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Changing the Paradigm For Optical and X-Ray Inspection of Backplanes and Large PCB Assemblies

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Abstract

Fully automatic X-ray Inspection (AXI) is an established technique for inspecting component mounting and solder joint integrity on PCBA's. It is occasionally used for the detection of faults on (or more precisely, under) press fit connectors. However, existing commercial *automatic* X-ray inspection systems limit the application of this technique to sample boards smaller than 610mm (24") x 508mm (20") and under 5mm (0.2") thick. This is far too small an envelope to test most backplane assemblies and other large PCBA's. These systems also use higher X-ray energies than is required to find all the types of assembly faults found on backplanes thereby unnecessarily increasing the weight and cost of the safety enclosures.

Existing *manual* systems can handle the largest of backplanes, but expecting a human operator to consistently recognise minor defects in the several hundred images required for a single large backplane (never mind production volumes) is unrealistic.

The authors describe a novel concept for a test system where a *low energy* micro focus X-ray source, and a 4 mega pixel detector, are mounted in separate robotically controlled heads. Each head is also fitted with a high resolution colour machine vision camera. The resulting RXI (Robotic X-ray Inspection) system provides both high resolution AXI for detecting faults *under* connectors, and full colour high resolution optical AOI for detecting faults *within* connectors, in the same machine, and in a single test activity. This fully automatic test system is a reliable, high speed, and highly cost effective test system for backplanes and other large PCB assemblies up to 1000mm (39.4") x 1600mm (63") in size and over 18mm (0.7") thick.

Backplane assembly defects

Meeting the combined challenges of high speed serial data communication, and high channel density interconnection, has dramatically changed backplane connectors from relatively sturdy 2mm pitch assemblies to fragile 1.2mm and smaller pitch assemblies. These modern connector types have proven to be more susceptible to pressing defects such as those illustrated in figure 1. Many of these errors are not reliably detected by the existing electrical ATE techniques applied to backplane test $_6$.

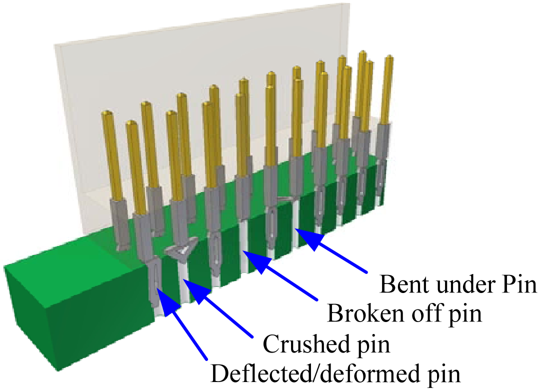


Figure 1 - Press fit connector assembly defects

Press-fit pin defect detection is a known and existing problem on all back plane assemblies as recognised in the iNEMA manufacturing report 2009$_6$. As the requirement for higher data rates in backplane designs increases then these problems will also grow in frequency. This is particularly recognised as a problem for mid-plane systems where via barrels are shared between connectors on both sides of the board. It is no longer sufficient to perform electrical tests to evaluate continuity, isolation, and even functional tests to validate the performance of backplanes and other large PCBA samples. In the same way that BGA assemblies are routinely tested by X-ray inspection, it is crucially important to know what is going on underneath, as well as inside, the signal interconnects. The iNEMA 2009 report proposes the development of a scalable X-ray or vision methodology that is capable of doing 100% inspection of pins pressed into the same via barrel on the largest of backplanes as a key research and development requirement. This paper describes a machine that exactly satisfies this methodology.

Impact of press-fit assembly defects on signal integrity

A largely unrecognised side effect of pressing defects is their impact on signal integrity. The effect of standing wave resonances on the signal integrity of interconnect circuit trace features is well established (see [1, 2, 3, 4] for example). These resonances exacerbate cross talk and insertion loss at frequencies between 2.5GHz and 5GHz. This is a critical frequency range for contemporary serial data transmission rates. The PCBA design strategies (via size, stub length, anti pad size and shape) to essentially "tune" any resonances on the backplane interconnect away from critical frequency bands are also well established. Each of the common press fit defects is itself an un-tuned circuit resonance feature[5] (similar to an un-tuned via) and they will detrimentally affect interconnect losses by as much as 30dB[4] and dramatically reduce the data transmission bandwidth.

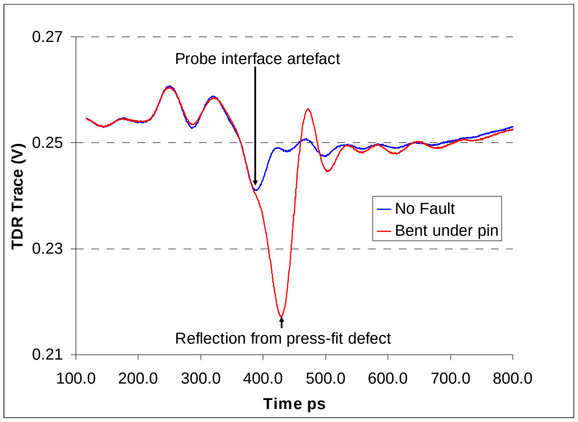


Figure 2 - TDR trace of typical press-fit defect

Figure 2 shows the start of a TDR trace of a high Gbps (Giga bit per second) backplane circuit with and without a bent under pin defect. This defect was not evident in ATE tests as contact continuity was maintained. The effect of the defect is obvious[5], and the result on the circuit bandwidth profound. Similar deficiencies in a backplane that passes ATE test may not be discovered until full system integration. Worse still is that a backplane that performs adequately at today's data transmission rates may not work at all if the system daughter boards are upgraded in the future to meet the demands of higher communication rates. Interconnect systems for 10Gbps Ethernet are already widely available. Future interconnect systems utilising both press-fit technology and SMT mounting techniques that quote data rates exceeding 20Gbps are already openly discussed in the literature[1]. These high data rate systems utilise interconnect systems that are increasingly susceptible to pressing problems of this type.

Assembly defect detection utilising AOI techniques

Some bent under pin situations can be detected using "pin-in-hole" AOI techniques. In this method a camera is used to image the reverse side of the PCBA from the press fit insertion direction. The objective is to image the tip of the compliant pin down the via hole. This is proposed in the iNEMA 2009 manufacturing report as a suitable method for detecting press-fit pin defects. This approach needs to be treated with some caution.

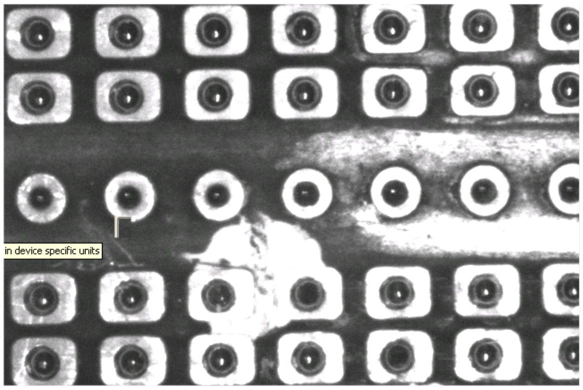


Figure 3 - Pin in hole image of a 10mm thick PCBA

In figure 3 there are two pins that are not visible in the vias. In this example the pins had been deliberately removed from the connector. This is a particularly easy example where the compliant pins are quite large and the via holes are 0.6mm in diameter. Still there are many occasions when the pin tip is simply not visible down the hole even though it is present. This leads to false alarms on testing. Using axial illumination methods (diffuse and otherwise) reduces the number false alarms but the issue remains for production volume testing. For most modern high density connectors the via diameters may be even smaller. The narrow aspect ratio offered by the via hole (that the compliant pin is pressed into) limits the visibility of the pin tip. Particularly for thicker backplanes, or where a variable diameter via's have been used to tune the interconnect resonances. This situation will not be significantly improved by the use of transparent materials for the fabrication of the connector housings. Simple geometry is the enemy. This dictates why this technique is unreliable as a primary production test. Pin in hole is not possible at all for mid-plane systems where the via barrel is often shared by compliant pins from connectors on both sides of the board.

While AOI is an excellent method for detecting gross insertion position errors, orientation issues, and bent interconnection side pins within the connectors the method of choice for detecting errors underneath the press fit connectors is soft X-ray imaging. At X-ray frequencies the body of the connector, and the PCB laminate material, is transparent and the crucial details underneath can be more simply observed.

Robotic X-ray Inspection (RXI)

The inability of existing electrical and optical ATE methods to adequately detect press fit assembly errors has created a testing problem which has yet to be adequately addressed by the industry. Automated X-ray Inspection (AXI) has become the established method of choice for the inspection of SMT component mounting and solder joint integrity on PCB assemblies. It has occasionally been used for the detection of problems in (or more precisely under) press-fit connectors. The fundamental problem with automatic X-ray inspection systems for testing backplanes is one of scalability. Typical AXI systems will only handle PCBA samples up to 610mm (24") by 508mm (20"). This is far too small for the test of a majority of backplane samples.

Manual X-ray inspection systems are capable of inspecting the largest backplanes. These methods require a human operator to visually identify and interpret often minor visual defects in images presented on a computer display screen. Even a moderately sized backplane could result in several hundred images of connector pins that require inspection. This is an excellent technique for confirming the cause of faults detected using other, often electrical, test methods. For a human being to do this task reliably as a primary test is unrealistic even for prototype volumes and completely impractical for a production volume test.

The requirement is clearly for a fully automatic inspection system that is fully scalable to test both the largest backplanes, and other large PCB assemblies. The technique needs to be fast enough to "keep-up" with the pace of a production test environment. The results of an AOI test and an AXI test complement each other. Often one can be used to provide "illumination" and clarification on the results of the other. To provide a fully comprehensive test, that fully complements existing electrical ATE test methods, the inspection system should ideally provide both optical inspection and X-ray inspection within the same test process.

The X-ray imaging process is a "shadow" technique based on the classic design of the "pin-hole camera" as shown in figure 4.

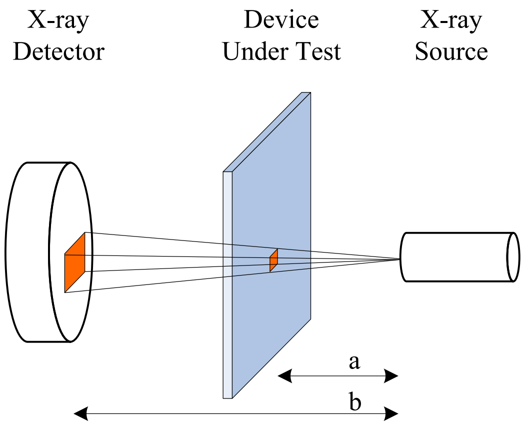


Figure 4 - Anatomy of an X-ray system

The source of the X-rays is a micro focus X-ray tube. This can be considered as a point source of X-rays (typically less than 100µm across). The X-rays spread out as a cone to illuminate the test object. At the test object some of the X-rays are absorbed and the remainder continue to form a shadow of the test object on the flat surface of the X-ray detector. Any object within the analysed sample that has material of higher density than the surroundings will absorb more of the x-ray beam and so cast a shadow on the detector (see figure 4). In this way, solder and copper tracks appear dark compared with the laminated circuit board in a PCBA, for example. The shadow image is magnified due to the diverging cone of X-rays that emerge from the source as is shown in figure 4. The shadow image is magnified by the ratio of the distances "b/a" in the figure. This is known as the geometric magnification.

Our proposed solution to the test conundrum is to mount the X-ray source, and the X-ray detector systems in separate robotically controlled heads positioned on either side of the device under test (DUT). This allows the position, and orientation, of both the X-ray source and detector to be positioned independently in a fully flexible manner on each side of the DUT. The DUT is mounted vertically in the machine with the long axis of the DUT vertical. This allows the largest backplane sample to be accommodated without requiring a huge test floor footprint or risking board sag. Also mounted within each robotic head is a high resolution colour machine vision camera. This fulfils our requirement for a single test system that will perform both full AOI plus X-ray inspection. To facilitate our development testing we utilised the robotic test platform of our existing fixtureless electrical test product. The added bonus is that the RoBAT platform already includes comprehensive AOI processing software facilities including most of the functionality required to automatically process the X-ray images. The resultant system is capable of testing backplanes and other PCB's up to 1000mm (39.4") wide by 1600mm (63") high. This is as large as any of the backplanes that we have ever been asked to test but inherently the size of DUT that can be tested is only limited by the travel of the robotic heads and the size of the enclosure that the system is contained within. This combination of AOI and AXI in the same machine we refer to as Robotic X-ray Inspection (RXI).

Figures 5 and 6 show the practical arrangement we used for mounting X-ray source and detector mounted on opposite robotic heads of our development prototype system. The detector utilised was a 35mm field of view 4 megapixel camera. The DUT shown in figure 6 was one of the many backplane and larger PCBA samples we tested. In this case the backplane was a small (550mm wide by 700mm high) mid plane system with press fit connectors on both sides of the backplane sharing via barrels. The source can just be seen in figure 6 on the opposite side of the DUT.

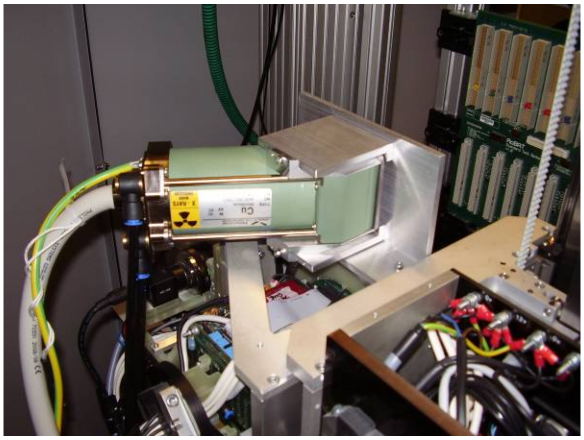


Figure 5- Source mounted in the test system

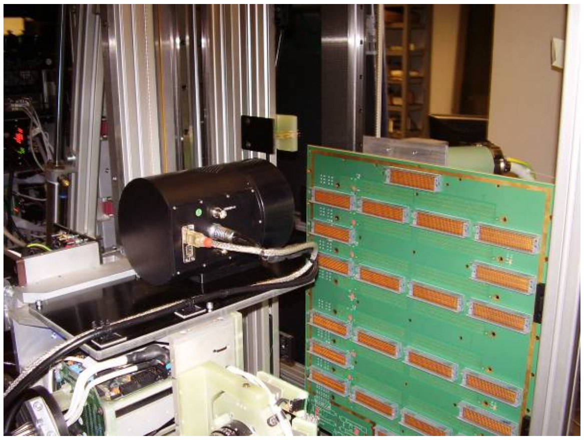


Figure 6 – Detector mounted in the test system

Optimum X-ray parameters for backplane test

The heart of any X-ray system is the X-ray source. This is the device that produces the X-ray radiation. In essence, an X-ray source is an evacuated cylinder within which electrons are produced by heating a wire filament, accelerated by an applied voltage and driven into a metal target (often called the "anode"). Typically more than 98% of the energy from the electron beam leads to the production of heat in the anode. The remainder results in the production of X-rays. The vacuum is required within the tube so that the electrons can travel down to the target without colliding with, and being scattered by, air molecules.

The two key parameters that are generally quoted in X-ray inspection system specifications are the source energy and the focal spot diameter. Perusing the specifications of AXI systems that are available very soon becomes a numbers game as manufacturers contend for higher and higher X-ray energies, and smaller and smaller focal spot sizes. But what do these values mean and what values are actually required to test large, and thick, backplane sample?

The principal parameter for any AXI system is the source energy. The value quoted is usually specified in kV (Kilo Volts) or keV (Kilo Electron Volts) and is actually the voltage that is applied to accelerate the electron beam that is focussed on the source anode. Typical values quoted are in the range 30-160kV. This then defines the upper limit of the energy of the X-ray photons produced. The principal process for generating X-rays for imaging is known as Bremsstraulung (or breaking radiation). The theoretical relationship between the intensity of the Bremsstraulung X-rays with reducing energy is for practical purposes a straight line (see figure 7) whose intersection is at the source voltage. Any very low energy photons are absorbed by the source window (usually made from beryllium) and never get to the DUT. This gives a very broad energy spectrum of useful X-rays. A system quoted as having a 160kV source does not mean that all of the X-rays used for the image are at that level. The energy spread of the X-rays will be over a range from a few kV up to a theoretical maximum of 160kV. The modal value (the energy with the highest intensity) will typically be in the range 20kV to 40kV depending on the thickness and transmission properties of the exit window of the source. Typically for a source operating at 100kV, most of the X-ray photons produced would have an energy of less than 50kV.

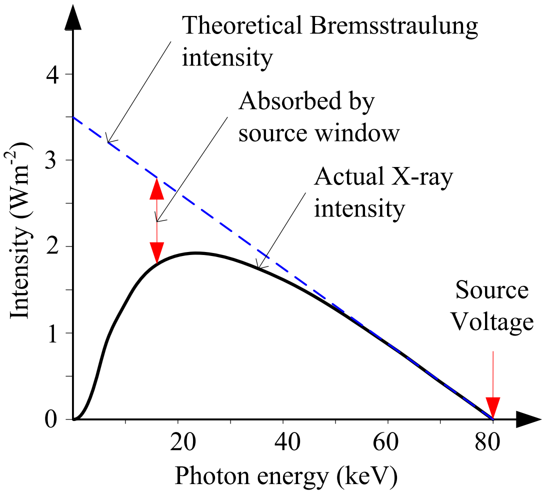


Figure 7 - Typical X-ray source energy spectrum

A simple rule of thumb that can be learned from any medical diagnostic X-ray technician is that the higher the energy of the X-rays, the higher the penetration power, and the lower the contrast in the image. To understand how this effects the detection of press fit defects we do need to delve briefly into the fundamental physics of the two physical process involved in the absorption of soft X-rays$_7$ (see figure 8). This is the photoelectric effect, and Compton Scattering.

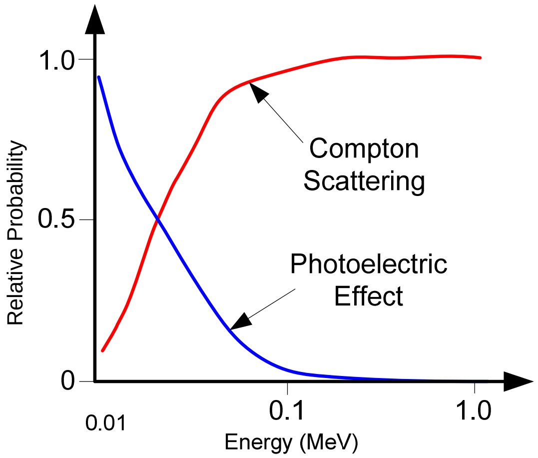


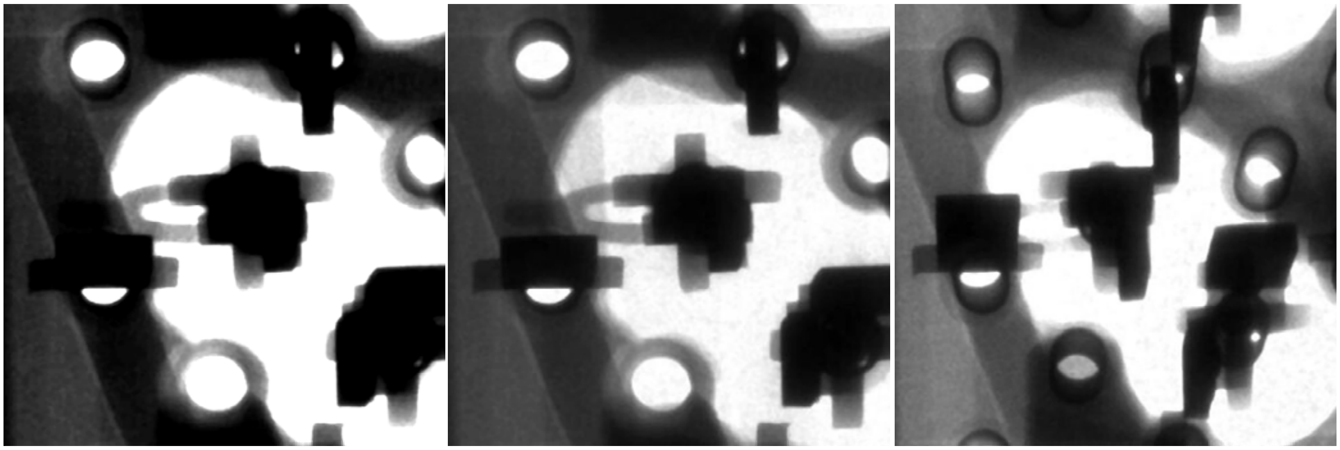
Figure 8 - X-ray absorption and scattering in materials

The principal beneficial process to creating contrast in an X-ray image is the photoelectric effect. Here the X-ray photon interacts with the electrons in the atoms of the material resulting in the emission of a photoelectron and the absorption of the X-ray photon. The probability of this occurring depends on the atomic number of the atoms in the material and the energy of the X-ray photon. The higher the atomic number of the material (or the denser the material) the more likely the X-ray will be absorbed. The higher the energy the less likely the X-ray will be absorbed. This is the physical process that gives rise to all of the contrast in an X-ray image. At low energy there is a very high probability of photon absorption so the image contrast is very good. At high energies most of the X-rays go straight through and image contrast is reduced.

The physical process that is responsible for the majority of the noise in an X-ray image is Compton scattering. In Compton scattering the X-ray photon interacts with the electrons in the atoms of the material but is deflected, and slowed down, rather than being absorbed. The probability of Compton scattering occurring is independent of the atomic number of the material and increases dramatically as the photon energy is increased. The visual effect of this is that the contrast in the image is worse and edges become blurred.

As any medical diagnostic X-ray technician will know there is an optimum X-ray energy that produces the best images of every material. In our situation this optimum energy is a compromise between test time and the ability to automatically detect fault artefacts in the image. This is easily demonstrated by experiment. We determined the optimum value of source energy required by imaging a faulty connector on the highest density backplane sample we had available at a number of different source energy levels (see figure 9). This back plane was a 40 layer assembly with 3 of the layers being 2 OZ/ft^2 the remainder being 1 OZ/ ft^2. Hence the total possible thickness of copper in the PCBA bare board (should all of the copper layers coincide) is 1.5mm. The thickness of the compliant pin for a high density connector is typically 0.2mm thick. We are looking to detect a 12% increase in the thickness of the absorbing material. Hence in order to image any deformed compliant pins the image needs contrast. Hence lower energies would logically be expected to produce better images and so be preferred.

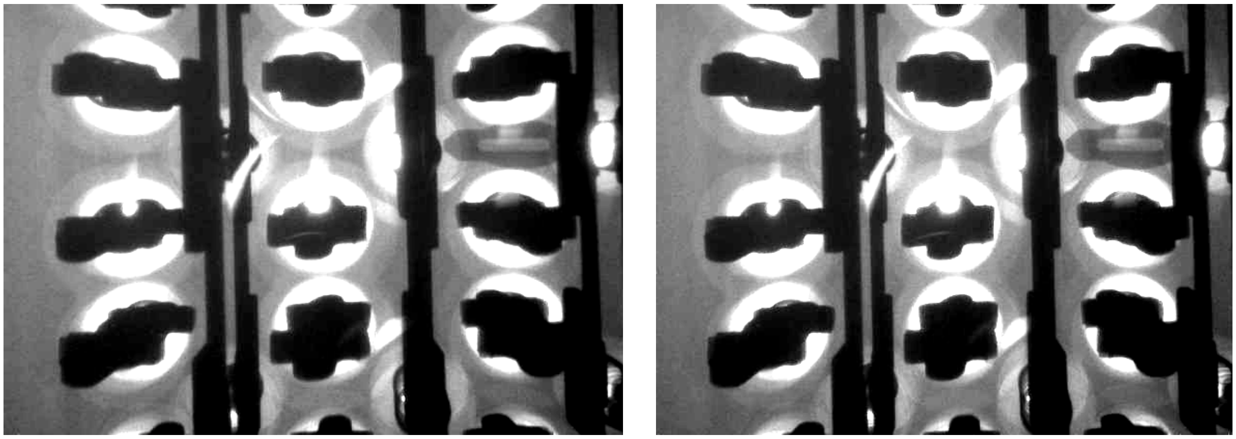
Figure 9 shows images of a mid plane sample fitted with FCI Airmax connectors. The images show a bent under compliant pin on a signal trace. At source energies above 80 kV it was difficult to image the defect artefact at all due to further loss of contrast in the image. The higher the source energy, the more narrow the tolerance window on exposure time. In this case the ideal energy to image the artefacts was 60kV. Repeating this process for a variety of backplane configurations 50-60kV appears the ideal energy for most backplane test applications. Utilising a source energy of between 50 and 60 kV produced optimum results in terms of clarity of images, insensitivity to precise exposure timing, and low test times. The remainder of sample images in this paper were all obtained at 60kV source energy.



40keV source, 3.4s exposure 60keV source, 1s exposure 80keV source, 0.5s exposure

Figure 9 - Effect of source voltage on image contrast

The second key parameter is the focal spot diameter of the source. This is the diameter of the focussed beam of electrons that strikes the anode of the source to produce the X-rays. This is hence the same as the size of the point source of the X-rays used to create the image. The smaller the focal spot diameter the sharper the images produced (and the more expensive the source). 95% of the energy of the electrons in the source is converted to heat in the anode. The smaller the focal spot means that the heat generated is confined within a smaller area. There is a limit to the power density that can be dissipated by the anode without melting. So this means the smaller the focal spot, the lower the maximum luminescence (brightness) of the source. Many systems quote a large range of focal spot diameters from as little as 0.1µm to as much as 100µm. But how small a focal spot do you need to reliably detect the assembly defect features we have been discussing. Figure 10 show images taken with our system of a 10mm thick, 32 layer mid plane PCBA with back to back connectors sharing the via barrels of the PCBA. The only difference between the images is the focal spot diameter that was used. The bent under pin on a ground bar is clearly visible on both images. Examining the pixel by pixel grey levels at the sharp edges does confirm the relative focal spot sizes. Full scale and full resolution images show that the 20µm image appears marginally “sharper” but there is very little visible difference and images obtained using a 50µm focal spot size system will automatically detect all of the backplane assembly errors discussed. The added system benefit (other than the cost of the source) of operating the source with a 50µm focal spot is that it can be operated at up to 6 times the intensity than the 20µm diameter spot source without causing damage to the anode. This results in shorter test times.



Focal Spot Diameter 50µm Focal Spot Diameter 20µm

Figure 10 – Effect of focal spot diameter on backplane images

These images were acquired with a geometric magnification of approximately 2. This is the maximum geometric magnification factor that is practically required for the detection of any of the backplane faults expected. But is this suitable for all X-ray inspection tasks? Figure 11 shows an oblique image through a Raid controller IC on a PC motherboard. The separation of the individual pins of the 128 QFP package is 0.5mm.

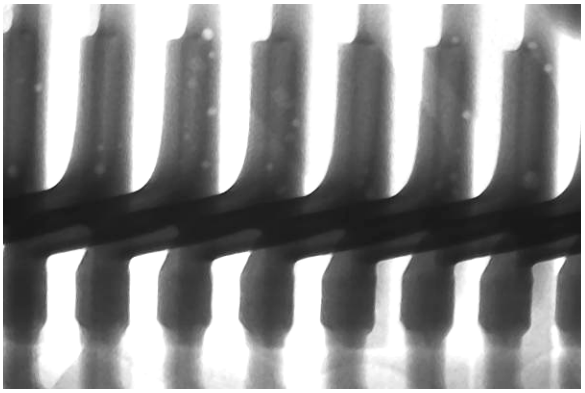


Figure 11 – Higher geometric magnification image with 20µm focal spot

The geometric magnification used for this image was 9. The blurring on the image edges due to the focal spot diameter in the source is slightly more obvious but the image quality is still highly acceptable and easily capable of displaying the texture on the surface of the IC pins and the integrity of the solder joints themselves. The white “bubbles” visible in the image are voids in the solder joint. These images are average samples from the many we have obtained on a wide variety of boards and image targets. All confirm that a source with a focal spot size that is controllable in the range 20 to 50 µm is adequate for all of the needs of our application.

Transmissive radiography versus laminographic tomography for backplane samples

Laminography (or 3D X-ray as it is commonly referred to) is the process used in some X-ray system to isolate the X-ray absorption on a given single plane in the image. In Laminography a series of individual 2-D transmissive images are obtained of a particular location on the sample board with the source and detector at different positions. These transmissive views of the sample board at an angle relative to the perpendicular plane of the X-ray beam gives rise to a two-dimensional image that can be mapped to a simulated three-dimensional representation. A computer tomographic reconstruction can then be performed to synthesize the 2D view on a given plane.

There is much debate as to whether two-dimensional X-ray inspection (transmissive radiography as utilised in this paper), which has a well defined history, is more beneficial than three-dimensional X-ray (laminographic tomography). But which method is most appropriate for testing large backplane samples?

The advantages of the transmissive radiology method are that the images are sharper and have a higher resolution. The laminography reconstruction can be considered as "Smearing out" the images on the layers above and below the plane of interest. The more images that are utilised in the reconstruction then the better the layer selection in the resulting image but the longer the image acquisition time. The disadvantages of the transmissive method are its inability to clearly distinguish objects on different layers in the PCBA. The laminographic method allows for the viewing of solder joint volume including the respective component lead and pad. The 2D transmissive image will still determine if there is a defect in the connection itself.

For backplane samples the extensive structures, perpendicular the board surface, presented by the connectors themselves complicate the picture. Here the connector construction completely blocks the access of the X-rays to the particular plane of interest at many points and in many different directions. So for backplane inspection, and pressing defect detection, a high quality 2D image is preferred to a tomographic reconstruction.

Safety considerations

The optimum source conditions for routine imaging and detection of faults on press-fit connectors is with a source energy of 50-60 KV and a focal spot diameter of 20-50µm. Ideally both of these should be programmable on an image by image basis. Providing the facility for higher source energy, or smaller focal spot size, both increase the manufacturing cost of the system often by multiples. This is not only in the cost of the component parts of the system. The higher the X-rays energy, the lower their absorption rates (the higher their penetrating power). The absorption is inversely proportional to the cube of the X-ray energy. This also means that the higher the energy the X-rays, then the thicker the shielding material required protecting the operators.

A possible disadvantage of the robotic system is that the position and orientation of the X-ray source is random over the extent of travel of the robotic heads. This requires the use of a continuous "beam stop" in the machine face behind the detector, plus a thinner shield behind the source to contain backscattered radiation. As we are limiting the energy of the source to 60kV then this is not difficult to achieve. The amount of shielding required to contain 160kV X-rays is nearly 20 times the thickness required to contain 60kV X-rays at the same luminance.

Our system has been designed to fully meet the safety requirements in the UK[9]. These are more stringent than the safety requirements elsewhere in Europe, North America or Asia. The levels of radiation leakage from the system are less than 0.25µSv. This allows the system to be operated without specific zone restrictions on the area surrounding the machine.

System capability

We have tested the capability of the system to detect press-fit connector defects on a wide range of backplane samples. This includes many mid-plane boards with press fit connector a pins sharing via barrels in the PCBA.

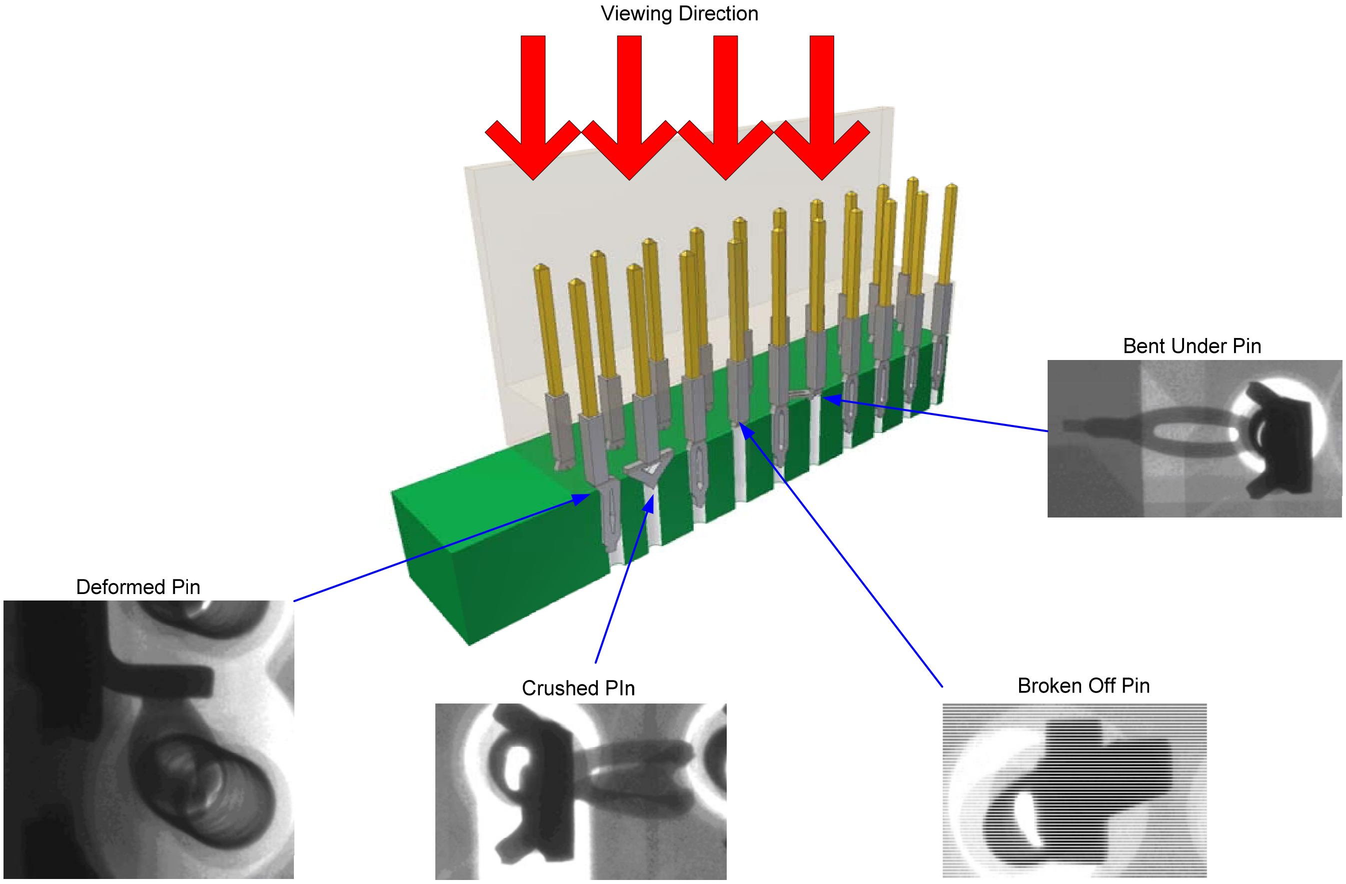


Figure 12 - Sample images of press fit connector assembly faults

Figure 12 shows example images of each of the types of faults that are commonly experienced in press fit connectors. The geometric magnification used to acquire the images was between 1 and 2. So in each case the source is far enough above the DUT to eliminate parallax issues from clouding the detail on the images. The detail and sharpness of the images of the fault defects is superb. The broken off pin image in figure 12 is a good example of the use of oblique imaging to confirm the presence of the fault. This is common technique where the image is obtained at an angle through the board rather than perpendicular to the board's surface.

In the RXI system we utilize a multi scan approach to X-ray inspection. Firstly an exploratory image at low magnification is obtained and analysed by the computer to identify any suspect faults (see figure 13). This scan is performed at very low geometric magnification, 50µm focal spot diameter and high source brightness. In the image in figure 13 the computer has identified 5 suspect areas on the connector. Any suspect faults are then analysed in detail, at higher magnification, and using a small focal spot size and even a different X-ray energy. The broken pin image in figure 12 is one of these detail images. This image clearly shows that the compliant pin has broken off completely at the point where it clears the connector housing. This is a very subtle fault that would be missed by many systems.

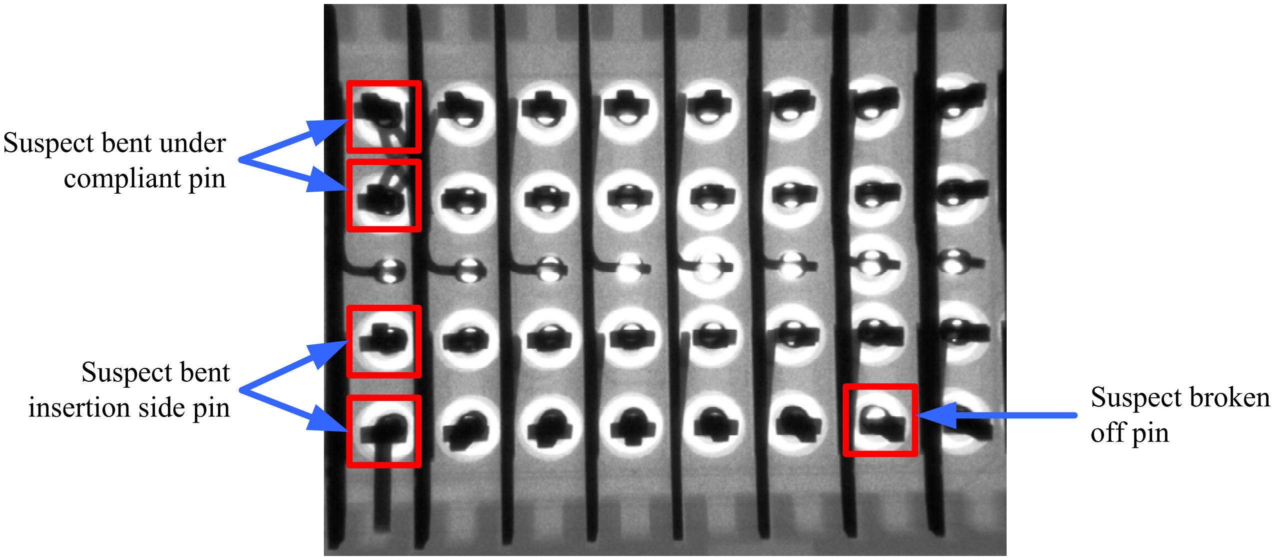


Figure 13- Example exploratory image

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Image parallax is a common problem encountered when inspecting press-fit connector defects using systems optimised for normal PCBA AXI. The problem is caused by the high aspect ratio of a connector compared with a typical electronic component. The typical procedure in standard PCBA X-ray inspection is to acquire the image with the source as close as practical to the sample under test. This minimises the exposure time and maximises the available geometric magnification. Inspecting backplane samples is very different! In effect we are viewing the base of the connector through the gap between the pins. As the viewing point gets closer and closer to the top of the connector, more and more of the PCBA surface becomes occluded by the bodies of the pins themselves. The effect is that only a small area of the connector base is sufficiently visible to clearly view any defect artefacts that may be present. Figure 14 is an image acquired with the X-ray source 75mm above the unit under test. Although the pressing defect is still visible in the image the impact of the parallax in the image means that only 50% of the detector field of view is useful. Determining the ideal source height for a given field of view, and a given connector height, is a matter of simple geometry.

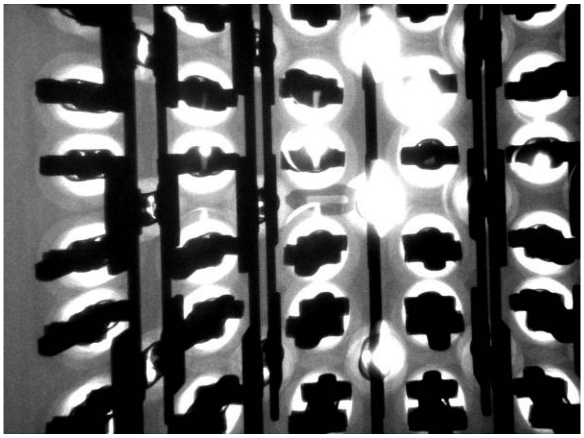

Figure 14 - Effect of parallax on image

Figure 15 is an image of an 11mm thick backplane board fitted with 210 FCI Zipline connectors. The connectors are mounted back to back on the board with 105 individual connectors on each side of the board. The connectors on the rear of the board are mounted orthogonally to the connectors on the front. Hence the “crosses” on each of the via holes (the compliant pins are at right angles to each other. This image is obtained using a geometric magnification of 1.5. This image is presented to highlight the importance of automatic computer inspection rather than manual inspection. At this magnification there will be 4 images obtained for each connector giving over 420 images to inspect the Zipline connectors on the board alone. These are very detailed images which would be physically impossible for a human operator to inspect thoroughly. The only realistic expectation is to confirm the presence of a fault already localised by other means.

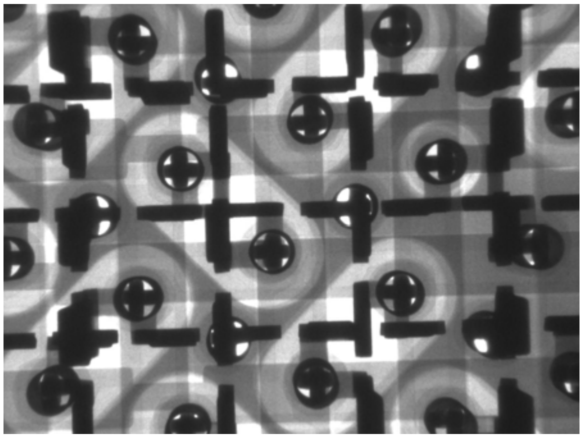

Figure 15 - Back to back FCI Zipline connectors sharing via barrels

So the system performs well in detecting press fit connector faults. But can it also be used for routine inspection of more typical PCBA's? The following images confirm that RXI is also perfectly capable of performing the typical tasks expected from any other X-ray inspection system in terms of solder joint integrity (see figures 16 and 18), BGA analysis (figure 17), and counterfeit component detection (figure 18).

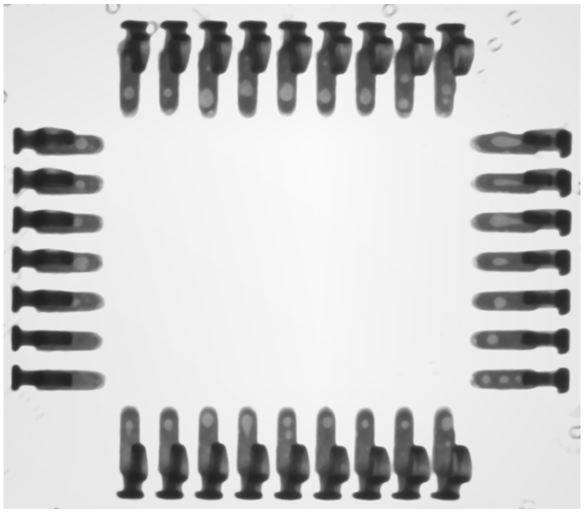

Figure 16 - Solder voids on a PLLMC surface mount IC socket

Figure 16 shows an image of a PLLMC surface mount socket on a PC motherboard. Here the solder joints are all physically underneath the housing packaging and hence impossible to inspect using any other technique but X-ray inspection. The voids in the solder joints appear as bubbles underneath each of the solder pads. In this case every pin has some evidence of solder voids. In some cases more than 60% of the pad area is voided. In automatic inspection the computer analyses these joints by measuring the percentage of the pad area that is covered by the void. When this area exceeds a given percentage then a fault is flagged.

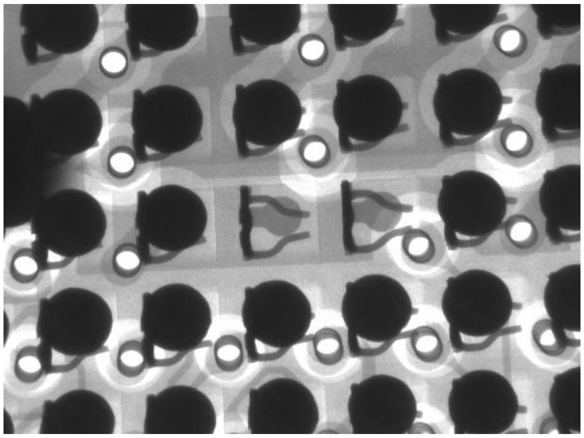

Figure 17 - Missing "Balls" on a FLGA connector

No paper on X-ray inspection would be complete without an image of a BGA joint. This is one of ours. Figure 17 is of a FLGA processor socket on a PC motherboard. The diameter of the BGA balls is 500µm and the pitch is 800µm. The image is slightly more complicated in that the pin contacts in the housing body overlay the BGA balls. Still the absence of the two balls in the array is clearly obvious. BGA assemblies with ball diameters down to 200µm are also straightforward to detect. As with a majority of AXI systems our system software detects discrepancies in ball diameter, position, and shape.

The final figure (18) presents a montage of two 4 mega pixel images side by side of the area surrounding two SOIC packaged IC's on a PCBA. The resulting image is 8 megapixels. The size of the actual board area in the image is 70mm by 35mm. This is nearly 600 pixels per cm resolution. The image resolution has been reduced by 80% to match the printing process in this document. The registration of the images is an excellent indication of the positional accuracy of the camera positions. The IC bonding wires are clearly visible even in this low magnification image and very evident in the full resolution image. Solder joint integrity is tested by measuring the area of the solder joint and by measuring the grey scale profile along the axis of each joint and comparing this with a mask which has been learned through measurement of a number of known good joints. Tolerances can be specified for or both of these parameters. SMT resistors down to 0201 can be tested in this way. The X-ray image of the internals structure of the IC can be correlation pattern matched against a known sample for counterfeit detection.

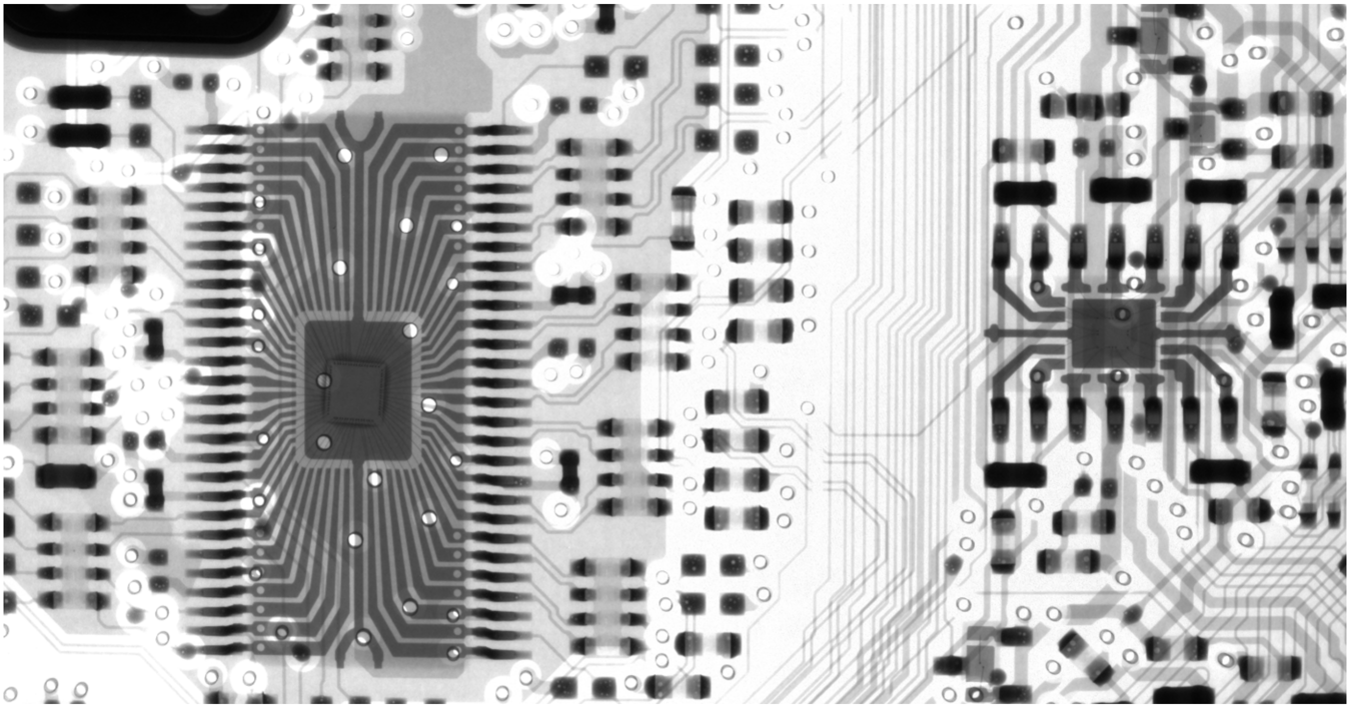

Figure 16 - Counterfeit component detection and component solder joint inspection

Conclusions

The iNEMA 2009 manufacturing report Research and Development requirement for an automated X-ray methodology capable of doing 100% inspection of pins pressed into the same via barrel and scalable to test the largest backplanes is fully realised in this robotic test system.

Utilising a low energy X-ray source, the resulting RXI (Robotic X-ray Inspection) system provides both high resolution AXI for detecting faults *under* connectors, and full colour high resolution optical AOI for detecting faults *within* connectors, in the same machine, and in a single test sequence. This fully automatic test system is a reliable, high speed, and highly cost effective test system for backplanes and other large PCB assemblies up to 1000mm (39.4") x 1600mm (63") in size and over 18mm (0.7") thick.

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