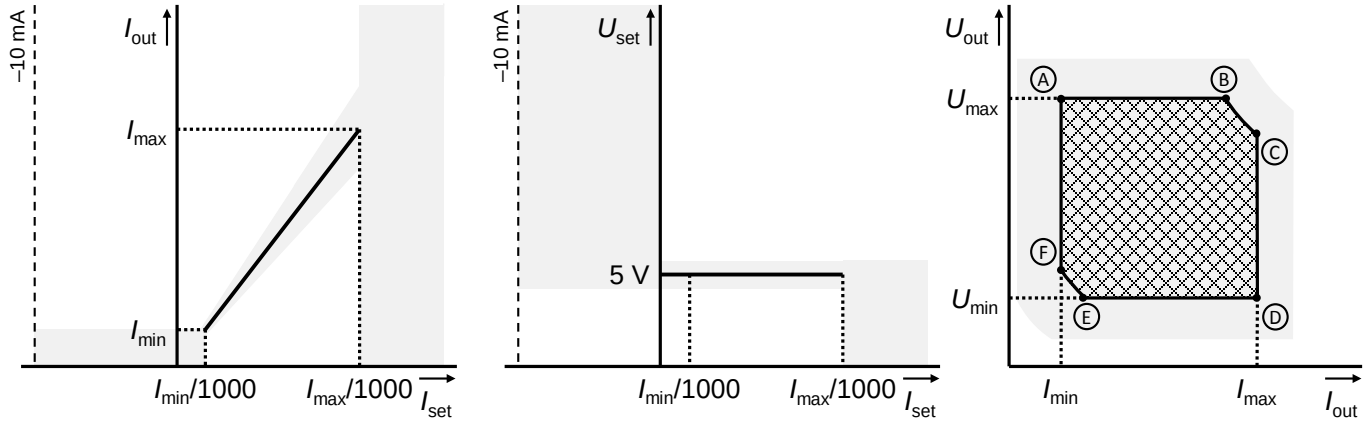

Figure 2: Current and voltage characteristics of the LEDset window driver (not drawn to scale)

The relation between the output current I_{out} and setting current I_{set} is valid if

a) the setting current I_{set} is in the range from I_{min} / 1000 to I_{max} / 1000, where I_{min} and I_{max} are the rated minimum and maximum output currents of the window driver; and

b) the voltage at the LED+ terminal is in the rated operating window of the window driver

This is illustrated as the hatched area in the right diagram of Figure 2. For setting currents below I_{min}/1000, the output current is at most I_{min}. For setting currents above I_{max}/1000 and/or output voltages outside the rated operating window, the output current is not defined. The manufacturer's product documentation typically specifies operation of the window driver in those regimes.

The window driver maintains the voltage at the LEDset terminal at 5 V, provided that the setting current I_{set} is in the range from 0 to I_{max} / 1000. For setting currents I_{set} above the upper limit, the voltage may decrease. For reverse setting currents I_{set}, the circuit connected to the LEDset terminal may cause the voltage to increase. However, precautions should be taken to ensure that the reverse current does not increase above 10 mA. See section 8.

The interface can be used in a variety of ways. A number of example circuits that can be connected to the LED+, LEDset and LED– terminals of the LEDset window driver are described below.

Figure 3 shows an example circuit in which a current setting resistor R_{set} is connected to the I_{set} and LED– terminals of the window driver, a LED module between the LED+ and LED– terminals. The R_{set} value is calculated as follows:

$$R_{set} = 1000 \times \frac{5\ \text{V}}{I_{out}}.$$

In this equation, I_{out} represents the desired output current of the window driver. The product documentation of the window driver can indicate a range of R_{set} values with which the window driver can operate. The boundaries of this range, R_{min} and R_{max}, follow from the above equation by substituting the rated maximum and minimum output current for I_{out}. See also Figure 4.

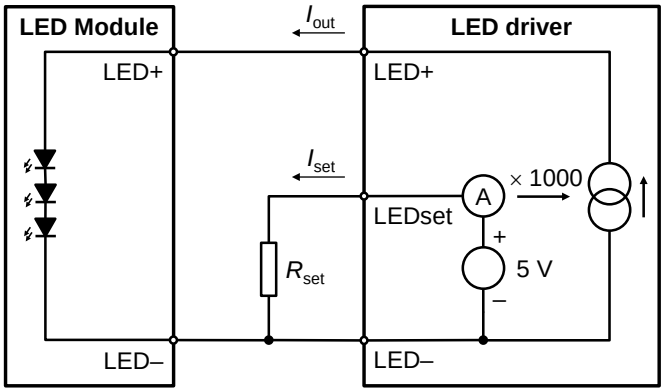

Figure 3: Example circuit: a setting resistor R_{set} plus an arbitrary LED module

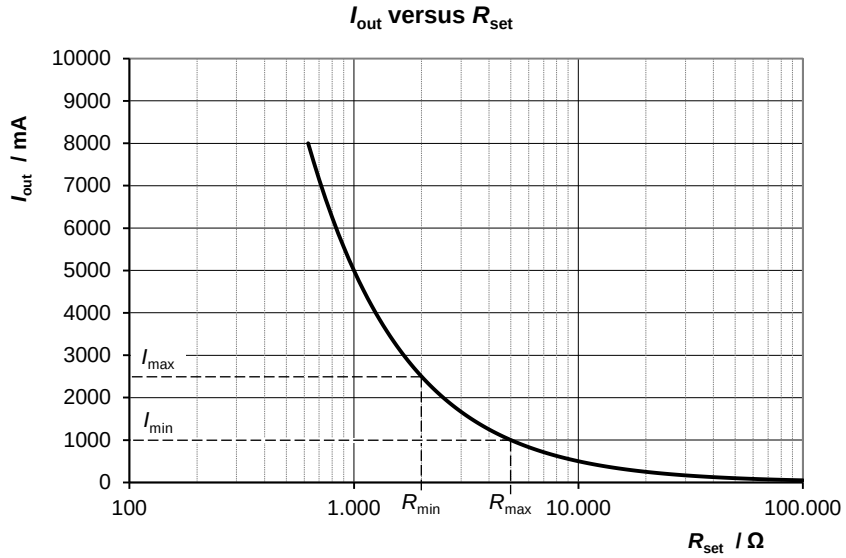

Figure 4: Relation between the current setting resistor R_{set} and the output current I_{out}

Figure 5 shows an example in which a current source is used instead of a resistor R_{set}. This current source fixes the current to $I_{set} = I_{out} / 1000$, with I_{out} representing the desired output current of the window driver.

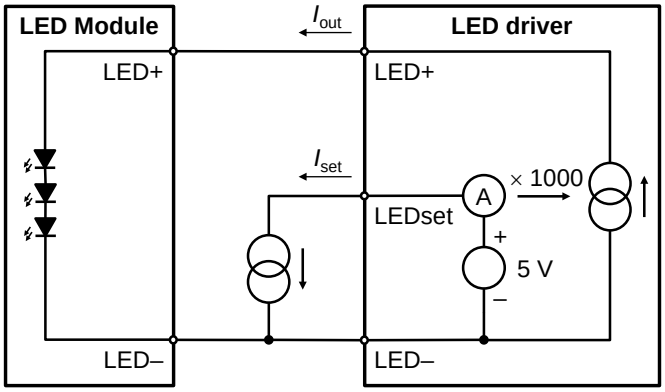

Figure 5: Example circuit: a current source plus an arbitrary LED module

Figure 6 shows an example of a LED module that contains an integrated R_{set} resistor. Similar to the window driver, this LED module has three terminals. Note that in this example and all following ones, the R_{set} resistor on the LED module may be replaced with a current source (similar to the preceding two examples).

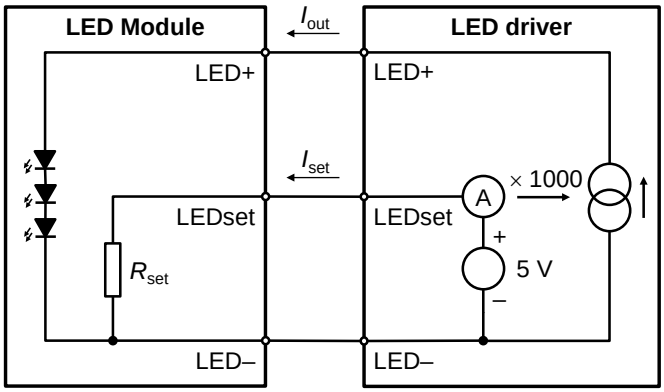

Figure 6: Example circuit: a LED module with integrated R_{set} resistor

Figure 7 shows an example LED module that contains an integrated R_{set} resistor as well as thermal de-rating functionality. The latter is represented as a variable current source, which can reduce the I_{set} current drawn from the window driver. Based on the temperature at the t_p point of the LED module, the thermal de-rating functionality can therefore reduce the output current I_{out}, and thus reduce the temperature in the case of e.g. an over-temperature event. Note that operation of the thermal de-rating functionality is constrained by the requirements on the current and voltage at the LEDset terminal of the window driver (see also Figure 2).

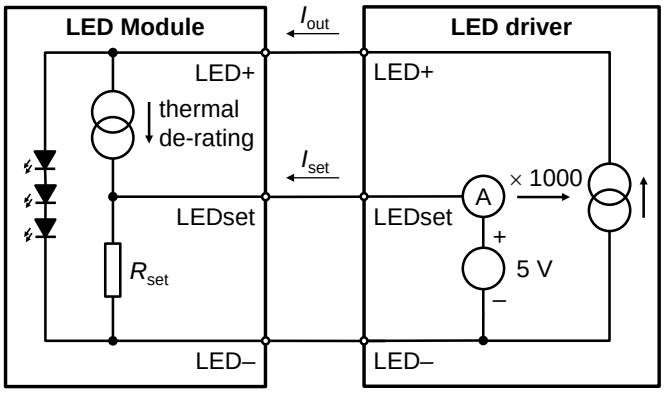

Figure 7: Example circuit: a LED module with integrated thermal de-rating

Figure 8 shows an example of multiple LED modules—of the same type—that are connected in parallel. The setting currents of all LED modules add up, resulting in a cumulative output current I_{out} of the window driver.

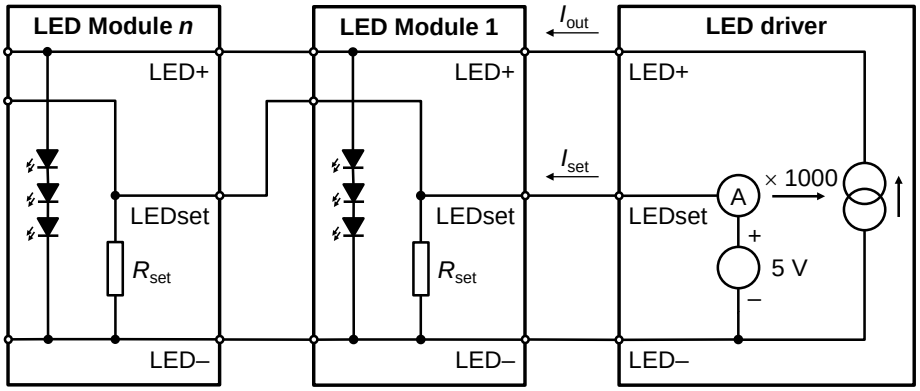

Figure 8: Example circuit: multiple LED modules in parallel

Finally, Figure 9 shows an example of multiple LED modules—which have the same rated supply current I_{LED}—that are connected in series. In this case, only one of the LED modules has its setting resistor R_{set} connected to the LEDset terminal of the window driver to properly setup its output current I_{out}.

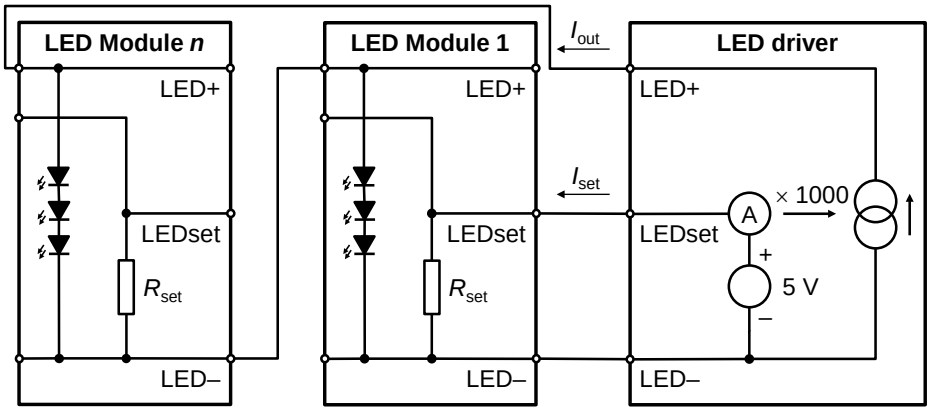

Figure 9: Example circuit: multiple LED modules in series

6 General requirements

The LED module

- shall be designed for constant current operation; and
- may provide a LEDset terminal to communicate its rated supply current.

The window driver

- shall be designed for constant current operation; and
- shall provide a LEDset terminal to determine its output current.

NOTE: In the case that the LED driver provides additional mechanisms to configure and/or control its output current, the manufacturer's product documentation should describe the interaction of such additional mechanisms with the output current setting functionality that is defined in this standard. For example, the additional mechanism may completely override the provisions of this standard, or may simply reduce the output current (as is the case with e.g. optional dimming functionality).

6.1 Insulation requirements

The LEDset terminal as well as the GNDset terminal—if provided—of the window driver should have the same class of insulation to the mains supply voltage as the output terminals LED+ and LED−.

7 Functional requirements

Unless indicated otherwise, all currents referred to in this standard are dc currents.

7.1 Setting of the output current

Within the rated operating window of a window driver, its output current I_{out} shall be a scaled version of the current I_{set}, which is drawn from its LEDset terminal:

$$I_{out} = 1000 \times (1 \pm \delta S) \times I_{set} .$$

where δS represents the tolerance of the scaling factor.

In addition, within this operating window, the window driver shall maintain the voltage at its LEDset terminal at

$$U_{set} = 5 \times (1 \pm \delta U) \text{ V},$$

where δU represents the tolerance on the voltage.

Here, the sum of the tolerances δS and δU shall comply with

$$\delta U \leq 5\% \text{, and } \delta S + \delta U \leq 10\% .$$

Outside the rated operating window of the window driver, its output current and LEDset terminal voltage may deviate from these relations. It is recommended that the manufacturer's product documentation specifies the electrical output characteristics in this operating range. As a special case, for a setting current I_{set} in the range of 0 to I_{min} / 1000, the output current I_{out} shall not exceed the rated minimum output current I_{min}.

NOTE: If the window driver supports dimming of the LED module, and if such optional dimming is active, the output current may be reduced below the level derived from the above relation. The window driver may implement this dimming by means of PWM of its output current. During such PWM operation, the peak output current satisfies the above relation.

The LEDset terminal of a LED module shall have an impedance of

$$R_{set} = (5 \pm 0{,}1)\,\text{V} \times \frac{1000}{\text{I}_{\text{LED}}},$$

where I_{LED} is the rated current of the LED module.

NOTE: The setting current may be generated by means of an external setting resistor, which is either placed on a LED module or directly plugged into the window driver. In that case, the output current of the window driver follows from the value R_{set} of such a setting resistor as:

$$I_{out} = \frac{5\ \text{V}}{R_{set}} \times 1000 .$$

7.2 Dynamic response of the output current

A window driver shall respond to a dynamic change of the current I_{set} drawn from the control terminal, with a response time that shall not exceed 10 s.

NOTE: The LED module may contain thermal de-rating functionality, which aims to reduce the LED current if the temperature at its t_p reference point crosses a threshold level. For this purpose, this thermal de-rating functionality may dynamically adjust the I_{set} current during operation of the LED module.

NOTE: In designs for emergency lighting applications, it should be ensured that thermal de-rating functionality does not cause the luminous flux from the luminaire to decrease below applicable minimum levels.

NOTE: If the LED module implements thermal de-rating functionality, it should be ensured that this LED module is used with a window driver that can reduce its output current below the LED module's rated supply current, according to the maximum de-rating of the LED module that can occur in the application.

7.3 Settling time of the setting current

Figure 10 shows the signals related to the settling time T_{s1} of the setting current I_{set} after switching on the setting voltage U_{set}. In this diagram, I_1 is the steady state value of I_{set}. The circuit connected to the LEDset terminal of a window driver shall limit the settling time T_{s1} to at most 50 µs.

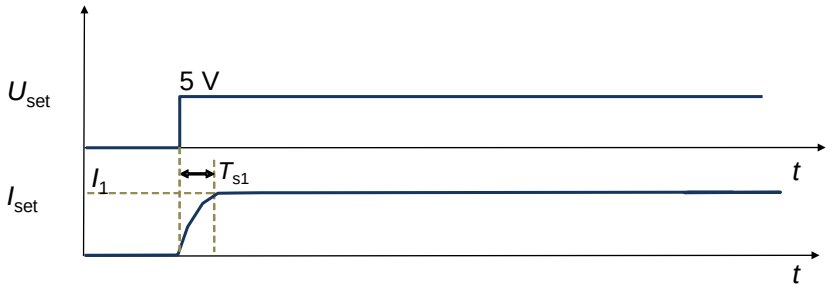

Figure 10: Settling time T_{s1}

Figure 11 shows the signals related to the settling time T_{s2} of the setting current I_{set} after switching the output current I_{out} on and off. In this diagram, I_1 is the steady state value of I_{set} with the LED string switched off, and I_2 is the steady state value of I_{set} with the LED string switched on. The circuit connected to the LEDset terminal of a window driver shall limit the settling time T_{s2} to at most 50 µs. In addition, this circuit shall ensure that the setting current I_{set} satisfies the relation $I_2 < I_{set} < I_1$.

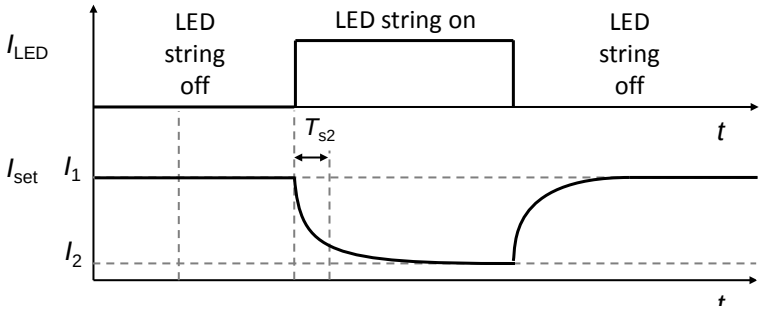

Figure 11: Settling time T_{s2}

NOTE: A decrease in the current from I_1 to I_2 may result from the activation of a thermal de-rating circuit that is connected to the LEDset terminal of a LED module.

NOTE: The settling time T_{s2} is of particular relevance to a window driver that implements optional dimming by means of a PWM mode of operation.

8 Robustness requirements

It is recommended that the window driver's LEDset terminal can withstand at least 10 V.

For the current I_{set} in the range of -10 mA to 0 mA, the driver shall withstand this current and the output current shall be less than or equal I_{min}.

If a LED module contains thermal de-rating functionality, and such functionality is active, a reverse current can flow from the LED module into the window driver's LEDset terminal. The LED module shall limit this reverse current to 10 mA.

NOTE: Under reverse current operation, the voltage at the (LED module and window driver) LEDset terminals may increase to be at equipotential with the LED+ terminal.

9 Marking and technical information

9.1 Window driver

The power output terminals shall be marked “LED+” and “LED−“.

The control interface terminal shall be marked “LEDset”.

An additional low power terminal, which is connected to the same potential as the LED− terminal, shall be marked “GNDset“. The provision of such a terminal is optional.

The product documentation shall declare the behavior in the case of a short circuit of the control interface (LEDset) terminal to the LED− and/or GNDset terminal(s). The behavior in case of open circuit of the control interface is defined in section 7.1.

9.2 LED module

The power input terminals shall be marked “LED+” and “LED−“.

The control interface terminal shall be marked “LEDset”.

The manufacturer’s product documentation shall provide the LED module’s rated supply current and rated operating voltage.

9.2.1 LED module that provides thermal de-rating functionality

If the LED module contains thermal de-rating functionality, manufacturer’s product documentation shall indicate above which operating temperature the thermal de-rating functionality is active. This operating temperature shall be measured at the t_p reference point, which shall be a marked spot on the LED module (see IEC 62717). In addition, the manufacturer’s product documentation shall indicate the current characteristics at the control interface (LEDset) terminal in relation to the thermal de-rating functionality.

10 Compliance tests

10.1 Driver compliance tests

For all window driver compliance tests defined below, any functionality that can override the information contained in the setting current—as well as optional dimming functionality—shall be disabled for the duration of test.

10.1.1 Compliance test for a window driver – setting of the output current (rated operating window, $I_{min} \leq I_{out} \leq I_{max}$)

The purpose of this test is to verify compliance with the requirements in section 7.1.

Test setup:

a) The LEDset terminal and the LED− and/or GNDset output terminal(s) of the window driver under test shall be connected to a setting resistor having a value that is derived from the relation

$$R_{set} = \frac{5\ V}{I_{test}} \times 1000\,,$$

where I_{test} is the intended output current of the window driver under test as given in step (c). The resistance of the setting resistor shall not deviate by more than ±0,5% from the value calculated from the above relation.

b) Test circuit 1 shall be connected to the output terminals LED+ and LED− of the window driver under test (see Annex B, Figure B.1).

c) The setting resistor R_{set} and the voltage source U1 of test circuit 1 shall be adjusted for operation of the window driver under test with an intended output current I_{test}, which corresponds with the following points of its rated operating window:

- The rated maximum output current and the thereby rated maximum output voltage +0/−3 V (point C in Figure 2).
- The rated maximum output current and the thereby rated minimum output voltage +3/+0 V (point D in Figure 2).
- The rated minimum output current and the thereby rated minimum output voltage +3/−0 V (point F in Figure 2).
- The rated minimum output current and the thereby rated maximum output voltage +0/−3 V (point A in Figure 2).

At each of the four above operating points, R1 of test circuit 1 shall be set to the value $R_{diff,min} + 0{,}3 \cdot (R_{diff,max} - R_{diff,min}) \pm 25\%$, where $R_{diff,min}$ and $R_{diff,max}$ are the rated minimum and maximum differential resistances at the operating points.

NOTE: The $R_{diff,min}$ and $R_{diff,max}$ values required for setting the R1 are listed in Annex B of the LEDset Power Interface Specification.

d) The voltage U_{set} at the LEDset terminal of the window driver under test shall be measured relative to both the LED− and GNDset terminal(s).

Compliance criteria:

a) The average of the measured output current I_{out} for each of the four cases listed in step (c) shall not deviate from the intended output current I_{test} by more than ±10%.

NOTE: The output current should be averaged to remove the effects of ripple and transients on the measurement result.

b) Each measured voltage U_{set} shall be (5 ±0,25) V.

10.1.2 Compliance test for a window driver - setting of the output current (low output current operation, $I_{out} < I_{min}$)

The purpose of this test is to verify compliance with the requirements in section 7.1.

Test setup:

a) The LEDset terminal and the LED- and/or GNDset output terminal(s) of the window driver under test shall be connected to a setting resistor, which yields a setting current I_{set} in the ranges of 0% to 10%, 45% to 55%, and 70% to 80% of I_{min} / 1000, where I_{min} is the rated minimum operating current of the window driver. In addition, the LEDset terminal of the window driver under test shall be placed in open-circuit mode.

b) Test circuit 1 shall be connected to the output terminals LED+ and LED− of the window driver under test (see Annex B, Figure B.1).

c) The voltage source U1 of test circuit 1 shall be adjusted for operation of the window driver under test at rated maximum output voltage +0/−3 V.

   R1 of test circuit 1 shall be set to the value $R_{diff,min} + 0,3 \cdot (R_{diff,max} – R_{diff,min}) \pm 25\%$, where $R_{diff,min}$ and $R_{diff,max}$ are the rated minimum and maximum differential resistances at the operating point A.

   NOTE: The $R_{diff,min}$ and $R_{diff,max}$ values required for setting the R1 are listed in Annex B of the LEDset Power Interface Specification.

d) The voltage U_{set} at the LEDset terminal of the window driver under test shall be measured relative to the LED- and/or GNDset terminal(s).

Compliance criteria:

a) The measured output current I_{out} for each of the four cases listed in step (a) shall not exceed the rated minimum output current I_{min}. Outside the rated operating window, the window driver under test may operate in PWM mode; in that case, the output current shall be measured during the on phase of PWM cycle.

b) The voltage U_{set} shall be (5 ± 0,25) V.

10.1.3 Compliance test for a window driver – dynamic response

The purpose of this test is to verify compliance with the requirements in section 7.2.

Test setup:

a) The LEDset terminal and the LED- and/or GNDset output terminal(s) of the window driver under test shall be connected to a setting resistor having a value that is derived from the relation

$$R_{set} = \frac{5\,V}{I_{test}} \times 1000$$

   where I_{test} is the intended output current of the window driver under test as given in step (c). The resistance of the setting resistor shall not deviate by more than ±0,5% from the calculated value.

b) Test circuit 1 shall be connected to the output terminals LED+ and LED− of the window driver under test (see Annex B, Figure B.1).

c) The setting resistor R_{set} and the voltage source U1 of test circuit 1 shall be adjusted for operation of the window driver under test with an intended output current I_{test}, which corresponds with the following points of its rated operating window:

   - The rated maximum output current and the thereby rated maximum output voltage +0/−3 V (point C in Figure 2)
   - The rated maximum output current and the thereby rated minimum output voltage +0/−3 V(point D in Figure 2)

   At each of the two above operating points, R1 of test circuit 1 shall be set to the value $R_{diff,min} + 0,3 \cdot (R_{diff,max} – R_{diff,min}) \pm 25\%$, where $R_{diff,min}$ and $R_{diff,max}$ are the rated minimum and maximum differential resistances at the operating point.

   NOTE: The $R_{diff,min}$ and $R_{diff,max}$ values required for setting the R1 are listed in Annex B of the LEDset Power Interface Specification.

d) The test circuit shall be driven for at least 20 s at the rated maximum output current of the window driver. Subsequently, the setting resistor R_{set} shall be switched to a value that yields the rated minimum output current of the window driver within a tolerance of ±0,5%. The switch used shall have a rating of maximum 0,1s switching time.

e) The output current I_{out} of the window driver under test shall be measured at a rate of ten or more samples per second, in a time window that runs from 10 s to 15 s after switching the setting resistor.

Compliance criteria:

a) All samples of the measured output current I_{out} for each of the two cases listed in step (c) shall not deviate from the rated minimum output current of the window driver by more than ±10%.

10.1.4 Compliance test for a window driver - robustness

The purpose of this test is to verify compliance with the requirements in section 8.

Test setup:

a) The LEDset terminal and the LED- and/or GNDset output terminal(s) of the window driver under test shall be connected to a current source, which outputs a setting reverse current I_{set} of 2 mA, 4 mA, 6 mA, 8 mA and 10 mA, respectively. The tolerance on each listed reverse current is –1/0 mA

b) Test circuit 1 shall be connected to the output terminals LED+ and LED− of the window driver under test (see Annex B, Figure B.3).

c) The voltage source U1 of test circuit 1 shall be adjusted for operation of the window driver under test at rated maximum output voltage +0/−3 V.

   R1 of test circuit 1 shall be set to the value $R_{diff,min} + 0,3 \cdot (R_{diff,max} – R_{diff,min}) \pm 25\%$, where $R_{diff,min}$ and $R_{diff,max}$ are the rated minimum and maximum differential resistances at the operating point A.

   NOTE: The $R_{diff,min}$ and $R_{diff,max}$ values required for setting the R1 are listed in Annex B of the LEDset Power Interface Specification.

Compliance criteria:

a) The measured output current I_{out} for each of the five cases listed in step (a) shall not exceed the rated minimum output current I_{min} by more than 10%. Outside the rated operating window, the window driver under test may operate in PWM mode; in that case, the output current shall be measured during the on phase of PWM cycle.

10.2 LED module compliance tests

10.2.1 Compliance test for a LED module

The purpose of this test is to verify compliance of the LED module with the requirements in section 7.1 to cover applications with non-PWM mode drivers.

Test setup:

a) The LED module under test shall be connected to a reference window driver, which comprises a constant voltage source and a current source (see Annex B, Figure B.2).

b) The current source shall be set to the rated supply current of the LED module under test +0/-10%. In case the LED Module documentation shows multiple rated currents, the highest value shall be used for this test.

c) The constant voltage source of the reference window driver shall be set to U_{set} = (5 ±0,025) V and shall be limited to a maximum current of (20 ± 2) mA.

d) The temperature at the t_p reference point of the LED module under test shall be adjusted such that temperature de-rating functionality—if present—is not activated.

Compliance criteria:

a) The current that is output from the constant voltage source shall not deviate from the current I_{set} by more than ±2% at any time during the test, where I_{set} is derived from the relation

$$I_{set} = \frac{I_{LED}}{1000},$$

with I_{LED} being the rated supply current of the LED module under test.

10.2.2 Compliance test for a LED module - setting of the input current

The purpose of this test is to verify compliance with the requirements in section 7.1 to cover applications with PWM-dimming mode drivers.

This test may be omitted in the following cases:

- The LED module does not provide a LEDset terminal or
- The LED module does provide a LEDset terminal and the circuitry on the LED Module between the LEDset terminal and the LED- terminal consists of a single resistor (see figure 6). The fact that the circuitry on the LED Module between the LEDset terminal and the LED- terminal consists of a single resistor may be established by visual inspection or by a written confirmation by the manufacturer.

Test setup:

a) The LED module under test shall be connected to a reference window driver, which comprises a constant voltage source and a current source (see Annex B, Figure B.2).

b) The current source of the reference window driver operates in PWM mode. The PWM frequency shall be (500 ± 50) Hz. The transition time of the current slopes concerning the PWM mode shall not exceed 5 µs, where the transition time is measured from 10% to 90% of the maximum current value.

c) During the on phase of the PWM signal, the current source shall be set to the rated maximum supply current of the LED module under test +0/-10%.

d) The duty cycle of the PWM signal shall be set to 2%, 3%, 4%, 5%, 20%, 40%, 60% and 80%, respectively. A duty cycle of *x*% means that the on phase of the PWM signal lasts for *x*% of the PWM period. The tolerance on each listed duty cycle is ±1%. For clarity, 5% represents a duty cycle in the range of 4% to 6%.

e) The constant voltage source of the reference window driver shall be set to U_{set} = (5 ±0,025) V and shall be limited to a maximum current of (20 ± 2) mA.

f) The temperature at the t_p reference point of the LED module under test shall be adjusted such that temperature de-rating functionality—if present—is not activated.

Compliance criteria:

a) For each of the ten duty cycles listed in step (d), the current that is output from the constant voltage source shall not deviate from the current I_{set} by more than ±2% at any time during the test, where I_{set} is derived from the relation

$$I_{set} = \frac{I_{LED}}{1000},$$

with I_{LED} being the rated supply current of the LED module under test.

10.2.3 Compliance test for a LED module – settling time (T_{s1})

The purpose of this test is to verify compliance with the requirements in section 7.3.

This test may be omitted in the following cases:

- The LED module does not provide a LEDset terminal or
- The LED module does provide a LEDset terminal and the circuitry on the LED Module between the LEDset terminal and the LED- terminal consists of a single resistor (see figure 6). The fact that the circuitry on the LED Module between the LEDset terminal and the LED- terminal consists of a single resistor may be established by visual inspection or by a written confirmation by the manufacturer.

Test setup:

a) The LED module under test shall be connected to the reference window driver which consists of a voltage source and a constant current source (see Annex B, Figure B.2).

b) The current source of the reference window driver shall be set to the rated maximum current of the LED module under test +0/-10%.

c) The voltage source of the reference window driver shall be stepped from zero to U_{set} = (5 ±0,25) V within 5 µs, and shall be limited to a maximum current of (8 ± 0,4) mA.

d) The settling time T_{s1} shall be measured from the step transition to the point where the setting current I_{set} reaches and stays above 90% of I_1.

Compliance criteria:

a) The measured settling time T_{s1} shall not exceed 50 µs.

10.2.4 Compliance test for a LED module – settling time (T_{s2})

The purpose of this test is to verify compliance with the requirements in section 7.3.

This test may be omitted in the following cases:

- The LED module does not provide a LEDset terminal or
- The LED module does provide a LEDset terminal and the circuitry on the LED Module between the LEDset terminal and the LED- terminal consists of a single resistor (see figure 6). The fact that the circuitry on the LED Module between the LEDset terminal and the LED- terminal consists of a single resistor may be established by visual inspection or by a written confirmation by the manufacturer.

Test setup:

a) The LED module under test shall be connected to the reference window driver which consists of a constant voltage source and a current source (see Annex B, Figure B.2).

b) The current source of the reference window driver operates in PWM mode. The PWM frequency shall be (500 ± 50) Hz. The transition time between the 10% and 90% current levels shall be less than 5 µs.

c) The duty cycle of the PWM signal shall be set to a value in the range of 40% to 60% A duty cycle of *x*% means that the on phase of the PWM signal lasts for *x*% of the PWM period.

d) During the on phase of the PWM signal, the current source shall be set to the rated maximum current of the LED module under test +0/-10%.

e) The constant voltage source of the reference window driver shall be set to (5 ± 0,25) V and shall be limited to a maximum current of (20 ± 2) mA.

f) If the LED module under test contains temperature de-rating functionality, the temperature at the t_p reference point of the LED module under test shall be varied in steps of at most 5 °C, from a minimum value, where the thermal de-rating functionality of the LED module under test is not active, to a level where the setting current I_{set} is at least 5% below the level where thermal de-rating functionality of the LED module under test is not active (i.e. I_1 in Figure 11).

g) The settling time T_{s2} shall be measured from an off-to-on transition in the PWM signal to the point where the setting current I_{set} reaches and stays below 110% of I_2 if I_2 is positive, or reaches and stays above 90% of I_2 value if I_2 is negative.

Compliance criteria:

a) The setting current I_{set} shall satisfy the relation $I_2 < I_{set} < I_1$ throughout the measurement.

b) Each measured settling time T_{s2} shall not exceed 50 µs.

10.2.5 Compliance test for a LED module – Robustness

The purpose of this test is to verify compliance with the requirements in section 8.

This test may be omitted in the following cases:

- The LED module does not provide a LEDset terminal or
- The LED module does provide a LEDset terminal and the circuitry on the LED Module between the LEDset terminal and the LED- terminal consists of a single resistor (see figure 6). The fact that the circuitry on the LED Module between the LEDset terminal and the LED- terminal consists of a single resistor may be established by visual inspection or by a written confirmation by the manufacturer.

Test setup:

a) The LED module under test shall be connected to a reference window driver, which comprises a constant voltage source and a current source (see Annex B, Figure B.2).

b) The current source of the reference window driver shall be set to the rated maximum supply current of the LED module under test +0/-10%.

c) The constant voltage source of the reference window driver shall be set to U_{set} =(5 ± 0,25) V and shall be limited to a current in the range of –20 mA to 20 mA.

d) If the LED module under test contains temperature de-rating functionality, the temperature at the t_p reference point of the LED module under test shall be varied in steps of at most 5 °C, from a minimum value, where the thermal de-rating functionality of the LED module under test is not active to a level where the setting current I_{set} is at least 5% below the level where thermal de-rating functionality of the LED module under test is not active (i.e. I_1 in Figure 11).

e) Measure the current I_{set}.

Compliance criteria:

a) Each measured current I_{set} shall be less than 10 mA in the reverse direction, i.e. flowing from the LED module to the reference window driver.

Annex A Window driver terminals (informative)

Figure A.1 and Table A.1 show the recommended window driver output terminal configuration and colour coding. In addition, it is recommended to use a pitch of 3.5 mm for the window driver terminals.

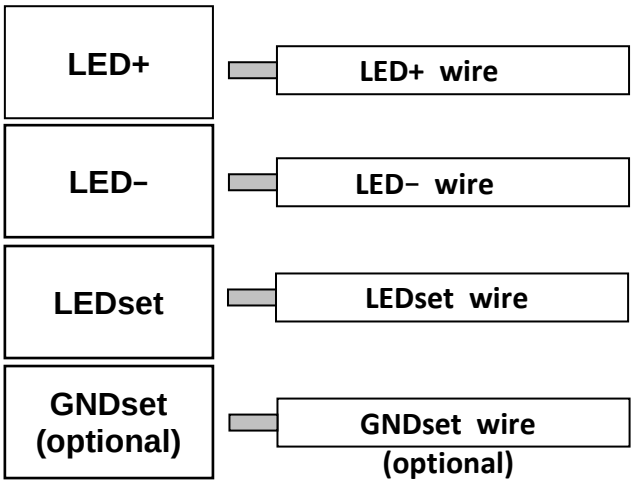

Figure A.1: Recommended window driver terminal configuration and colour coding

LED+	window driver terminal for the positive power supply wire connection	RED coloured
LED−	window driver terminal for the negative power supply wire connection	BLACK coloured
LEDset	window driver terminal for the control wire connection	WHITE coloured
GNDset	optional window driver terminal at equipotential with the LED− terminal	BLACK coloured

Table A.1: Recommended colour coding of the window driver terminals

Annex B Test setup (normative)

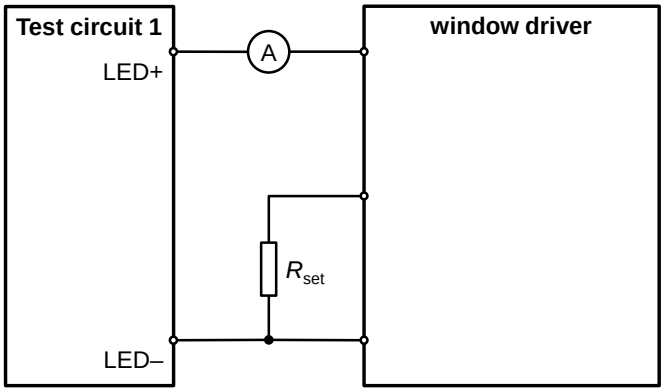

Figure B.1: Testing setup – Remote setting of the output current (1)

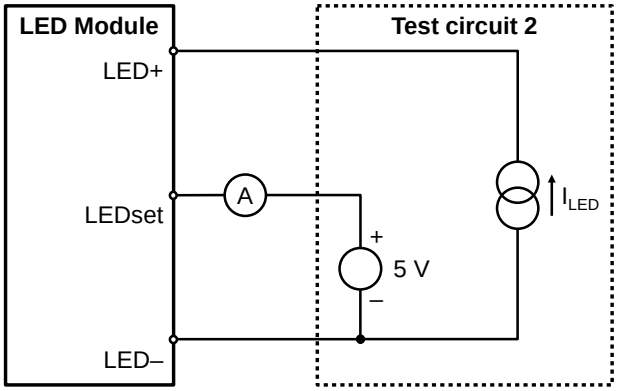

Figure B.2: Testing setup – Remote setting of the output current (2)

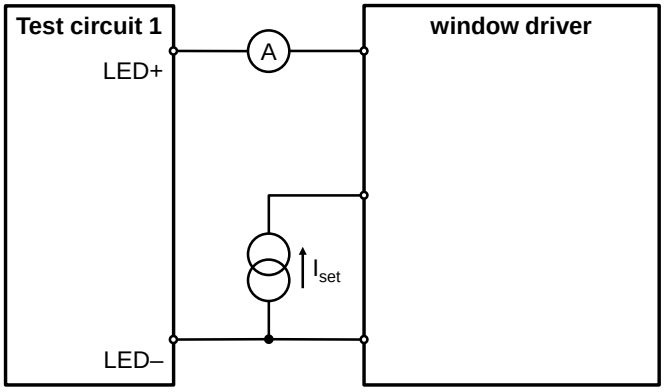

Figure B.3: Testing setup – Reverse setting current (3)

Annex C List of test equipment (informative)

- Current meter; 50 mA to 10 A; 0,5%
- Current meter; 50 µA to 10m A; 0,5%
- Voltage meter; 1 V to 10 V; 0,1%
- High power resistor; load capability and resistance dependent on DUT
- Test circuit 1 as defined in Annex A of the LEDset Power Interface Specification.
- Current source; 50 mA to 8 A; 1%; output voltage dependent on DUT
- Voltage source; 1 V to 20 V; 50 mA; 0,5%
- High power load resistors; 1%
- Controllable ambient temperature equipment w/o air ventilation
- A measurement system which provides a bandwidth of more than 200 kHz and an accuracy of ±5% to measure the timing constraints of I_{set}

  Examples:

  a) Compensated hall transducers and oscilloscope. The number of turns is allowed to be adjusted to the sensitivity of the transducer.

  b) A DC to 200 kHz current probe and oscilloscope. The number of turns is allowed to be adjusted to the sensitivity of the probe.

  c) An active electronic circuit which provides the supply of V_{set} and measurement of I_{set} in a combined function.

- A system which provides a bandwidth of 1 MHz and an accuracy of ±5% (i.e. oscilloscope with standard voltage probe) to measure the timing constraints of V_{set}.