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Entertainment Technology—Lighting Control Systems - 0 to 10 V Analog Control Specification

Approved by the ANSI Board of Standards Review on _____________.

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Key to Interest Categories

CP = custom-market producer	DE = designer
DR = dealer rental company	G = general interest
MP = mass-market producer	U = user

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1 Scope
This standard describes a method of controlling equipment by means of an analog control voltage. It is primarily intended for lighting control equipment (controllers and dimmers) although any equipment which might be controlled by a lighting controller (intelligent lighting, strobe lights, fog machines, etc.) could use this control method.

Some 0 to 10 V controlled devices (such as dimmable fluorescent ballasts) require current-sink controllers. E1.3 controllers are current-source devices and cannot control these receivers without modification or additional interface components.

This standard does not address electro-magnetic compatibility (EMC) issues, which might result from control line oscillations caused by poorly designed controllers or cabling practices.

2 History
Prior to digital and analog multiplex control systems, most remote control of lighting dimmers was done using a wire-per-dimmer system. Each dimmer had a dedicated control wire (or pair of wires). The output voltage of the dimmer was proportional to the signal on the control wire. Some of these wire-per-dimmer systems required that the control voltage be the same frequency and in phase with the dimmer's AC output. Some systems used high voltage control signals. Some systems used low voltage direct current control signals.

The safety and flexibility of the low voltage DC control system gradually made it the system of choice. Many different low voltage systems were used. Some common control signals were 0 to 10 V, 0 to 15 V, 0 to 24 V, 0 to 28 V. In most cases zero volts was considered "off." Negative control voltages were also common: 0 to -10 V, 0 to -15 V, 0 to -28 V. Again in most cases zero volts was off. Some control signals used a voltage other than zero for off; for example 2 to 7.6 V and 2 to 10.5 V. In these, the lower voltage was typically "off."

Over time the 0 to 10 V control system became the most popular. As of the writing of this specification, 0 to 10 V control systems are popular not only in lighting but for motor control and industrial automation as well. Many digital to analog converters have a standard 0 to 10 V setting. The 0 to 10 V control system is easy to convert to percentage (add a zero), is easy to implement using operational amplifiers and consumer circuits, is a low enough voltage to be safe and is a high enough voltage to avoid most noise problems.

3 Purpose
The purpose of this specification is to document the now common 0 to 10 V direct current control system as typically used in lighting applications and provide specifications for new designs.

4 Applicability
This specification is intended for the use of:

- System specifiers who wish to insure that the equipment they specify meets an industry standard control system.
- Equipment manufacturers seeking to adopt an industry standard control system for basic controller/receiver interfacing.
- Lighting technicians who wish to understand and troubleshoot analog control systems.

Adoption of this standard is strictly voluntary. It is not intended as a replacement for existing protocols already in use, but as an addition to existing protocols and a basis for future products. The goal is to broaden the installed base of controllers, dimmers and other equipment that can communicate with each other.

5 Terminology and use

5.1 General
This specification does not require adherence to any particular level of performance. The guidelines presented here are intended to show typical uses of 0 to 10 V control.

5.2 Zero
When a controller is sending a level of "zero" it shall set its control voltage to within the levels defined as “zero” in section 6.1.1. When a dimmer, or other receiving device, has a "zero" control signal (see section 6.2.1 for voltage

limits) it shall be at its minimum state. In the case of motion control, the receiver shall position itself at one extreme. In the case of speed or rate control, the receiver shall set speed to minimum or stopped.

This specification does not define the minimum level, position extreme, or minimum rate. These are performance criteria left up to the users and manufacturers. In the case of dimmers, minimum may be some idle voltage or may be completely off. In the case of motion control, "zero" may be fully clockwise, fully counter-clockwise, fully up, or fully down. In the case of a rate control it may be minimum rate or completely stopped. In the case of audio volume it could be off or maximum attenuation.

Note that when a console or other transmitting device is powered down or disconnected, it does not send any voltage to the receivers. The "zero" condition of a receiver shall always be in a state which is acceptable in a default/off situation.

5.3 Full

When a controller is sending a level of "full" it shall set its control voltage to within the levels defined as “full” in section 6.1.1. When a dimmer, or other receiving device, has a "full" control signal (see section 6.2.1 for voltage limits) it shall be at its maximum state. In the case of motion control, the receiver should position itself at the opposite extreme from "zero." A rate or speed control should go to its fastest speed.

This specification does not define the maximum level, extreme, or rate. These are performance criteria left up to the users and manufacturers.

5.4 Scale

The 0 to 10 V control is intended to be linear (as opposed to logarithmic). It is generally intended that "zero" be represented by about 0 volts, "full" be represented by about 10 volts, and midway between "zero" and "full" be represented by about 5 volts. Since this specification does not require any specific performance between "zero" and "full" there is no guarantee that these voltages will be met.

The response of the receiving device to control input shall be specified in the manufacturer’s literature. This documentation can be in the form of a table, graph, or other appropriate format.

6 Electrical specifications

6.1 Transmitter specifications

6.1.1 Amplitude (Transmitter)

The output of the controller shall be a steady DC. When the control level is constant, the output shall not change by more than +/- 20 mV. The output is intended to vary between 0 and 10 volts. Zero volts shall represent the full off condition and ten volts shall represent the full on condition. The output voltage shall never be less than -0.2 volts nor more than +12.0 volts with respect to signal common.

To allow for variations in manufacturing tolerances the minimum and maximum control voltages may vary as shown in the table below:

Condition:	Minimum:	Maximum:
Console output at “zero," with a load resistance of 100,000 ohms	-0.2 volts	0.2 volts
Console output at “full," with a load resistance of 20,000 ohms	10.0 volts	12.0 volts

If the controller is capable of varying the maximum or minimum output voltage, then the manufacturer's specifications shall state the range of adjustment. Controllers shall be shipped adjusted for 0 to 10 V operation in accordance with this standard. Controllers not adjusted for 0 to 10 V operation in accordance with this standard shall not be marked "E1.3, 0 to 10 V Analog Control Specification." Any printing on the console referring to the E1.3 specification shall be covered with a label that shows the adjusted voltage range. For example:

"Outputs adjusted for 0 to 15 volt operation"

6.1.2 Current source capacity and output impedance (Transmitter)
Controllers or output devices should have a low output impedance to minimize loading effects. Passive controllers, with unbuffered outputs, shall use potentiometers with a resistance value of 10K ohms or less (which yields an output impedance of 2.5K ohms or less). Active controllers with buffered outputs shall have a source impedance of 100 ohms or less and be capable of continuously sourcing at least 2.0 milliamperes without dropping below 10 V. Controllers or output devices shall have a sinking impedance greater than 50K ohms, even when power is removed.

The more current source capacity a controller has the more receivers it can drive. (More is better). The manufacturers' specifications shall state the output capability as both the maximum source current and the lowest load impedance at which an output of 10.0 volts can be maintained.

6.1.3 Diode protection
Controllers and output devices shall be provided with a blocking diode (or equivalent circuit) such that each output presents an open circuit (50K ohms or more) to any source of voltage more positive than itself. The operation of the product shall be unaffected by the presence of such a more positive voltage. This diode or equivalent circuit shall be capable of blocking voltages of +30 D.C. volts or greater.

The blocking diodes allow multiple controllers or output devices to be paralleled to control the same dimmers or receiving devices. Whichever controller has the higher control voltage has control of that channel. This method of control is commonly referred to as "highest takes precedence" or "pile-on."

6.2 Receiver specifications

6.2.1 Amplitude (Receiver)
The dimmer or other receiving device shall be at “zero” (its specified minimum state, position, speed, etc.) with any control signal below 0.3 volts. The dimmer or other receiving device shall be at “full” (its specified maximum state, position, speed, etc.) with any control signal above 9.8 volts.

These conditions are summarized in the table below:

Input Control Voltage:	Action:
-0.5 volts to 0.3 volts	Receiver shall remain at “zero”
0.3 volts to 9.8 volts	Receiver shall vary between “zero” and “full”
9.8 volts to 30 volts	Receiver shall remain at “full”

It is suggested that receiving devices that switch between "off" and "on," such as relay packs, should consider incorporating hysteresis in switching between "off" and "on." For example a switch "on" point of 60% and a switch "off" point of 40% may be selected. In this case a device in the "off" state would not switch on until the control voltage exceeds 6 volts. A device in the "on" state would not switch off until the control voltage drops below 4 volts.

It is suggested that receiving devices that have variable outputs, but that must determine an absolute "off" condition (for example to turn off fans or go into standby mode), consider any control signal below 0.5 volts as "off."

If the receiver is capable of varying the "zero" or "full" control voltages, then the manufacturer's specifications shall state the range of adjustment. Receivers shall be shipped adjusted for 0 to 10 V operation in accordance with this standard. Receivers not adjusted for 0 to 10 V operation in accordance with this standard shall not be marked "E1.3, 0 to 10 V Analog Control Specification." Any printing on the receiver referring to the E1.3 specification shall be covered with a label that shows the adjusted voltage range. For example:

"Inputs adjusted for 0 to 15 volt operation"

6.2.2 Input impedance (Receiver)

The input impedance of a dimmer or other receiving device shall be a nominal 100K ohms (+/- 20%) between each input and signal common when in normal operation. The input impedance shall not drop below a nominal 50K ohms (+/- 20%) when in a powered down condition.

In 0 to 10 V control, multiple dimmers and receivers are often grouped onto a single controller output. The input impedance of the paralleled receivers combine to lower the impedance seen by the controller. A controller, therefore, will often be driving a load lower than 100K ohms.

Note: Prior to the writing of this specification the input impedance of dimmers varied widely. When interfacing with dimmers designed prior to this specification the user should check their input impedance.

6.2.3 Input filtering
Analog 0 - 10 V control signals are commonly carried on unshielded wire. These signals can pick up radio frequency interference (RFI) and line frequency "hum." The receiver must incorporate sufficient input filtering to prevent RFI and hum from adversely affecting the performance of the receiver.

6.3 Short circuit protection
E1.3 devices shall not be damaged by shorts between any control connector pin and any other control connector pin. Protection can be in the form of series resistors, current limited op-amps, or circuit protection fuses.

6.4 Isolation
The control signal and all control connector pins shall be isolated from any source of hazardous voltage or charge (e.g. AC mains) to the full extent required in the relevant product safety standard(s), treating the control signal as an accessible conductive part. Safety standards may vary dependent on country of use.

Bonding the control common to earth ground can result in ground loops between receivers that are earth grounded to power sources which have different ground potentials. These ground loops can cause improper receiver operation. Ground loops can sometimes cause sufficient current to flow through the control cable to heat the cable causing safety problems as well as cable damage. Therefore it is recommended that the control signal be isolated from earth ground at line frequencies (i.e. 60 Hz) to a minimum of 50 volts AC. A high resistance connection between common and earth ground may be provided to cause the common potential to remain near earth ground. A low impedance high frequency connection between common and earth ground may be provided for electro-magnetic compatibility (EMC) considerations.

Some manufacturers believe it is necessary to bond control common to earth ground to meet the requirements of local legislation. Products that bond control common to earth ground shall be clearly labeled in large type with the following text:

"Control common bonded to earth ground"

7 Cabling
Unlike digital and analog multiplex control cables, 0 to 10 V cables can be almost any type of conductor or cable. Twelve gauge building wiring can work just as well as shielded 24 gauge cables. Even 28 gauge ribbon wire and telephone cable will work fine for physically protected runs of reasonable lengths.

System designers should design the cable installation within all the applicable electrical and other building codes, as well as using good engineering practices.

7.1 Cable length
The maximum cable length is related to the gauge of the cable, the total load impedance of the receivers and any power supply current provided for transmitting devices flowing in the common conductor. The primary concern on cable length is the DC resistance of the conductors.

7.1.1 Channel conductors
The individual channel conductors shall have a DC resistance low enough that their voltage drop is less than 0.1 V.

7.1.2 Common conductor

The common conductor carries the return current for all the channels to the transmitter, or the return current from the transmitter to the power supply, if the transmitter is remotely powered by a supply at the receiver end of the cable. In all cases, the voltage drop in the common conductor shall be no more than 0.1V. Several conductors in parallel or a larger conductor (numerically smaller gauge) may be used for the common conductor to reduce voltage drop.

8 Connectors

8.1 Dimmers or receiving devices shall use connectors with male contacts (pins). Controllers or transmitting devices shall use connectors with female contacts (sockets).

In cases where chassis-mount connectors are not available in both sexes, the same connector may be used on dimmers and controllers. (The 8-pin DIN is commonly used in this manner).

8.2 Voltages higher than 30 volts peak shall not be present at a sending or receiving connector. Power supply pins when present at connectors should be current limited.

8.3 Pinouts of all control connectors shall be labeled adjacent to connector showing all pin assignments. If a power supply is required, then the necessary voltage, current and polarity should be indicated. For example:

Pin number = Channel number
Pin 24 = +15 volts at 100 mA
Pin 25 = Signal and 15 V power common

8.4 Where possible, and when not in conflict with existing manufacturers' connectors, the pinout should follow a pin number equals channel number configuration with the highest pin number used as signal common.

8.5 No specific connector or type of connector is specified by this standard. In critical applications it is recommended that a locking connector be used to prevent accidental disconnection. Common existing connector types and pinouts should be used when practical.

9 Markings

Connectors on dimmers, controllers, and other receiving/sending devices, whose inputs and outputs conform to this specification may be marked with "E1.3" or "E1.3 Compatible." Marking should be clearly visible adjacent to the connector.

Products that are normally E1.3 compatible, but are shipped adjusted for some other control voltage must have the marking removed or covered up. See sections 6.1.1 and 6.2.1.

NOTE: Compliance with this standard is the responsibility of the manufacturer. Such labeling on equipment does not constitute endorsement by ESTA.