FRONTGRADE

CATEGORY

Frontgrade UT8QNF8M8 64Mb QCOTS Nor Flash

X-ray Inspection Considerations

1/24/2025

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Overview

The application note intends to inform users of the effects of x-ray inspection on microelectronics and specifically towards NOR/SPI/NAND flash products. It provides qualification test conditions and recommendations when x-ray inspection is necessary. It recommends flash based memory products be reprogrammed after x-ray inspection. Frontgrade will not guarantee the specified data retention for devices which are exposed to x-ray or other radiographic inspection.

This application note is specifically applicable to the titled Frontgrade 64Mb Nor Flash product UT8QNF8M8 (SMD# 596212204 all device types).

Background

The aforementioned Frontgrade QCOTS (Quantified Commercial Off-The-Shelf) product offering is manufactured by Frontgrade utilizing a onetime purchase of a single commercial die source. Frontgrade intends this one time purchase to meet our needs for the entire product life cycle. The die source was acquired from Spansion Inc. Since that time, Spansion Inc. was acquired by Cypress Semiconductor who subsequently was acquired and is currently operated by Infineon Technologies. The following three embedded Infineon application notes are provided by Frontgrade with permission of Infineon Technologies.

Embedded Infineon Application Notes

3.1 Specific Infineon application note titles

- 3.1.1 X-ray Inspection Considerations for Surface-Mounted Flash ICs
- 3.1.2 X-ray Inspection Test Conditions for NOR/SPI/NAND Flash
- 3.1.3 Dose Minimization During X-ray Inspection of Surface –Mounted Flash ICs

AN98522

X-ray Inspection Considerations for Surface-Mounted Flash ICs

About this document

Scope and purpose

AN98522 is intended to help those customers who perform X-ray inspection of the surface-mounted integrated circuits (ICs) on their circuit boards.

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1 Summary

This document is intended to help those customers who perform X-ray inspection of the surface-mounted integrated circuits (ICs) on their circuit boards. X-rays behave basically the same as visible light rays, since both are wavelike forms of electromagnetic energy carried by particles called photons. The difference between X-rays and visible light rays is only the energy level of the individual photons, which is also expressed through the wavelength of the rays. Just as filtering of visible light wavelengths (that is, energies) can be used effectively to prevent damage to photosensitive materials, Infineon has shown that filtering of specific X-ray energy levels can be used to prevent damage to X-ray sensitive semiconductor ICs.

It has been well established that semiconductor ICs can suffer irreversible damage from charging effects caused by X-ray energy. While this phenomenon does not always result in a hard failure, customers often have no way to recover from the effects of the X-ray exposure. The following table shows the approximate total X-ray dose damage of commercial off-the-shelf (COTS) devices:

Type of Semiconductor Device (COTS)	Total Dose Threshold (K Rads)
Linear	2-50
Mixed Signal	2-30
Flash Memory	5-15
DRAM	15-50
Microprocessors	15-70

Infineon studies have also shown that there is a substantial X-ray dose variation among inspection equipment suppliers as shown in the table below:

Supplier	Approx. Dose (Rads)
A	0.057
B	3
C	10
D	12
E	25
F	35
G	60
H	700

We found that in most cases, these suppliers have recommended X-ray doses that are significantly higher than what is necessary to achieve successful inspection results. The key is to minimize the total cumulative dose to the IC while achieving a useful inspection image.

The original goal of Infineon experimentation was to detect 50 µm copper traces (typical for a PWB) and the underlying 0.5 mm IC solder balls at the lowest possible X-ray dose. We quickly proved that the X-ray tube voltage is not the predominant factor for damaging charge storage cells. After discussing our results with several suppliers, it became apparent that the choice of X-ray tube filtering is the key factor of concern.

It was concluded that silicon dose is sensitive ONLY to X-rays with energy in the range 2-9 KeV; that 50 µm Cu traces are best imaged with X-ray energy of 9-20 KeV; and that tin and lead are well-imaged by X-rays over the energy range of 30-50 KeV and higher. While many thick metal filters effectively reduce Si dose, they also have the effect of making the relatively thin copper traces in a PWB very difficult to image by strongly absorbing X-rays in the energy range 9-20 KeV. A thin 300 µm zinc filter will be a very effective agent to absorb very soft X-

X-ray Inspection Considerations for Surface-Mounted Flash ICs

Summary

rays to which silicon is vulnerable, yet transmit soft and medium energy X-rays required to obtain good radiographs of thin copper traces and solder balls. Zinc foil can be integrated with the inspection “carrier” or put near the X-ray source.

As a general rule, if customers have no filtering capability, they should limit the cumulative X-ray inspection exposure to the SMT memory devices to 1,000 Rads or less. Infineon has submitted a patent for the use of zinc filtering that will enable X-ray suppliers to produce systems that are better ‘tuned’ for the electronics industry.

Revision history

Document version	Date of release	Description of changes
**	2007-05-21	Initial version
*A	2015-10-09	Updated to template
*B	2017-08-03	Updated logo and Copyright
*C	2021-03-19	Updated to Infineon template

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AN98527

X-Ray Inspection Test Conditions for NOR/SPI/NAND Flash

About this document

Scope and purpose

AN98527 discusses the X-ray inspection test conditions and recommendations for NOR/SPI/NAND Flash products that should be used to prevent damage to ICs.

Table of contents

1 Introduction

It has been well established that semiconductor ICs can suffer damage caused by X-ray inspection. While this phenomenon does not always result in a system level failure, customers might have no means to recover from the effects of the X-ray exposure if data corruption or other failure mode occurs. Infineon studies have shown that programmed cells within a flash array may experience a change in threshold voltage (Vt) as a result of certain X-ray inspection conditions. Any significant negative perturbation in the Vt of a programmed cell will result in incorrect sensing of the programmed bit logic state during a read operation, resulting in such bits incorrectly reading in the unprogrammed logic state.

2 X-ray Qualification Test Conditions

Below are the test conditions and equipment parameters that employs when conducting X-ray inspection as part of the product qualification process. Infineon can guarantee that its products will suffer no damage when these conditions are applied:

- X-ray Inspection Test Equipment
  - Shimadzu (Model SMX-160GT) [1]
  - Dosimeter: High Dose LiF TLD
  - 300-µm thick Zn Filter
- X-ray Inspection System Conditions
  - Tube Voltage: 110 kV
  - Tube Current: 40 µA
  - Center Distance to Source: 40 mm
  - Exposure Time: 240 seconds
- X-ray Inspection Test Procedure
  - Products are functionally tested and programmed to a known data pattern containing both programmed '0' and unprogrammed '1' logic states prior to X-ray inspection.
  - Products are arranged in a circular pattern around the center of the X-ray system stage to insure uniform exposure.
  - The Zn filter is placed between the X-ray source and the products being inspected.
  - A dosimeter is included in each batch of units to record the X-ray dose absorbed during inspection.
  - Products are exposed to the X-ray beam for 240 seconds (4 minutes), which corresponds to the worst-case inspection time of most circuit board inspection systems and has been determined to be adequate to assess any board assembly issues.
  - After exposure, products are retested to insure there is no loss of functionality or change in pre-programmed data pattern has occurred.
  - With this test procedure, X-ray dose received by the products will not exceed 10 rads, while still enabling adequate imaging and resolution required for circuit board inspection.

1 **Note:** Equipment is mentioned as a point of information and not as a product endorsement.

3 X-ray Inspection Recommendations

There are many commercially available circuit board inspection systems and each employs different X-ray set up conditions and exposure doses. It is not possible to provide a single set of recommendations that will apply to all inspection systems. However, in order of effectiveness, the following are the mitigation techniques Infineon recommends minimizing the effects of any potential damage resulting from X-ray inspection:

1. If X-ray inspection is performed after the flash has been programmed, consider erasing and reprogramming the flash data.
2. Use a 300-µm thick Zn filter; 1-mm thick Al or Brass filters are also effective.
3. Use the smallest X-ray tube kV-peak possible that still produces adequate images during board inspection.
4. Use the smallest X-ray tube current possible that produces adequate images.
5. Use the largest X-ray tube to sample distance (i.e. lowest magnification) possible.
6. Use the shortest inspection time possible, preferably on a sampling basis rather than 100% board inspection.

Revision history

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**	2012-07-11	Initial version
*A	2015-10-12	Updated to template
*B	2017-08-02	Updated logo and Copyright
*C	2018-08-02	Updated Document Title to read as “AN98527 - X-Ray Inspection Test Conditions for NOR/SPI/NAND Flash” Updated Abstract Removed “X-ray Inspection References” Updated to new template Completing Sunset Review
*D	2021-03-19	Updated to Infineon template

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AN98547

Dose Minimization During X-ray Inspection of Surface-Mounted Flash ICs

About this document

Scope and purpose

AN98547 is intended to help customers who perform X-ray inspection of surface-mounted ICs on circuit boards.

Table of contents

1 Introduction

This document is intended to help customers who perform X-ray inspection of surface-mounted ICs on circuit boards. X-rays behave basically the same as visible light rays, since both are wavelike forms of electromagnetic energy carried by particles called photons. The difference between X-rays and visible light rays is the energy for individual photons (energy is inverse to wavelength). Just as filtering of visible light wavelengths (i.e. energies) can be used effectively to prevent damage to photosensitive materials, Infineon and AMD® have shown that filtering of specific X-ray energy levels can be used to minimize damage to X-ray sensitive semiconductor ICs. (See **http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=1176469**.)

It has been well established that semiconductor ICs can suffer damage from (dis)charging effects caused by X-ray energy. While this phenomenon does not always result in a hard failure, customers might have no way to recover from the effects of the X-ray exposure. Infineon studies have shown that there is a change in threshold voltage as a function of X-ray dose. It is the purpose of this Application Note to show how such damage can be mitigated and how a user can achieve a state where X-ray effects will be undetectable.

In many cases inspection instruments subject ICs to X-ray dose values that are significantly greater than what is necessary to achieve successful inspection. The key is to minimize the total cumulative dose to the IC while achieving a useful inspection image.

The goal of Infineon recent experimentation was to extend from small floating gate devices to large capacity MirrorBit™ devices. As memory capacity has grown roughly 50-fold in the interim, it is now necessary to see more subtle effects. When we examine normal probability plots for threshold voltage of current devices, we see wider "tails." As there are so many more bits on these high capacity devices, some bits are closer to the point at which we would see read errors. This larger number of "tail bits" increases the probability of a read failure on a given device.

We observe a perfect Gaussian (normal) threshold voltage distribution for programmed bits (erased bits are not affected by X-rays). After X-ray irradiation a small number of the bits are found in a second normal distribution, but Infineon expects no read errors if recommendations 1-5 are followed, as the change in V_t would be so small. As X-ray dose increases, the size of the perturbed population (number of bits affected) increases linearly with X-ray inspection time. However, threshold voltage change is NOT linear with dose or time. We find the change in threshold voltage to vary as square root of time, while dose varies as the 1.5 power of time. More importantly, dose varies as the square of the KV_{peak} used during inspection, linearly with tube current, and inversely with distance from X-ray tube to IC being inspected. Apart from X-ray energy and flux, we find a Zinc filter to be extraordinarily effective, for which we estimate that read errors would be reduced by more than 100X. While there is no condition which is absolutely safe against X-ray exposure, it is possible to make X-ray inspection mild enough that read errors will not be seen.

2 Recommendations

1. Using a 300 µm thick Zn filter is the single most important change. A thin zinc filter is a very effective agent to absorb very soft X-rays to which silicon is particularly vulnerable, yet transmit soft and medium energy X-rays required to obtain good. Zinc foil can be integrated with the inspection "carrier" or put near the X-ray source. AMD was issued a patent (free usage is encouraged) for the use of zinc filtering that enables X-ray inspection users to protect proper performance (enter 6,751,294 into **http://www.freepatentsonline.com** to get full text PDF for this patent).
2. Using the smallest KV_{peak} possible that still produces adequate images, recommending near 50 KV_{peak} rather than 80-110 KV_{peak}. This action reduces number of bits affected by 5-fold (for 50 vs. 110 KV_{peak}) and threshold voltage change by 2-fold.
3. Using the smallest X-ray tube current possible that still produces adequate images, recommending near (or smaller than) 20 µA rather than traditional 40 µA. This action reduces number of bits affected by 2-fold and threshold voltage change by 1.4-fold.
4. Use as a large X-ray tube to sample distance as possible (low magnification) because X-ray dose varies inversely with distance.
5. Use the shortest inspection time possible, preferably on a sampling basis rather than 100%. If X-ray inspection is used after Surface Mount Technology (soldering components to Printed Circuit Boards), refresh data, i.e. program same data again in system without erasure for floating gate devices, but erase and reprogram for MirrorBit™ devices.

Prudent Practice, Best Known Methods – Future

6. Another strategy is NOT to use X-ray inspection at all, but instead to use an electrical detection technique, namely IEEE 1149 Boundary Scan (See **http://ieeexplore.ieee.org/iel5/7481/20326/00938734.pdf and http://www.ieee.li/pdf/viewgraphs_jtag_boundary_scan.pdf**) IEEE 1149 permits "internal nodes" on the PCB to be examined by reading a shift register. However, this method does require an extra design feature for future system-level products.

As a general rule, customers should limit the cumulative X-ray inspection exposure to the SMT memory devices to as small a value as possible, as this minimizes the number of bits affected AND the perturbation to each affected bit.

Revision history

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**	2008-10-10	Initial version
*A	2015-10-09	Updated in template
*B	2017-07-06	Updated logo and Copyright
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Revision History

Date	Revision #	Author	Change Description	Page #
4/16/2022	1.0.0	MJL	Initial Release	
1/24/2025	1.0.1	MJL	Converted to FG format. Verified imbedded Infineon app notes are current revision.	all