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INTERNATIONAL STANDARD

colour inside

Digital load side transmission lighting control (DLT) – Part 1: Basic requirements

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DIGITAL LOAD SIDE TRANSMISSION LIGHTING CONTROL (DLT) –

Part 1: Basic requirements

FOREWORD

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International Standard IEC 62756-1 has been prepared by subcommittee 34C: Auxiliaries for lamps, of IEC technical committee 34: Lamps and related equipment.

The text of this standard is based on the following documents:

CDV	Report on voting
34C/1054/CDV	34C/1081B/RVC

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 62756 series, published under the general title *Digital load side transmission lighting control (DLT)*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

This standard concerning Digital Load Side Transmission Lighting Control (DLT) describes a protocol for simple control of brightness, colour, colour temperature, and other parameters for the purpose of controlling lighting sources such as CFLi, LED light engines, electronic control gear and any other light source with integrated or external control gear.

This protocol uses existing wiring and allows easy retrofit of standard switches, dimmers and lamps with the new devices described in this standard, with little or no configuration.

The following standards contain safety requirements for control devices and control gear:

– IEC 60669-2-1, Switches for household and similar fixed electrical installations – Part 2-1: Particular requirements – Electronic switches,
– IEC 61347, Lamp control gear,
– IEC 60968, Self-ballasted lamps for general lighting services – Safety requirements,
– IEC 62560, Self-ballasted LED-lamps for general lighting services by voltage $>$ 50 V – Safety specifications.

DIGITAL LOAD SIDE TRANSMISSION LIGHTING CONTROL (DLT) –

Part 1: Basic requirements

1 Scope

This International Standard specifies a protocol, electrical interface and test procedures for control of electronic lighting equipment by digital signals over the load side mains wiring.

Safety requirements are not covered by this standard.

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 60364 (all parts), *Low-voltage electrical installations*

IEC 60038, *IEC standard voltages*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
load side
wire from the output of the control device to the supply input of one or more control gear

3.2
interface
wires used for both supply of AC mains power and data transfer

3.3
control device
device that is connected to the interface and sends commands to at least one control gear

[SOURCE: IEC 62386-101:2009, 3.1, modified — "in order to control other devices (for example lamp control gear) connected to the same interface" has been replaced by "to at least one control gear"]

3.4
control gear
one or more components between the supply and one or more lamps which may serve to transform the supply voltage, limit the current of the lamp(s) to the required value, provide starting voltage and preheating current, prevent cold starting, correct power factor or reduce radio interference.

Note 1 to entry: Lamps may have an integrated control gear such as an integrated compact fluorescent lamp or integrated LED lamp. Any references to control gear will include any such integrated lamps.

[SOURCE: IEC 62386-101:2009, 3.2]

3.5
master
device that initiates transmission of data on the interface

3.6
slave
device that reacts to data on the interface

3.7
supply period
time period during which power is supplied to a control device

3.8
operating period
time period during which power is supplied to a control gear

3.9
data period
time period during which data is transmitted

3.10
brightness
lumen output of the light source

3.11
frame
sequence of consecutive bits

3.12
telegram
complete sequence of consecutive frames causing a reaction in the slave

3.13
group number
number used to address a collection of control gear

3.14
response time
time taken from the end of a telegram to the reaction of a control gear

3.15
half wave
positive or negative 180° of an a.c. sine wave starting and ending at the zero crossing point

3.16
lighting system
combination of a control device and one or more control gear

3.17
telegram type
specific content of the telegram defining the message transmitted

3.18
two-wire device
control device where the current for the internal power supply flows through the control gear

3.19
three-wire device
control device where the current for the internal power supply is supplied directly from the mains

3.20
transmission signal
difference of the voltage across the control device between logical states during the data period

3.21
start-up
transition from zero light output to a state with greater than zero light output

4 General description

4.1 General

The standardization of the control protocol for control of electronic lighting equipment by load side digital signals is intended to achieve multi-vendor interoperabilityy between control devices and control gear, including but not limited to: CFL integrated lamps, LED integrated lamps and light sources with external control gear.

4.2 Master-slave structure

The control gear operates in slave mode only. Consequently the control gear receives information only.

The control device operates in master mode only. Consequently the control device transmits information only.

NOTE Bi-directional communication could be introduced in future parts or editions of this standard.

4.3 Specification overview

Below is a list of key capabilities of this protocol:

– Only one control device on the interface operates as a master.
– The control gear operates as a slave.
– The maximum number of control gear on one interface is limited only by the capabilities of the control device.
– The capabilities of a control device include the maximum permissible power of total connected control gear and the maximum permissible number of connected control gear.
– The maximum number of individual groups addressable on one interface is three.
– Bi-phase coding (Manchester coding) with error detection.
– Effective transmission rate: 200 bit/s at 50 Hz and 240 bit/s at 60 Hz.
– Compatible with mains voltages 100 V to 277 V.
– Supply of power to two-wire control devices is provided.

5 General requirements

5.1 Voltage rating

This standard applies to one or more of the following mains voltages: 100 V, 120 V, 200 V, 230 V, 277 V, according to IEC 60038.

5.2 Frequency rating

This standard applies to one or more of the following mains frequencies: 50 Hz, 60 Hz, according to IEC 60038.

5.3 Marking of control devices and control gear

The following information shall be provided by the manufacturer.

Supported telegram types.

Indication if a control gear does not support group number assignment.

Factory assigned group number for control gear with a fixed factory group assignment other than group 0.

Maximum number of group number assignments for control gear with limited number of group number assignments.

Required minimum number of connected control gear for control devices requiring more than one control gear to be connected.

NOTE Two-wire control devices could need a supply current that exceeds the current-carrying capability provided by a single control gear.

6 Electrical specification

6.1 General

To describe the electrical characteristics of the interface, the following abbreviations are used:

V_{M}	Mains voltage (rated nominal value)
$V_{\mathrm{M}}(\mathrm{t})$	Instantaneous value of V_{M}
V_{Pk}	Peak voltage of V_{M}
V_{CD}	Voltage between the line side (L) and load side terminals of the control device (see Figure 1)
I_{CD}	Current through the load side terminal of the control device (see Figure 1)
Z_{CD}	Impedance between the line side (L) and load side terminals of the control device
V_{CG}	Voltage across the input terminals of the control gear (see Figure 1)
I_{CG}	Current through the input terminals of the control gear (see Figure 1)
Z_{CG}	Impedance across the input terminals of the control gear
P_{CG}	Rated input power of the control gear
n	Number of control gear connected with one control device
V_{SW}	Voltage across the input terminals of the control gear at the time that leads to disabling (supply period) or enabling (data period) the bypass
V_{Data}	Voltage between the line side (L) and load side terminals of the control device during the data period (see 6.7)
V_{TS}	Transmission voltage, difference of the voltage between the line side (L) and load side terminals of the control device between logical states; signal amplitude of the transmission signal
V_{CDmin}	Voltage between the line side (L) and load side terminals of the control device when its impedance Z_{CD} is minimal

I_{CG_LC} Current-carrying capability of the control gear during the low current intervals and the data period

I_{CG_HC} Current-carrying capability of the control gear during the high current interval

V_{CG_HC} Maximum value for V_{CG} during the high current phase with $I_{CG} = I_{CG\_HC}$

I_{CD_HC} Limit for current I_{CD} during the high current interval, defined by the control device

t_{HB} Period time of one half-bit (see Figure 7)

t_{rise} Time needed to increase the voltage between the line side (L) and load side terminals of the control device (V_{Data}) from $V_{CDmin} + 0{,}1\times V_{TS}$ to $V_{CDmin} + 0{,}9\times V_{TS}$

t_{fall} Time needed to decrease the voltage between the line side (L) and load side terminals of the control device (V_{Data}) from $V_{CDmin} + 0{,}9\times V_{TS}$ to $V_{CDmin} + 0{,}1\times V_{TS}$

t_{CD_S} Time after zero crossing when the control device stops applying voltage to the control gear

I_{PO_low} Lower most level for current carrying capability of the control gear during power controlled off state

I_{PO_high} Upper most level for current carrying capability of the control gear during power controlled off state

V_{PO_low} Lower limit for voltage across the input terminals of the control gear to provide a current carrying capability $IPO_{\_low}$ during power controlled off state

V_{PO_high} Upper limit for voltage across the input terminals of the control gear to provide a current carrying capability $IPO_{\_high}$ during power controlled off state

6.2 Wiring method

The wiring of the devices is in accordance with the installation rules given in the IEC 60364 series, and also with the national wiring rules applicable in the country where the devices are installed.

6.3 Wiring diagram

The wiring of the lighting system uses the traditional method of breaking the control device into the mains connection to the control gear. Figure 1 is an example of a lighting system with one control device and one or two control gear.

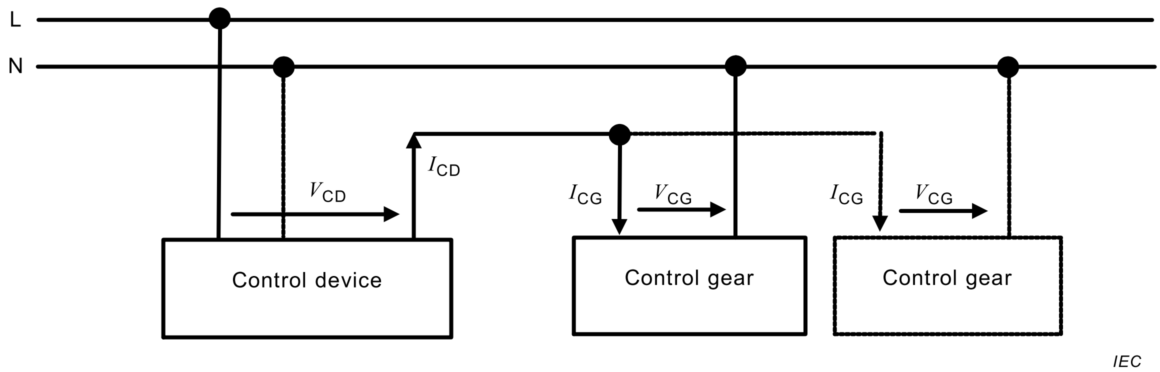

Figure 1 – Example wiring diagram

6.4 Block diagram of the control gear

For the DLT function, in addition to the parts usually used in a control gear, the following may be required (see Figure 2):

- a rectifier unit for rectifying the mains voltage;
- a bypass that is able to carry specified currents as defined for different periods;

- a decoupling unit that decouples the transmitted data from the mains and forwards the transmission signal to a processing unit;
- a processing unit that acts on the received telegram to drive the lamp controller;
- a lamp controller to supply light emitting elements, such as low pressure discharge lamps or LEDs;
- a decoupling diode if the input capacitance of the lamp controller would disturb the reception of the transmission signal.

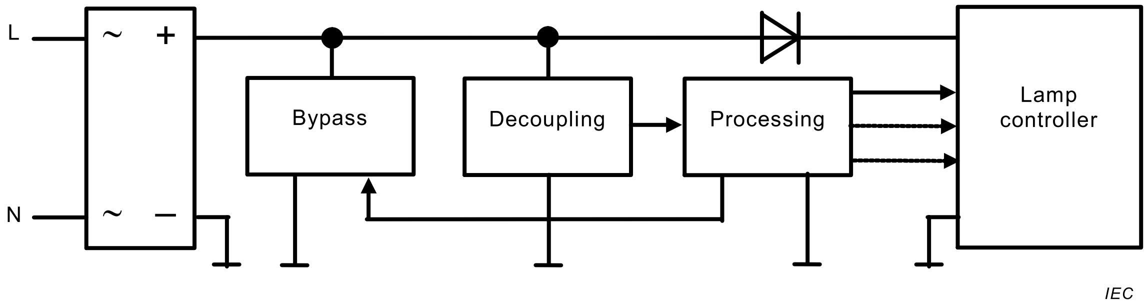

Figure 2 – Example of block diagram of control gear

6.5 Block diagram of the control device

A control device (see Figure 3) comprises an electronic power switch with integrated logic and zero crossing detection to control the supply period, the operating period and the data period. For proper operation, a power supply with an integrated current limiter is necessary for driving the circuitry of the control device. The power required by the control device depends on the design of the user interface.

A data modulator provides the data for the control gear.

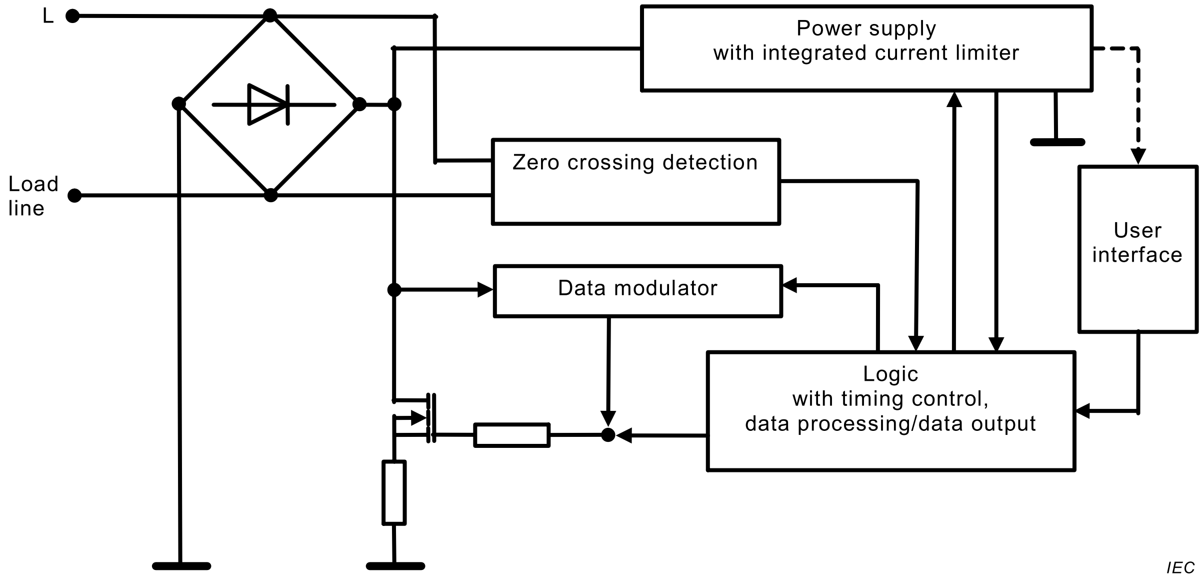

Figure 3 – Example of block diagram of control device

6.6 Electrical characteristics in different periods of the mains waveform

6.6.1 General

All values in this subclause are relevant for both 2-wire and 3-wire control devices.

6.6.2 Separation of the half-wave into time periods

All information given in this standard is related to a half-wave of the mains. Due to the polarity change between subsequent half-waves, all values are regarded as absolute values.

Each half wave is divided into three periods: Supply period, operating period and data period, as described in Figure 4 and 6.6.3 to 6.6.5.

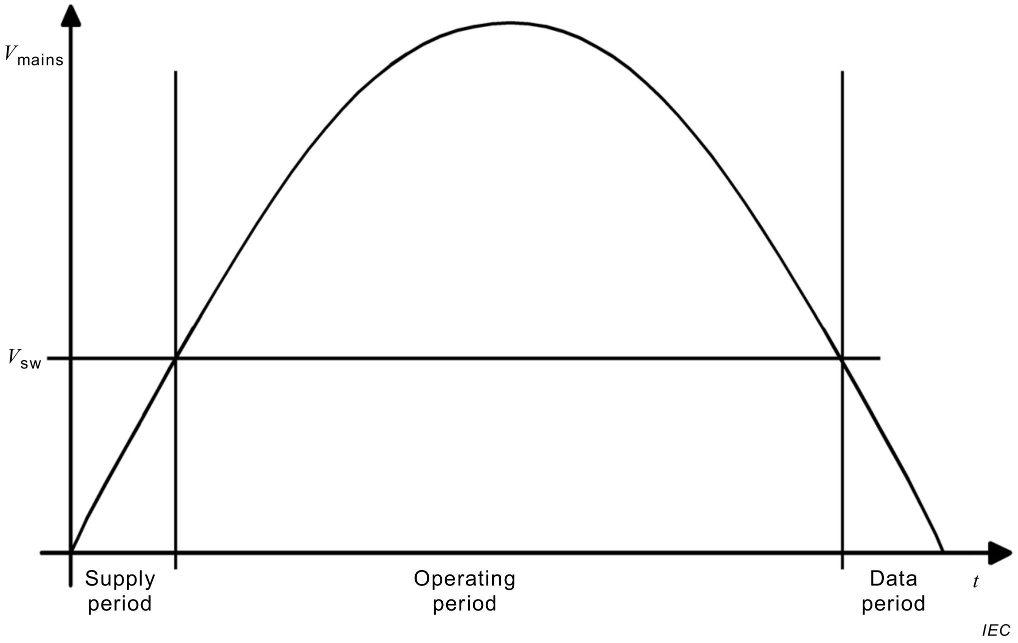

Figure 4 – Time periods of each half-wave

6.6.3 Electrical characteristics of the supply period

6.6.3.1 General

During the supply period the control gear has to be able to conduct a current, which allows the supply of power to the control device even in a two-wire installation.

The supply period is divided into 3 intervals; first low current interval, high current interval and second low current interval (see Figure 5).

During all three intervals, the control device and the control gear shall comply with the electrical characteristics listed in 6.6.3.2. to 6.6.3.4.

The control gear may deactivate its current-carrying capability during the supply period after it has not received a valid telegram for two minutes.

NOTE This is for reducing power losses in case a control gear is used without a control device.

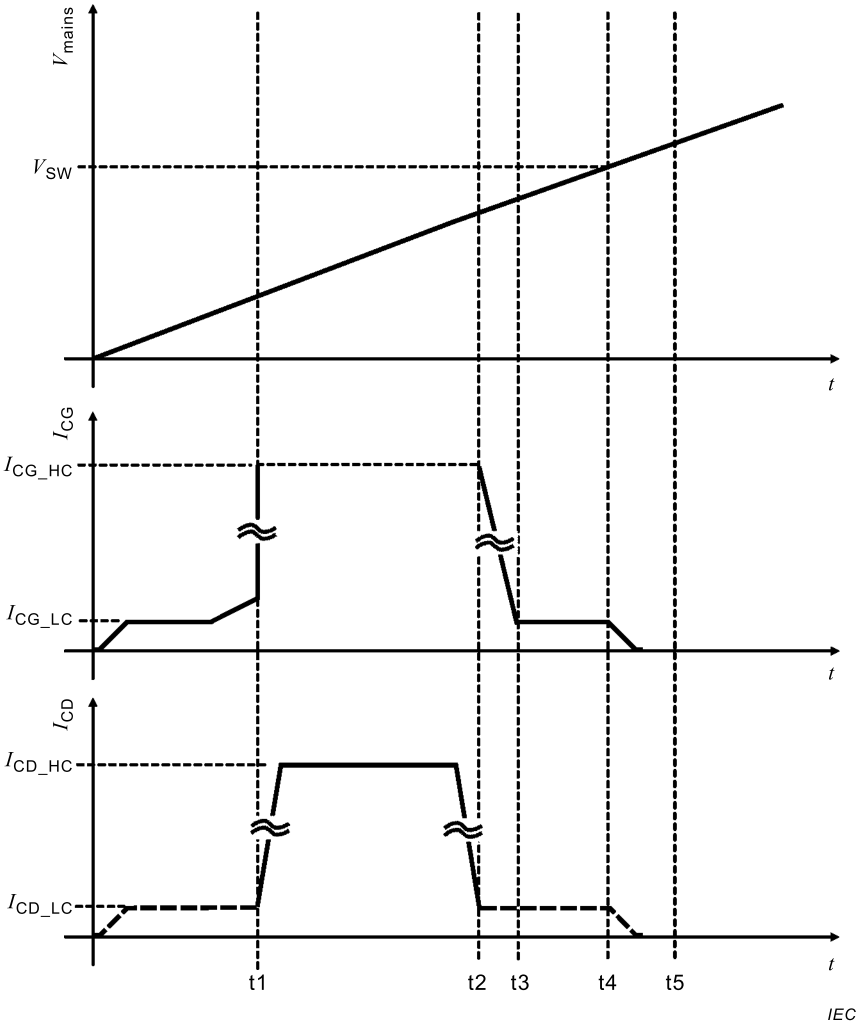

Figure 5 – Timing of supply period

6.6.3.2 First low current interval

The purpose of the first low current interval is that the control gear provides defined impedance starting from the zero crossing of the mains, enabling the zero crossing detection in the control device. This makes synchronization with the phase of the mains possible.

This interval starts with the zero crossing of the mains and ends at time t1.

During this interval, the control gear shall provide a current path with a minimum current-carrying capability of $I_{\text{CG\_LC}}$. The current $I_{\text{CG\_LC}}$ may be carried through the bypass circuitry and/or through the lamp controller of the control gear (see Figure 2). At small input voltages of the control gear when $I_{\text{CG\_LC}}$ cannot be reached due to the characteristics of its input circuitry (e.g. inrush current limiting elements), only its impedance Z_{CG} is defined.

During this interval, the instantaneous value of the current I_{CG} shall not exceed I_{CG}(t) as given in Tables 1 to 5.

At small input voltages of the control gear when $I_{\text{CG\_LC}}$ cannot be reached due to the characteristics of its input circuitry (e.g. inrush current limiting elements), its impedance and current-carrying capability are defined as listed in Tables 1 to 5.

6.6.3.3 High current interval

The purpose of the high current interval is to supply power to the control device.

This interval starts at time t1 and ends at time t3.

From time t1 to time t2, the control gear shall provide a current path with a minimum current-carrying capability of I_{CG_HC}. The current I_{CG_HC} may be carried through the bypass circuitry and/or through the lamp controller of the control gear (see Figure 2). The impedance of the control gear shall be low enough that the voltage drop does not exceed V_{CG_HC} when current I_{CG} is lower than or equal to I_{CD_HC}.

The control gear may reduce its current-carrying capability to I_{CG_LC} when the voltage V_{CG} across its terminals exceeds V_{CG_HC}.

From time t1 to time t2, the control device shall limit the current I_{CD} through its terminals to I_{CD_HC}.

From time t2 to time t3, the control gear shall reduce the current-carrying capability of its current path from I_{CG_HC} to I_{CG_LC}.

It is recommended that the control device limits the current I_{CD} through its terminals from time t2 to time t3 as listed in tables 1 to 5.

6.6.3.4 Second low current interval

The purpose of the second low current interval is to provide a low current path to allow the control device to reduce the voltage V_{CD} across its terminals with a defined slew rate.

From time t3 to time t4, the control gear shall provide a current path with a minimum current-carrying capability of I_{CG_LC}. The current I_{CG_LC} may be carried through the bypass circuitry and/or through the lamp controller of the control gear (see Figure 2). During this interval, the instantaneous value of the current I_{CG} shall not exceed $I_{CG}(t)$ as given in Tables 1 to 5 except for a single small overshoot which has a maximum length of 10µs and a maximum amplitude of $I_{CG}(t)$ * 1,5.

Time t4 is when the input voltage of the control gear V_{CG} exceeds the value V_{SW}.

From time t4 on, the impedance of the control gear is no longer defined; the bypass may be deactivated.

From time t3 to time t5, the control device shall decrease its impedance Z_{CD}. The voltage V_{CD} across the control device is V_{CDmin} from the time t5 at the latest.

Table 1 – Nominal mains voltage 100 V, frequency 50 Hz or 60 Hz

	Time related to previous zero crossing of mains voltage	Control gear: current, voltage and impedance limits	Control device: current, voltage and impedance limits
First low current interval	0 µs to t1 = 520 µs	0 V ≤ V_{CG} ≤ 3 V: Z_{CG} not defined 3 V < V_{CG} ≤ 6 V: Z_{CG} ≤ 330 Ω V_{CG} > 6 V: I_{CG_LC} ≥ 18 mA $I_{CG}(t) \le \frac{V_M(t) \cdot P_{CG}}{V_M^2} + 25$ mA	I_{CD} and Z_{CD} not defined I_{CD} < 18 mA recommended
High current interval	t1 = 520 µs to t2 = 790 µs	I_{CG_HC} ≥ 550 mA; V_{CG} ≤ V_{CG_HC} = 15 V if I_{CG} ≤ 550 mA	I_{CD_HC} ≤ 500 mA
	t2 = 790 µs to t3 = 860 µs	18 mA ≤ I_{CG} ≤ 550 mA	I_{CD} < 18 mA recommended
Second low current interval	t3 = 860 µs to t4; V_{SW} = 55 V (-0 / +5 V)	I_{CG_LC} ≥ 18 mA $I_{CG}(t) \le \frac{V_M(t) \cdot P_{CG}}{V_M^2} + 25$ mA See Cl 6.6.3.4 for overshoot.detail.	Z_{CD} decreases monotonically to minimum V_{CD} decreases monotonically to V_{CDmin}
	t4 to t5 = 1 200 µs	I_{CG} and Z_{CG} not defined	
Operating period	t > t5 = 1 200 µs		Z_{CD} = Minimum; V_{CD} = V_{CDmin}

Table 2 – Nominal mains voltage 120 V; frequency 50 Hz or 60 Hz

	Time related to previous zero crossing of mains voltage	Control gear: current, voltage and impedance limits	Control device: current, voltage and impedance limits
First low current interval	0 µs to t1 = 500 µs	0 V ≤ V_{CG} ≤ 3 V: Z_{CG} not defined 3 V < V_{CG} ≤ 6 V: Z_{CG} ≤ 330 Ω V_{CG} > 6 V: I_{CG_LC} ≥ 18 mA $I_{CG}(t) \le \frac{V_M(t) \cdot P_{CG}}{V_M^2} + 25$ mA	I_{CD} and Z_{CD} not defined I_{CD} < 18 mA recommended
High current interval	t1 = 500 µs to t2 = 790 µs	I_{CG_HC} ≥ 550 mA; V_{CG} ≤ V_{CG_HC} = 15 V if I_{CG} ≤ 550 mA	I_{CD_HC} ≤ 500 mA
	t2 = 790 µs to t3 = 860 µs	18 mA ≤ I_{CG} ≤ 550 mA	I_{CD} < 18 mA recommended
Second low current interval	t3 = 860 µs to t4; V_{SW} = 65 V (-0 / +5 V)	I_{CG_LC} ≥ 18 mA $I_{CG}(t) \le \frac{V_M(t) \cdot P_{CG}}{V_M^2} + 25$ mA See 6.6.3.4 for overshoot.detail.	Z_{CD} decreases monotonically to minimum V_{CD} decreases monotonically to V_{CDmin}
	t4 to t5 = 1 200 µs	I_{CG} and Z_{CG} not defined	
Operating period	t > t5 = 1 200 µs		Z_{CD} = Minimum; V_{CD} = V_{CDmin}

Table 3 – Nominal mains voltage 200 V; frequency 50 Hz or 60 Hz

	Time related to previous zero crossing of mains voltage	Control gear: current, voltage and impedance limits	Control device: current, voltage and impedance limits
First low current interval	0 μs to t1 = 300 μs	0 V ≤ V_{CG} ≤ 3 V: Z_{CG} not defined 3 V < V_{CG} ≤ 6 V: Z_{CG} ≤ 330 Ω V_{CG} > 6 V: I_{CG_LC} ≥ 18 mA $I_{CG}(t) \le \frac{V_M(t) \cdot P_{CG}}{V_M^2} + 25$ mA	I_{CD} and Z_{CD} not defined I_{CD} < 18 mA recommended
High current interval	t1 = 300 μs to t2 = 700 μs	I_{CG_HC} ≥ 400 mA; $V_{CG} \le V_{CG\_HC}$ = 20 V if I_{CG} ≤ 400 mA	I_{CD_HC} ≤ 350 mA
	t2 = 700 μs to t3 = 770 μs	18 mA ≤ I_{CG} ≤ 400 mA	I_{CD} < 18 mA recommended
Second low current interval	t3 = 770 μs to t4; V_{SW} = 105 V (-0 / +10 V)	I_{CG_LC} ≥ 18 mA $I_{CG}(t) \le \frac{V_M(t) \cdot P_{CG}}{V_M^2} + 25$ mA See 6.6.3.4 for overshoot.detail.	Z_{CD} decreases monotonically to minimum V_{CD} decreases monotonically to V_{CDmin}
	t4 to t5 = 1 200 μs	I_{CG} and Z_{CG} not defined	
Operating period	t > t5 = 1 200 μs		Z_{CD} = minimum; $V_{CD} = V_{CDmin}$

Table 4 – Nominal mains voltage 230 V; frequency 50 Hz or 60 Hz

	Time related to previous zero crossing of mains voltage	Control gear: current, voltage and impedance limits	Control device: current, voltage and impedance limits
First low current interval	0 μs to t1 = 300 μs	0 V ≤ V_{CG} ≤ 3 V: Z_{CG} not defined 3 V < V_{CG} ≤ 6 V: Z_{CG} ≤ 330 Ω V_{CG} > 6 V: I_{CG_LC} ≥ 18 mA $I_{CG}(t) \le \frac{V_M(t) \cdot P_{CG}}{V_M^2} + 25$ mA	I_{CD} and Z_{CD} not defined I_{CD} < 18 mA recommended
High current interval	t1 = 300 μs to t2 = 700 μs	I_{CG_HC} ≥ 400 mA; $V_{CG} \le V_{CG\_HC}$ = 20 V if I_{CG} ≤ 400 mA	I_{CD_HC} ≤ 350 mA
	t2 = 700 μs to t3 = 770 μs	18 mA ≤ I_{CG} ≤ 400 mA	I_{CD} < 18 mA recommended
Second low current interval	t3 = 770 μs to t4; V_{SW} = 120 V (-0 / +10 V)	I_{CG_LC} ≥ 18 mA $I_{CG}(t) \le \frac{V_M(t) \cdot P_{CG}}{V_M^2} + 25$ mA See 6.6.3.4 for overshoot.detail.	Z_{CD} decreases monotonically to minimum V_{CD} decreases monotonically to V_{CDmin}
	t4 to t5 = 1 200 μs	I_{CG} and Z_{CG} not defined	
Operating period	t > t5 = 1 200 μs		Z_{CD} = Minimum; $V_{CD} = V_{CDmin}$

Table 5 – Nominal mains voltage 277 V; frequency 50 Hz or 60 Hz

	Time related to previous zero crossing of mains voltage	**Control gear: current, voltage and impedance limits**	**Control device: current, voltage and impedance limits**
First low current interval	0 µs to t1 = 300 µs	$0\ V \le V_{CG} \le 3\ V$: Z_{CG} not defined $3\ V < V_{CG} \le 6\ V$: $Z_{CG} \le 460\ \Omega$ $V_{CG} > 6\ V$: $I_{CG\_LC} \ge 13$ mA $I_{CG}(t) \le \frac{V_M(t) \cdot P_{CG}}{V_M^2} + 25$ mA	I_{CD} and Z_{CD} not defined $I_{CD} < 13$ mA recommended
High current interval	t1 = 300 µs to t2 = 700 µs	$I_{CG\_HC} \ge 400$ mA; $V_{CG} \le V_{CG\_HC} = 20$ V if $I_{CG} \le 400$ mA	$I_{CD\_HC} \le 350$ mA
	t2 = 700 µs to t3 = 770 µs	$13\ mA \le I_{CG} \le 400$ mA	$I_{CD} < 13$ mA recommended
Second low current interval	t3 = 770 µs to t4; V_{SW} = 145 V (-0 / +10 V)	$I_{CG\_LC} \ge 13$ mA $I_{CG}(t) \le \frac{V_M(t) \cdot P_{CG}}{V_M^2} + 25$ mA See 6.6.3.4 for overshoot.detail.	Z_{CD} decreases monotonically to minimum V_{CD} decreases monotonically to V_{CDmin}
	t4 to t5 = 1 200 µs	I_{CG} and Z_{CG} not defined	
Operating period	t > t5 = 1 200 µs		Z_{CD} = Minimum; $V_{CD} = V_{CDmin}$

6.6.4 Electrical characteristics of the operating period

During this period, the mains voltage minus V_{CDmin} shall be applied to the control gear in order to supply the control gear with power.

During this period, the impedance of the control device Z_{CD} shall be at its minimum, and therefore the voltage across the control device V_{CD} is V_{CDmin}.

6.6.5 Electrical characteristics of the data period

6.6.5.1 General

In this period, the control device generates the data for controlling the control gear.

The control device and the control gear shall comply with the electrical characteristics listed in 6.6.5.2.

The control gear may deactivate its current-carrying capability during the data period after it has not received a valid telegram for two minutes.

NOTE This is for reducing power losses in case a control gear is used without a control device.

During the data period, the control gear provides defined impedance, enabling the zero crossing detection in the control device and in the control gear. This makes synchronization with the phase of the mains possible.

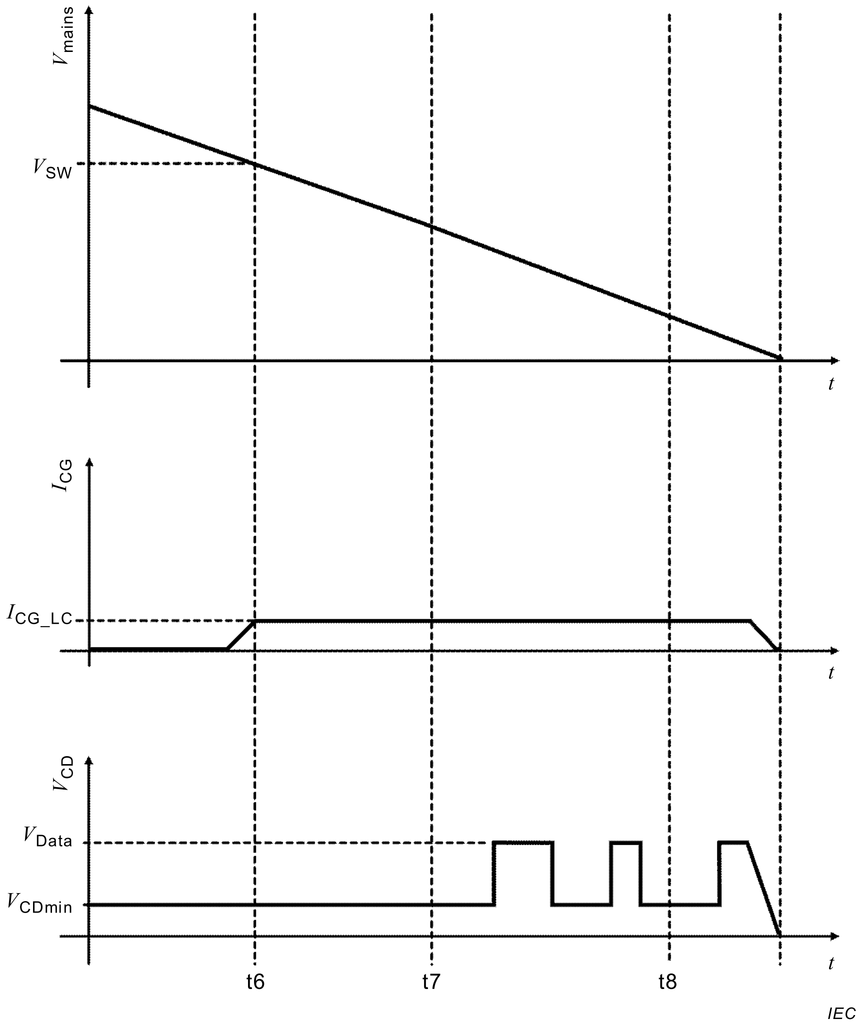

Figure 6 – Timing data period

6.6.5.2 Characteristics of DLT devices during the data period

The data period starts at time t6 and ends at the next zero crossing of the mains. See Figure 6.

Time t6 is when the input voltage of the control gear V_{CG} falls below the value V_{SW}.

From time t6 to the end of the period, the control gear shall provide a current path with a minimum current-carrying capability of I_{CG_LC}. The current I_{CG_LC} may be carried through the bypass circuitry and/or through the lamp controller of the control gear (see Figure 2).

During this period, the instantaneous value of the current I_{CG} shall not exceed I_{CG}(t) as given in Tables 6 to 10.

At small input voltages of the control gear when I_{CG_LC} cannot be reached due to the characteristics of its input circuitry (e.g. inrush current limiting elements), its impedance and current-carrying capability are defined as listed in Tables 6 to 10.

From time t7 to time t8, the control gear shall be ready for data reception.

The control device shall transmit a single frame between time t7 and time t8 complying with 6.7 (see Clause 7 for data timing).

From time t8 to the end of the period, V_{CD} shall not exceed $V_{Data} = V_{TS} + V_{CDmin}$.

Table 6 – Nominal mains voltage 100 V; frequency 50 Hz or 60 Hz

Time before next projected zero crossing of mains voltage	Control gear: current, voltage and impedance limits	Control device: current, voltage and impedance limits
t6 to t7 = 800 μs; V_{SW} = 55 V (-0 / +5 V)	$I_{CG\_LC} \geq$ 18 mA $I_{CG}(t) \leq \dfrac{V_M(t) \cdot P_{CG}}{V_M^2}$ + 25 mA	Z_{CD} = minimum $V_{CD} \leq V_{CDmin}$
t7 = 800 μs to t8 = 250 μs		Z_{CD} = minimum $V_{CD} = V_{Data}$
t8 = 250 μs to 0 μs	0 V ≤ V_{CG} ≤ 3 V: Z_{CG} not defined 3 V < V_{CG} ≤ 6 V: Z_{CG} ≤ 330 Ω V_{CG} > 6 V: $I_{CG\_LC} \geq$ 18 mA $I_{CG}(t) \leq \dfrac{V_M(t) \cdot P_{CG}}{V_M^2}$ + 25 mA	$V_{CD} \leq V_{Data}$

Table 7 – Nominal mains voltage 120 V; frequency 50 Hz or 60 Hz

Time before next projected zero crossing of mains voltage	Control gear: Current, voltage and impedance limits	Control device: current, voltage and impedance limits
t6 to t7 = 800 μs; V_{SW} = 55 V (-0 / +5 V)	$I_{CG\_LC} \geq$ 18 mA $I_{CG}(t) \leq \dfrac{V_M(t) \cdot P_{CG}}{V_M^2}$ + 25 mA	Z_{CD} = minimum $V_{CD} \leq V_{CDmin}$
t7 = 800 μs to t8 = 250 μs		Z_{CD} = minimum $V_{CD} = V_{Data}$
t8 = 250 μs to 0 μs	0 V ≤ V_{CG} ≤ 3 V: Z_{CG} not defined 3 V < V_{CG} ≤ 6 V: Z_{CG} ≤ 330 Ω V_{CG} > 6 V: $I_{CG\_LC} \geq$ 18 mA $I_{CG}(t) \leq \dfrac{V_M(t) \cdot P_{CG}}{V_M^2}$ + 25 mA	$V_{CD} \leq V_{Data}$

Table 8 – Nominal mains voltage 200 V; frequency 50 Hz or 60 Hz

Time before next projected zero crossing of mains voltage	Control gear: Current, voltage and impedance limits	Control device: Current, voltage and impedance limits
t6 to t7 = 800 μs; V_{SW} = 105 V (-0 / +10 V)	I_{CG}_LC ≥ 18 mA $I_{CG}(t) \leq \dfrac{V_M(t) \cdot P_{CG}}{V_M^2}$ + 25 mA	Z_{CD} = minimum V_{CD} ≤ VCDmin
t7 = 800 μs to t8 = 250 μs		Z_{CD} = minimum V_{CD} = VData
t8 = 250 μs to 0 μs	0 V ≤ V_{CG} ≤ 3 V: Z_{CG} not defined 3 V < V_{CG} ≤ 6 V: Z_{CG} ≤ 330 Ω V_{CG} > 6 V: $I_{CG\_LC} \geq$ 18 mA $I_{CG}(t) \leq \dfrac{V_M(t) \cdot P_{CG}}{V_M^2}$ + 25 mA	$V_{CD} \leq V_{Data}$

Table 9 – Nominal mains voltage 230 V; frequency 50 Hz or 60 Hz

Time before next projected zero crossing of mains voltage	Control gear: current, voltage and impedance limits	Control device: current, voltage and impedance limits
t6 to t7 = 800 μs; V_{SW} = 120 V (-0 / +10 V)	$I_{CG\_LC} \geq 18$ mA $I_{CG}(t) \leq \frac{V_M(t) \cdot P_{CG}}{V_M^2} + 25$ mA	Z_{CD} = Minimum $V_{CD} \leq V_{CDmin}$
t7 = 800 μs to t8 = 250 μs		Z_{CD} = Minimum $V_{CD} = V_{Data}$
t8 = 250 μs to 0 μs	0 V ≤ V_{CG} ≤ 3 V: Z_{CG} not defined 3 V < V_{CG} ≤ 6 V: $Z_{CG} \leq 330\ \Omega$ V_{CG} > 6 V: $I_{CG\_LC} \geq 18$ mA $I_{CG}(t) \leq \frac{V_M(t) \cdot P_{CG}}{V_M^2} + 25$ mA	$V_{CD} \leq V_{Data}$

Table 10 – Nominal mains voltage 277 V; frequency 50 Hz or 60 Hz

Time before next projected zero crossing of mains voltage	Control gear: current, voltage and impedance limits	Control device: current, voltage and impedance limits
t6 to t7 = 800 μs; V_{SW} = 145 V (-0 / +10 V)	$I_{CG\_LC} \geq 13$ mA $I_{CG}(t) \leq \frac{V_M(t) \cdot P_{CG}}{V_M^2} + 25$ mA	Z_{CD} = minimum $V_{CD} \leq V_{CDmin}$
t7 = 800 μs to t8 = 250 μs		Z_{CD} = minimum $V_{CD} = V_{Data}$
t8 = 250 μs to 0 μs	0 V ≤ V_{CG} ≤ 3 V: Z_{CG} not defined 3 V < V_{CG} ≤ 6 V: $Z_{CG} \leq 460\ \Omega$ V_{CG} > 6 V: $I_{CG\_LC} \geq 13$ mA $I_{CG}(t) \leq \frac{V_M(t) \cdot P_{CG}}{V_M^2} + 25$ mA	$V_{CD} \leq V_{Data}$

6.7 Data signal voltage range and timing

The shape of the received and transmitted data signal shall be as illustrated in Figure 7 and Table 11.

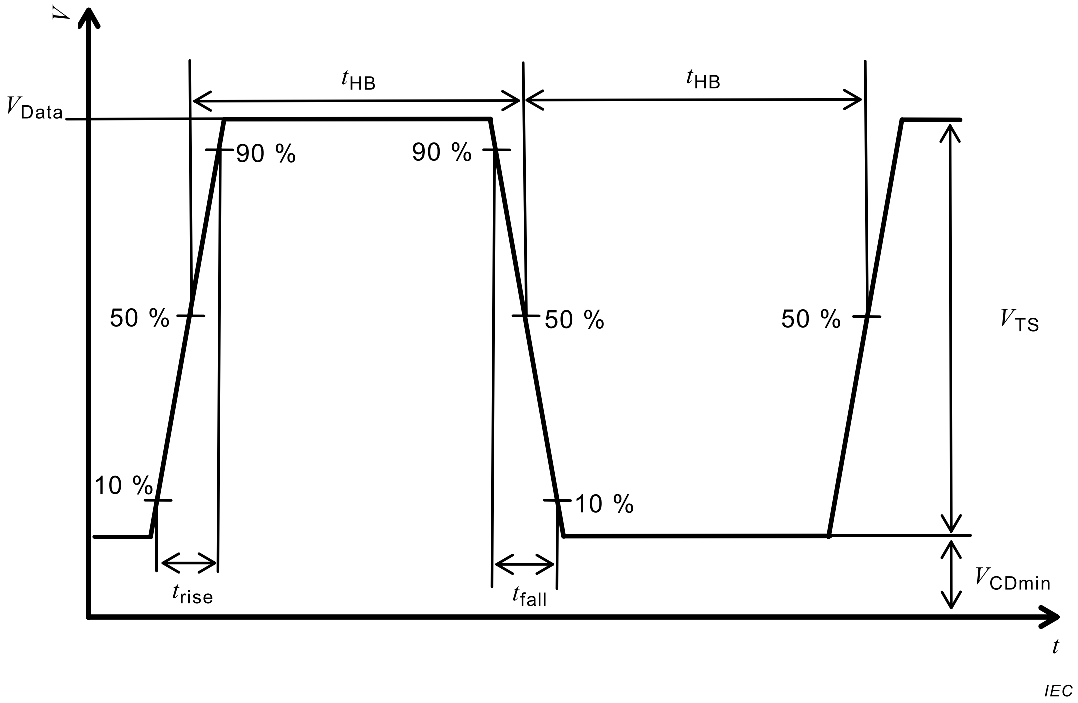

Figure 7 – Rise time and fall time at the control interface

Table 11 – Electrical characteristics of the data signal

Mains	100 V	120 V	200 V	230 V	277 V
t_{HB} [µs]	42,5 to 57,5 typ: 50	42,5 to 57,5 typ: 50	42,5 to 57,5 typ: 50	42,5 to 57,5 typ: 50	42,5 to 57,5 typ: 50
t_{fall} [µs]	7 to 20 typ: 14	7 to 20 typ: 14	15 to 30 typ: 22,5	15 to 30 typ: 22,5	15 to 30 typ: 22,5
t_{rise} [µs]	7 to 20 typ: 14	7 to 20 typ: 14	15 to 30 typ: 22,5	15 to 30 typ: 22,5	15 to 30 typ: 22,5
V_{TS} [V]	5 to 8 typ: 7	5 to 8 typ: 7	14 to 16 typ: 15	14 to 16 typ: 15	14 to 16 typ: 15

6.8 Power up timing

During power up, the control device and the control gear shall comply with the characteristics defined for the power controlled off state (see 6.9.2).

The master shall start transmitting data within 2 minutes after the mains power is supplied continuously to the control gear.

It is recommended that the master starts transmitting data within six complete half waves after the mains power is supplied continuously to the control gear.

The slave shall be ready for reception of data within 40 complete half waves of the mains power being supplied continuously to the control gear.

The slave shall be ready to provide a current path with a current-carrying capability of I_{CG_HC} (see 6.6.3.3) within three complete half waves of mains after mains voltage is supplied continuously to the control gear.

6.9 Electrical characteristics during the off state of control gear

6.9.1 General

The off state of a control gear is when a connected lamp is not emitting light.

There are two types of off state of a control gear, depending on the functionality of the control gear: a power controlled off state and a telegram controlled off state.

6.9.2 Power controlled off state

To set a control gear in the power controlled off state, the control device will increase its impedance Z_{CD} until the control gear is not sufficiently supplied with power to operate the lamp.

A control device that needs no supply during the off state of all connected control gear may open the current loop of the system, e.g. by means of a mechanical switch.

A control device that needs a power supply also during the off state of all connected control gear requires that the connected control gear provide a current path, although no lamp is operated.

If none of the connected control gear is able to provide the current path due to power not being supplied, the impedance Z_{CG} of the control gear will increase.

The control device may reduce its impedance Z_{CD} to supply power to the connected control gear in order to form a current path that carries the needed supply current I_{CD}.

By reducing Z_{CD}, the voltage V_{CD} will decrease and the voltage V_{CG} will increase, thus, all connected control gear are energized and the required current path is generated in the system to carry the required supply current I_{CD} of the control device.

The control gear shall provide a current path with a minimum current carrying capability of I_{PO_low} when the voltage V_{CG} is in the range of V_{PO_low} to V_{PO_high}. When the voltage V_{CG} is in the range of V_{PO_high} to V_{SW}, the control gear shall provide a current path with a minimum current carrying capability of I_{PO_high} (see Table 12).

The current carrying capability of the control gear is not defined for V_{CG} below V_{PO_low}.

The control gear shall not operate the lamp when the voltage V_{CG} is below V_{SW}.

The control device shall limit the current to a level that ensures the voltage V_{CG} does not exceed V_{SW}.

Table 12 – Currents and Voltages for control gear during the power controlled off state

V_M [V]	100	120	200	230	277
V_{PO_low} [V]	15	15	15	15	15
V_{PO_high} [V]	30	30	50	50	50
I_{PO_low} [mA]	≥ 3	≥ 3	≥ 3	≥ 3	≥ 3
I_{PO_high} [mA]	≥ 15	≥ 15	≥ 15	≥ 15	≥ 15

6.9.3 Telegram controlled off state

To set a control gear in telegram controlled off state, the brightness value 0 (see 10.2.3) shall be transmitted to this control gear.

A control gear set in telegram controlled off state shall comply with the requirements listed in 6.6.2 (electrical characteristics of supply period).

To reduce power losses telegram controlled off state should not be used to turn off all connected control gear. Power controlled off state should be used instead (see 6.9.2).

7 Data timing

7.1 General

Information is transmitted using Manchester coding (bi-phase coding).

One frame shall be transmitted during each half-wave. In each frame, two bits forming a data frame or the “start of telegram” frame shall be transmitted.

7.2 Information bit timing

The length t_{HB} of a half-bit shall comply with 6.7 (see Figure 7 and Table 11).

7.3 Permissible frames

There are 5 types of frame; these are shown in Figures 8 to 12.

The first half-bit of a frame transmitted by the control device shall be V_{TS} = high.

Each frame shall be terminated with one half-bit with V_{TS} = low.

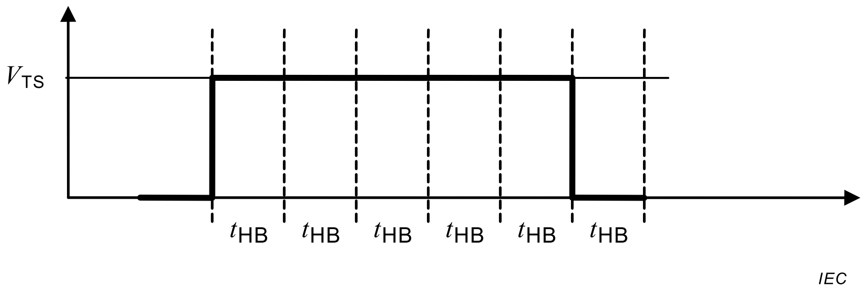

Figure 8 – Transmission of “start of telegram”

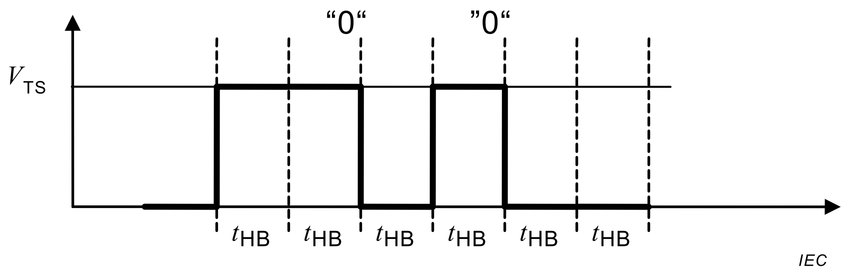

Figure 9 – Transmission of first bit 0, second bit 0

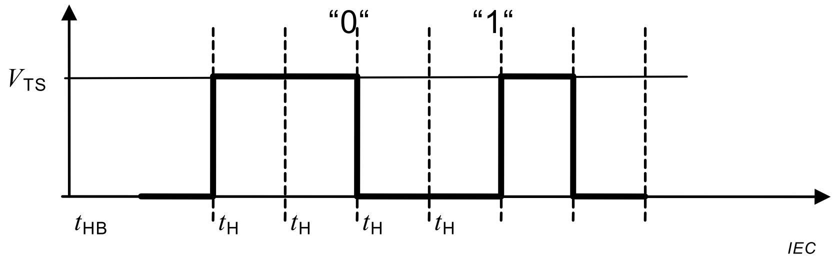

Figure 10 – Transmission of first bit 0, second bit 1

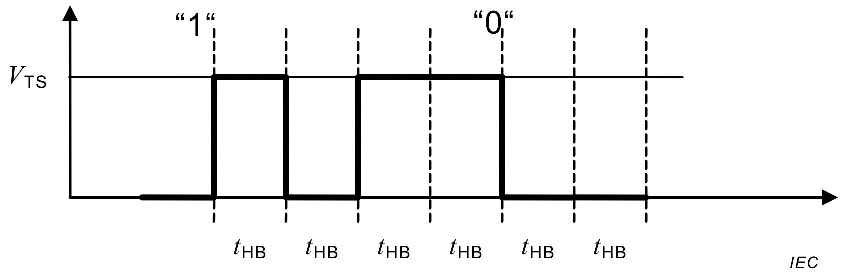

Figure 11 – Transmission of first bit 1, second bit 0

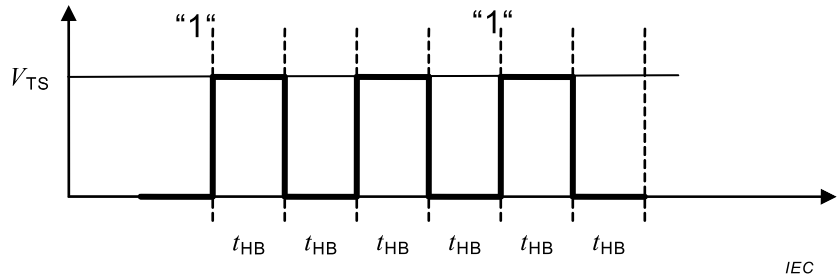

Figure 12 – Transmission of first bit 1, second bit 1

8 Telegram structure

8.1 General

A telegram consists of several consecutive frames. During normal operation, one frame of the telegram shall be transmitted during every half wave of the mains. Frames shall comply with 7.3.

The first frame of a telegram shall always be a "start of telegram" frame (see Figure 8).

The second and all subsequent frames of a telegram shall be data frames (see Figures 9 to 12).

Every data transmission starts with the most significant bit (MSB), followed by bits with decreasing significance and ends with the least significant bit. This structure is valid within every data frame and for every part of the telegram with identical type of information.

Each slave shall analyse the telegram for framing errors, parity errors, and length. If an error is detected or a telegram is received incompletely or incorrectly, the slave shall ignore the entire telegram. If the length of a received telegram is too short, the slave shall ignore the incomplete telegram. If the length of a received telegram is too long (at least one erroneous additional frame), the control gear may react to the already received frames.

The slave shall be ready to start reception of a new telegram at any “start of telegram” frame.

Telegrams are continuously transmitted by the master. For telegrams requiring fast response time, masters may abort transmission of a current telegram at any point and immediately start transmission of a new telegram at the next data period.

8.2 Telegrams

8.2.1 General

Following the “start of telegram” frame, data frames are transmitted containing group number, telegram type, parity bit and data bits needed to control the slaves in accordance with the telegram type.

8.2.2 Group number

The data frame 1 shall represent a group number from 0 to 3. Devices that do not support group number assignment shall only transmit or react to group number 0.

8.2.3 Telegram type

The data frame 2 and 3 shall represent the telegram type, telegram types shall be from 0 to 7 (see Table 13).

8.2.4 Parity bit

The second data bit of data frame 3 shall be a parity bit which includes all the bits in the telegram.

A parity bit 1 shall be transmitted if the number of bits within a complete telegram with value 1 is odd.

A parity bit 0 shall be transmitted if the number of bits within a complete telegram with value 1 is even.

8.2.5 Data for control of the control gear

Following the parity bit (see 8.2.4), the data for controlling the control gear is transmitted. The structure of this control data is defined in accordance with the telegram type that is addressed (see Clause 9).

9 Definition of telegram types

9.1 Summary of telegram types

There are 8 defined telegram types as listed in Table 13.

Table 13 – Telegram types

Type	Telegram
0	Brightness
1	Colour control
2	Colour temperature control
3	Reserved
4	Reserved
5	Commissioning, groupi number assignment
6	Manufacturer specific telegrams
7	Reserved for extended telegrams

9.2 Telegram type 0: Brightness

The structure of the Brightness telegram shall be as shown in Figure 13.

Frame “start of telegram”	Data frame 1	Data frame 2	Data frame 3
	g1, g2	0, 0	0, p
Data frame 4	Data frame 5	Data frame 6	Data frame 7
b1, b2	b3, b4	b5, b6	b7, b8

g = group number (0 to 3); g1 = MSB

p = parity

b = brightness (0 to 255); b1 = MSB

NOTE Brightness value 0 triggers a telegram controlled off state of the control gear (see 6.9.2).

Figure 13 – Brightness telegram

9.3 Telegram type 1: Colour control

The structure of the colour control telegram shall be as shown in Figure 14.

See 10.3 for description of colour x and colour y.

Frame “start of telegram”	Data frame 1	Data frame 2	Data frame 3		
	g1, g2	0, 0	1, p		
Data frame 4	Data frame 5	Data frame 6	Data frame 7	Data frame 8	Data frame 9
x1, x2	x3, x4	x5, x6	x7, x8	x9, x10	x11, x12
Data frame 10	Data frame 11	Data frame 12	Data frame 13	Data frame 14	Data frame 15
y1, y2	y3, y4	y5, y6	y7, y8	y9, y10	y11, y12

g = group number (0 to 3); g1 = MSB

p = parity

x = Colour × (0 to 4095); x1 = MSB

y = Colour y (0 to 4095); y1 = MSB

Figure 14 – Colour control telegram

9.4 Telegram type 2: Colour temperature control

The structure of the Colour temperature telegram shall be as shown in Figure 15.

NOTE See 10.4 for description of colour temperature.

Frame “start of telegram”	Data frame 1	Data frame 2	Data frame 3
	g1, g2	0,1	0, p
Data frame 4	Data frame 5	Data frame 6	Data frame 7
c1, c2	c3, c4	c5, c6	c7, c8

g = group number (0 to 3); g1=MSB

p = parity

c = colour temperature (0 to 255); c1 = MSB;

Figure 15 – Colour temperature telegram

9.5 Telegram type 3

Telegram type 3 is reserved for future use.

9.6 Telegram type 4

Telegram type 4 is reserved for future use.

9.7 Telegram type 5: commissioning: Group number assignment

The structure of the Group number assignment telegram shall be as shown in Figure 16.

NOTE Each telegram contains one frame with commission mode bits (m1, m2), values other than “0,0” are reserved for future use

Frame “start of telegram”	**Data frame 1**	**Data frame 2**	**Data frame 3**	**Data frame 4**
	g1, g2	1, 0	1, p	m1, m2

g = group number 0 to 3; g1=MSB

p = parity

m = commission mode bits

Figure 16 – Group number assignment telegram

9.8 Telegram type 6: Manufacturer specific

The structure of a Manufacturer specific telegram shall be as shown is Figure 17.

Frame “start of telegram”	Data frame 1	Data frame 2	Data frame 3		
	g1, g2	1,1	0, p		
Data frame 4	**Data frame 5**	**Data frame 6**	**Data frame 7**	**Data frame 8**	**Data frame 9**
m1,m2	m3, m4	m5, m6	m7, m8	m9, m10	m11, m12
Data frame 10	**Data frame 11**	**Data frame 12**	**Data frame 13**	**Data frame 14**	**Data frame 15**
n1, n2	n3, n4	x, x	x, x	x, x	x, x
Up to 15 additional bytes (60 data frames)					

g = group number (0 to 3); g1=MSB

p = parity

m = manufacturer identifier (0 to 2047 free to use, 2048-4095 are reserved and shall not be used.)

n = number of bytes in payload (0 to 15 = 1 to 16 payload bytes)

x = undefined payload data bits.

Figure 17 – Manufacturer specific telegram

9.9 Telegram type 7: extended telegram

Telegram type 7 is reserved for extended telegrams and is for future use.

10 Method of operation

10.1 General

Control gear shall react only to telegram types that are supported by the control gear.

All connected control gear shall react to telegrams corresponding to group number 0.

Control gear may be capable of being assigned to one group number: 1, 2 or 3. In the case of a control gear with multiple outputs, each output may be assigned to any one group number: 1, 2 or 3.

Control gear supporting group number assignment shall react to telegrams with group numbers corresponding to the assigned group number 1, 2 or 3 in addition to group number 0.

Control gear not assigned to group number 1, 2 or 3 shall not react to telegrams with group number 1, 2 or 3.

Control gear capable of changing group number assignment shall have either a manual means to set the group number, such as a mechanical switch or it shall react to sequences as described in 10.5. Both methods may be employed. If both methods are employed, the control gear shall ignore telegram controlled group assignment if its manual means is set to group numbers other than 0.

It is recommended that any control gear capable of group assignment should not be factory assigned to group number 1, 2 or 3.

All control devices shall be capable of sending telegrams with group number 0. In addition, control devices may be capable of sending telegrams with group number 1, 2 and 3.

10.2 Brightness

10.2.1 General

A control gear that accepts the brightness telegram shall meet the following requirements.

10.2.2 Response time

If the lamp is emitting light, the control gear shall react within 100 ms after successful reception of a brightness telegram with a change in brightness value.

10.2.3 Light output level

The control gear shall provide suitable output to a connected lamp to meet the light output level requirements shown in Table 14.

Table 14 – Dimming characteristic

Brightness value	Light output level
0	Telegram controlled off state (see 6.9).
1	Minimum stable light output that the lamp is capable of producing
255	Maximum stable light output that the lamp is capable of producing
180	45 % to 55 % of (maximum light output – minimum light output)
1 to 255	Monotonic light level changes from minimum to maximum light output

It is recommended that the control gear manufacturer employ means to provide smooth light level transitions from one brightness level to another and that a square-law dimming curve is used.

Based on DLT-system capability, it is recommended that the control gear manufacturer employ means to provide a minimum brightness level lower or equal to 10 %.

10.2.4 Start-up

The brightness telegram type 0 with a value greater than 0 shall be transmitted first at start-up.

It is recommended that the brightness as last adjusted should be the control gear's output upon start-up from power controlled off state.

10.3 Colour control

10.3.1 General

Control gear that accepts the colour telegram shall meet the following requirements.

10.3.2 Colour (x, y)

The output colour shall correspond as closely as possible to that shown in Figure 18 for that point in colour space defined by the x and y coordinates. The total output light intensity shall depend on the requested x and y coordinates and the brightness level.

The chosen 12-bit resolution is sufficient to distinguish all colours. The scaling of x and y by a factor of 0,84 leads to an enlarged resolution.

The integer value representing x shall be x / 0,84 * 4096

The integer value representing y shall be y / 0,84 * 4096

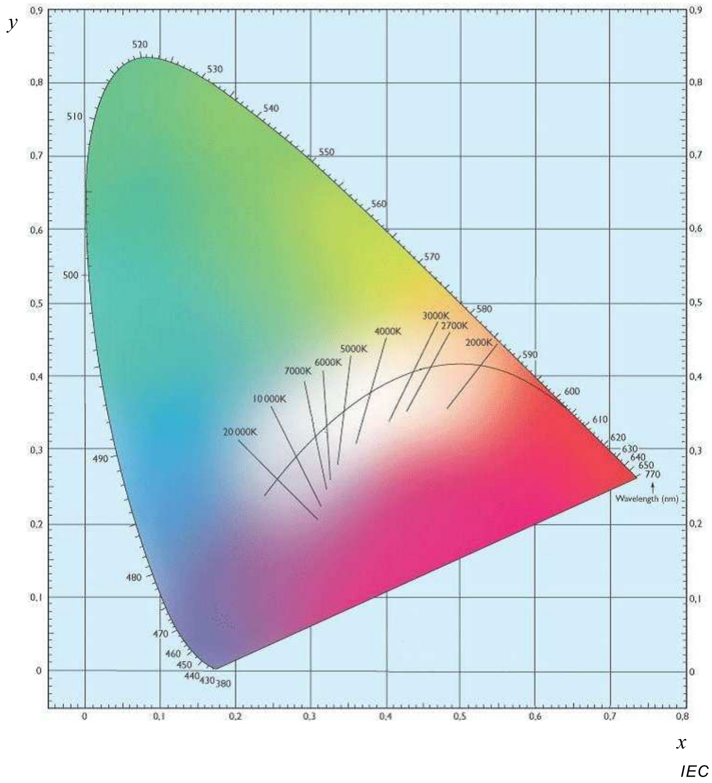

Figure 18 – The CIE 1931 colour space chromaticity diagram

10.3.3 Response time

If the lamp is on, the control gear shall react with a change in colour value within 100 ms after successful reception of a colour control telegram.

10.3.4 Colour gamut

Lamps may use any appropriate set of primaries to establish a colour display gamut.

Correction of out-of-gamut colours may be done by projecting these outliers on the intermediate border of the gamut with respect to the white point E (x = 1/3; y = 1/3).

10.3.5 Start-up

At start-up from power controlled off state, the brightness telegram type 0 with a value greater than 0 shall be transmitted first.

It is recommended that the colour as last adjusted should be the control gear's output upon start-up from power controlled off state.

It is recommended that the control gear manufacturer employ means to provide smooth colour transitions from one colour to another. The change from the current (x, y)-coordinate to a new (*x*, *y*)-coordinate is recommended to be along a straight line in the (*x*, *y*) colour space (shortest distance between the two points), while the colour is within the attainable colour space.

10.4 Colour temperature control

10.4.1 General

Control gear that accepts the colour temperature telegram shall meet the following requirements.

10.4.2 CCT (correlated colour temperature)

A black body (perfect radiant body) changes its colour from red through yellow to white as its temperature increases (black body line – BBL). The absolute temperature T (Kelvin) of the black body is referred to as the colour temperature TC (see Figure 18). The total output light intensity shall depend on the requested colour temperature TC and the set brightness. Many light sources (e.g. LED or fluorescent lamp) do not emit a light colour caused by the temperature of the light source itself, and do not exactly follow the black body line. The colour emitted from the light source that is perceived by the human eye and that most closely matches the black body line is called correlated colour temperature (CCT).

The correlated colour temperature of the light output shall be as close as possible to the requested colour temperature.

The integer value representing CCT shall be c = integer (250 000 / CCT – 0,5).

10.4.3 Response time

If the lamp is on, the control gear shall react with a change in colour temperature value within 100 ms after successful reception of a colour temperature telegram.

10.4.4 Start-up

At start-up from power controlled off state, the brightness telegram type 0 with a value greater than 0 shall be transmitted first.

It is recommended that the colour temperature as last adjusted should be the control gear's output upon start-up from power controlled off state.

It is recommended that the control gear manufacturer employ means to provide smooth transitions from one colour temperature to another. The change from the current colour temperature TC to a new colour temperature TC should follow the black body line as closely as possible using the CCT lines if needed.

10.5 Telegram controlled group number assignment

To realize telegram controlled group number assignment, the Group number assignment telegram as shown in Table 17 is used.

The control device shall repeat every transmitted telegram five times consecutively. The control gear shall react after three consecutive receptions of an identical telegram. This is to make group number assignment more reliable.

In the following, this repetition of transmissions is not explicitly named. For simplification, only the term "telegram" is used.

A control gear which has not been assigned to any group number 1, 2 or 3 is member of group number 0 and reacts to telegrams with group number 0 only. It can be assigned to any other group number with the Group number assignment telegram.

Any control gear which is assigned to any group number 1, 2 or 3 ignores any Group number assignment telegrams for group number 1, 2 or 3.

When a control gear which is member of group number 0 receives the Group number assignment telegram, it shall adopt the group number.

If a control gear which has been assigned to group number 1, 2 or 3 receives a Group number assignment telegram for group number 0, it becomes member of group number 0 and shall react to telegrams with group number 0 only. This allows subsequently an assignment of the control gear to group number 1, 2 or 3.

All connected control gear may be assigned to any group number with any further Group number assignment telegram if the maximum amount of group number assignments has not been reached.

The amount of assignments of control gear to group numbers may be limited. Any control gear with limited amount of group number assignments should permanently react to telegrams with group number 0 only, after the last possible group number assignment is removed with an assignment to group number 0. Any control gear capable of telegram controlled group number assignment shall provide at least 32 group number assignments.

It is recommended to use a flashing function to confirm a successful group number assignment of control gear

For examples of telegram controlled group number assignment see Annex A.

10.6 Manufacturer specific telegram

A control gear that accepts the manufacturer specific telegram shall meet the following requirements.

A control device may transmit a telegram that is unique to a control gear manufacturer. The telegram shall use manufacturer specific telegram type 6 and may contain up to 16 bytes of payload data. The contents of the payload data may be freely defined by a manufacturer for any purpose. The telegram may be directed to any group number.

Each telegram type 6 shall contain a 12 bit identifier to identify the manufacturer.

NOTE Identifiers 0 to 2047 are available for free use while identifiers 2048-4095 are reserved for future use.

11 Test procedures

11.1 General

There are five categories of test procedures concerning the digital load side transmission lighting interface (DLT):

– test procedures concerning the electrical specifications (defined in Clause 6);
– test procedures concerning data timing (defined in Clause 7);
– test procedures concerning the telegram structure (defined in Clause 8);
– test procedures concerning the telegram types (defined in Clause 9);
– test procedures concerning the method of operation (defined in Clause 10).

11.2 Electrical characteristics tests

11.2.1 General

Tests concerning the electrical characteristics shall ensure compliance of devices with this standard in terms of electrical behaviour of control gears and control devices during different periods of mains waveform according to 6.6 to 6.9.

Table 15 – Parameters for testing purposes

V_M [V]	100	120	200	230	277
R_R [Ω]	30	30	70	70	70
V_{CG_HC} [V]	15	15	20	20	20

11.2.2 Test of control device

11.2.2.1 Test circuit 1

A test circuit as shown in Figure 19 shall be used to test the control device. The control gear shall be represented by one equivalent CG circuit (EC_CG).

The number of EC_CG applied to the control device under test depends on the tested criteria as named in relevant subclauses.

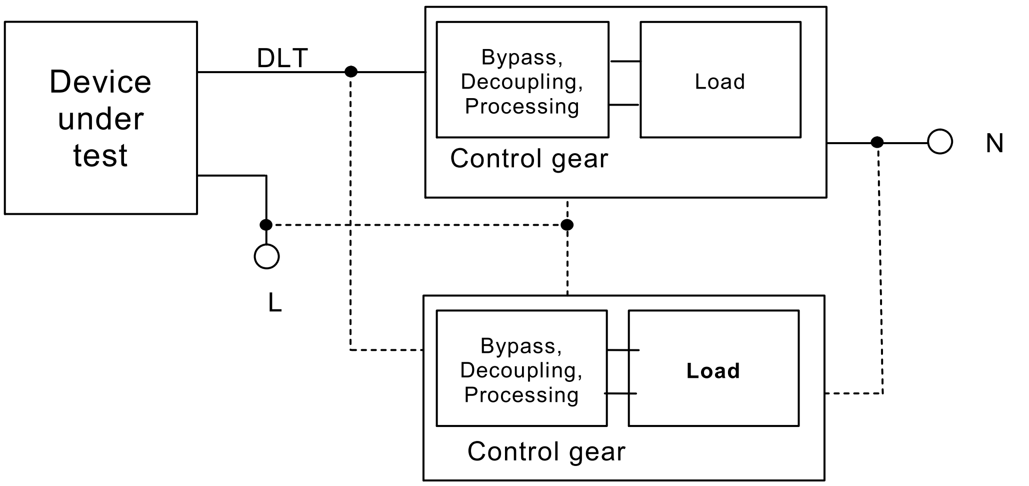

Figure 19 – Test Circuit for testing the Control Device

11.2.2.2 Supply period

11.2.2.2.1 General

Following are tests for the Supply Period.

11.2.2.2.2 High current interval

Pre-conditions:
Control device loaded with an ohmic load having a max. resistance R_R (see Table 15)

NOTE Special mains waveform could be required

Time related to last zero crossing: t1 to t2

Test: Measure I_{CD}

Expected result: $I_{CD} \le I_{CD\_HC}$

11.2.2.2.3 Second low current interval

Pre-conditions: maximum permissible number of EC_CG applied to control device

Time related to last zero crossing: t3 to t5

Test: Measure V_{CD}

Expected result: V_{CD} decreases monotonically

Pre-conditions: maximum permissible number of EC_CG applied to control device

Time related to last zero crossing: ≥ t5

Test: Measure V_{CD}

Expected result: $V_{CD} = V_{CDmin}$

11.2.2.3 Operating period

Pre-conditions: maximum permissible number of EC_CG applied to Control device

Time related to last zero crossing: t5 to t6

Test: Measure V_{CD}

Expected result: $V_{CD} = V_{CDmin}$

11.2.2.4 Data period

Pre-conditions: maximum permissible number of EC_CG applied to Control device

Time related to next zero crossing of mains voltage: t6 to t7

Test: Measure V_{CD}

Expected result: $V_{CD} = V_{CDmin}$

Pre-conditions: maximum permissible number of EC_CG applied to control device

Time related to next zero crossing of mains voltage: t7 to t8

Test: Measure V_{CD}, measure t7

Expected results: $V_{CDmin} \le V_{CD} \le V_{Data}$, t7 according to Tables 6 to 10

NOTE See 11.2.2.5 for testing of detailed values for rise- and fall times of V_{CD}

Pre-conditions: Required minimum number of EC_CG applied to control device

Time related to next zero crossing of mains voltage: t7 to t8

Test: Measure V_{CD}, measure t7

NOTE See 11.2.2.5 for testing of detailed values for rise- and fall times of V_{CD}

Pre-conditions: maximum permissible number of EC_CG applied to control device

Time related to next zero crossing of mains voltage: t7 to t8

Test: Check frame transmission, measure t8

Expected results: Transmission of complete frame according to clause 7 within t7 < t < t8, t8 according to Tables 6 to 10.

Pre-conditions: Required minimum number of EC_CG applied to control device

Time related to next zero crossing of mains voltage: t8 to 0

Test: Measure V_{CD}

Expected result: $V_{CD} \leq V_{Data}$;

11.2.2.5 Data signal voltage range and timing tests.

11.2.2.5.1 General

Following are tests for the voltage range and timing.

Pre-conditions:
Tests shall be performed with one connected EC_CG and with maximum number of permissible number of EC_CG connected.

11.2.2.5.2

Test: Measure t_{HB}

Expected result: t_{HB} according to Table 11

11.2.2.5.3

Test: Measure t_{fall}

Expected result: t_{fall} according to Table 11

Test: Measure $t_{\mathbf{rise}}$

Expected result: t_{rise} according to Table 11

11.2.2.5.4

Test: Measure V_{TS}

Expected result: V_{TS} according to Table 11

11.2.2.6 Test of power up timing

Pre-conditions: control device connected with required minimum number of EC_CG, system ready to connect with mains

Test: apply mains voltage to the DLT system, measure number of half waves until control device starts transmission after mains is supplied continuously to the control gear

Expected result: transmission starts latest 6 complete half waves after mains is supplied continuously to the control gear

11.2.2.7 Power controlled off state

This test shall only be performed with control device that support the power controlled off state (see 6.9.2)

Pre-conditions: control device connected with minimum requested number of EC_CG, system connected to mains, control device sets control gear to power controlled off state

Test: Measure V_{CG}

Expected result: Voltage applied to the EC_CG does not exceed V_{SW}

11.2.2.8 Telegram controlled off state

This test shall only be performed with control device that support the telegram controlled off state (see 6.9.3)
Pre-conditions: control device connected with required minimum number of EC_CG, system connected to mains, activate command to set connected control gear in telegram controlled off state

Test: Check transmitted brightness telegram

Expected result: control device transmits brightness telegram with brightness value 0

11.2.3 Test of control gear

11.2.3.1 Test circuit 2

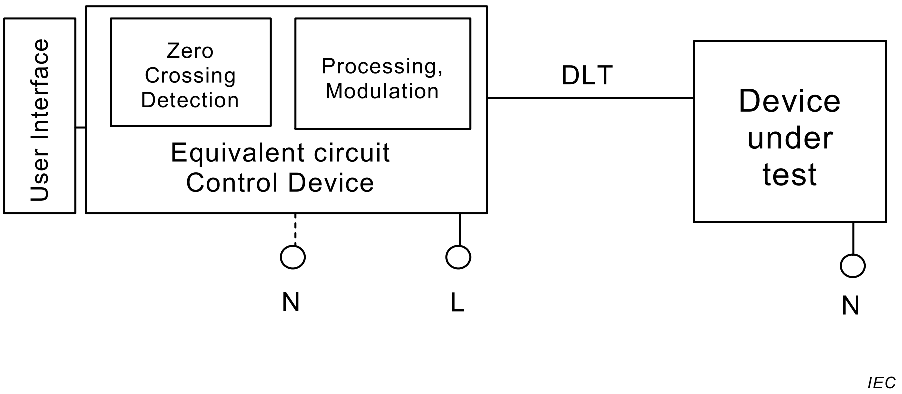

Figure 20 – Test Circuit for testing the Control Gear

A test circuit as shown in Figure 20 shall be used to test the control gear. The control device shall be represented by an equivalent circuit for the control device (EC_CD).

11.2.3.2 Supply period

11.2.3.2.1 General

Follow are tests for the supply period.

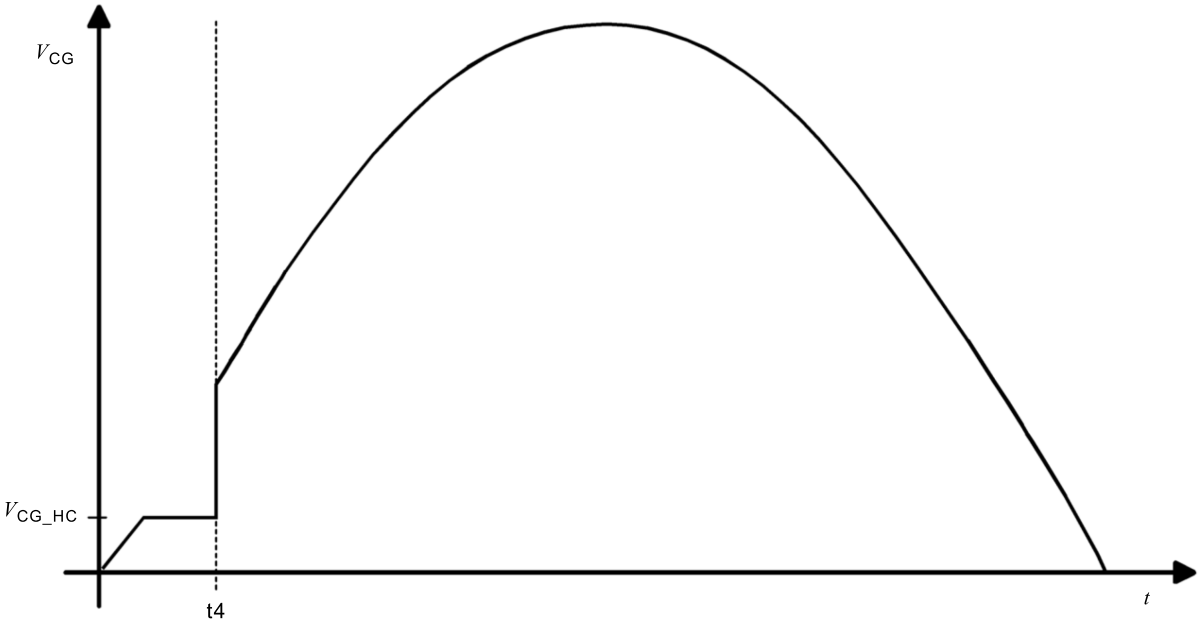

Figure 21 – Voltage applied to control gear for test procedure

11.2.3.2.2 First low current interval

Pre-conditions: Control gear connected directly to mains (no control device used)

Time related to last zero crossing: 0 to t1

Test: Measure I_{CG}

Expected results: $I_{CG} \geq I_{CG\_LC}$, $I_{CG} \leq I_{CG}$(t)

Note: I_{CG} can be smaller than I_{CG_LC} when voltage applied to control gear limits I_{CG} due to impedance Z_{CG} of control gear. Impedance Z_{CG} can be measured according to V_{CG} / I_{CG}.

11.2.3.2.3 High current interval

Pre-conditions:
Control gear supplied with a voltage with special waveform according to Figure 21 .

Time related to last zero crossing: t1 to t2

Test: Measure I_{CG}, measure t1 and t2

Expected result: $I_{CG} \geq I_{CG\_HC}$ at t1 ≤ t ≤ t2 according to Tables 1 to 5

Pre-conditions:
Control gear supplied with a voltage with special waveform according to Figure 21 and Table 15.

Time related to last zero crossing: t2 to t3

Test: Measure I_{CG}, measure t3

Expected result: I_{CG} decreases from I_{CG_HC} to I_{CG_LC}; I_{CG}(t3) = I_{CG_LC}

11.2.3.2.4 Second low current interval

Pre-conditions: Control gear connected directly to mains (no control device used)

Time related to last zero crossing: t3 to t4

Test: Measure I_{CG}, V_{CG}

Expected results: $I_{CG} \geq I_{CG\_LC}$, $I_{CG} \leq I_{CG}(t)$ with $V_{CG} \leq V_{SW}$

11.2.3.3 Data period

Pre-conditions: Control gear connected directly to mains (no control device used)

Time before next zero crossing: t6 to t8

Test: Measure I_{CG}, V_{CG}

Expected results: $I_{CG} \geq I_{CG\_LC}$, $I_{CG} \leq I_{CG}(t)$ with $V_{CG} \leq V_{SW}$

Pre-conditions: Control gear connected directly to mains (no control device used)

Time before next zero crossing: t8 to 0

Test: Measure I_{CG}

Expected results: $I_{CG} \geq I_{CG\_LC}$, $I_{CG} \leq I_{CG}(t)$

NOTE: I_{CG} can be smaller than I_{CG_LC} when voltage applied to control gear limits I_{CG} due to impedance Z_{CG} of control gear. Impedance Z_{CG} can be measured according to V_{CG} / I_{CG}.

Pre-conditions: control gear connected with one EC_CD, system ready to connect with mains. EC_CD starts transmission of every frame immediately at t7

Test: Check of control gear behaviour

Expected results: control gear is reacting according to transmitted telegram

11.2.3.4 Test of power up timing

Pre-conditions: control gear connected with one EC_CD, system ready to connect with mains. EC_CD transmits an applicable single telegram without repetition 40 half waves after mains power is applied continuously to the control gear.

Test: Check of control gear behaviour

Expected result: control gear is reacting according to transmitted telegram

Pre-conditions: control gear connected with one EC_CD, system ready to connect with mains.

Test: Measure I_{CG}

Expected result: control gear is providing current path with capability I_{CG_HC} latest 3 complete half waves after mains is supplied continuously to the control gear

11.2.3.5 Power controlled off state

Pre-conditions: control gear connected to a DC supply providing variable voltages up to V_{SW}

Test: Measure I_{CG}, check control gear behaviour

Expected results:
Control gear provides a current path with capability I_{PO_low} at $V_{PO\_low} \leq V_{CG} < V_{PO\_high}$

Control gear provides a current path with capability I_{PO_high} at $V_{CG} \geq V_{PO\_high}$

Control gear does not operate the lamp at $V_{CG} \leq V_{SW}$

11.2.3.6 Telegram controlled off state

This test shall only be performed with control gear that are marked that the telegram controlled off state is supported (see 6.9.3)

Pre-conditions: control gear connected with one EC_CD, system connected to mains, control device sets control gear telegram controlled to off state (brightness telegram with brightness value 0). Transmitted group number has to enable telegram controlled off state of control gear under test

Test: Check control gear behaviour according to 11.2.3.2

Expected results: according to 11.2.3.2

Pre-conditions: control gear connected with one EC_CD, system connected to mains, control device transmits group number 0 and brightness telegram with brightness value 0.

Test: Check control gear behaviour

Expected result: control gear does not react

11.3 Test of data timing

Test of permissible frames.

Pre-conditions: control device connected with required minimum number of EC_CG, system connected to mains, control device sends suitable telegram, sent telegrams shall require transmission of all types of permissible frames

Test: Measure waveform and timing of transmitted frames (e.g. with oscilloscope) for every halfwave

Expected results:

One frame is transmitted during each halfwave

Timing and waveform of all transmitted frames comply with Clause 7.

11.4 Test of telegram structure

11.4.1 Test of control device

Pre-conditions: control device connected with required minimum number of EC_CG, system connected to mains.

Test:

Control device sends one of each supported telegram types.

Measure voltage across control device and check if logical states fit to programmed telegram (e.g. with oscilloscope).

Expected results:

Timing of all transmitted telegrams complies with requirements given in Clause 8.

11.4.2 Test of control gear

Pre-conditions: control gear connected to EC_CD, system connected to mains.

Test: EC_CD transmits erroneous telegram with framing error.

Expected results:

Control gear does not react to telegram.

Pre-conditions: control gear connected to EC_CD, system connected to mains.

Test: EC_CD transmits erroneous telegram with parity error.

Expected results:

Control gear does not react to telegram.

Pre-conditions: control gear connected to EC_CD, system connected to mains.

Test:

EC_CD initially transmits an erroneous telegram with too short of length and subsequently a correct telegram.

Expected result:

Control gear only reacts to correct telegram.

11.5 Test of telegram types

11.5.1 General

Following test procedures are concerning the telegram types (defined in Clause 9). Tests described in 11.5.3 through to 11.5.7 are performed only if device under test supports the respective telegram type.

11.5.2 Rejection of unsupported telegram types

Pre-conditions: control gear connected to EC_CD, system connected to mains.

Test: EC_CD transmits the following telegrams:

Telegram type 0 (Brightness) with g = 0,b = 255 (see 9.2).

Telegram type 1 (Colour) with g = 0, × = 2048, y = 2048 (see 9.3).

Telegram type 2 (Colour temperature) with g = 0, c = 128,(see 9.4).

Expected results:

The control gear does not react to telegram types which are not supported.

11.5.3 Test of telegram type 0: brightness

Pre-conditions: control gear connected to EC_CD, system connected to mains.

Test: EC_CD transmits the following two telegrams:

Telegram type 0, group number 0 with brightness value of 1.

Wait 100 ms.

Telegram type 0, group number 0 with brightness value of 255

Expected results:

The control gear reacts to the received content.

11.5.4 Test of telegram type 1: colour control

Pre-conditions: control gear connected to EC_CD, system connected to mains.

Test: EC_CD transmits the following two telegrams:

- Telegram type 1, group number 0 with colour value of x,y.
- Wait 100 ms.
- Telegram type 1, group number 0 with colour value of x,y.

NOTE The x,y values for each telegram can be different colour values specified by the manufacturer.

Expected results:

The control gear reacts to the received content.

11.5.5 Test of telegram type 2: colour temperature control

Pre-conditions: control gear connected to EC_CD, system connected to mains.

Test:

EC_CD transmits the following two telegrams:

- Telegram type 2, group number 0 with colour value of c.
- Wait 100 ms.
- Telegram type 2, group number 0 with colour value of c.

NOTE The c value for each telegram can be different colour temperature values specified by the manufacturer.

Expected results:

The control gear reacts to the received content.

11.5.6 Test of telegram type 5: commissioning

See test 11.6.2.2.5.

11.5.7 Test of telegram type 6: manufacturer specific

Pre-conditions: control gear connected to EC_CD, system connected to mains.

Test:

The EC_CD transmits at least two type 6 telegrams specified by the manufacturer.

Expected results:

The reaction to all received telegrams complies with manufacturer’s specified operation.

11.6 Test of method of operation

11.6.1 General

Test of control devices and control gear shall be done using a system comprising either a control device under test and an EC_CG or an EC_CD and a control gear under test.

11.6.2 Group number operation

11.6.2.1 Test of control device

Pre-conditions: control device connected to EC_CG, system connected to mains.

Test:

Control device sends a supported telegram with group number = 0.

If control device supports group number assignment then control device also sends telegrams with group number = 1, 2, and 3.

Measure voltage across control device and check if logical states fit to programmed telegram (e.g. with oscilloscope). .

Expected results:

Content of all transmitted telegrams complies with requirements given in Clause 9.

11.6.2.2 Test of control gear

11.6.2.2.1 General

Table 16 lists the command sequences used in the tests in 11.6.2.2.2 through 11.6.2.2.8.

Table 16 – Group number test telegram sequence

Sequence	Telegram
0	Telegram type 1 with g=0, b=255
1	Telegram type 1 with g=0, b=0
2	Telegram type 1 with g=1, b=255
3	Telegram type 1 with g=1, b=0
4	Telegram type 1 with g=2, b=255
5	Telegram type 1 with g=2, b=0
6	Telegram type 1 with g=3, b=255
7	Telegram type 1 with g=3, b=0

11.6.2.2.2 Test of reaction to group number 0

Pre-conditions: control gear connected to EC_CD, system connected to mains, the control gear is not a member or group number 1,2,or 3 or group number assignment is not supported.

Test: The EC_CD transmits the telegrams in Table 16

Expected results:

The control gear reacts only to group number 0 telegrams.

11.6.2.2.3 Test of mechanical switch or other manual means to change group number

Pre-conditions: control gear connected to EC_CD, system connected to mains. The switch or manuals means of changing group number is tested in all valid settings.

Test: The EC_CD transmits the telegrams in Table 16 for each setting.

Expected results:

The control gear reacts to group number 0 telegrams and group number telegrams with group number matching the setting of the switch or manual means.

11.6.2.2.4 Test telegram controlled group number assignment does not affect group number set by manual means.

Pre-conditions: control gear connected to EC_CD, system connected to mains. The switch or manual means of changing group number is tested in all valid settings other than group number 0.

Test: For each setting of the switch or manual means:

The EC_CD transmits the Group number assignment telegram 3 times for a group number other than the group number corresponding to the switch or manual means.

The EC_CD transmits the telegrams in Table 16.

Expected results:

The control gear reacts to group number 0 telegrams and group number telegrams with group number matching the setting of the switch or manual means.

11.6.2.2.5 Test of telegram controlled group number assignment

Pre-conditions: control gear connected to EC_CD, system connected to mains.

Test: For each group number 1, 2 and 3:

The EC_CD transmits the Group number assignment telegram 3 times for a group number 0.

The EC_CD transmits the Group number assignment telegram 3 times for a group number 1, 2 or 3.

The EC_CD transmits the telegrams in Table 16.

Expected results:

The control gear reacts to group 0 telegrams and group telegrams with group number matching the group number of the group assignment.

11.6.2.2.6 Test of telegram controlled group number assignment to group number 0

Pre-conditions: control gear connected to EC_CD, system connected to mains.

Test: For each group number 1,2 and 3:

The EC_CD transmits the Group number assignment telegram 3 times for a group number 1, 2 or 3.

The EC_CD transmits the Group number assignment telegram 3 times for a group number 0.

The EC_CD transmits the telegrams in Table 16.

Expected results:

The control gear reacts to group number 0 telegrams only.

11.6.2.2.7 Test of Group number assignment telegram received 3 times

Pre-conditions: control gear connected to EC_CD, system connected to mains.

Test: For each group number 1, 2 and 3:

The EC_CD transmits the Group number assignment telegram 3 times for a group number 0.

The EC_CD transmits the Group number assignment telegram 1 time for a group number number 1, 2 or 3.

The EC_CD transmits the telegrams in Table 16.

The EC_CD transmits the Group number assignment telegram 2 times for a group number 1, 2 or 3.

The EC_CD transmits the telegrams in Table 16.

The EC_CD transmits the Group number assignment telegram 3 times for a group number 1, 2 or 3.

The EC_CD transmits the telegrams in Table 16.

Expected results:

The control gear reacts to group number 0 telegrams only after Group number assignment telegram is sent 1 or 2 times. The control gear reacts to group number 0 and 1, 2 or 3 telegrams after Group number assignment telegram is sent 3 times.

11.6.2.2.8 Test of telegram controlled group number assignment 32 times

Pre-conditions: control gear connected to EC_CD, system connected to mains.

Test:

Repeat below until total number of group number assignments of device under test is equal to 32.

The EC_CD transmits the Group number assignment telegram 3 times for a group number 0.

The EC_CD transmits the telegrams in Table 16.

The EC_CD transmits the Group number assignment telegram 3 times for a group number 1, 2 or 3.

The EC_CD transmits the telegrams in Table 16.

Expected results:

The control gear reacts to group number 0 telegrams only after each set of group number removal telegrams.

The control gear reacts to group number 0 telegrams and corresponding group number only after each set of Group number assignment telegrams.

Annex A
(informative)

Examples of procedures for telegram controlled group number commissioning

A.1 Telegram controlled group number assignment of a new system

Control gear that are currently not a member of group number 1, 2 or 3 are assigned a group number when the following sequence is performed.

Control gear that have already been assigned a group number have to be assigned to group number 0 before performing this sequence.

- Step 1: Connection of control gear that will become a members of group number 1.
- Step 2: Control device transmits the Group number assignment telegram with group number 1. With this telegram, all connected control gear are assigned to group number 1.
- Step 3: Connection of control gear that will become a member of group number 2.
- Step 4: Control device transmits the Group number assignment telegram with group number 2. With this telegram, all connected control gear that are member of group number 0 are assigned to group number 2.
- Step 5: Connection of control gear that will become a member of group number 3.
- Step 6: Control device transmits the Group number assignment telegram with group number 3. With this telegram, all connected control gear that are member of group number 0 are assigned to group number 3.
- Step 7: Connection of all control gear that will remain member of group number 0.

A.2 Telegram controlled group number assignment of replacement control gear

To change the group number assignment of the replacement control gear, a simplified group number changing procedure may be applied. To use this procedure, the replacement control gear shall be assigned to group number 0.

To change the group number assignment of the replacement control gear, the following sequence will be performed.

- Step 1: Control gear that should be replaced is removed from the system. Control gear that should remain in group number 0 are physically disconnected from the system.
- Step 2: Connection of replacement control gear that will become member of group number 1.
- Step 3: Control device transmits the Group number assignment telegram with group number 1. With this telegram, all connected control gear that are member of group number 0 are assigned to group number 1.
- Step 4: Connection of replacement control gear that will become member of group number 2.
- Step 5: Control device transmits the Group number assignment telegram with group number 2. With this telegram, all connected control gear that are member of group number 0 are assigned to group number 2.
- Step 6: Connection of replacement control gear that will become member of group number 3.

- Step 7: Control device transmits the Group number assignment telegram with group number 3. With this telegram, all connected control gear that are member of group number 0 are assigned to group number 3.
- Step 8: Connection of all remaining control gear.

A.3 Telegram controlled changing of group numbers

To change the group number of all already connected and group number assigned control gear, the Group number assignment telegram for group number 0 shall be transmitted, followed by a sequence similar as the telegram controlled group number assignment of a new system.

To change the group number number only of some already connected and group number assigned control gear, the following sequence shall be performed:

- Step 1: Control gear that should not be reassigned a group number shall be physically disconnected from the system.
- Step 2: Control device transmits the Group number assignment telegram for group number 0. With this telegram, all remaining control gear in the system that were previously a member of group number 1, 2 or 3 remove their group number assignment and become member of group number 0.
- Step 3: Disconnect of all remaining control gear except the control gear that will become member of group number 1.
- Step 4: Control device transmits the Group number assignment telegram with group number 1. With this telegram, all connected control gear that are member of group number 0 are assigned to group number 1.
- Step 5: Connection of control gear that will become member of group number 2.
- Step 6: Control device transmits the Group number assignment telegram with group number 2. With this telegram, all connected control gear that are member of group number 0 are assigned to group number 2.
- Step 7: Connection of control gear that will become member of group number 3.
- Step 8: Control device transmits the Group number assignment telegram with group number 3. With this telegram, all connected control gear that are member of group number 0 are assigned to group number 3.
- Step 9: Connection of all remaining control gear.

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