# American National Standard

Approved: February 11, 2011 Secretariat: American National Standard Lighting Group

*for lamp ballasts:*

High Frequency Fluorescent Lamp Ballasts

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**Foreword** (This foreword is not part of American National Standard C82.11-2011)

Suggestions for improvement of this standard should be submitted to the Secretariat C78, American National Standard Lighting Group, 1300 North 17th Street, Suite 1752, Rosslyn, VA 22209.

This standard was processed and approved by the Accredited Standards Committee on lamp ballasts, C82, and its Working Group C82WG01. Working Group approval of the standard does not necessarily imply that all working group members voted for that approval.

This 2011 edition is the revision of its predecessor, the ANSI C82.11 Consolidated-2002. This is the third revision of the first edition of 1993. The 2011 edition includes changes to paragraph 1.2, Annex "A" and all Figures "C". In the matter of the figure rework, most of that work was nothing more than an electronic redrawing of the 1993 drawings.

The reader will note that changes have been marked by redline.

| Amendment / Change | CDV | RV |
|---|---|---|
| Revision/Consolidation | CDV 82_m742 | RV 82_m743 |

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## 1.0 Scope

**1.1** This standard is intended to cover high frequency ballasts which have rated open-circuit voltages of 2000 volts or less, operate the lamp at frequencies between 10 kHz and 500 kHz., and are intended to operate at a supply frequency of 50 Hz or 60 Hz. This comprises ballasts for hot-cathode fluorescent lamps, either switch-start (preheat-start), rapid-start (continuously heated cathodes), modified rapid start, programmed start, or instant start used primarily for lighting purposes. The ballast and lamp combinations covered by this specification are normally intended for use in room ambient temperatures of 10$^{O}$C to 40$^{O}$C. At ambient temperatures outside this range, certain special operating characteristics may be required.

### 1.2 Important Patent Disclaimer

It is possible that some of the elements of this document may be the subject of patent rights. When this document was approved for publication, ANSLG did not know of any patent applications, patents pending, or existing patents. ANSLG shall not be held responsible for identifying any or all such patent rights.

## 2 Normative references

The following standards contain provisions, which through reference in this text constitute provisions of this American National Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this American National Standard are encouraged to investigate the possibility of applying the most recent edition of the standards indicated below.

ANSI/NFPA No. 70-2008, *National Electrical Code*

ANSI/IEEE C62.41-2002 (Parts 1 & 2), *Guide for Surge Voltages in Low-Voltage AC Power Circuits*

ANSI_IEC C78.81-2010, *Double-capped Fluorescent Lamps—Dimensional and Electrical Characteristics*

ANSI_IEC C78.901-2005, *Single Base Fluorescent Lamps—Dimensional and Electrical Characteristics*

ANSI C82.2-2002, *American National Standard Methods of Measurement of Fluorescent Lamp Ballasts*

ANSI C82.3-2002, *American National Standard Specification for Fluorescent Lamp Reference Ballasts*

ANSI C82.13-2002, *Definitions for fluorescent lamps and ballasts*

ANSI C82.77-2002, *Harmonic Emission Limits—Related Power Quality Requirements for Lighting Equipment*

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CAN/CSA C22.2 No.0.16 M92, *Measurements of Harmonic Currents, General Requirements, A National Standard of Canada*

IESNA LM40-2001, *Life Performance Testing of Fluorescent Lamps*

US Code of Federal Regulations #47, Chapter 18. (Federal Communications Commission Requirements for RFI)

Public Law 100-357, *National Appliance Energy Conservation Amendments of 1988*

ANSI/UL 935-2007, *Underwriters Laboratories Inc., Standard for Fluorescent Lamp Ballasts*

## 3 Characteristics

**3.1 Input power factor:** Power Factor is dependent upon the current's wave shape as well as the phase relationship between the current and voltage. The power factor is to be calculated by determining the ratio of the active power to the apparent power. The active power is to be measured with a wattmeter capable of indicating the true rms power in watts. The apparent power is to be the product of the true rms values of the input voltage and current.

$$\text{Power Factor} = \frac{\text{Active Power (watts)}}{\text{Apparent Power (volt amperes)}}$$

### 3.2 High frequency current crest factor

The high frequency current crest factor is equal to the peak current of the modulated or unmodulated envelope divided by the effective rms current.

## 4.0 Ballast marking

### 4.1 Marking

Ballasts shall be marked to indicate the input supply voltage, frequency, and current, the manufacturer or supplier, ballast type designation, and the number, type and wattage or current of fluorescent lamps the ballast is to operate.

#### 4.1.1 Power factor

Only ballasts operating with an average power factor of 90% or above shall be labeled as high-power factor type. Ballasts of the uncorrected type and operating at a power factor of less than 90% need not be marked for power factor.

#### 4.1.2 High-frequency

High frequency ballasts may be marked H.F. or electronic.

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## 4.2 Color coding of ballast leads

### 4.2.1 Supply leads

The following color codings are for the supply lead wires of ballasts:

On ballasts with two supply lead wires, when one lead wire connects to a neutral wire, that lead wire shall be white or neutral gray and the other shall be black.

On ballasts with two supply lead wires that connect to ungrounded lines, both leads shall be black and white.

Ballasts that connect to both single ended and polyphase can have white and black wires. When the white wire is not at neutral potential, it shall be indicated by a marker stripe added by the installer at the time of installation

### 4.2.2 Lamp lead wires – table 1

The following color codings are for the lamp leads of electronic ballasts:

On a single-lamp ballast of the continuously heated cathode type (rapid start), the leads to that lamp cathode operated at the highest voltage with reference to either of the supply leads shall be RED. The lead wires connected to the other cathode shall be BLUE.

On a multi-lamp ballast of the series connected continuously heated cathode type (rapid start), or series connected instant start type, the leads to that lamp cathode operated at the maximum voltage with reference to either of the supply leads shall be RED. The leads connected to the cathode at the other extreme of voltage relative to the RED cathode shall be BLUE. For two-lamp rapid start ballasts, the leads to the pair of common cathodes shall be either YELLOW-BLUE TRACER OR YELLOW.

When more than two lamps are operated in a rapid start mode, the leads to each cathode or pair of cathodes, beginning at the highest voltage (RED) end shall have colors used in the order shown in Table 1. If a circuit-interrupting feature is required for instant start ballasts, the lamps leads for the circuit-interrupting leads shall be YELLOW.

On a (1), (2), or (3) lamp instant start ballast where the lamps are operated independently and have a common connection, the common lamp lead shall be RED, and the independent lamps lead wires shall be BLUE.

On a (4) lamp instant start ballast where the lamps are operated independently and have a common connection, the common lead wires shall be YELLOW or YELLOW/WHITE and the independent lamp leads shall consist of two BLUE and two RED leads.

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If a circuit-interrupting feature is required, the lamp lead wires for the circuit-interrupting lead wires shall be YELLOW and the independent lamp lead wires shall be BLUE.

#### 4.2.3 Other ballast types

Ballasts not covered by 4.2.1 and 4.2.2 shall comply with these requirements insofar as possible.

**Table 1 - Color coding for lamp leads**

| **Series connected operation** | | |
|---|---|---|
| Lamp quantity | **Circuit** | Color coding for electronic ballast lamp leads |
| 1 | Rapid start | Red-blue |
| 2 | Rapid start | Red-yellow-blue |
| 3 | Rapid start | Red-yellow-blue/white-blue |
| 4 | Rapid start | Red-yellow-blue/white-brown-blue |
| 1 | Instant start with circuit interrupting requirement | Red-yellow-yellow |
| 2 | Instant start with circuit interrupting requirement | Red-yellow-yellow-blue |
| **Independent (parallel) lamp operation** | | |
| Lamp quantity | **Circuit** | Color coding for electronic ballast lamp leads |
| 1 | Instant start | Blue-red |
| 2 | Instant start | Blue-blue-red |
| 3 | Instant start | Blue-blue-blue-red |
| 4 | Instant start | Blue-red-blue-red-yellow-yellow |
| 2 | Instant start with circuit interrupting requirement | Blue-blue-yellow-yellow |
| **Caution:** Wire color and/or connections may differ in some instant start applications between 60HZ and high frequency ballasts | | |

Note: Program / programmed ballast may use the same lead wires colors like rapid star ballast.

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## 5.0 Ballast performance

### 5.1 General

Measurements necessary to determine ballast performance shall be made in accordance with ANSI C82.2 or ANSI_ANSLG C82.11 Annex C as applicable.

### 5.2 Starting conditions

#### 5.2.1 Starting

For satisfactory lamp starting, a ballast, when operated at any supply voltage between 90% and 110% of its rated supply voltage and frequency, shall follow the requirements of this standard or as specified otherwise in the normative referenced ANSI…C78.81 or ANSI…C78.901 (to be referred to hereafter as C78.81 or C78.901).

When ballasts are designed to operate lamps in parallel circuits, the relevant requirements shall be met for each separate lamp, both with and without lamps operating or preheating in other circuits.

#### 5.2.2 Fixture and circuit grounding

Rapid-start lamps, and switch-start (preheat-start) lamps when operated in circuits of the rapid-start type, require a starting aid consisting of a metal strip (usually an integral part of the fixture), the width of which shall be at least equal to the lamp diameter.

This surface shall extend essentially the full length of the lamp and shall be connected to ground. The distance from the starting aid to the bulb wall, as measured in a direction normal to the surface of the starting aid, shall not be greater than specified in the normative referenced C78.81 or C78.901.

Lamp shall not contact the ground plane. Minimum distance to be 0.12 inch (3 mm). For remote mounted lamps and dimming applications, greater spacing may be needed.

Rapid start ballast circuits and connections (including ground connections) shall be such that the potential difference between the starting aid and one of the cathodes of each lamp will be greater than the minimum specified in C78.81 or C78.901. Use on ungrounded supplies is not recommended. (Unless specifically designed to accommodate ungrounded supplies)

#### 5.2.3 Lamp starting time vs. starting current requirement

High frequency ballasts shall meet the requirements of starting time and starting current as listed and as graphically defined in figure 1a and 1b.

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On testing starting time on high frequency rapid start ballasts, tests shall be made in ambient temperatures of 25°C +/- 1°C with proper starting aid spacing and grounding conditions. The test shall be repeated on six sets of seasoned lamps (minimum 100-hour lamps), using the average as the results. If erratic results begin to occur lamps should be changed.

At rated line voltage the preheat time ($t_1$ to $t_2$) shall be 500 milliseconds minimum, or be equal to or greater than 90% of the results of a corresponding supply frequency commercially available from two lamp magnetic ballasts that meets the requirements of C82.1, C78.81 or C78.901 using the same lamps. Other starting scenarios, which effectively produce the same electrode temperatures prior to starting as those just defined, are under consideration.

At 90% rated line voltage, the transition time ($t_2$ to $t_3$) shall be 100 milliseconds or less, or equal to or less than the results of a corresponding supply frequency commercially available magnetic ballasts that meets the requirements of C82.1 and C78.81 or C78.901 using the same lamps.

On a high frequency rapid start system, the maximum ionization (starting) lamp current is defined as the average value of the RMS glow current from the onset of the glow current to $t_2$ and shall not exceed 25 ma.

On testing starting time on high frequency instant start ballasts, tests shall be made in ambient temperatures of 25°C +/- 1°C, be made at 90% of the rated supply voltage, and be repeated on six sets of lamps, using the average as the results.

The maximum start time ($t_1$ to $t_3$) shall be 100 milliseconds or less, or less than the corresponding supply frequency commercially available magnetic ballast that meets the requirements of ANSI C82.1 and C78.81 or C78.901 using the same lamps.

If the corresponding commercially available magnetic ballast that meets the requirements of ANSI C82.1, C78.81 or C78.901 does not exist the starting time ($t_1$ to $t_3$) shall be 100 ms or less.

Each lamp of a multi-lamp ballast must be tested to assure the requirements of this paragraph are met. Multi-lamp ballasts shall be tested for combinations of rated lamp footage and quantities.

## 5.3 Ballast output

An electronic ballast shall provide the operating characteristics given in 5.3.1 and 5.3.2 when connected to any specified complement of reference lamps.

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### 5.3.1 Ballast factor (relative lamp light output):

1. Ballast factor is the ratio of light output of the subject ballast on a reference lamp to the light output of a 60-Hertz or HF reference ballast on the same reference lamp measured in accordance with ANSI C82.2, at rated voltage.
2. For those linear lamps that are characterized by a 60 Hz reference ballast, the minimum ballast factor for normal light output shall be 0.85. (Lower ballast factors are under consideration)
3. For all compact lamps, the minimum ballast factor for normal light output shall be 0.95.
4. For those linear lamps that are characterized by a HF reference ballast, the minimum ballast factor for normal light output ballasts shall be 0.95. ( The BF limit as described does not apply to T8 lamps, see lamp data sheets)
5. For ballasts other than normal light output ballasts, the ballast factor shall not be less than 95% of the ballast manufacturer's declared nominal value.
6. For all lamps, if a minimum (or maximum) ballast factor is specified on the lamp data sheet, it shall be observed. The maximum ballast factor is normally limited by the maximum allowed lamp current as specified in the C78.81 or C78.901.

### 5.3.2 Lamp light output

With rated voltage applied to the input of the ballast, the light output shall be the product of the ballast factor and the light output of the same reference lamp when operated on its reference ballast at rated voltage.

### 5.3.3 Lamp current

With rated voltage applied to the input to the ballast, the lamp current shall not exceed the maximum specified in C78.81 or C78.901. Minimum limits when specified on a specific lamp data sheets must also be met.

## 5.4 Cathode preheating current

Ballasts designed for the operation of switch start lamps shall provide preheating current within the limits required by C78.81 or C78.901 as appropriate.

## 5.5 Regulation

### 5.5.1 Rapid-start ballasts

Rapid start ballasts shall, at 90% and 110% of rated supply voltage, operate a reference lamp at a level of light output not less than 75% or greater than 125%, respectively, of the light output of the same lamp when it is operated with the same ballast at rated input voltage.

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### 5.5.2 Instant-start ballasts

The instant/programmed start ballasts shall, at 90% and 110% of rated supply voltage, operate a reference lamp at a level of light output not less that 85% or greater that 115% respectively, of the light output of the same lamp when it is operated with the same ballast at rated input voltage.

## 5.6 Operating-current waveshape

### 5.6.1 Normal operating conditions

With rated voltage applied to the input of the ballast, the current waveshape supplied to a warmed-up reference lamp shall have a high frequency crest factor that does not exceed 1.70[1] unless otherwise specified on the lamp data sheet. Successive half cycles of lamp current shall show substantially the same shape.

### 5.6.2 Special operating condition

If multi-lamp ballasts are so designed that the failure of one lamp permits the other lamps to continue in operation, the current waveshape under these conditions shall meet the same requirements as given in 5.6.1 for normal operation.

## 5.7 Supplementary cathode heating

### 5.7.1 Switch-start ballasts

Switch-start ballasts shall not furnish a current greater than 110% of the 60 Hz arc stream current to any cathode terminal of a lamp in normal operation.

### 5.7.2 Rapid-start ballasts

Rapid-start ballasts shall provide supplementary cathode heating as follows: When two cathodes (or more) are supplied from a common winding, they shall be connected in parallel.

The cathode heating voltage shall be measured using non-inductive load resistors. All cathode windings must be loaded during this measurement. With the rated voltage applied to the input of the ballast, the cathode heating windings shall deliver voltages to the dummy resistors within the limits shown on the appropriate lamp data sheet.

When reference lamps are in normal operation at rated input voltage, the voltage across any cathode shall be within the limits shown on the appropriate lamp data sheet.

[1] SECRETARIAT NOTE: The table was editorially converted to text.

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### 5.8 Electro-magnetic interference suppression

Fluorescent lamp systems may be a source of electromagnetic radiation at radio frequencies. High-frequency ballasts shall comply with FCC regulations, Title 47 of the US Code of Federal Regulations, Part 18.

### 5.9 Ballast safety

Ballast shall comply with ANSI/UL 935.

### 5.10 Input current, harmonic distortion

**5.10.1** This is a requirement for protection of the neutral wire in 3-phase, 4-wire "Y"-connected systems where the neutral wire is the same size as the phase wire. It is also to minimize voltage distortion on the power lines.

**5.10.2** A non-sinusoidal (distorted) input current waveform is the root-sum-square of the fundamental and harmonic components. The 3rd harmonic and odd multiples of the 3rd harmonic (9th, 15th, 21st, etc.) add in the neutral conductor on a 3-phase, 4-wire "Y"-connected system. The fundamental and other harmonics will cancel in the neutral conductor with a balanced system load.

**5.10.3** The harmonic distribution of the input current shall meet each of the limits as specified in ANSI C82.77.

**Caution:**

(1) The National Electrical Code and the Canadian Electrical Code do not allow reduction of neutral capacity for that portion of the load which consists of electric-discharge lighting. However, more stringent limits may be required for distribution systems wherein the neutral wire is smaller than the phase wire.

(2) The harmonics and other aspects of the harmonic factor can also play a role in system interactions (i.e.: components, unbalanced loads, type of distribution system, etc.)

### 5.11 Line transient requirements

Electronic high-frequency ballasts are more susceptible to line transients than line frequency magnetic ballasts. Therefore, transient protection shall be included. The requirement for this transient protection is in ANSI/IEEE C62.41, Class A operation.

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The line transient test shall consist of seven strikes of a 100KHz Ring Wave, 2.5 KV[2] level, for both common mode and differential mode

### 5.12 Inrush currents

There is a need to control inrush current transients caused by capacitor charging.

A ballast (circuit) shall limit inrush current transients caused by capacitor charging.

For the primary specified lamp configuration, a ballast must have a maximum allowable input capacitance as specified in table 2 or;

Incorporate a means of limiting the aggregate peak inrush current amplitude and duration for each value of steady state current to less than the values shown in table 3 when tested on a power line circuit having an impedance of 450mΩ and 100uh. Pulse duration must satisfy the equation $I^2t$ where I is the inrush current measured in rms amps for the pulse duration period and t is the pulse duration period in seconds at 10% of the peak current level.

**Table 2 – Bulk energy capacitances**

| **System (Volts)** | **120** | **277** | **347** |
|---|---|---|---|
| **Bulk energy capacitance: μF per Ampere of steady state current** | 175 | 125 | TBD |

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**Table 3 – Peak current requirements**

| **Steady state current (A)** | **Peak current (A), 120 VAC** | **$I^2t$ ($A^2$ sec), 120 VAC See Note.** | **Peak current (A), 277 VAC** | **$I^2t$ ($A^2$ sec), 277 VAC See Note.** | **Peak current (A), 347 VAC** | **$I^2t$ ($A^2$ sec), 347 VAC See Note.** |
|---|---|---|---|---|---|---|
| 5 | 192 | 74 | 320 | 205 | TBD | TBD |
| 8 | 221 | 98 | 370 | 274 | TBD | TBD |
| 10 | 230 | 106 | 430 | 370 | TBD | TBD |
| 12 | 235 | 110 | 440 | 387 | TBD | TBD |

[2] Higher values may be used as appropiate

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| | | | | | | |
|---|---|---|---|---|---|---|
| 15 | 239 | 114 | 458 | 420 | TBD | TBD |
| 16 | 242 | 117 | 480 | 461 | TBD | TBD |
| NOTE | $I^2t$ values based on peak current with a 2 ms duration. | | | | | |

For lamp configurations that do not meet the limits specified above, the ballast manufacturer must specify, in its literature, circuit loading that meets the above guidelines.

### 5.13 Ballast efficiency[3]

NOTE: Measurements necessary to determine ballast efficiency shall be made in accordance with future information to be included in the annex to this standard.

## 6.0 Design center voltages

The following voltages are the design center input voltages for fluorescent lamp ballast:

| | |
|---|---|
| 120 | 240 |
| 127 | 277 |
| 208 | 347 |
| 220 | 480 |

See ANSI/NFPA 70, National Electrical Code, for maximum voltage-to-ground limitations and grounding requirements.

## 7.0 Application requirements

### 7.1 Wiring and contact resistance requirements

Even relatively small amounts of resistance in series with the cathode of a rapid start lamp may seriously interfere with lamp starting and operation because of lowered heater circuit voltage. The added resistance in any cathode circuit shall not exceed at any time the following values.

| Lamp Type (mA) | Maximum Added Resistance Any Cathode Circuit (Ohms) |
|---|---|
| 500 or less | 0.5 |
| 800 (high output) | 0.2 |
| 1500 | 0.2 |

[3] Future ongoing development to occur in this section.

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In addition, good installation practice requires that lead lengths from the ballast to the lamps be kept to the minimum length necessary. Excess wires should not be coiled or bundled in order to keep inductances to a minimum. Unless otherwise specifically allowed by the manufacturer, leads from the ballast to the lamp should not exceed 6 feet in length in order to minimize resistive and high frequency line losses thus assuring more power to the lamps.

Note: at higher lamp drive frequencies the distributed inductive reactance $X_L$ and capacitive reactance $X_C$ components have a greater effect on the proper starting and operation of the lamp particularly as lead lengths increase. The manufacturer should be consulted for proper wiring practice appropriate for the intended installation.

## 7.2 Operating temperature limits

The service installation must be designed so that the temperature at the hottest spot on the ballast case shall not exceed 90$^{O}$C under actual operating conditions. High-frequency ballasts shall also not exceed manufacturer's recommendations if less than 90$^{O}$C is specified.

## 7.3 Supply voltage limits

### 7.3.1 Average voltage for satisfactory ballast operation

The average voltage of the supply system should not vary more than minus 7.5% or more than plus 5% from the input voltage rating shown on the ballast label.

### 7.3.2 Voltage excursions

For satisfactory ballast operation, the supply voltage excursions must not exceed ± 10% of the ballast input rating.

## 7.4 Equipment grounding

Exposed non-current-carrying metal parts of fluorescent lamp ballasts (such as the ballast case) shall be grounded.

## 7.5 Audible sound level

Noise is an inherent characteristic of all ballasts and cannot be completely eliminated.

Care should be exercised in the selection of the ballast location and the method of mounting because ballast noise can be amplified by reflections from surrounding objects and by resonance of the mechanical mounting and electrical connections. This unintentional amplification can make the ballast appear to produce considerably more noise than that generated by the ballast. The ballast or luminaire manufacturer, or both, should be consulted for specific recommendations for a quiet installation.

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## 8.0 End of life

Some lamps can experience elevated cap temperatures at the end of their life. Ballasts that contain circuitry to minimize this increase in temperature are designated as having "end of life protection". The end of lamp life protection requirements have their origin in C78.81, paragraph 12.6, and C78.901, paragraph 13.8. The specific requirements that apply to electronic ballasts are listed below.

It is to be noted that this section contain three figures specific to understanding this section.

Test methods are shown in C82.11 Annex C Method Of Measurement.

For ballasts designated as having lamp "end of life protection" one of the following three tests, as declared by the ballast manufacturer, must be satisfied:

### 8.1 Asymmetric pulse test

Compliance is checked by the following test.
The following values of maximum cathode power *P*max apply:
– For 13 mm (T4) lamps, *P*max = 5.0 W;
– For 16 mm (T5) lamps, *P*max = 7.5 W.
(Other diameters are under study.)

### 8.2 Asymmetric power test

Compliance is checked by the following test.

The following values of maximum cathode power *P*max apply:
– For 13 mm (T4) lamps, *P*max = 5.0 W;
– For 16 mm (T5) lamps, *P*max = 7.5 W.
(Other diameters are under study.)

### 8.3 Open filament test

Compliance is checked by either test procedure A or B as determined by the value of *I*max below.
During the test the following values of maximum lamp current *I*max apply:
– For 13 mm (T4) lamps, *I*max = 1 mA;
– For 16 mm (T5) lamps, *I*max = 1.5 mA.
(Other diameters are under study.)

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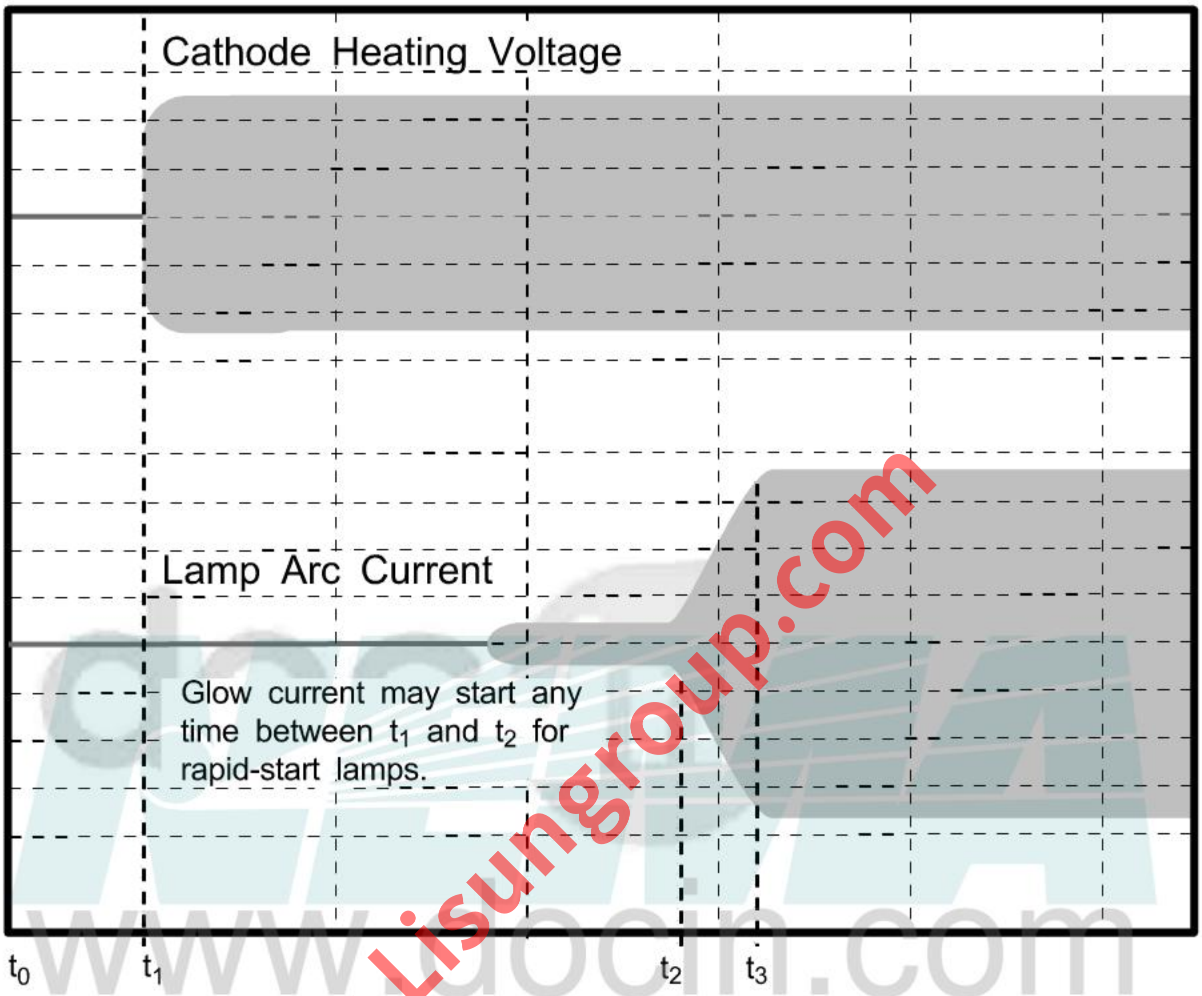
**Figure 1 a**




## Rapid Start Time (t) Definitions

$t_0$ Application of power

$t_1$ Appearance of cathode heating voltage

$t_2$ When rms value of glow current reaches 10% of the rms lamp current at $t_3$

$t_3$ Peak of the first half cycle that is at least 90% of the waveform and is sustained at that value

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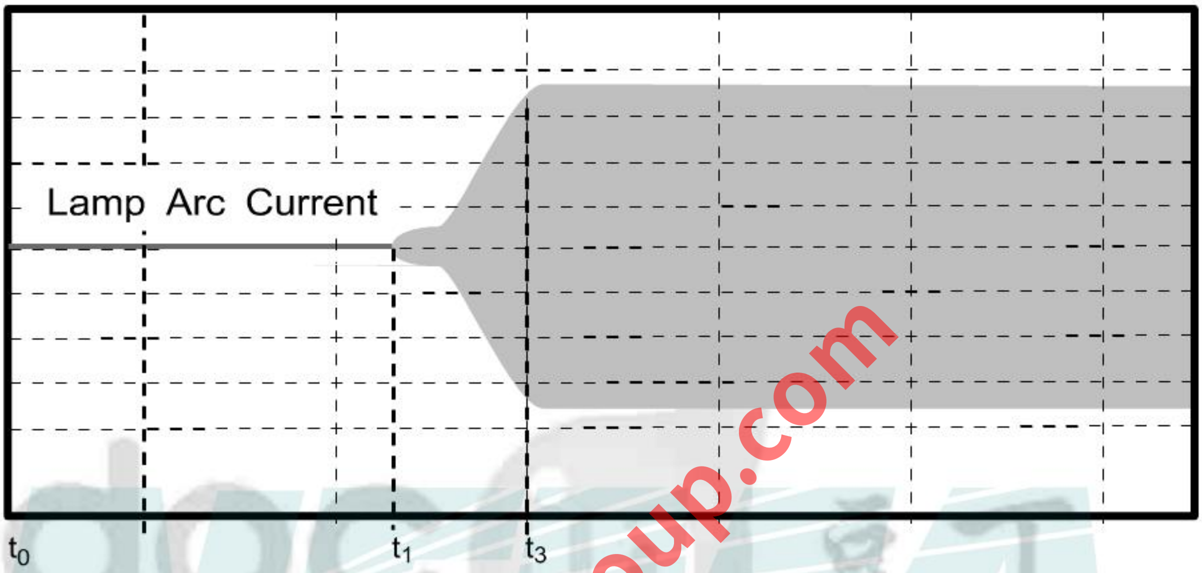
**Figure 1 b**




**Instant Start Time (t) Definitions**

$t_0$ Application of power

$t_1$ First appearance of glow current

$t_3$ Peak of the first half cycle that is at least 90% of the waveform and is sustained at that value

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# ANNEXES

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# ANNEX A
# (Normative)
# Specification for Low Voltage Control Interface for Controllable Ballasts

## A1.0 Purpose

**A1.1** This annex specifies the control interface for controllable ballasts. The lamp power (light output) of the ballast is controlled between minimum/off and maximum values by the control signal applied to the control terminals or lead wires of the ballast. This Annex provides the general and performance criteria for different control interfaces used to control the light output of electronic fluorescent lighting ballasts. If the control signal is not connected, the ballast shall give the maximum value of lamp power as defined in the main body of this standard. This annex does not cover any requirements for the control unit.

## A2.0 Definitions

**A2.1 Controllable ballasts** — Ballasts capable of controlling the lamp power (light output) between the minimum value (or OFF) and the maximum value by the signal on the control terminals of the ballast.

**A2.2 Control terminals** — Connections to the controllable electronic ballast which are used to apply a control signal for changing the light output. The power supply terminals can also act as control terminals.

**A2.3 Control signal** — Signal, which may be an A.C. or D.C. voltage or current, and which by analog, digital or other means may be modulated to convey the necessary information to the ballast for the purpose of controlling the light output.

**A2.4 Maximum value of lamp power (of a controllable ballast)** — Lamp power (light output) which complies with ANSI_ANSLG C82.11, section 5, unless otherwise declared by the manufacturer or responsible vendor.

**A2.5 Minimum value of lamp power (of a controllable ballast)** — Lowest percentage of the lamp power (light output) as defined ANSI_ANSLG C82.11, section 5, or otherwise declared by the manufacturer or the responsible vendor.

## A3.0 Control methods

## A3.1 Control by D.C. voltage (ANSI Type 1)

## A3.2 Voltage specifications

In Figure A-1, the lamp power (light output) of a controllable ballast is controlled by the D.C. voltage on the control input of the controllable ballast. The D.C. voltage has the following characteristics:

Control signal range

| | |
|---|---|
| $V_{1,2} = 10$ V | maximum value of lamp power |
| $V_{1,2} = 1$ V | minimum value of lamp power |
| 1 V $<= V_{1,2} <=$ 10 V | lamp power rising from min. to max. value |
| 0 V $< V_{1,2} <$ 11 V | stable lamp operation |
| 0 V $< V_{1,2} <$ 1 V | minimum light output |

Depending on current-carrying capacity, several controllable ballasts can be connected to one control unit in the way shown in Figure A-2.

The controllable ballast is current sourcing. (See Figure A-3).

The ballast shall not be damaged when the control input voltage $V_{1,2}$ is between -15 V and +15 V.

The ballast shall not produce voltages that exceed the limiting values for the control unit and under no circumstances shall exceed the following:
-15 V $< V_{1,2} <$ +15 V.

The control terminals shall be reverse polarity protected. In that case the ballast shall operate with minimum light output or shall not operate.

At control voltages between 0V and 11V there shall be stable light output. This shall be tested by visual inspection.

### A3.3 Control input current limits

Limits for the control input current, to be supplied to the control unit, are 10 μA minimum and 2mA maximum. (See Figure A-3)

The value of the control input current shall be declared by the manufacturer of the ballast.

### A3.4 Switch-on

Switch-on is allowed at any dimming position.

### A3.5 Lead wire colors

The lead wire color shall be violet for the "+V" designation. The lead wire color shall be gray for the "-V" designation.

### A3.6 Control by future types of controls (ANSI Type xx)

(Reserved for future technology and control methods).

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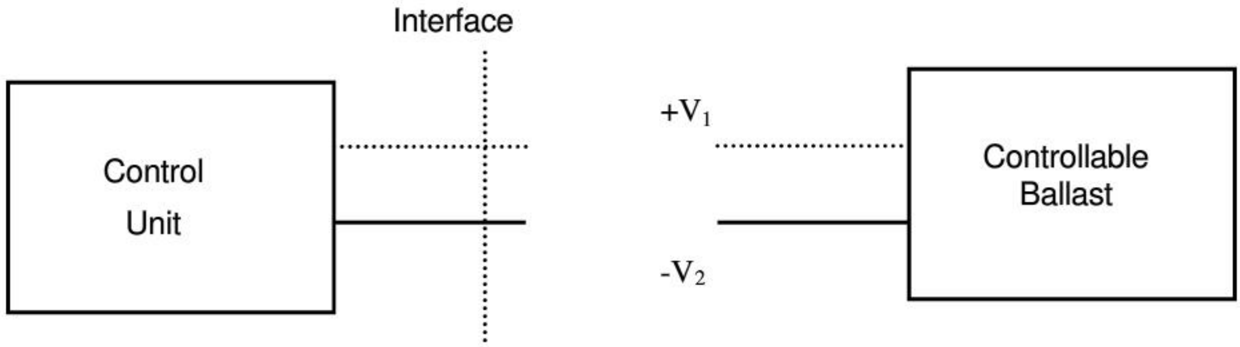


**Figure A-1**

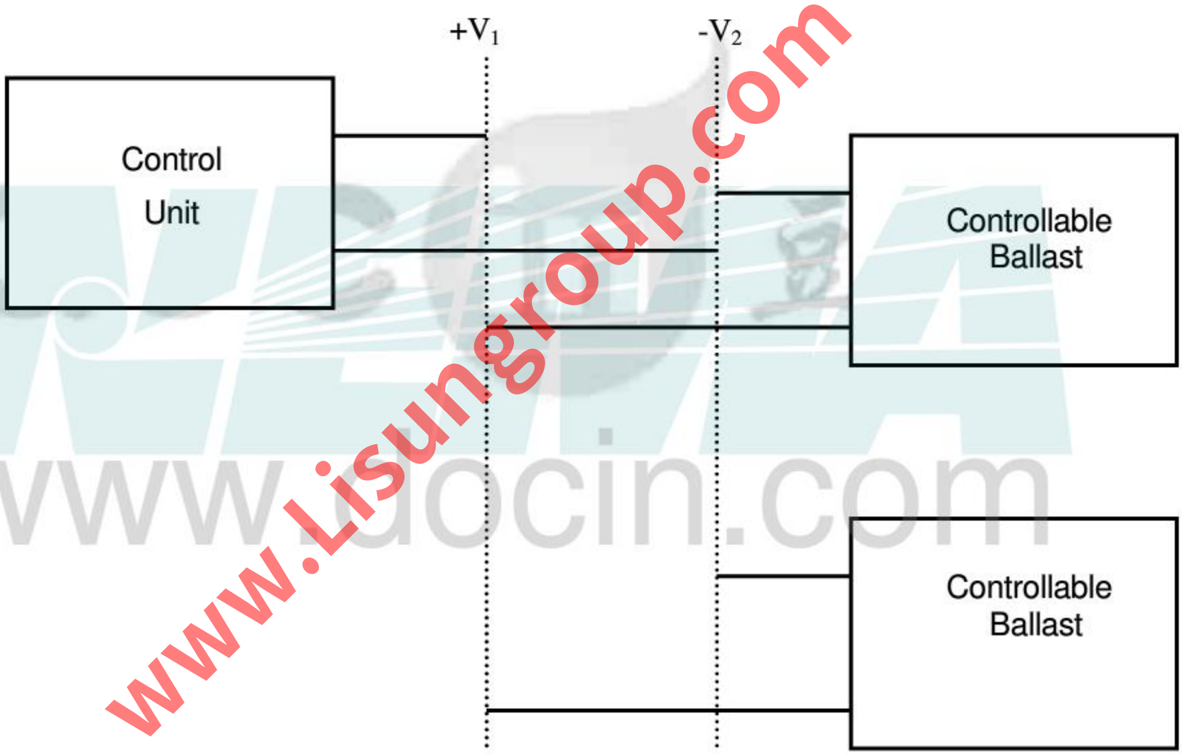


**Figure A-2**

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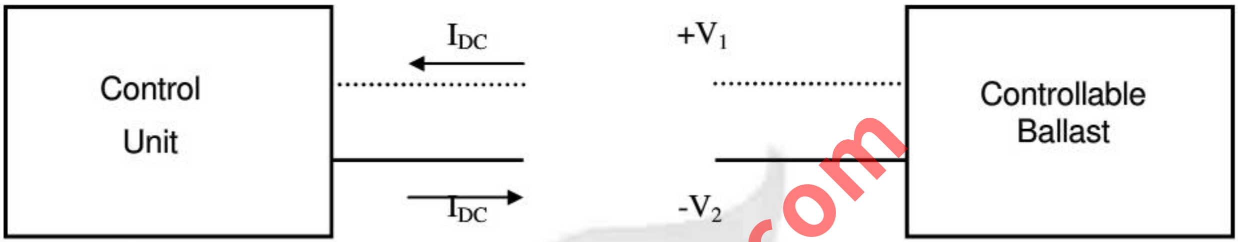


**Figure A-3**

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# ANNEX B
## (Informative)
## Specification for Marking Nomenclature for Controllable Ballasts

### B1.0 Purpose

**B1.1** This annex describes a recommended system of designation and method of nomenclature for identifying circuits used for dimming control of fluorescent lighting ballasts.

**B1.2** The purpose of the system of designation is to identify, by a code, the interchangeability of fluorescent ballasts within a given dimming control system. The code is intended to be marked on the ballast and in its documentation. The code would be used by specifiers and installers for the selection and installation of fluorescent ballasts.

**B1.3** The recommended system of designation is established in a manner that is intended to allow for revision as the technology and manner of dimming control evolves.

**B1.4** The electrical parameters described in this Annex are mainly to ensure expected performance. New or incompatible technology shall comply with all applicable safety standards.

### B2.0 Technical parameters

### B2.1 Power source
The ballast can either be a source (come from the ballast) or a sink (come from an external supply) for the controlling voltage or current.

### B2.2 Circuit type
The dimming control circuit voltage or current can be one of the types described in A3.0.

#### B2.2.1 High voltage
Between primary (supply) lead wires or terminals, or between a primary (supply) lead wire or terminal and a tertiary primary lead wire or terminal.

#### B2.2.2 High voltage, carrier current
Between primary (supply) lead wires or terminals and where the dimming signal is a high frequency by one of the modulation types (below) and superimposed onto the primary supply circuit.

#### B2.2.3 Low voltage
Between two lead wires or terminals. If the control circuit is low voltage, the varying voltage shall be in the range from 0 volts to 50 volts (rms if AC or peak if DC). If the voltage is greater than 50 volts, the control circuit shall be considered to be a high

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voltage circuit.

Between two lead wires or terminals AND designated as a power limited, Class 1, 2, or 3 circuit according to ANSI/NFPA 70 (The National Electrical Code™) and ANSI/UL 935.

Between two lead wires or terminals and designated as “ANSI Type 1” or "ANSI 1". Such a designation shall comply with Annex A of this standard, ANSI_ANSLG C82.11. Such a designation may additionally be designated as a limited energy type as described in 3.2.4.

### B3.0 Current type

If the control circuit is low voltage, the current can be either a varying AC or DC.

### B4.0 Modulation type

The control circuit method of modulation can be either amplitude (analog), pulse width (analog), phase cut (analog), or digital. The digital form complies with the industries practices. All forms of control should comply with the industry practices.

### B5.0 Range of varying voltage

The range of the varying voltage is the normal range expected for the intended dimming operation. The range of control voltage is the normal expected for the intended dimming operation. As examples, see B6.1. All similar marking requirements should be replaced as this one.

### B6.0 Nomenclature of designation

The nomenclature consists of the fields identified above according to the following coding shown in Figure B-1.

### B6.1 Examples

Code is ILDA 0-10v - this means the dimming control voltage is supplied by the ballast, it is low voltage, is direct current, the varying amplitude (typically by a potentiometer) adjusts the dimming, and the range is 0 volts for dim and 10 volts for full brightness.

Code is E2AP - this means the dimming control voltage comes from an external source (typically by a master controller or an energy management system), the external source circuit is designated as Class 2 (the ballast is capable of being connected to a Class 2 circuit and will not cause a hazardous condition on the dimming circuitry), is alternating current, and the dimming is by a pulse width modulation scheme.

### B7.0 Administration of this document

### B7.1 Revision

Requests for additional parameter fields because of technical innovations can be addressed to ANSI Subcommittee Administrator for C82-1.

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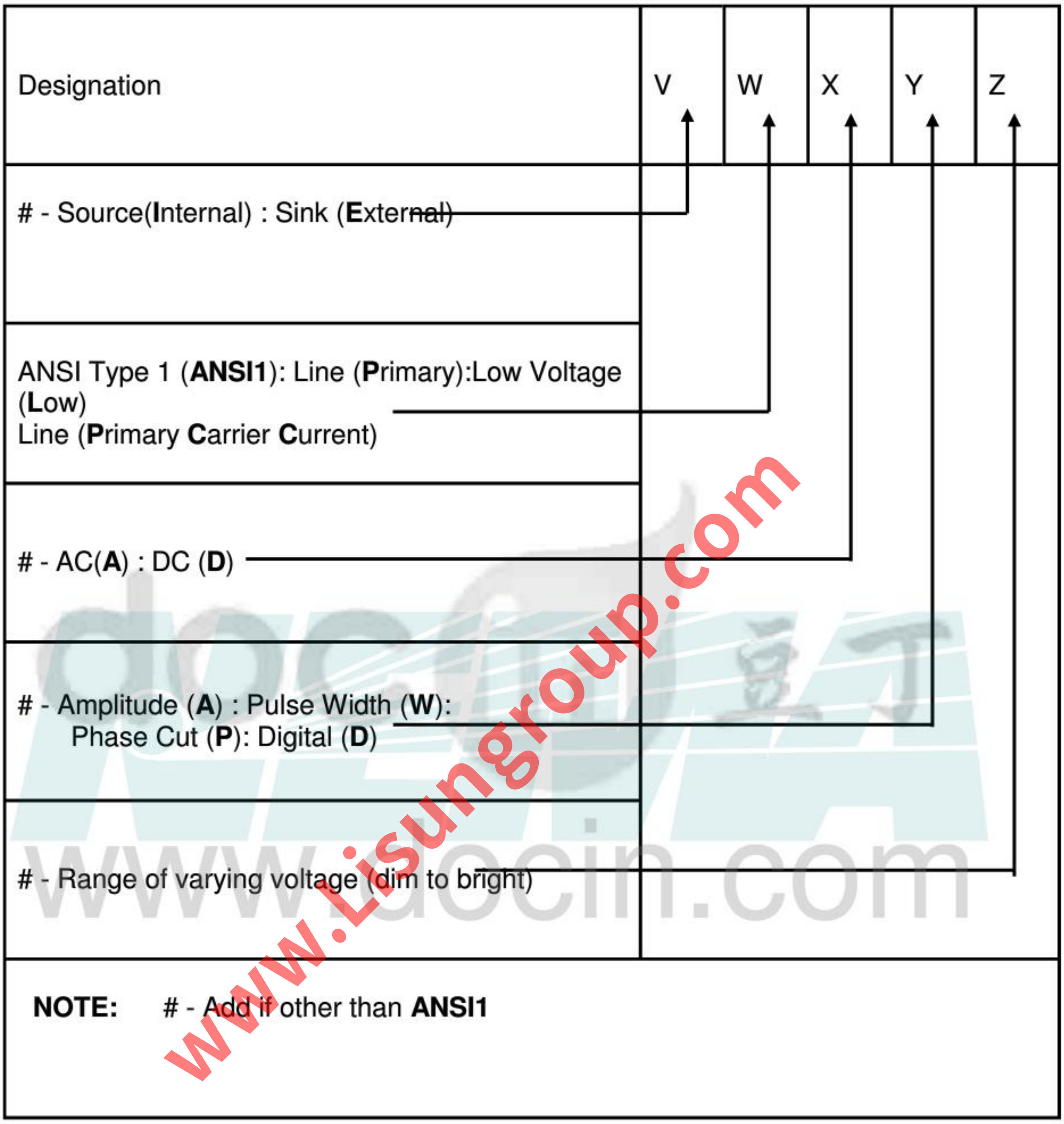


Figure B-1

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# ANNEX C
# (Normative)
# Method of Measurement

## C1.0 Pertinent measurements

## C1.1 Output (lamp) circuit measurements

### C1.1.1 Lamp starting conditions

(1) Lamp Starting Time vs. Starting Current
(2) Preheat Voltage
(3) Ignition Voltage
(4) OCV

### C1.1.2 Lamp operating conditions

(1) RMS Current
(2) Peak Current
(3) Relative light output of lamp
(4) Cathode heating voltage and current (rapid-start)
(5) Lamp current waveshape (crest factor)
(6) Ballast Output Regulation
(7) Ballast Factor

## C1.2 Input (ballast) circuit measurements

### C1.2.1 Operating conditions

(1) RMS Voltage
(2) RMS Current
(3) Input Power
(4) Power Factor
(5) Input Current
(6) THD%
(7) Inrush Current

## C2.0 Electrical supply characteristics

## C2.1 Test voltage and rated frequency

For test purposes, ballasts shall be operated at either their rated voltage, or for certain types of tests at other voltages, as specified in ANSI_ANSLG C82.11. Where ballasts are labeled for a range of primary voltages, it shall be conducted at minimum and maximum nominal voltages.

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### C2.2 Line-voltage waveshape

The ac voltage supply at the input terminals to the ballast-lamp combination, throughout the full range of test requirements, shall have a Waveshape such that the rms summation of the harmonic components does not exceed 3% of the fundamental.

### C2.3 Stability of supply voltage

The line voltage shall be as steady and free from sudden changes as possible. For best results, the voltage should be regulated to within ±0.5%. If adequate automatic regulation is not available, constant checking and readjustment are essential for obtaining accurate measurements.

NOTE: If the static-type voltage stabilizer is used, it is particularly important to check the waveshape to see that it meets the specifications given in 3.2. This should be checked both with and without load.

### C2.4 Supply-source impedance

The supply source shall have sufficient power capacity and low impedance, compared with the ballast impedance, to ensure that the voltage to the lamp-ballast combination does not vary by more than 2% with the lamp-ballast combination in and out of the circuit. The maximum supply source impedance should be 450 mOhms and 100uH.

## C3.0 Ambient conditions for lamp measurements

### C3.1 General

The electrical characteristics and light output of fluorescent lamps are significantly affected by variation in ambient temperature and by air movement along the bulb surface.

### C3.2 Temperature

The temperature conditions for testing are described in ANSI C78.375 Sec. 4.

### C3.3 Drafts

The drafts conditions for testing described in ANSI C78.375 Sec. 4.

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## C3.4 Lamp position

The lamp position stabilization requirements from ANSI C78.375 apply.

When two or more lamps are operating simultaneously, they shall be spaced far enough apart so that the heat produced by one lamp does not significantly affect the temperature of the other. For lamps rated at 40 watts or less, 6 inches (152mm) is sufficient. For lamps that are rated more than 40 watts, a minimum of 9 inches (228mm) should be observed. A lamp shall not be operated directly above another operating lamp.

## C4.0 Reference lamps

## C4.1 Choice of lamps

Several of the ballast tests outlined below specify the use of reference lamps. The reference lamp, definition of ANSI C82.13 applies.

## C4.2 Lamp connections

### C4.2.1 Preheat-start lamps

Preheat-start hot cathode lamps are provided with two contact pins on each end of the lamp.

The marked contacts shall be to the two points of greatest potential difference in the ballast circuit whenever the lamp is being operated. Each cathode heating circuit is connected to the two contacts at one end of the lamp.

To facilitate consistent tests, reference lamps should have one pin on each end marked to identify the ballast circuit connection points.

### C4.2.2 Instant-start and cold-cathode lamps

No marking is needed for these lamps.

### C4.2.3 Single-based fluorescent lamps

Twin tube (long twin tubes) lamps have four inline contacts at one end of the lamp. The two pins, to which the voltage potential is applied, shall be permanently marked, as indicated. For rapid-start twin tube lamps, each cathode heating circuit is connected between each outer pair of contacts.

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Compact fluorescent, circular, and square shaped lamps have 4 pins arranged in a square cluster. Two pins, positioned diagonally from each other, shall be chosen as the permanently marked contacts.

### C4.2.4 Rapid-start and programmed-start lamps

Rapid-start lamps have two contacts at each end of the lamp and these shall be marked in the same manner as described for preheat lamps (see section C4.2.1). The marked contacts shall be to the two points of greatest potential difference in the ballast circuit whenever the lamp is being operated. Each cathode heating circuit is connected to the two contacts at one end of the lamp.

## C5.0 Reference ballasts

### C5.1 General characteristics, $f_o$ = 60Hz

Reference ballast operation is detailed in ANSI C82.3. The specific reference ballast values of impedance, current, and rated input voltage for each type of lamp are given in the applicable lamp standards in C78.81 or C78.901.

While in use, a reference ballast shall be located to prohibit extraneous magnetic materials or leads carrying substantial current within 1 inch (25mm) of any face of the ballast.

### C5.2 General characteristics, $f_o$ = 25KHz

The circuit diagram for the high frequency reference circuit is illustrated in Figure C-4. Note that the circuit is the same for rapid, pre-heat and instant-start lamps. For rapid and preheat lamp connections, refer to Figure C-4.

The basic components are a sine wave signal generator, power amplifier, adjustable line impedance matching transformer; non-inductive power

resistors (fixed and variable) of adequate current rating, power analyzer and current transformers.

### C5.3 Rapid-start, preheat, and instant-start circuit

The reference ballast circuit for rapid-start lamps (Figure C-4) is similar to that for switch-start lamps, except low-voltage transformers are added to heat the

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lamp cathodes. The primary voltage of the transformers must be adjustable to provide the desired output voltage. The voltage supplied by the cathode transformers shall subtract from the voltage of the ballast circuit. Voltage subtraction is accomplished by reverse phasing one of the cathode transformers 180° from the other.

Supply voltage A (V1), is the specified input voltage for the reference ballast circuit for the type of lamp being measured.

Supply voltage B (V2), the cathode heating circuit, should come from the same power source, but it shall have a separate variable-voltage transformer so that it can be adjusted independently of A. The voltage sources A and B should preferably come from the same line, and should not come from different phases of a polyphase power supply. V3 measures lamp voltage.

An option is to have independent variacs for each of the filaments, but from the same voltage sources. In this way, each filament can be set exactly.

## C5.4 Test circuit 60 Hz reference ballast

The basic circuits shown in Figure C-4 can be paralleled to accommodate testing of multi-lamp ballasts. When measuring multi-lamp ballasts, each lamp shall be operated on its own reference ballast. All lamps must be switched simultaneously when transferring between the Ballast Under Test (BUT) and the instrument connections (Reference Ballast) shown in Figure C-4.

Test instruments shall meet all the requirements outlined in ANSI C78.375, Section 6.2.

The resistance of the measurement circuit, including the contact resistance of all switches and relays, should not be high enough to contribute a voltage drop exceeding 0.75 percent of the lamp voltage. This limitation applies to the part of the circuit that is between the ballasts and the lamp sockets.

## C5.5 Test circuit 25 KHz reference ballast

The circuit is first calibrated, using the reference ballast circuit information from the applicable C78.81 or C78.901 lamp data sheet. A fixed resistor close to,

but less than, the stated impedance of the reference circuit resistance for the lamp is chosen. A variable resistor is added in series to the fixed resistor. The two resistors are measured with an ohmmeter and adjusted to match the

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stated impedance in the reference ballast characteristics. The impedance matching transformer is set to the value that is most identical to the circuit impedance. A current transformer is connected to the output leads, which are shorted together. A power analyzer monitors the input voltage and current. A voltage, which is determined by multiplying the stated reference impedance by the reference current, is applied to the circuit. The adjustable resistor is varied until the proper current is obtained, while monitoring the applied calibration voltage to make sure it stays exactly at the value desired. The circuit is de-energized, the short is removed from the output leads, and a lamp is connected. The reference voltage is adjusted to the proper setting, and re-adjusted if necessary, as the lamp reaches thermal stability.

The length of wire and switching devices in the output of the high frequency reference system should be kept to a minimum to prevent attenuation of the signal.

## C5.6 Connection pins

For pre-heat start and rapid-start lamps, the lamp voltmeter shall be connected to the same pins that are connected to the reference circuit ballast output. The voltage coil of the wattmeter/power analyzer in the lamp circuit shall be connected to the same pins used for the voltmeter.

## C5.7 Instruments

| HIGH FREQUENCY INSTRUMENTATION | | | | |
|---|---|---|---|---|
| Instrument | Components | Impedance | Bandwidth when the frequency of interest is "f" | Basic Accuracy at the frequency of interest. |
| Voltmeter | AC+DC | >10MΩ | 5Xf | 0,5 |
| Ammeter | AC+DC | <0.1 MΩ | 5Xf up to 50KHz, 3Xf up to 100KHz | 0,5 up to 50KHz, 1,5 up to 100Khz |
| Wattmeter | AC+DC | Per voltmeter and Ammeter | 5Xf | 0,5 |

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A digital Oscilloscope should have a memory capability equal or larger than 1 MS /sec.

The Light output sensor should have a calibrated linear response to different light levels; a color corrected and cos corrected sensor will be preferred; the light output sensor should have a basic accuracy of 3%.

## C6.0 Test measurements – high frequency commercial electronic ballast

### C6.1 General

When making measurements on high frequency ballasts connected to fluorescent lamps, it is essential that the length of wire between the ballast and the lamp be kept to a minimum. Excessive lead length in the ballast output circuit may cause power attenuation and/or parasitic capacitance, yielding unsatisfactory and inconsistent results. Special care must be observed when additional test circuitry, such as relays and switches, are employed to facilitate the testing process. Switching devices must be appropriately rated for current and voltage, and the switching contacts of these devices should be periodically examined for wear.

### C6.2 Connection of test ballast to lamp pins

### C6.3 Rapid-start ballast and program start ballast.

Two filament wires are connected to each end of each lamp. Refer to the wiring diagram printed on the ballast label for correct lead placement.

### C6.4 Instant-start ballast

It is important to note that many electronic instant-start ballasts are designed to operate rapid-start and preheat-start lamps. The two pins at each end of the rapid-start or preheat-start lamp are shorted together, and one filament wire from the ballast is connected. Refer to the wiring diagram printed on the ballast label for correct lead placement.

### C6.5 Preheat-start ballast

Refer to the wiring diagram printed on the ballast label for correct lead placement.

## C7.0 Ballast output (ballast factor)

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## C7.1 Electronic ballast output

For all types of electronic ballasts, ballast output (ballast factor) is specified in terms of the relative light output.

$$BF = \frac{ballast\_under\_test\_light\_output}{reference\_ballast\_light\_output} * 100$$

The reference lamp shall be operated first on the reference ballast at rated line voltage and frequency. When the lamp has warmed up and reached stable operation, the light output of the lamp shall be accurately measured. The lamp shall then be transferred to a test ballast and its light output again measured within 30 seconds. In some instances, when a linear fluorescent lamp is warmed up on a reference ballast and then transferred to different ballast for electrical and light output measurement, an additional period of burning may be necessary to bring the lamp to equilibrium. The length of the additional burning period can be kept to a minimum if the lamp does not extinguish during the transfer. If the lamp is extinguished during transfer, or if the energy delivered to the lamp by the reference ballast does not match the energy to the lamp delivered by the test ballast, the additional burning time may be longer, possibly as long as 5 or 10 minutes. The ballast light output may also change as the test ballast reaches thermal stability.

For compact fluorescent lamps, a period of 15 minutes should be sufficient to obtain stability after transferring from the reference ballast to the ballast under test. Some compact fluorescent lamps may take longer, especial attention to amalgam low mercury is needed.

A silicon type photodiode is recommended for measuring light output of linear and twin tube style fluorescent lamps. The photometer shall have a linear response over the entire measurement range. If other types of detectors and circuits are used, fatigue as well as linearity shall be characterized. The cell shall be mounted at least 5 inches (127mm) from the lamp, and shall be baffled to avoid extraneous light. The photocell shall be aimed at the horizontal and vertical center of the lamp being measured. Before light output readings are taken, the photocell shall be stabilized by being exposed to light of about the same intensity as that to be measured for a least ½ hour. During this time, the photocell shall be connected to the measurement circuit so that normal current will be flowing.

When measuring the light output of twin or U-shaped lamps, the detector should be aimed at the straight portion of the tube, avoiding the bent portion.

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When measuring the light output of compact, circular or square shaped fluorescent lamps, an integrating sphere will produce more accurate and repeatable measurements than the direct photocell method.

## C7.2 High-current lamps

Fluorescent lamps of the higher current types (800 milliamperes and above) are more sensitive to air movement and temperature than the lower current types of lamps. For these lamps, extra care should be taken. When the light output of these heavily loaded lamps is being measured, it may be desirable, in addition to observing all precautions previously mentioned, to provide additional shielding around the lamps in order to obtain reproducible comparative light output data.

## C7.3 Ballast regulation

The lamp light output when derived by test ballast, is measured at:

Dedicated voltage: 90%, 100% and 110% of (design) input voltage, and in accordance with ANSI_ANSLG C82.11.

Multi voltage: -10% of the minimum (system design voltage) input voltage and +10% of the maximum (system design voltage) input voltage and in accordance with ANSI_ANSLG C82.11.

## C8.0 Lamp current

The lamp current parameter refers to current flowing through the lamp, sometimes called arc current.

It is possible to find electronic ballasts that produce a modulated lamp current; such phenomena should be taken into consideration to determine the rms current value. Such consideration can be expressed as follows:

$$Irms = \sqrt{\frac{1}{tb-ta} * \sum_{a}^{b} i^2 * \Delta t}$$

*a* is the point/time where the lamp current envelope starts.
*b* is the point/time where the lamp current envelope ends.
*i* is the instantaneous current.

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It is a good practice to extend the length of the measurement to at least five full modulation cycles.

$$Irms = \sqrt{\frac{1}{5tb-ta} * \sum_{a}^{5b} i^2 * \Delta t}$$

Lamp Current Measurement-Dimming Ballasts

When measuring high frequency current that is low in magnitude, such as with dimming electronic ballasts, it is recommended that the filament lead wires be wrapped 10 times around a current transformer to provide better signal to noise ratio.

## C8.1 Rapid-start

Measurement of lamp current on a commercial ballast of the rapid-start type requires special instrumentation to provide a vector summation of the currents in the two leads to a cathode. It will be necessary to use a high frequency current transformer connected to a suitable voltmeter, power analyzer or scope.

Figure C-2 illustrates a suitable method of measurement for lamp current in rapid-start lamps.

## C8.2 Instant-start

Measurements are made using the same circuitry described in the rapid-start measurement. To minimize circuit loading when measuring the lamp current of an electronic ballast, the use of a high frequency current transformer is recommended.

## C8.3 Crest factor

Measurements of peak and RMS currents may be made with instruments connected in a circuit as shown in Figure C-6. Peak current may be measured using either a peak-reading high-impedance voltmeter or a calibrated oscilloscope. A power analyzer may also be used to calculate the crest factor.

$$CF = \frac{Ipk}{Irms}$$

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It is common to find modulating lamp currents; the crest factor shall be calculated utilizing the highest peak value of a full-modulated cycle.

$$CF = \frac{Max\_Ipk}{Irms}$$

## C8.4 Waveshape determination

The general characteristics of the waveshape may be examined, and a comparison made of successive half-cycle peak values, using an oscilloscope in the circuit shown in Figure C-6.

The current transformer shall be placed as close to the lamp as possible. This will reduce the noise that may be detected closer to the ballast.

## C9.0 Cathode heat

The RMS cathode heating voltages of rapid-start ballasts shall be measured while the ballast is starting and operating at nominal line voltage, and comply with the values stated in the appropriate C78.81 or C78.901 lamp data sheet.

The cathode heating voltages may be modulated; the rms determination should consider these phenomena by means of the following:

$$Vrms = \sqrt{\frac{1}{tb-ta} * \sum_{a}^{b} v^2 * \Delta t}$$

*a* is the point/time where the cathode heating voltage envelope starts.
*b* is the point/time where the cathode heating envelope ends.
*v* is the instantaneous voltage.

It is a good practice to extend the length of the measurement to at least 5 full-modulated cycles.

$$Vrms = \sqrt{\frac{1}{5tb-ta} * \sum_{a}^{5b} v^2 * \Delta t}$$

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## C9.1 Cathode heat – normal operation

The RMS voltages are measured while the filament leads are terminated into a full compliment of reference lamps. It is also possible to measure the filament voltages connecting the ballast to dummy loads.

## C9.2 Cathode heat rapid-start ballast type – dummy load operation

All cathode windings of the ballast shall be simultaneously loaded with non-inductive, wire-wound resistors as specified in the applicable C78.81 data sheet. A resistance of half the value used for the single cathode winding shall load cathode windings intended to supply two lamp cathodes in parallel, ⅓ the resistance for three windings in parallel, ¼ for 4 windings. The total cathode circuit resistance, including wiring, contact resistance, etc., shall conform to the dummy-load resistance as specified in C78.81.

A dummy resistor (s) will be place in the circuit to represent the lamp operation; the resistor value should be selected in such way that the current through it is in between +/- 2% of the lamp current when the ballast drives a reference lamp. Figure C-1 shows a schematic of a one lamp connection. For non-programmed and modified rapid-start ballasts, measurements can be made with a voltmeter with a resistance of at least 1000 ohms per volt, or an oscilloscope using a differential probe. The heating voltage will be measured with a true RMS voltmeter or with a long memory scope and a differential probe. Care should be taken since a modulated heating voltage waveform may be present.

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## C10.0 Lamp starting tests using electronic ballasts – lamp starting time vs. starting current

Starting tests should be performed using lamps that (1) have been seasoned for a minimum of 100 hours, (2) comply with applicable C78.81 or C78.901 electrical operating characteristics, and (3) have not been energized at least 12 hours prior to testing. Each starting test described below is to be performed on each lamp circuit of the ballast under test.

The starting tests' values should be reported as the average of the six lamps described here; the standard deviation should also be reported as a tests results repetition indication.

In case of doubt, the test should be repeated with a reference lamp.

## C10.1 Rapid-start lamp ballast, program-start ballast and programmed ballast

## C10.2 Cathode heat – dummy load operation for programmed-start and modified rapid-start ballasts

The dummy load resistor values should be selected per C9.2.

For ballasts that have a programmed or modified rapid-starting sequence, it may be necessary to measure the cathode dummy load voltage with a differential probe connected to an oscilloscope, capable of reading RMS voltage. The ballast will produce a short burst of filament voltage, then shut down, and continuously cycle. The RMS voltage is measured only when the voltage is present in the time domain (the off-time voltage is not averaged with the on-time voltage).

Not all of the program or programmed ballasts necessarily reduce the filament voltage. In addition, some applications may have a slightly higher voltage at the starting scenario than the steady state scenario.

For a programmed and modified rapid-start, it is necessary to determine the filament voltage at the steady state scenario.

A differential probe connected to the digital memory scope should be used.

## C10.3 Starting Scenarios

### C10.3.1 Program and programmed ballast type:

The starting scenario is defined as the period of time between the power on of the ballast and the time the full OCV is applied to the ballast.

### C10.3.2 Rapid-start ballast:

The starting scenario is defined as the time between the power on of the ballast and the time the discharge current of the lamp reaches a stabilized 90% of the lamp current.

#### C10.3.2.1 Preheat time ($T_1$-$T_2$)

Refer to ANSI_ANSLG C82.11 for explicit definitions, waveform illustrations, and other test specifications. A high frequency current transformer connected to an oscilloscope is required to perform this measurement. The oscilloscope should have a high sampling rate to

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avoid aliasing.

The preheat time is measured on six reference lamps that exhibit stable characteristics. After striking the lamp, it is suggested that it be allowed to stay illuminated for no less than 30 seconds. Refer to Fig. 1a.

### C10.3.2.2 Glow current

The glow current may be modulated; such phenomena should be taken into consideration by the following means:

$$Iglowrms = \sqrt{\frac{1}{tb-ta} * \sum_{a}^{b} i^2 * \Delta t}$$

*a* is the point/time where the glow current envelope starts.
*b* is the point/time where the glow current envelope ends.
*i* is the instantaneous current.

It is a good practice to extend the length of the measurement as long as the ballast is in the pre-heat stage; a minimum of 5 full-modulated cycles should be used.

$$Iglowrms = \sqrt{\frac{1}{5tb-ta} * \sum_{a}^{5b} i^2 * \Delta t}$$

In a multi-lamp ballast, only one lamp glow current will be measured at a time; a dummy load will be placed in the other positions. As an example, in a two-lamp ballast, one will first look at the glow current of the lamp in position 1, with a dummy load in position 2. After the six readings, one will look at the glow current in position 2 with a dummy load in position 1.

The glow current is expected to be small; values of 5 to 10 mA rms are common in today's practice. The frequency of the glow current is the frequency of the pre-heat voltage. A high frequency, low current voltage is a very sensitive measurement.

The glow current value to report will be the average value of the 6 readings from the 6 lamps.

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### C10.3.2.3 Glow to arc transition ($T_2$-$T_3$)

The transition time can be measured using the same circuitry as above. The test is performed at 90% rated line voltage. The measurement is made using 6 reference lamps. Refer to Fig. 1a.

### C10.3.2.4 Instant-start

The starting time $T_0$-$T_2$ can be measured using the circuitry described in Figure C-7, and is performed at 90% rated line voltage. If irregular results occur, the lamp is removed and a replacement lamp is used. The measurement is repeated with 6 reference lamps. Refer to Fig. 1b.

### C10.3.2.5 Filament resistance hot to cold ratio

The Rh/Rc test is a procedure to determine whether the ballast is sufficiently heating a lamp filament for proper ignition just before the glow to arc transition is initiated. Rh is the hot filament resistance, which is calculated by measuring the filament voltage and current, at nominal line voltage, at the point just before the glow to arc transition. Rc is the resistance of the filament measured to three decimal positions with a four-wire milliohm meter, at 25°C. For correct starting operation, a ballast must produce Rh/Rc values from 4.0 to 6.6, which correspond to filament temperatures of 700°C to 1200°C; the proper Rh/Rc values may be found in the individual lamp standards to which this requirement applies. Refer to the test set-up in Figure C-7.

The hot to cold ratio measurements are to be performed with reference lamps (see ANSI C82.13).

A digital storage oscilloscope with suitable acquisition memory should be used to prevent ailasing of each measured signal.

The approximate temperature of the filament can be calculated, using the formula:

$$T_h = (T_c)(R_h/R_c)^{0.814}$$

$T_h$ = calculated hot resistance of the tungsten filament, °K
$T_c$ = cold temperature of tungsten filament before being energized, °K
$R_h/R_c$ = hot to cold cathode resistance ratio

NOTE: The current reference lamp definition does not imply the same filament impedance at 25°C for all reference lamps.

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The Rh/Rc determination may be accomplished by different means, from a direct reading from the scope to digital acquired data.

A direct filament voltage and current RMS measurement before the lamp glow to arc transition could be used to determine the hot resistance (Rh) as follows:

$$RhVrms = \sqrt{\frac{1}{tb-ta} * \sum_{a}^{b} v^2 * \Delta t}$$

$$RhIrms = \sqrt{\frac{1}{tb-ta} * \sum_{a}^{b} i^2 * \Delta t}$$

*a* is the point/time where the cathode heating voltage envelope starts few cycles before the glow to arc.

*b* is the point/time where the cathode heating envelope ends before the glow to arc.

*v* is the instantaneous voltage.

It is possible to determine the hot resistance by the filament voltage to the filament current ratio when one assumes that all the current runs through the filament before the lamp glow transition:

$$Rh = \frac{VhVrms}{IhIrms}$$

Another way to determine the hot resistance uses a long memory digital scope in the X/Y mode. One may measure the filament voltage with differential probe and the filament current with a current probe, plotting them with the scope in the X/Y mode. The trace is a representation of the filament impedance.

The trace is a straight line before the lamp glow to current ignition stage starts because all the current goes through the filament. The maximum slope value before the lamp ignition transition (while the trace is still a straight line) is the hot resistance.

A third way to determine the Rh will involve only digital processing. A digital acquisition of the instantaneous filament voltage and filament current may be triggered by the pre-heat voltage and stopped just at the point where the ignition voltage collapses. The Rh may be calculated as the ratio of the peak voltage to the peak current in the cycle before the ignition voltage collapses or

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by the ratio of the rms voltage to the rms current before the same ignition voltage collapses.

Different methodologies may be used as long as they have a good correlation with the first method described in this section.

## C11.0 Ballast input

These measurements can be made with a suitable power analyzer. Measurements should be taken at a point of stabilization. Stabilization is

determined by monitoring the light output of the reference lamps, and the electrical characteristics of the ballast. The input measurements of the ballast should be made while the light output is measured.

## C11.1 Input current

The rms input current can be measured with an rms multimeter or power analyzer; some electronic ballasts will operate with a high harmonic distortion and a low power factor. The instrument selected for this measurement should be able to respond to such condition. Only true rms instrumentation should be used.

There are two basic methods to measure current, through a shunt or through a current transformer. Either way is acceptable as long as the inserted impedance to the input circuit becomes negligible.

$$Irms = \sqrt{\frac{1}{tb-ta} * \sum_{a}^{b} i^2 * \Delta t}$$

## C11.2 Input power

The input power should be measured with a power analyzer. The power analyzer may determine power by a thermal element or by the means of acquiring the instantaneous voltage and current data and determining the power by means of software. Different software solutions will be acceptable as long as the power analyzer has been calibrated and meets the requirements in the instrumentation section.

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One of the practices for such measurement today consists in calculating the average of the instantaneous power over several full cycles.

$$w = \frac{1}{tb-ta} * \sum_{a}^{b} v \quad * i * \Delta t$$

where:

*ta* is the point and time the power calculation envelope starts.
*tb* is the point and time the power calculation envelope ends.

*v* is the instantaneous voltage.
*i* is the instantaneous current.
Δt is the time partition between two consecutive instantaneous readings.

## C11.3 Power factor

The input power factor should be measured with a power analyzer; most power analyzers will determine the power factor by software. The power analyzer will acquire the instantaneous voltage and current, then it will calculate the power factor by software means. Different software solutions will be acceptable as long as the power analyzer has been calibrated and meets the requirements in the instrumentation section.

The power factor should always be equal to:

$$PF = \frac{ActiveW}{ApparentVA}$$

## C11.4 Input current THD (Total Harmonic Distortion)

Total harmonic distortion should be calculated as the square root of ratio of the rms value of the harmonic currents sum through order 40 to the rms value of the fundamental. ANSI_ANSLG C82.77 applies.

$$THD = \sqrt{\sum_{a=2}^{b=40} \left[\frac{In}{I1}\right]^2} * 100$$

*In* is the rms value of the n current harmonic.
*I1* is the rms value of the fundamental current harmonic.

The ballast should be operated with a power source described in this

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standard, with pre-seasoned lamps. The test may be repeated with reference lamps in case of doubt. The input voltage (power source) harmonic contribution should be always in the limits described in this standard. A voltage source, free of voltage harmonics, will help to produce more repeatable test results.

### C11.5 Inrush current (NEMA 410 applies)

The compliance with the inrush limits may be verified by different methodologies as follows:

### C11.6 Indirect verification

The bulk (principal) input (energy storage) rated capacitor should be recorded as well as the ballast rated input current to calculate the capacitance per amp ratio. This methodology is the simplest one and it provides a very accurate repeatable way to define the inrush limits of electronic ballasts

### C11.7 Inrush current model basics

The ballast inrush current always depends on the ballast design; different ballasts may incorporate technology and/or components designed to limit the inrush current.

The inrush current may be evaluated by the means of a digital model.

The components before the switch define the line impedance (0.45 ohms or 450m$\Omega$) while the components after the switch represent the input stage of a given ballast.

The switch has been programmed to close at the peak of the sine wave (power source).

The inrush current waveform is the fundamental output to obtain from the simulation.

Two parameters from this waveform will be recorded, the inrush peak current and the pulse wide.

The pulse width has been defined as the plane at 10% of the inrush peak current base.

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## C11.8 Inrush current model calibration

The accuracy of the model should be verified by the means of a comparison between the model peak current and the peak wide to the readings obtained by practical testing of the ballast on the bench (see Figures C-9 and C-10).

The computer model calibration verification procedure follows:

A power source with the impedance described in this standard with programming capabilities should be used. The power source will be programmed to connect to the ballast at the peak of the voltage (power source).

A current probe capable to handle the inrush current described by the simulation and a digital scope with the proper bandwidth and rise response should be used.

The ballast should be connected to the power source with the current probe attached to one of the ballast input leads. The trigger of the scope should be set to 5% of the inrush current waveform described by the simulation in a one-shoot mode.

The power source will be powered on and the waveform recorded in the digital scope memory.

Repeat the testing with 5 different samples.

When compared, the average of the five-scope waveform peak and wide values and the simulation waveform should be within +/- 2%. If the model and the test are outside of the limit, then the model and the ballast should be reviewed.

It is common to use electrolytic capacitors as the main/bulk capacitor. This type of capacitor may have tolerances as large as +/-20%.

It is possible to include additional components in the simulation input stage if needed. The basic model has been used to simulate ballasts with active PFCs, passive (large magnetic) PFCs and with NTCs without the need to modify the input stage simulation.

Simulation Execution

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Once the simulation has been calibrated, the ballast input stage should be repeated in parallel until the steady state current of the number of equivalent

ballasts represented, matches the steps in the ANSI_ANSLG C82.11/NEMA 410 table to measure. See Figures C-9 and C-10.

The new (complete) simulation inrush waveform should be recorded. The peak and the wide of this new waveform should be comparable with the step in the table used to determine the number of ballast to model.

The pulse wide and pulse height are the key parameters to represent the inrush current.

NOTE: Components' selection is for simulation purposes:

The (C1) capacitance value should be at least the rated bulk capacitor.

The series resistance (R2) should represent the capacitor's ESR and pulse the ohmic part of the impedance in series with the bulk capacitor.

The inductor (L2) should represent the inductive part of the impedance in series with the bulk capacitor for the first half cycle. It may be a large 60Hz magnetic winding for a passive front end ballast or a combination of the EMI coil pulse and the boost coil of an active front-end ballast.

### C11.9 Direct testing measurement

It is also possible to connect in parallel the group of ballasts that will bring the line current to the described/desired value in the ANSI_ANSLG C82.11/NEMA 410 steps. The power source should be able to handle such load and meet all the power source requirements (power capability, inrush capability; source impedance and THDv content).

A current sensing device, shunt or current transformer with the power capability to handle the steady state and transitory energy generated in this test should be chosen. The oscilloscope should be able to handle the rise time needed for this test.

A power source programmed to connect the mains at the peak of the waveform should be used.

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The ballast group will be connected to the power source with the current sensing device sensing all the input currents at the same time. The oscilloscope should be triggered with a 5% current over the steady state current and it should operate in a one-shoot mode.

The pulse width is measured in the time it takes the pulse current to go from the 10% of the value to return to this same 10%. The pulse height is the maximum peak current.

### C11.10 BEF (Ballast Efficacy Factor)

The Ballast Efficacy Factor has been defined as the ratio of the ballast factor to the input power.

$$\text{BEF} = \frac{\text{Ballast Factor*100}}{\text{Input Power}}$$

Ballast Factor = light output delivered to a reference lamp by the comercial ballast devide by the light output deliverd to the reference lamp by the reference ballast.

(Note: if the ballast operates more than one lamp, the light output of all lamps is averaged together).

### C12.0 Line transients

Line transient surge suppression testing is performed in accordance with the methods and limits described in ANSI/IEEE C62.41 and this standard, ANSI_ANSLG C82.11.

Nominal line voltage is applied to the test ballast, operating a full compliment of lamps in a grounded fixture. A 2.5 kV, 0.5 μs, 100 kHz ring wave is applied to the ballast input at 90° into the voltage phase, with a short circuit current capability of of 0.083 kA.

The surge is applied 7 times in both the differentiall mode, and each of the common mode configurations (diffeential mode is defined as phase to neutral or phase to phase. The 3 common modes are phase to ground, neutral to ground, and phase and neutral to ground).

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## C13.0 Conducted emissions testing

FCC Part 18 applies.

## C14.0 EOL (End of Life)

### C14.1 Asymmetric pulse test[4]

Refer to the diagram in Figure C-11.

If only one connection per electrode is available at the ballast and/or lamp, T1 shall be removed and then the ballast shall be connected to J2 and the lamp to J4. The ballast manufacturer should be asked which of the output terminals has to be connected to J4 and, in case two output terminals per electrode exist, whether they can be short-circuited or be bridged with a resistor.

(1) Close switches S1 and S4, and set switch S2 to position A.
(2) Turn on the ballast under test and allow lamp(s) to warm up for 5 min.
(3) Close S3, open S1, and wait for 15 s. Open S4 and wait for 15 s.
(4) Measure the sum of the average power dissipated in the power resistors, R1A to R1C and R2A and R2B, and the Zener diodes, D5 to D8.

NOTE: The power should be measured at the average value of the product of the voltage between terminals J5 and J6 times the current flowing from J8 to J7. The voltage should be measured with a differential voltage probe, and the current should be measured with a dc current probe. A digital oscilloscope can be used for the multiplication and averaging functions. If the ballast operates in a cycling mode, the averaging interval should be set to cover an integer number of cycles. (Each cycle is typically greater than 1 s.) The sampling rate and number of samples included in the calculations should be sufficient to avoid aliasing errors.

The power dissipation shall be below *P*max.

If the power dissipation is greater than *P*max, the ballast has failed and the test is discontinued.

(5) Close S1 and S4.
(6) Set S2 to position B.
(7) Repeat steps (2), (3) and (4).
The ballast shall pass both position “A” and position “B” tests.
(8) For multi-lamp ballasts, repeat steps (1) to (7) for each lamp position.
A multi-lamp ballast shall pass the tests for each lamp position.

[4] Future ongoing development to occur in this section.

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(9) For ballasts that operate multiple lamp types (e.g. 26W, 32W, 42W), each lamp type specified shall be tested. Repeat steps (1) to (8) for each lamp type.

### C14.2 Asymmetric power test

Refer to the schematic diagram in Figure C-12.

(1) Set switch S1 to position A.
(2) Set resistance of resistor R1 to 0 (zero) Ω.
(3) Start lamp(s) by turning on power to ballast under test and allow lamp(s) to warm up for 5 min.
(4) Increase the resistance of R1 rapidly, (within 15 s) until the power dissipated by resistor. R1 equals the test wattage value of 10 W for a T4 lamp or 15 W for a T5 lamp. If the ballast limits the power in R1 to a value less than the test wattage, set R1 at the value which produces the maximum wattage. If the ballast switches off before reaching the test wattage, continue with (5). If the ballast does not switch off and limits the power in R1 to a value less than the test wattage, set R1 at the value which produces the maximum wattage.
(5) If the test wattage value was reached in step (4), wait for an additional 15 s. If the test wattage value was not reached in step (4), wait for an additional 30 s. Measure the power in R1.

The power dissipation in resistor R1 shall be below or equal to $P$max.
If the power dissipation in resistor R1 is greater than $P$max, the ballast has failed and the test is discontinued.

(6) Turn off power to ballast. Set switch S1 to position B.
(7) Repeat test procedure steps (3) to (5) above.
The ballast shall pass both position "A" and position "B" tests.
(8) For multi-lamp ballasts, repeat test procedure steps (1) to (7) for each lamp position. A multi-lamp ballast shall pass the tests for each lamp position.
(9) For ballasts that operate multiple lamp types (e.g. 26W, 32W, 42W) each lamp type specified shall be tested. Repeat steps (1) to (8) for each lamp type.

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### C14.3 Open filament test[5]

Refer to the schematic diagram in Figures C-13, C-14 and C-15.

The ballast shall have adequate protection to prevent lamp cap overheating at the end of the lamp life cycle under open filament conditions. Compliance is checked by either test procedure A or B as determined by the value of Imax below.

During the test the following values of maximum lamp current Imax apply:
- for 13 mm (T4) lamps, Imax = 1 mA;
- for 16 mm (T5) lamps, Imax = 1,5 mA.

(Other diameters are under study.)

If these current values are exceeded, test procedure B shall be applied; otherwise test procedure A shall be applied.

Test procedure.

Determine the r.m.s. currents, *I*LL(1), *I*LH(1), *I*LL(2), *I*LH(2), at the ECG output terminals, by using a current probe and mark the terminals respectively, where:

*I*LL(1) is the lower of the r.m.s. currents through lead-in wire of electrode 1.

*I*LH(1) is the higher of the r.m.s. currents through lead-in wire of electrode 1.

*I*LL(2) is the lower of the r.m.s. currents through lead-in wire of electrode 2.

*I*LH(2) is the higher of the r.m.s. currents through lead-in wire of electrode 2.

Connect the circuit according to Figure C-13.

Test Procedure A[6]

Refer to schematic diagram in Figure C-13

(1) Set S to position 1.

(2) Turn on the ballast under test and allow lamp(s) to warm up for 5 min.

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5 Future ongoing development to occur in this section.
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(3) Set S to position 2 and wait for 30 s.

(4) Measure the r.m.s. current value of *I* lamp with the current probe near to the lamp end. If *I* lamp is pulsing, the r.m.s. value shall be computed over one complete pulse cycle including the off time.
The lamp discharge current *I* lamp shall not be greater than *I* max.
If the lamp discharge current is greater than *I* max, the ballast has failed and the test is discontinued.

Refer to Figure C-14.

(5) Set S to position 1.

(6) Turn on the ballast under test and allow lamp(s) to warm up for 5 min.

(7) Set S to position 2 and wait for 30 s.

(8) Measure the r.m.s. current value of *I* lamp with the current probe near to the lamp end. If *I* lamp is pulsing, the r.m.s. value shall be computed over one complete pulse cycle including the off time.
The lamp discharge current *I* lamp shall not be greater than *I*max.

(9) For multi-lamp ballasts, repeat test procedure steps 1 to 8 for each lamp position. A multi-lamp ballast shall pass the tests for each lamp position to pass the end-of-lamp life test.

(10)For ballasts that operate multiple lamp types (e.g. 26W, 32W, 42W), each lamp type specified shall be tested. Repeat steps (1) to (9) for each lamp type.

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Test Procedure B

Connect the lamp as shown in Figures C-13 and C-14 with the measurement arrangement according to Figure C-15. If the ballast has an

isolation transformer, connect the 1 MΩ resistor to the corresponding terminal defined in ANSI_ANSLG C82.11.

(1) Set S to position 1.

(2) Turn on the ballast under test and allow lamp(s) to warm up for 5 min.

(3) Set S to position 2 wait for 30 s.

Measure the RMS voltage value with the differential probe placed as indicated in Figure C-15. If the voltage is pulsing, the RMS value shall be computed over one complete pulse cycle including the off time.

(4) The voltage shall not be greater than 25% of the rated lamp voltage. If the voltage is greater than 25%, discontinue the test. Refer to Figure C-14.

(5) Repeat test procedure steps (1) to (4) above.

(6) For multi-lamp ballasts, repeat test procedure steps (1) to (5) for each lamp position. A multi-lamp ballast shall pass the test for each lamp position to pass the end-of-lamp life test.

(7) For ballasts which operate multiple lamp types (e.g. 26W, 32W, 42W), each lamp type specified shall be tested. Repeat steps (1) to (6) for each lamp type. A multiple lamp ballast shall pass the test for each lamp type.

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# FIGURES

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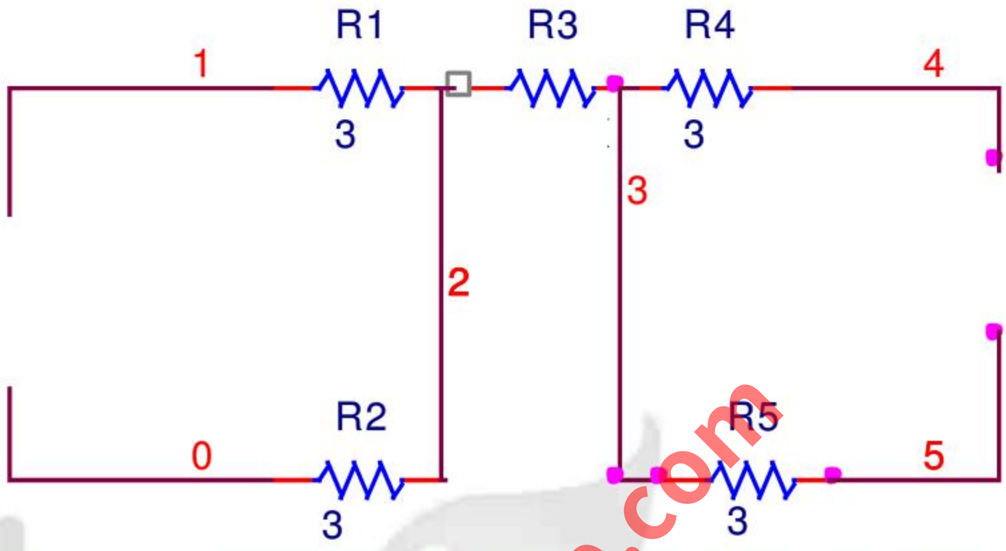


This circuit represents the dummy load network connection for a two-pin lamp ballast; R1, R2, R4 and R5 are half of the filament resistance. R3 is selected in a way that the current through it, is +/2% of the lamp current when driven with a high frequency reference ballast.

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**Figure C-1**
**Dummy Load Connection**

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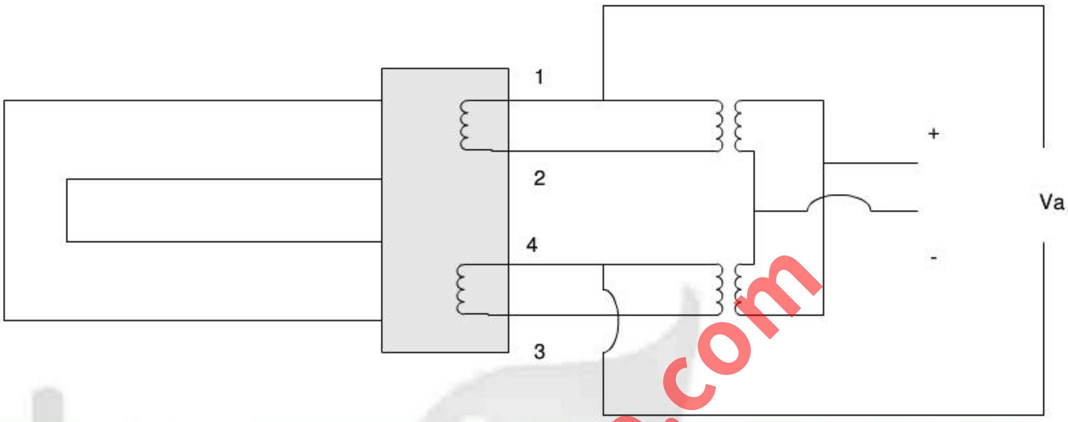


Apply reference circuit voltage potential between pins 1&4 Va

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**Figure C-2**
**Single Lamp Connection**

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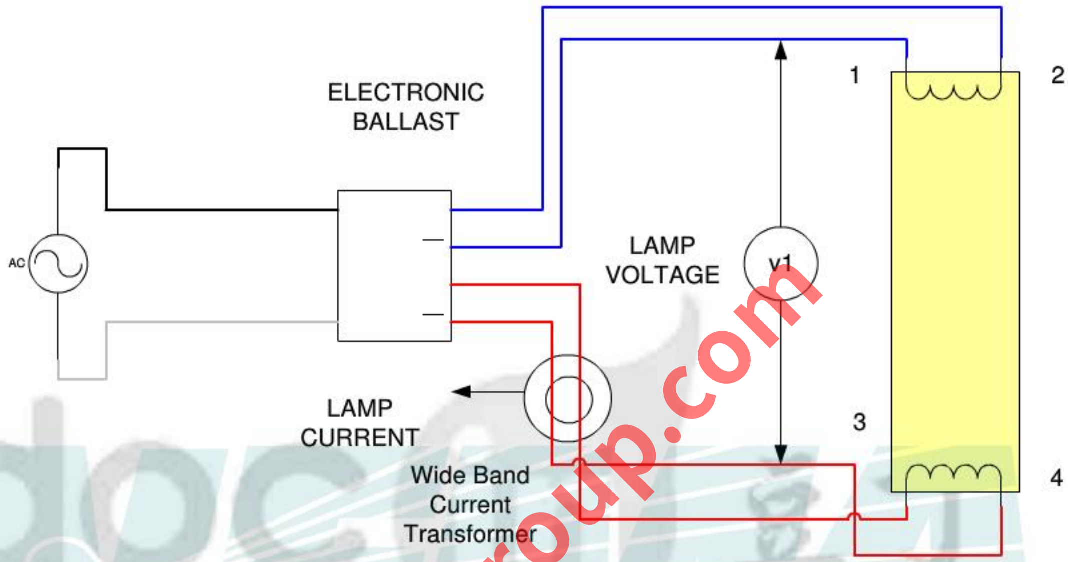


Voltage V1 shall be selected to be the lowest potential between any red wire and any blue wire

Voltage and current sensing devices are typically part of power analyzers

**Figure C-3**
**Rapid Start and Program Start**

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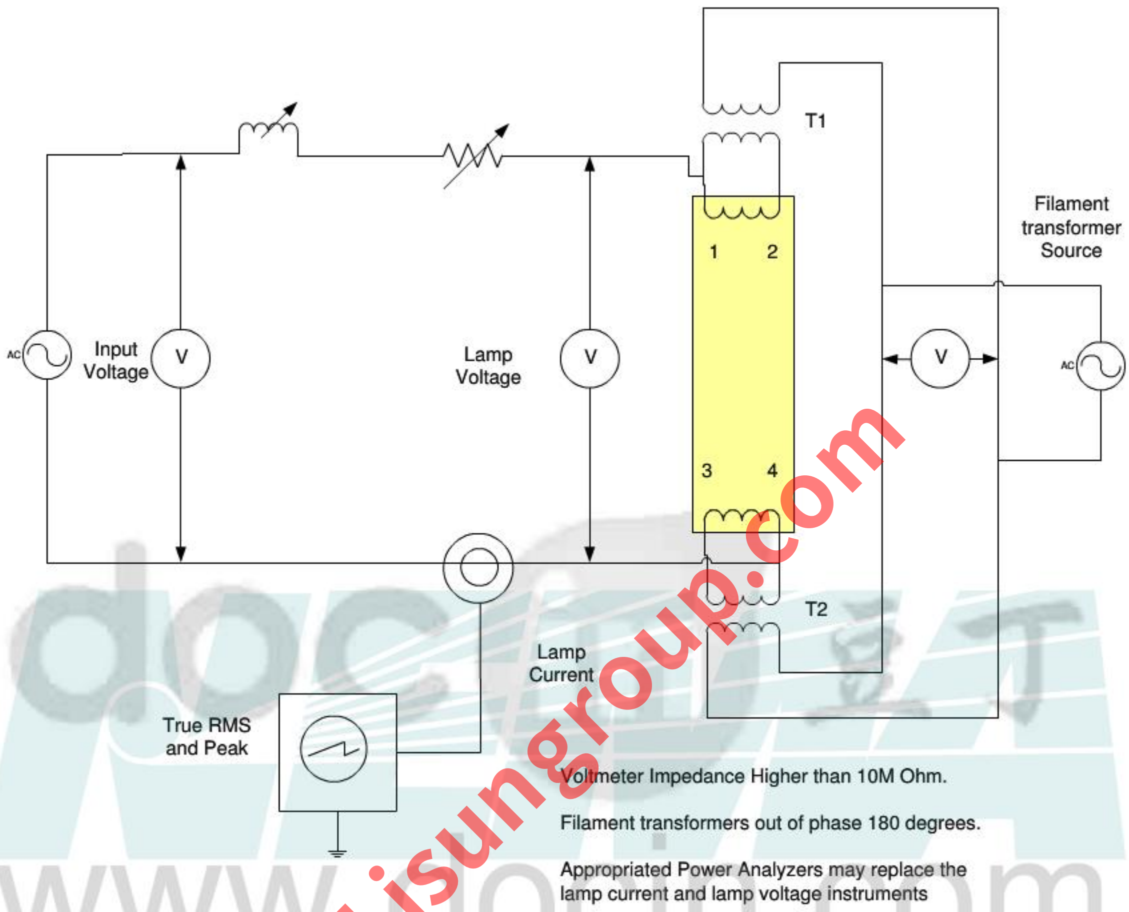


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**Figure C-4**
**Reference Ballast**

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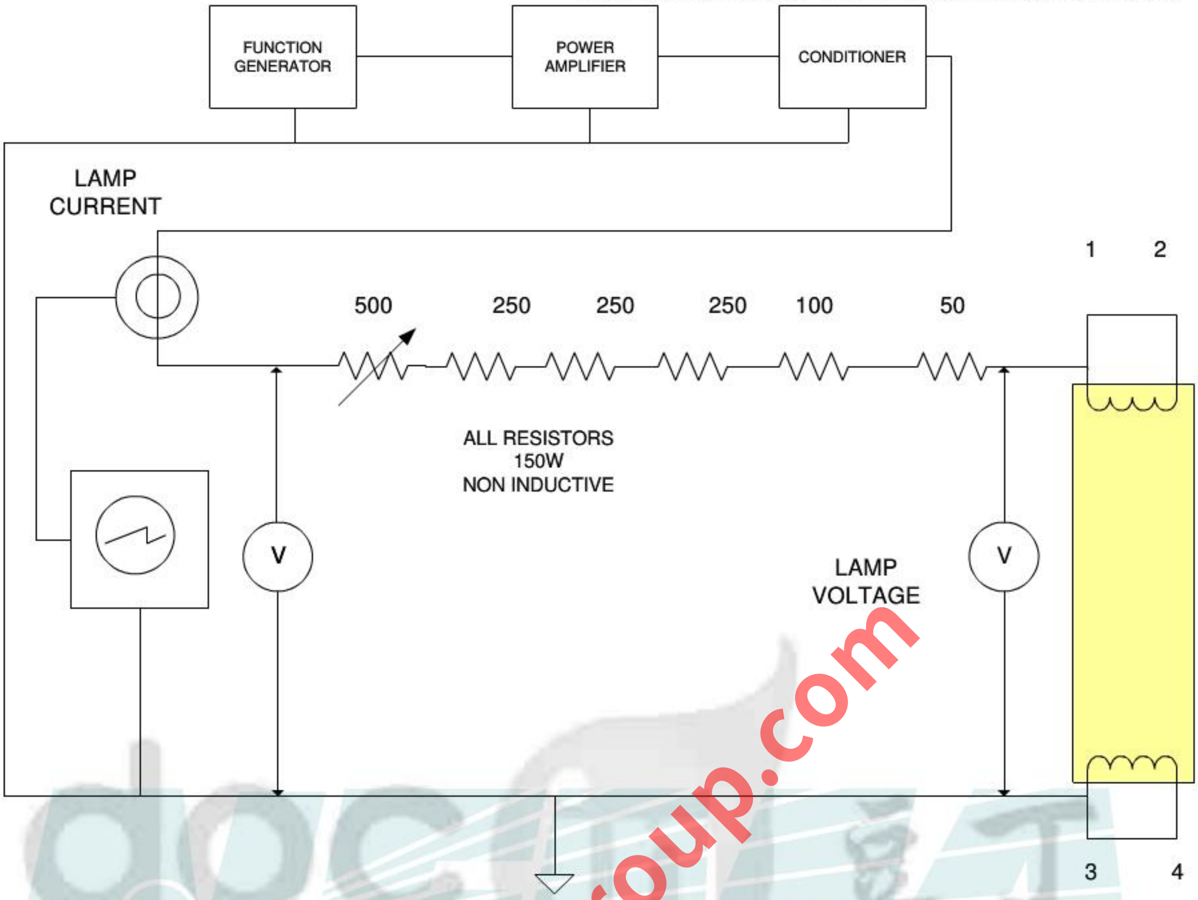


RESISTANCE VALUES ARE FOR REFERENCE ONLY.

**Figure C-5**
**H.F. Reference Ballast**

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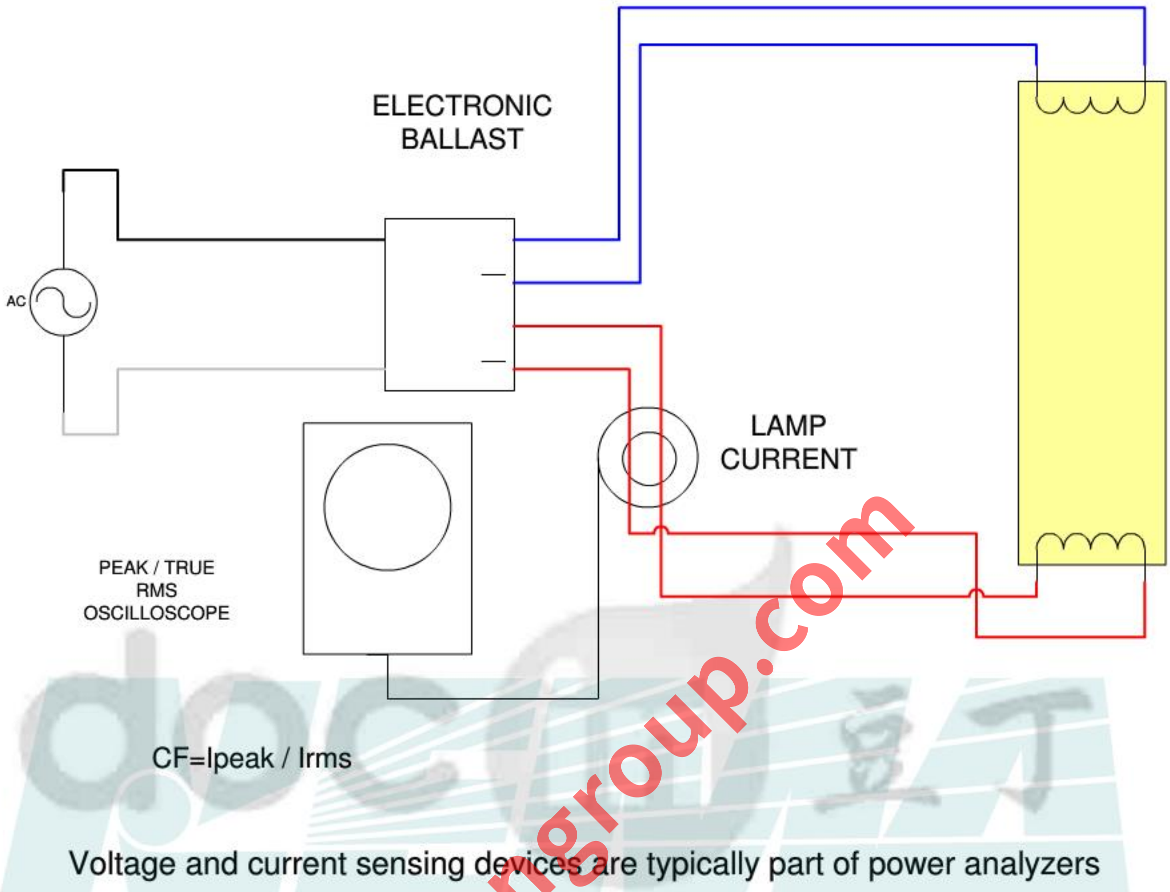


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**Figure C-6**
**Crest Factor Measurement**

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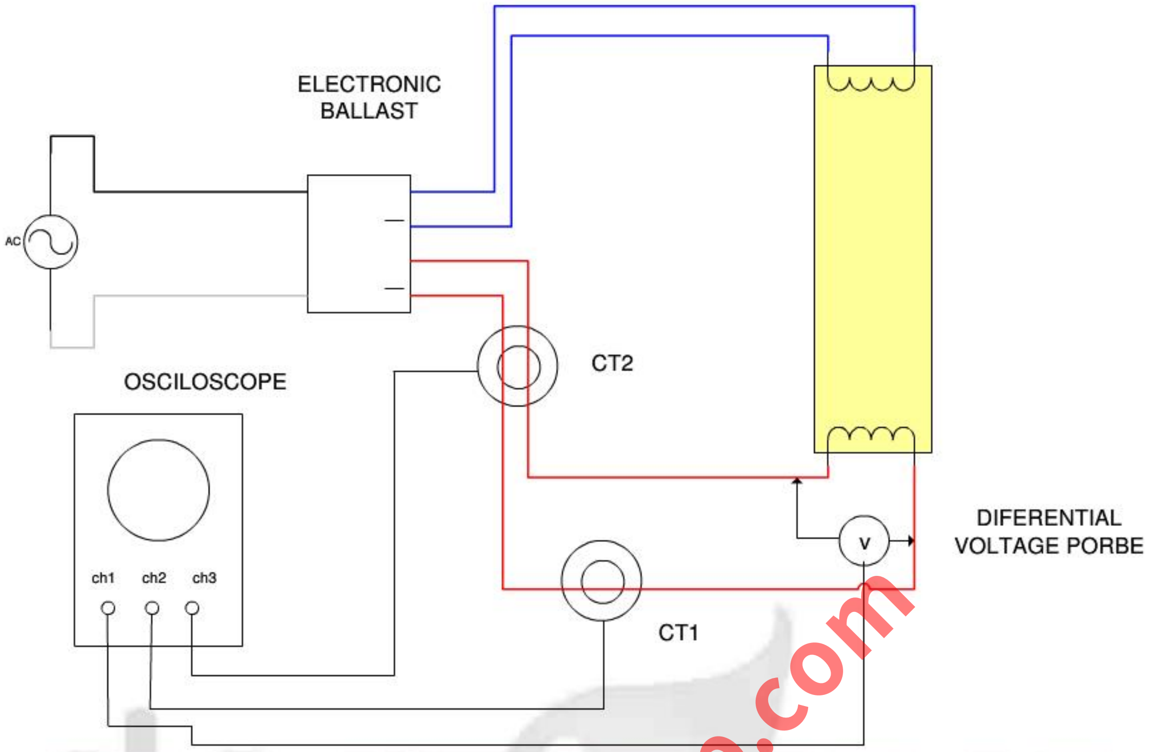


CT1 measures filament current
CT2 measures arc current

**Figure C-7**
**Preheat Time**

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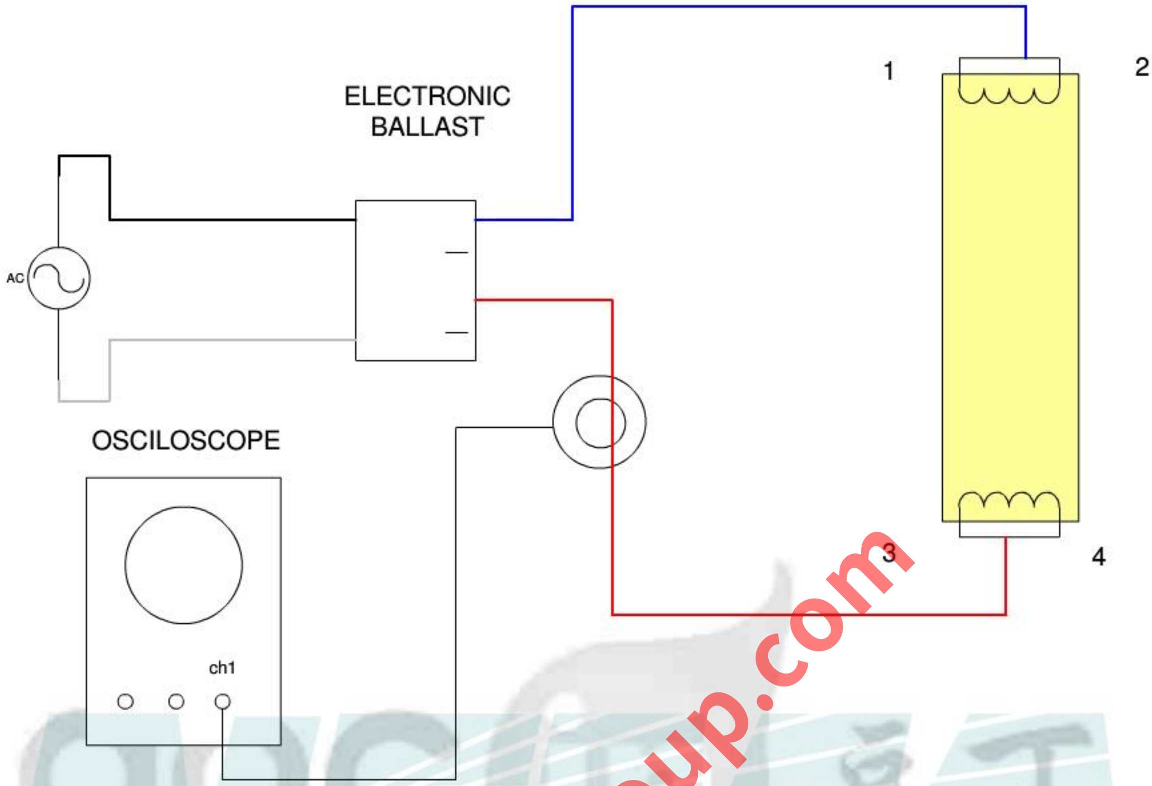


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**Figure C-8**
**Instant Start**

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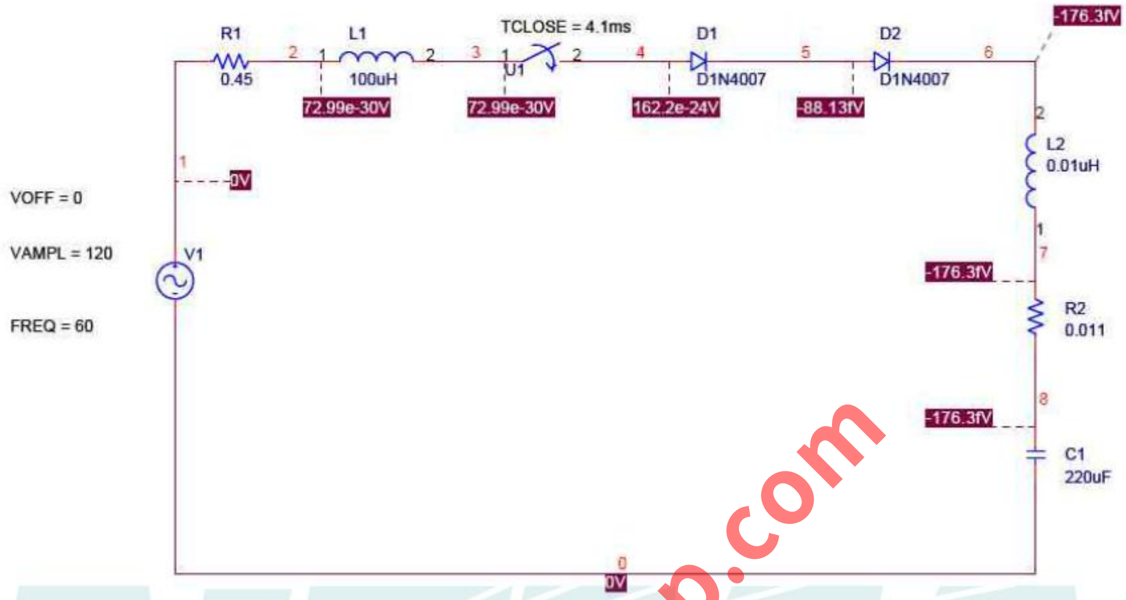


**Figure C-9**
**Inrush Current One Ballast Model**

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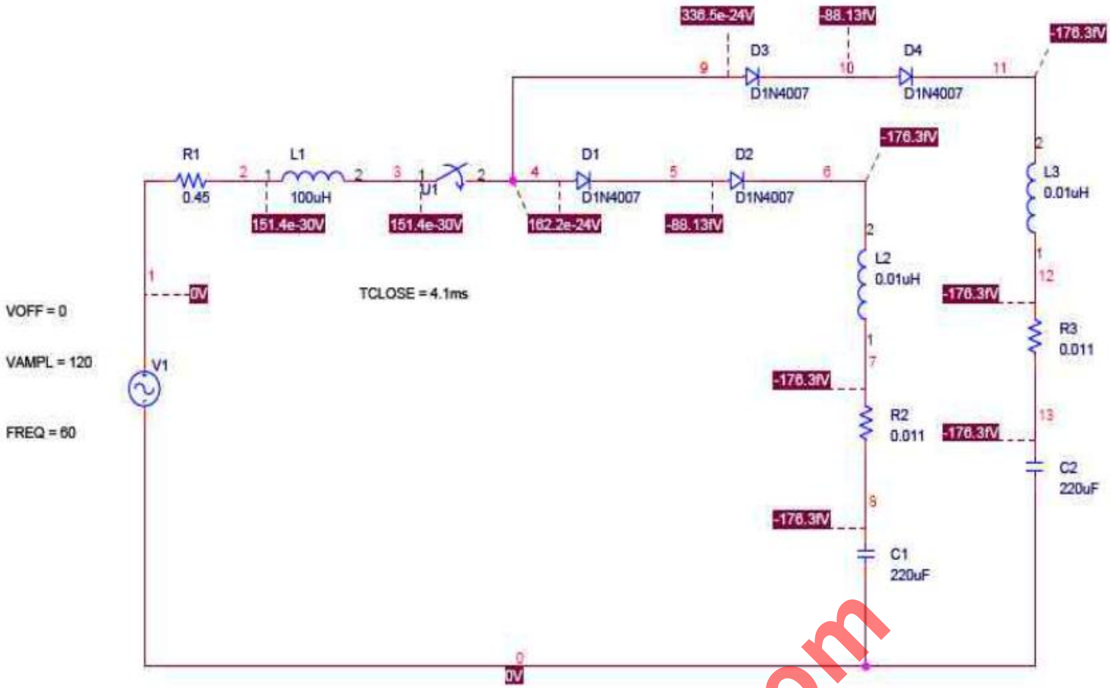


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**Figure C-10**
**Inrush Current Multiple Ballast Model**

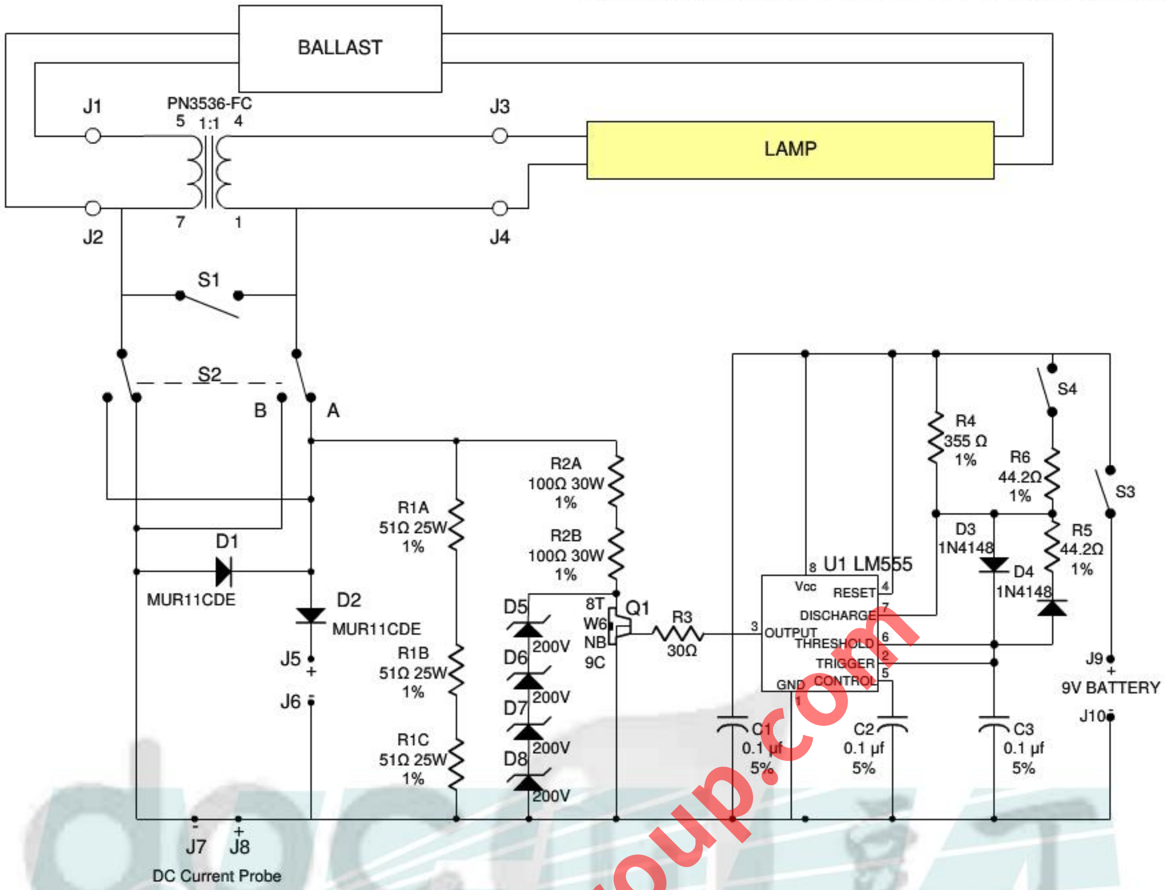


**Figure C-11**
**Asymmetric Pulse Test Circuit**

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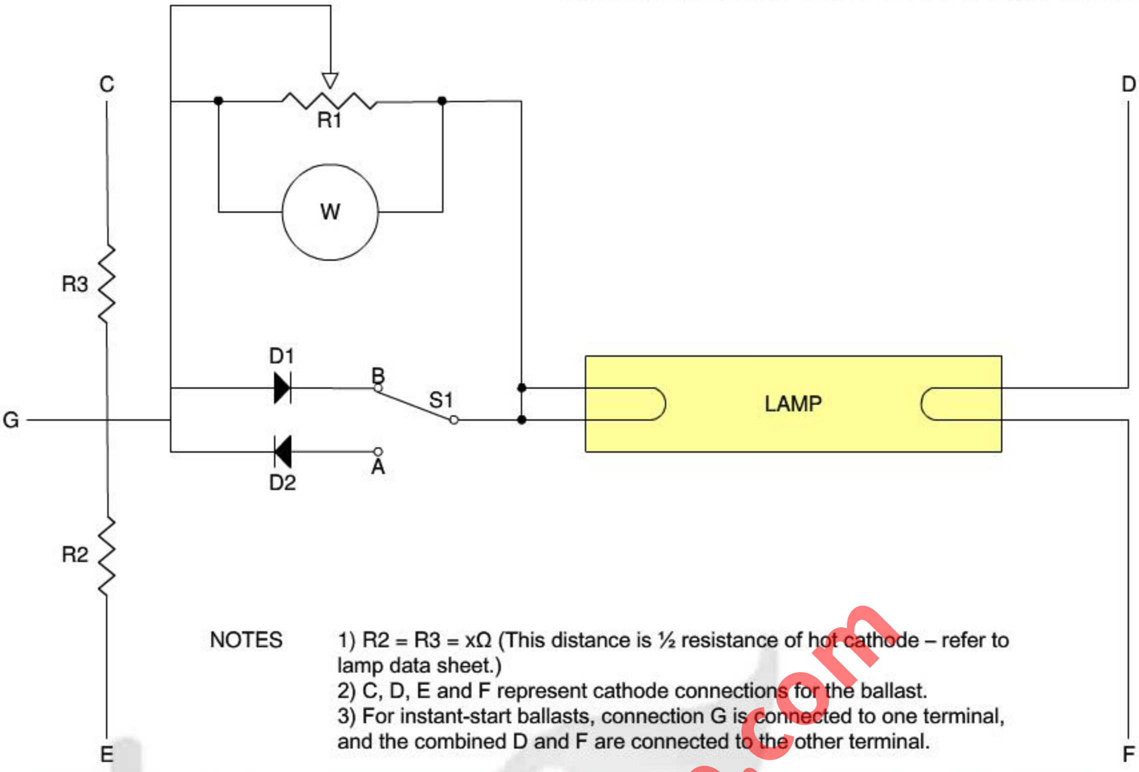


NOTES
1) R2 = R3 = xΩ (This distance is ½ resistance of hot cathode – refer to lamp data sheet.)
2) C, D, E and F represent cathode connections for the ballast.
3) For instant-start ballasts, connection G is connected to one terminal, and the combined D and F are connected to the other terminal.

**Figure C-12**
**Asymmetric Power Test**

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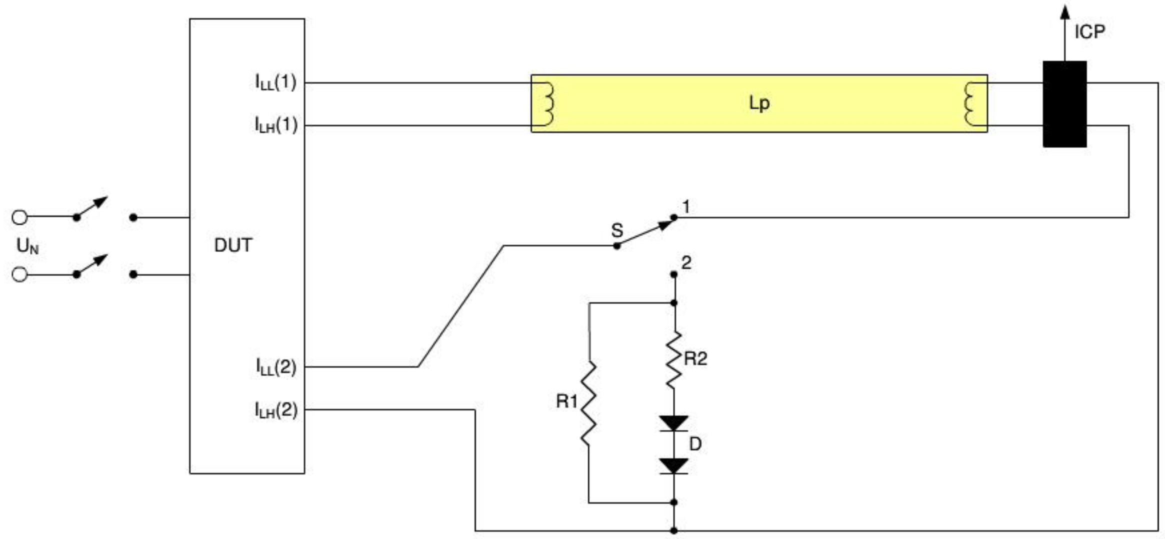


Lp = lamp
Lp1 = straight lamp, copper foil width 4 cm
Lp2 = bent lamp (single-based and circular), copper foil width twice 2 cm, foils connected
$U_N$ = supply
F = copper foil, width 4 cm or 2 cm x 2 cm
ICP = $I_{lamp}$ current probe

R1 = 10 kΩ
R2 = 22 Ω, 7 W
R3 = 1 MΩ

D = fast diodes
DUT = device (ballast) under test
Dp = differential probe ‹ 10 pF

**Figure C-13**
**Open Filament Test (a)**

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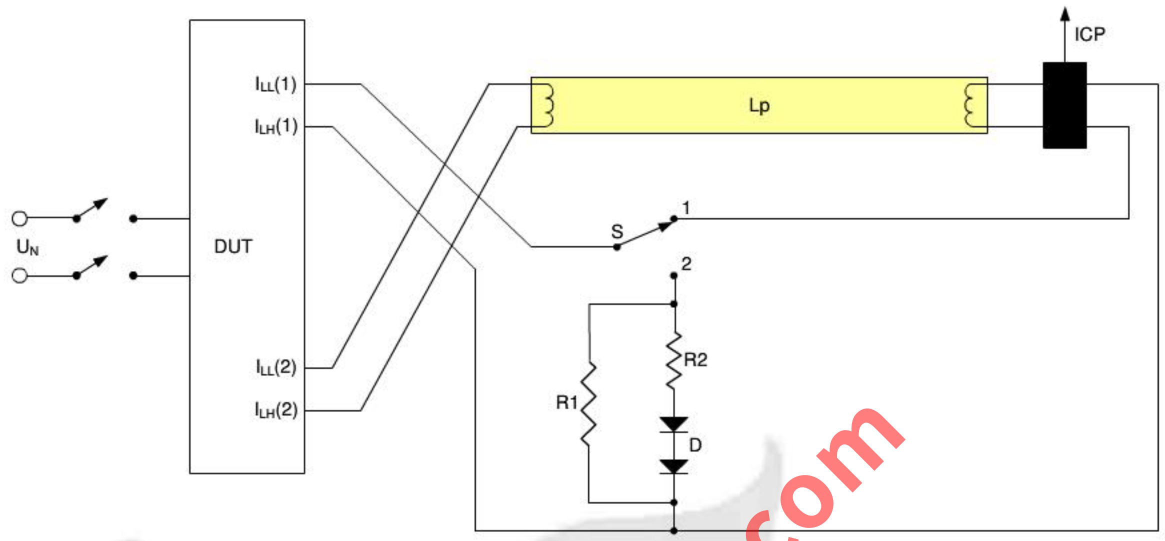


**Figure C-14**
**Open Filament Test (b)**

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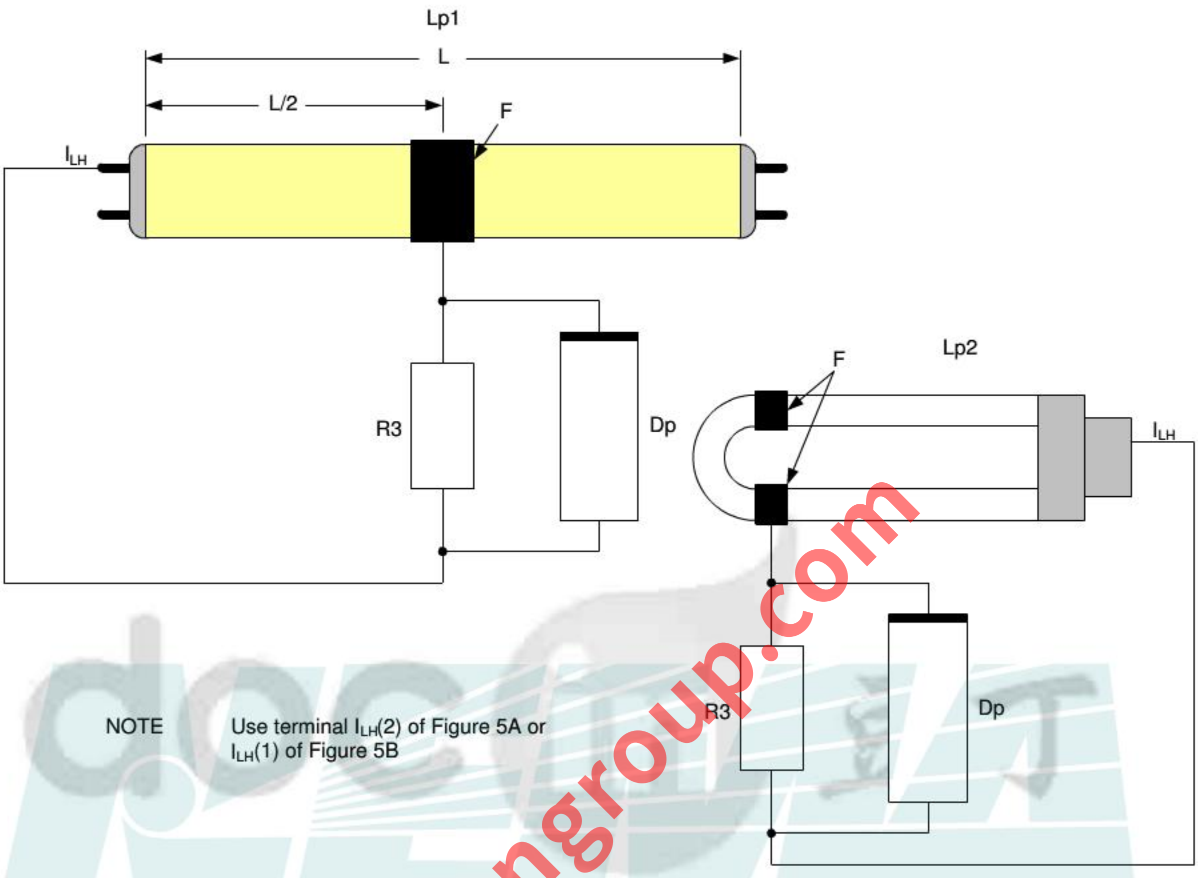


NOTE Use terminal $I_{LH}$(2) of Figure 5A or $I_{LH}$(1) of Figure 5B

**Figure C-15**
**Open Filament Lamp Current Detection Test**

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