



Standard Practice for Contact Performance Classification of Electrical Connection Systems¹

This standard is issued under the fixed designation B868; 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 (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice provides a uniform method of specifying performance requirements for (or reporting test results of) electrical contact and connection systems. Both conductor and connector system performance may be specified by this practice, separately or in combination.

1.2 This practice may be used for separable or permanent contacts employing metallic conductors and contacts.

1.3 This practice provides methods for both signal and power applications.

1.4 This practice does not specify the sample preparation or test sequences required for determining contact performance. It is the responsibility of the user of this practice to determine the applied test sequence(s) appropriate for the application.

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 become familiar with all hazards including those identified in the appropriate Material Safety Data Sheet (MSDS) for this product/material as provided by the manufacturer; to establish appropriate safety and health practices, and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:²

B539 Test Methods for Measuring Resistance of Electrical Connections (Static Contacts)

¹ This practice is under the jurisdiction of ASTM Committee B02 on Nonferrous Metals and Alloys and is the direct responsibility of Subcommittee B02.11 on Electrical Contact Test Methods.

Current edition approved Oct. 1, 2013. Published October 2013. Originally approved in 1996. Last previous edition approved in 2008 as B868 – 96 (2008). DOI: 10.1520/B0868-96R13.

² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

B542 Terminology Relating to Electrical Contacts and Their Use

B812 Test Method for Resistance to Environmental Degradation of Electrical Pressure Connections Involving Aluminum and Intended for Residential Applications

2.2 UL Standard:

UL 486B Wire Connectors for Use with Aluminum Conductors, Third Edition, 1991³

3. Terminology

3.1 Terms used in this practice are defined in Terminology **B542** except as noted in 3.2.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *conductor, n*—electrically conductive member carrying current to a contact interface. Examples are wire and cable, busbar, and conductive paths on an etched printed circuit board.

3.2.2 *contact performance, n*—contact interface behavior as indicated by initial electrical resistance and resistance change under the applied test conditions.

4. Summary of Practice

4.1 The prescribed performance specification (or reporting) statement consists of three sections, as follows:

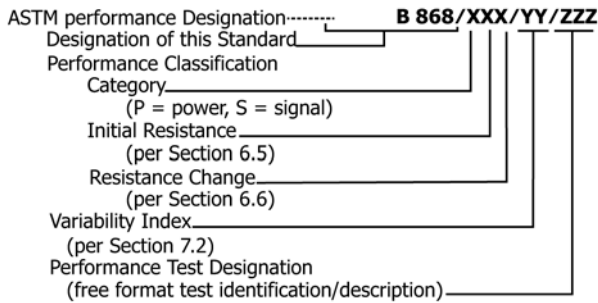
4.1.1 *Performance Classification*, in accordance with this practice (Section 6).

4.1.2 *Variability Index*, determined by sample size and distribution of resistance values measured at end of test, in accordance with this practice (Section 7).

4.1.3 Statement of test method employed to determine performance classification.

4.2 The format for the performance specification (or reporting) statement is as follows:

³ Available from Underwriters Laboratories (UL), 333 Pfingsten Rd., Northbrook, IL 60062-2096, http://www.ul.com.



5. Significance and Use

5.1 This practice is based on the use of electrical resistance as an indicator of contact performance.

5.2 Existing standards, such as those referenced in Section 2 as representative examples, provide the basis for applied test conditions. Modifications in procedure or sample size, or both, of existing standards may have to be made to provide for resistance measurement and to meet variability index requirements that a user may specify.

5.3 This practice accommodates the use of multiple test methods, as may be required to assure satisfactory performance in a given application.

6. Performance Classification

6.1 The performance classification statement consists of three letters in sequence indicating, respectively, category of contact (signal or power), average initial contact resistance, and change of average contact resistance as a consequence of the applied test conditions.

6.2 For this standard classification method, the performance of a connection system for power applications is expressed as the ratio of the contact resistance to the equivalent resistance of the attached conductor. The equivalent resistance of the conductor is the resistance of a length of solid circular conductor exactly one diameter in length. The conductor size used for the evaluation shall be that which is normally specified or utilized with the particular connection system being evaluated.

6.2.1 For connection systems involving solid circular conductors, the equivalent resistance R_d is calculated according to the formula:

$$R_d = R \times D$$

where:

R_d = equivalent resistance,

R = resistance per unit length, Ω , and

D = diameter of conductor (in same length unit).

6.2.1.1 [Appendix X1](#) provides representative nominal data for some common sizes of copper and aluminum conductors of circular cross section for the purpose of establishing instrumentation requirements.

6.2.2 For conductors with other than solid circular cross section, equivalent diameter based on actual conductive cross-section area shall be used. For example: a conductor of rectangular cross section 0.5 by 6 mm has a cross-section area

equal to that of a solid circular conductor 1.95 mm in diameter, and therefore D in the equation in [6.2.1](#) is 1.95 mm.

6.2.3 For contacts incorporating or connecting conductors of different materials or cross section, or both, the R_d value used for contact performance determination shall be based on the conductor of minimum resistance per unit length.

6.2.4 For contacts involving a connector, the conductor material and cross section used for determination of the R_d value to be used shall be the wire, busbar, circuit board conductive strip, or other, as appropriate for the rating or representative application of the connector. The conductor size may be determined according to the connector manufacturer's specification, current rating, or conventional application practice.

6.2.5 Conductor resistance per unit length is preferably determined by measurements incorporating the same instrumentation used for contact resistance measurements, at the same ambient temperature and current as for the contact performance test being applied.

6.2.6 When conductor resistance is determined at the same time as contact performance in accordance with [6.2.5](#), and the conductor is solid with circular cross section, potential drop measurements may be used without conversion for the purpose of determining contact performance. (See example, [Appendix X2](#).)

6.3 Contact resistance shall be measured in accordance with Test Methods [B539](#).

6.3.1 For power connections, resolution of resistance determination shall be $0.1 R_d$ or better. For most applications, this requires potential drop resolution of $10 \mu\text{V}$ at a measurement current density approximately equal to conductor ratings. (See [Appendix X1](#).) Use Test Method B of Test Methods [B539](#) adjusting the current to meet the stated current requirements.

6.3.2 For signal connections, resolution of resistance determination shall be at 10 % of the average initial contact resistance or better, using Test Method C of Test Methods [B539](#).

6.3.3 For contact configurations in which bulk conductor or connector resistance is included in the measured contact resistance, a single value of measured bulk resistance (see Test Methods [B539](#)) shall be subtracted from the measured contact resistance values. Resolution of the bulk resistance measurement shall be $0.1 R_d$ or finer, and the bulk resistance measurement error tolerance shall be no greater than $\pm 0.2 R_d$.

6.4 The first letter of the performance classification, indicating contact category, shall be "P" for power contacts and connections and "S" for signal contacts and connections. The letter is assigned according to the intended application for each of the applied test conditions.

6.4.1 A given connector type may be intended for multiple applications, both signal and power (example: circuit board connector). The category used for performance classification for each test sequence applied shall be that for which the test sequence is intended.

6.5 The letter indicating performance with respect to average (arithmetic mean) initial resistance of all samples tested shall be in accordance with [Table 1](#).

TABLE 1 Initial Resistance Indicator

Initial Resistance Indicator	Average Initial Resistance	
	Power Category (P)	Signal Category (S)
A	$R_c < 1.1 R_d$	$R_c < 5 \text{ m}\Omega$
B	$< 2 R_d$	$< 10 \text{ m}\Omega$
C	$< 5 R_d$	$< 20 \text{ m}\Omega$
D	$< 10 R_d$	$< 50 \text{ m}\Omega$
E	$< 100 R_d$	$< 100 \text{ m}\Omega$
F	$< 1000 R_d$	$< 200 \text{ m}\Omega$
G	$\geq 1000 R_d \dagger$	$\geq 200 \text{ m}\Omega \dagger$

† corrected editorially.

6.6 The letter indicating performance with respect to resistance change of the worst-case sample tested shall be in accordance with [Table 2](#).

TABLE 2 Resistance Change Indicator

Change Indicator	Power Category (P)	Signal Category (S)
	Ratio: Final/Initial Resistance of Worst-Case Sample	Resistance Change of Worst-Case Sample (Initial to Final R_d), mΩ
A	< 1.1	< 0.5
B	< 2	< 1.0
C	< 5	< 2.0
D	< 10	< 5.0
E	< 100	< 10
F	< 1000	< 20
G	$\geq 1000 \dagger$	$\geq 20 \dagger$

† corrected editorially.

7. Variability Index

7.1 Variability Index for Power Category (P):

7.1.1 The variability index V for power category connections is calculated from the resistance values determined at the end of the test sequence, expressed to two significant figures or to a resolution of $0.1 R_d$.

7.1.2 For power category connections, the variability index is calculated by the following formula (see [Note 1](#)):

$$V = \sqrt{\frac{\sum_{i=1}^n (R_f/R_d - \bar{R}_f/R_d)^2}{n-1}} \quad (1)$$

where:

R_f = final resistance for each connection tested, and
 \bar{R}_f = arithmetic mean final resistance for the total set of n connections tested.

NOTE 1—While the variability index is numerically the same as the statistical sample standard deviation, it should not be used for statistical predictions of contact performance.

7.2 Variability Index for Signal Category (S):

7.2.1 The variability index V for signal category connections is calculated from the resistance change from beginning to end of the test sequence, expressed to two significant figures or to a resolution of $0.1 \text{ m}\Omega$.

7.2.2 For signal category connections, the variability index is calculated by the following formula (see [Note 1](#)):

$$V = \sqrt{\frac{\sum_{i=1}^n (R_c - \bar{R}_c)^2}{n-1}} \quad (2)$$

where:

R_c = resistance change for each connection tested, $\text{m}\Omega$, and
 \bar{R}_c = arithmetic mean resistance change for the total set of n connections tested, $\text{m}\Omega$.

8. Format

8.1 A format for specifying connection or contact performance is: “Connections shall meet or exceed ASTM B868 Class XXX with YY variability index when tested according to the applied conditions of ZZZ,” where “XXX” is the performance classification (Section 6), “YY” is the variability index (Section 7.1.1), and “ZZZ” is the specified test method. A condensed form is: “Connections shall meet or exceed ASTM B868 Class XXX/YY/ZZZ.”

8.2 A format for reporting contact performance test results is: “Performance is ASTM B868 XXX with YY variability index when tested according to the applied conditions of ZZZ.” A condensed form of the statement is: “Tested contact performance is ASTM B868 Class XXX/YY/ZZZ.”

8.3 Parentheses may be used to indicate specific applied conditions, sample size, conductors used, duration of test, portion of procedure applicable, or other necessary information.

8.4 When a connections system is rated for application to multiple types or combinations of conductors, but is specified by a single classification, the worst-case performance classification shall be used. Multiple classifications may be utilized, provided that the conductor combinations for which the classifications apply are adequately described. (Examples are provided in [Appendix X2](#).)

8.5 The value of R_d used shall be reported for other than solid circular conductors.

8.6 According to the requirements of the application, more than one test procedure can be specified.

8.7 Example of use, including multiple test procedures and additional parenthetical information is: “Connections shall meet or exceed ASTM B868 Class PAB/1.0/ASTM B812 – 90 (20 weeks, with any number of conductors, conductor material combinations, conductor size combinations for which the connector is rated to be used); ASTM B868 Class PAB/0.4/UL486B (Section 6.11 of UL486B, with any number of conductors, conductor material combinations, or conductor size combinations for which the connector is rated to be used).”

8.8 A detailed test record, including description of applied conditions, test data, and the calculations for equivalent diameter, if other than solid circular conductor and R_d , shall be available.

8.9 Examples of application of the performance classification method to several connection systems are provided in [Appendix X2](#). (Note: the examples provided in [Appendix X2](#) to illustrate application of the classification method are not to be interpreted as specifications of test requirements.)

9. Precision and Bias

9.1 Precision and bias are those of the test method(s) applied.

10. Keywords

10.1 classification; conductor; connector; contact; electrical contact; electrical connection systems; metallic; resistance

APPENDIXES
(Nonmandatory Information)
X1. EXAMPLES OF RESISTANCE AND POTENTIAL DROP PER R_d

X1.1 **Table X1.1** and **Table X1.2** of **Appendix X1** are provided for illustration purposes only and should not be interpreted as specifications for test conditions or ratings.

X1.4 Sample Calculation: for #1 AWG copper wire, 0.126 ohm/1000 ft, 0.289-in. diameter.

$$R_d = R \times D \text{ (in same length units)}$$

$$= 0.126 \times 0.289 \times 1/(12 \times 1000) = 3.03 \mu\Omega$$

$$\text{Potential drop per } R_d \text{ at 110-A current} = I \times R_d$$

$$= 110 \times 3.03 = 333 \mu\text{V}$$

TABLE X1.1 Copper Conductors, Common Sizes

Am. Wire Gage Diameter	Diameter, in.	Cross Sec. Area, sq in.	Copper, ohms per 1000 ft	R_d , micro-ohm	Measurement Current, amps	Micro-volts per R_d at Measurement Current
000	0.41	0.132	0.063	2.15	165	355
00	0.365	0.105	0.0795	2.42	145	351
0	0.325	0.0829	0.1	2.71	125	339
1	0.289	0.0657	0.126	3.03	110	333
2	0.258	0.0521	0.159	3.42	95	325
3	0.229	0.0413	0.201	3.84	85	326
4	0.204	0.0328	0.253	4.30	70	301
6	0.162	0.0206	0.403	5.44	55	299
8	0.128	0.013	0.641	6.84	40	274
10	0.102	0.00815	1.02	8.67	30	260
12	0.081	0.00513	1.62	10.94	25	274
14	0.064	0.00323	2.58	13.76	20	275
16	0.051	0.00203	4.09	17.38	15	261
18	0.04	0.00128	6.51	21.70	11	239
20	0.032	0.000802	10.4	27.73	9	250
22	0.0253	0.000505	16.5	34.79	7	243
24	0.0201	0.000317	26.2	43.89	6	263
26	0.0159	0.0002	41.6	55.12	5	275

TABLE X1.2 Aluminum Conductors, Common Sizes

Am. Wire Gage Diameter	Diameter, in.	Cross Sec. Area, sq in.	Aluminum, ohms per 1000 ft	R_d , micro-ohm	Measurement Current, amps	Micro-volts per R_d at Measurement Current
000	0.41	0.132	0.1014	3.46	130	450
00	0.365	0.105	0.1278	3.89	115	447
0	0.325	0.0829	0.1612	4.37	100	437
1	0.289	0.0657	0.2033	4.90	85	416
2	0.258	0.0521	0.2564	5.51	75	413
3	0.229	0.0413	0.3233	6.17	65	401
4	0.204	0.0328	0.4076	6.93	55	381
6	0.162	0.0206	0.6482	8.75	40	350
8	0.128	0.013	1.03	10.99	30	330
10	0.102	0.00815	1.638	13.92	25	348
12	0.081	0.00513	2.606	17.59	20	352

X2. EXAMPLES OF APPLICATION

NOTE X2.1—The examples in Appendix X2 demonstrate application of the performance classification method using actual test data. The examples are not to be interpreted as specifications of tests or test conditions.

X2.1 Full Compression Splicing Connectors (Power Category) With Different Conductor Combinations:

NOTE X2.2—Potential drop measurements are utilized directly in this example, in accordance with 6.2.6.

Measurement current = 12 A, instrument resolution = 0.01 mV, power connectors
 Conductor data (calculated from measurement of a 100-diameter length)

For Test A below, potential drop per R_d is 0.165 mV at 12 A

For Test B below, potential drop per R_d is 0.207 mV at 12 A

X2.1.1 Connection Performance Data and Classification:

X2.1.1.1 Conductor Combination A:

	Initial		Final	
	mV	ratio	mV	ratio
(114 specimens)				
Mean contact potential drop	0.42	2.6 R_d	0.55	3.3 R_d
Variability index	0.71	4.3 R_d	1.22	7.4 R_d

Classification—ASTM B868 Class PCB/7.4/(3-year cycling at 17.5 A 10 % duty cycle, then 10-year normal in-wall environment exposure, 2 #10 AWG Type 1 and 1 #12 Type 2 conductors, tested with current through Type 1 conductors.)

X2.1.1.2 Conductor Combination B:

	Initial		Final	
	mV	ratio	mV	ratio
(114 specimens)				
Mean contact potential drop	0.07	0.3 R_d	0.07	0.3 R_d
Variability index	0.04	0.2 R_d	0.04	0.2 R_d

Classification—ASTM B868 Class PAA/0.2/(3-year cycling at 13.5 A 10 % duty cycle, then 10-year normal in-wall environment exposure, 2 #12 AWG Type 1 and 1 #12 Type 2 conductors, tested with current through Type 2 conductor.)

X2.1.1.3 In accordance with 8.4, a single performance classification for the connection system in the example above would be based on the worst case, as follows:

Classification: ASTM B868 Class PCB/7.4/(3-year cycling at 90 % of conductor-rated current 10 % duty cycle, then 10-year normal in-wall environment exposure).

X2.2 Two-Wire Splices (Power Category), Hand-Applied Connector:

NOTE X2.3—Potential drop measurements are utilized directly in this example in accordance with 6.2.6.

Measurement current = 13.5 A, instrument resolution = 0.01 mV, power connectors

Conductor data (calculated from measurement of a 100-diameter length)

Type 1 wire #12 AWG, potential drop per R_d is 0.225 mV at 13.5 A

Type 2 wire #12 AWG, potential drop per R_d is 0.144 mV at 13.5 A

X2.2.1 Connection Performance Data and Classification:

X2.2.1.1 Wires—(2) #12 Type 1 (58 specimens):

	Initial		Final	
	mV	ratio	mV	ratio
Mean contact potential drop	5.08	22.6 R_d	11.5	51.1 R_d
Variability index	1.30	5.8 R_d	5.18	23.0 R_d

Classification—ASTM B868 Class PEC/5.2/(10-year, normal in-wall environment exposure, no current, conductors—2 #12 Type 1.)

X2.2.1.2 Wires (2) #12 Type 2 (20 specimens):

	Initial		Final	
	mV	ratio	mV	ratio
Mean contact potential drop	2.48	17.2 R_d	2.33	16.2 R_d
Variability index	0.22	1.5 R_d	0.29	2.0 R_d

Classification—ASTM B868 Class PEA/2.0/(10-year, normal in-wall environment exposure, no current, conductors—2 #12 Type 2.)

X2.2.1.3 In accordance with 8.4, a single performance classification for the connection system in the example above would be based on the worst case, as follows:

Classification—ASTM B868 Class PEC/5.2/(10-year, normal in-wall environment exposure, no current.)

X2.3 Separable Connector (Signal Category):

X2.3.1 The following properties are obtained from samples tested in a 100°C heat age test for 1000 h (test EIA364-17A):

Mean initial resistance	7.5 mΩ
Worst-case resistance change after aging	4.2 mΩ
Standard deviation of resistance change	1.32 mΩ

X2.3.1.1 Classification: ASTM B868 Class SBD/1.3/EIA364-17A (100°C, 1000 h).

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