

RATIONALE

Radiological inspection is a means to inspect the internal attributes of an electronic device. The inspection process is non-destructive, however it can be destructive for certain device types. Radiological inspection allows for expeditious inspection and detection of anomalies of numerous devices.

AS6171/5 has been reaffirmed to comply with the SAE Five-Year Review policy.

INTRODUCTION

Radiology is a tool that can be used for pinpointing defects or regions of interest in Electrical, Electronic, and Electro-mechanical before (EEE) Parts. Radiological inspection permits assessment of defects related to known counterfeiting techniques in EEE devices. The inspection involves illuminating the sample with penetrating radiation and provides images based on variations in material density, thicknesses and atomic numbers. The technique allows for characterization of internal damage, defects, and degradation attributes such as wire bond damage, inconsistent lead frames, die characteristics, and internal damage. The test is typically nondestructive for most part types immune to low levels of radiation, but could be destructive for some device types that are sensitive to radiation.

DISCLAIMER: The images contained herein are provided to illustrate the application of detection methods identified in the document, and are by no means intended to imply that a manufacturer identified in an image and text is involved with the suspect product.

TABLE OF CONTENTS

1.	SCOPE.....	3
2.	REFERENCES.....	3
2.1	Applicable Documents	3
2.2	Terms, Acronyms, and Definitions (as applicable)	4
3.	DESCRIPTION OF METHODOLOGY/PROCEDURE.....	4
3.1	Material Control.....	4
3.1.1	Handling EEE Components	4
3.1.2	Data Exchange Format	4
3.2	Description of Process	4
4.	TEST EQUIPMENT REQUIREMENTS	7
5.	REQUIREMENTS	7
5.1	Sampling	7
5.2	Categories of Testing/Best Practices.....	7
5.2.1	Test Tier Level and Risk Definitions	7
5.2.2	Recommended Best Practices.....	8
5.3	Testing Requirements	8
5.3.1	Information from the User/Requester.....	8
5.3.2	Test Laboratory Requirements	9

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Documents

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5.4	Counterfeit Detection Test Sequence	9
5.5	Test Plan	9
5.6	Analysis and Interpretation of Results	10
5.7	Test Report	13
5.8	Training and Certification	14
5.8.1	Personnel	14
5.8.2	Laboratory/Test Facility	18
5.8.3	Proficiency Requirements	19
5.9	Data Retention Requirements	19
6.	NOTES	20
6.1	Revision Indicator	20
APPENDIX A	SAMPLE REPORT	21
APPENDIX B	IQI AND LP	27
APPENDIX C	RADIATION EXPOSURE MITIGATION STRATEGIES	29
FIGURE 1	AN ILLUSTRATION OF THE USE OF LINE PAIR GAUGE FOR SYSTEM CALIBRATION (COURTESY: MATRIX-FOCALSPOT)	5
FIGURE 2	GENERIC DIAGRAM SHOWING A CROSS-SECTION OF A WIRE BONDED, PLASTIC ENCAPSULATED MICROCIRCUIT (COURTESY - UNIVERSITY OF MARYLAND, CALCE CENTER)	6
FIGURE 3	REPRESENTATION OF A TYPICAL REAL-TIME RADIOLOGICAL INSPECTION SYSTEM (COURTESY CREATIVE ELECTRON INC.)	6
FIGURE 4	RADIOLOGICAL IMAGES OF TWO QFP PARTS. THE PART ON THE LEFT HAS A SHORTER DAMBAR THAN THE QFP PART SHOWN ON THE RIGHT. ALTHOUGH THIS IS AN EXAMPLE OF A FAILED RADIOLOGICAL TEST, AUTHENTICITY CANNOT BE DETERMINED BASED ON THESE IMAGES ALONE. ADDITIONAL TEST METHODS SHALL BE USED FOR COMPLETE ASSESSMENT OF PART AUTHENTICITY. (COURTESY - UNIVERSITY OF MARYLAND, CALCE CENTER)	10
FIGURE 5	RADIOGRAPH ON THE LEFT SHOWING A POOR SNR AND LACK OF ADEQUATE CONTRAST. RADIOGRAPH ON THE RIGHT SHOWS A CORRECTED SNR AND IMPROVED CONTRAST. (COURTESY - CREATIVE ELECTRON INC.)	11
FIGURE 6	RADIOGRAPH ON LEFT SHOWING A POOR CNR. RADIOGRAPH ON THE RIGHT SHOWS AN IMPROVED CNR. (COURTESY - CREATIVE ELECTRON INC.)	11
FIGURE 7	RADIOGRAPH ON THE LEFT SHOWING AN UNCORRECTED GAIN AND OFFSET. RADIOGRAPH ON THE RIGHT SHOWING A CORRECTED GAIN AND OFFSET. (COURTESY - CREATIVE ELECTRON INC.)	12
FIGURE 8	RADIOGRAPH ON THE LEFT SHOWING AN INADEQUATE BRIGHTNESS RESOLUTION. RADIOGRAPH ON THE RIGHT SHOWING A CORRECTED BRIGHTNESS RESOLUTION. (COURTESY - CREATIVE ELECTRON INC.)	12
FIGURE 9	RADIOGRAPH ON THE LEFT SHOWING A PART WITH BLURRED OUTLINE. RADIOGRAPH ON THE RIGHT SHOWING A PART WITH OPTIMIZED CONTRACT SETTINGS RESULTING IN A CLEARER OUTLINE. (COURTESY - CREATIVE ELECTRON INC.)	12
FIGURE 10	RADIOGRAPH SHOWING A ROW OF BAD PIXELS (COURTESY - CREATIVE ELECTRON INC.)	13

1. SCOPE

The intent of this document is to define the methodology for suspect parts inspection using radiological inspection. The purpose of radiology for suspect counterfeit part inspection is to detect deliberate misrepresentation of a part, either at the part distributor or original equipment manufacturer (OEM) level. Radiological inspection can also potentially detect unintentional damage to the part resulting from improper removal of part from assemblies, which may include, but not limited to, prolonged elevated temperature exposure during desoldering operations or mechanical stresses during removal.

Radiological inspection of electronics includes film radiography and filmless radiography such as digital radiography (DR), real time radiography (RTR), and computed tomography (CT). Radiology is an important tool used in part verification of microelectronic devices. Radiographic analysis is performed on parts to verify that the internal package or die construction is consistent with an exemplar. In case an exemplar is not available, comparisons should be made within a homogenous sample population using the technical data available for that item.

If AS6171/5 is invoked in the contract, the base document, AS6171 General Requirements shall also apply.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

- a. NAS-410: National Aerospace Standard, "NAS CERTIFICATION QUALIFICATION OF NONDESTRUCTIVE TEST PERSONNEL".
- b. ASNT SNT-TC-1A: American Society for Nondestructive Testing, "Recommended Practice for Personnel Qualification and Certification of Nondestructive Testing".
- c. EN 473: European Standard, "Qualification and Certification of NDT Personnel - General Principles".
- d. ASD-STAN PREN 4179: AeroSpace and Defence Industries Association of Europe, "Qualification and approval of personnel for non-destructive testing".
- e. ISO 9712 "Non-destructive testing - Qualification and certification of personnel".
- f. ASNT CP-189: American Society for Nondestructive Testing Standard for Qualification and Certification of Nondestructive Testing Personnel (2006)
- g. ASTM E1161: Standard Practice for Radiologic Examination of Semiconductors and Electronic Components
- h. ASTM E2339: Standard Practice for Digital Imaging and Communication in Nondestructive Evaluation (DICONDE)
- i. ASTM E1254: Standard Guide for Storage of Radiographs and Unexposed Industrial Radiographic Films
- j. ASTM E1453: Standard Guide for Storage of Magnetic Tape Media that Contains Analog or Digital Radioscopic Data
- k. MIL-STD-883: Method 2012 Radiography (Test Method for Microcircuits)
- l. MIL-STD-750: Method 2076 Radiography (Test Methods for Semiconductor Devices)
- m. MIL-STD-202: Test Method Standard, Electronic and Electrical Component Parts

2.2 Terms, Acronyms, and Definitions (as applicable)

See 2.2 and 2.3 of AS6171 General Requirements.

3. DESCRIPTION OF METHODOLOGY/PROCEDURE

3.1 Material Control

3.1.1 Handling EEE Components

Inspection of EEE components must be conducted following electrostatic discharge mitigation procedures as described in ANSI/ESD S20.20 (Protection of Electrical and Electronic Parts, Assemblies and Equipment), ANSI/ESD S6.1 (Grounding), and ANSI/ESD S4.1 (Work Surface-Resistance Measurements). Paragraph 3.9.5 (Device Handling Requirements) of AS6171 General Requirements provides additional guidelines on device handling.

3.1.2 Data Exchange Format

3.1.2.1 Data from User/Requester

The User/Requester should supply the test lab with data as described in 5.3.1.

3.1.2.2 Data to User/Requester

A report on radiological inspection of part verification shall include all the details as described in 5.7.

3.2 Description of Process

3.2.1 The radiological system should be prepared to expose the part to be examined. The system shall be operated per approved documented procedures, including the operator's manual provided by the manufacturer.

3.2.2 Filters should be used to harden the X-ray beam to reduce total radiation dose to the device(s).

3.2.3 When inspecting a large assembly with many installed devices, such as a printed circuit board, areas that are not under examination should be masked with appropriate shielding. Prop appropriate shielding up on blocks or other means so the weight of the shielding does not damage the assembly.

3.2.4 Prior to examination, a line pair (lp) gauge or other image quality indicator (IQI), representative quality indicator (RQI) shall be used to ensure that the system is operating at the proper resolution for the product being inspected. An IQI shall be imaged at the beginning of the examination of a lot of devices, and then re-image the same IQI at the end of the examination. IQIs or RQIs shall be imaged and verified with the full range of exposure settings (for example, when accelerating voltage is changed during an examination to view multiple features, IQIs and RQIs shall be subject to those same settings).

3.2.5 Prepare the Component for Exposure

- a. To prepare a single component or a group of components for horizontally oriented exposure, ensure the table or fixture is level with respect to the X-ray head. This may be accomplished by using a multi-directional leveling device.
- b. When inspecting multiple trays or reels, the operator should ensure that every tray or reel is properly aligned and oriented. The orientation can be horizontal or vertical.
- c. To prepare a component for a vertically oriented exposure, care needs to be taken to ensure the part is correctly oriented with respect to the X-ray aperture. Failure to do so could cause a distorted image.
- d. Setup the IQI per ASTM E1161. If the system in use has a calibrating function and the image to be taken will be used to verify a specific measurement, the system should be recalibrated prior to exposing the device for the radiograph. A line pair gauge may be used for calibration. An example of how a line pair gauge is used for calibration is shown in the Figure 1 (note that the 20 line pair per millimeter (lp/mm) shown in the example is for illustration purposes only). Multiple geometric magnifications may be required to inspect for the attributes described in 5.5, (a) - (n).

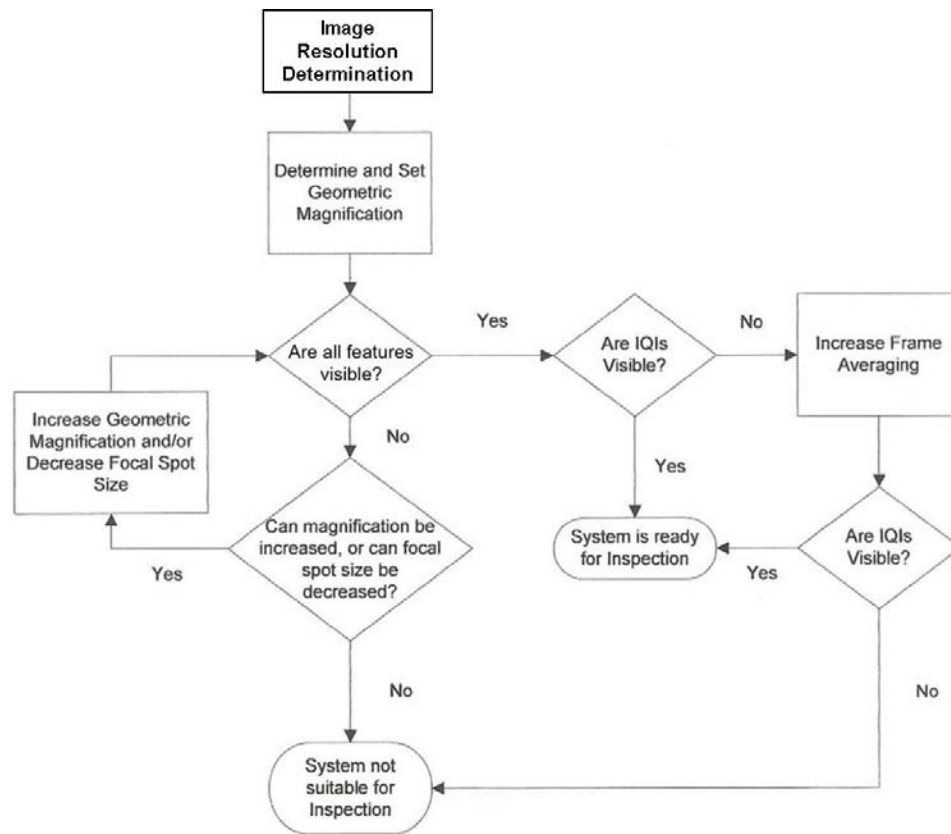


**Figure 1 - An illustration of the use of line pair gauge for system calibration
(Courtesy: Matrix-Focalspot)**

- e. To minimize effects of stray radiation on the image quality, it is good practice to use radiographically transmissive materials to construct any support or fixtures.

3.2.6 Select Appropriate X-ray Tube Parameters for Component Inspection

- a. Document the accelerating voltage and current settings to be used to accomplish the correct exposure rate for the size of component to be examined. Note: A low accelerating voltage will underexpose the radiograph while a much higher accelerating voltage will overexpose the radiograph. The operator should select the minimum value possible to obtain the required amount of radiographic detail.
- b. The use of an "Isowatt" or constant power type setting is recommended in systems that support such a feature. The use of this mode varies the current (in amperes) when the accelerating voltage is adjusted. This allows a setting which minimizes radiation exposure to the device.

3.2.7 Manipulation of the Part under the Beam

- a. Inspection of attributes such as leadframe layout, die position, size and other items a-l identified in 5.5 require a "top-down" orientation.
- b. Appropriate magnification should be used. This magnification should allow acquisition of images that include outer extremities of device under test (DUT) and allow for determining lot homogeneity.
- c. High magnification inspection and minimum number of views will be determined by the geometry, complexity and radiation sensitivity of the DUTs.

- d. For a side-view inspection on systems with either X-ray head or table mounting rotation in all three axes; the part may be manipulated to show the best angle and ensure consistent thickness of the die component and package thicknesses are consistent within the lot. Figure 2 shows a diagram of a typical plastic encapsulated microcircuit.
- e. Parts should be inspected for homogeneity, consistency, and uniformity. It is normal for there to be some variation across different date and lot codes but not normally in parts with the same date and lot code. It is recommended that additional inspection be performed on parts that exhibit anomalies that are observed in radiological inspection. Some follow-up techniques could include additional visual inspection and acoustic microscopy.

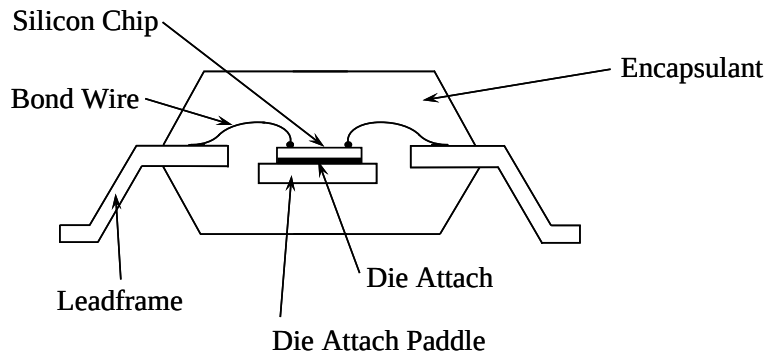


Figure 2 - Generic diagram showing a cross-section of a wire bonded, plastic encapsulated microcircuit (Courtesy - University of Maryland, CALCE Center)

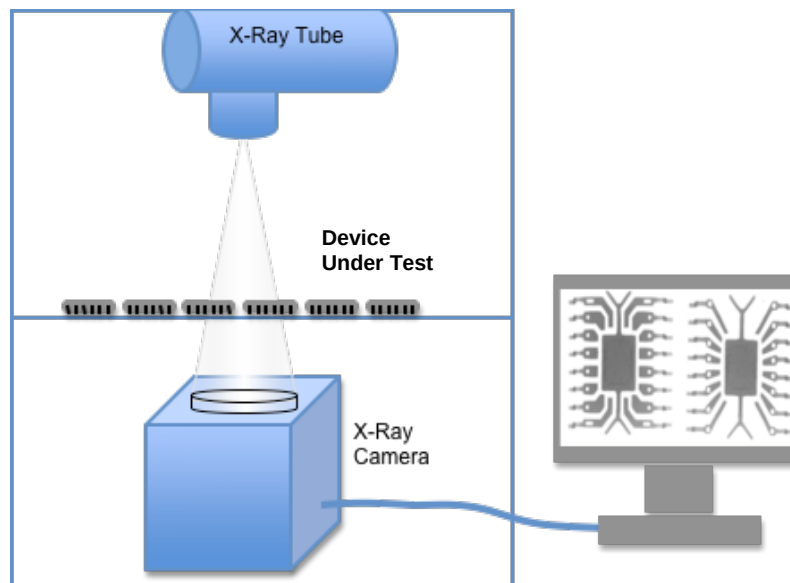


Figure 3 - Representation of a typical real-time radiological inspection system (Courtesy Creative Electron Inc.)

- 3.2.8 Digital, film and real time radiology provide two dimensional (2-D) images. If a part is used for a critical application and these radiology techniques are not sufficient for resolving counterfeiting related defects, then computed tomography (CT or three-dimensional, 3-D imaging) may be employed. Due to the long exposure time and relatively high X-ray voltages, CT may be considered destructive based on the parts' radiological sensitivity and expected dosage.
- 3.2.9 If the items being inspected are radiation sensitive, radiation exposure shall be measured. The User/Requester should provide the radiation tolerance of the items being inspected. Dosimeters or equivalent can be used to establish a dose versus distance and exposure time relationship for the radiological system. Multiple beam voltages at varying focal distances may need to be characterized. This will provide an exposure estimate that shall be shared with the User/Requester/client. Dosimeters can also be used to determine the variation in X-ray energy across a flat surface, which can be useful for film applications. Additional details are provided in Appendix C.

4. TEST EQUIPMENT REQUIREMENTS

- 4.1 The radiographic equipment shall be capable of part imaging and have adjustable tube voltage, current and X-ray beam spot size (refer to MIL-STD-883 Method 2012, or MIL-STD-750 Method 2076). The system shall be capable of handling parts supplied in tubes, reels or trays.
 - 4.1.1 The radiographic system shall use radiographic film, a high contrast detector, or an image intensifier capable of providing resolution adequate to acquire images for part verification. The radiographic system shall be capable of resolving a minimum feature size of 0.0254 mm or 0.001 inch.
 - 4.1.2 Requirement of a measurement device capable of measuring the amount of radiation that a part is subjected to during radiographic inspection. A dosimeter is an example of such a measurement device. Other radiation measuring devices may include Geiger Mueller (GM) detectors with pancake probes, alpha radiation survey meter, dose rate meter, etc.
 - 4.1.3 Facilities with filmless system shall have a viewer or a monitor that is capable of displaying a projection of the DUT.
 - 4.1.4 Facilities with radiographic film systems shall have development equipment, appropriate chemicals, radiographic film viewer.
- 4.2 Fixtures and other support equipment for either radiographic film type or filmless systems shall be in compliance with ASTM E1161.
- 4.3 Filters should be used to harden the X-ray beam to reduce total radiation dose to the device(s). A recommended thickness of 0.005 inch pure copper or pure zinc filter shall be placed at the X-ray tube window to harden the X-ray beam when performing film radiography. When performing geometric enlargement techniques with the device very close to the focal spot (for example, micro-focus X-ray tube/digital detector array (DDA)), secondary radiation from the filter may increase the dose to the device; in such cases proper filtering shall be determined prior to the actual examination. Other materials and thicknesses may be used when it is demonstrated that improvement in the radiological quality level is attained or further reduction in radiation dose is an overriding factor.
- 4.4 To protect areas around the DUT that are not under examination, where appropriate, the components should be masked with adequate shielding. This is applicable for radiographic film type and filmless systems.
- 4.5 All procedures for the operation of the radiological system and the interpretation of information displayed by the system shall be documented in the quality management system (QMS) of the facility utilizing the equipment.

5. REQUIREMENTS

5.1 Sampling

Sampling will be based on the AS6171 General Requirements sampling plan. See 3.5 (Sampling Plan) in AS6171 General Requirements.

5.2 Categories of Testing/Best Practices

5.2.1 Test Tier Level and Risk Definitions

Refer to AS6171 General Requirements for tier level definitions and risks.

5.2.2 Recommended Best Practices

Some general recommended best practices for part inspection are listed below:

- a. In addition to overview images, it is recommended that additional images with die coverage of at least 80% over the viewing area be acquired. These images can potentially help in inspection of wire bonds, die-attach fillet, and closer inspection of lead frame.
- b. The use of oblique views is recommended to inspect internal attributes. Attributes that can be inspected in oblique views include loop height, stacked ball bonds, die thickness and die attach fillet height.
- c. For radiation sensitive parts, lowering the radiation exposure may be necessary for the test to be considered non-destructive. Due to longer exposure times associated with CT, this technique may be considered a destructive test.
- d. Radiation exposure has been correlated to damage in certain types of integrated circuits. In order to keep radiation exposure as low as reasonably achievable, some guidelines have been provided in Appendix C of this document.

5.3 Testing Requirements

5.3.1 Information from the User/Requester

This section outlines the recommended information from the User/Requester to the organization that is performing the radiological inspection (the test lab):

- a. Statement of Work (SOW) or a Purchase Order should contain:
 1. Item type
 2. Number of items in the lot
 3. Number of parts being inspected
 4. Any special needs/requirements or modifications to the test procedures
- b. Item datasheet or specification document.
- c. Specify whether or not the parts can be inspected using radiology.
- d. Radiation tolerance of the parts being inspected.
- e. Describe the attributes of the radiograph or part used as the exemplar provided for comparison. The minimum requirements for an exemplar shall include identical:
 1. Part or item number
 2. Lot code
 3. Date code
 4. Manufacturing site
 5. External markings
 6. Construction of the part (e.g., plastic/ceramic/metal)
- f. Describe how the parts are packaged. Examples: crates, pallets, trays, tubes, reels or bags.

5.3.2 Test Laboratory Requirements

- a. Test laboratory shall measure and record the dose versus distance and exposure time relationship for the radiological system. This relationship shall be reported in the final report. This measurement and recording shall be repeated anytime the radiological system parameters are changed.
- b. Test laboratory shall be able to demonstrate the procedures and maintain records of the dose versus distance and exposure time relationship for the radiological system and the test parameters along with the results.
- c. If radiation tolerance levels have been specified by User/Requester, test laboratory shall ensure radiation levels used during inspection are below the tolerance of the parts being inspected. Parts exposed to excessive radiation beyond the tolerance levels shall be segregated and labeled as destructively tested parts.
- d. Test laboratory shall be able to verify the quality of the radiograph using image quality indicators (IQI). Once system parameters are selected (e.g., magnification, tube parameters, position) the operator shall produce a radiograph/image using an IQI to show that sufficient quality and resolution of the radiograph/image can be obtained. This exercise shall be repeated once the current inspection is complete. In the end, two IQI radiographs/images are required, once before the start of the inspection, and once after the completion of inspection. Refer to Appendix B for an illustration of IQI (ASTM E801 (for IQI)).

5.4 Counterfeit Detection Test Sequence

The test sequence is included with the SOW along with all other requirements from User/Requester to the test lab (refer to 3.4 of AS6171 General Requirements).

5.5 Test Plan

This section outlines the test lab's procedure to address requirements in the SOW. For specific inspection attributes of items listed in the product type applicability matrix, use the following list as a guide. A list of inspection steps can be created by populating the subject headers with item specific information. The following example provides guidance for creating such a list and is based on an example for a packaged integrated circuit. Figure 2 provides the relative positioning of the various features within an electronic integrated circuit package. If an exemplar is unavailable, the parts shall be compared for consistency within the homogenous lot and/or manufacturers' datasheets (or specification) shall be used to determine any indications of counterfeiting. While evaluating EEE parts within the homogenous lot, the following attributes shall be evaluated, as applicable to the EEE part type:

- a. Inspect the die or multiple die to determine that they are present, are of the consistent correct size, consistent orientation and of uniform planarity.
- b. Determine that the general shape and structure of the package is similar to the exemplar. Note that an exemplar may not be available.
- c. Determine that the general shape and structure of the package is similar to the other parts within the same lot.
- d. Determine that the lead-frame construction is consistent within the homogeneous lot.
- e. Determine that wire gauge is consistent within the homogeneous lot.
- f. Determine that the number of wire bonds and the positions are consistent within the homogeneous lot. Note: attributes such as wire sweeping, double wires (in high current carrying terminals) or crossings (in stacked die packages) may not be associated with counterfeiting.
- g. Document any evidence of internal damage. Internal damage can include die cracking, lead frame damage, unacceptable die attach voiding, broken wires or wire bonds.
- h. Document excessive die attach voiding. Die attach anomalies such as missing, partially missing, cracked or deformed die should be documented.