Technical Presentation

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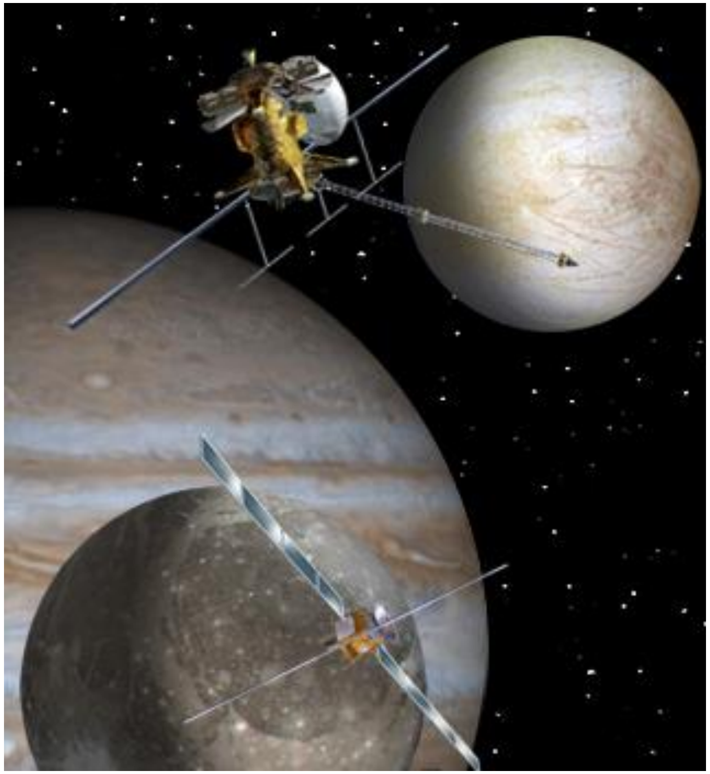
4th Annual ARDENT Workshop
22 – 26 Jun 2015, Prague



Artists`s impression of JUICE mission Courtesy: ESA

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   - Project Overview
   - Test candidates selected for testing
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What is JUICE?

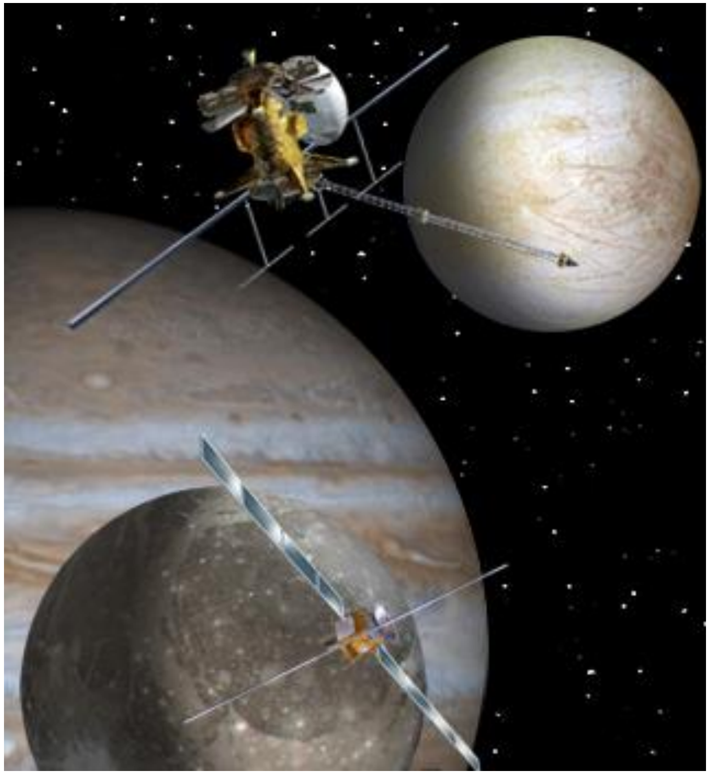
JUpiter ICy moons Explorer (JUICE) - ESA mission

Timeline:

- In 2022 - launch
- In 2030 - Jupiter, Ganymede, Callisto, Europa

Studies:

- Jupiter‘s atmosphere, magnetosphere, interaction with the 3 moons and Io
- Surfaces and interiors of the 3 moons, potential to host life



Artists`s impression of JUICE mission Courtesy: ESA

e^{2}RAD Project

e^{2-}RAD: **e**nergetic **e**lectrons **rad**iation assessment study for JUICE mission

<u>**Objectives:**</u> To investigate shielding-performance of 2-layered Shielding set-ups with different Geometries and relative composition of High-Z and Low-Z materials.

- High-Z : Tantalum, Lead
- Low-Z material : Aluminum
- Major Dose contribution: trapped electrons
- Energy range: 5 MeV – 50 MeV

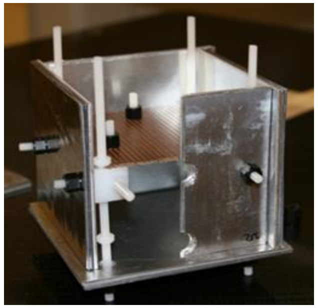


Fig 2:Box-shielding configuration

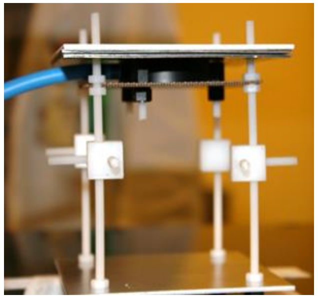


Fig 3: Plane-shielding configuration

Fig : Experiments at LINAC facility, AKH-Vienna.

SEIBERSDORF LABORATORIES

e^2RAD Project: Excerpt from Results

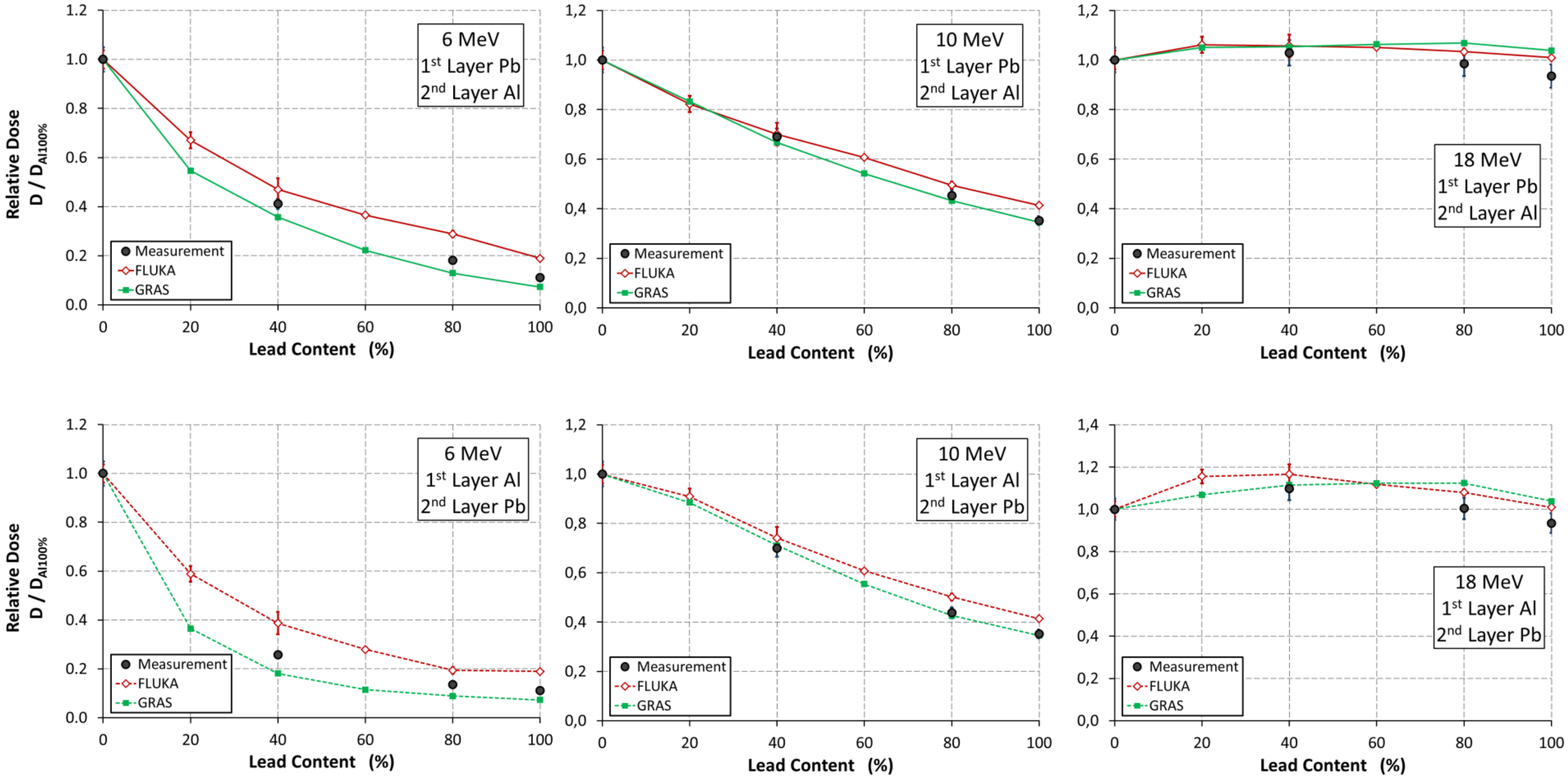
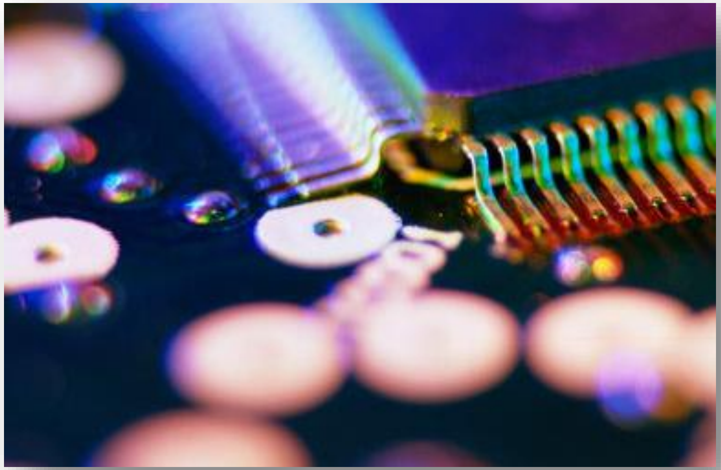


Figure : Comparison of experimental data and numerical data obtained with Monte Carlo codes FLUKA and GRAS. Y-axis shows the relative values (normalized to value for pure Aluminium shielding) of dose recorded in an Ionization chamber that is located directly behind a plane shielding. X-axis shows percentage of Lead content.

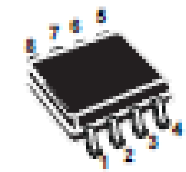
ECI Objectives

- To select and test European Commercial Off The Shelf (COTS) EEE components regarding Radiation Hardness Assurance according ESA standards
- To assess whether the tested components pass test requirements specified for space

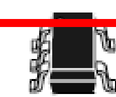


ECI Candidates for Testing

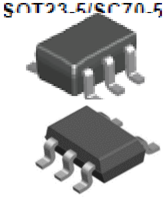
Part	Description	Manufacturer	RHA-Test
STS3P6F6	p-channel Power MosFET, V_{DS}: -60 V, I_D: -3 A	STM	TID SEGR
SPD04P10P G	SIPMOS p-channel Power MosFET, V_{DS}: -100 V, I_D: -4 A	Infineon	TID SEGR
TS331LT	Comparator	STM	TID
TS3011ILT	Comparator	STM	TID
AS1976-T	Comparator	AMS	TID
LM2904DT	Op-Amp	STM	TID

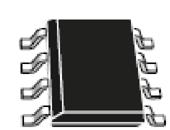


SO-8



SOT23-5/SC70-5





ECI TID Testing: Experiment conditions

- **Co-60 TID** radiation facility, Seibersdorf - EN/ISO IEC 17025 Accredited Test Lab
- **Sample size**: 5 biased, 5 unbiased, 2 control devices
- **Test standard**: ESA/SSC Basic Specification 22900
- **Annealing**: 24 hours room temperature, 168 hours 100°C

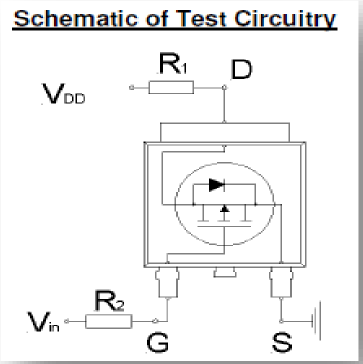
Electrical Parameter	Symbol	Unit
Drain-source Breakdown Voltage	$V_{BR(DSS)}$	V
Gate Threshold Voltage	V_{GS}	V
Static Drain-Source On-Resistance	$R_{DS(on)}$	Ω
Inverse Diode Forward Voltage	V_{SD}	V
Reverse Gate-Source Leak Current	$I_{GSS(R)}$	A
Forward Gate-Source Leak Current	$I_{GSS(F)}$	A
Forward Transconductance*	g_{fs}	S

Parameters measured

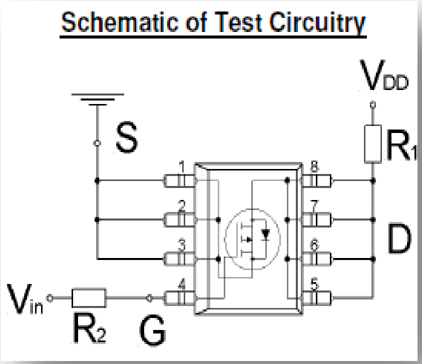
Co-60 TID Radiation Exposure Facility
EN/ISO IEC 17045 Test Lab, Seibersdorf

ECI TID Test Circuit (biased, unbiased), PCB Set-Up

SPD04P10G



STS3PF6

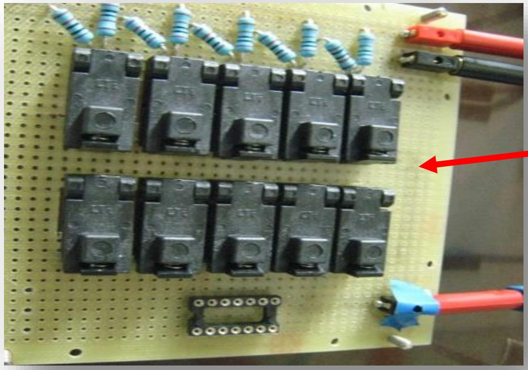


Biased

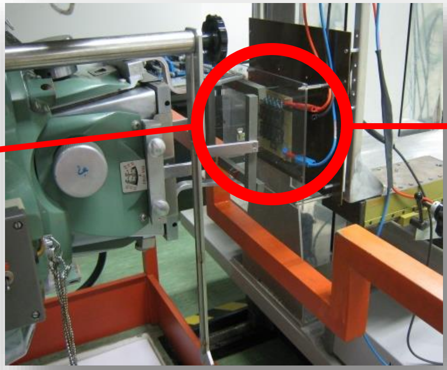
V_{DD}: 50V
V_{in}: -20V
Resistors: R1: 2kΩ, R2: 10 kΩ

Unbiased

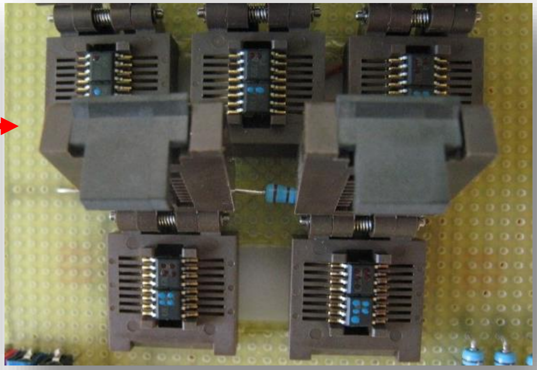
All terminals grounded; pin to ground resistance typically < 4 Ω



PCB: biased / unbiased TID test (**SPD04P10G**)



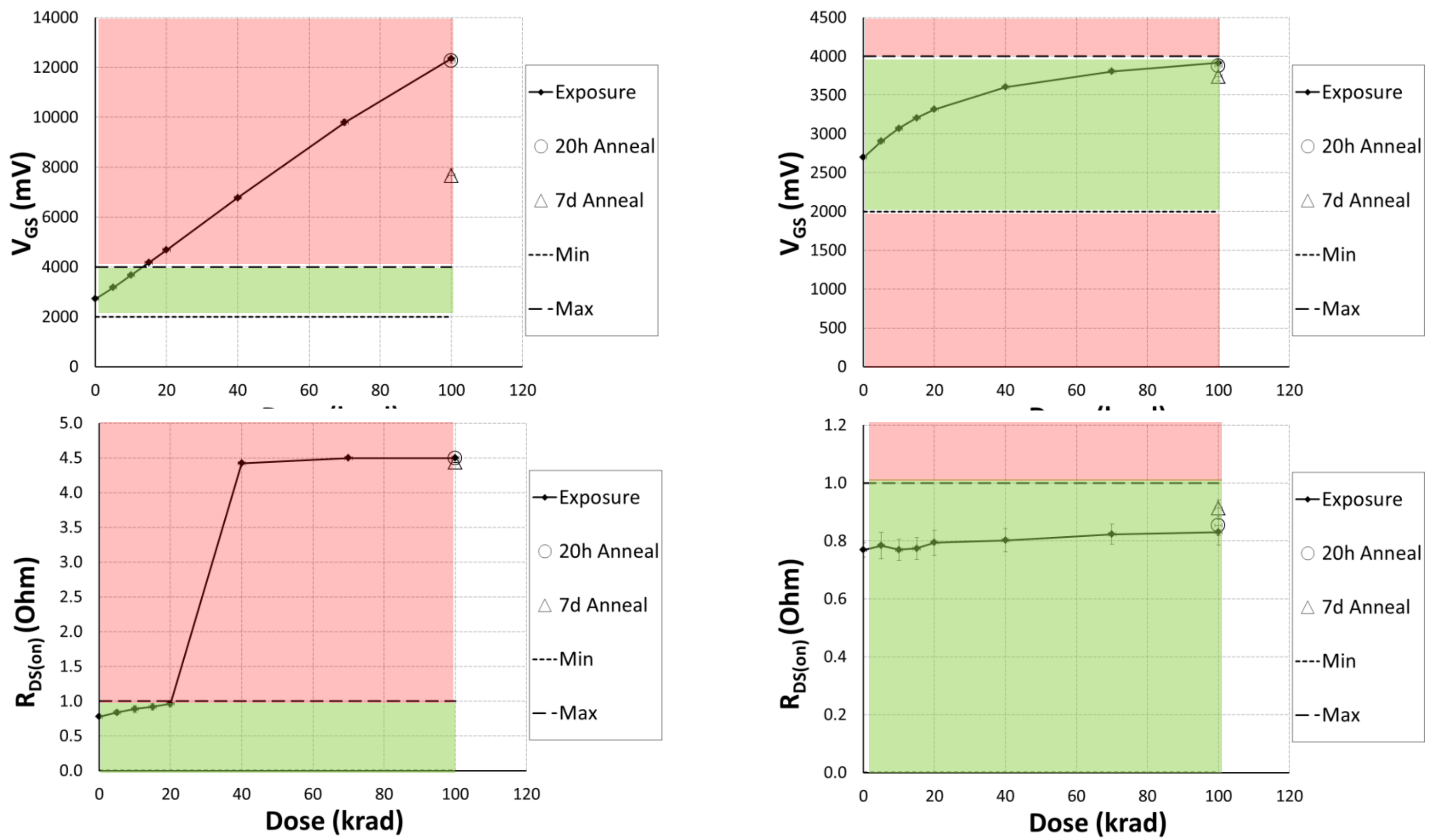
Co-60 Radiation Exposure Seibersdorf



PCB: biased / unbiased TID test (**STS3PF6**)

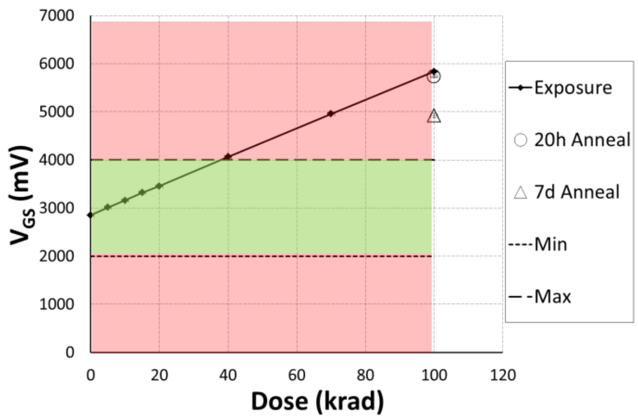
ECI TID Test Results: **SPD04P10G**

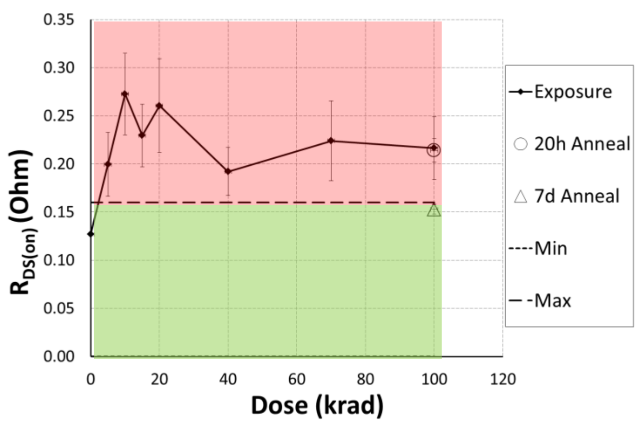
BIASED | **UNBIASED**



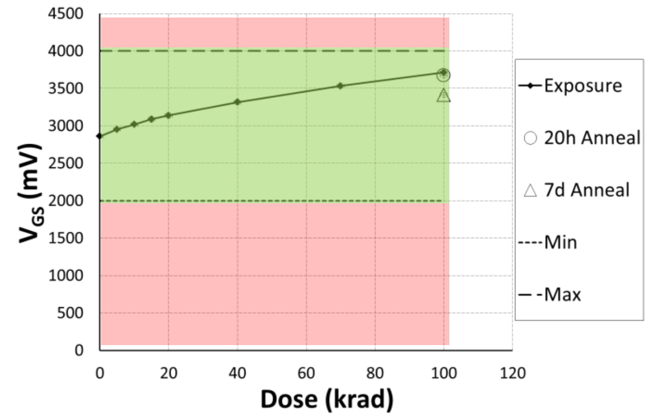
ECI TID Test Results: **STS3PF6**

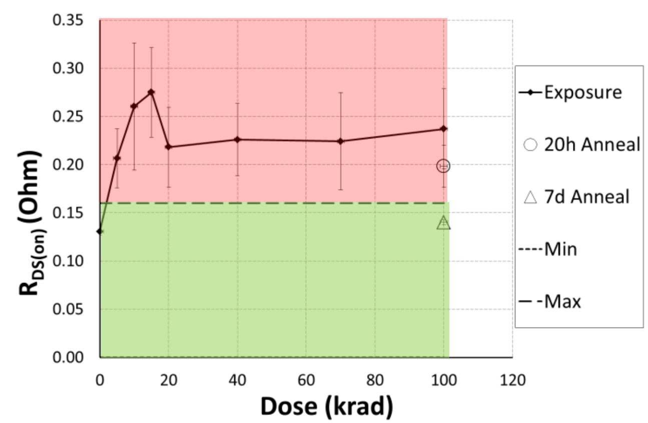
BIASED





UNBIASED





ECI TID Test Summary

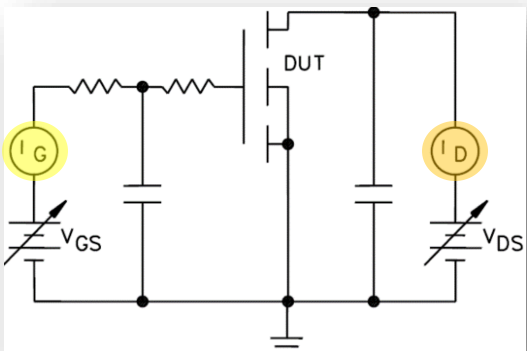
Parameters	Symbol	Unit	SPD04P10G		STS3PF6	
			Biased	Unbiased	Biased	Unbiased
Drain-source Breakdown Voltage	$V_{BR(DSS)}$	V	100 krad	100 krad	100 krad	100 krad
Gate Threshold Voltage	V_{GS}	V	15 krad	100 krad	40 krad	100 krad
Static Drain-Source On-Resistance	$R_{DS(on)}$	Ω	40 krad	100 krad	5 krad	5 krad
Inverse Diode Forward Voltage	V_{SD}	V	10 krad	5 krad	10 krad	15 krad
Reverse Gate-Source Leak Current	$I_{GSS(R)}$	A	100 krad	100 krad	100 krad	100 krad
Forward Gate-Source Leak Current	$I_{GSS(F)}$	A	100 krad	100 krad	100 krad	100 krad
Forward Transconductance	g_{fs}	S	40 krad	100 krad		

PASS

FAIL

SEGR Test Plan for STS3P6F6 and SPD04P10P

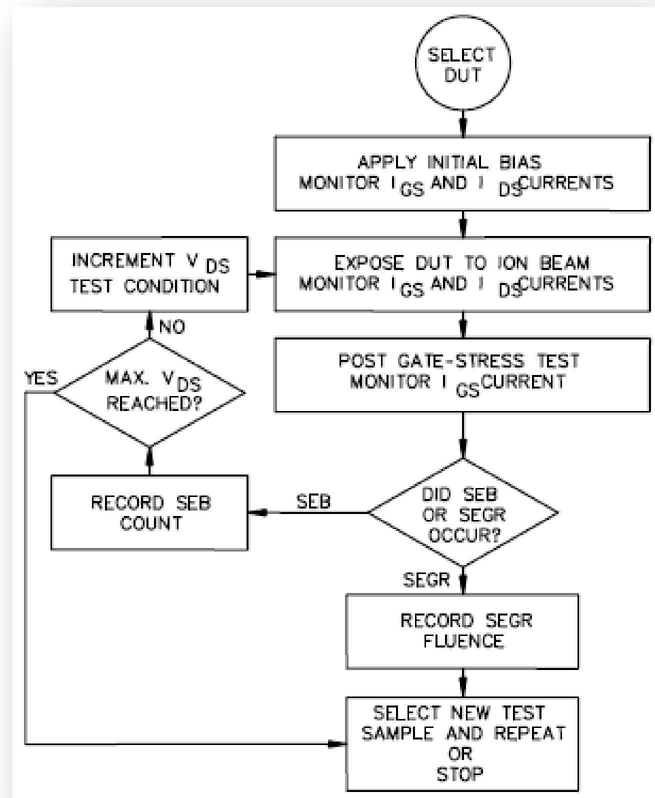
Schematic Test Circuit
(MIL-STD-750-1 Method 1080.1)



STS3P6F6 with and without lid

SPD04P10P prior and after etching

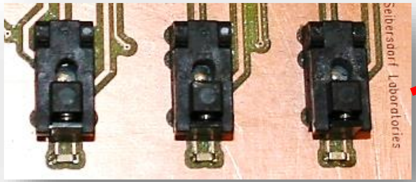
Characterization Flow Chart
(MIL-STD-750-1 Method 1080.1)

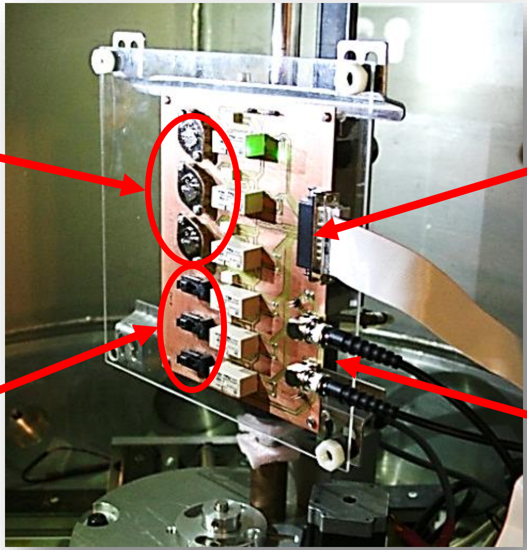


SEGR Test Set-Up at RADEF

STS3PF6

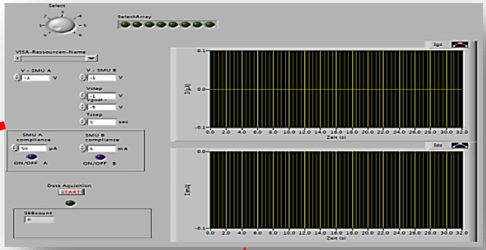
SPD04P10G





Test board mounted inside RADEF's vacuum chamber

LabVIEW: Relays, measurements



Keithley 2612 dual source meter

Sample Size	**27** devices per part type, **3** sample devices for each exposure sequence		
Parameters	V_{GS}: 0, 5, 10 V	V_{DS}: -50 V, …, - 100 V (**SDP04P10P**); -30 V,…, - 60 V (**STS3P6F6**)	
LET (MeV cm² mg⁻¹)	**18.5**	**32.1**	**60**
Heavy ions, energy	Fe / 523 MeV	Kr / 768 MeV	Xe / 1.2 GeV
Average Flux (cm^{-2} s^{-1})	$1.09 \cdot 10^4$	$1.18 \cdot 10^4$	$7.27 \cdot 10^3$
Fluence (cm^{-2})	$3 \cdot 10^5$		

SEGR Results: Safe Operating Area – SOA (SF=1)

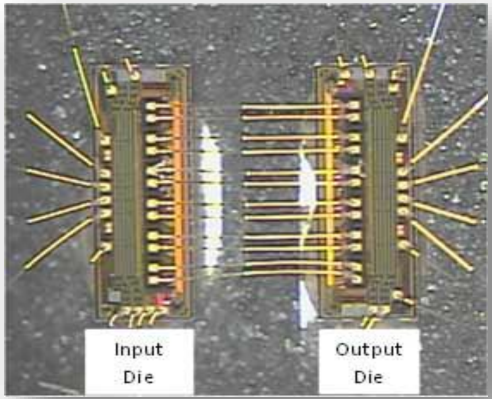
	SPD04P10P G										STS3P6F6										
LET (MeV/mg/cm²)	18.5			32.1			60				18.5			32.1			60				
	V_{GS} (V)			V_{GS} (V)			V_{GS} (V)				V_{GS} (V)			V_{GS} (V)			V_{GS} (V)				
V_{DS} (V)	0	5	10	0	5	10	0	5	10	15	0	5	10	0	5	10	0	5	10	15	20
-100																					
-90																					
-80																					
-70																					
-60																					
-55																					
-50																					
-40																					
-30																					
-25																					
-20																					
-15																					
-10																					

CONTENT

Overview: REDI- Radiation Evaluation of Digital Isolators

Objectives

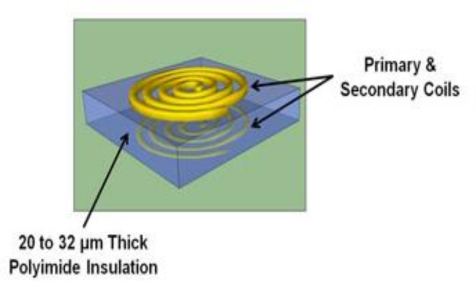
- Identify currently available commercial digital isolators for applications in space missions, specifically the JUICE mission, as replacement for optocouplers
- Perform detailed radiation evaluation (TID and SEE) of the selected digital isolators.



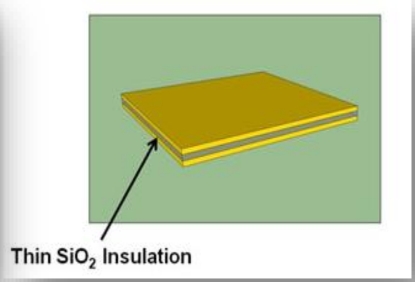
De-capsulated digital isolator
Courtesy: Silicon Labs

Digital Isolators

- CMOS technology
- Magnetic or Capacitive Coupling
- Polyimide or SiO2 insulation



Transformer with polyimide insulation



Capacitor with SiO2 insulation

Courtesy : Analog Devices

REDI Candidates Selected for Testing

Manufacturer	Texas Instruments	Texas Instruments	Silicon Labs	Analog Devices	Analog Devices	Maxim Integrated
Investigated Part	**ISO15DW**	**ISO7220MDR**	**SI8261ACC-C-IP**	**ADUM1201ARZ**	**ADUM1100URZ**	**MAX14850ASE+**
Technology	capacitive-coupling bulk CMOS	capacitive-coupling bulk CMOS	capacitive-coupling bulk CMOS	monolithic transformer high speed bulk CMOS	monolithic transformer high speed bulk CMOS	capacitive-coupling BiCMOS
Package Type	SOIC	SOIC	DIP	SOIC	SOIC-8	SOIC
Min Voltage / V	3,15	3,0	5,0	2,7	3,0	3,0
Max Voltage / V	3,6	5,5	30,0	5,5	5,5	5,5
Prop Delay / ns	340	16	40	150	11	7

REDI Test Plan

TID-Testing

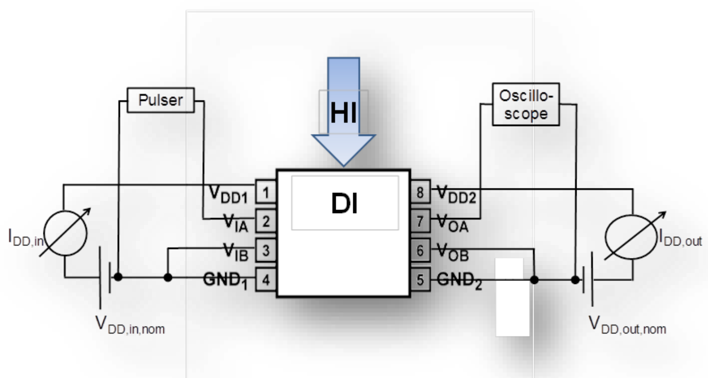
- Source: Co-60, electrons (JUICE mission)
- Parameter: Supply currents of i/p and o/p; isolation performance; Input Current; Output voltages at High and Low logic

SEE-Testing

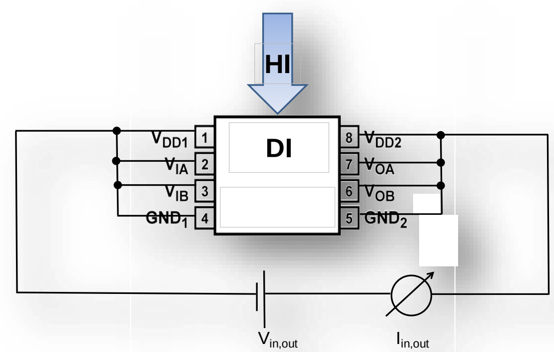
- SET and SEL, Single Event Dielectric Isolation Rapture (SEDIR)
- SEE testing for LETs between 4 - 55 MeV/mg/cm^2 (e.g. Ne, Si, Ar, Kr and Xe)

DD-Testing

- neutrons



Sketch of a combined heavy ion SET and SEL test

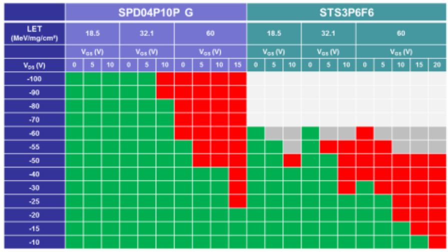


Sketch of a heavy ion SEDIR test

Summary and Conclusions

ECI – Power MOSFETS: SPD04P10P, STS3PF6

- We carried out **TID** and **SEGR** radiation tests of two **Power MosFET's** from **STM** and **Infineon** according ESA and MIL standards
- **TID:** maximum dose ***D*(Si) = 1kGy (100 krad); SEGR: LET: 18.5 - 60 MeV cm² mg^{-1}**
- **TID** testing for both components, biased and unbiased passed for doses ***D*(Si) < 5krad.**
- For larger doses, almost all parameters showed degradation for both components, biased and unbiased; just the three parameters: $V_{BR(DSS)}$, $I_{GSS(R)}$, and $I_{GSS(F)}$ passed for **1kGy (100krad)** radiation testing.
- **SEGR** tests showed for tested LET range **SOA** (SF=1) for:
  - **SPD04P10P G:** V_{DS} = 0 … -20 V, V_{GS} = 15V. V_{DS} = 0…-55 V, V_{GS} = 0V
  - **STS3P6F6:** V_{DS} = 0 … -10 V, V_{GS}= 15V. V_{DS} = 0 …-30 V, V_{GS} = 0V



REDI – Radiation Evaluation of Digital Isolators

- 3 candidates for testing, different manufacturers and technologies were identified and selected
- Experiments for **TID** in progress
- Test plans for **SEE/SEL** and **SEDIR** are under preparation

Secondments

- **Business and Administration Secondment, IBA Dosimetry**
  - 2-week training period (16 – 27 February 2015),Supervision of Mr. Salih Arican, Senior Product Manager.
  - Business-domain: Radiotherapy solutions, emphasis on Daily Quality Assurance activities.
  - Competition analyses for Daily Quality Assurance solutions, Market assessment, Financial calculations for profitability/viability of Product for a Positioning paper
- **Scientific Secondment, R2E Group (Radiation to Electronics) CERN**
  - Familiarization with Single Event Transient and Single Event Latchup experiments. Supervision: Dr. Markus Brugger, Mr. Salvatore Danzeca
  - Digital Isolator Experiments...
  - Outcome- Test plan draft for SET and SEL experiments.

Acknowledgements

- **ARDENT**, Marie Curie Early Initial Training Network Fellowship of the European Community's Seventh Framework Programme under contract number (PITN-GA-2011-289198-ARDENT)
- Radiation Hardness Assurance and Space Weather Group at Seibersdorf Laboratories: Dr. Michael Wind, DI. Marcin Latocha and Dr. Peter Beck for guidance in all activities.
- Dr. Markus Stock and Dr. Georg Dietmar for support in experiments at AKH, Vienna.

Work was carried out in projects contracted by **ESA** under contracts:

e^{2}RAD: ESA – C# 4000108163/13/NL/SC/fk

ECI: ESA C# 4000108163/13/NL/SC/fk

REDI: ESA C# 4000112480/14/NL/SW.

ARDENT

Advanced Radiation Dosimetry European Network Training

SEVENTH FRAMEWORK PROGRAMME

SEIBERSDORF LABORATORIES

FREQUENTLY ASKED SOLUTIONS

Thank you for your attention!