LA-UR-16-22320

Title: Preliminary report for using X-rays as verification and authentication tool

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Intended for: Report

Issued: 2016-04-06

Preliminary report for using X-rays as verification and authentication tool

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We examined x-rays for the use as authentication and verification tool in treaty verification. Several x-ray pictures were taken to determine the quality and feasibility of x-rays for these tasks. This document describes the capability of the used x-ray system and outlines its parameters and possible use.

Introduction

During treaty verification it is important to be able to verify and authenticate equipment. This authentication and verification process should be as non-intrusive and easy as possible, since this work is usually done in a space where the monitor has little to no freedom to adjust power meters or take equipment apart. Therefore, using x-rays is a desired possibility. The fact that x-rays can literally examine things behind visual barriers and thereby might not require an item to be disassembled is of huge advantage. We set up a golden x-ray generator coupled to a high-resolution dental x-ray detector from Hamamatsu. With this setup we x-rayed a variety of microchips that were used in the automotive design as well as a variety of modern memory banks, SD chips, and microcontrollers.

The experimental set up included a portable Golden x-ray generator XR200 24 inches away from a Hamamatsu x-ray detector used usually for dental x-rays. The figure below shows the experimental setup.

Figure 1: Experimental setup

The Golden XR200 is run by a 14.4 V DeWalt battery. The maximum photon energy is 150 KVP and the x-ray source size is 3 mm in diameter. The whole unit only weighs 12 pounds, and is approximately 13 x 5 x 8". It is capable of twenty-five pulses per second with a dose rate of 2.6 mR per pulse.
The Hamamatsu x-ray detector is a commercial off-the-shelf dental x-ray detector with USB output and data acquisition program that can be used on any Windows PC. The Hamamatsu CCD area image sensor used in the experiments has a pixel resolution of 20 micrometers per pixel. The detector is optimized as dental x-ray, which means for x-ray energies of approximately 16 keV energy. The detector was placed approximately 24 inches away from the Golden x-ray unit. X-ray images were taken from a variety of electronic hardware with the electronic hardware being directly placed on the face of the detector.

Intensity tests

One of the important settings for x-rays is the intensity with which an item is interrogated. The next four images display the same chip X-rayed with intensities of ten, twenty, thirty, forty, and fifty pulses. It can be clearly seen that the contrast level changes significantly.

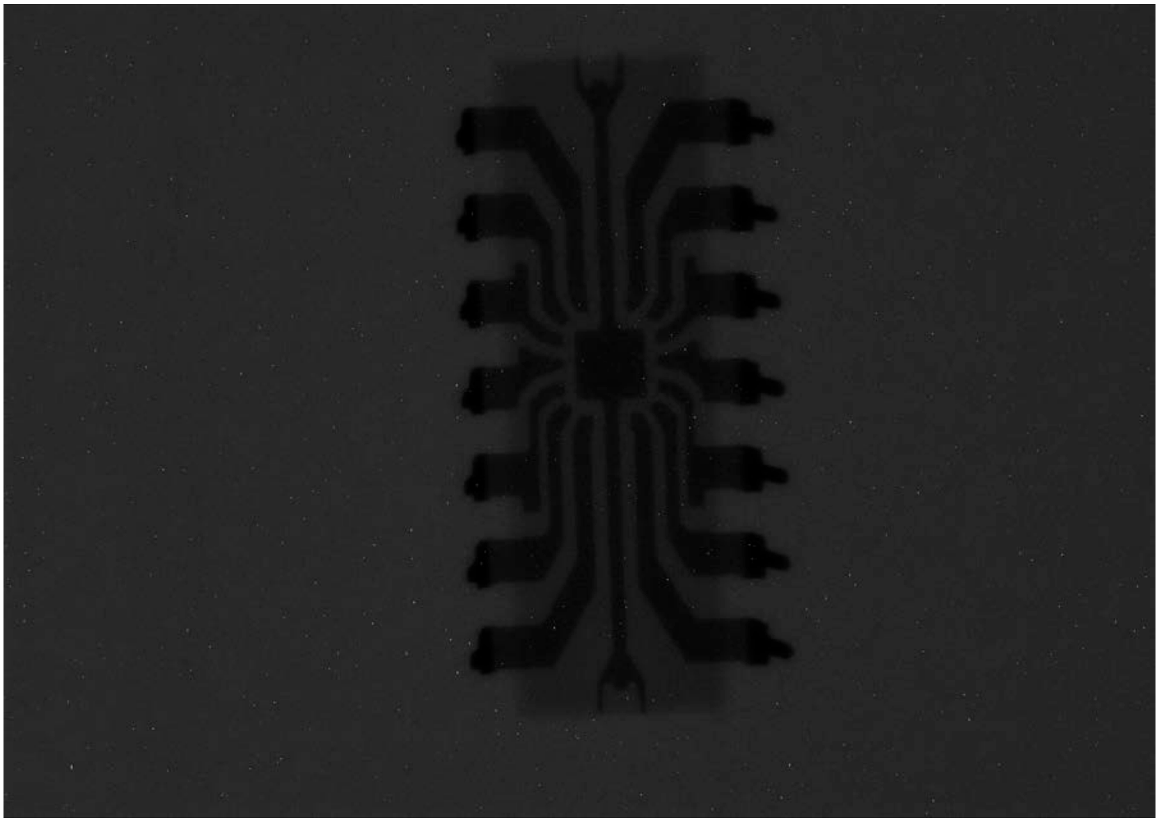

Figure 2: 10 x-ray pulses

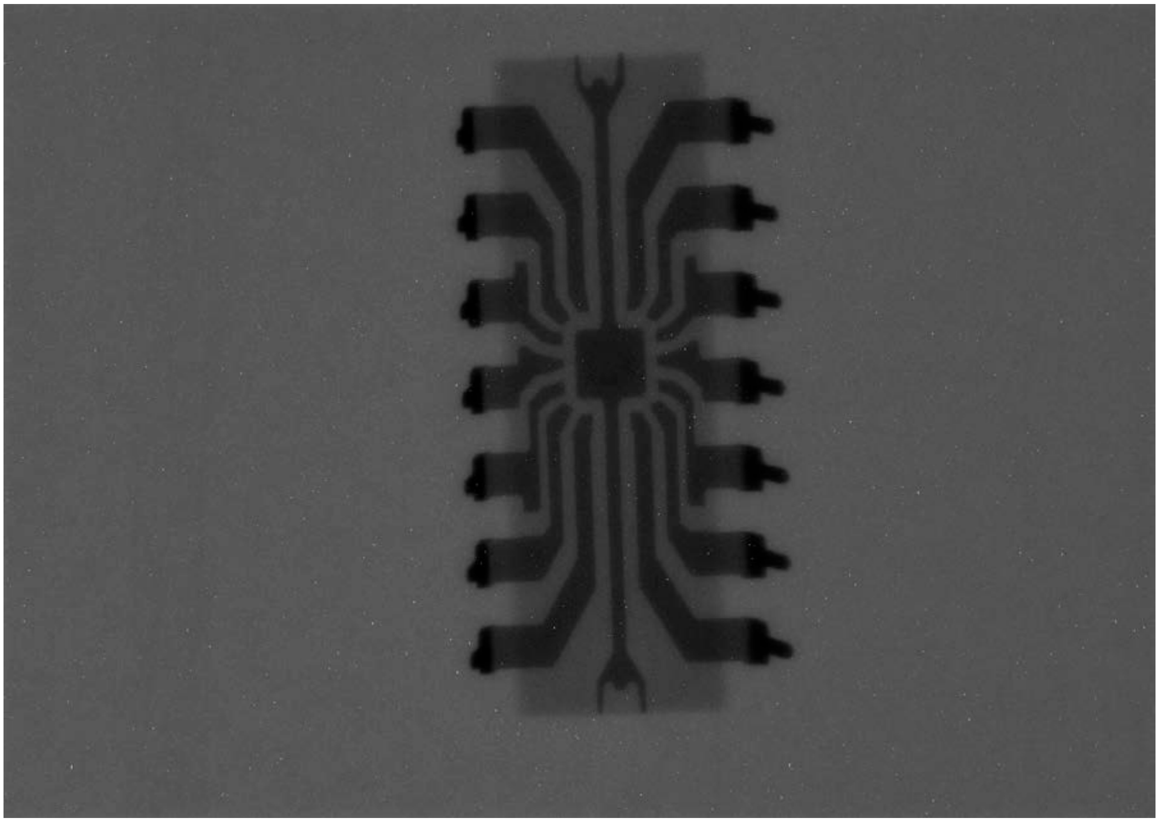

Figure 3: 20 x-ray pulses

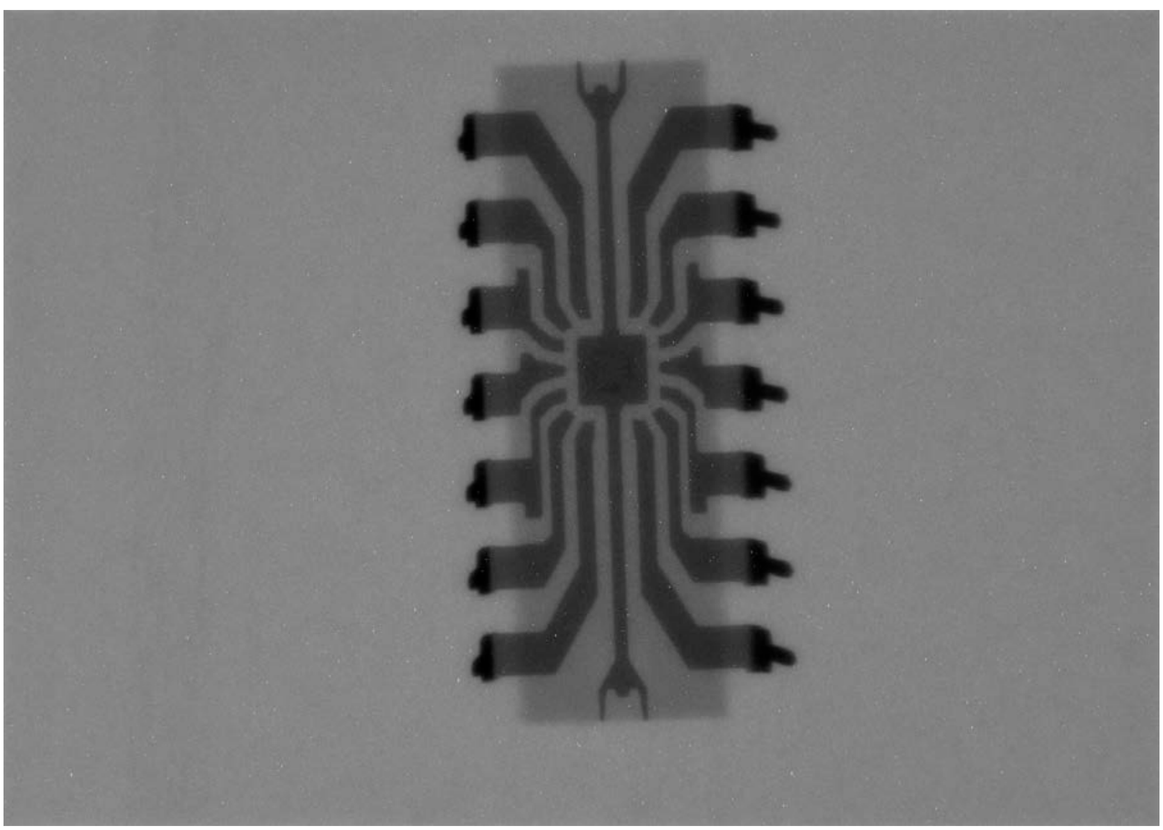

Figure 4: 30 x-ray pulses

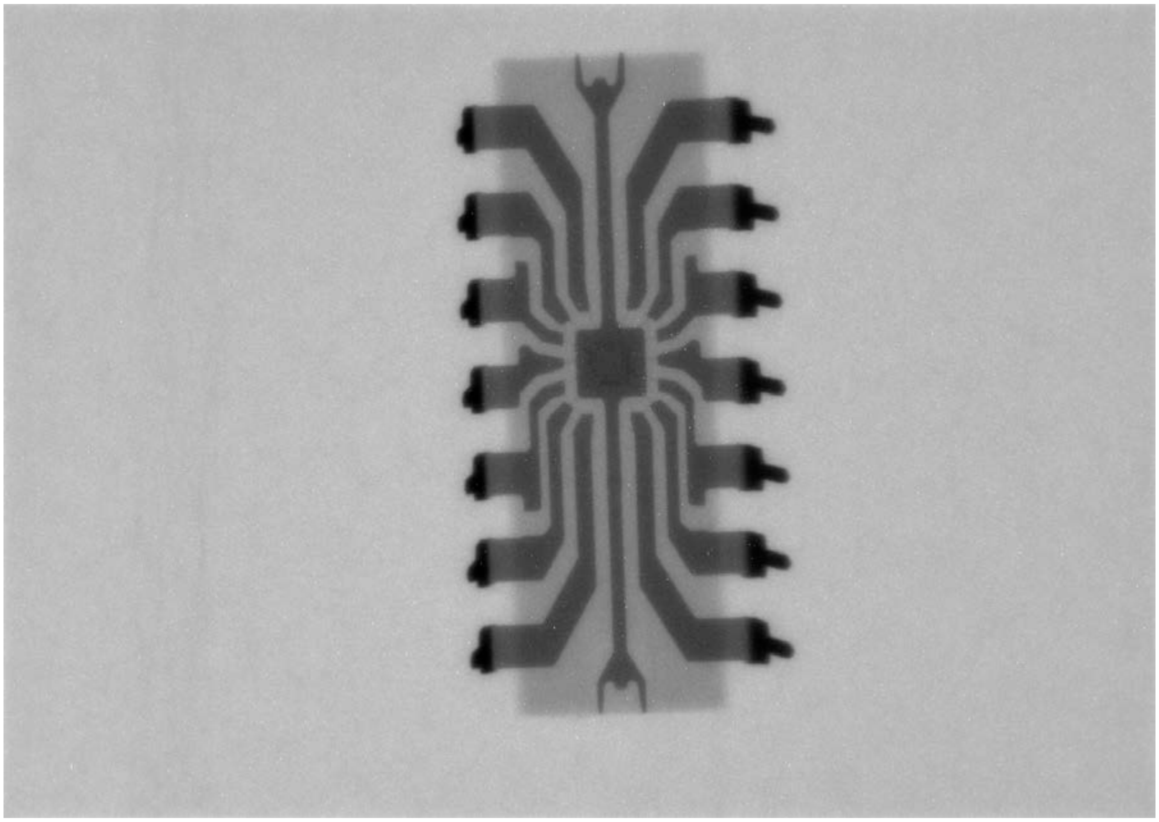
Figure 5: 40 x-ray pulses

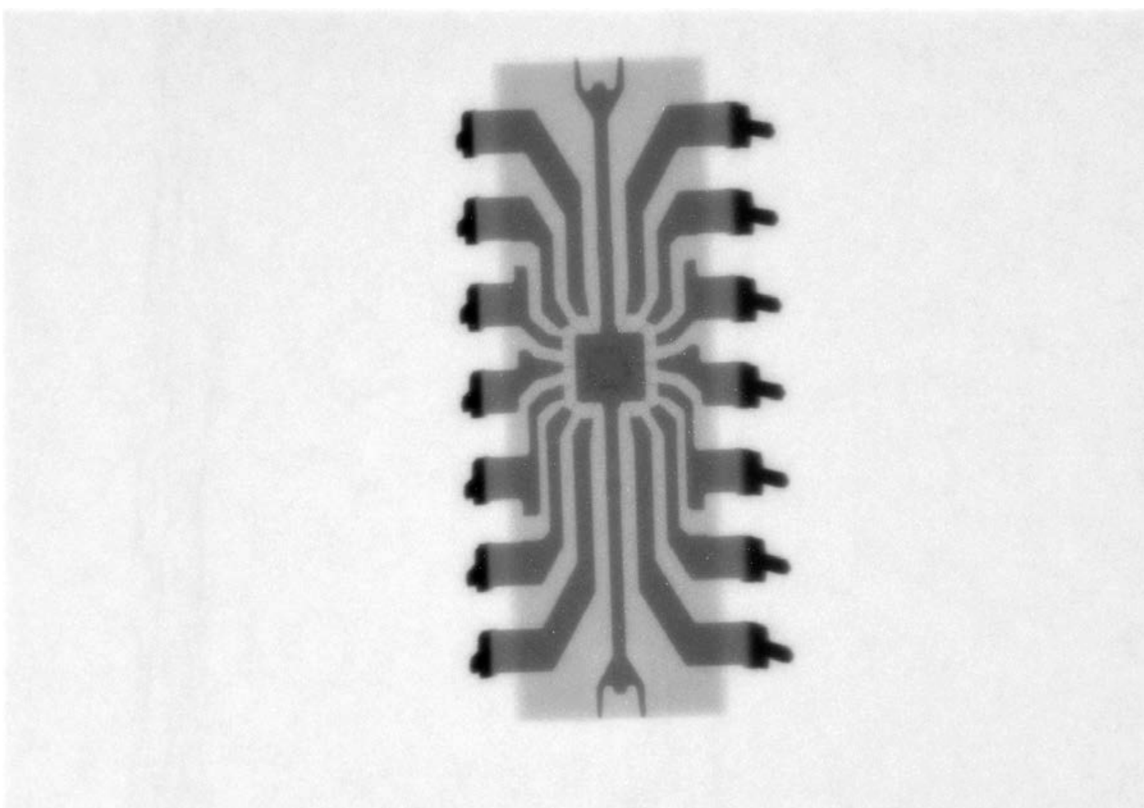
Figure 6: 50 x-ray pulses

The contrast achieved in Figure 5 and 6 with forty and fifty x-ray pulses seem to yield the best picture. In both pictures, the small bonding wires from the legs to the chip can actually be observed. The reason for the stark contrast of the chip in the center of the IC seems to be a metallic shield against electromagnetic frequencies.

Differentiation of electronic components

One question that needs to be answered is can we differentiate between different microchips. Figure 7 and 8 show pictures of a variety of microchips used in the current portal monitor data acquisition system. In Figure 7 the chips model numbers are (from left to right) SN74HC14N, SN74HC14N, SN74HC08N. The SN74HC14N is a Texas Instrument Schmitt trigger inverter, the SN74HC08N is also from Texas Instruments and consists of 4 independent AND gates.

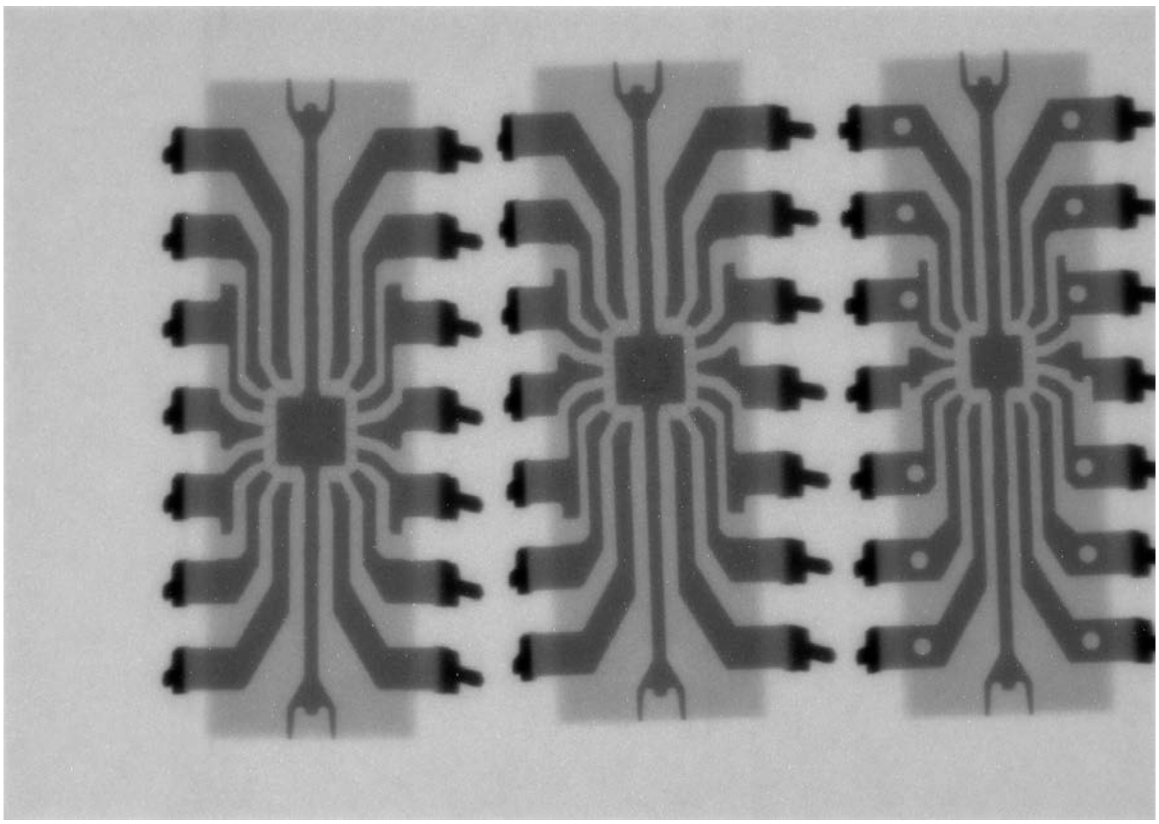

Figure 7: Microchips used in DAQ of portal monitor

Figure 8 displays the previously shown chips from Figure 7 (SN74HC14N) and a small microcontroller unit.

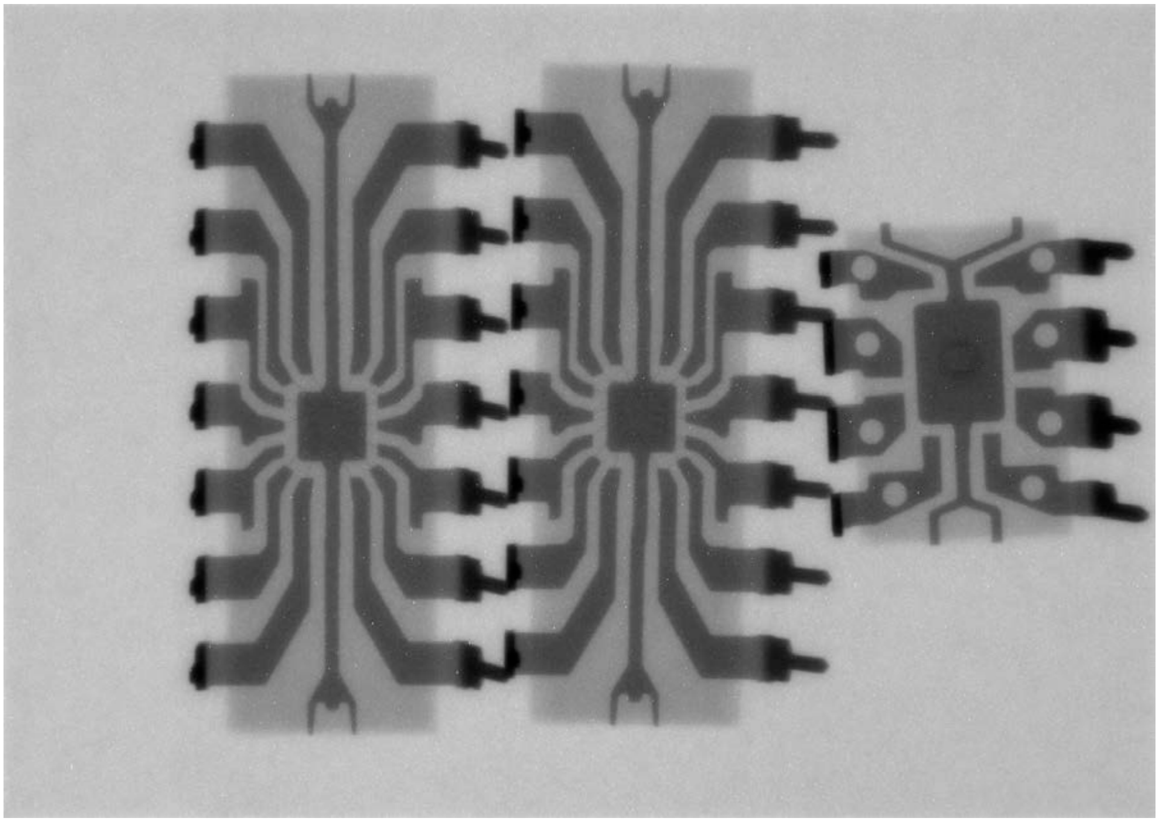

Figure 8: Two regular chips and a small micro controller

It is easily visible that with the current x-ray system chips legs and conductor layout can be observed. However, the contrast and resolution of the system are not good enough to actually see the logic components on the chips.

Figure 9 displays two chips that fulfill the same functions and fit the same hole pattern. However, they are over twenty years apart in their manufacturing date. Noteworthy is that the left chip is the modern chip, the right chip, where traces in the center of the chip can be observed, is the older version. It is believed that the older chip does not have any radiofrequency shield. The modern chip was built by Texas Instruments, the old ship was built by ATMEL. Even though they are based on different technologies, each one would function in the system for the portal monitor.

In Figure 10 two different timer chips are displayed, the size of the shield can be used as differentiating criteria. The actual silicone structure is not visible.
Three different micro controller are displayed in Figure 11. Each of them has a clear epoxy window in the center, but the layers connecting to the legs are not visible.

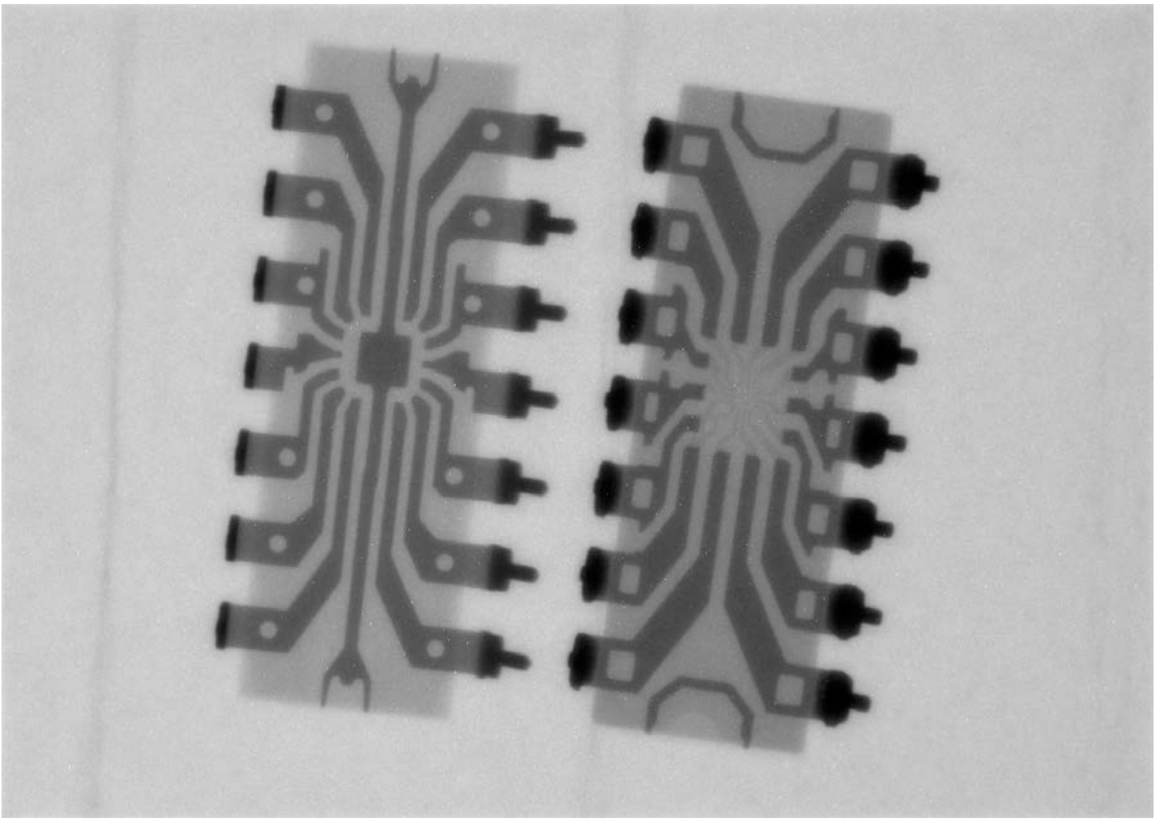

Figure 9: Two chips with the same function build over 20 years apart

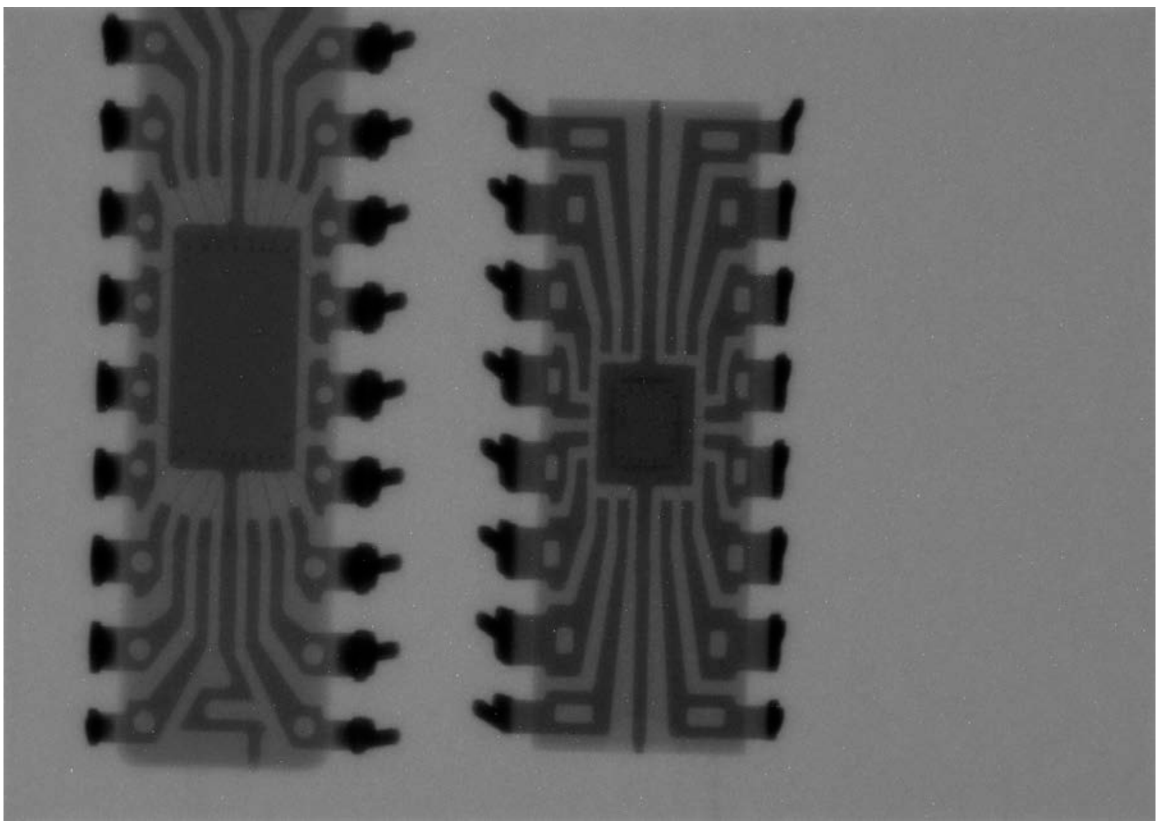

Figure 10: Timer micro chips

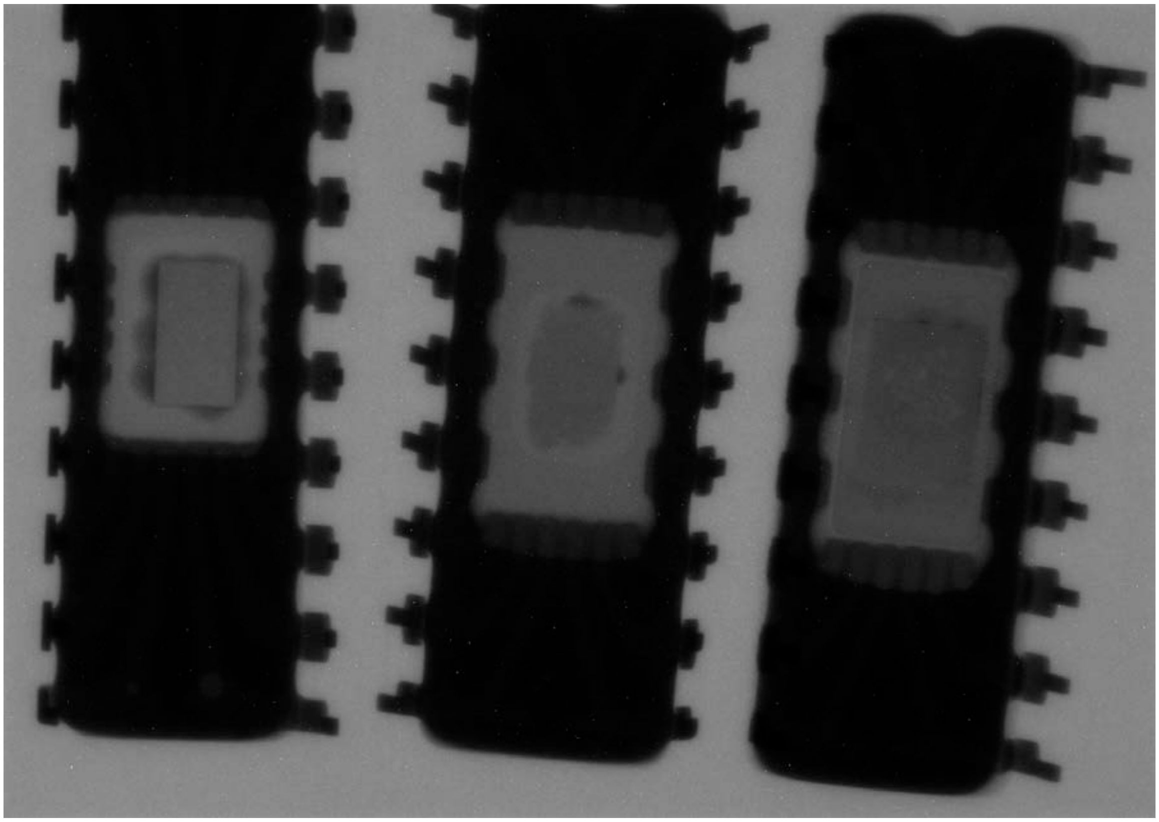

Figure 11: Micro controller chips

Modern electronics

Another question that needs to be answered is: is it possible to find modern electronic implants in these old-style microchips and later boards. In order to answer this question a small variety of modern electronics has been x-rayed by the system. Figure 12 shows the x-ray off a 2 GB SD card currently in use. As can be seen the electronic components in the card are tiny. The contrast is difficult to establish and the actual memory modules are hard to identify in the x-ray.
Figure 13 displays a 32 GB SD card. In that picture traces off conductors can be seen as well as soldering spots for surface mounted devices. However, identifying components other than the electrical connectors for the card appears to be difficult at best.

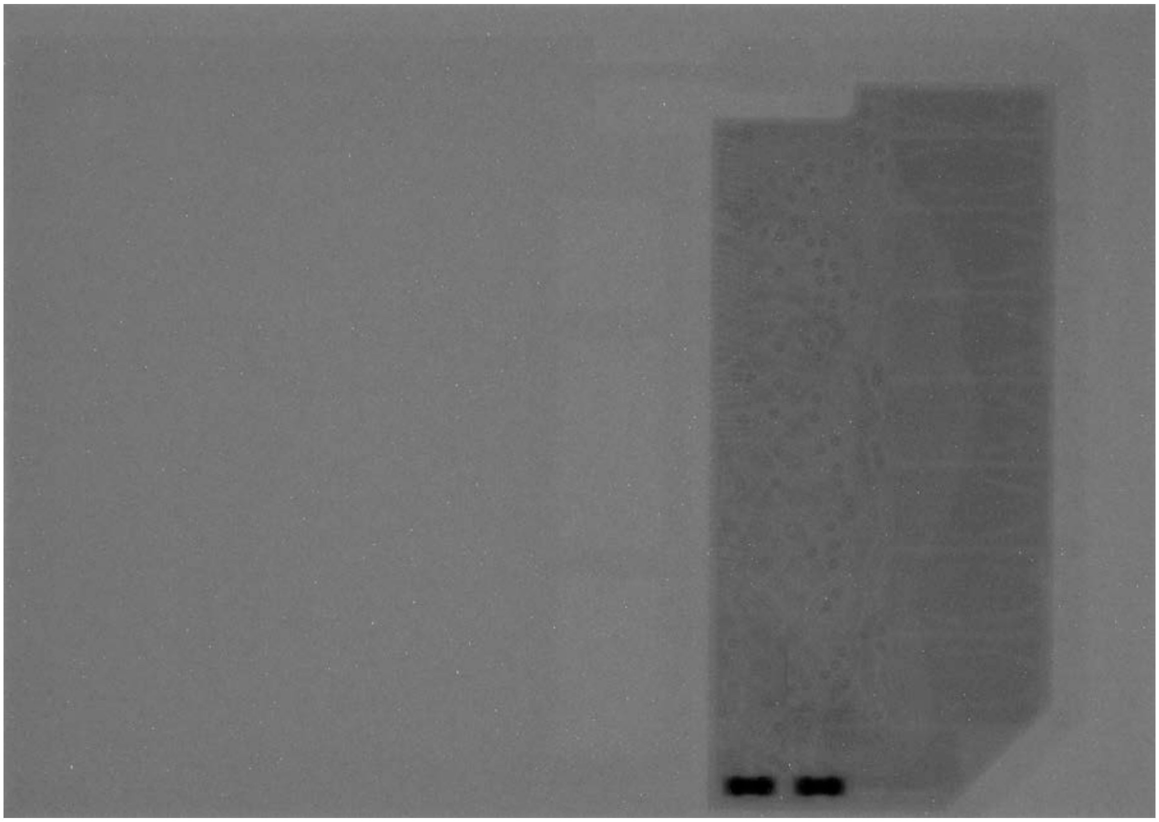
Figure 12: 2GB SD card

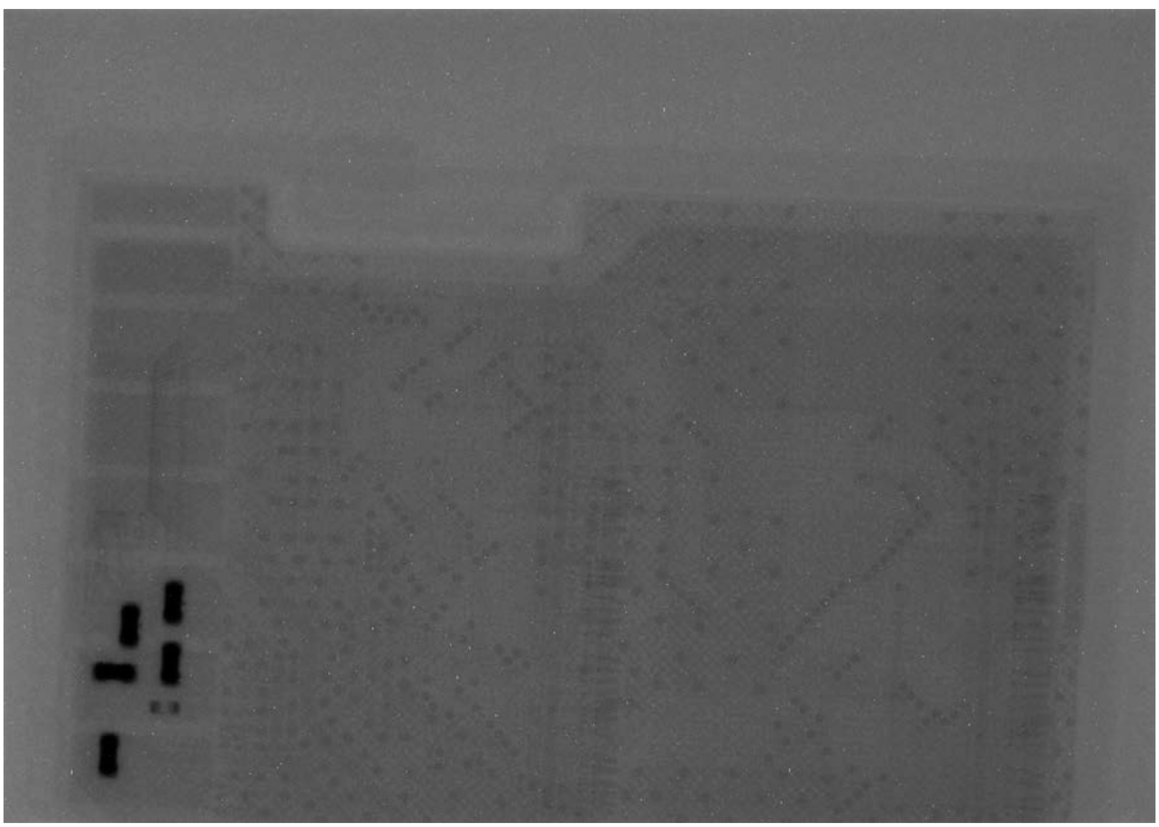
Figure 13: 32 GB SD card

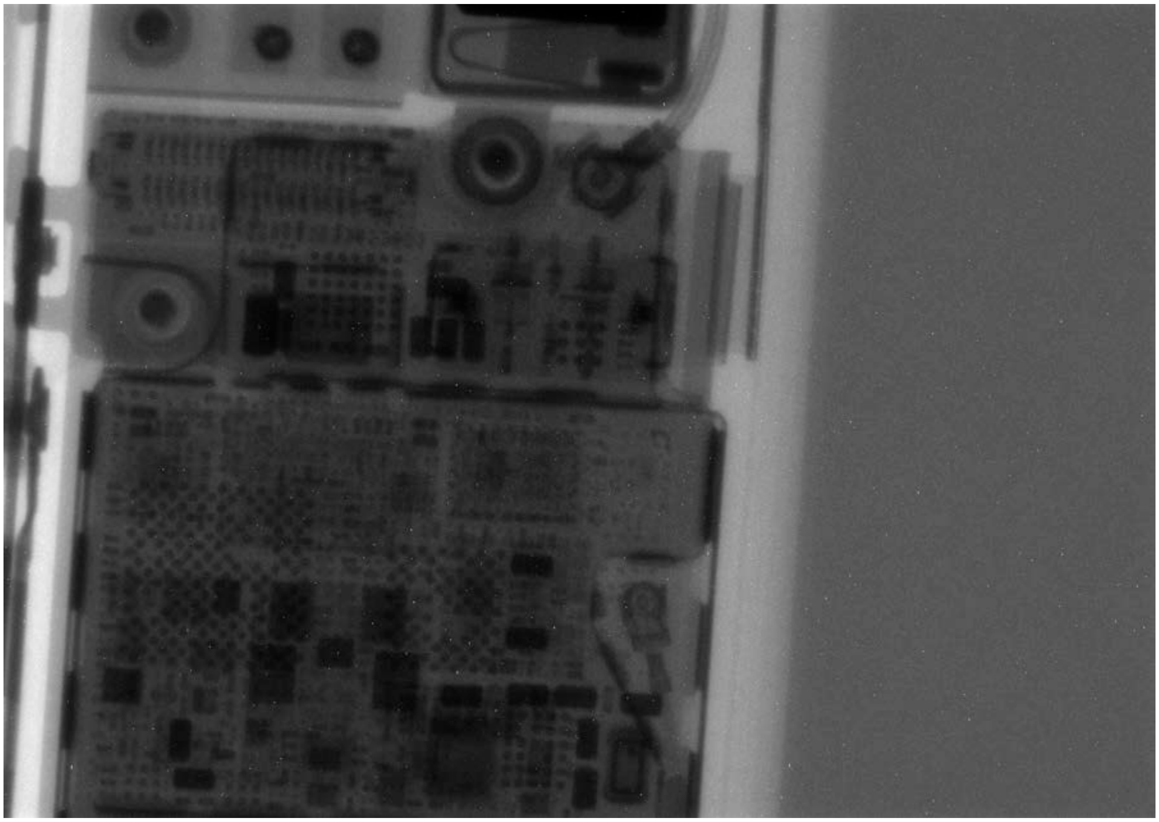

Figure 14: I-Phone

Figure 14 shows the x-ray of part of an iPhone, in this picture some electrical components with actual size can be observed, soldering Dot's for surface mounted devices can be seen, and some macroscopic building elements are visible. The picture also shows internal screws washers and grounding cables.

Figure 15 displays an x-ray of a Raspberry pie controller. Different soldering points and some electronic components are clearly visible in the surface mounted device technology. It is not clear if the electrical connector gems that are seen are sitting on different layers or on the two layers. However, the traces can be seen and made if necessary. In addition, this particular Raspberry pie had been covered with tamper indicating glitter paint. The paint flakes could not be seen in the picture.

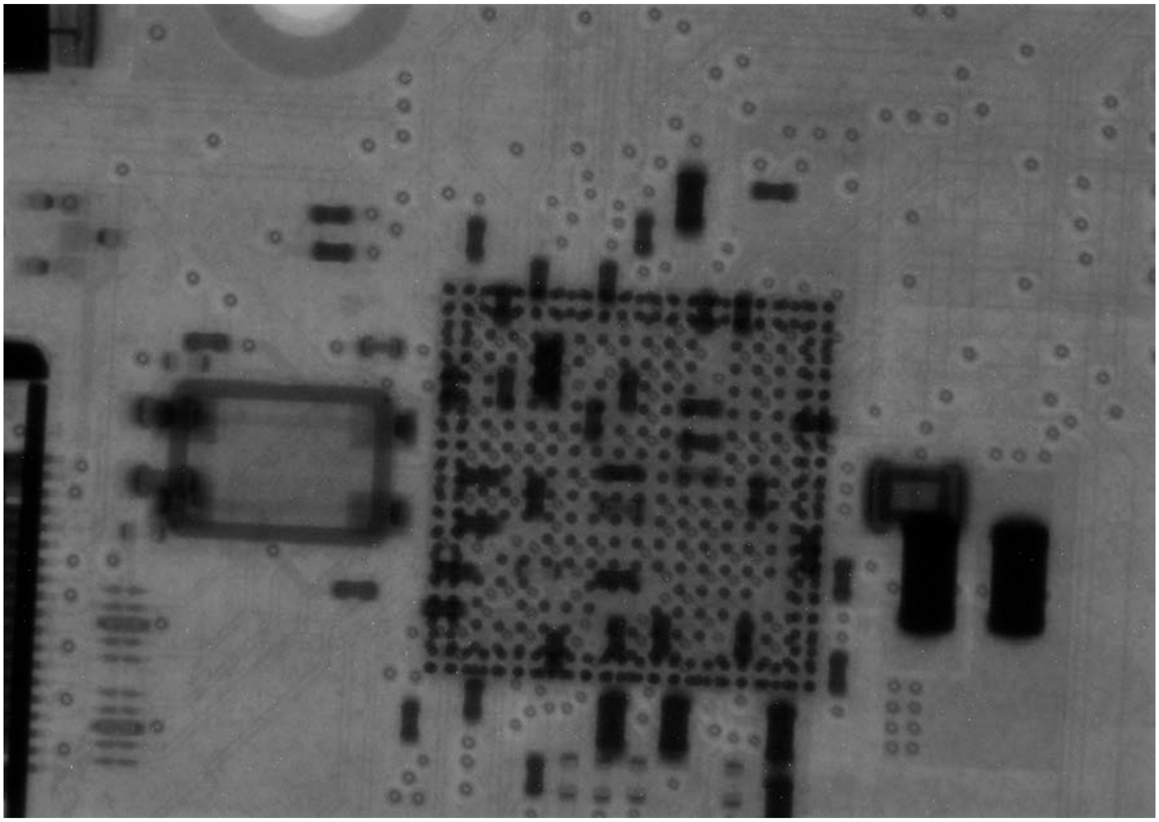

Figure 15: Raspberry Pie.

Figure 16 shows an Amtek A111 board and figure 17 shows the same board after tampering with the board. A wire of size xxx can be seen added to the circuit on the left integrated chip.

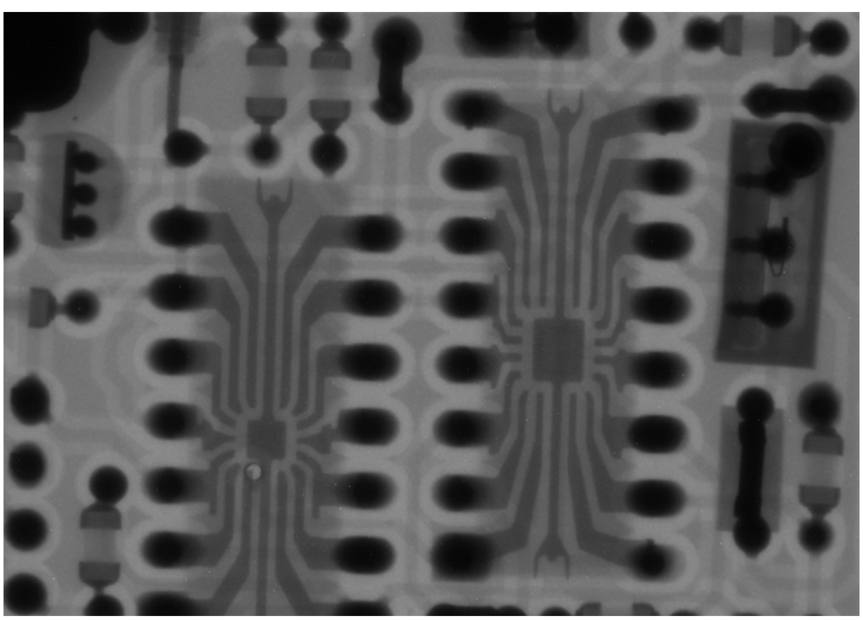

Figure 16: Amtek board A111 before modification.

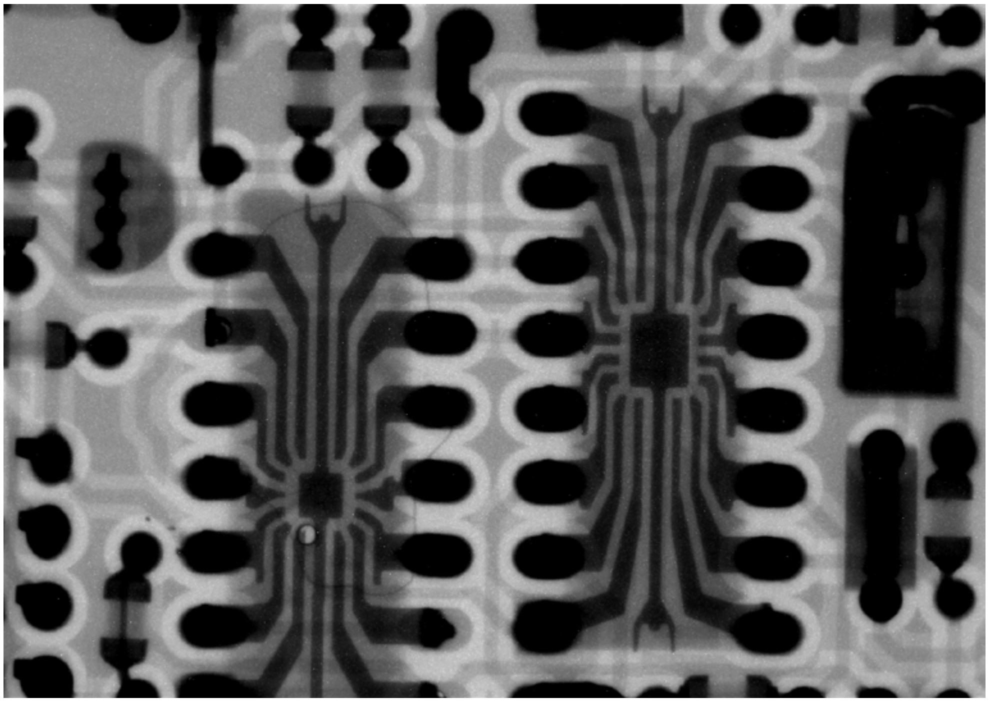

Figure 17: Amtek board after modification with a wire.

Conclusion

Even though the system as it was tested is far from optimal performance, the x-ray image allows us to see later traces, chip sizes, and microchip internal conductors. With the high x-ray energy endpoint of the Golden portable x-ray detectors it is nearly impossible to see silicon structure. In addition, as expected, the spatial resolution of the detector is much too crude to detect electronic gate structures. This system is able to detect copper and other heavier metals down to a 20 μm size.

For this system, one could imagine a larger area detector that covers large parts of analysis board. Images from these kind of x-rays could be done in an indexed set up. A before and after image could then be overlaid and subtracted to enhance the differences of the two images or the lack there off. The technique could be used to ensure that metallic objects in the box have not been changed. It would be very hard to argue that this technique can be used for an initial authentication to ensure that a piece of equipment has been built to specs.

It can be argued that if the x-ray system would be matched better, meaning an x-ray source with lower endpoint energy and a detector similar to the Hamamatsu detector used in this demonstration more information can be obtained. As a matter of fact, in dentistry x-rays revealed cavities which are basically a transmission difference between different densities of carbon calcium mixtures. A higher intensity lower energy x-ray source could be capable of finding extra hidden layers of silicone.

A more careful study of this certification and authentication tool needs to be done if more than layer traces and chips sizes need to be viewed.