LOW VOLTAGE SOLUTION FOR CBM MUCH

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Under the supervision

of

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OUTLINE OF WORK DONE

- Radiation testing of Low voltage components.

  Neutron Irradiation

  * *Damage Study*

  * Single Event upset analysis for control board

  Gamma Irradiation

  * *TID tolrrence*

- Fault tolrrence LV Board Design

  * *Hard On and Stable OFF*

- Implementation of reliable Ethernet communication .

  * *UDP Implemented successfully*

  * *TCP/IP Imlementation , yet to start*

- GUI Development for handling huge number of channels

  * 30 Channel control

  *60 parameter monitored

Radiation testing of Low voltage components

Neutron Irradiation

* *Damage Study*
* Single Event upset analysis for control BOARD

Gamma Irradiation

* *TID tolerance*

CONDITIONS

- No annealing , Continuous Radiation
- Accelerated life test (Acceleration factor 1000)
- No Cooling
- With greater SEU cross section and Damage factor

Neutron Irradiation testing of LVDB components

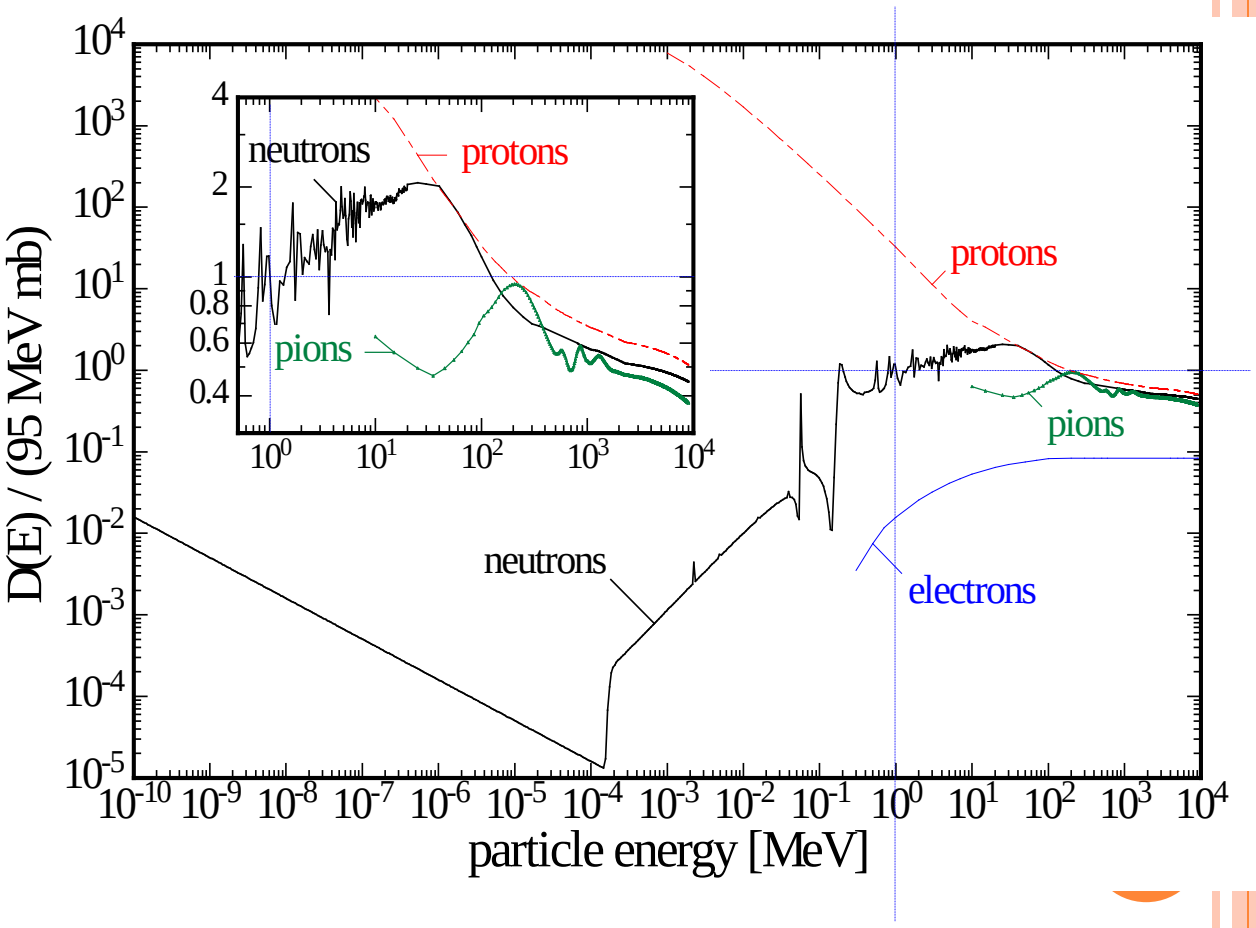
NIEL FACTOR VS PARTICLE TYPE, ENERGY

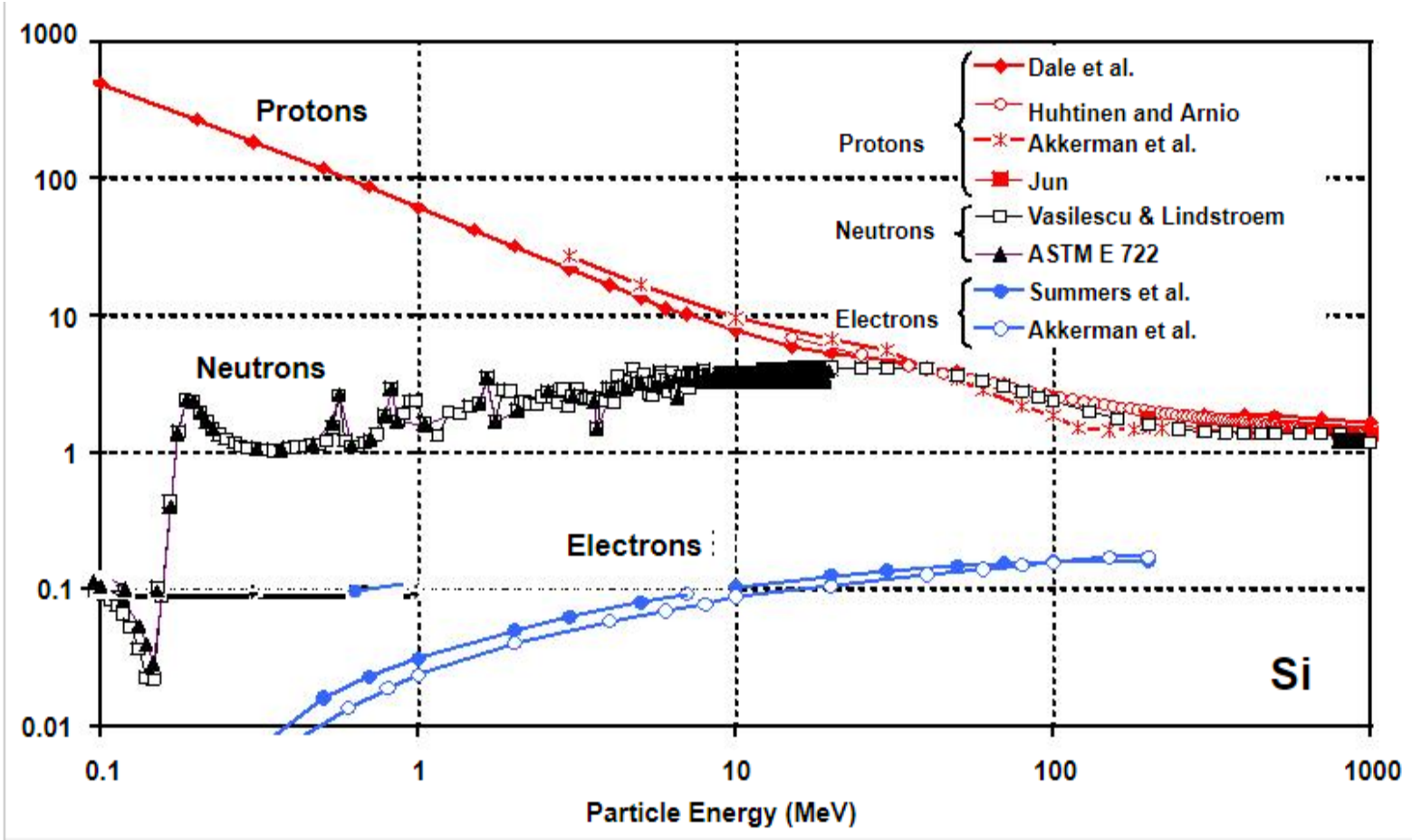
NIEL factor of Silicon

for comparison, normalized to 1 MeV neutron

$$\Phi_{eq} = \kappa_x \Phi_x$$

κ_p =0.62 (24 GeV/c protons)
κ_p = 1.85 (26 MeV protons)
κ_π = 1.14 (300 MeV pions)
κ_n = 0.92 (reactor neutrons >100 keV)





damage = k_{damage} x displacement damage dose

$$\int NIEL(E)\,\frac{d\varphi(E)}{dE}\,dE$$

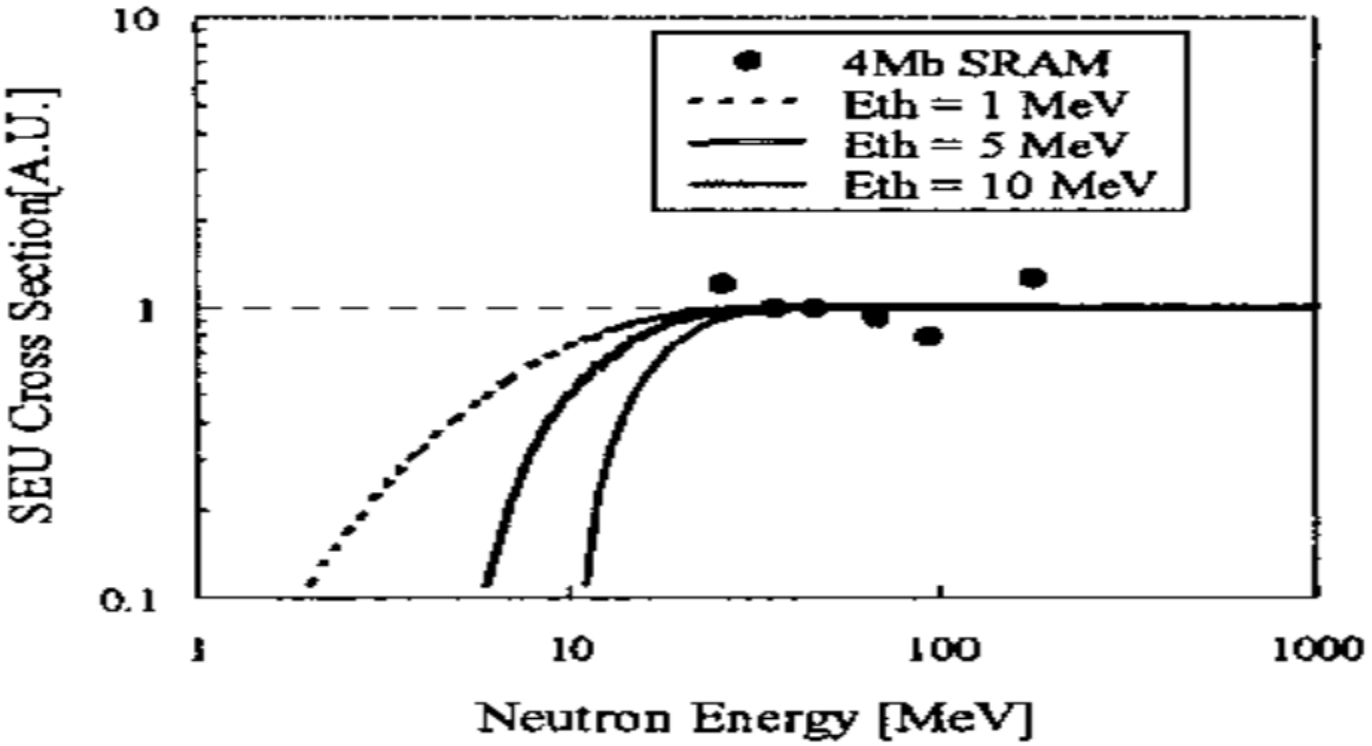
Reference https://rd50.web.cern.ch/rd50/NIEL/default.html

ENERGY	DAMAGE
6.750E-01	5.786E-01
7.050E-01	6.019E-01
7.400E-01	6.724E-01
7.800E-01	9.209E-01
8.200E-01	1.459E+00
8.600E-01	8.318E-01
9.000E-01	9.434E-01
9.400E-01	1.172E+00
9.800E-01	1.174E+00
1.050E+00	8.020E-01
1.150E+00	6.578E-01
1.250E+00	9.680E-01
1.350E+00	9.410E-01
1.450E+00	1.079E+00
1.550E+00	1.128E+00
1.650E+00	1.766E+00
1.750E+00	8.366E-01
1.850E+00	1.411E+00
1.950E+00	1.393E+00
2.050E+00	1.022E+00
2.150E+00	1.159E+00

ENERGY	DAMAGE
1.305E+01	1.862E+00
1.315E+01	1.828E+00
1.325E+01	1.793E+00
1.335E+01	1.806E+00
1.345E+01	1.839E+00
1.355E+01	1.802E+00
1.365E+01	1.780E+00
1.375E+01	1.804E+00
1.385E+01	1.870E+00
1.395E+01	1.808E+00
1.405E+01	1.787E+00
1.415E+01	1.817E+00
1.425E+01	1.830E+00
1.435E+01	1.843E+00
1.445E+01	1.845E+00
1.455E+01	1.791E+00
1.465E+01	1.765E+00
1.475E+01	1.774E+00

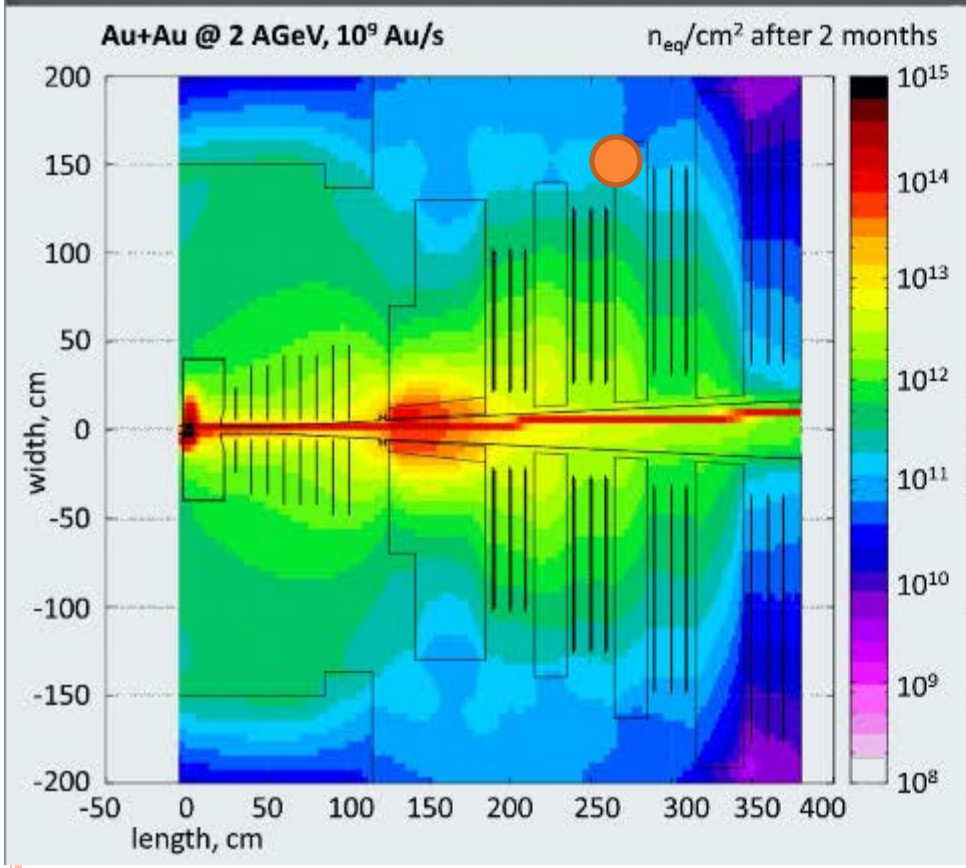
THRESHOLD ENERGY OF NEUTRON-INDUCED SINGLE EVENT UPSET AS A CRITICAL FACTOR

Y. Yahagi (yahagi@perl.hitachi.co.jp), E. Ibe, Production Engineering Research Laboratory, Hitachi Ltd.
Y. Takahashi, Y. Saito, A. Eto, M. Sato, Renesas Technology Corp.
H. Kameyama, Renesas Kodaira Semiconductor, Co.,Ltd.
M.Hidaka, Elpida Memory, Inc.
AND
K. Terunuma, T. Nunomiya, T. Nakamura, Dept. of Quantum Science and Energy Engineering, Tohoku Univ.



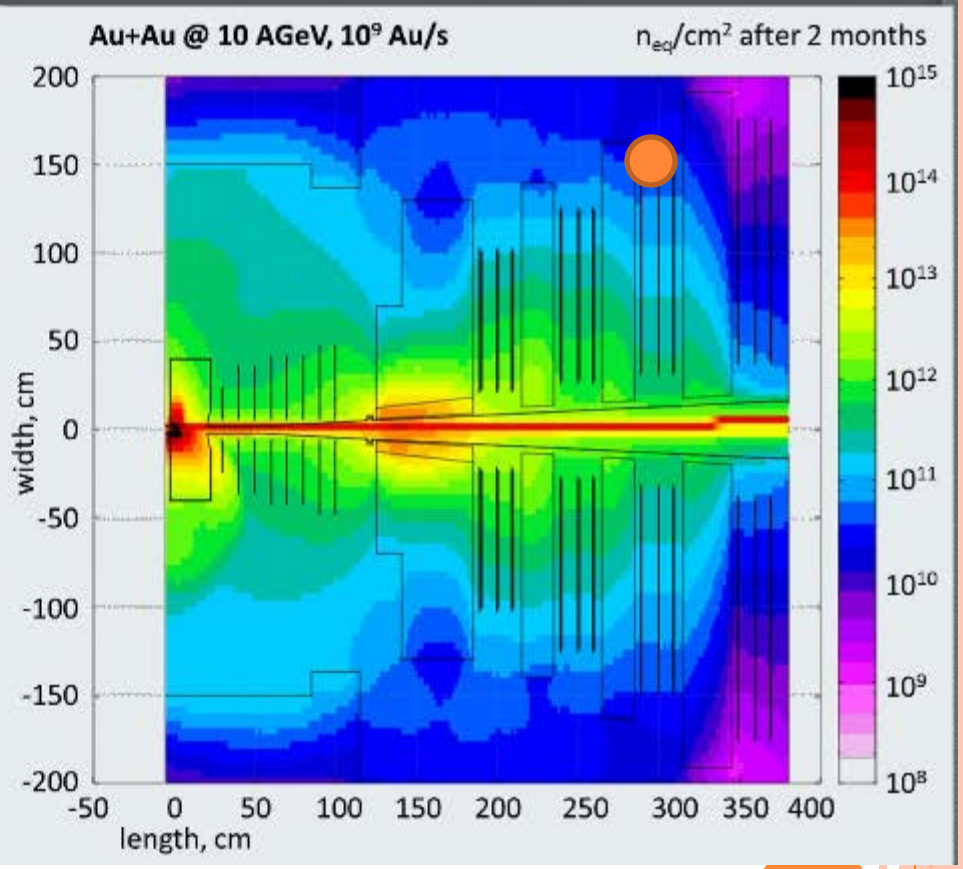
Non-ionizing energy loss

Au @ 2 AGeV



Neutron = 1 x 10^{12}

Au @ 10 AGeV



Neutron = 5 x 10^{11}

Neutron Irradiation

Exactly same set up were used

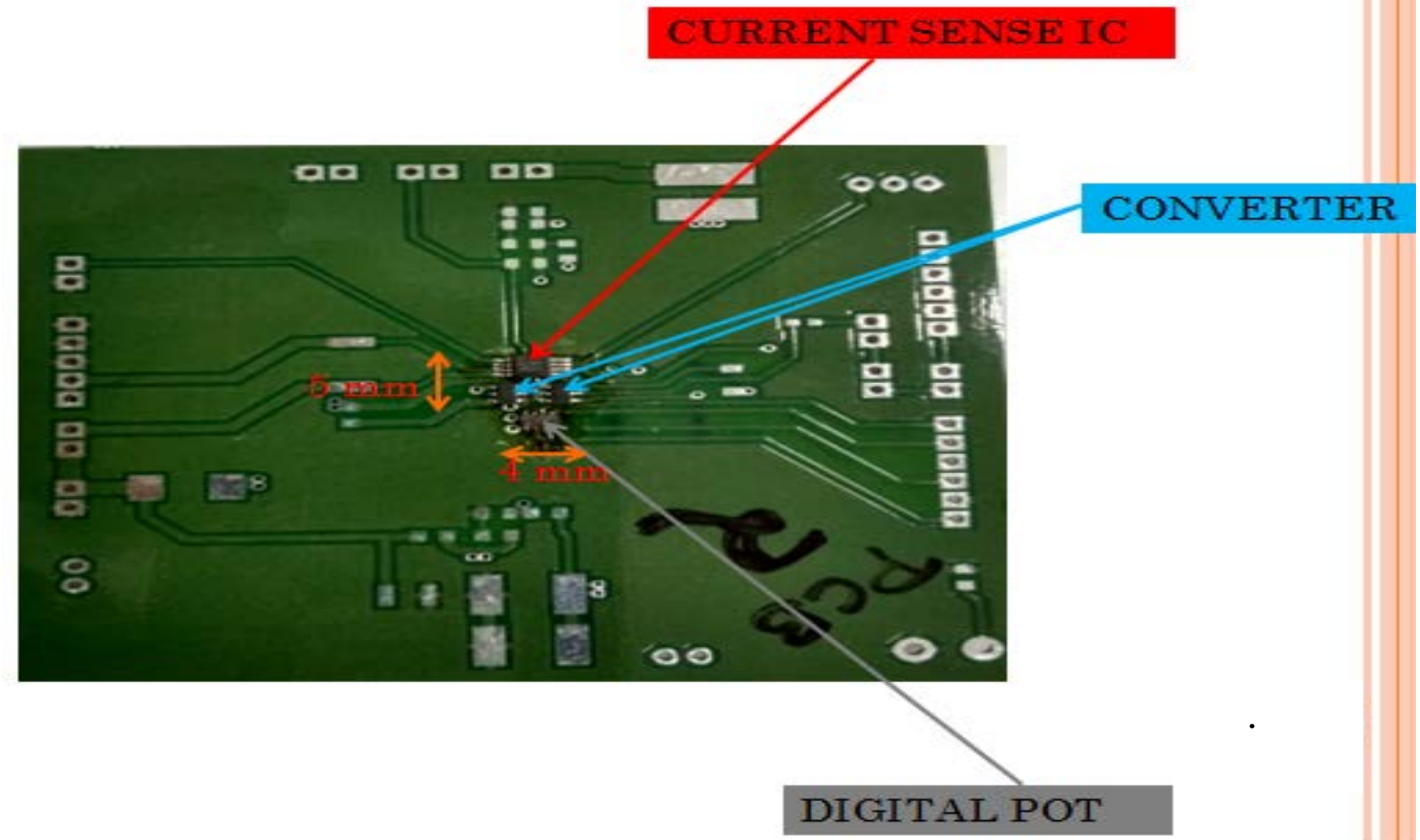
- 14 Mev mono-energetic neutron generator which works on D-T reaction with the threshold of 300kev.
  - Yield = $7.7 \times 10^{8} N_{14}$/s
  - Flux = $\frac{(6.132 \times 10^{7}) N_{14}}{R^{2}}$ /cm^{2} /s

  * Damage Factor = 2

Converter, multiplexer switch and NOT gate sustained dose of 4.46×10^{12}Neq/cm^{2}

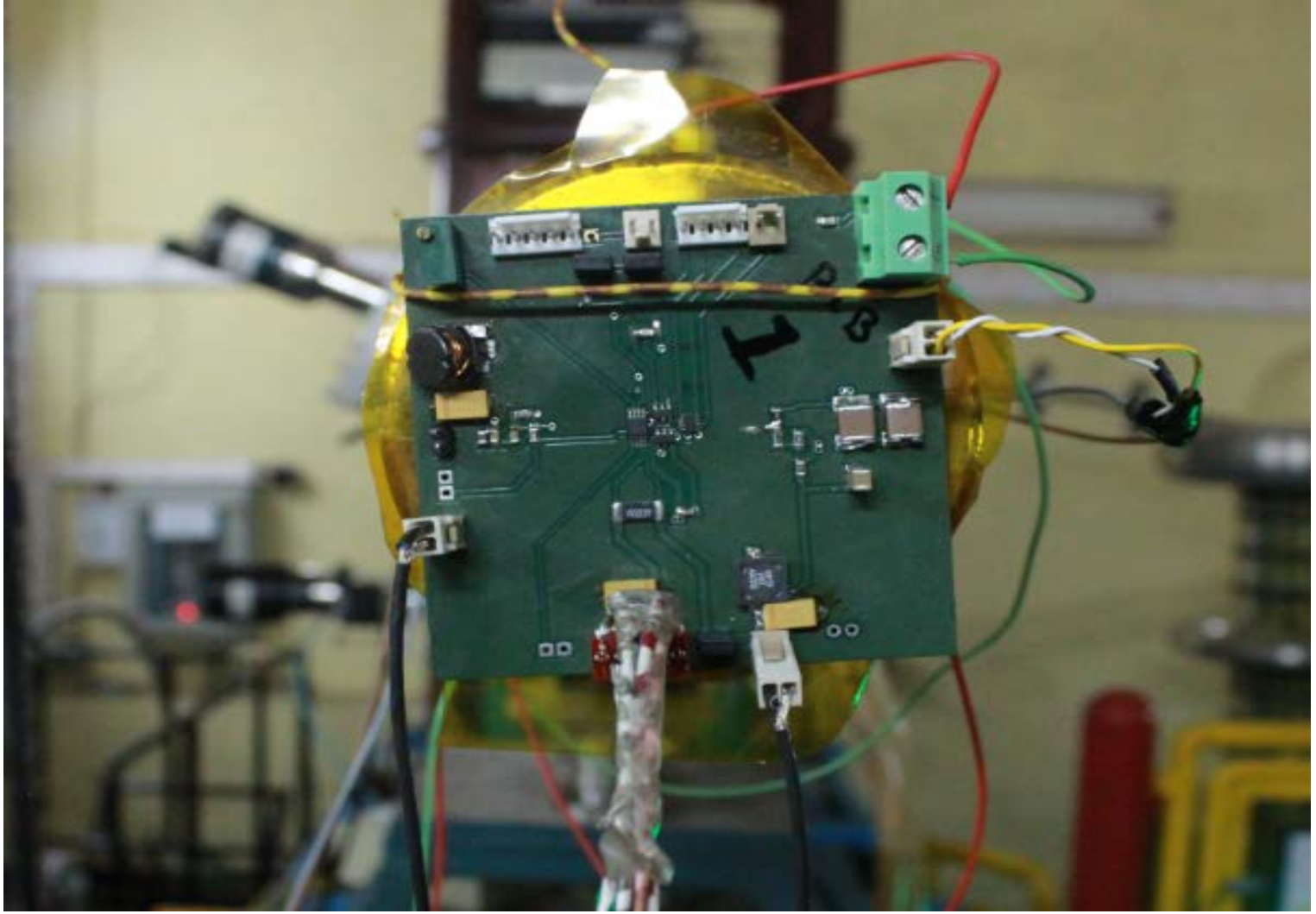
Observations

- Slight increment in peak to peak ripples.
- No effect on dc value of devices.
- Single event transient and upsets were observed



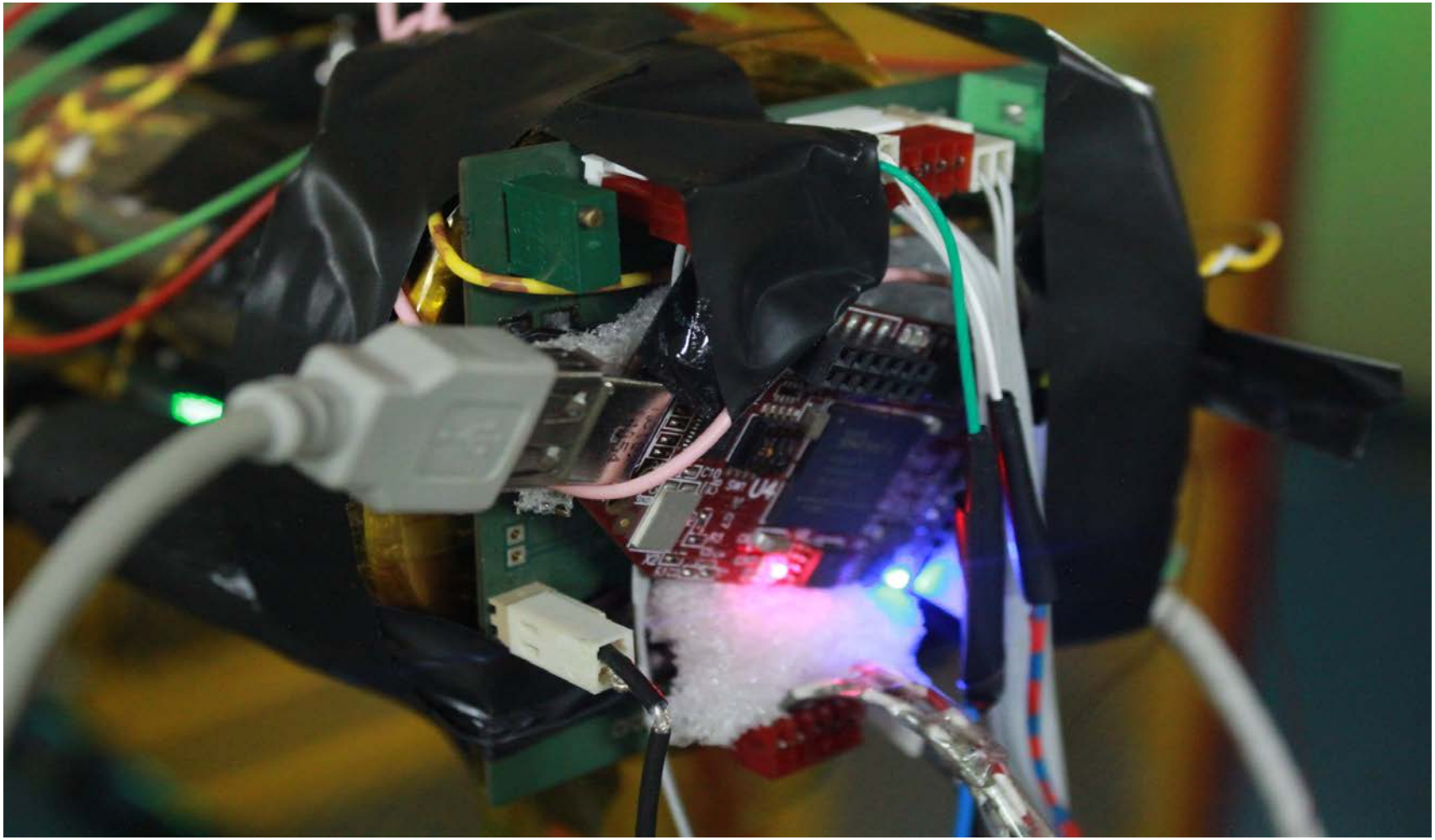
Converters
Current sensing IC
SPI Digital POT(LATCH)
Multiplexers

All the components were closely packed so that maximum beam exposure

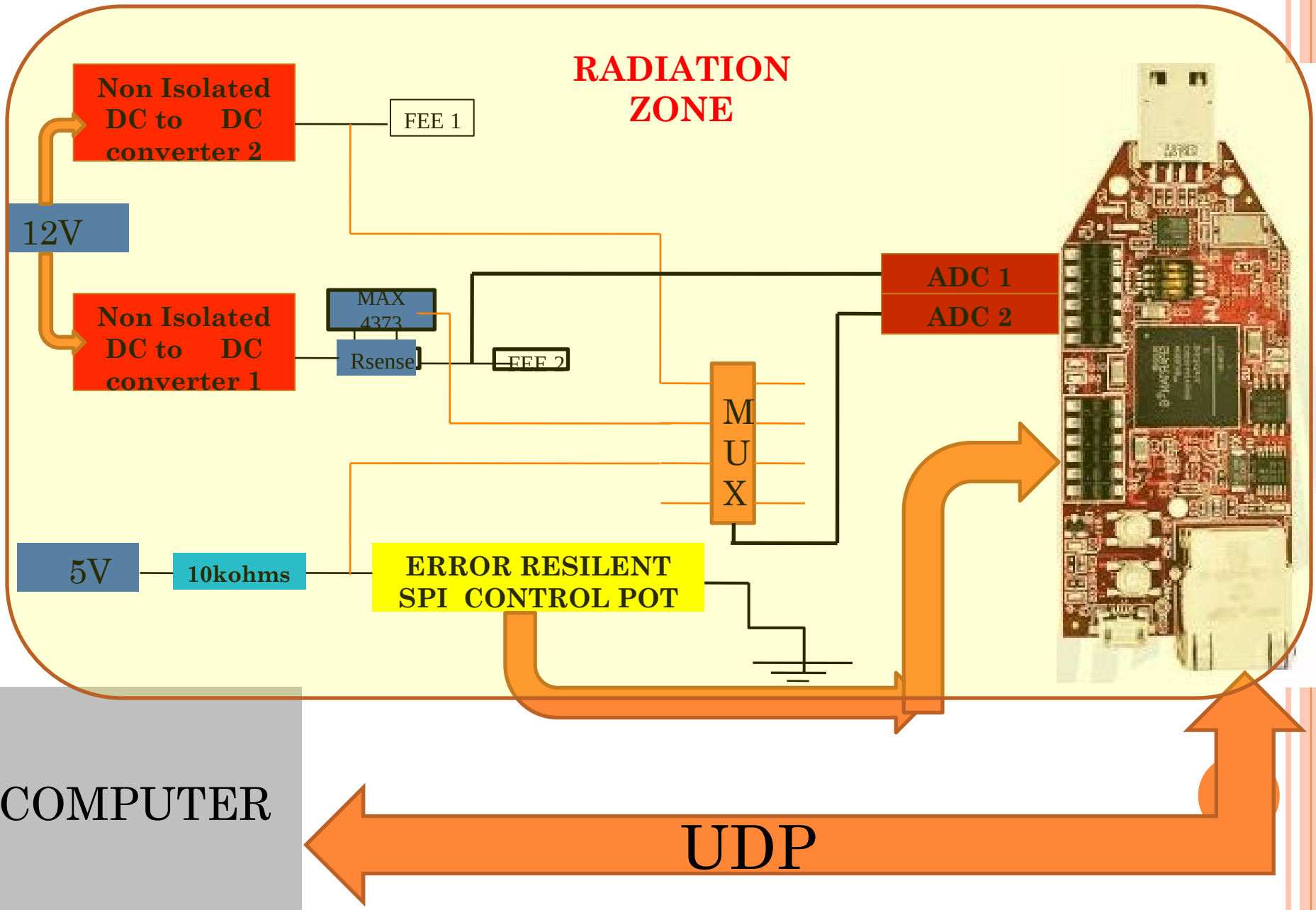


Converters
Current sensing IC
SPI Digital POT(LATCH)
Multiplexers

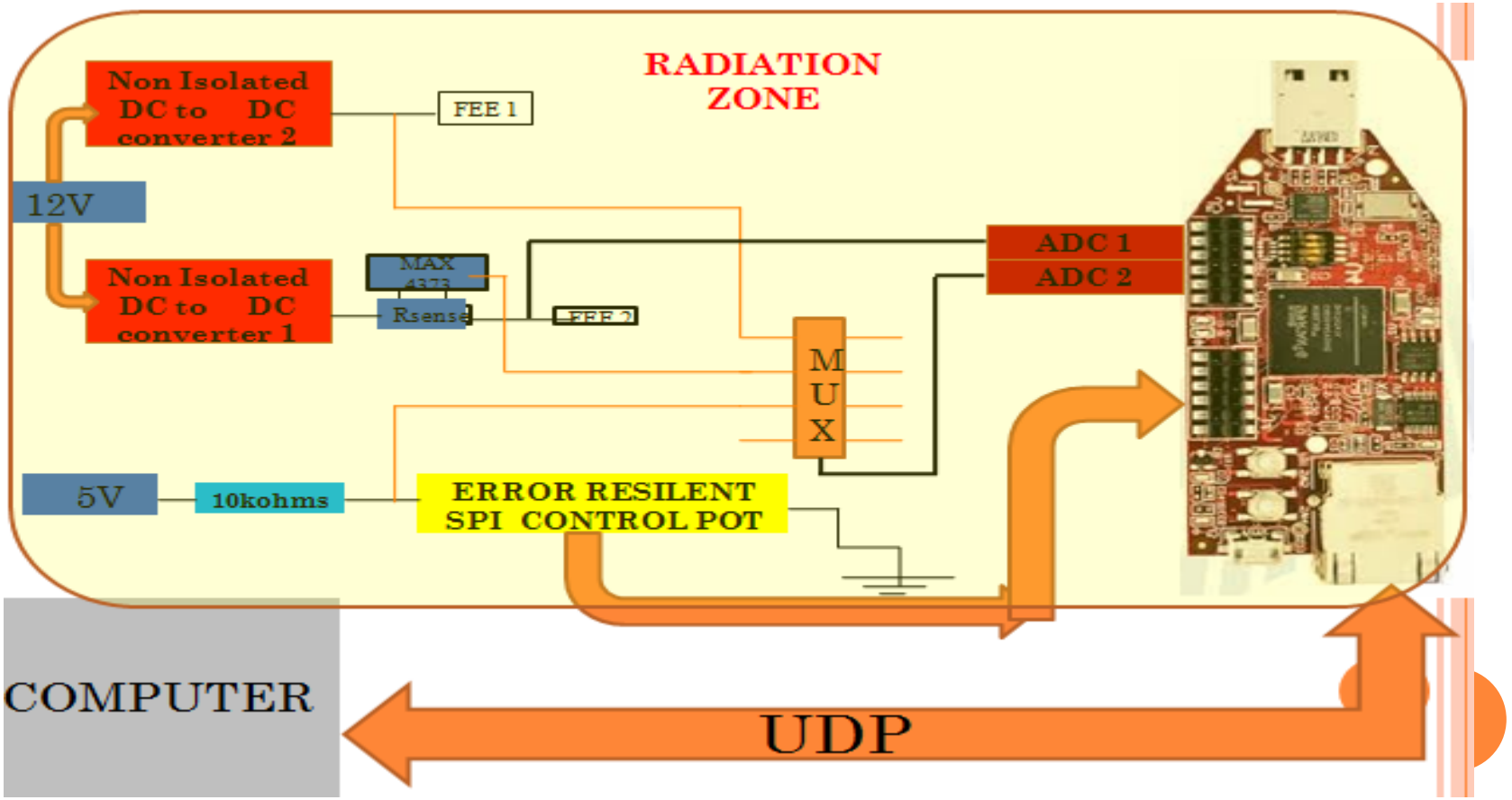
ALL COMPONENTS ARE PLACED AT < 1.3cm

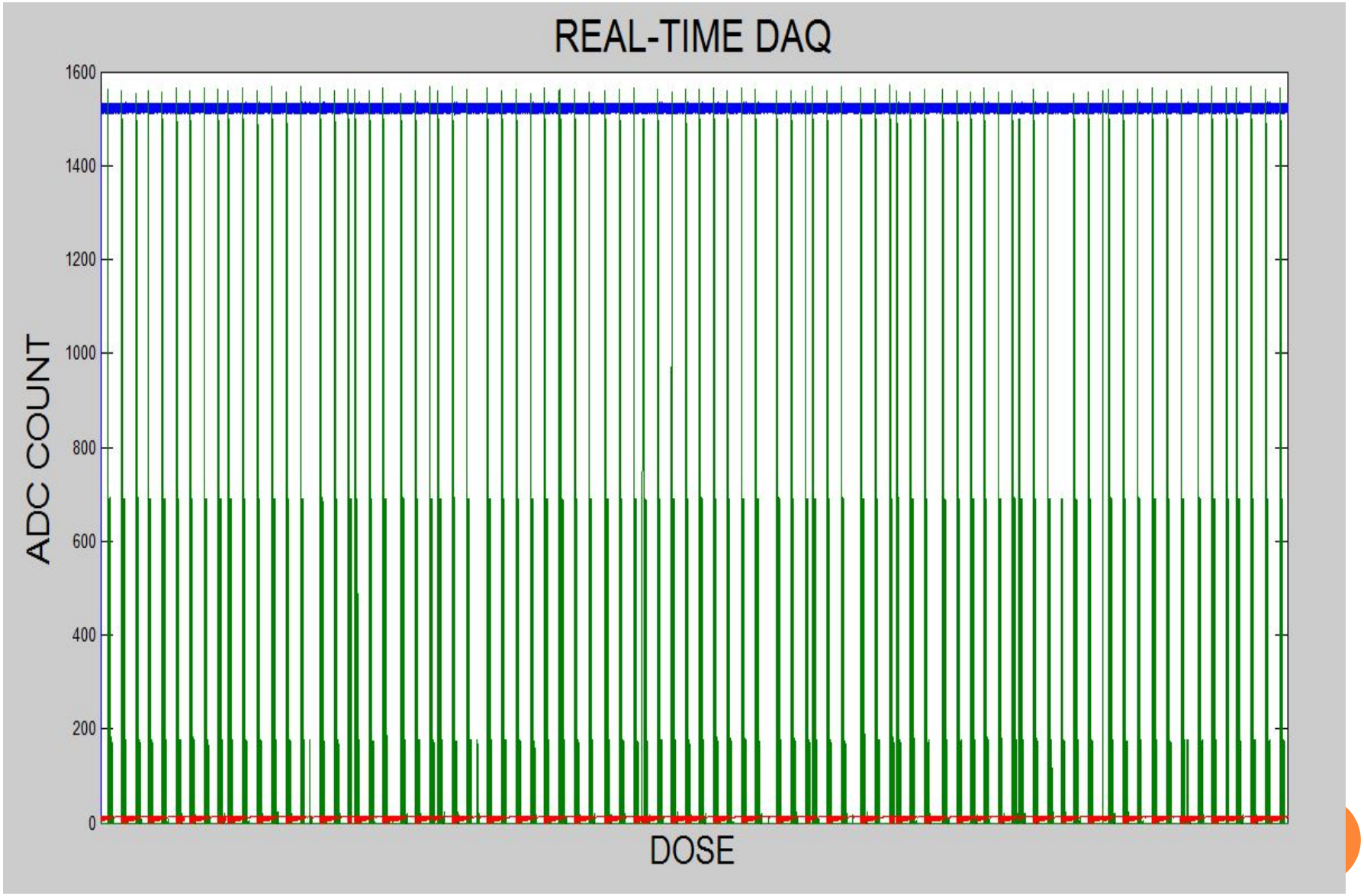


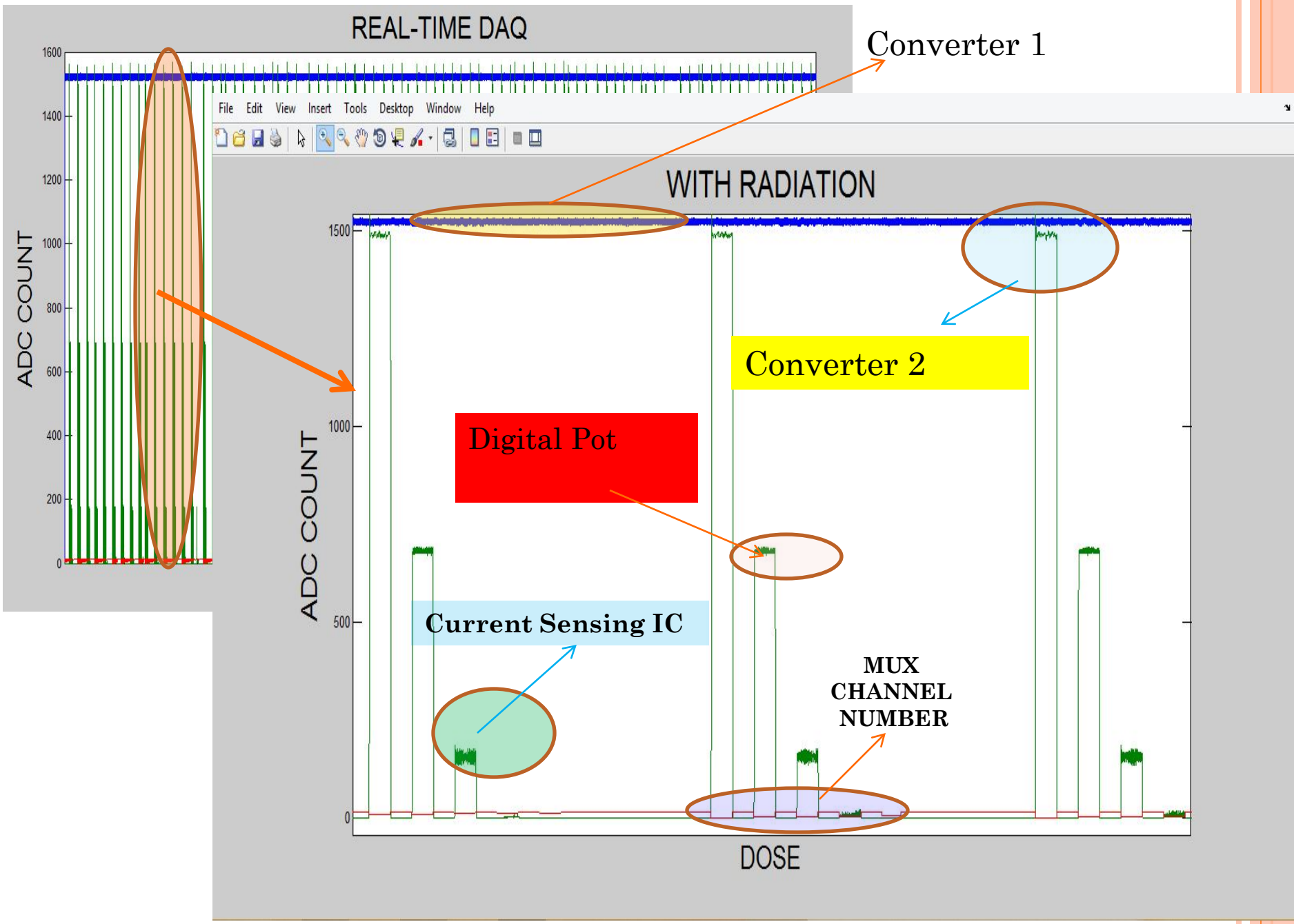
FPGA at < 1.5cm
SPI FLASH < 2.5 cm

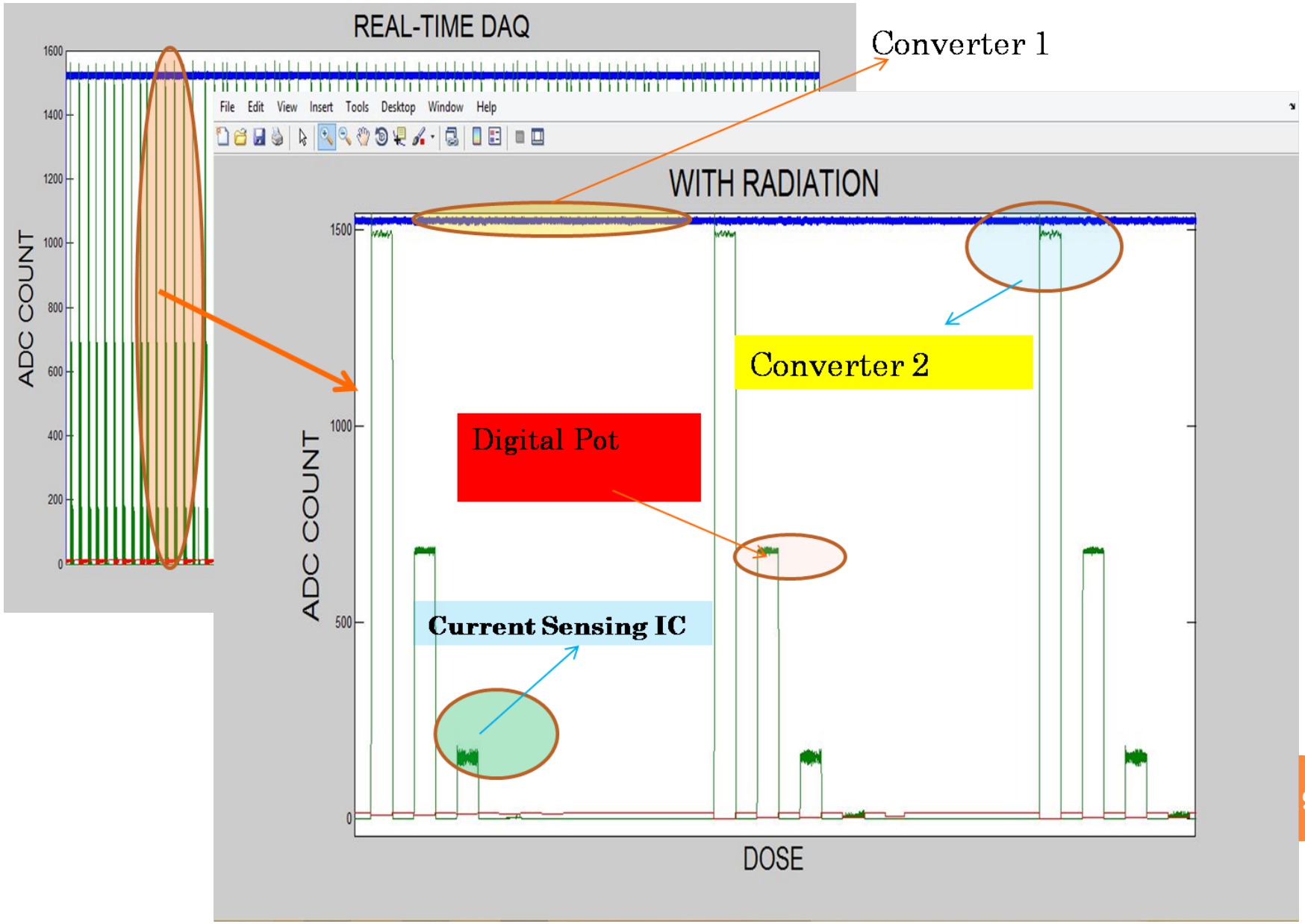

RADIATION ZONE
Non Isolated DC to DC converter 2
FEE 1
12V
Non Isolated DC to DC converter 1
MAX 4373
Rsense
FEE 2
ADC 1
ADC 2
MUX
5V
10kohms
ERROR RESILENT SPI CONTROL POT
COMPUTER
UDP

PCB exposed to radiation environment.
ADCs digitized and fetch different voltage and current of devices under test to Spartan 6 Lx9 FPGA boards.
FPGA send data to computer via UDP protocol
Online real time parameter monitoring and data logging were done in Matlab.

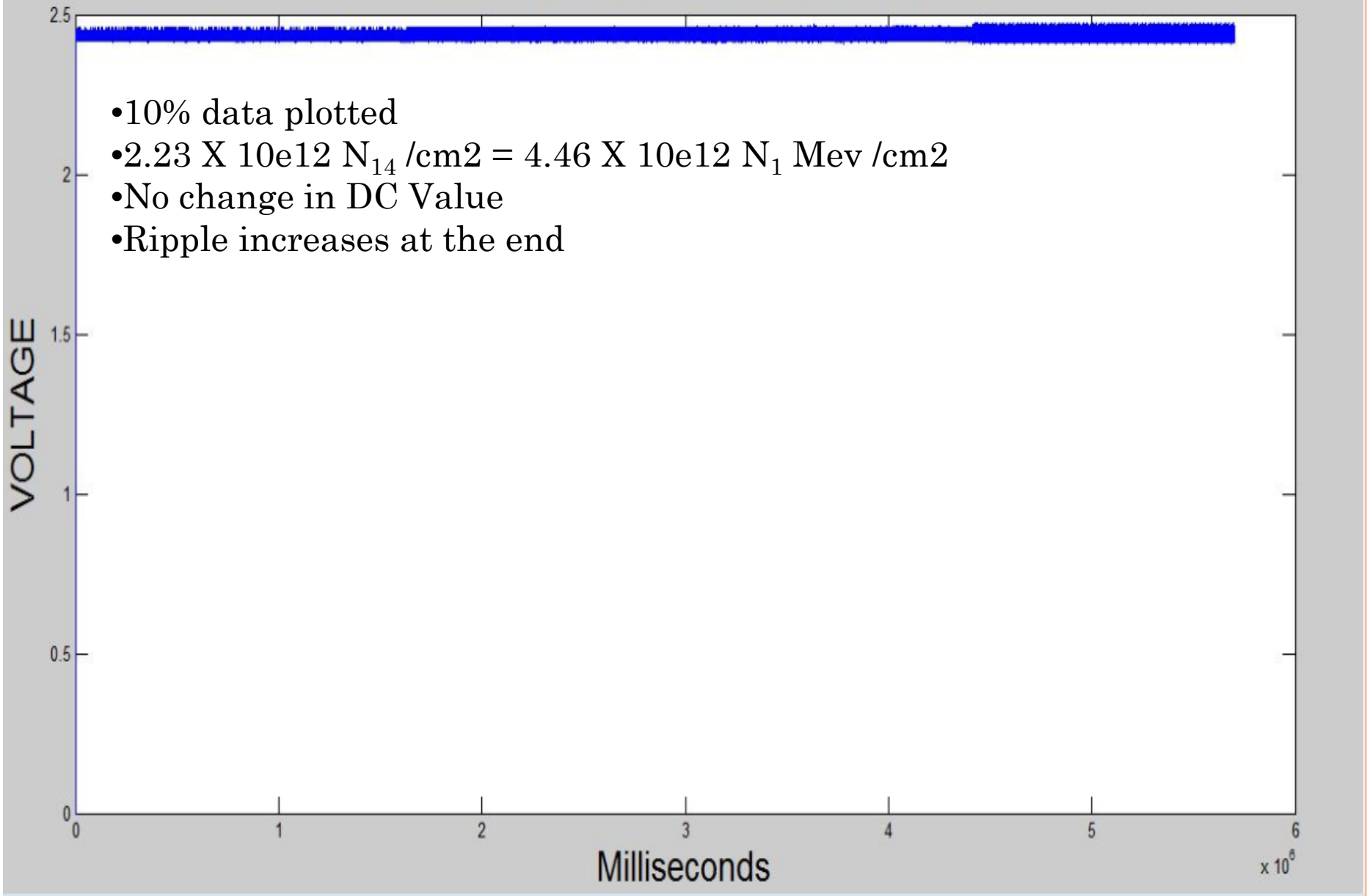



REAL-TIME DAQ
ADC COUNT
1600
1400
1200
1000
800
600
400
200
0
DOSE

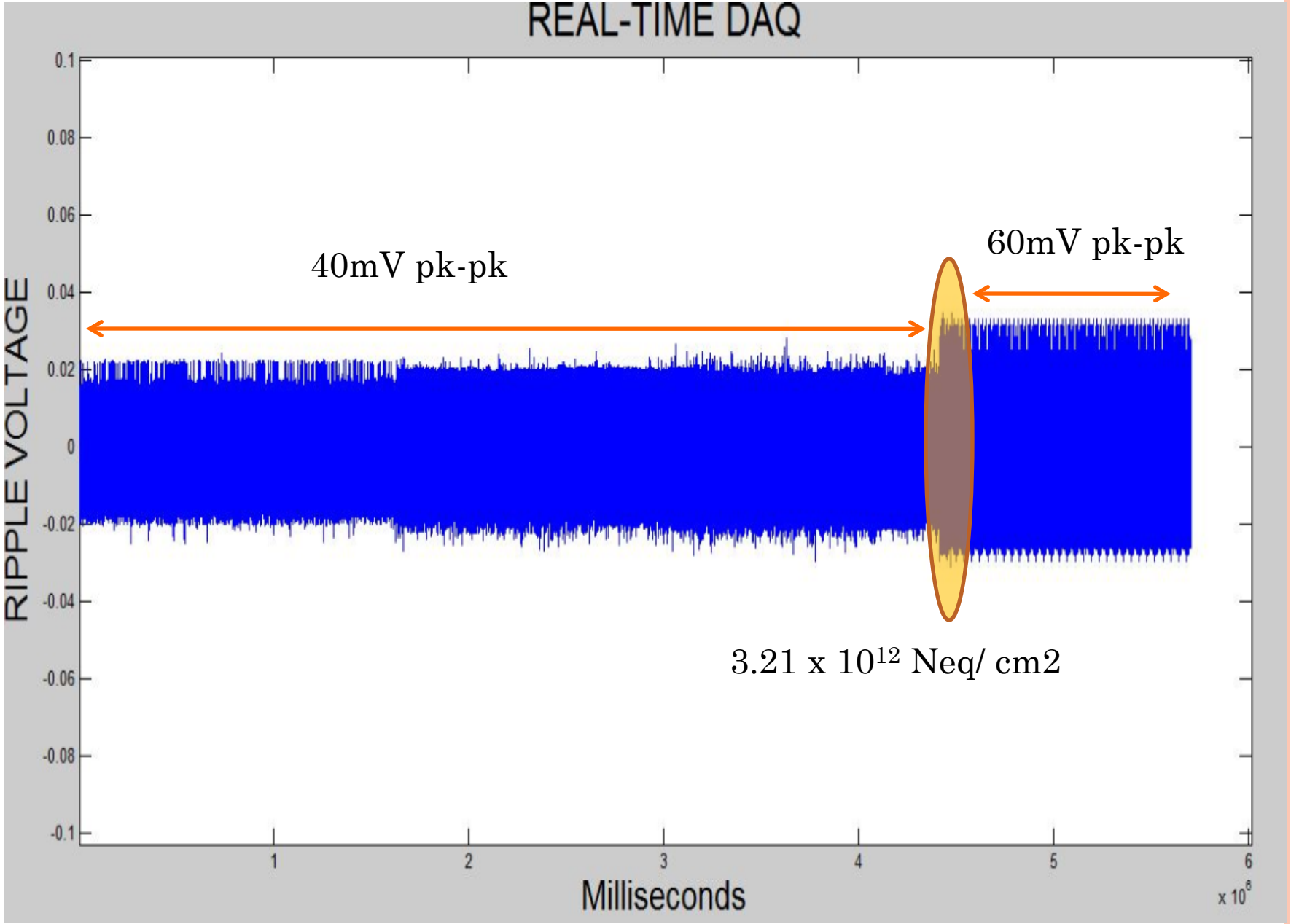

REAL-TIME DAQ
ADC COUNT
1600
1400
1200
1000
800
600
400
200
0
Converter 1
File Edit View Insert Tools Desktop Window Help
WITH RADIATION
ADC COUNT
1500
1000
500
0
Converter 2
Digital Pot
Current Sensing IC
MUX
CHANNEL
NUMBER
DOSE

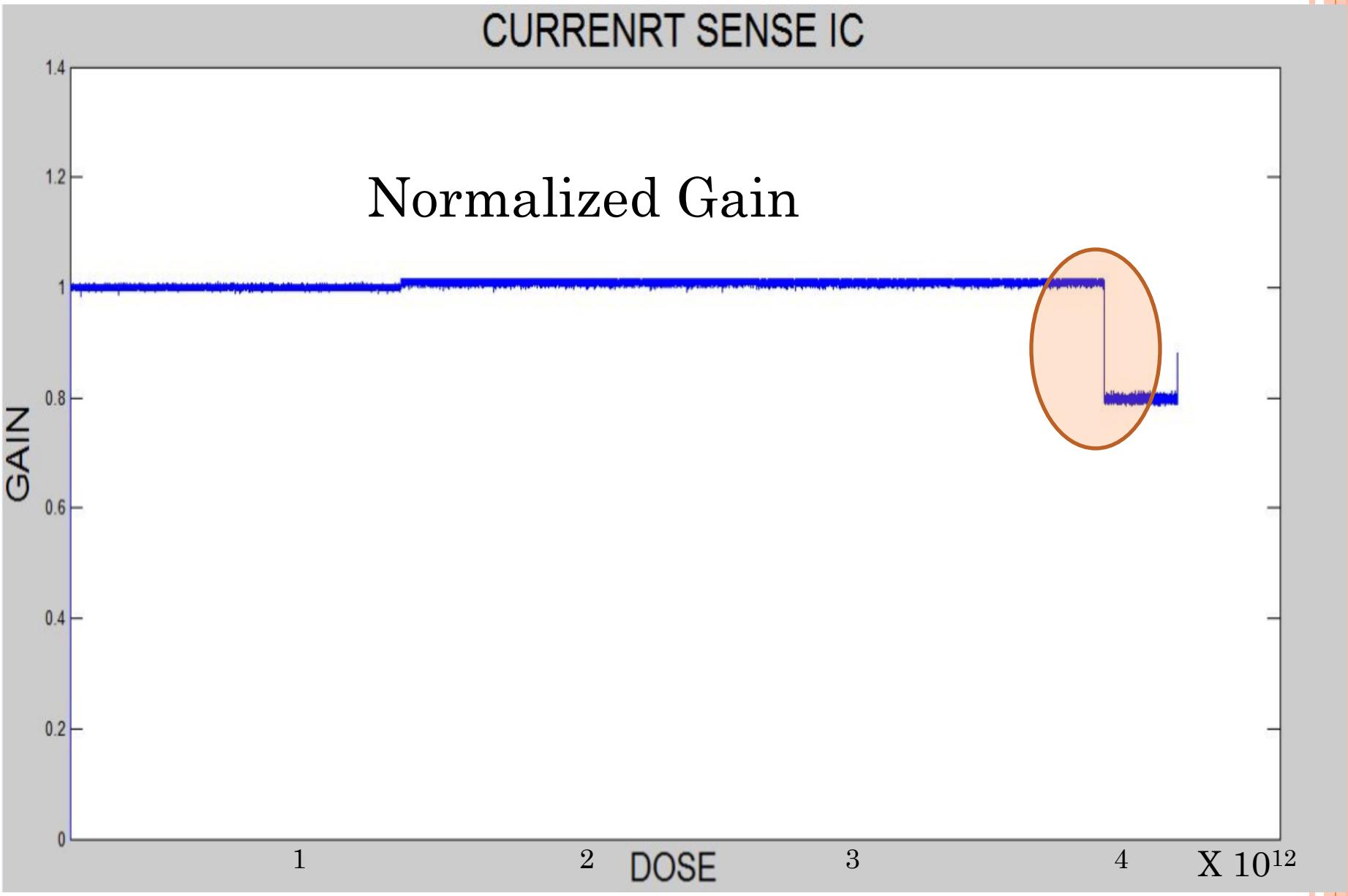

REAL-TIME DAQ
ADC COUNT
1600
1400
1200
1000
800
600
400
200
0
File Edit View Insert Tools Desktop Window Help
WITH RADIATION
Converter 1
Converter 2
Digital Pot
Current Sensing IC
ADC COUNT
1500
1000
500
0
DOSE

CONVERTER IN RADIATION



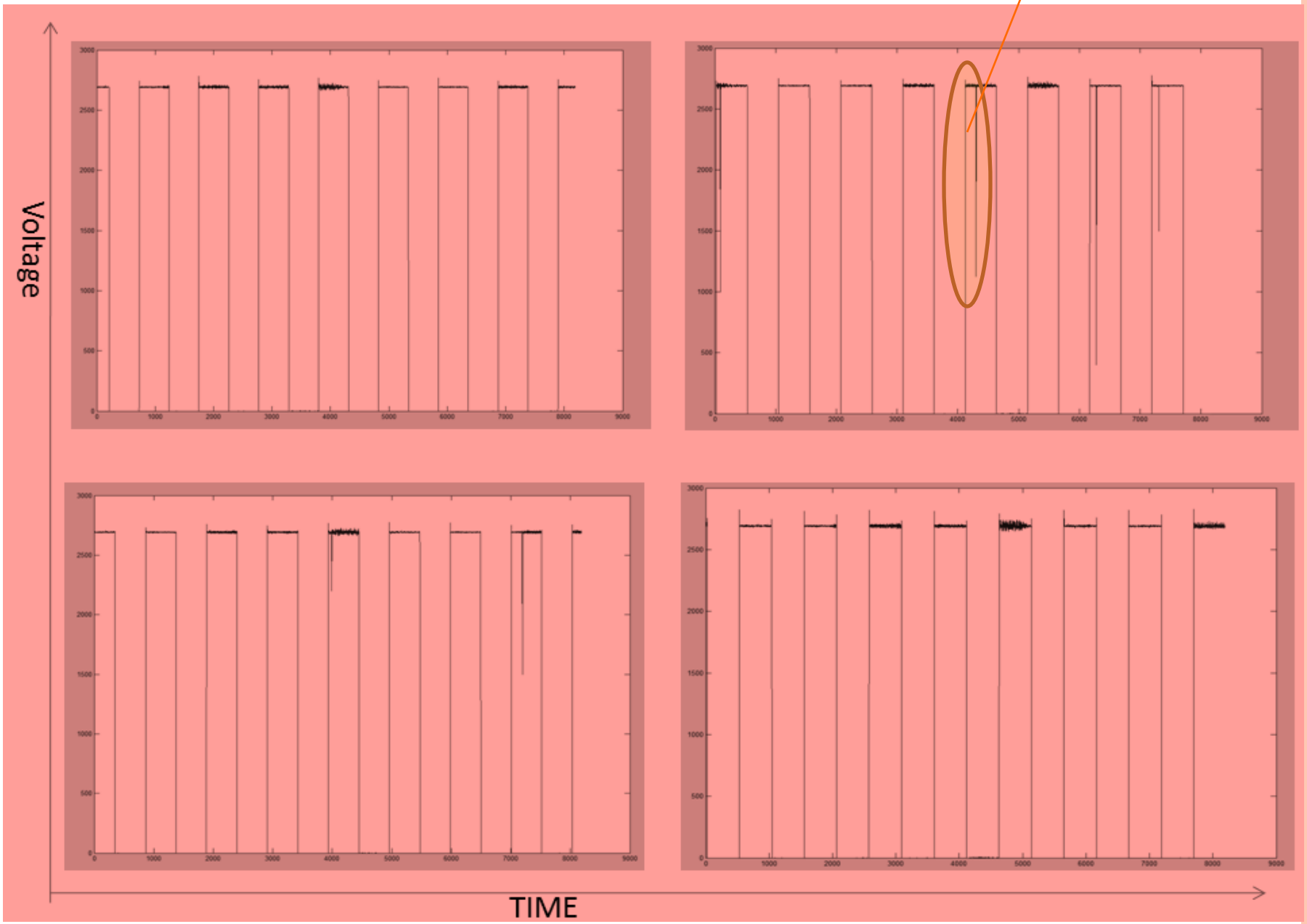
- 10% data plotted
- 2.23 X 10e12 N_{14} /cm2 = 4.46 X 10e12 N_1 Mev /cm2
- No change in DC Value
- Ripple increases at the end


REAL-TIME DAQ
RIPPLE VOLTAGE
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
1
2
3
4
5
6
Milliseconds
x 10^6
40mV pk-pk
60mV pk-pk
3.21 x 10^12 Neq/ cm2


CURRENRT SENSE IC
Normalized Gain
GAIN
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
2
3
4
DOSE
X 10^12

MUX Response

continue



Conclusion

Various component from different companies were irradiated and after multiple failures we have some components which can tolerate desire radiation level

S.No	Gamma	Neutron	Size
Converter1	600Gy	4.46 $\times 10^{12}$ Neq/cm^2	
Converter2	600Gy	4.46 $\times 10^{12}$ Neq/cm^2	
Mux	60Gy	4.46 $\times 10^{12}$ Neq/cm^2	
Digital Pot	300 Gy	4.46 $\times 10^{12}$ Neq/cm^2	
Current sensing IC	260 Gy	3.73 $\times 10^{12}$ Neq/cm^2	
Switch	>700Gy	4.46 $\times 10^{12}$ Neq/cm^2	
Not Gate	>700Gy	4.46 $\times 10^{12}$ Neq/cm^2	

All

CONTROL BOARD

RS-232 via USB-UART Bridge
10/100 Ethernet PHY
24 GPIOS
128MB SPI FLASH

Spartan 6 lx9 board

- Automatic rebooting of Bit- file in FPGA with desirable Refresh rates
- SPI Flash refreshed with the help of Diligent Software.
- Read-back of bit file can be done via impact.

SINGLE EVENT UPSETS(BIT-FILE)

Size = 2722512bits
Dimensions = 2cm X 2cm
Flux= 2.725 x 10 ^{7} Neq /cm2/s

```
1  Xilinx ASCII Bitst
2  Created by Bitstre
3  Design name:     Et
4  Architecture:    sp
5  Part:            6s
6  Type:            re
7  Date:            Tu
8  Bits:            27
9  0000000000000000
10 0000000000000000
11 0000000000000000
12 0000000000000000
13 0000000000000000
14 0000000000000000
15 0000000000000000
16 0000000000000000
17 0000000000000000
18 0000000000000000
19 0000000000000000
20 0000000000000000
21 0000000000000000
22 0000000000000000
23 0000000000000000
24 0000000000000000
25 0000000000000001
26 0000000000000000
27 0000000000000000
28 0000000000000000
29 0000000000000000
30 0000000000000000
31 0000000000000000
32 0000000000000000
```

```
1  Xilinx ASCII Bitstream
2  Created by Bitstream P.20131013
3  Design name:     Ethernet_Module.ncd;UserID=0xFFFFFFFF
4  Architecture:    spartan6
5  Part:            6slx9csg324
6  Type:            readback
7  Date:            Tue jan 9 15:38:46 2018
8  Bits:            2722512
9  0000000000000000
10 0000000000000000
11 0000000000000000
12 0000000000000000
13 0000000000000000
14 0000000000000000
15 0000000000000000
16 0000000000000000
17 0000000000000000
18 0000000000000000
19 0000000000000000
20 0000000000000000
21 0000000000000000
22 0000000000000000
23 0000000000000000
24 0000000000000000
25 0000000000000000
26 0000000000000000
27 0000000000000000
28 0000000000000000
29 0000000000000000
30 0000000000000000
31 0000000000000000
32 0000000000000000
```

ISE iMPACT (P.68d) - [Boundary Scan]

File Edit View Operations Output Debug Window Help

REFRESH RATE 1 HOUR

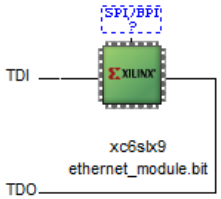
iMPACT Flows

- Boundary Scan
- SystemACE
- Create PROM File (PROM File Format...
- WebTalk Data

iMPACT Processes

Available Operations are:

- Program
- Verify
- Get Device ID
- Get Device Signature/Usercode
- Read Device Status
- One Step SVF
- One Step XSVF
- Read Device DNA



13935
13656
13985

Verify Failed

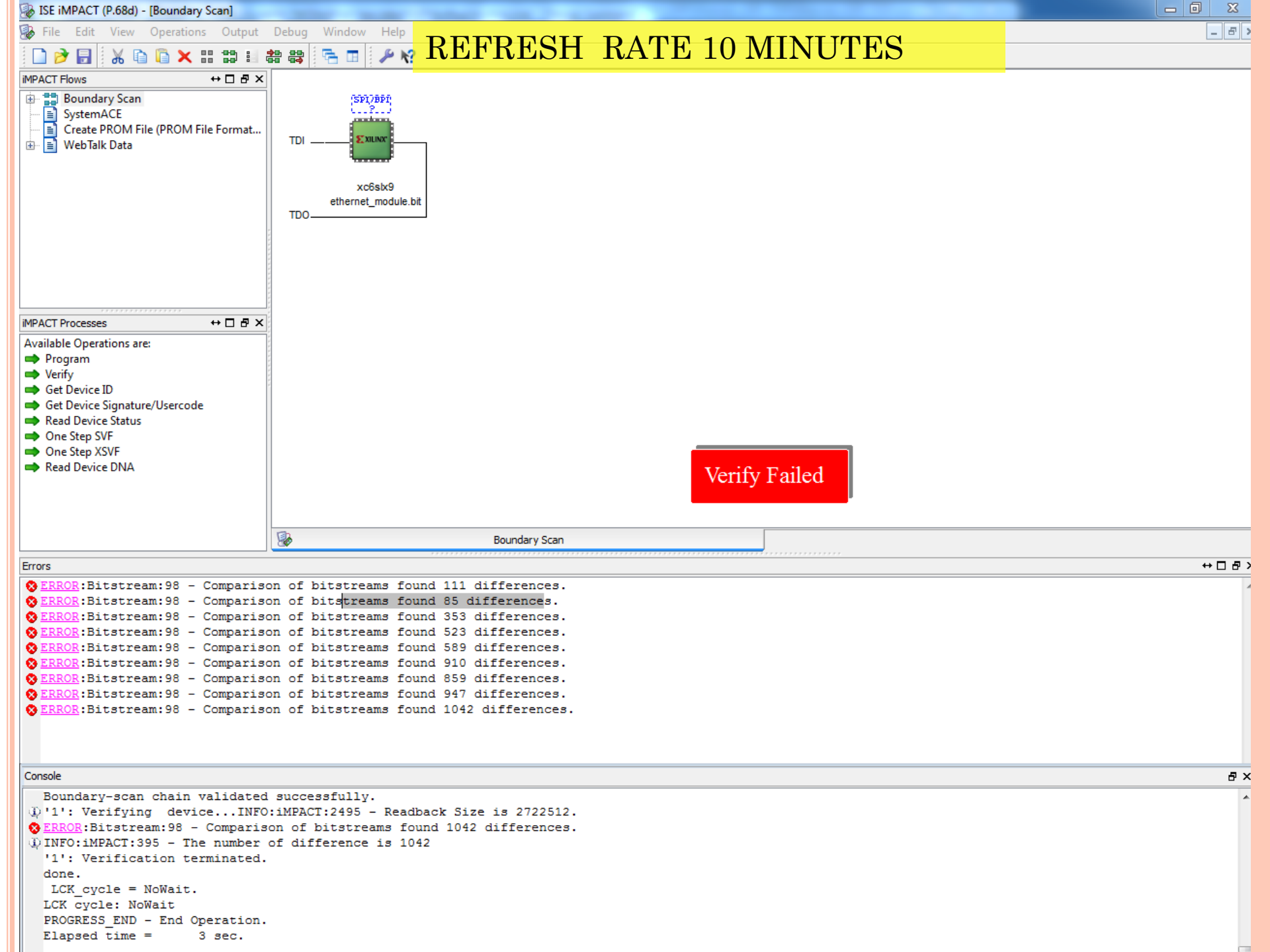
Boundary Scan

Errors

ERROR:Bitstream:98 - Comparison of bitstreams found 13686 differences.
ERROR:Bitstream:98 - Comparison of bitstreams found 13935 differences.
ERROR:Bitstream:98 - Comparison of bitstreams found 13985 differences.

Console

```
Boundary-scan chain validated successfully.
'1': Verifying  device...INFO:iMPACT:2495 - Readback Size is 2722512.
ERROR:Bitstream:98 - Comparison of bitstreams found 13985 differences.
INFO:iMPACT:395 - The number of difference is 13985
'1': Verification terminated.
done.
 LCK_cycle = NoWait.
LCK cycle: NoWait
PROGRESS_END - End Operation.
Elapsed time =      3 sec.
```


ISE iMPACT (P.68d) - [Boundary Scan]
File Edit View Operations Output Debug Window Help
REFRESH RATE 10 MINUTES
iMPACT Flows
Boundary Scan
SystemACE
Create PROM File (PROM File Format...
WebTalk Data
SPI/BPI
TDI
TDO
xc6slx9
ethernet_module.bit
iMPACT Processes
Available Operations are:
Program
Verify
Get Device ID
Get Device Signature/Usercode
Read Device Status
One Step SVF
One Step XSVF
Read Device DNA
Verify Failed
Boundary Scan
Errors
ERROR:Bitstream:98 - Comparison of bitstreams found 111 differences.
ERROR:Bitstream:98 - Comparison of bitstreams found 85 differences.
ERROR:Bitstream:98 - Comparison of bitstreams found 353 differences.
ERROR:Bitstream:98 - Comparison of bitstreams found 523 differences.
ERROR:Bitstream:98 - Comparison of bitstreams found 589 differences.
ERROR:Bitstream:98 - Comparison of bitstreams found 910 differences.
ERROR:Bitstream:98 - Comparison of bitstreams found 859 differences.
ERROR:Bitstream:98 - Comparison of bitstreams found 947 differences.
ERROR:Bitstream:98 - Comparison of bitstreams found 1042 differences.
Console
Boundary-scan chain validated successfully.
'1': Verifying device...INFO:iMPACT:2495 - Readback Size is 2722512.
ERROR:Bitstream:98 - Comparison of bitstreams found 1042 differences.
INFO:iMPACT:395 - The number of difference is 1042
'1': Verification terminated.
done.
LCK_cycle = NoWait.
LCK cycle: NoWait
PROGRESS_END - End Operation.
Elapsed time = 3 sec.

ISE iMPACT (P.68d) - [Boundary Scan]

File Edit View Operations Output Debug Window Help

REFRESH RATE 10 MINUTES

iMPACT Flows

- Boundary Scan
- SystemACE
- Create PROM File (PROM File Format...
- WebTalk Data

TDI

TDO

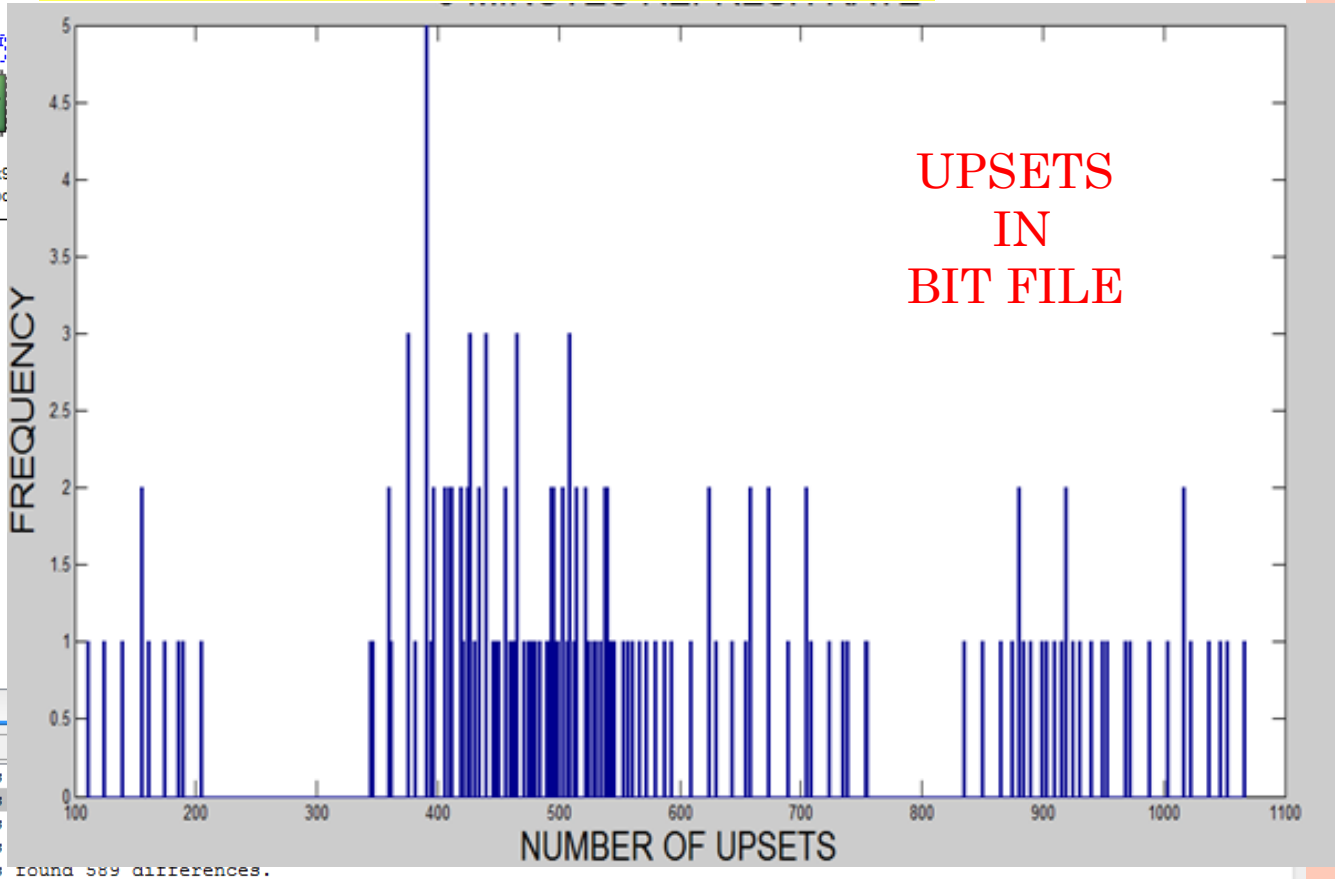
xc6slx9

ethernet_moc

iMPACT Processes

Available Operations are:

- Program
- Verify
- Get Device ID
- Get Device Signature/Usercode
- Read Device Status
- One Step SVF
- One Step XSVF
- Read Device DNA



Errors

ERROR:Bitstream:98 - Comparison of bitstreams
ERROR:Bitstream:98 - Comparison of bitstreams
ERROR:Bitstream:98 - Comparison of bitstreams
ERROR:Bitstream:98 - Comparison of bitstreams
ERROR:Bitstream:98 - Comparison of bitstreams found 589 differences.
ERROR:Bitstream:98 - Comparison of bitstreams found 910 differences.
ERROR:Bitstream:98 - Comparison of bitstreams found 859 differences.
ERROR:Bitstream:98 - Comparison of bitstreams found 947 differences.
ERROR:Bitstream:98 - Comparison of bitstreams found 1042 differences.

Console

```
Boundary-scan chain validated successfully.
'1': Verifying  device...INFO:iMPACT:2495 - Readback Size is 2722512.
ERROR:Bitstream:98 - Comparison of bitstreams found 1042 differences.
INFO:iMPACT:395 - The number of difference is 1042
'1': Verification terminated.
done.
 LCK_cycle = NoWait.
LCK cycle: NoWait
PROGRESS_END - End Operation.
Elapsed time =      3 sec.
```

Bin Size = 5

Total entities = 140

Max Occurrence = 398

ISE iMPACT (P.68d) - [Boundary Scan]

File Edit View Operations Output Debug Window Help

REFRESH RATE 2 MINUTES

iMPACT Flows

- Boundary Scan
- SystemACE
- Create PROM File (PROM File Format...
- WebTalk Data

iMPACT Processes

Available Operations are:

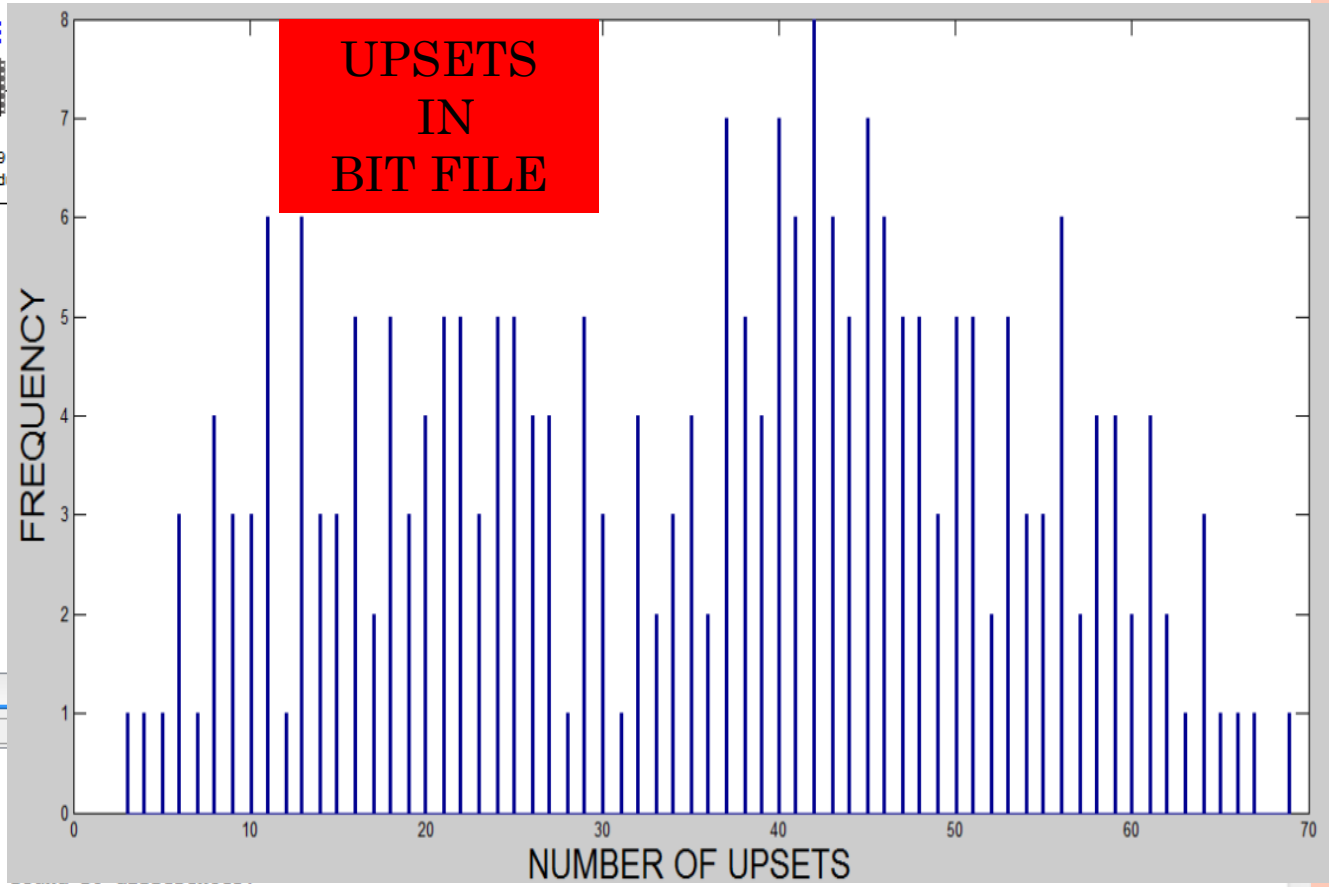
- Program
- Verify
- Get Device ID
- Get Device Signature/Usercode
- Read Device Status
- One Step SVF
- One Step XSVF
- Read Device DNA

TDI

xc6slx9

ethernet_mod

TDO



Errors

ERROR:Bitstream:98 - Comparison of bitstreams
ERROR:Bitstream:98 - Comparison of bitstreams
ERROR:Bitstream:98 - Comparison of bitstreams
ERROR:Bitstream:98 - Comparison of bitstreams
ERROR:Bitstream:98 - Comparison of bitstreams
ERROR:Bitstream:98 - Comparison of bitstreams
ERROR:Bitstream:98 - Comparison of bitstreams found 20 differences.
ERROR:Bitstream:98 - Comparison of bitstreams found 14 differences.
ERROR:Bitstream:98 - Comparison of bitstreams found 40 differences.
ERROR:Bitstream:98 - Comparison of bitstreams found 60 differences.

Console

```
  Boundary-scan chain validated successfully.
'1': Verifying  device...INFO:iMPACT:2495 - Readback Size is 2722512.
ERROR:Bitstream:98 - Comparison of bitstreams found 60 differences.
INFO:iMPACT:395 - The number of difference is 60
'1': Verification terminated.
done.
 LCK_cycle = NoWait.
LCK cycle: NoWait
PROGRESS_END - End Operation.
Elapsed time =      3 sec.
```

Bin Size = 1

Total entities = 240

Max Occurrence = 42

UPSETS IN FLASH MEMORY

- 128Mb
- Size 10 X 7.10 mm2
- FLUX= 10^7 Neq/cm2/s
- Read-back by Diglent software
- File format .mcs (Hex-File)

```
C:\Users\Susanta Pal\Desktop\super_golden\lx9_flash_programming_option1\sfutil>s
futil -d obp -m N25Q128 -w C:\dully\udp.mcs -fh
Data format or syntax error in input file

C:\Users\Susanta Pal\Desktop\super_golden\lx9_flash_programming_option1\sfutil>s
futil -d obp -m N25Q128 -r C:\dully\udp.hex -fi
Reading flash memory and writing to file: C:\dully\udp.hex
Bytes written to file: 16777216

C:\Users\Susanta Pal\Desktop\super_golden\lx9_flash_programming_option1\sfutil>s
futil -d obp -m N25Q128 -w C:\dully\udp.hex -fi
Doing partial erase of flash memory device
Writing file: C:\dully\udp.hex to flash memory device
Bytes written to flash: 16777216

C:\Users\Susanta Pal\Desktop\super_golden\lx9_flash_programming_option1\sfutil>s
futil -d obp -m N25Q128 -w C:\dully\udp.hex -fi
Doing partial erase of flash memory device
Writing file: C:\dully\udp.hex to flash memory device
Bytes written to flash: 16777216

C:\Users\Susanta Pal\Desktop\super_golden\lx9_flash_programming_option1\sfutil>
```

UPSETS IN FLASH MEMORY

- 128Mb
- Size 10 X 7.10 mm2
- FLUX= 10^7 Neq/cm2/s
- Read-back by Diglent softw
- File format .mcs (Hex-File)

udp.asv | new 1.txt | new 2.txt | ethernet_module.rbd | udp.mcs | udp.mcs

```
:020000040000FA
:10000000FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF00
:10001000AA99556630A10007200031A10380314123
:100020003D08316109EE31C20400109330E100CF88
:1000300030C10081200020002000200020002008E
:10004000200020002000200020002000200020002000B0
:10005000200020002000033813CC8318108813421F8
:10006000000003201001F31E1FFFF33210005334161
:10007000004330101003261000032810000032A12E
:10008000000032C1000032E1000033A11BE233C2A4
:10009000000000002000200030220000000030A1FD
:1000A0000001506000029BAD00000000000000000058
:1000B0000000000000000000000000000000000040
:1000C0000000000000000000000000000000000030
:1000D0000000000000000000000000000000000020
:1000E0000000000000000000000000000000000010
:1000F0000000000000000000000000000000000000
:10010000000000000000000000000000000000000EF
:10011000000000000000000000000000000000000DF
:10012000000000000000000000000000000000000CF
:10013000000000000000000000000000000000000BF
:10014000000000000000000000000000000000000AF
:100150000000000000000000000000000000000009F
:100160000000000000000000000000000000000008F
:100170000002000000000000000000000000000007D
:100180000000000000000000000000000000000006F
:100190000000000000000000000000000000000005F
:1001A0000000000000000000000000000000000004F
:1001B0000000000000000000000000000000000003F
:1001C0000000000000000000000000000000000002F
:1001D0000000000000000000000000000000000001F
:1001E0000000000000000000000000000080007
```

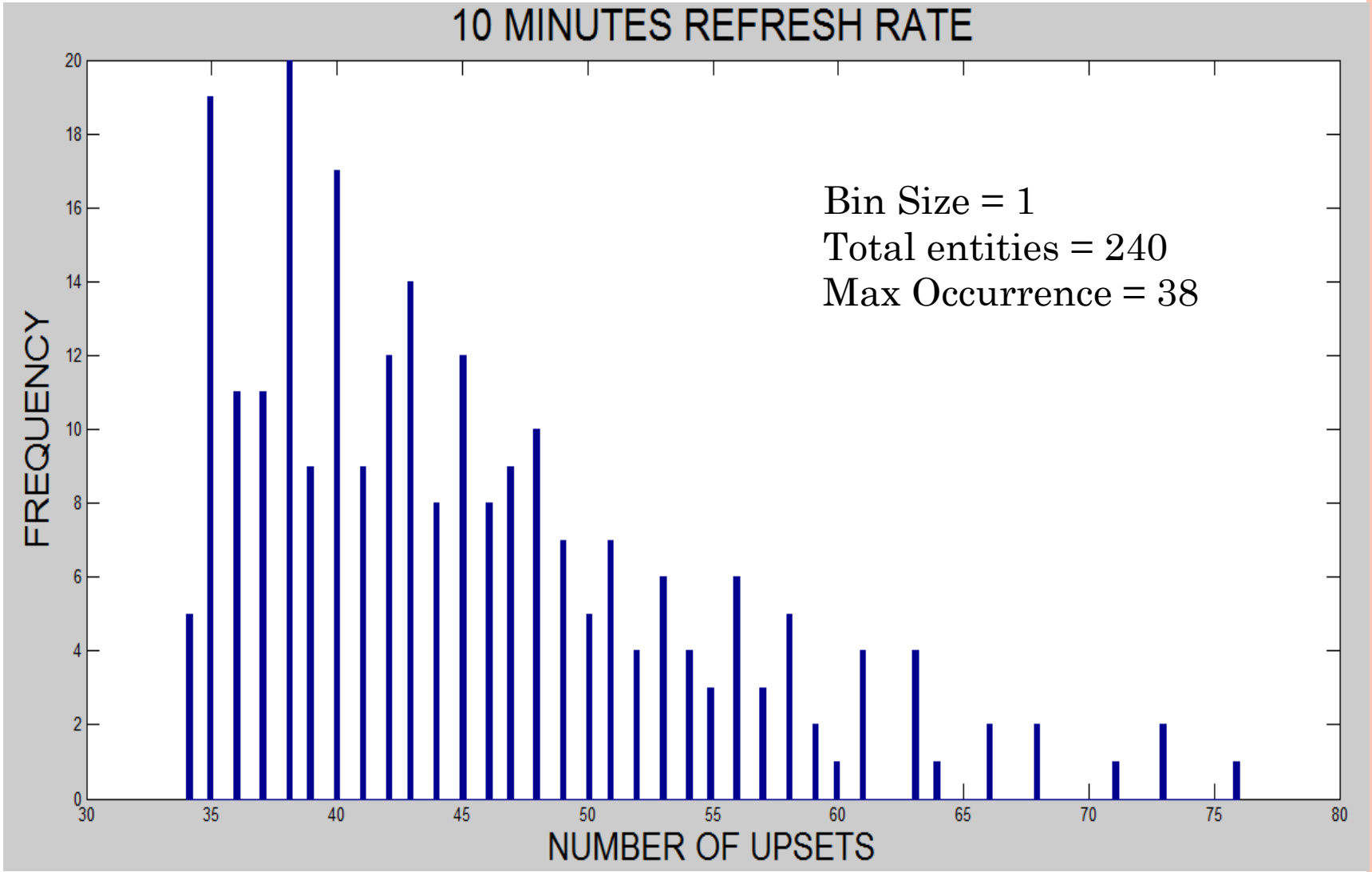
```
C:\Users\Susanta Pal\Desktop\su
futil -d obp -m N25Q128 -w C:\d
Data format or syntax error in

C:\Users\Susanta Pal\Desktop\su
futil -d obp -m N25Q128 -r C:\d
Reading flash memory and writin
Bytes written to file: 16777216

C:\Users\Susanta Pal\Desktop\su
futil -d obp -m N25Q128 -w C:\d
Doing partial erase of flash me
Writing file: C:\dully\udp.hex
Bytes written to flash: 1677721

C:\Users\Susanta Pal\Desktop\su
futil -d obp -m N25Q128 -w C:\d
Doing partial erase of flash me
Writing file: C:\dully\udp.hex
Bytes written to flash: 16777216

C:\Users\Susanta Pal\Desktop\super_golden\lx9_flash_programming_option1\sfutil>
```

UPSETS IN FLASH MEMORY

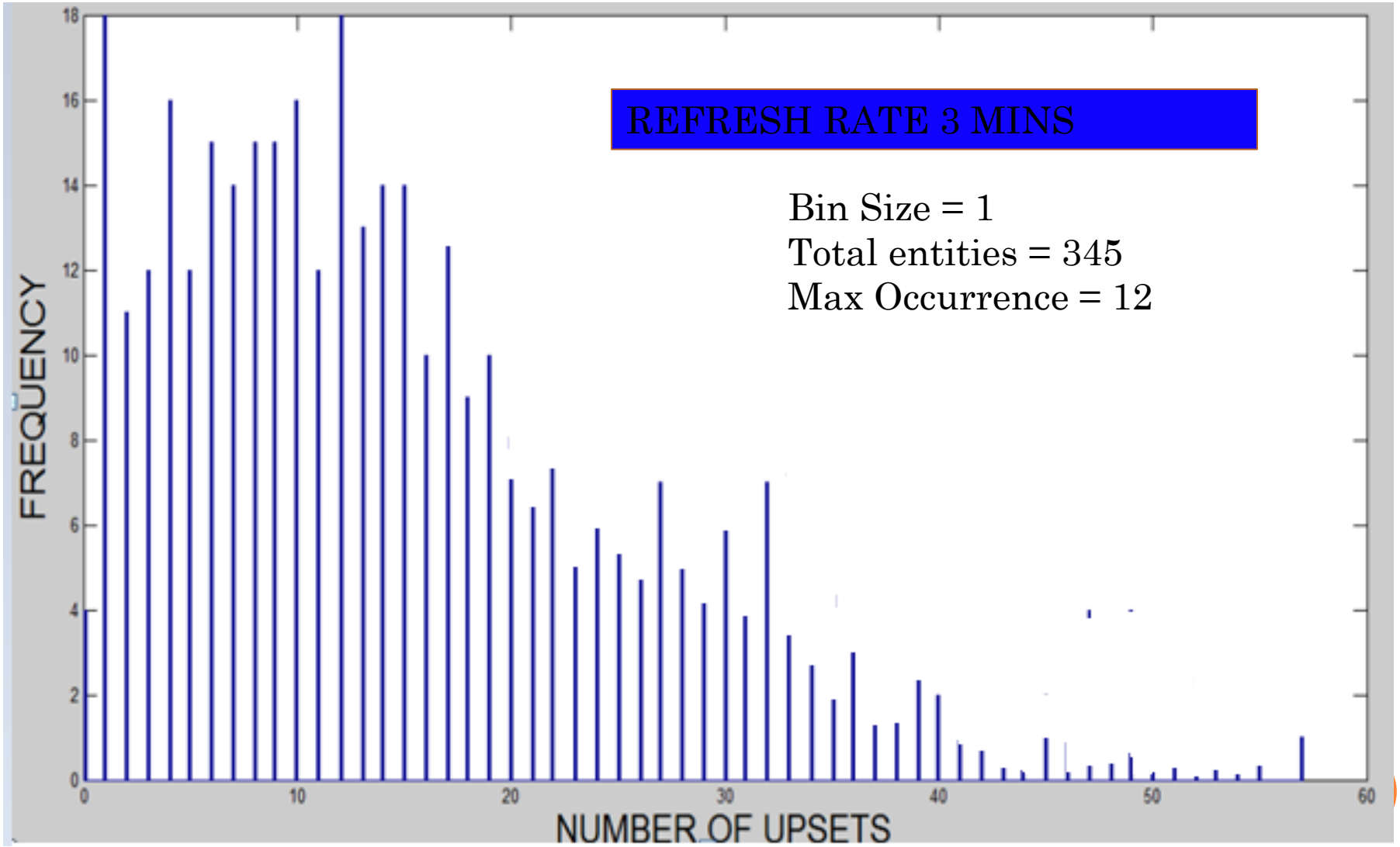
- 128Mb
- Size 10 X 7.10 mm2
- FLUX= 10^7 Neq/cm2/s
- Read-back by Diglent software
- File format .mcs (Hex-File)

```
C:\Users\Susanta Pal\Desktop\super_golden\lx9_flash_programming_option1\sfutil>s
futil -d obp -m N25Q128 -w C:\dully\udp.mcs -fh
Data format or syntax error in input file

C:\Users\Susanta Pal\Desktop\super_golden\lx9_flash_programming_option1\sfutil>s
futil -d obp -m N25Q128 -r C:\dully\udp.hex -fi
Reading flash memory and writing to file: C:\dully\udp.hex
Bytes written to file: 16777216

C:\Users\Susanta Pal\Desktop\super_golden\lx9_flash_programming_option1\sfutil>s
futil -d obp -m N25Q128 -w C:\dully\udp.hex -fi
Doing partial erase of flash memory device
Writing file: C:\dully\udp.hex to flash memory device
Bytes written to flash: 16777216

C:\Users\Susanta Pal\Desktop\super_golden\lx9_flash_programming_option1\sfutil>s
futil -d obp -m N25Q128 -w C:\dully\udp.hex -fi
Doing partial erase of flash memory device
Writing file: C:\dully\udp.hex to flash memory device
Bytes written to flash: 16777216

C:\Users\Susanta Pal\Desktop\super_golden\lx9_flash_programming_option1\sfutil>
```

UPSETS IN FLASH MEMORY



UPSETS IN FLASH MEMORY

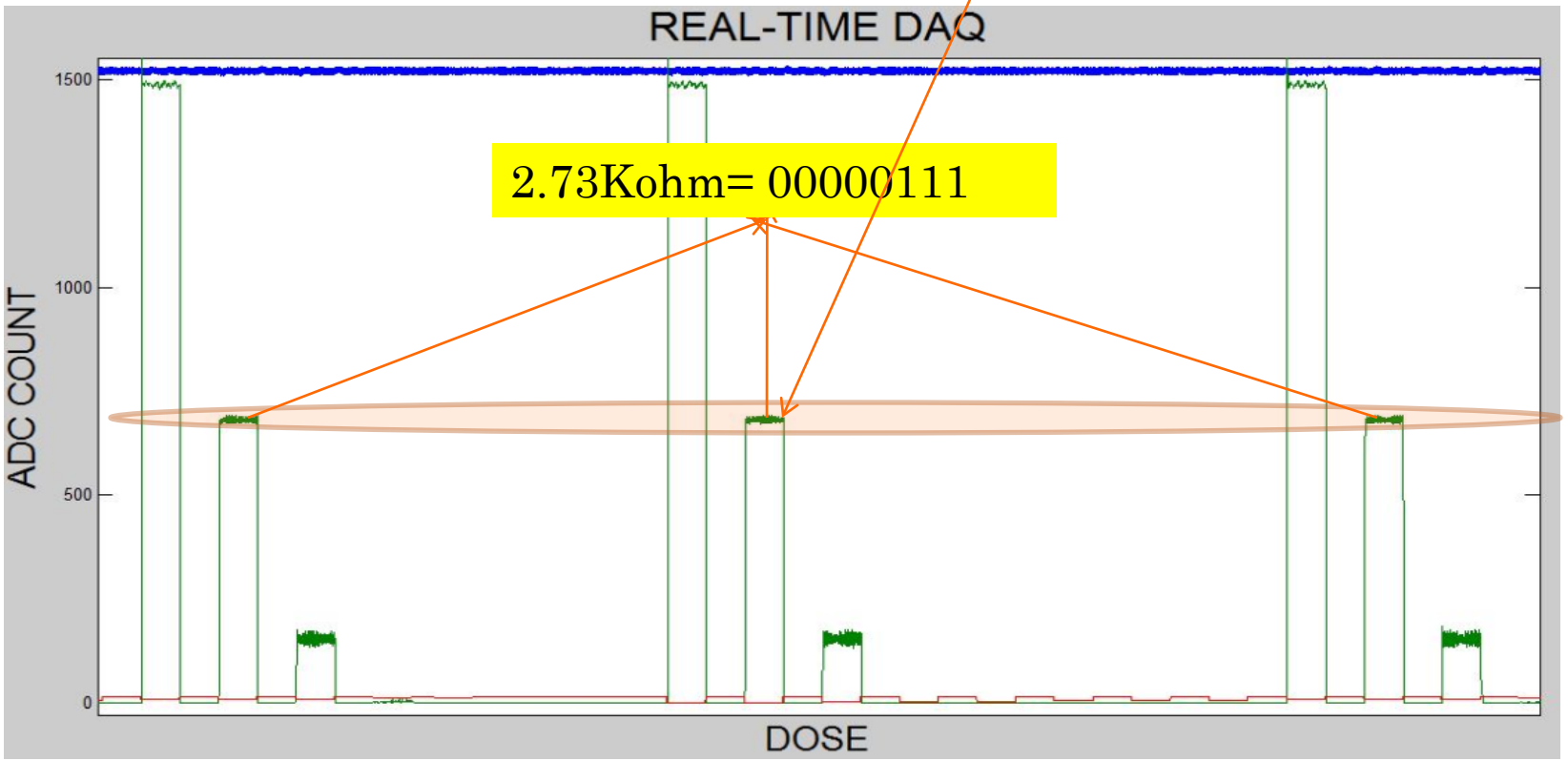


Digital Pot

Size 8 bit

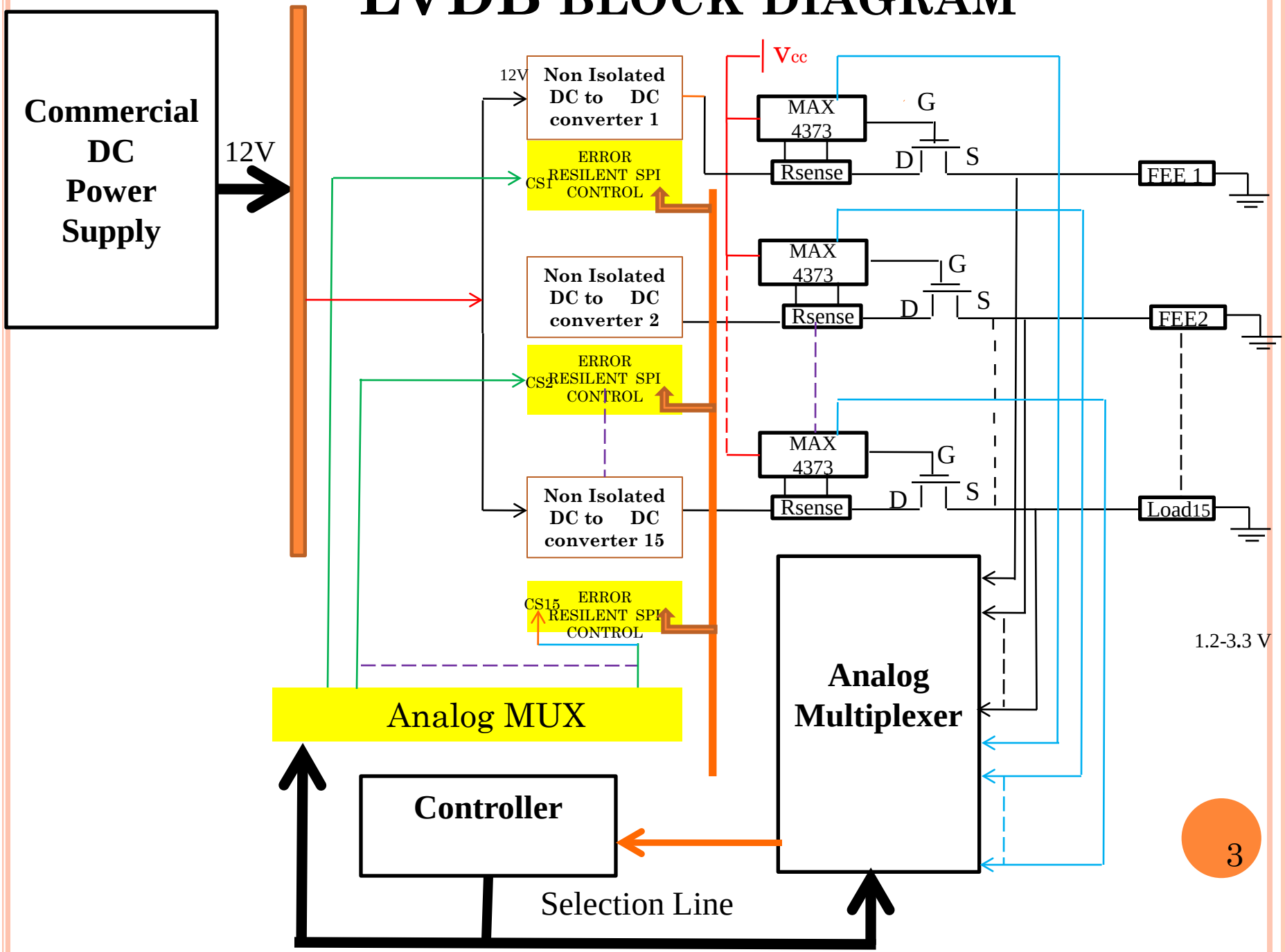
Dimensions =1.63mm x 2.9mm

Flux = 3.62 x 10^7 N_{14} /cm^2 /s



REFRESH RATE / DURATION	BEFORE VALUE	NUMBER OF UPSETS	AFTER VALUE
2MINS (2)Hrs	00000111	Nil	00000111
10 MINS(2Hrs)	00000111	Nil	00000111
25MINS (2Hrs)	00000111	Nil	00000111
60 MINS(2Hrs)	00000111	14	00001010
120 MINS(2Hrs)	00000111	31	10010110
240 MINS(6Hrs)	00000111	33	11011011

LVDB BLOCK DIAGRAM

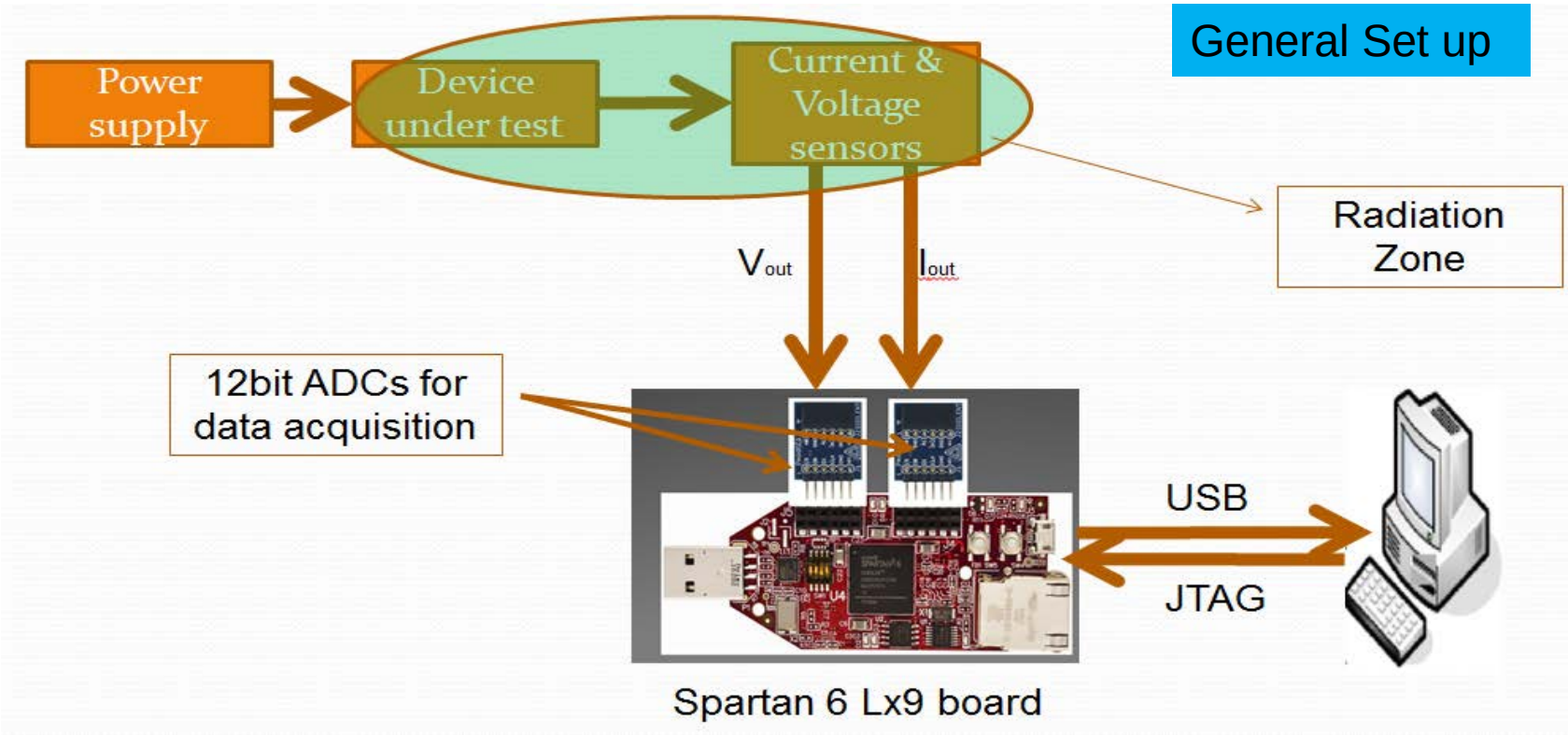


Gamma Irradiation Test

- Converter, Multiplexer, Switches , NOT gate were tested
- Gamma Irradiation with cobalt 60 source(1.17Mev)
- Dose rate 240Krad/hr
- Resolution of ADC 0.8mV
- Sampling rate 5Msps
- Fan cooling
- On line data acquisition, data logging .
- Offline data segregation , data merging.
- Analysis of segregated data on mat-lab.

Irradiation test set ups

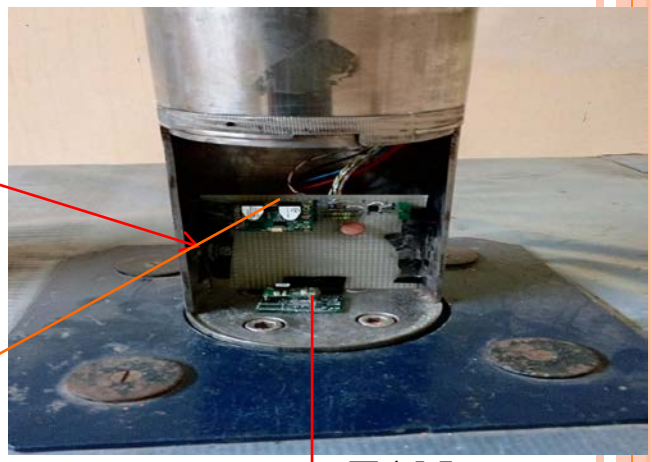
- Device under test exposed to radiation environment
- ADCs digitized and fetch different voltage and current of device under test to Spartan 6 Lx9 FPGA boards
- Online real time parameter monitoring(Chip-scope pro)and data logging of device under test .
- Analysis of stored data for understanding the effect of accumulated dose



Experimental Set Up

continue

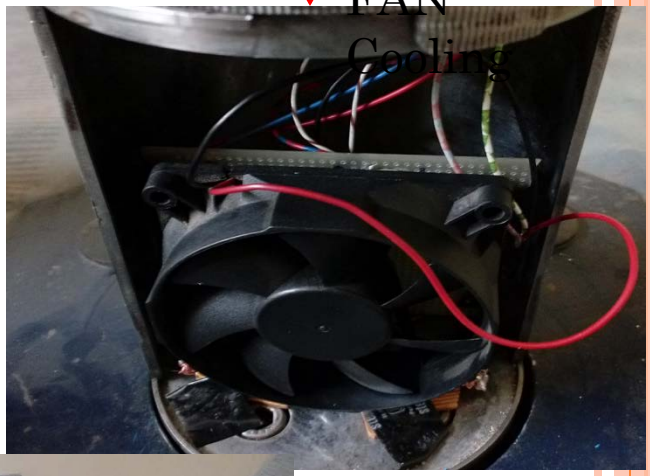
Gamma Chamber

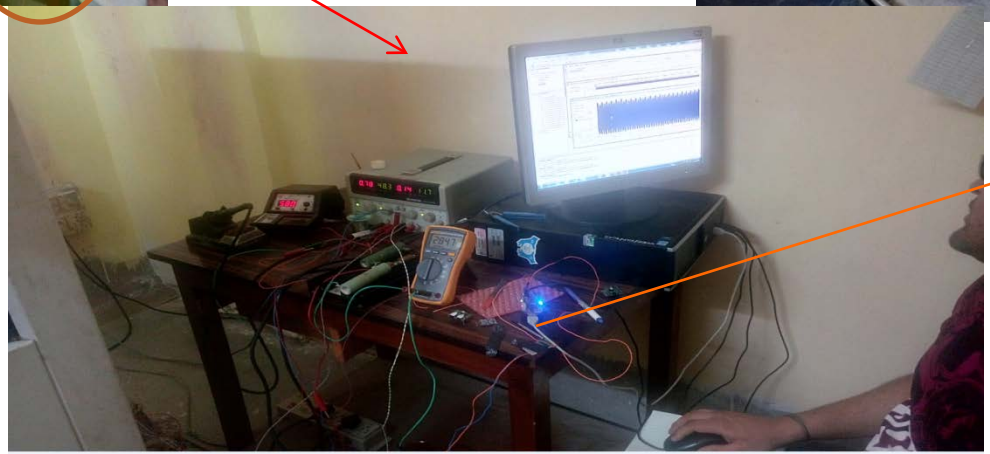


Converter

FAN Cooling

Online data monitoring and logging

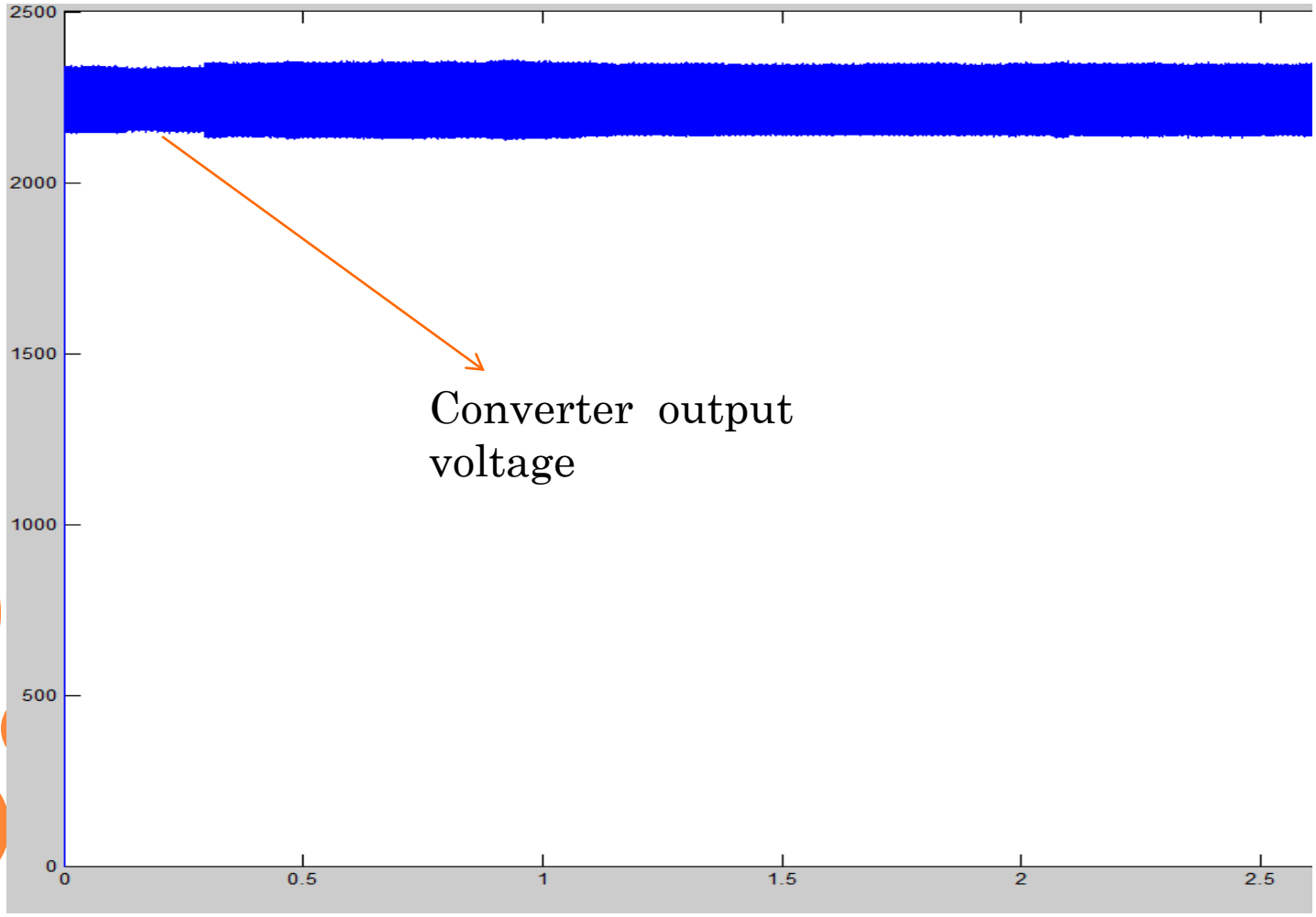




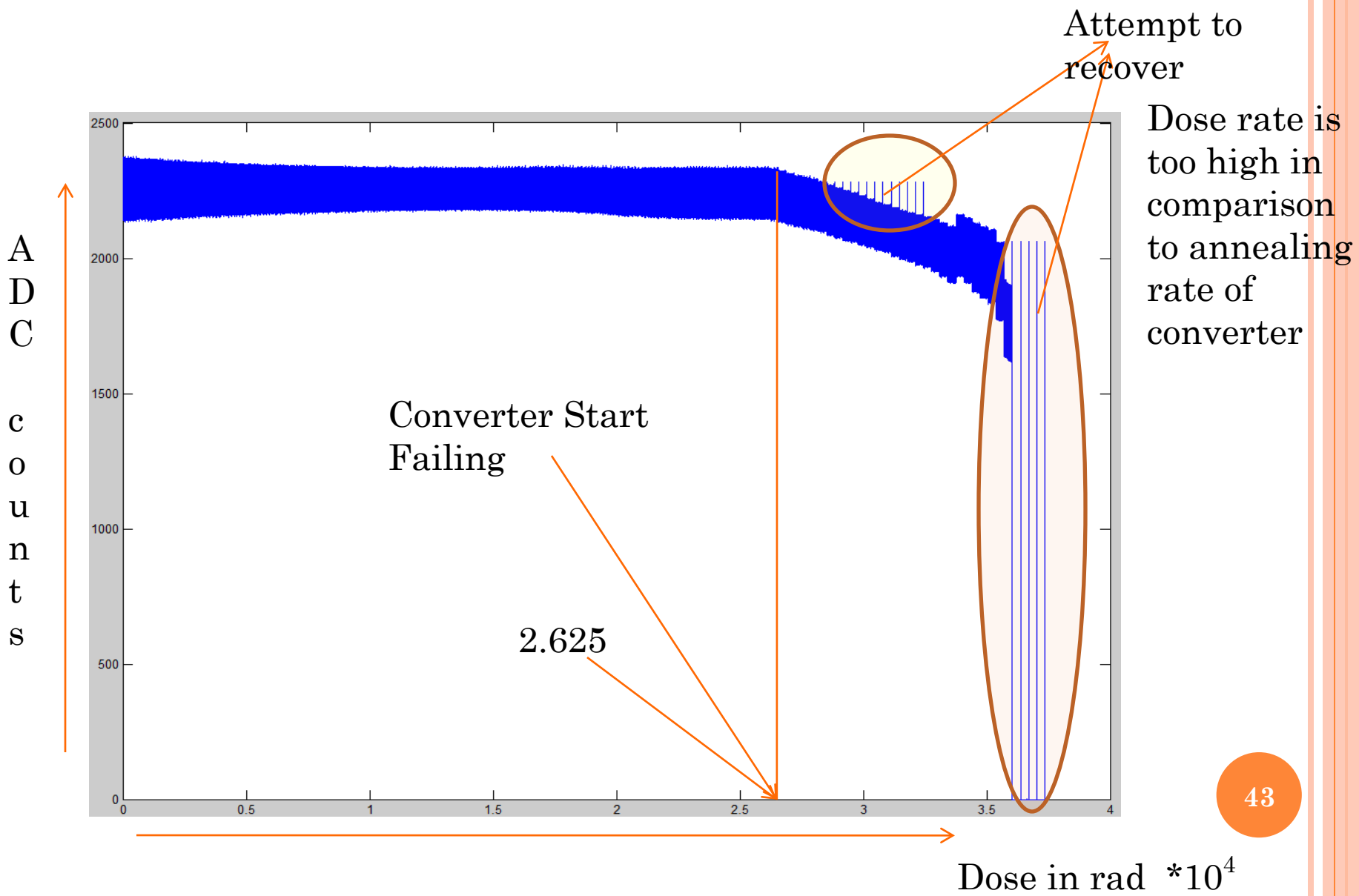
FPGA

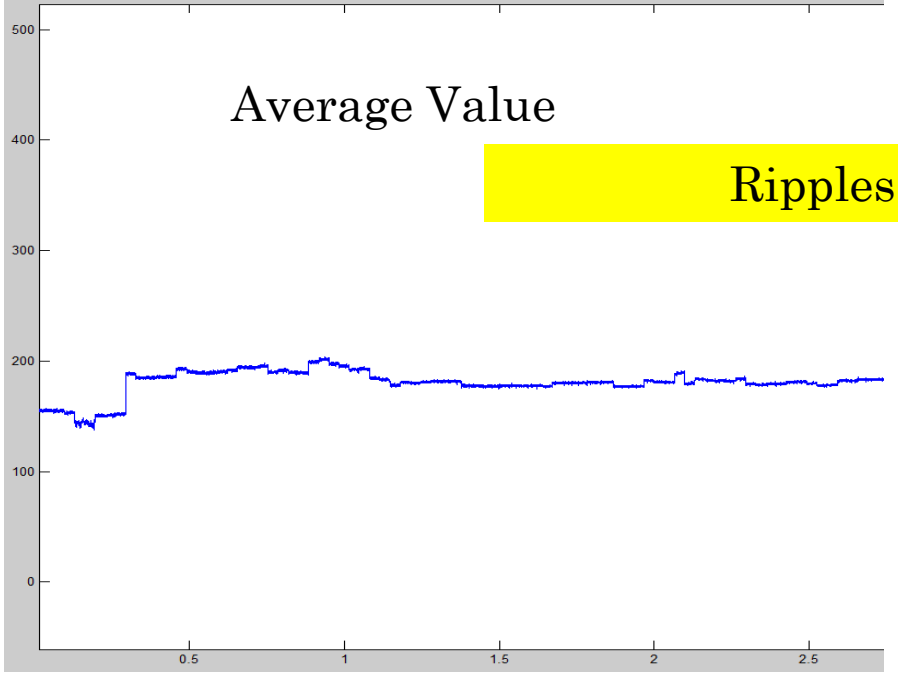
TEST RESULTS WITHOUT RADIATION

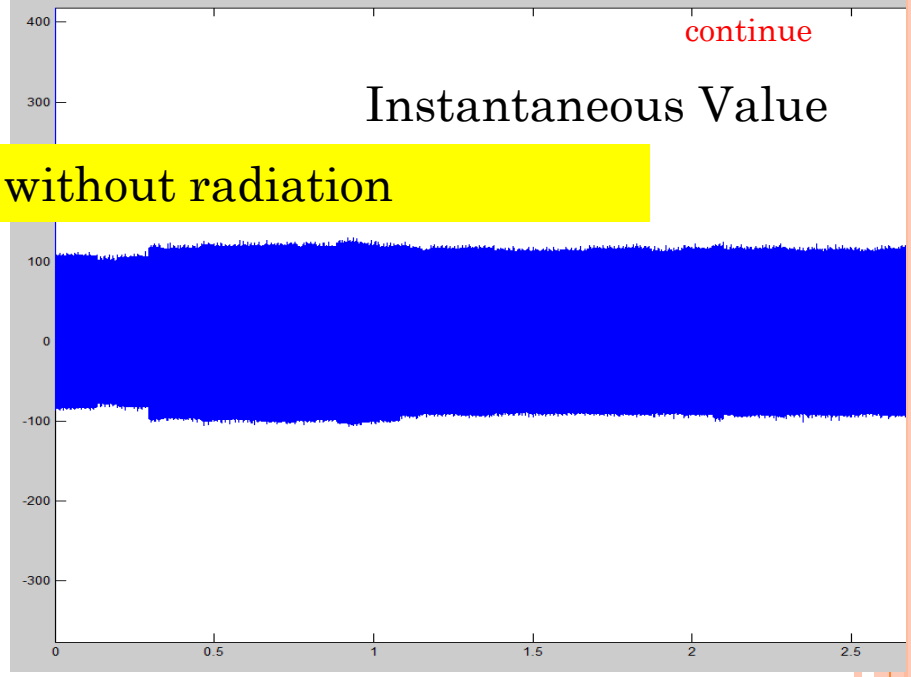
continue



DC RESPONSE OF CONVERTER1



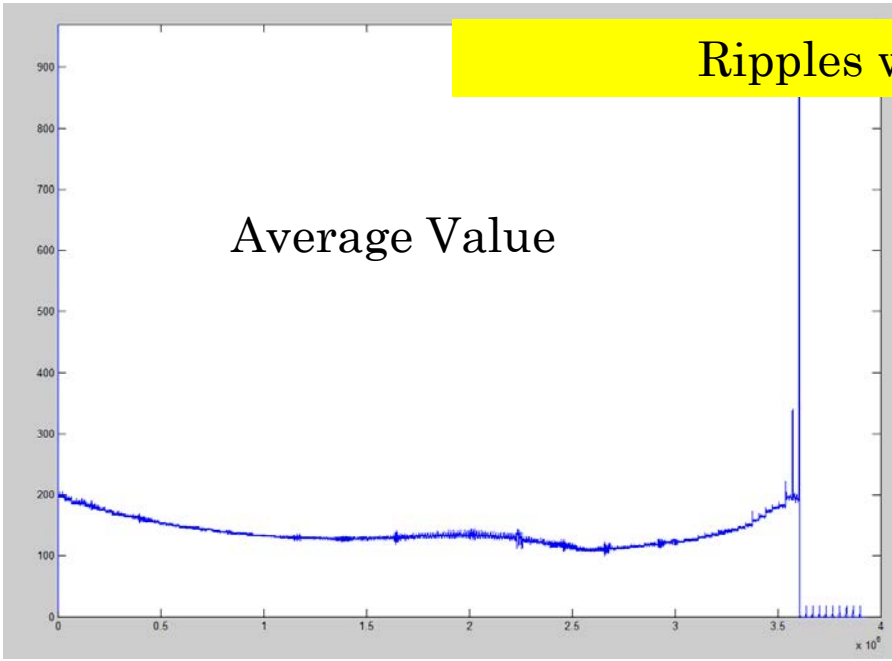


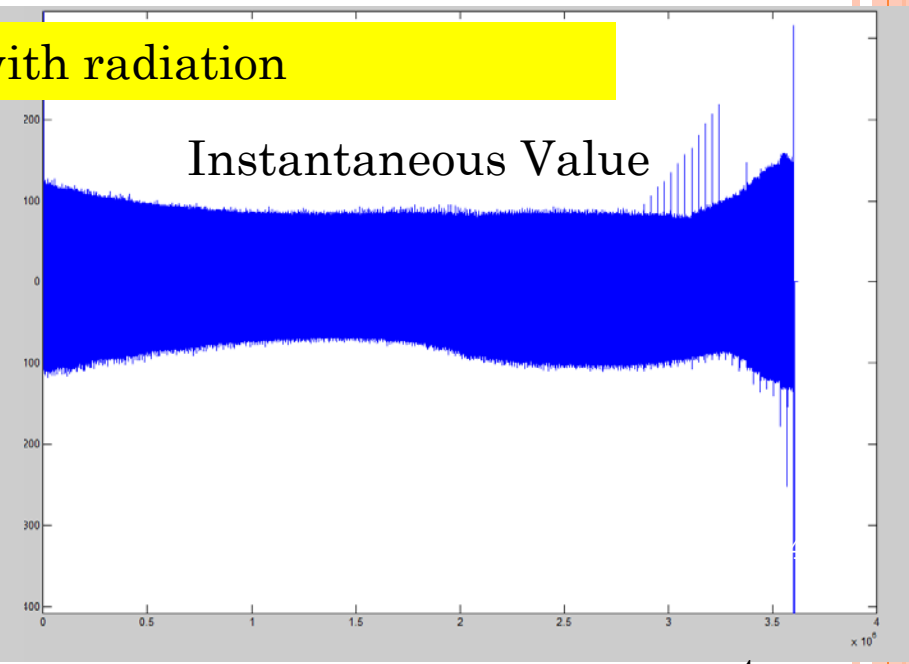


Ripples without radiation

ADC counts

Time in minutes

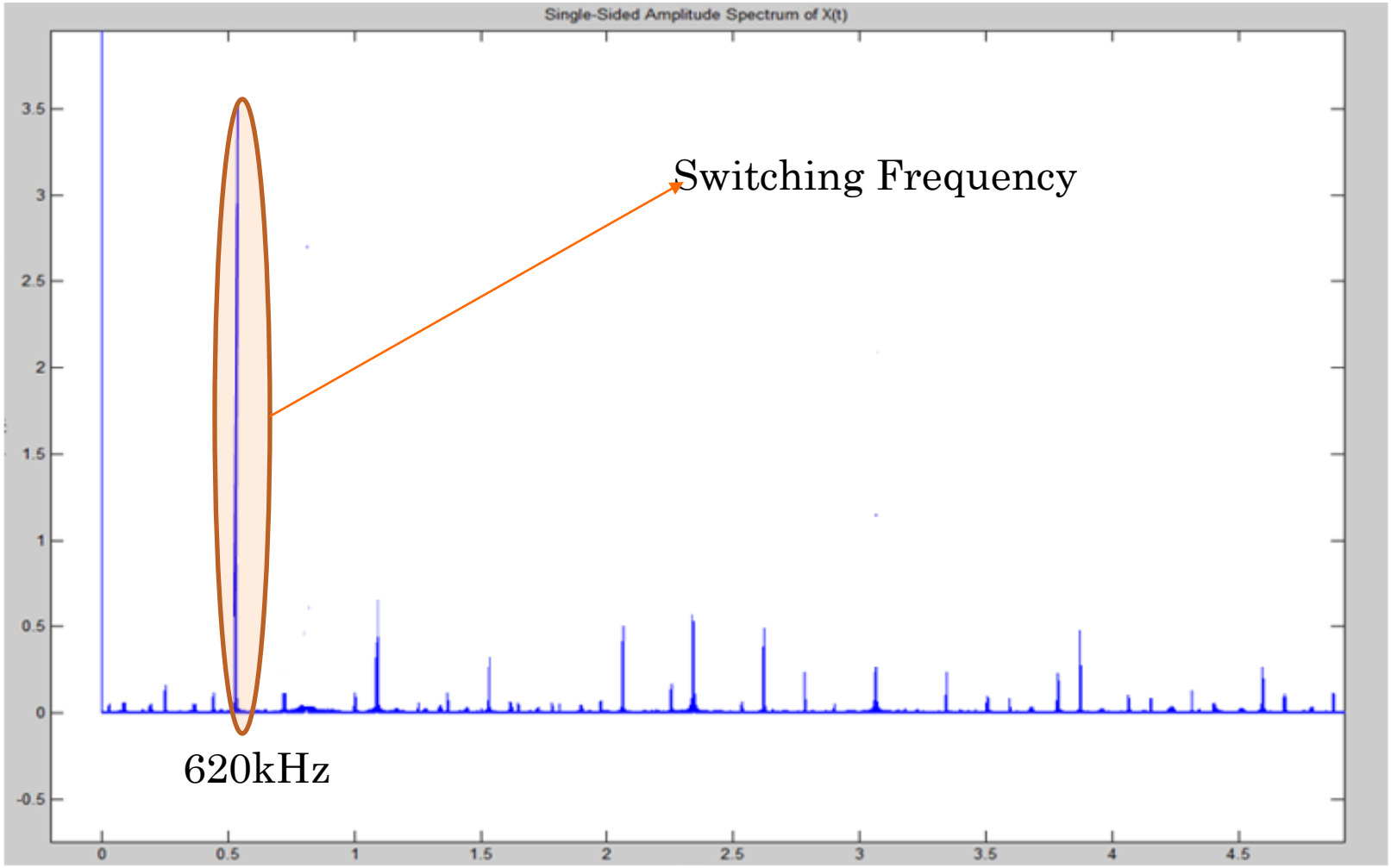




Ripples with radiation

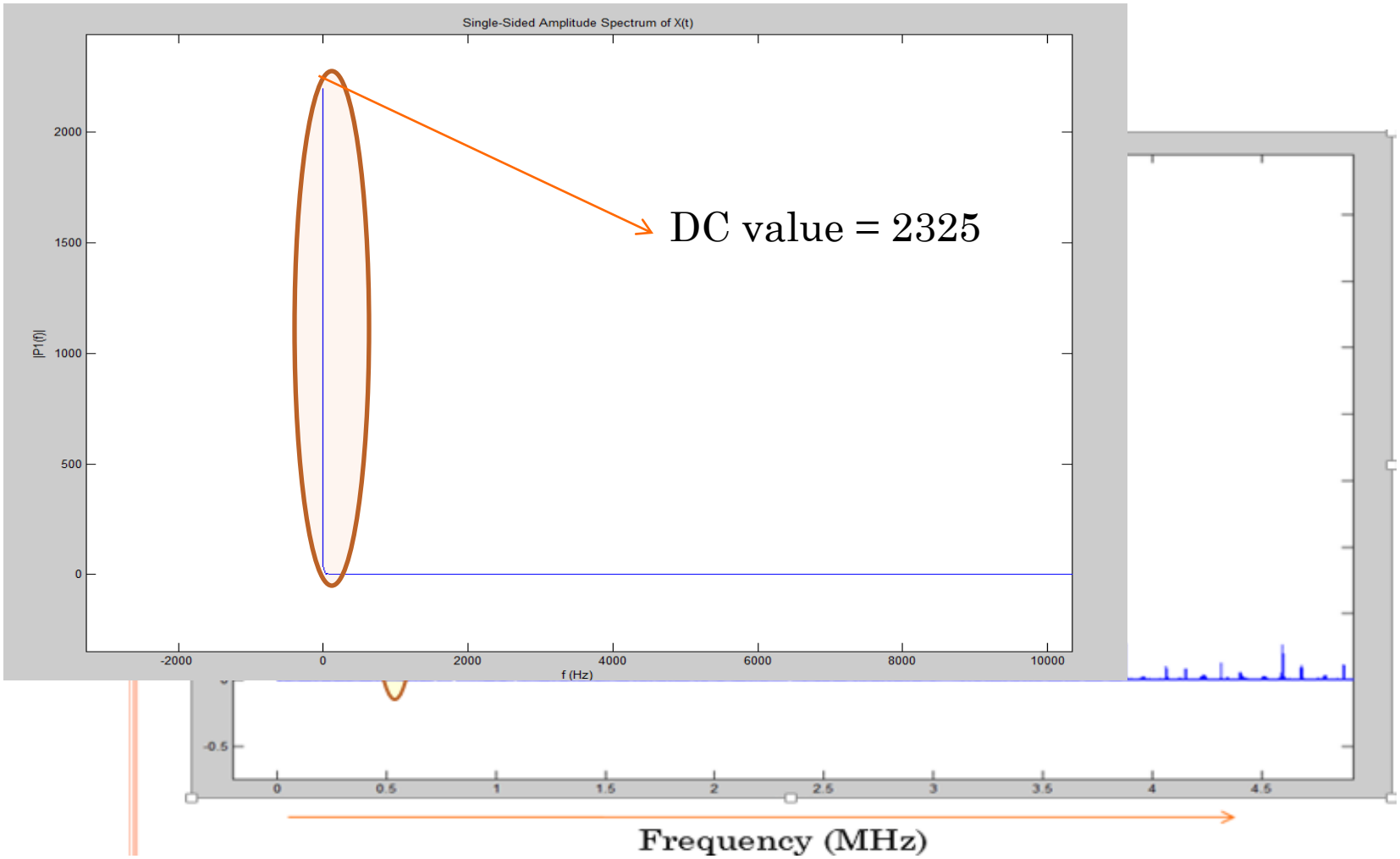
Dose in rad *10^4

FFT WITHOUT RADIATION

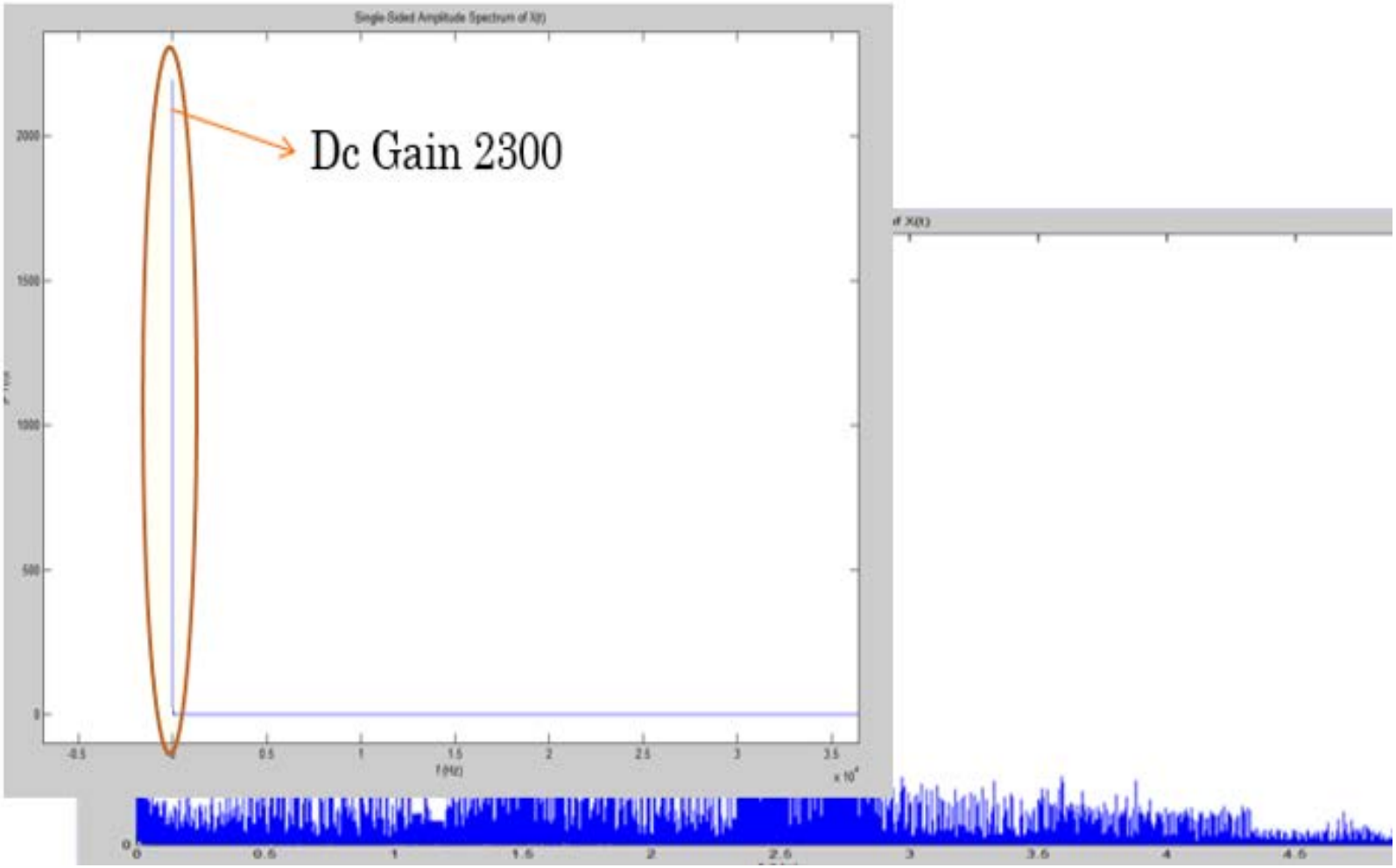


continue

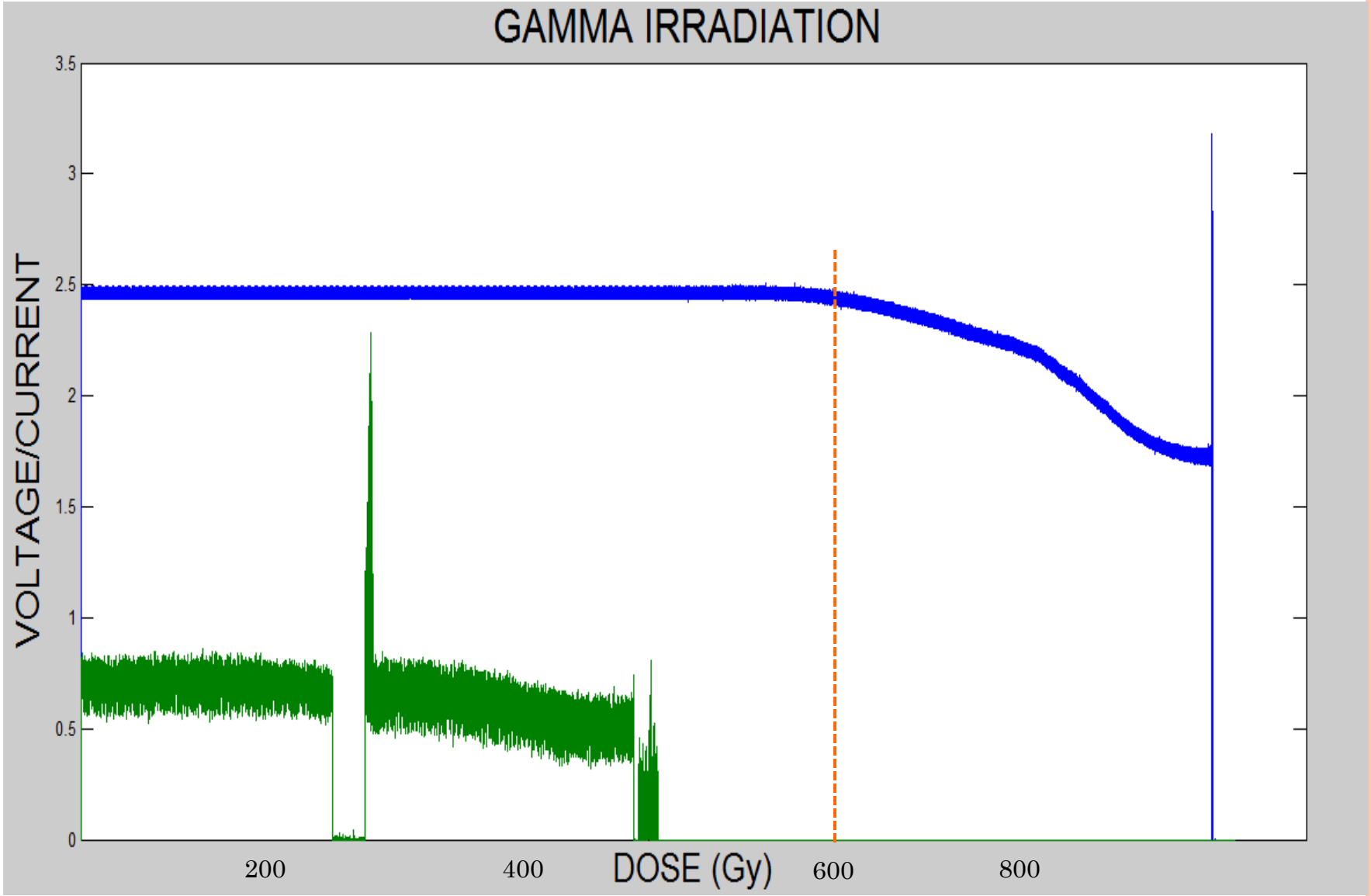
FFT WITHOUT RADIATION



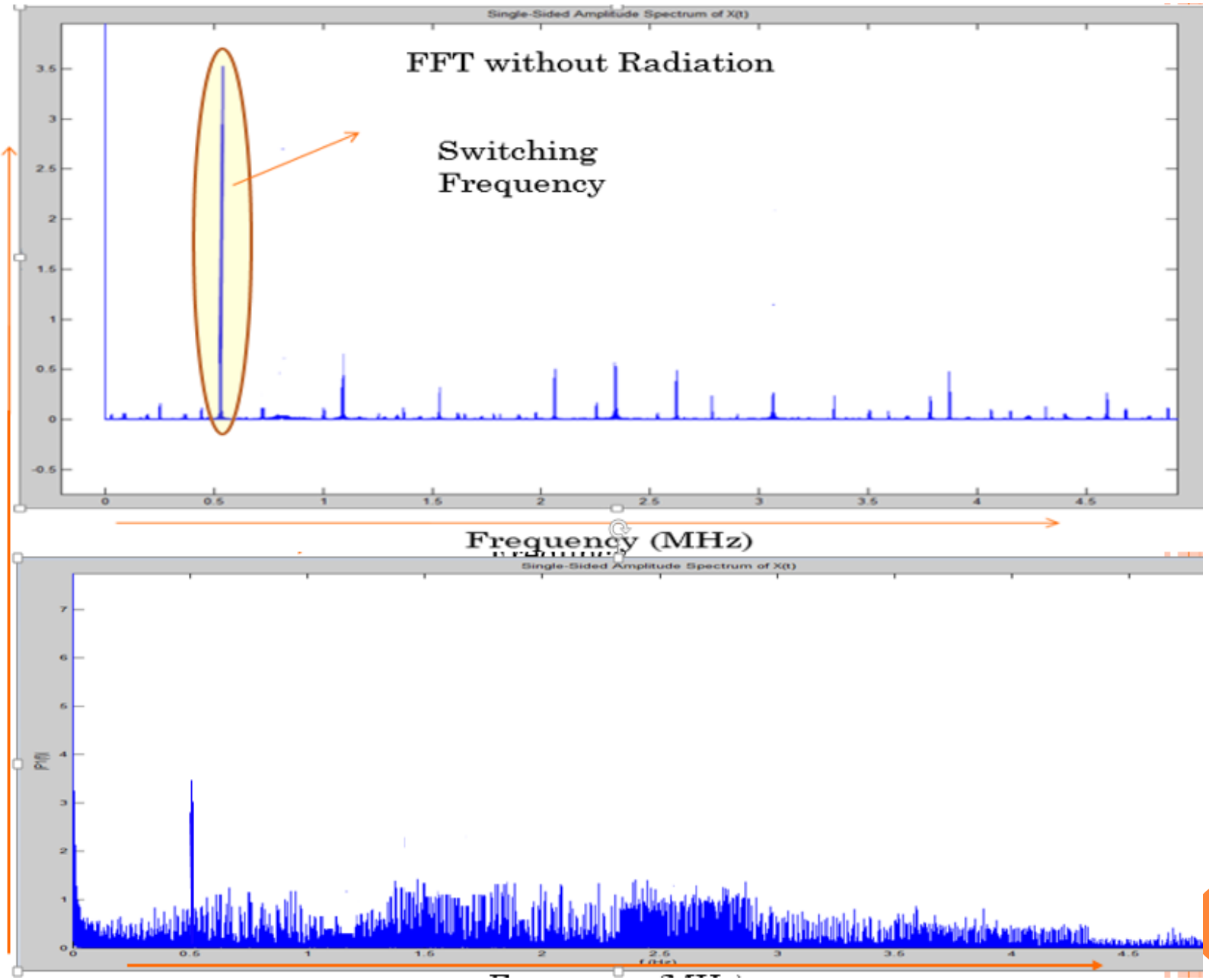
FFT WITH RADIATION



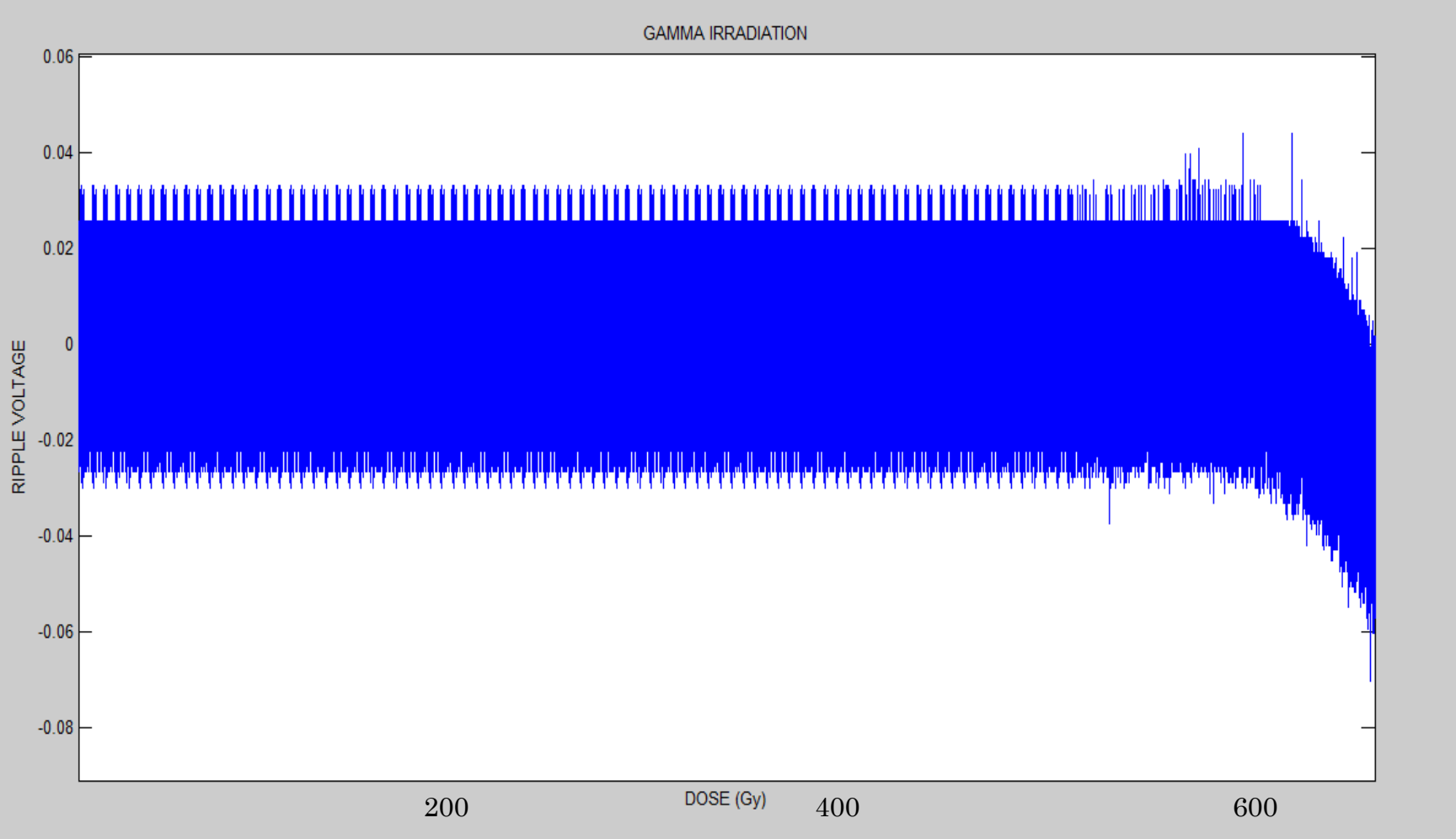
DC response of Converter2

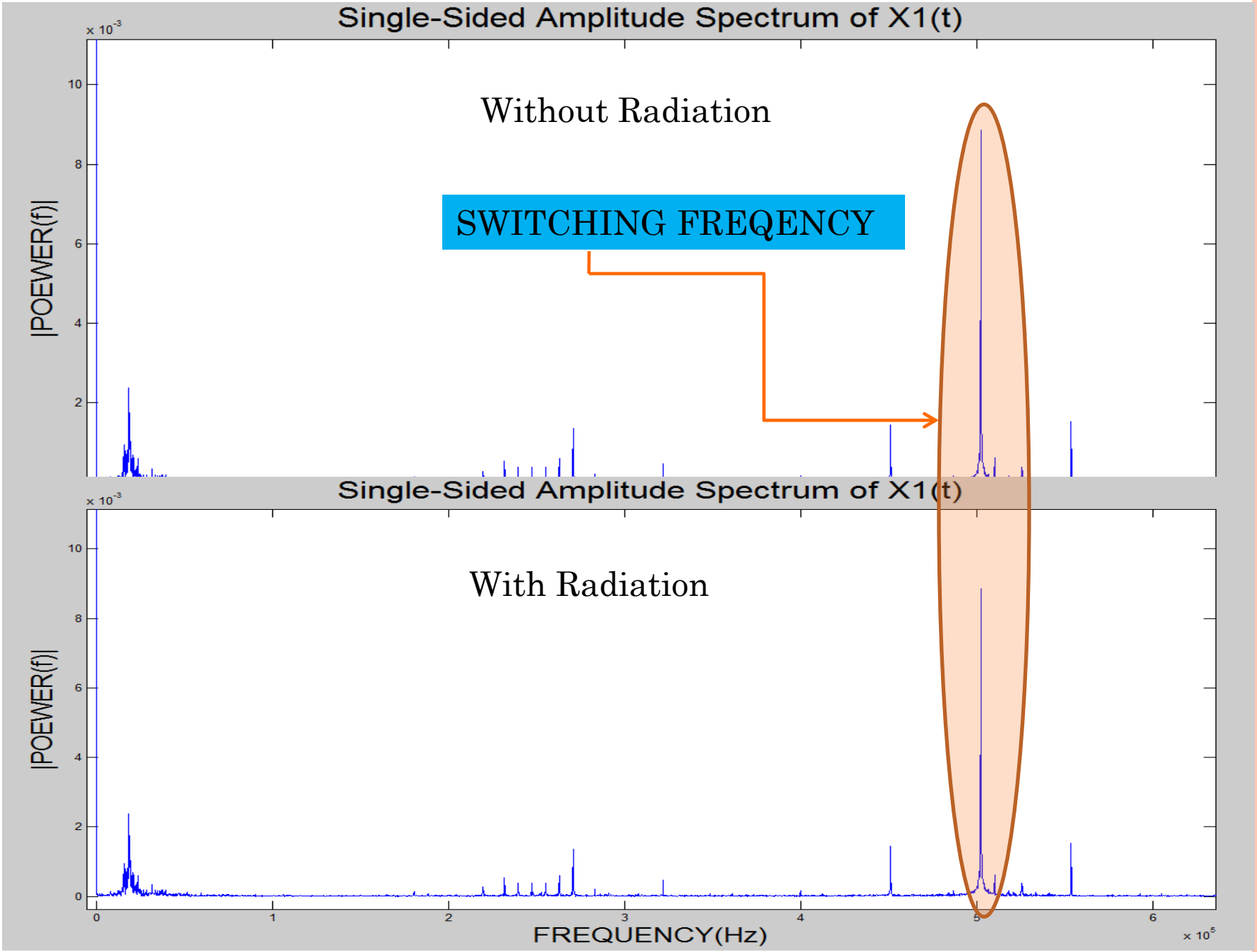


continue


Single-Sided Amplitude Spectrum of X(t)
FFT without Radiation
Switching Frequency
Power Spectral Density
Frequency (MHz)
Single-Sided Amplitude Spectrum of X(t)
Frequency (MHz)

Ripples with radiation

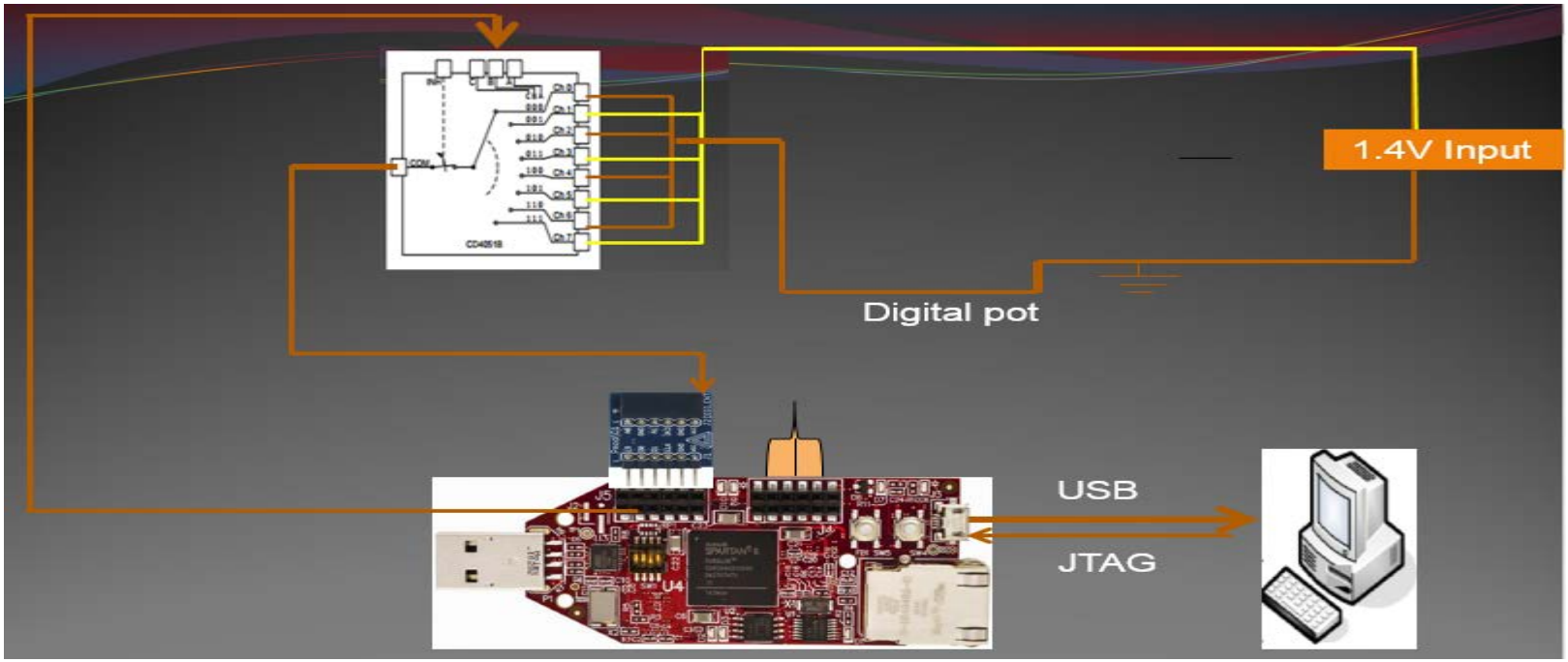



Single-Sided Amplitude Spectrum of X1(t)
x 10^-3
|POEWER(f)|
Without Radiation
SWITCHING FREQENCY
Single-Sided Amplitude Spectrum of X1(t)
x 10^-3
|POEWER(f)|
With Radiation
FREQUENCY(Hz)
x 10^5

Observations

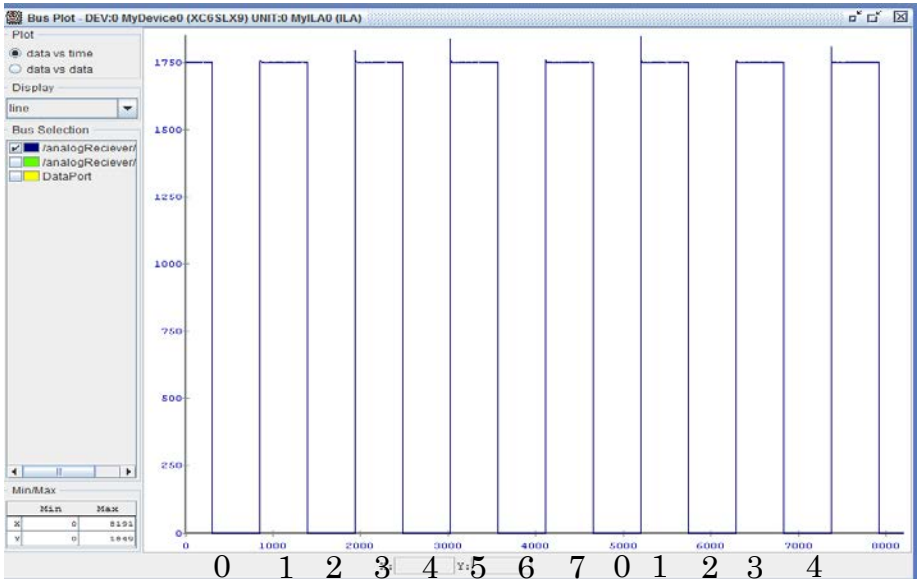
- Average peak to peak value of ripple is more or less same before and after irradiation.
- Converter start failing after 26.25krad.
- Upto 26.25krad Dc gain is more less same before and after irradiation so is the efficiency.
- Due to gamma radiation ion hole pair are generated in subtract which alter the number of charge particle in current thus shot noise is introduced.
- FFT spectrum(without radiation) shows peaks other with switching frequency and folded version of high frequency noise.

Irradiation set up for multiplexers



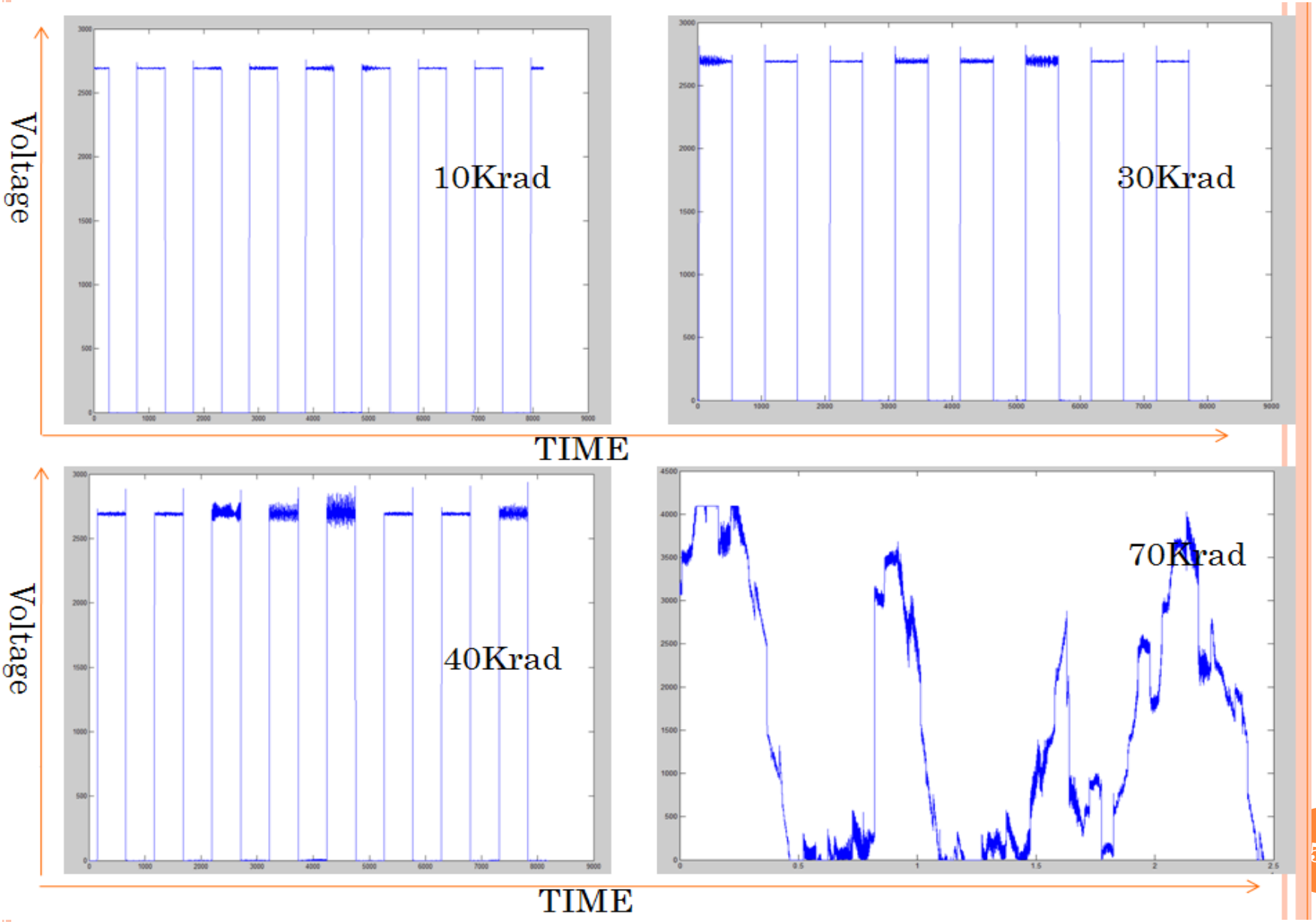
Ch#0 ---Gnd
Ch#1 --- 1.4V
Ch#2 ---Gnd
Ch#3 --- 1.4V
Ch#4 ---Gnd
Ch#5 ---1.4V
Ch#6 ---Gnd
Ch#7 ---1.4V

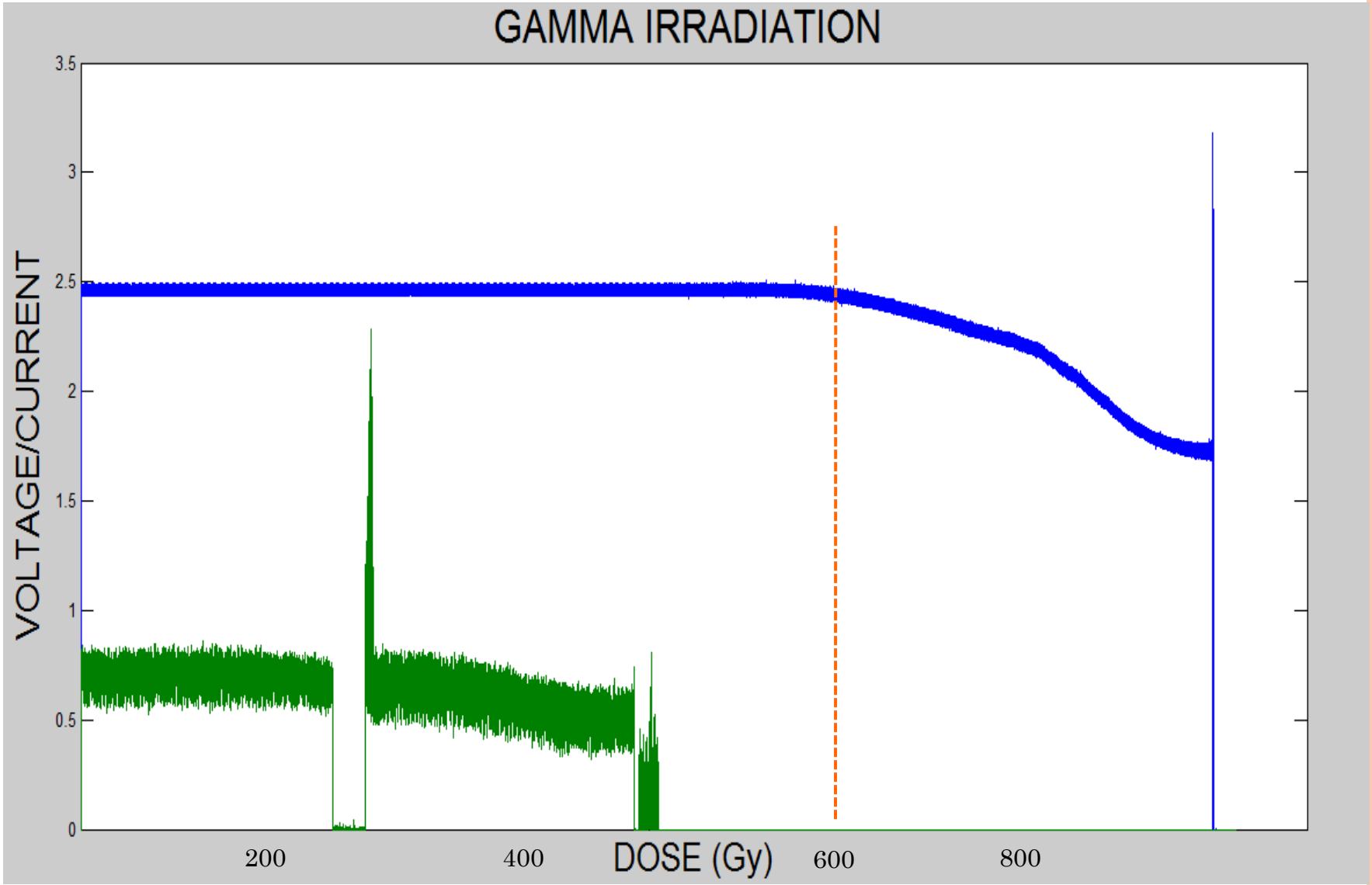
Expected Output of Multiplexer



MUX RESPONSE

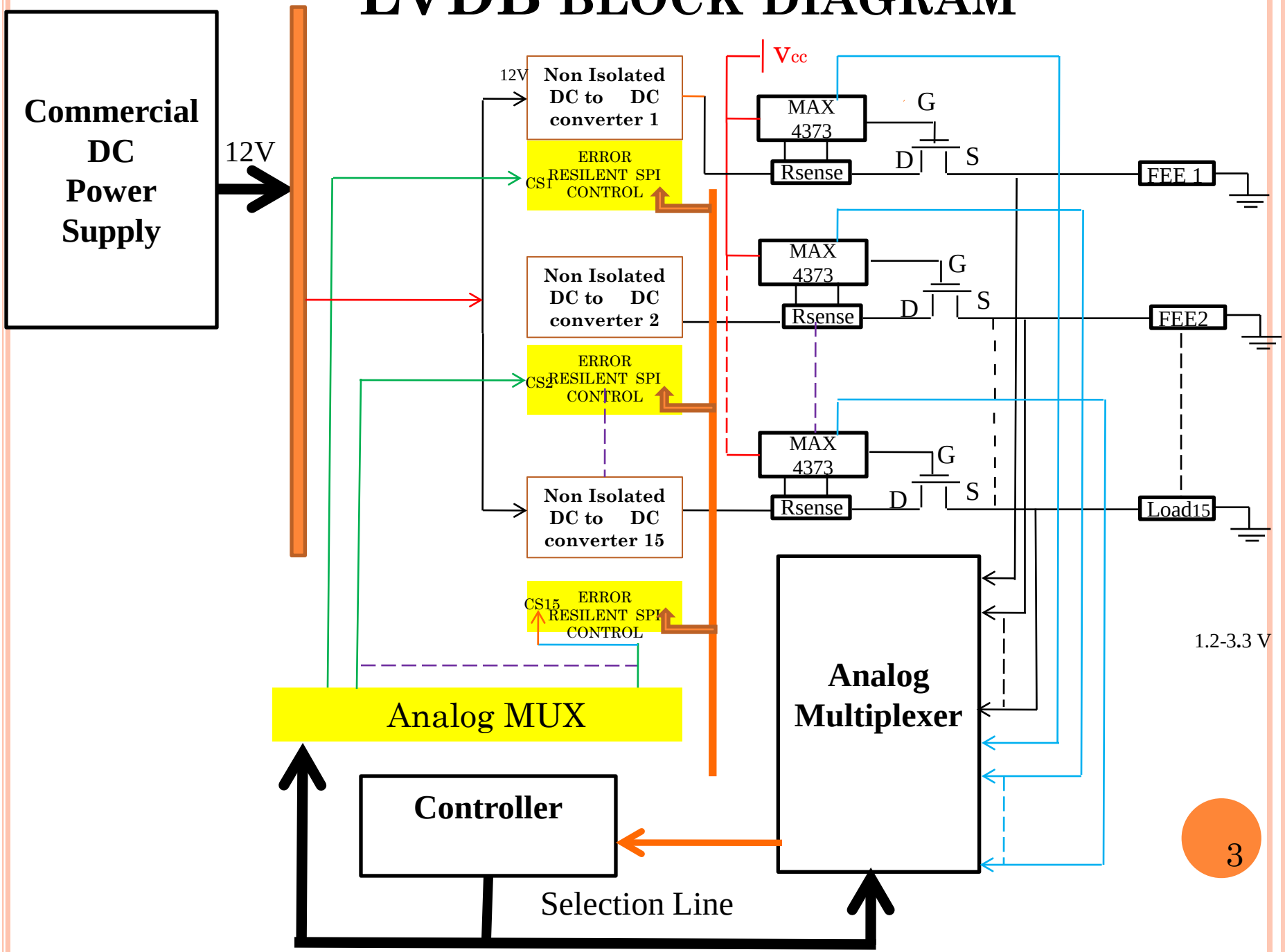
continue




GAMMA IRRADIATION
VOLTAGE/CURRENT
3.5
3
2.5
2
1.5
1
0.5
0
200
400
DOSE (Gy)
600
800

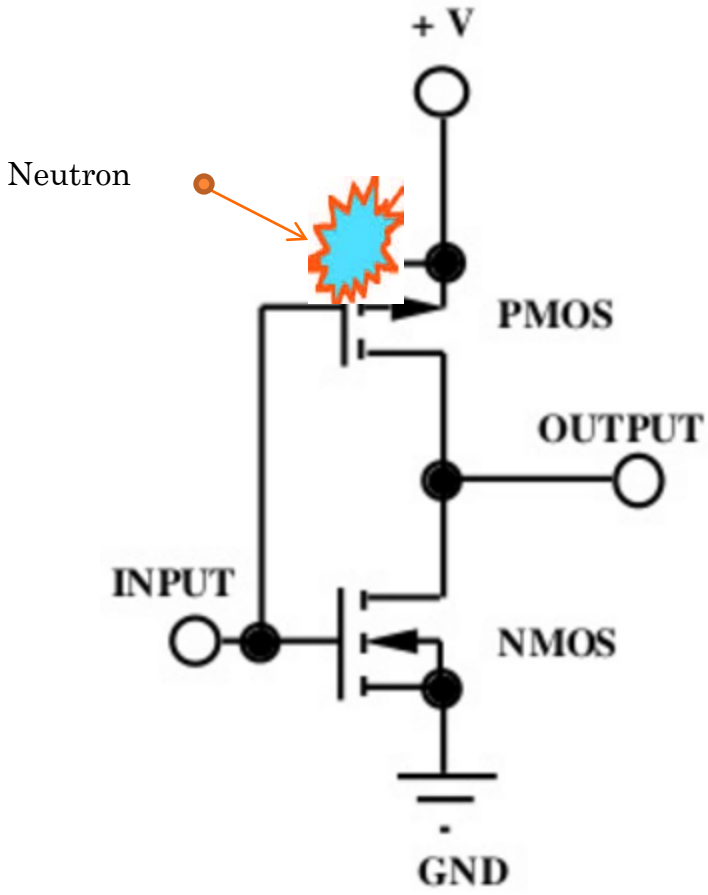
Error Resilient control system

LVDB BLOCK DIAGRAM



Single CMOS output

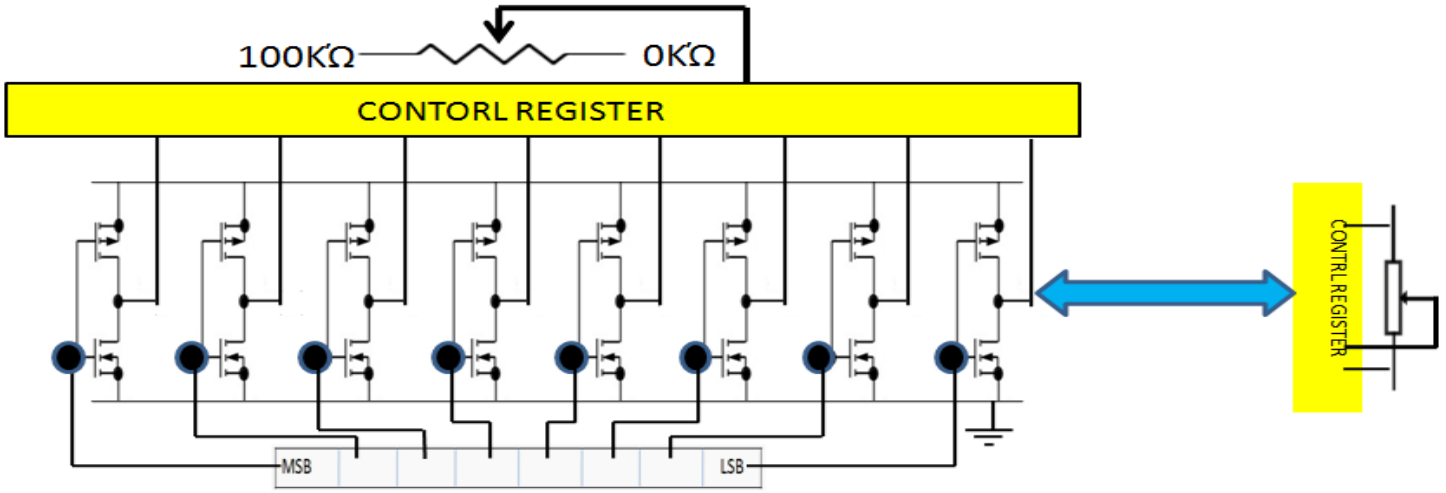
If single CMOS logic is used then control system will be very unreliable.



Head on collision with potential neutron can upset the stored output with very high probability

Reliable approach

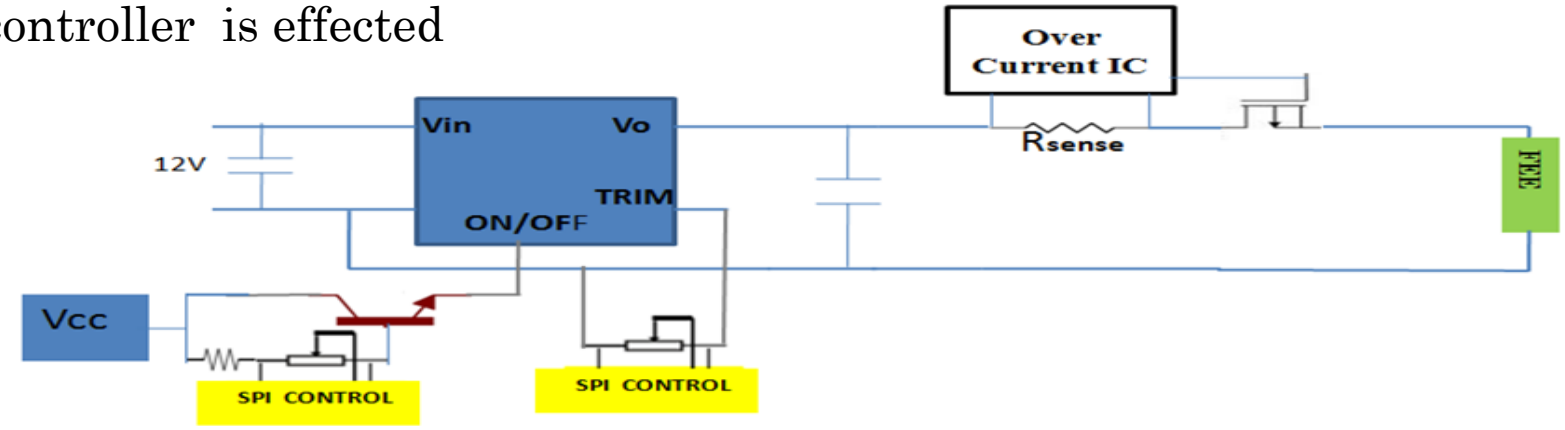
- SPI control resistor based control system with **Hard ON and Stable OFF**
- 100Kohm resistance had been divided into 256 division



BINARY COUNT	RESISTANCE
00000000	99.61
00000001	99.22
11111110	0.78Kohms
11111111	0.31Kohms

•Base current of npn transistor is controlled by SPI control resistor such that on binary count of 00000000 converter is OFF and 11111111 make it ON

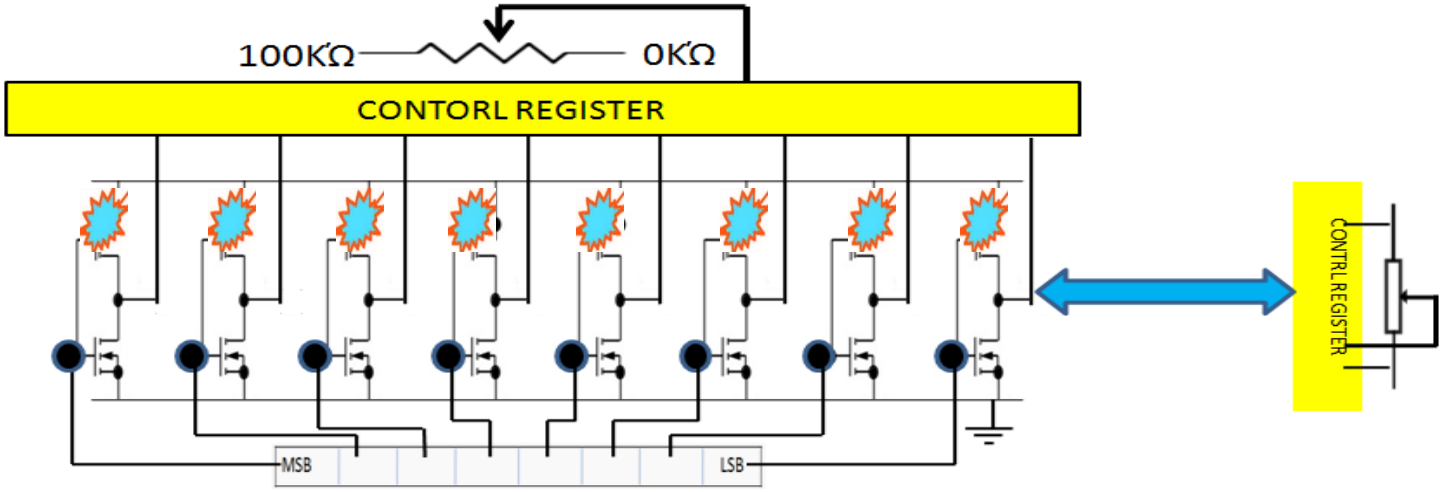
•Incoming neutron should change status of all eight bit then only output of controller is effected



	BINARY COUNT	RESISTANCE	
ON →	00000000	99.61	Deeply buried I_B
	00000001	99.22	**Inside Cut off region**
	11111110	0.78Kohms	
OFF →	11111111	0.31Kohms	Just above the I_B **threshold**

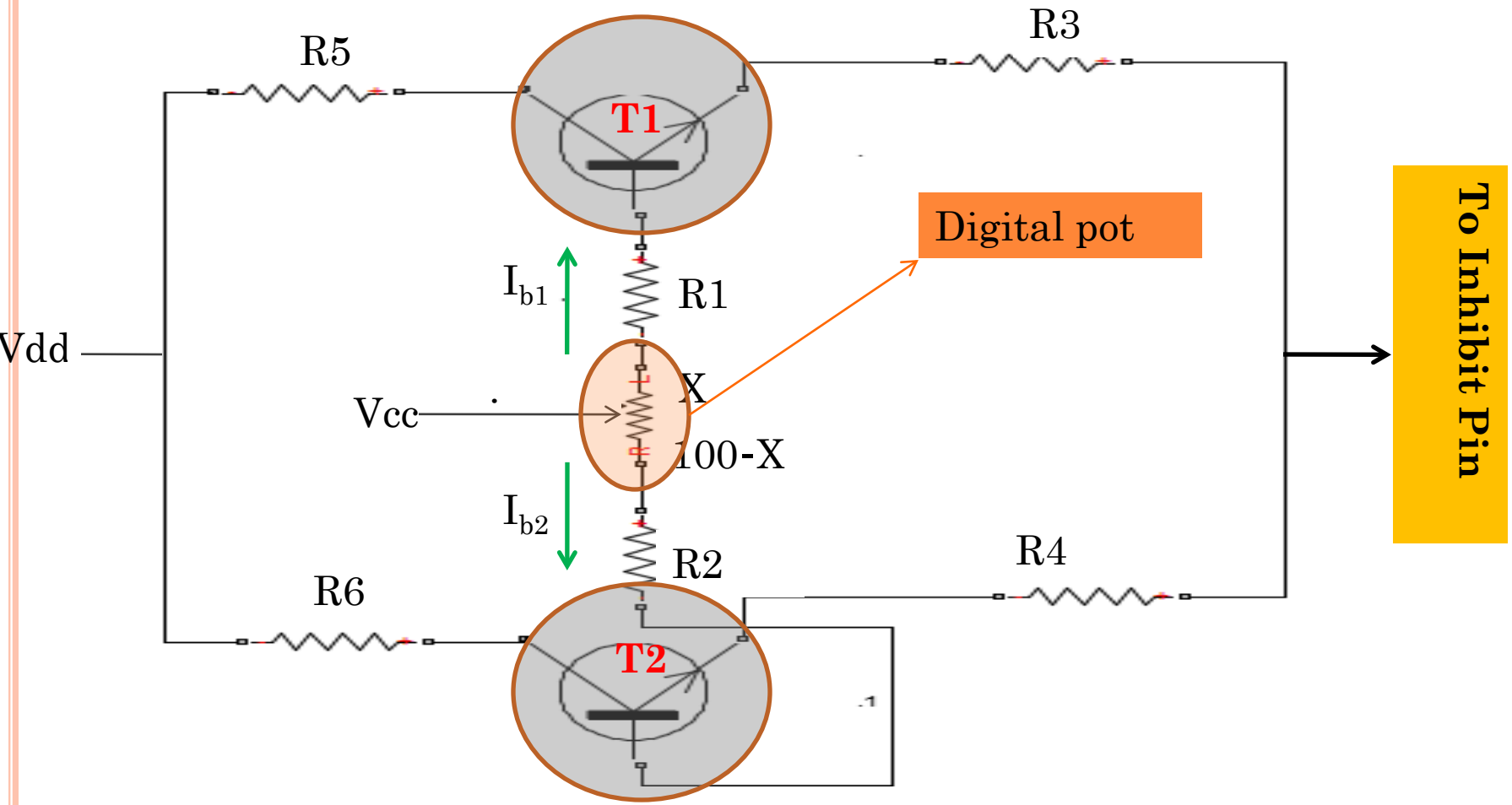
Reliable approach

- Neutron Flux upsetting all six or seven bit simultaneously
- Chances are one in million



BINARY COUNT	RESISTANCE
00000000	99.61
00000001	99.22
11111110	0.78Kohms
11111111	0.31Kohms

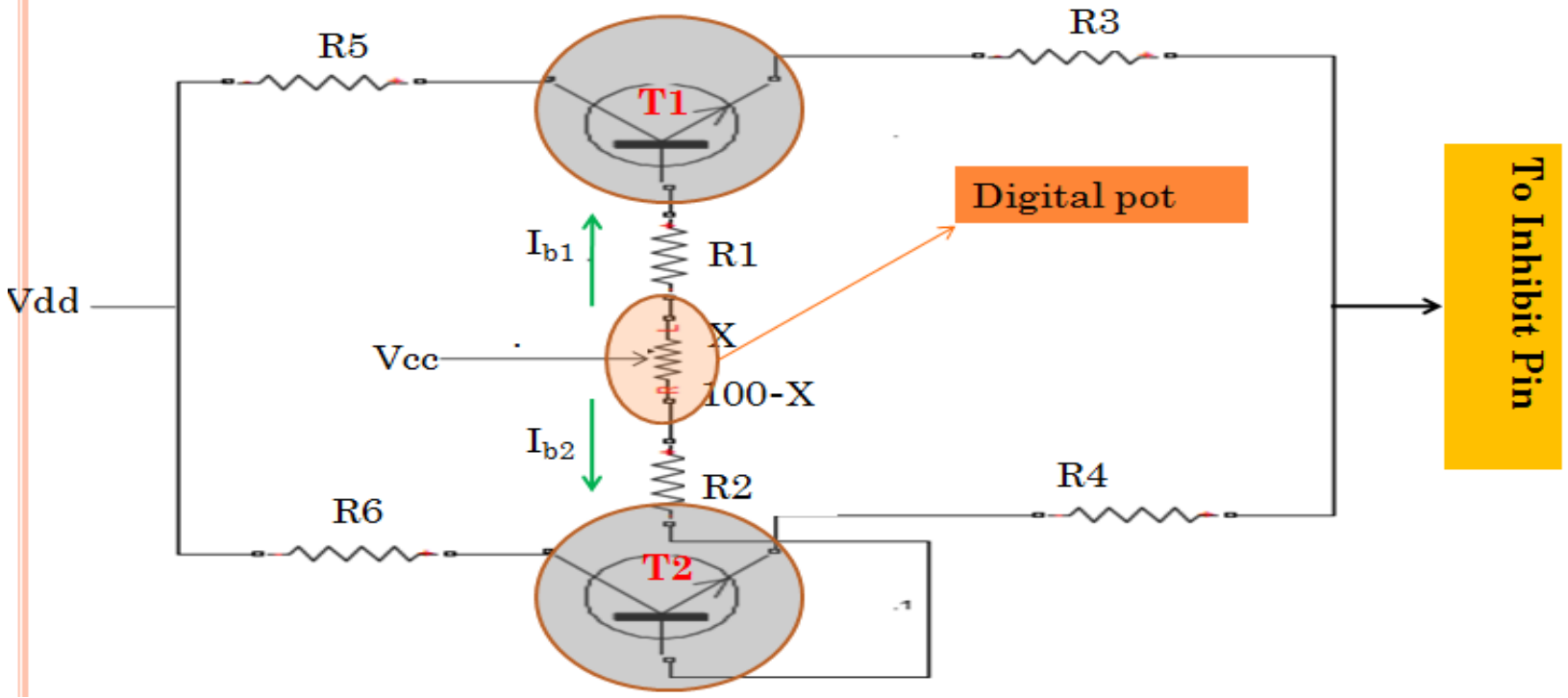
FAULT TOLERANT CONTROL WITH SPI POT



LOGIC(HARD ON STABLE OFF)

T1 , T2 Both in deep cut off----------ON

Either one of them ON----------OFF



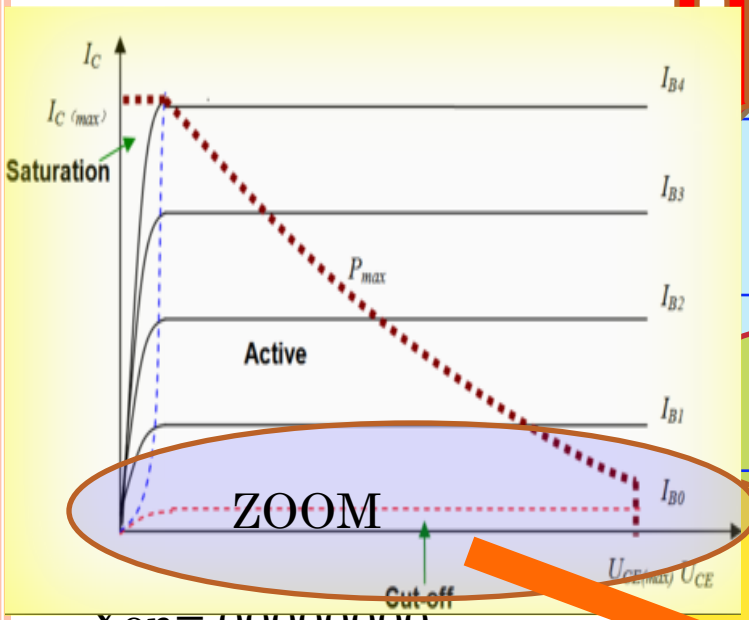
R1 + Xon
R2 + 100- Xon

DEEP INTO CUT OFF REGION

R1 + Xoff
R2 + 100- Xoff

JUST ABOVE CUT OFF REGION
AND
R1 + Xoff =R2 + 100- Xoff

$$Xoff = \frac{R2-R1+100}{2}$$



Xon= 00000000
Xoff= 11111000

- **Floating enable= ON**
- **Disable voltage >0.8-3.3**
- **Enable voltage < 0.8**

Hard ON
And
Stable off

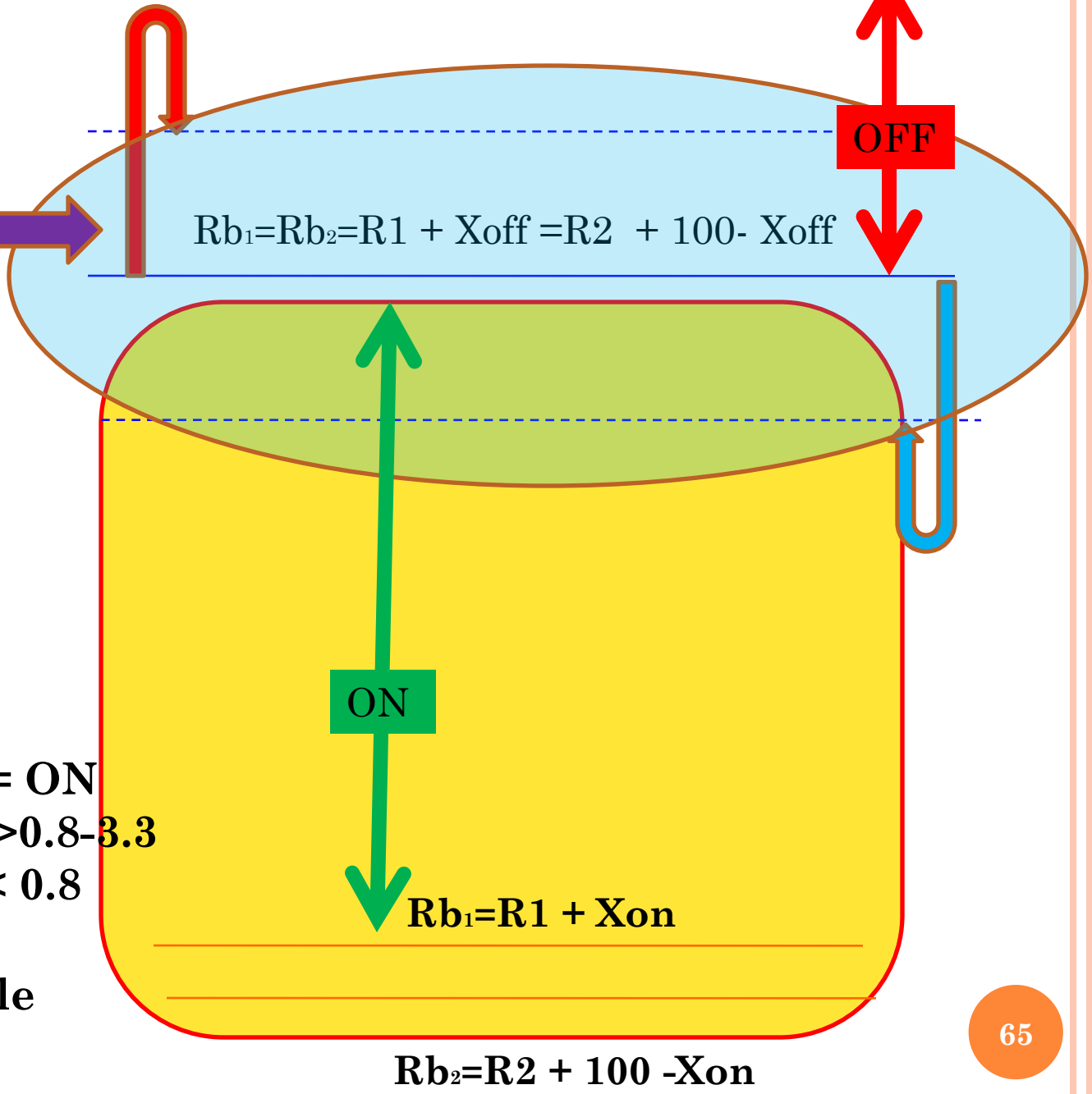
OFF

$Rb_1=Rb_2=R1 + Xoff = R2 + 100- Xoff$

ON

$Rb_1=R1 + Xon$

$Rb_2=R2 + 100 -Xon$



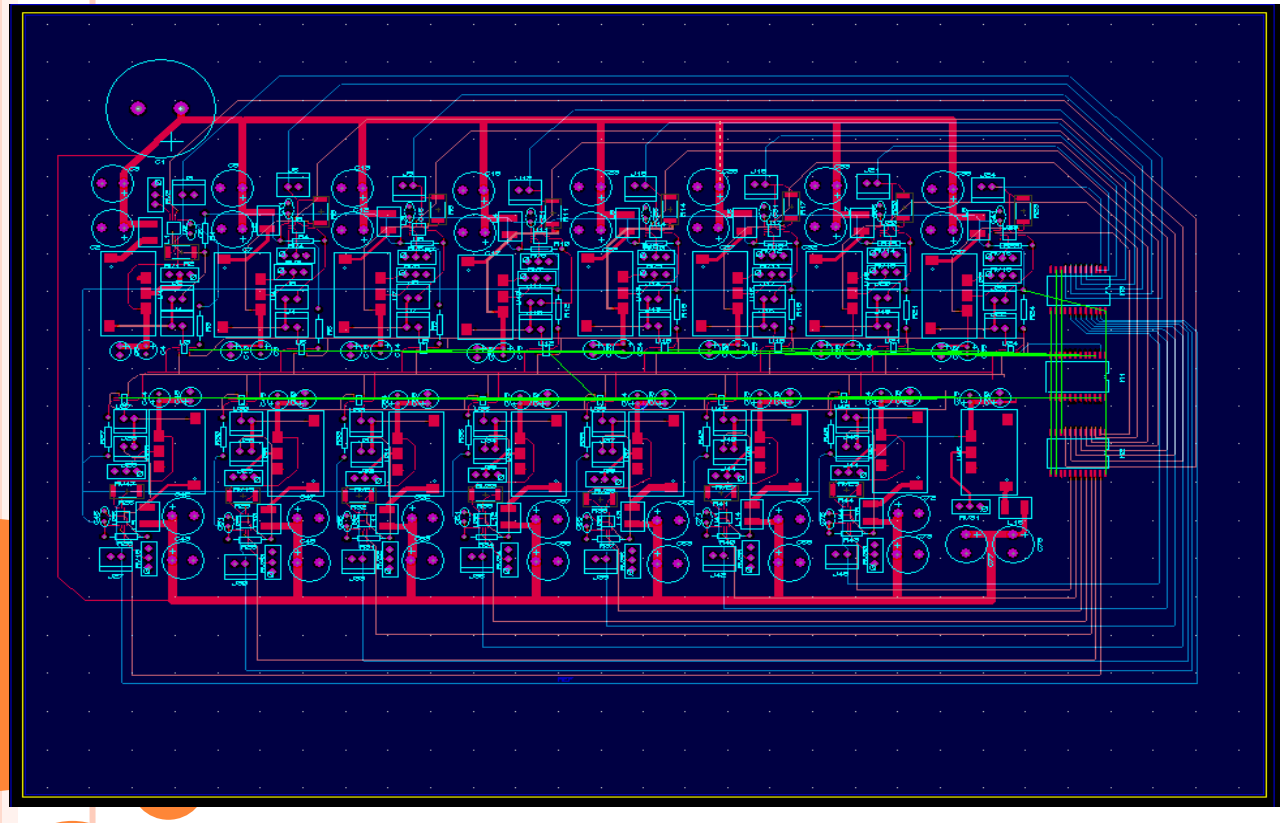
UPSET CAUSE BY RADIATION

Xon= 00000000
Xoff= 11111000

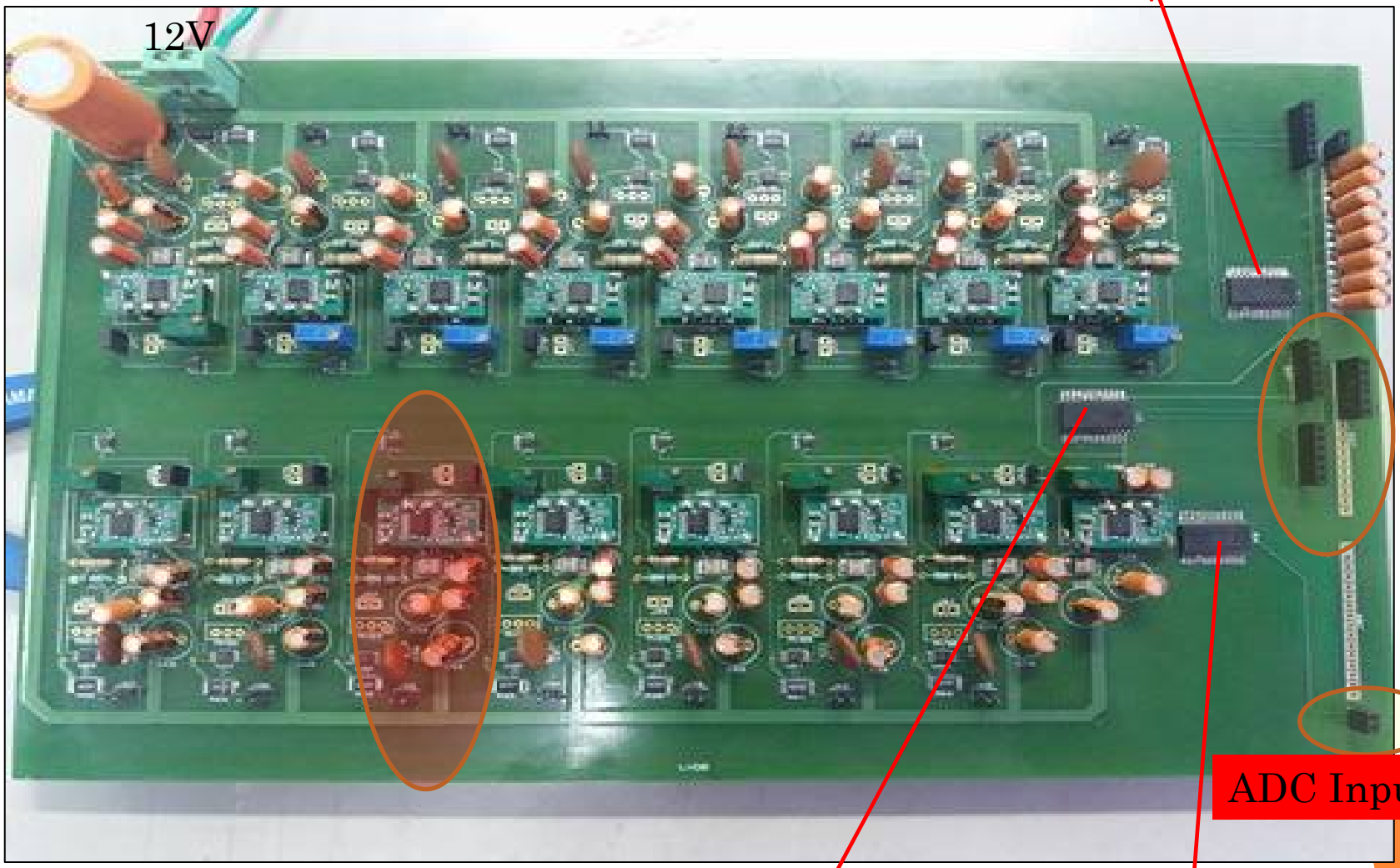
- **Floating enable= ON**
- **Disable voltage >0.8-3.3**
- **Enable voltage < 0.8**

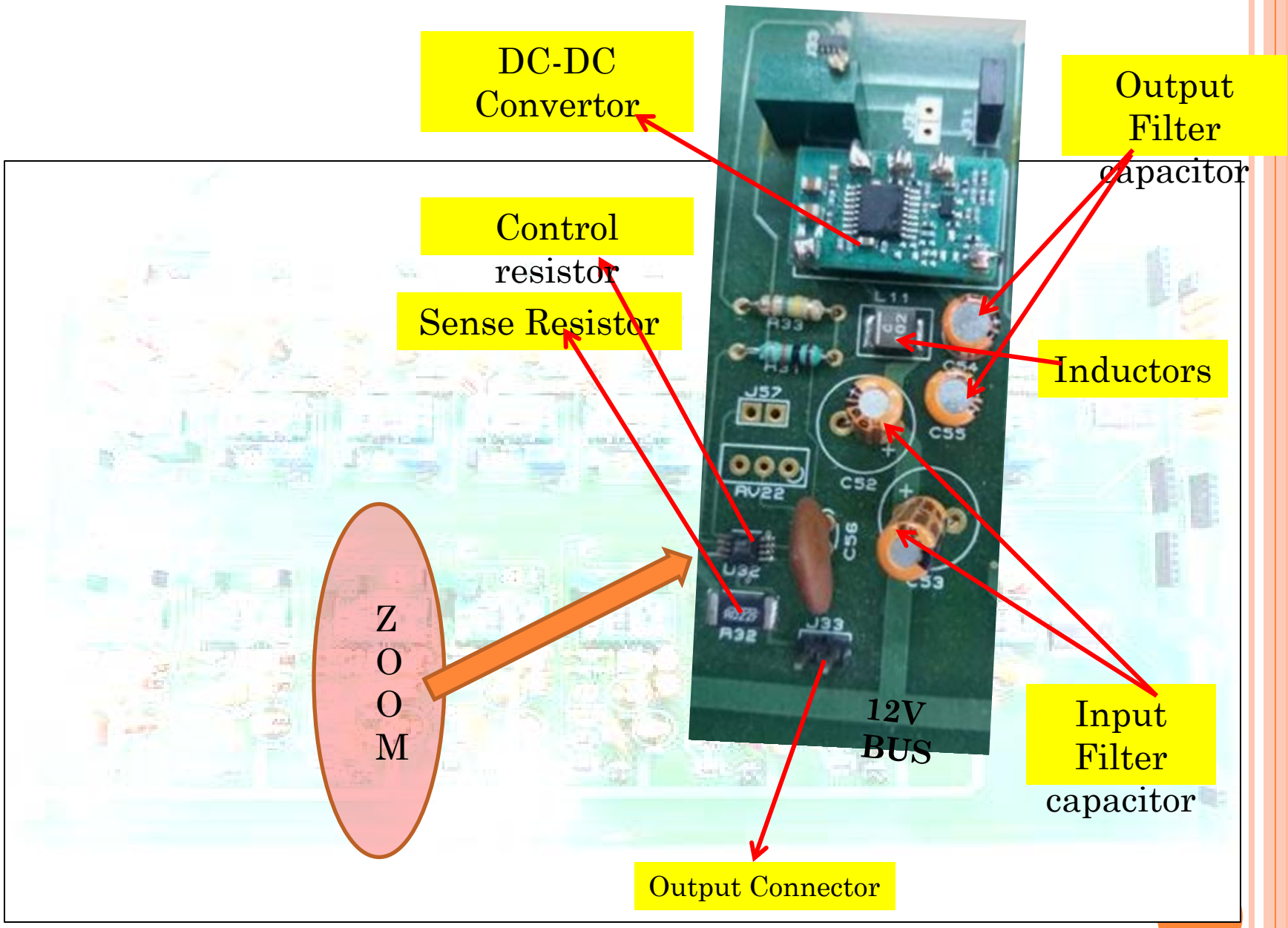
Hard ON and Stable OFF

First prototype of LVDB Board



- 4 layer PCB
- Voltage and Current monitoring points
- On- Off control
- Radiation hard components

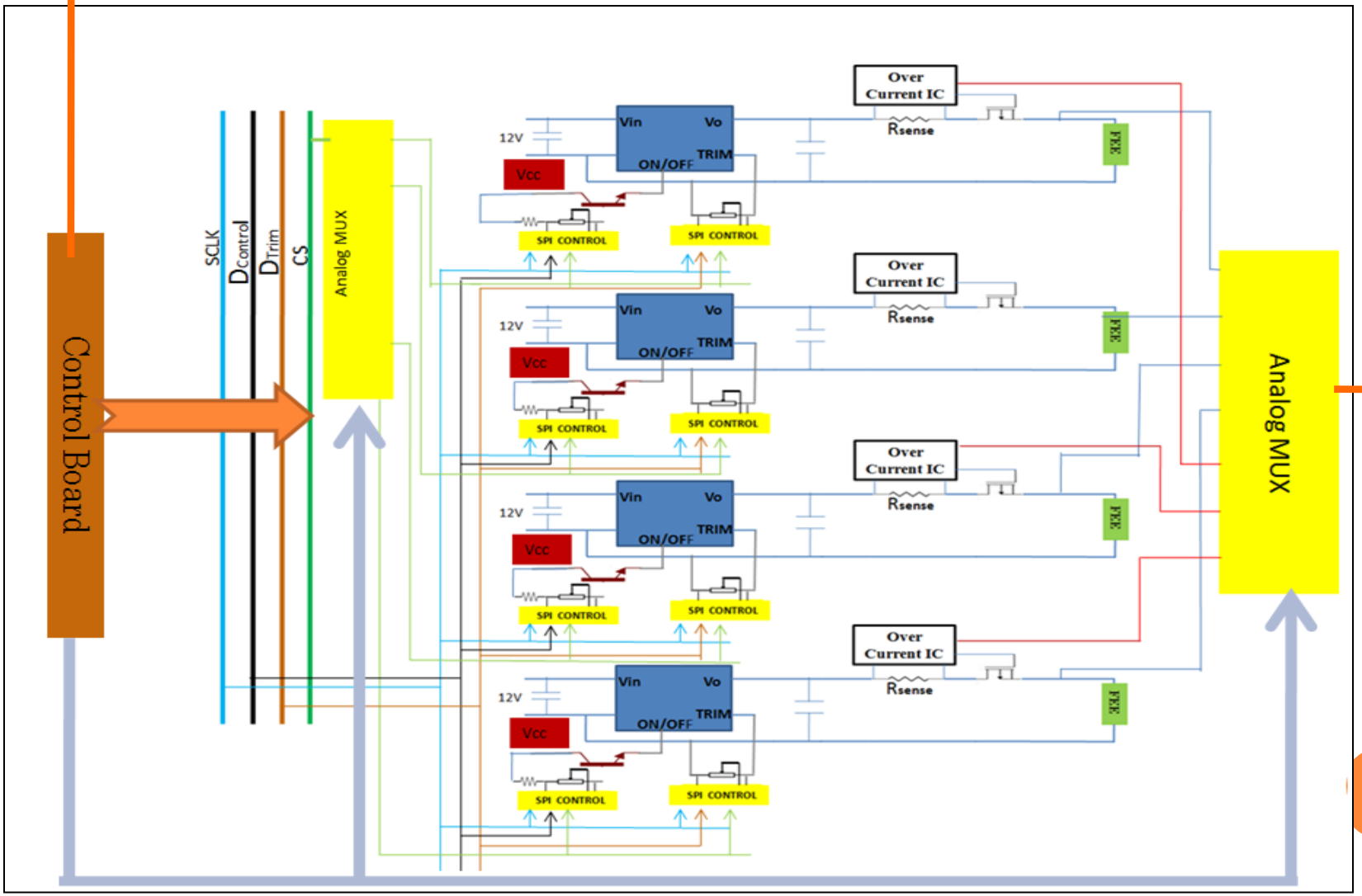

12V
Current monitoring MUX
Control Ports
ADC Input
Control MUX
Voltage monitoring MUX


DC-DC Convertor
Output Filter capacitor
Control resistor
Sense Resistor
Inductors
ZOOM
12V BUS
Input Filter capacitor
Output Connector

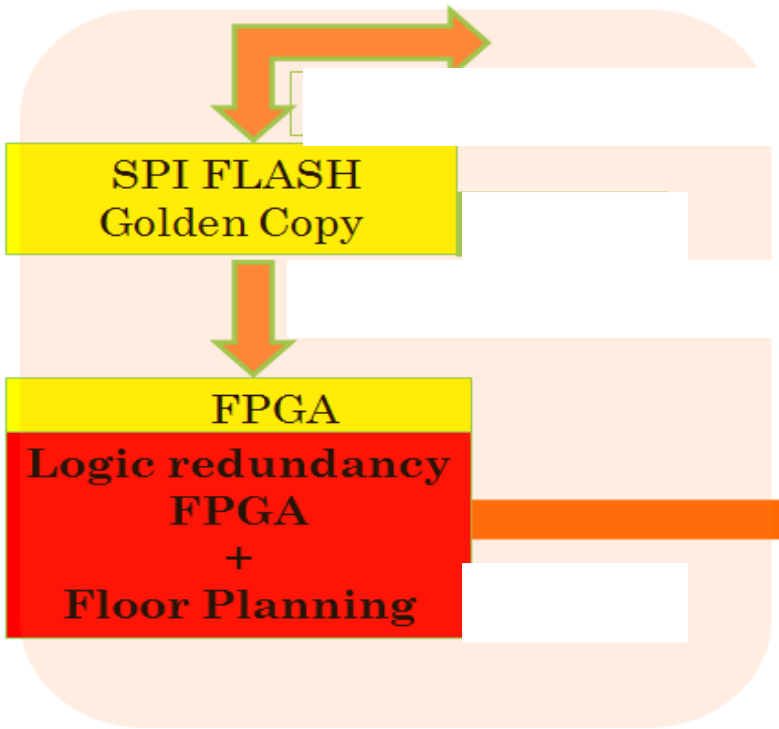
4:1 design

SPI control register is keep on refreshing with 1Khz rate via multiplexer

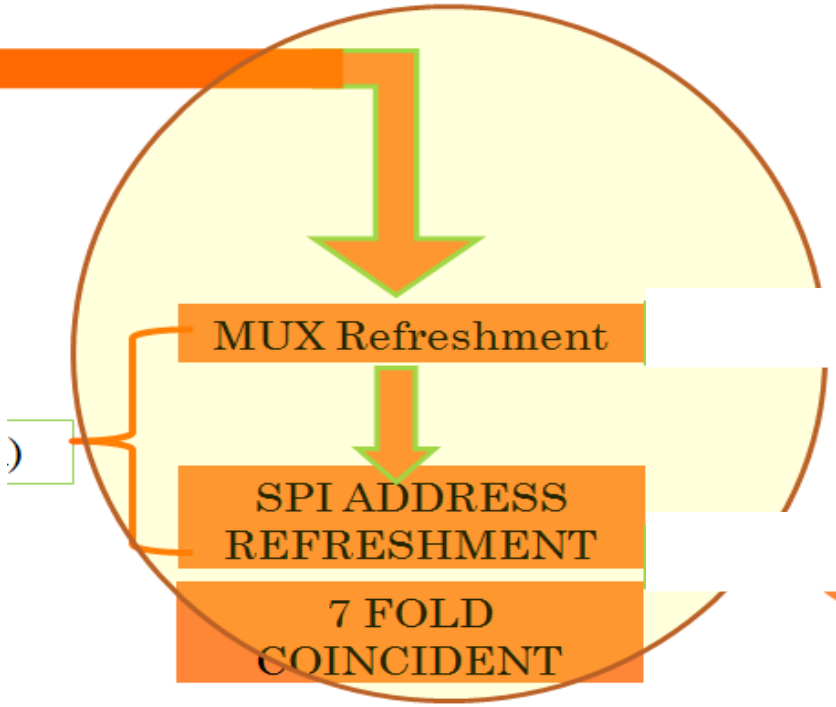
Current and voltage monitoring of each channel



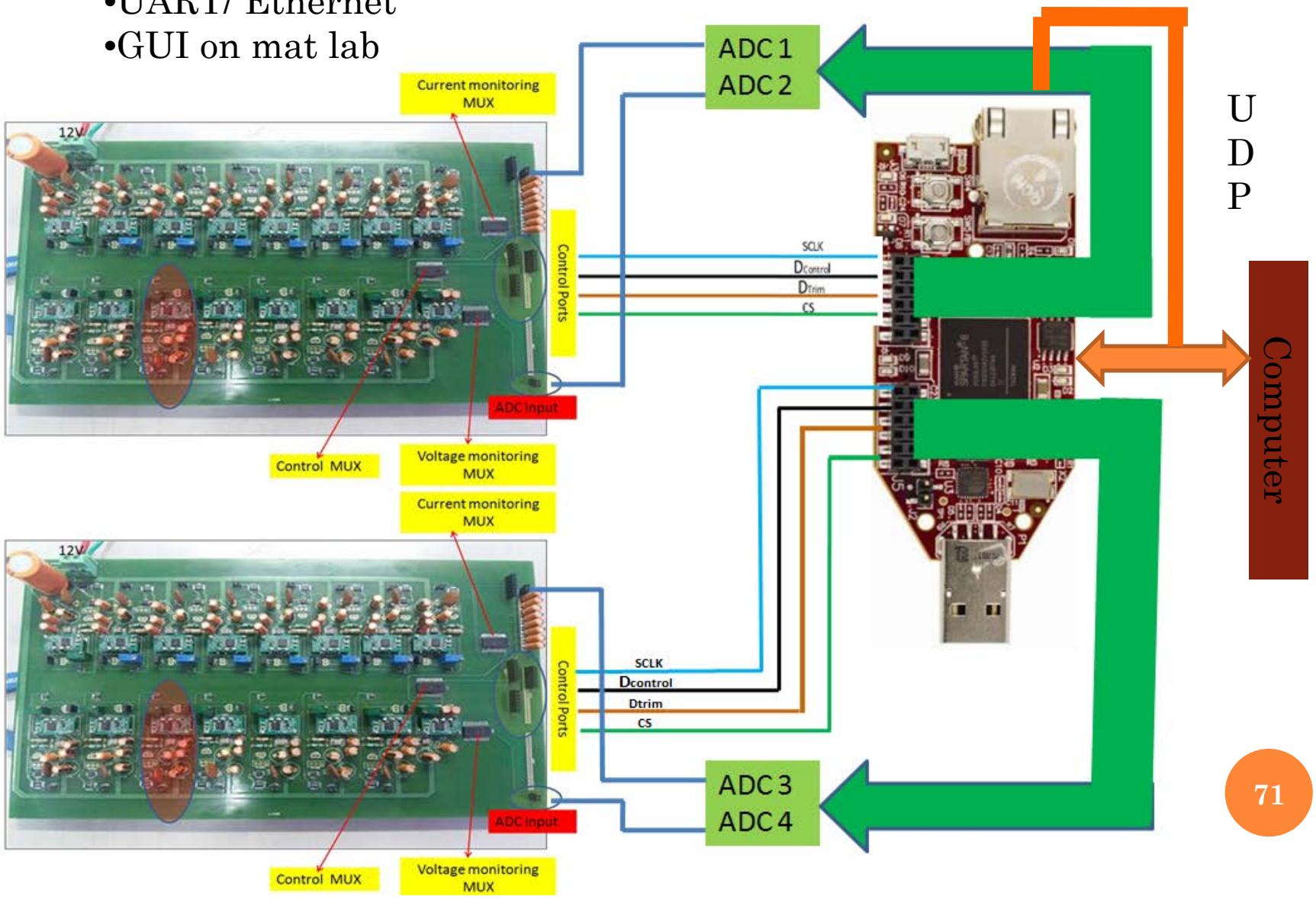
Controller Scrubbing



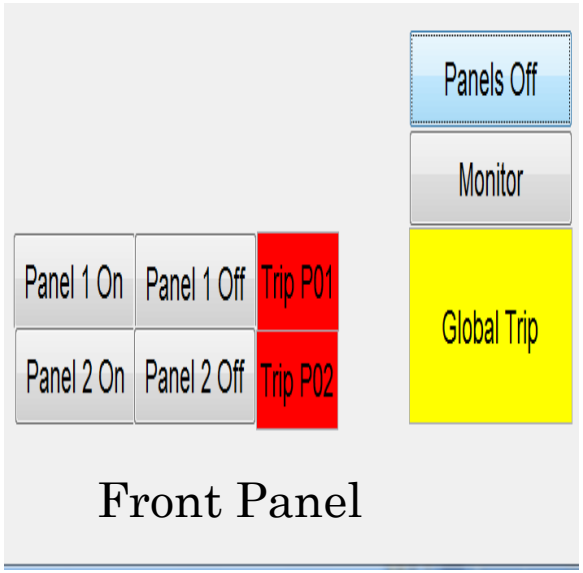
Error Resilient design of board



•Maximum four board can be interface with Spartan six lx9 board
•In our design we had connected two boards
•UART/ Ethernet
•GUI on mat lab



Monitoring and control GUI on mat-lab



Front Panel

Board 1

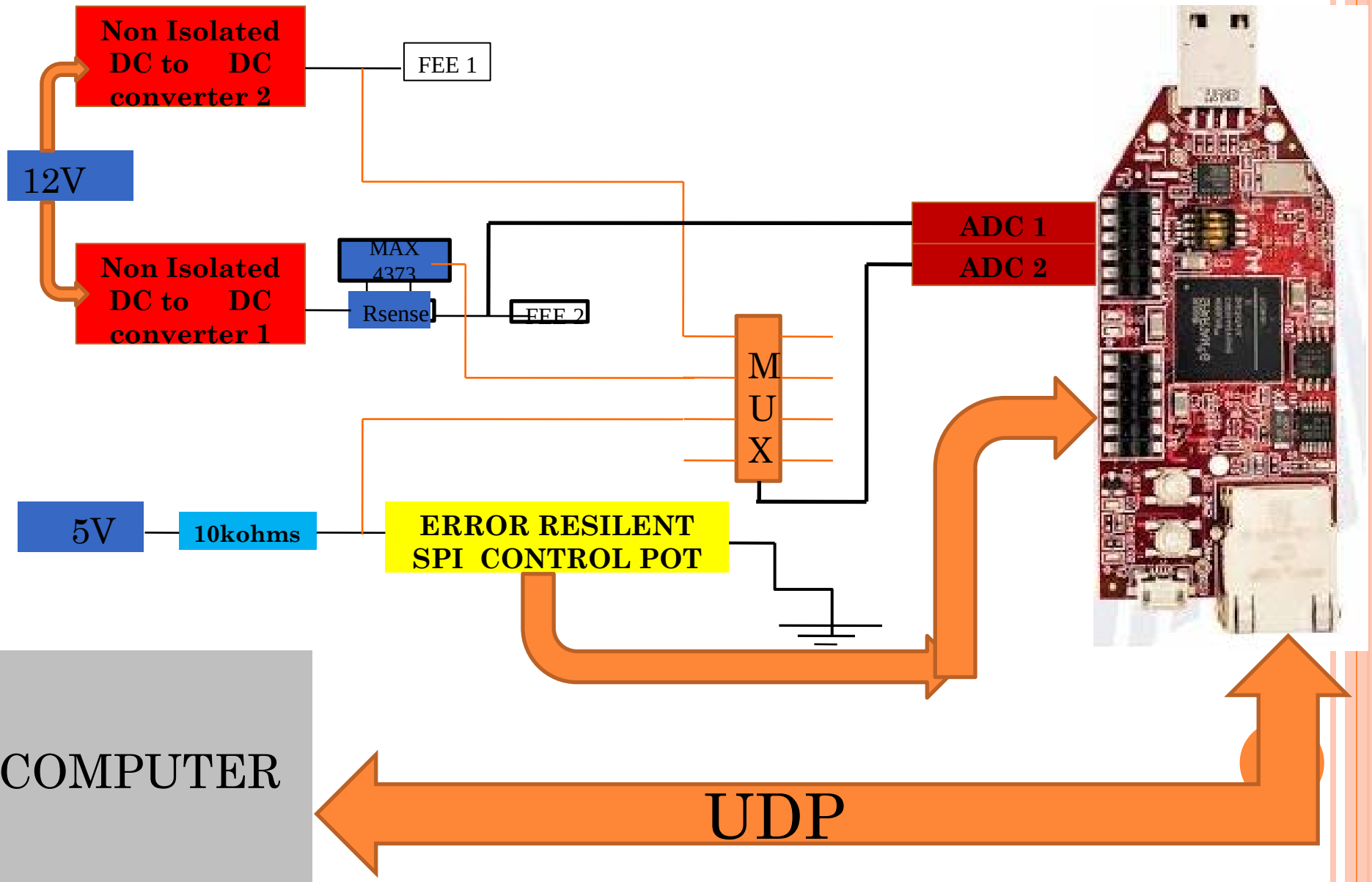
Board 2

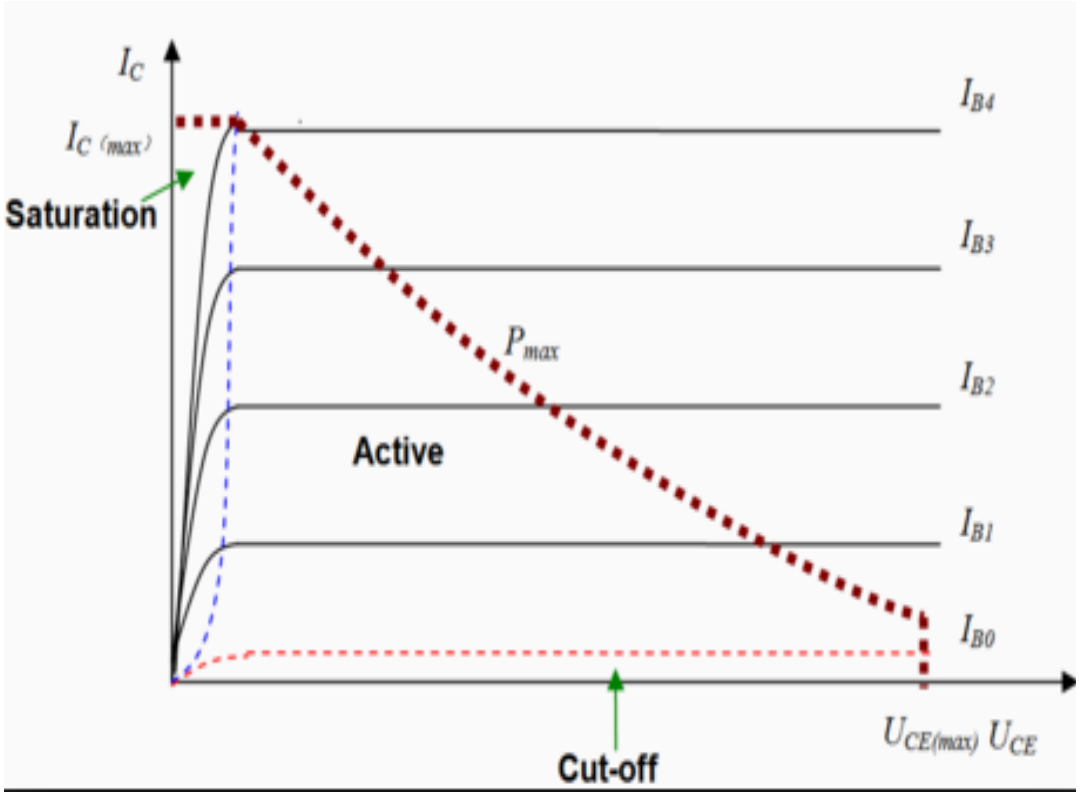
HEIP FROM COLLABORATION

EPICS ????

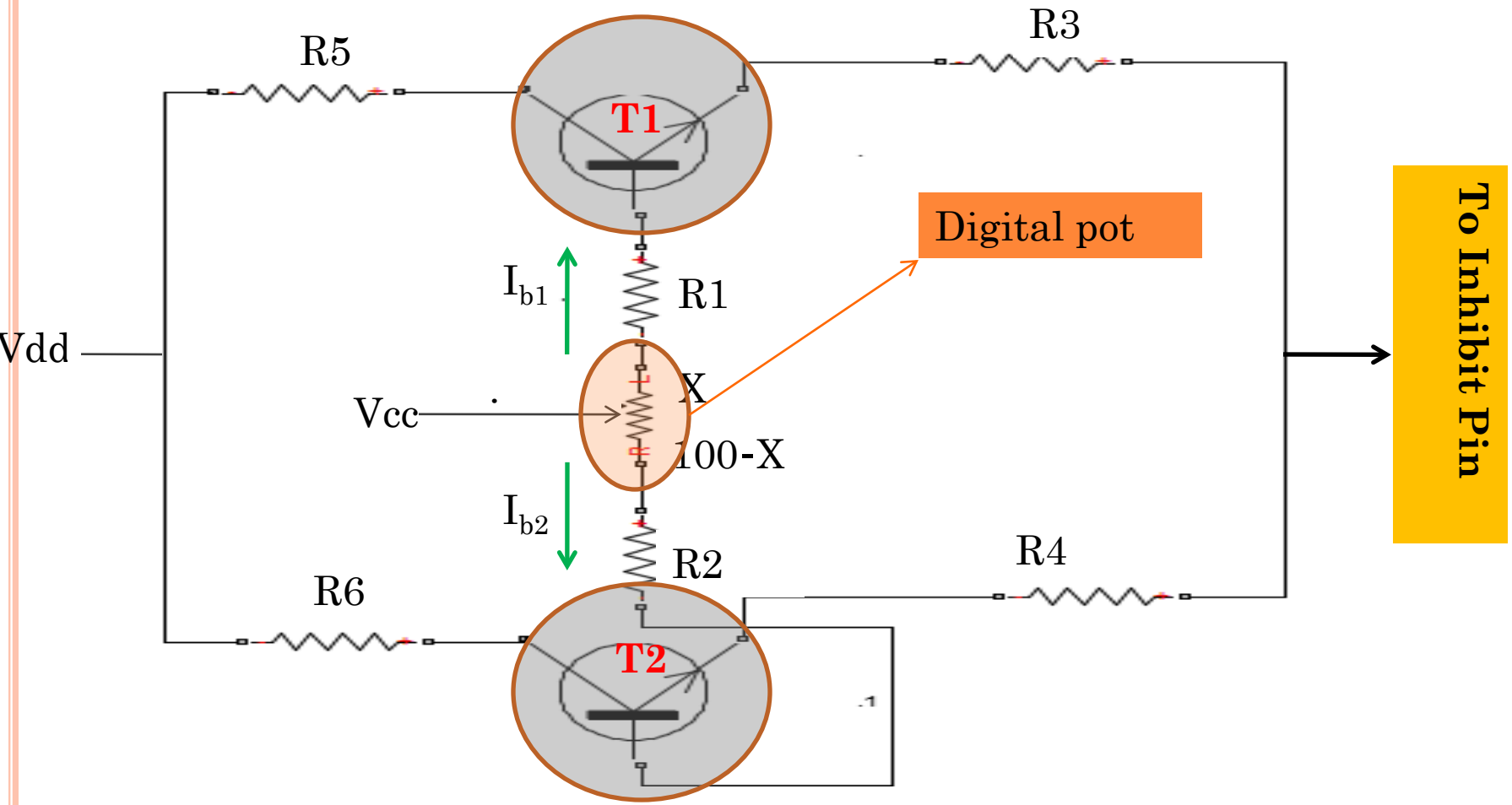
Thank you

For more information regarding the radiation hard components, please contact me at vnegi@vecc,gov.in


Non Isolated DC to DC converter 2
FEE 1
12V
Non Isolated DC to DC converter 1
MAX 4373
Rsense
FEE 2
ADC 1
ADC 2
MUX
5V
10kohms
ERROR RESILENT SPI CONTROL POT
COMPUTER
UDP


I_C
$I_{C\,(max)}$
Saturation
I_{B4}
I_{B3}
P_{max}
I_{B2}
Active
I_{B1}
I_{B0}
$U_{CE(max)}$ U_{CE}
Cut-off

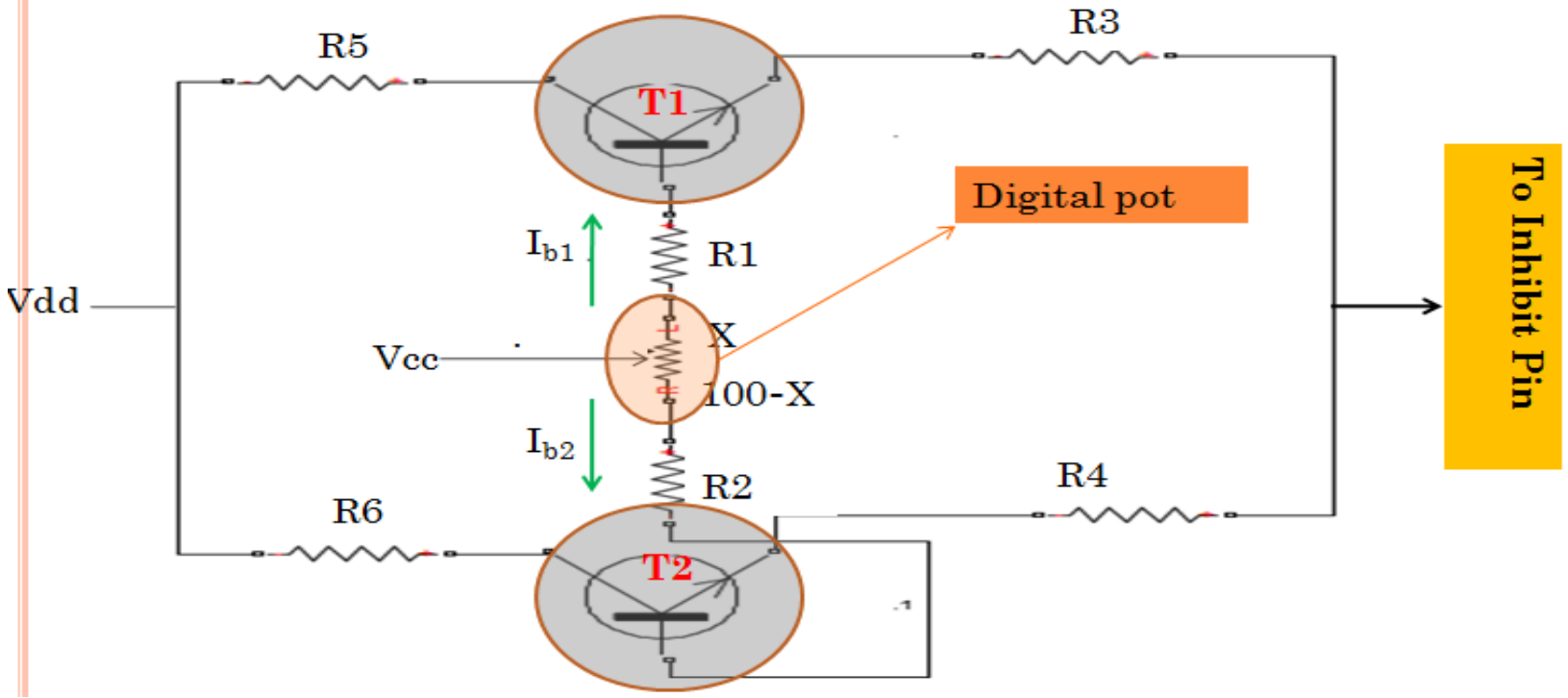
FAULT TOLERANT CONTROL WITH SPI POT



LOGIC(HARD ON STABLE OFF)

T1 , T2 Both in deep cut off----------ON

Either one of them ON----------OFF



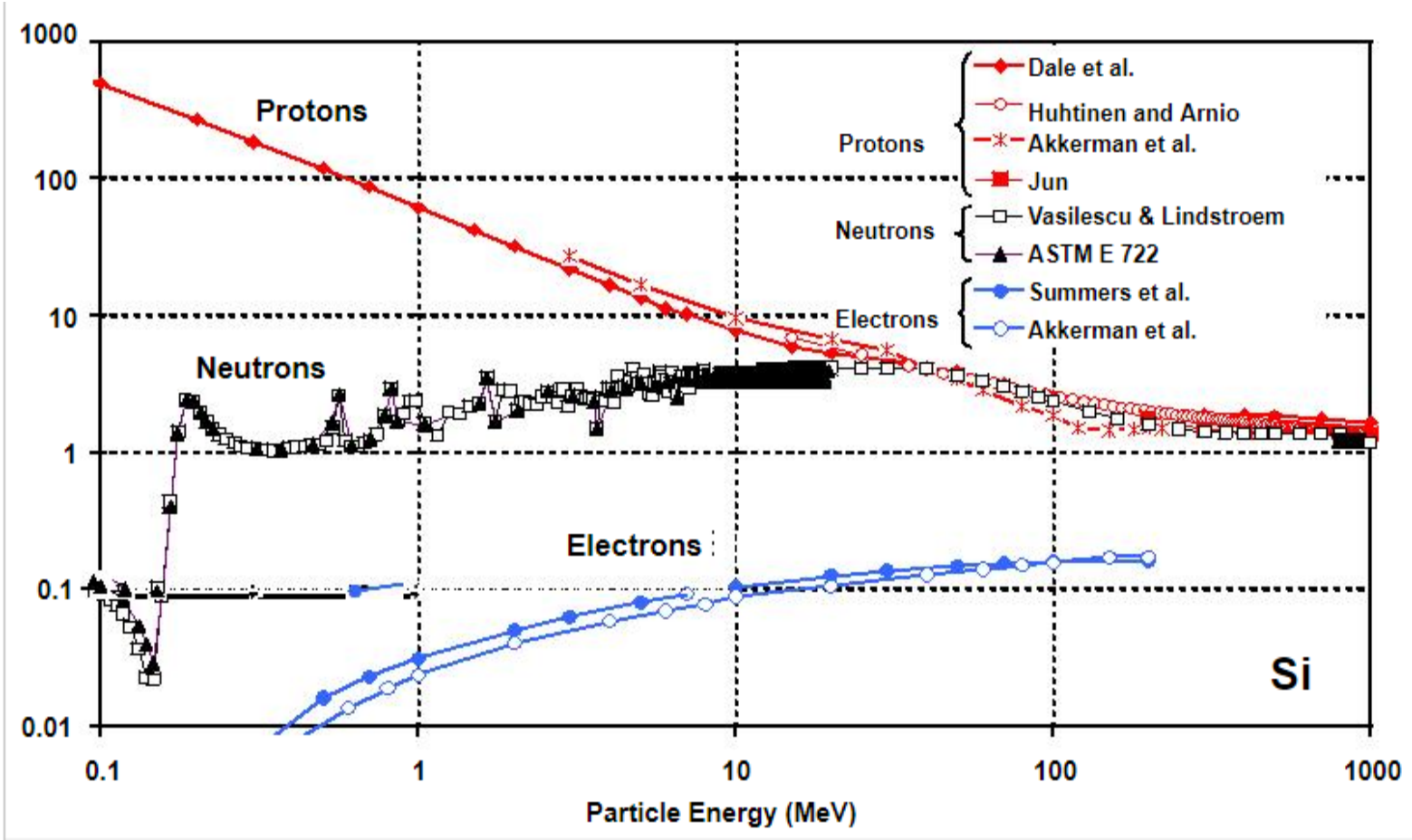
R1 + Xon
R2 + 100- Xon

DEEP INTO CUT OFF REGION

R1 + Xoff
R2 + 100- Xoff

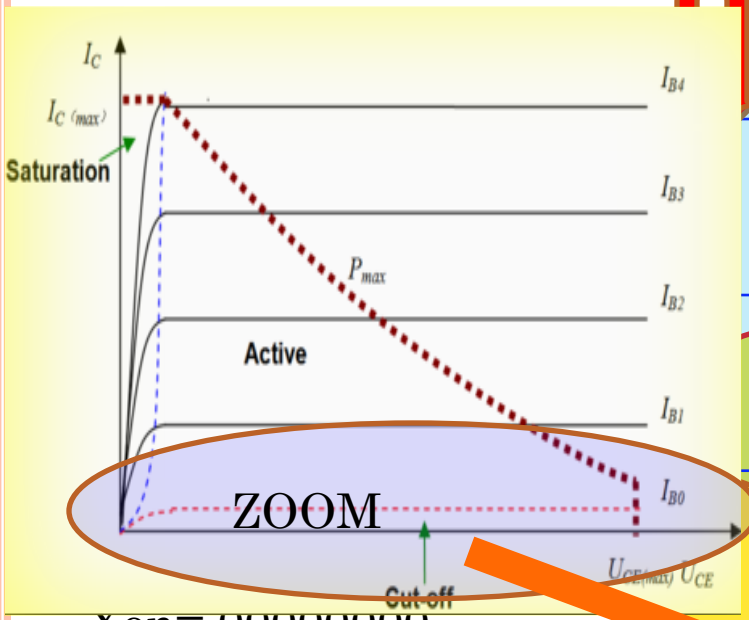
JUST ABOVE CUT OFF REGION
AND
R1 + Xoff =R2 + 100- Xoff

$$Xoff = \frac{R2-R1+100}{2}$$

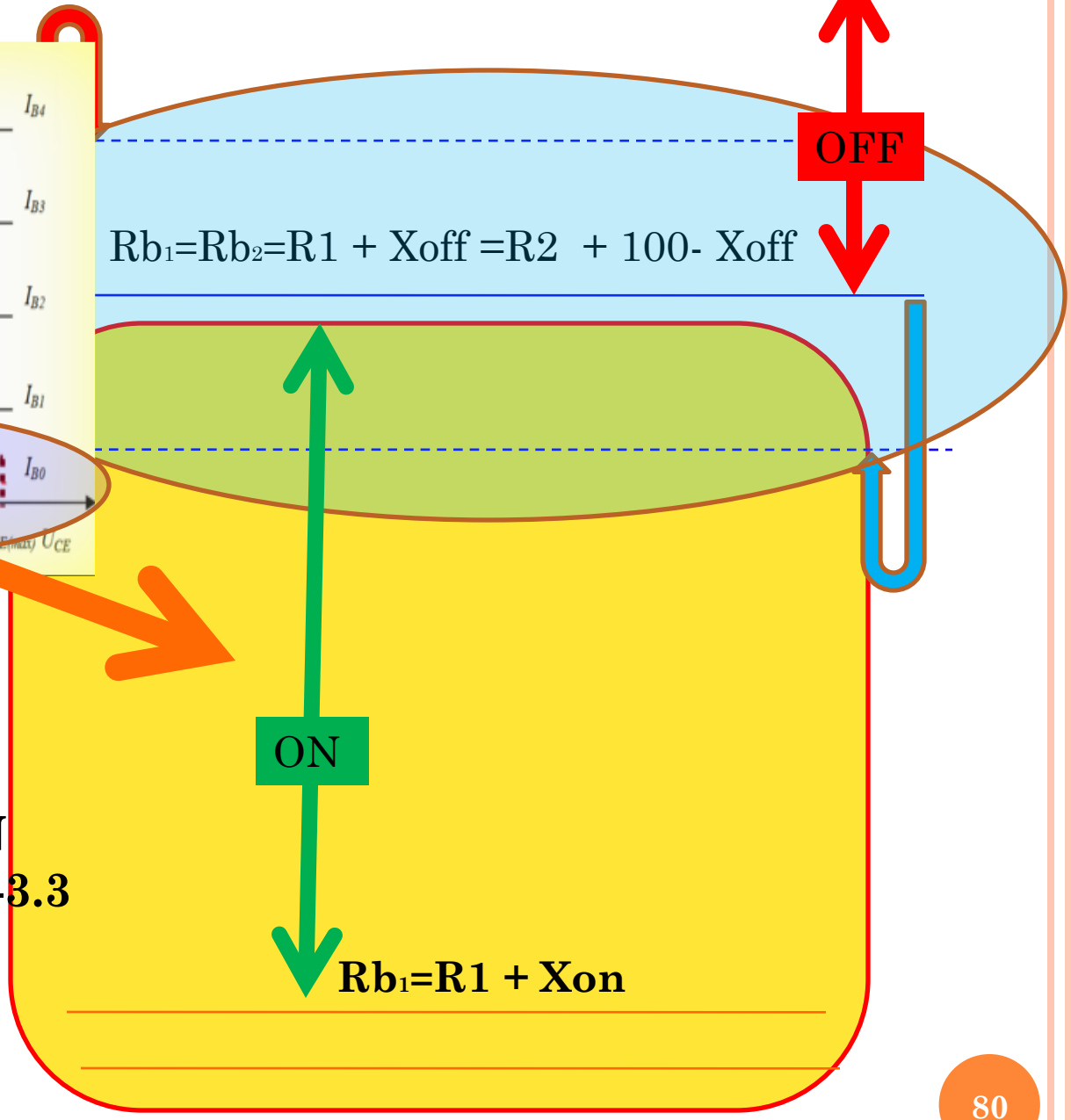


damage = k_{damage} x displacement damage dose

$$\int \overline{NIEL(E)} \frac{d\varphi(E)}{dE} dE$$

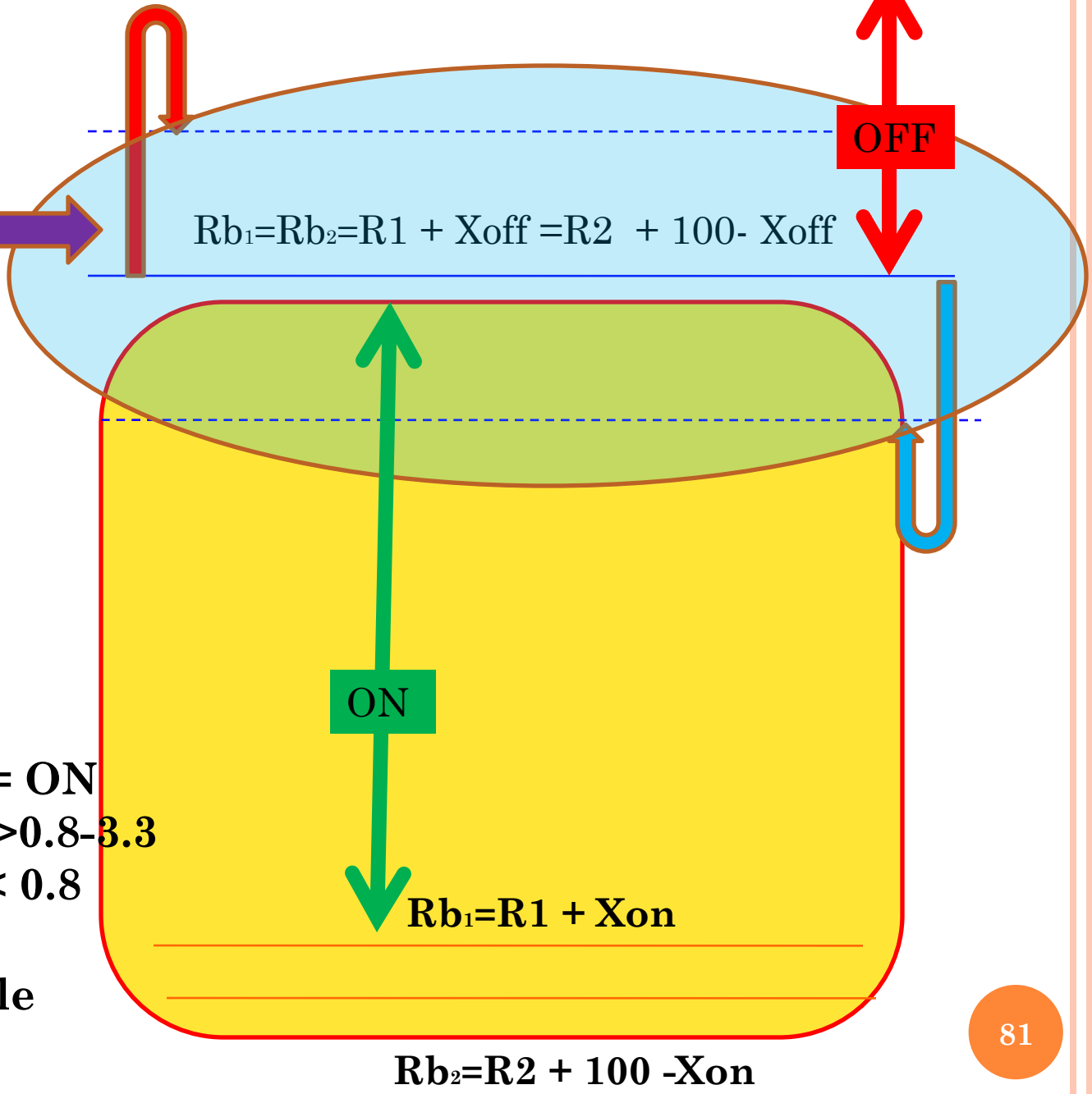


Xon= 00000000
Xoff= 11111000



- **Floating enable= ON**
- **Disable voltage >0.8-3.3**
- **Enable voltage < 0.8**

Hard ON
And
Stable off

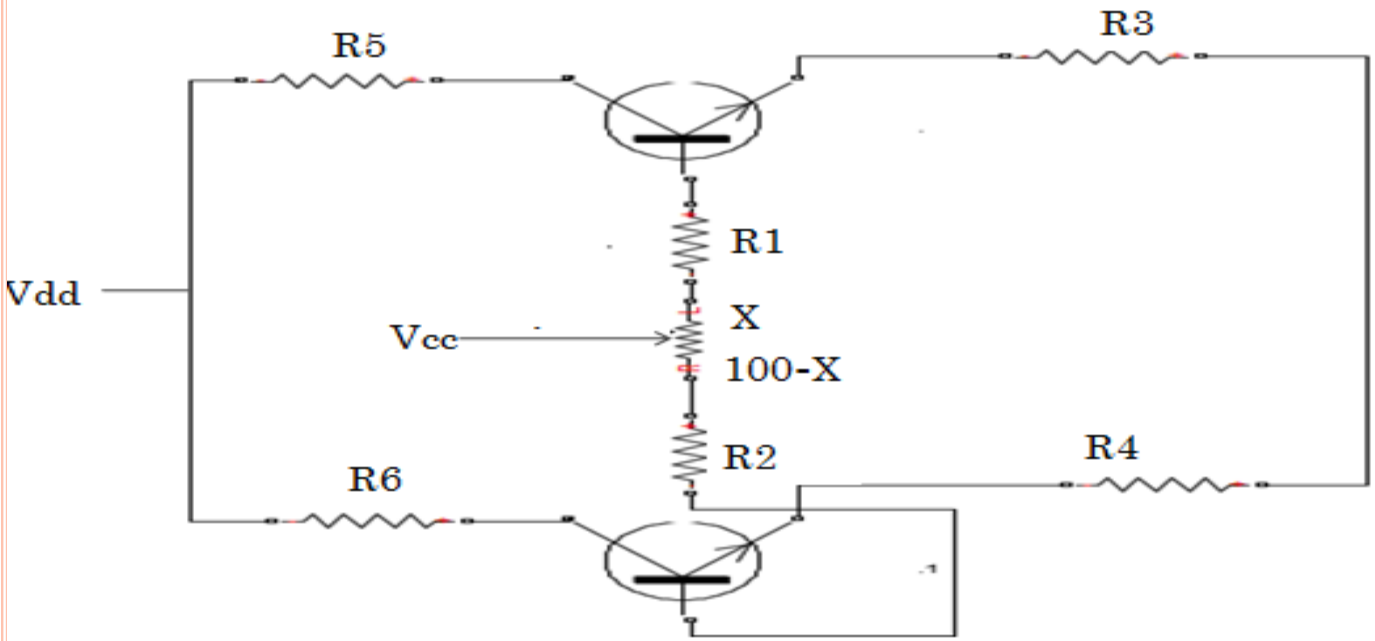


UPSET CAUSE BY RADIATION

Xon= 00000000
Xoff= 11111000

- **Floating enable= ON**
- **Disable voltage >0.8-3.3**
- **Enable voltage < 0.8**

Hard ON and Stable OFF



R1 + Xon
R2 + 100- Xon

DEEP INTO CUT OFF REGION

R1 + Xoff
R2 + 100- Xoff

JUST ABOVE CUT OFF REGION
AND
R1 + Xoff =R2 + 100- Xoff

$$Xoff = \frac{R2-R1+100}{2}$$