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USING X-RAY SYSTEMS TO DETECT COUNTERFEIT AND REWORKED ELECTRONIC COMPONENTS

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ABSTRACT
Much has been said and written about the accuracy of visual attribute inspections of potentially counterfeit components. The techniques and procedures being used to inspect counterfeit and reworked electronic components in the open marketplace can be quite effective in most cases.

The *Independent Distributors of Electronics Association* (www.IDofEA.org) has produced an industry accepted inspection standard, *IDEA-STD-1010*. It provides a wealth of information about visually inspecting components and in most cases will allow the inspector to make preliminary decisions about the legitimacy of any given part.

This paper will provide additional knowledge about new techniques using x-ray photography acquisition methods recently developed that will speed the detection and accuracy during the process of inspecting counterfeit components.

X-ray photographs of counterfeited parts along with the explanations detailing how they were detected are explained in this document. Often overlooked clues left behind by even the most experienced counterfeiters are discussed.

Key words: Counterfeit, Component, X-ray, Inspection

INTRODUCTION
There are positive aspects of using X-ray systems during the inspection process that if properly administered, will enable the inspector to make a well informed conclusion about the authenticity of an electronic component.

Additionally, there are some limitations of X-ray systems that the inspector of electronics will need to understand while using the system as a diagnostic tool.

LIMITATIONS OF USING AN X-RAY SYSTEM
- When real-time radiography is used for screening, the dose rate that the equipment emits should be estimated. Certain types of radiography can expose microcircuits to unusually high dose rates, such that damage can be introduced to sensitive parts. (PEM-INST-001, NASA/TP-2003-21224)

- The most reliable method of examining a die with an x-ray system is to have a photo of a known good die from this exact P/N, D/C and L/C produced by the same manufacturing plant. Device die's will change through revision control and will vary in appearance depending on their manufacturing plant.

NOTE: Taking a single x-ray photo of one part in the absence of having another comparative photo or obtaining confirmation from the OCM will leave the inspector with an incomplete analysis report.

- An X-ray system will not detect the die logo and part number for verification purposes.

BENEFITS OF USING AN X-RAY SYSTEM
- While viewing an increased sample size, the inspector can quickly compare one die against the other. This will identify components that have been remarked using a variety of visually similar components with different dies inside.

Note: If all of the dies are the same in appearance, unless there is a comparative photo available, the diagnostician cannot determine if the die is correct.

- An X-ray system will quickly identify components with no internal die.

- Additionally, broken or misplaced bond wires can be quickly detected.

- Most government and aerospace contracts will require the use of X-ray photography depending on the source of the purchase. See AS5553 standard.

- The effects of ESD and EOS can be easily detected unless they are microburns located on the die structure.

- X-ray examination is recommended prior to decapsulation. This will prevent decapping a device that has no die. It will also show the location and relative size of the die for a more accurate decap process.

- X-ray systems allow for single layer inspections of factory sealed packages without having to break the seal on the moisture barrier bag.

HIERARCHY OF INSPECTION PROCEDURES
There is a recommended hierarchy of preliminary procedures to follow involving the various counterfeit detection systems that are available currently. The

diagnostician should not proceed directly to the X-ray system with the intent of determining a part is fraudulent. Several other proceedures need to be followed initially.

It is recommended the inspector first access the data sheet for the component to be inspected. Once the technical data on the part is available, the inspector should familarize themselves with the information describing this component.

Using the *IDEA-STD-1010* inspection standard, adminster a thorough examination of the part. This standard when administered by an IDEA Professional Inspector certified under the *IDEA-ICE-3000* certification program has the skill set to detect most counterfeited or reworked components.

The next steps the diagnostician should employ are the two commonly used “resistance to solvents” tests.

If the component is ink stamped, a sample should be subjected to the Marker Permenancy Test as described in Mil-STD-883. The test when properly administered will detect uncurred ink placed on the part by someone who has remarked the component. If the ink smears and comes off, the part is likely to to have been counterfeited. Further verification on the component should be conducted to ensure the component is not an authentic part.

If the component appears to have a false top coat the inspector should administer an acetone scrub test. Most false top coatings that are carbon based and do not have a protective coating will begin to disolve with the acetone applied. A factory fresh component coming directly from the Original Component Manufacturer (OCM) will not be affected by acetone. If the top coating material begins to smear and come off it should be suspected as being a counterfeited component.

If the component has passed these preliminary tests, the inspector should now proceed to the X-ray system for futher analysis of the part.

GOOD PARTS PROVEN THROUGH COMPARISON:
Figure-1 demonstrates how two components with the same part number but manufactured over two years apart can look so different yet will operate the same functionally.

The two photos shown in Figure-1 were sent to the OCM for verification, with the request to have them verify they were manufacturered by that company. The OCM quickly verified the two components were authentic and the part numbers shown on the parts were correct.

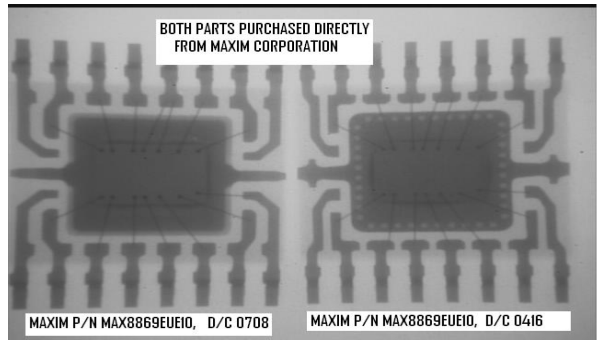


Figure-1, X-ray sample of 2 parts that appear different but are the same functionally

TWO LEAD FRAME DESIGNS IN ONE TAPE
Components shipped in either tape or trays are easy to compare and detect issues. Figure-2 demonstrates two lead frame designs detected with an X-ray system. The two designs were side by side in the same tape and reel container.

It is recommended that X-ray photographs be taken of components and stored on the company server for future references. Photos of known good components are invaluable evidence to compare with when the inspector is unsure if the internal structure is not authentic.

In Figure-2, the two components are stamped with the same date code, same lot code and part number. The parts were suspected as having a false top coating during the initial visual inspection. A sample was then submitted to an X-ray examination and it was determined that even though the parts had the same markings and appeared to be the same size physically, they had a varying number of internal structures with different lead frames and dies. These parts should be rejected.

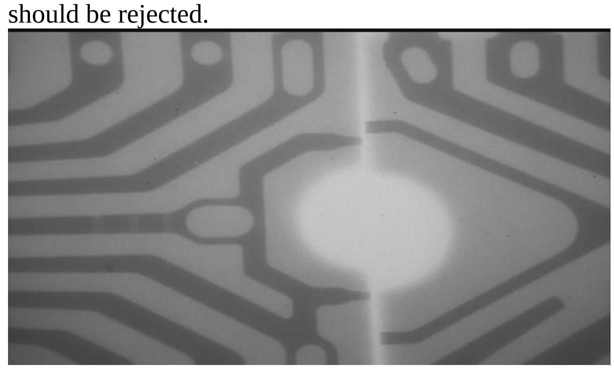


Figure-2, two different dies side by side in a tape

TWO DIES WITHIN THE SAME DATE CODE
Note in Figure-3 that the bond wires are evenly spaced around the die perimeter. Without the use of an X-ray system, the diagnostician would be unable to determine the variances between Figure #3 & #4. The two components were found in the same reel of tape with exactly the same markings and country of origin.

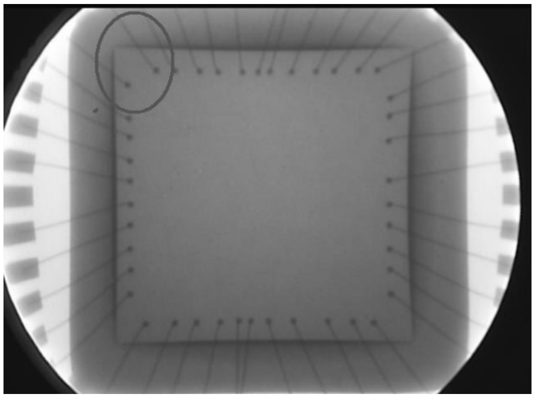


Figure-3 is the good component

The bond wires attached to the die in Figure-4 are not evenly spaced around the die. Notice the gaps in each of the four corners of this die and the two different die sizes between the two parts.

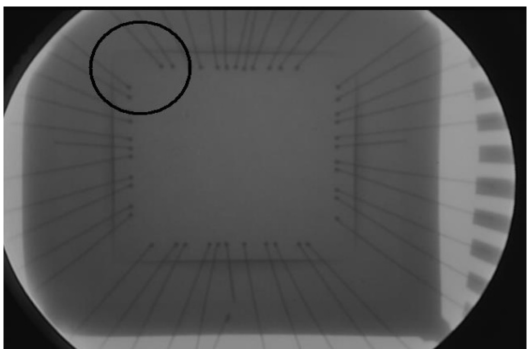


Figure-4 is the incorrect die for this part

BROKEN BOND WIRES SEEN WITH X-RAY

Figure-5 & 6 show broken bond wires that showed up during a routine check of the component internals with the X-ray system. The inspector would be unable to detect such a defect without an X-ray system. These photos were taken from a group of components that had a high fallout rate during a production run and were returned as being defective.

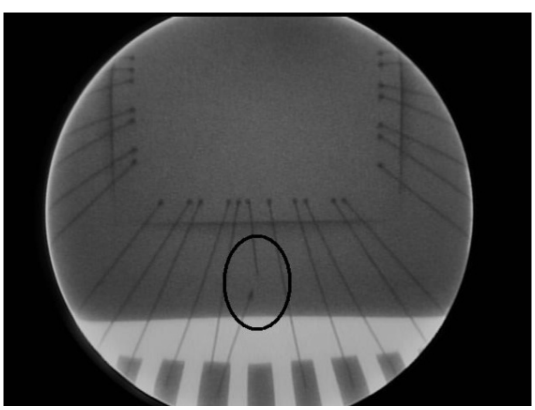


Figure-5, Broken wire in the center

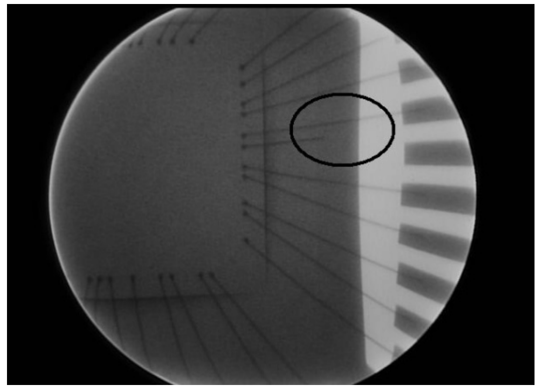


Figure-6, broken bond wire inside the circle

FAKE COMPONENT DETECTION WITH X-RAY

The component shown in Figure-7 should have the characters readable with the single lead facing up. This component has the markings upside down. This was the first clue that the parts were not genuine when they were compared with the markings shown on the data sheet.

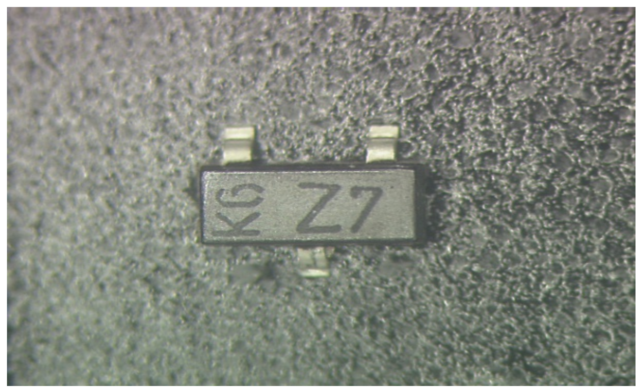


Figure-7, shows the top surface of a fake part

Figure-8 shows a non-standard "S" shaped wire bond connecting the two leads. Also notice the large bubble under the wire connection on the center lead. This is also non-standard and is of suspect.

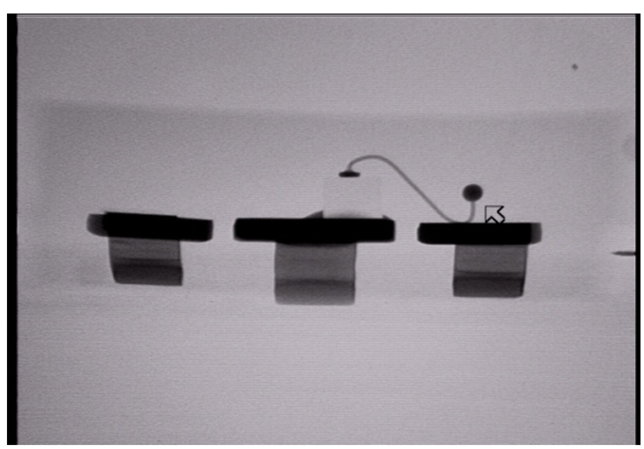


Figure-8, fake part side view

Figure-9 shows the suspected fake component. It looks properly spaced in this top down angle view. This could be a misleading view without also being compared to the other views.

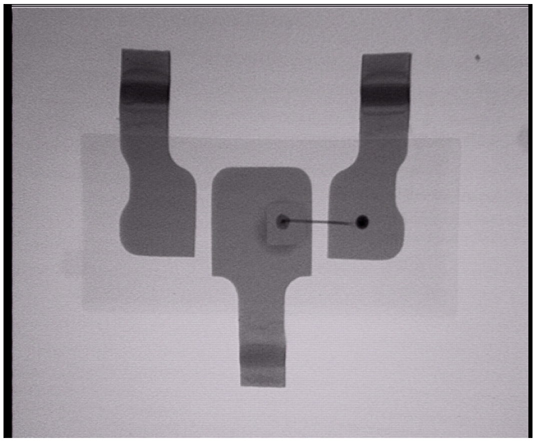


Figure-9, fake part top view

Figure-10 is the side view of a known good component. Notice the bond wire does not have the "S" shaped bond wire shown in the suspected fake component photo.

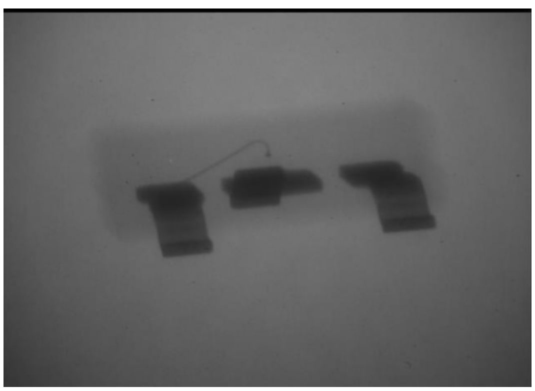


Figure-10, good part side view

Figure-11 is the top down view of a known good component. This view compared to the suspected photo shows very little difference between these components.

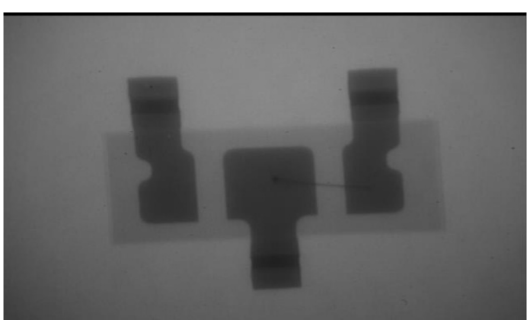


Figure-11, good part top view

CONCLUSION OF PHOTOS # (7-11)

In this series of photos the diagnostician has compared the component's data sheet with the view shown in Figure-7. Notice the variance in lead layout versus the top surface markings, the decision was made to X-ray the parts.

When these components were compared against known good components the inspector was able to conclude they were most likely not the part number inscribed on the top surface. The parts were rejected and returned to the supplier.

This quick and reliable decision could not have been made without the use of an X-ray system capable of seeing the internal construction of these parts.

FAKE PART WITH NO DIE INSIDE

The two dies shown on the left are from known good components and the two on the right are taken of fake components that have no dies.

Notice in Figure-11 the dies on the right are missing from the components. The X-ray system has quickly established these components to be counterfeit.

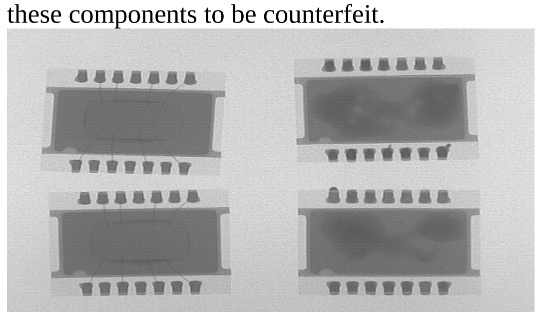


Figure-11, fake parts on right with no die

FAKE PARTS DETECTED BY X-RAY

Figure-12 was taken to demonstrate that the components in this tube were correctly aligned in their tubes when the following X-ray photos were taken.

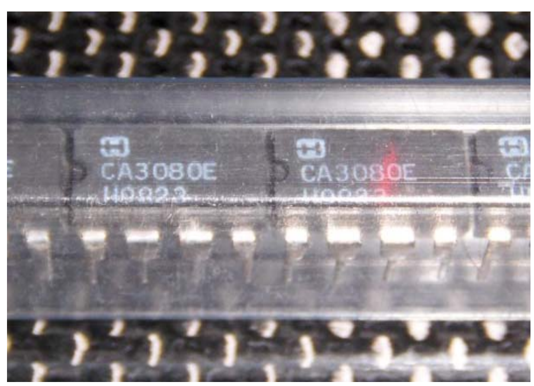


Figure-12, view of parts still in their tubes

Figure-13 demonstrates two adjacent components have the same dies that are oriented in the same direction. This is the way they should appear in an X-ray photo.

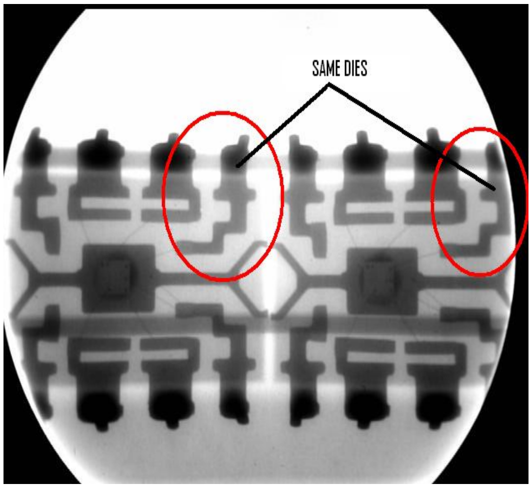


Figure-13, lead designs compare

Figure-14 shows how two adjacent components in this reel of components have dies mounted differently within the component structure. Notice the comparison between the two red circles.

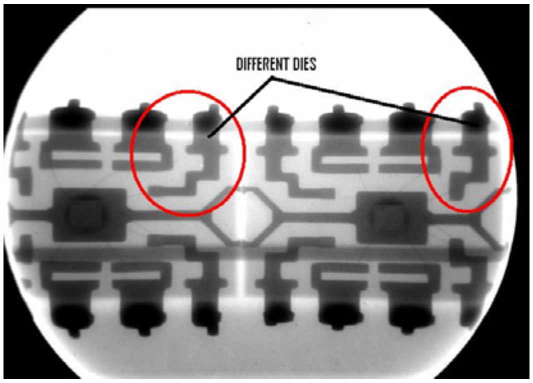


Figure-14, lead designs do not compare

USING X-RAY TO DETECT FAKE PARTS:

Figure-15 is a sample of a part in a single tube where there were four distinctly different internal component arrangements. Notice the red circle in the upper left corner showing the construction of the lead and how it compares with the hooked version in figure-16.

Also in figure-15 notice the bond wire leading from the third lead on the left connects with the smaller coil in the middle left. In figure-16 the wire coming from the same third lead is connected to the larger coil on the left. This is clear evidence the two components shown in figures 15 & 16 are not the same part number.

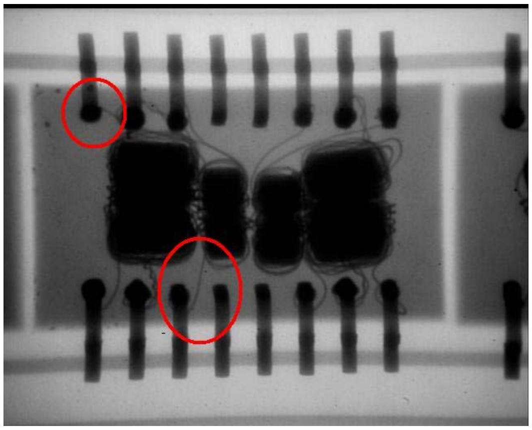


Figure-15, sample-1 lead design

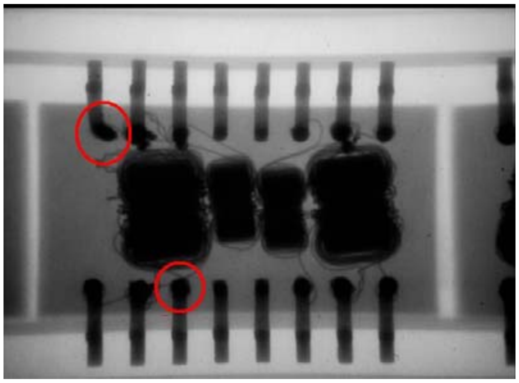
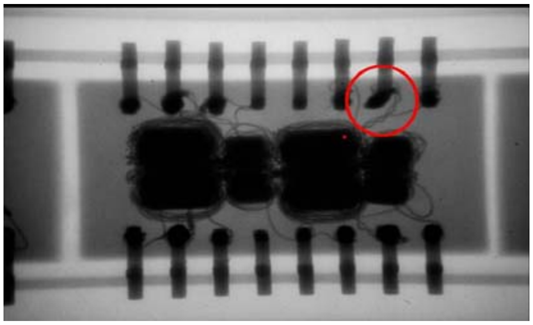


Figure-16, sample-2 lead design

From the same tube shown in the previous two X-ray photos, figures-17 & 18 are shown below.

Figure-17 shows a lead that has a distinct hook to the left as shown in the red circle where this same lead shown in figure-18 does not have the hook.



Fugure-17, sample-3 lead design

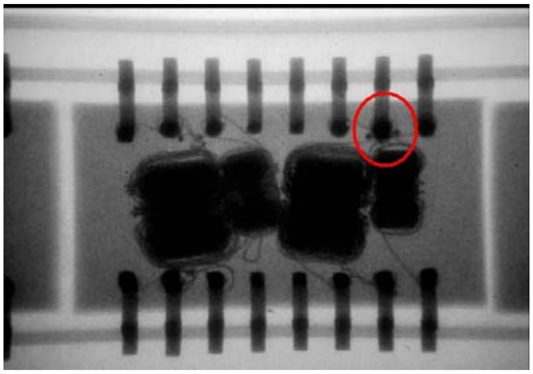


Figure-18, sample-4 lead design

CONCLUSIONS FOR PHOTOS # (15-18)

- Each of the components shown in these four photos came from the same tube.
- Each component was marked identically with the same D/C, L/C, P/N and country of origin.
- There are four different lead frame designs represented in these four photos.
- Notice that figures-15 & 16 show the two small coils in the center between the two larger coils on the outside. While the other two photos show a staggered arrangement.
- This entire shipment should be rejected.

EXAMPLE OF A FALSE REJECTION

Figure-19 shows a component that has a die that is canted to one side. Do not presuppose it is a manufacturing defect. This component was verified by the OCM to be correct.

Always verify with all the means available including data sheets, archived photos, OCM contacts or other QA inspectors in a network of associates prior to assuming an unusual component like this is fake or is a manufacturing defect.

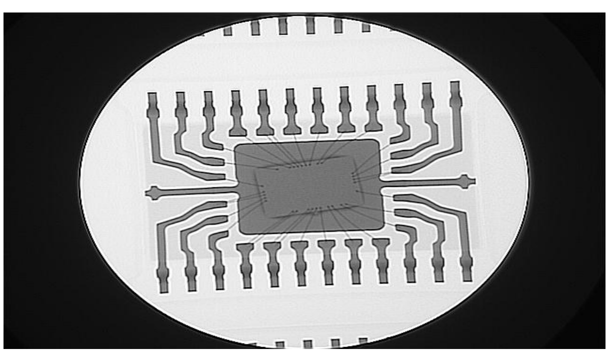


Figure-19, canted die, view-1

CONCLUSIONS

Given that a detail oriented counterfeit electronic component diagnostician that has been certified to conduct Quality inspections can be quite effective, basing an evaluation solely on a visual attribute process will always have its limitations.

With the current trend over the last 12-18 months in increased craftsmanship displayed by the groups who engage in the act of counterfeiting, it is becoming nearly impossible to detect every style used. It is obvious that more money is being used to increase the Quality of methodologies that produce counterfeit components. Quality inspectors can no longer just look at parts under a microscope and make the final judgment about their legitimacy.

Without the use of an X-ray system to verify the internals of a component, an inspection process has an exposure by making false assumptions about component Quality.

This study has shown examples of how X-ray was used to verify a group of parts with different dies to be certified by the OCM as meeting specifications. It has shown examples of how the inspector has proven parts to be fake, even to the point of not having a die inside the component.

The aerospace, military and especially the medical industries will soon make X-ray a required requisite step that must be included before any organization may certify a group of components to be production ready.

The single most important limitation of utilizing an X-ray system to verify a part is valid, is the inspector cannot usually make a final judgment in the absence of a picture of a known good part for comparison. This can be resolved over time by creating a library of photos that pass all the specifications.

The study has also shown that certain types of manufacturing defects can be seen using X-ray systems along with major EOS/ESD type damages.

Finally, most counterfeit components have had modifications done to the exterior or the component. Not all of these will be detected by visual examination. Some will require the inspector to use an X-ray system. This requirement will become more prevalent as the counterfeiters increase the quality of their work.

FUTURE WORK

Research is in progress that will study the entire process of certifying electronic components. It will encompass each of the major pieces of test equipment currently available in use today.

The companion document to this paper, when published will include a matrix showing all the test systems currently in use versus the myriad ways to counterfeit a component and their likelihood they will be successful in detecting the parts as fake.

It shall also assign a level of predictability to each step in the process as the parts move from one step to the next allowing an inspection station to be equipped with whatever hardware is needed to provide a presumed level of comfort that the parts being tested are meeting their specifications.