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The pros and cons of *in-situ* testing – going beyond the test standards

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In-situ testing

- Introduction
- What do the standards say?
- Assumptions made in the standards
- Advantages and disadvantages of *in-situ* measurement
- Case study
- Points to take away today

Introduction

- *In-situ* testing means the measurement of parameters of electronic components at the same time as they are being irradiated during a total integrated dose (TID) test
- *In-situ* means that the test samples are left in the radiation field at the same time as being measured, i.e. the irradiation is continuous
- Remote testing means that, each time the electrical parameters are measured, the irradiation is stopped, the test samples are removed from the irradiation facility, electrically tested and then returned for the next stage of irradiation

What do the standards say?

- ESA ESCC 22900
- In-situ testing is permitted either during or after irradiation
- "In the case of applications for which TDE is important, the advantages of each method shall be carefully weighed against the disadvantages"
- "… a control device shall be measured with the measurement system before the insertion of the test devices and again upon completion of the irradiation and measurement series …"
- For evaluation testing, remote testing is mandated: "Multiple exposures shall be used, with monitoring of electrical parameters in between"
- For qualification and LAT, remote testing is assumed but *in-situ* measurement is implicitly permitted

What do the standards say?

- Mil-Std-883 method 1019
- In-flux testing is permitted
- "The use of in-flux testing may help to avoid variations introduced by post-irradiation time dependent effects"
- The language of the standard is generally neutral between in-flux and remote testing, allowing both in all circumstances

Assumptions in the standards

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- Whilst both standards permit in-situ measurement, the majority of the text assumes that remote measurement is undertaken with a small number of discrete irradiation steps, yielding data at only a small number of values of total dose
- Recommendations are made concerning the number of dose steps (implied remote testing) and the time constraints around remote testing
  - 22900: minimum of three dose steps
  - 1019: no minimum number, i.e. one data point is acceptable
- Both standards note that in cases where post-irradiation time dependent effects have an influence then this shall be considered when selecting the test method
- In practice, most tests use remote measurement and a very small number of dose steps

Advantages of *in-situ* testing

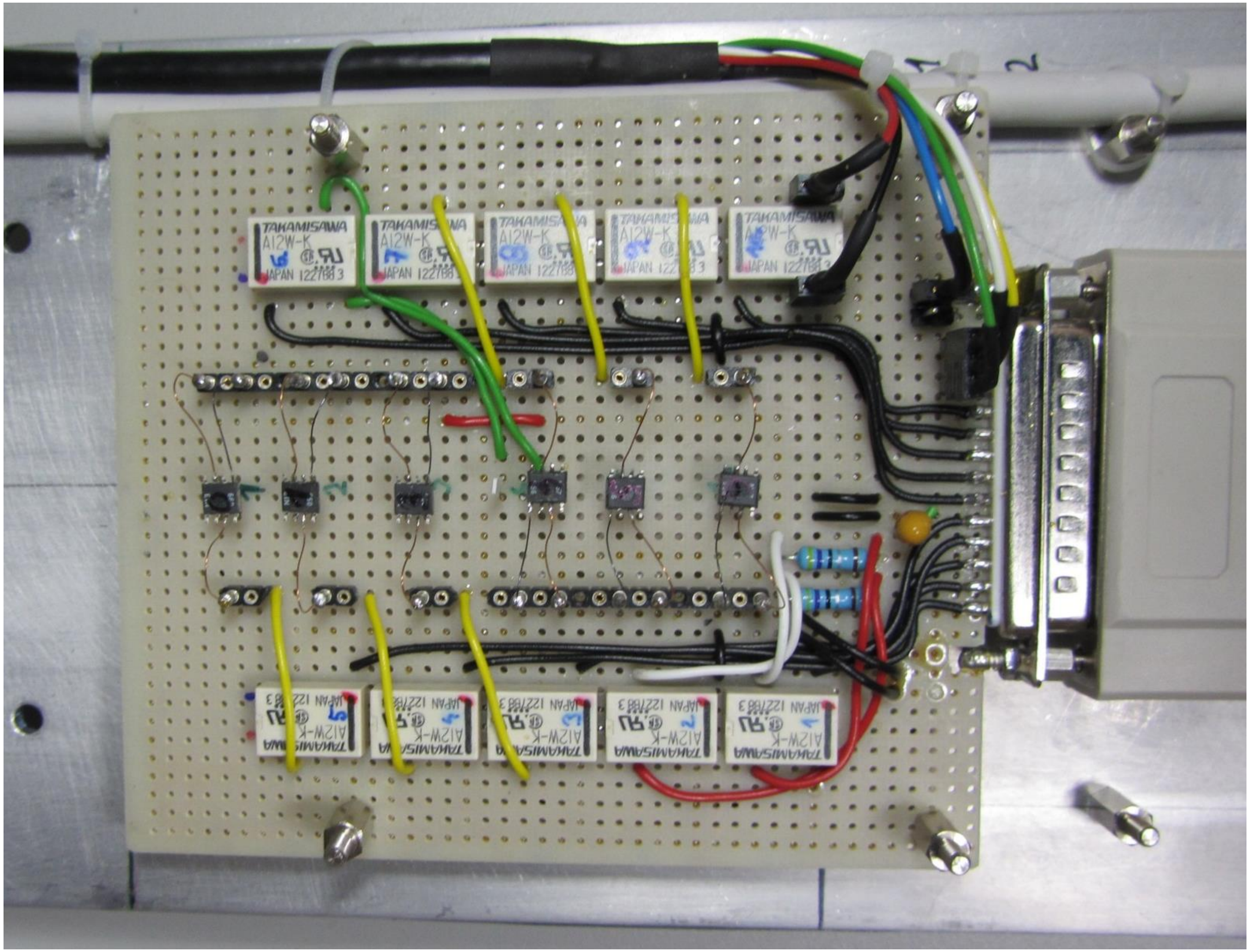
- More data give much finer resolution on the total dose scale
- Subtle and non-linear effects can be identified
- Avoids errors due to annealing/TDE between the end of an irradiation step and measurement
- Measurement can continue uninterrupted after removal of the source, i.e. capturing the immediate annealing behaviour (magnitude and rate)
- Particularly suitable for DC and low frequency parameters
- Relay multiplexing techniques allow a single instrument to measure multiple DUTs, especially for the total dose range of relevance to space applications

Disadvantages of *in-situ* testing

- Requires a more complex measurement system
- Long lead lengths make high speed and high frequency measurements difficult
- Beware of potential radiation effects on the measurement system
- Complex, digital devices may always need to be taken to a tester
- Take care to match the bias conditions during measurements to those during static conditions or to minimise the duty cycle
- Consider measuring a control device periodically to verify no drift has taken place

Case study

- Description of the test
- TID test of a voltage reference with a nominal output of 2.048V
- Ultralow noise voltage reference using XFET (eXtra implanted junction FET) technology from Analog Devices
- Three devices irradiated in a ^{60}Co facility at 360 rad[Si]/hr
- Output voltage measured with a 6.5 digit DMM
- Constant, stable bias conditions (5V dc) and stable temperature
- 20 metre cable between the samples and the DMM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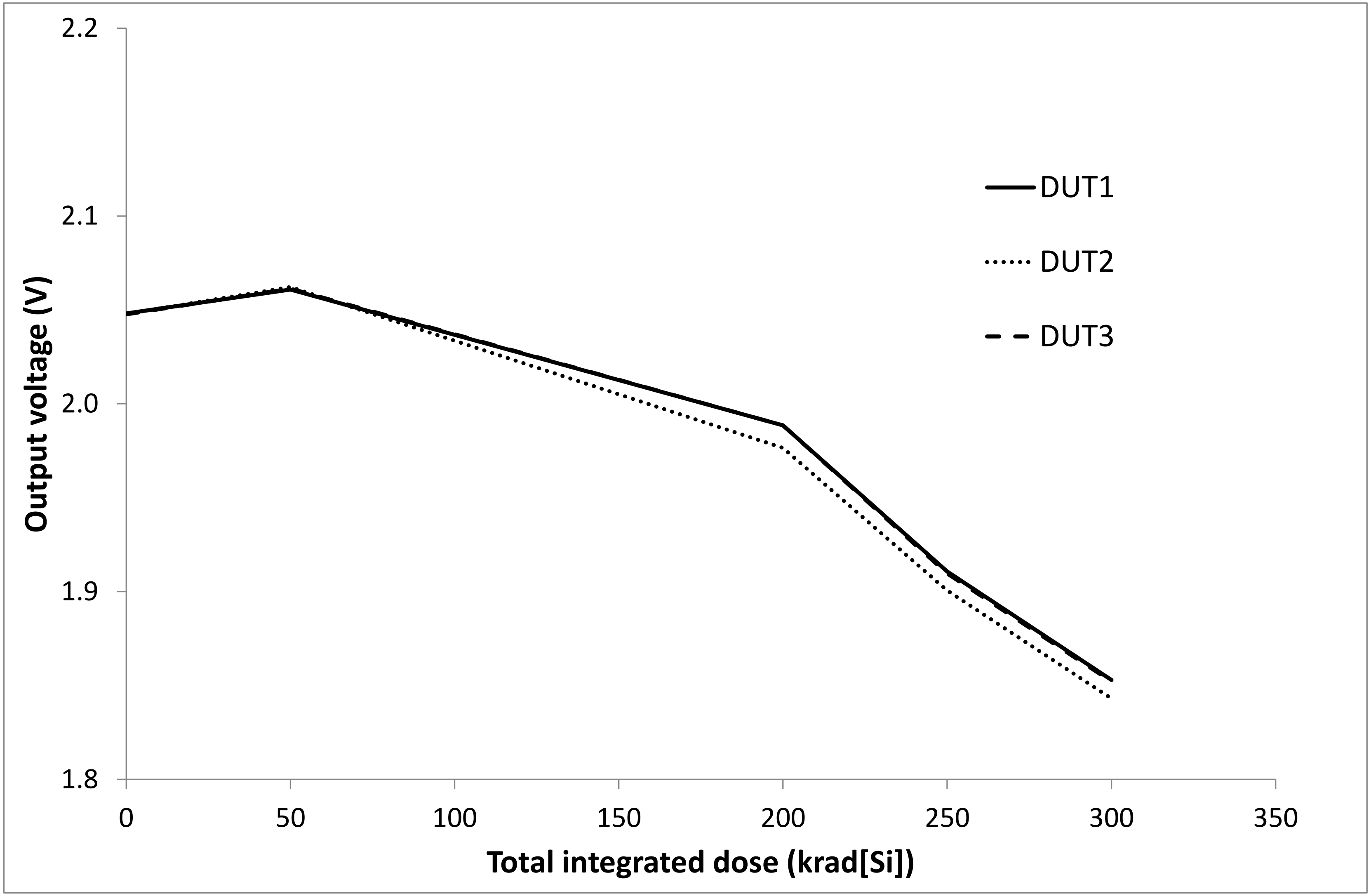
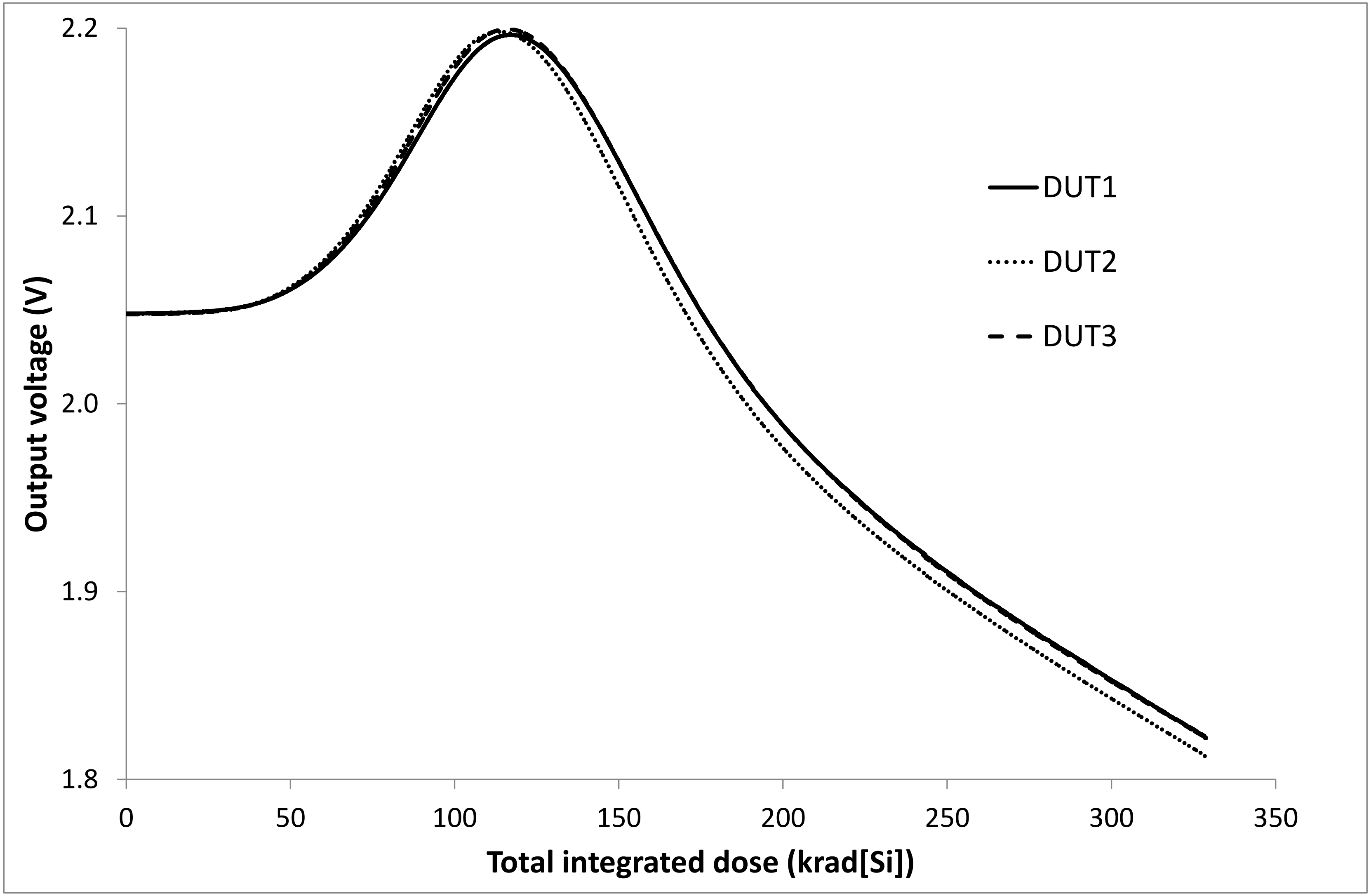
Data from three dose steps



Data from *in-situ* measurements



Learning points

- DC and LF signals are easy to measure using in-situ techniques, whereas high speed signals and very low voltages/currents are more difficult to instrument
- In-situ measurement can reveal unexpected behaviour and yield valuable insights to the radiation-induced changes, especially for parts that exhibit a non-linear response
- Dose steps should be selected with care to ensure that any unexpected behaviour is captured
- *In-situ* testing could be used as a screening test (e.g. evaluation testing) to check for non-linear changes and so to inform the choice of dose steps for a full TID test (qualification or LAT) based upon remote testing