Designation: F458 – 13

Standard Practice for Nondestructive Pull Testing of Wire Bonds[1,2]

This standard is issued under the fixed designation F458; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope

1.1 This practice covers nondestructive testing of individual wire bonds made by either ultrasonic, thermal compression or thermosonic techniques. The test is intended to reveal (by breaking) nonacceptable wire bonds but is designed to avoid damage to acceptable wire bonds.

NOTE 1—Common usage at the present time considers the term "wire bond" to include the entire interconnection: both welds and the intervening wire span.

1.2 The practice covers wire bonds made with small-diameter (from 0.0007 to 0.003-in. (18 to 76-μm)) wire such as the type used in integrated circuits and hybrid microcircuits, system in package, and so forth.

1.3 This practice can be used only when the loop height of the wire bond is large enough to allow a suitable hook for pulling to be placed under the wire.

1.4 While the procedure is applicable to wire of any composition and metallurgical state, criteria are given only for gold and aluminum wire.

1.5 A destructive pull test is used on wire bonds of the same type and geometry to provide the basis for the determination of the nondestructive pulling force to be used in this practice. This may only be used if the sample standard deviation, s, of the pulling forces required to destroy at least 25 of the same wire bonds tested by the destructive pull-test method is less than or equal to 0.25 of the sample average, $\bar{x}$. If $s > 0.25\ \bar{x}$, this practice may not be used.

NOTE 2—If $s > 0.25\ \bar{x}$, some aspect of the bonding process is out of control. Following corrective action, the destructive pull-test measurements should be repeated to determine if the $s \leq 0.25\ \bar{x}$ criterion is met.

1.6 The nondestructive wire-bond pull test is to be performed before any other treatment or screening following bonding and at the same point in processing as the accompanying destructive test. Preferably, this is done immediately after bonding.

1.7 The procedure does not ensure against wire-bond failure modes induced after the test has been performed.

1.8 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.9 *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:*[3]

F459 Test Methods for Measuring Pull Strength of Microelectronic Wire Bonds

2.2 *Military Standard:*[4]

MIL-STD-883 Method 2023

3. Summary of Practice

3.1 The use of nondestructive wire-bond pull tests is predicated on data obtained from destructive pull tests on typical samples selected from a lot. The maximum safe nondestructive pull-force levels are determined as a function of the metallurgical properties of the wire and from the calculated mean ($\bar{x}$) and standard deviation (s) of the destructive pull-test data determined in accordance with Test Methods F459.

3.2 In some cases, rather than use a calculated nondestructive pull force, a fixed pull force may be agreed upon by test participants. This value may be based upon industry practice, or some other accepted value, such as that in MIL STD 883, Method 2023. All other parts of the present ASTM standard will apply.

[1] This practice is under the jurisdiction of ASTM Committee F01 on Electronics and is the direct responsibility of Subcommittee F01.03 on Metallic Materials, Wire Bonding, and Flip Chip.

Current edition approved Jan. 1, 2013. Published January 2013. Originally approved in 1976 as F458 – 76 T. Last previous edition approved in 2006 as F458 – 06. DOI: 10.1520/F0458-13.

[2] This procedure, with current status and limitations, was published in: Harman, G. G., *Wire Bonding in Microelectronics*, 3rd Edition, McGraw Hill, 2010, Appendix 4B.2.

[3] 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.

[4] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111–5094, Attn: NPODS.

3.3 The maximum safe nondestructive bond-pull force is then applied as a screen for individual wire bonds to identify all bonds with pull strength below the predetermined level of acceptability.

4. Significance and Use

4.1 The nondestructive wire-bond pull test provides a screen for evaluating wire-bond quality and is capable of detecting weak or nonadherent bonds.

4.2 The test is not destructive and does not damage acceptable wire bonds.

4.3 This practice provides a procedure for identifying a bonding situation that requires corrective action.

4.4 The purpose of this practice is to identify wire bonds that may fail during subsequent screening procedures or field operation.

4.5 The procedure is to be applied after bonding and before any further treatment.

5. Interferences

5.1 The same interferences apply as given in Test Methods F459 (Section 6, Interferences); in addition this test cannot be used on multi-tiered devices.

6. Apparatus

6.1 The apparatus used for the procedure is identical to that used in Test Methods F459 except that the lifting mechanism shall have the capability of stressing the wire bond up to a predetermined level. As this predetermined level may change in accordance with the results of a successive series of tests using Test Methods F459, as well as to accommodate changes in wire composition and metallurgy, the lifting mechanism must be capable of applying an adjustable maximum force.

7. Sampling

7.1 As the test is nondestructive. As such it may be used as a 100 % production line screen so that sampling is not required.

7.2 The test may be used as a lot acceptance test with the sampling scheme agreed to by the participating parties.

8. Calibration and Standardization

8.1 Calibrate the nondestructive stressing device in the same manner as is used in calibrating the destructive wire-bond pull-test apparatus as specified in Test Methods F459.

8.2 Carry out the destructive wire-bond pull test in accordance with either Method A or B of Test Methods F459, whichever is appropriate to the particular wire bond being tested. Use a rate of force application within the range from 1 to 30 gf/s (10 to 290 mN/s) inclusive. Record the force required to break the wire bond, as well as identifying the wire bond, the device, and whether Method A or B was used.

8.2.1 For noncontinuous use of a particular bonding machine, apply either Method A or Method B (whichever is appropriate) of Test Methods F459 to a minimum sample of at least 25 of the same wire bonds once the bonding machine has been turned on, thermally stabilized, and set up by the manufacturers' procedure.

8.2.2 For continuous use of a particular bonding machine, apply either Method A or B (whichever is appropriate) of Test Methods F459 to a sample of approximately 0.1 % (at least 25 bonds) of the particular wire bond under study after every 2-h period of bonding.

8.3 Given a set of n observed values of the destructive wire-bond pull strength $\{x_i\}$, $i = 1, ..., n$, calculate the mean, $\bar{x}$, and the standard deviation, s, of the destructive wire-bond pull test in accordance with the following:

8.3.1 Calculate the average wire-bond pull strength, $\bar{x}$, as follows:

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

8.3.2 Calculate the standard deviation for the sample, s, by either of the following:

$$s = \left\{ \frac{1}{n-1}\sum_{i=1}^{n} (x_i - \bar{x})^2 \right\}^{1/2},$$

or (equivalently)

$$s = \left\{ \frac{1}{n-1}\left[\sum_{i=1}^{n} (x_i{}^2 - n\,\bar{x})^2 \right] \right\}^{1/2}$$

8.4 Using Table 1, select the wire composition and elongation (obtainable from the wire manufacturer), and the relation between $\bar{x}$ and s appropriate to the wire bond to be tested and determine the recommended maximum safe nondestructive pull (NDP) force from the corresponding entry in the last column.

9. Procedure

9.1 Mount the specimen to be tested and set the lifting (pulling) mechanism to apply the force level determined in 8.4.

9.2 Carefully place the hook under the center of the wire-bond loop, as in the previously performed destructive wire-bond pull test.

9.3 Set the rate of force application at the same as that used in the destructive test.

9.4 Actuate the lifting mechanism to stress the wire bond.

9.5 Observe whether the bond breaks. (Some modern pull testers can automatically determine/record breaks.)

9.5.1 If the bond breaks, record the identification of the bond and the device containing the bond.

TABLE 1 Recommended Maximum Safe Nondestructive Pull Force for Aluminum and Gold Wire

NOTE 1—$s > 0.25\ \bar{x}$ is inapplicable

Wire		Relation Between $\bar{x}$ and s on the Wire-Bond Pull Test	Recommended Maximum Safe NDP Force
Composition	Elongation, %		
Aluminum	<5	$0.15\bar{x} < s \le 0.25\bar{x}$	$0.9\ (\bar{x} - 3s)$
Aluminum	<5	$s \le 0.15\bar{x}$	$0.9\ (\bar{x} - 4s)$
Aluminum	5 to 20	$s \le 0.25\bar{x}$	$(\bar{x} - 3s)/2$
Aluminum	>20	$s \le 0.25\bar{x}$	$(\bar{x} - 3s)/3$
Gold	all	$0.15\bar{x} < s \le 0.25\bar{x}$	$0.7\ (\bar{x} - 3s)$
Gold	all	$s \le 0.15\bar{x}$	$0.7\ (\bar{x} - 4\ s)$

9.5.2 If the bond does not break, accept it as satisfactory.

9.6 Repeat 9.1 through 9.5 for all bonds to be tested.

9.7 Record the total number of wire bonds that fail when subjected to the predetermined stress.

9.8 Record the number of devices that failed the test.

10. Report

10.1 Report the following information:

10.1.1 Name of the person performing the test,

10.1.2 Date of the test,

10.1.3 Identification of the microelectronic specimen/device,

10.1.4 Identification of the specific wire bond tested,

10.1.5 Identification of wire by spool and lot,

10.1.6 Identification of bonding machine and pull tester,

10.1.7 Mean and standard deviation of the destructive wire-bond pull tests, as well as the total number of wire bonds so tested,

10.1.8 Percentage of wire bonds that failed upon application of the predetermined safe maximum NDP force.

NOTE 3—Information pertaining to the failure modes observed during the nondestructive test may be useful in failure analysis studies.

11. Keywords

11.1 nondestructive pull test; wire bonds