



# Standard Test Method for Determining the Linearity of a Photovoltaic Device Parameter with Respect To a Test Parameter<sup>1</sup>

This standard is issued under the fixed designation E1143; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This test method determines the degree of linearity of a photovoltaic device parameter with respect to a test parameter, for example, short-circuit current with respect to irradiance.

1.2 The linearity determined by this test method applies only at the time of testing, and implies no past or future performance level.

1.3 This test method applies only to non-concentrator terrestrial photovoltaic devices.

1.4 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>2</sup>

E772 Terminology Relating to Solar Energy Conversion

E948 Test Method for Electrical Performance of Photovoltaic Cells Using Reference Cells Under Simulated Sunlight

E1036 Test Methods for Electrical Performance of Nonconcentrator Terrestrial Photovoltaic Modules and Arrays Using Reference Cells

E1328 Terminology Relating to Photovoltaic Solar Energy Conversion

## 3. Terminology

3.1 **Definitions**—For definitions of terms used in this test method, see Terminologies E772 and E1328.

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee E44 on Solar, Geothermal and Other Alternative Energy Sources and is the direct responsibility of Subcommittee E44.09 on Photovoltaic Electric Power Conversion.

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

## 3.2 Definitions of Terms Specific to This Standard:

3.2.1 **photovoltaic device parameter**—a characteristic of a photovoltaic device, such as short-circuit current or open-circuit voltage.

3.2.2 **test parameter**—a characteristic of the test conditions to which the photovoltaic device is exposed, such as irradiance or temperature.

## 3.3 Symbols:

| Meaning                         | Symbol |
|---------------------------------|--------|
| Test parameter                  | $X$    |
| Device parameter                | $Y$    |
| Number of data pairs taken      | $n$    |
| Slope of the linear function    | $m$    |
| Fit to the data                 |        |
| Estimated variance of the slope | $s^2$  |

## 4. Summary of Test Method

4.1 This test method requires the measurement of the parameters in question at or near the anticipated device operating conditions. The number of measurements made must be sufficient to cover the range of operating conditions expected.

4.2 Device electrical parameters shall be measured in accordance with Test Methods E948 or Methods E1036, whichever is applicable.

4.3 A linear function that passes through the origin is fit to the data, and the deviation of these data from the function is used as the criterion for determining linearity.

## 5. Significance and Use

5.1 This test method is used to evaluate the applicability of other ASTM test methods to a photovoltaic device.

5.2 The procedure described in this test method is intended to be used to determine the degree of linearity between the short-circuit current of a photovoltaic device and the irradiance level incident on the device. This test method can be used for other device parameters, provided the function passes through the origin.

## 6. Procedure

6.1 Measure the device parameter for at least five values of the test parameter. Choose the values of the test parameter such that they span the expected operating range in approximately

equal intervals. For determining the linearity of short-circuit current with respect to irradiance, use four equally spaced irradiance intervals over the range of approximately 750 to 1100 W/m<sup>2</sup>.

6.1.1 All applicable electrical measurements must be performed in accordance with Test Methods **E948** or Methods **E1036**, whichever is applicable.

## 7. Calculation <sup>3</sup>

7.1 The slope,  $m$ , of the linear function is calculated using the following equation:

$$m = \frac{\sum_{i=1}^n X_i Y_i}{\sum_{i=1}^n X_i^2} \quad (1)$$

7.2 The estimated variance of the slope is given as follows:

$$s^2 = \frac{\sum_{i=1}^n (Y_i - mX_i)^2}{(n-1) \sum_{i=1}^n X_i^2} \quad (2)$$

<sup>3</sup> Natrella, Mary, "Characterizing Linear Relationships Between Two Variables," NBS Handbook, Vol 91, 1966.

7.3 Device electrical parameters may be considered linear with respect to the test parameter if the criterion is met as follows:

$$s/m \leq 0.02$$

7.3.1 For other device parameters, other criteria may need to be defined.

## 8. Precision and Bias

8.1 The precision and bias of this test method is limited by the precision and bias of the parameter measurements. Estimates of the precision and bias of these electrical measurements are given in Test Methods **E948** and Methods **E1036**.

8.2 The limit on  $s/m$  of 2 % will limit any electric current measurement error due to a nonlinear current versus irradiance relationship to 2 %.

## 9. Keywords

9.1 linearity; photovoltaic device; photovoltaics; testing

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