Step-down DC-DC converters irradiation tests at Calliope Nov-Dec 2013

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CALLIOPE

Previous tests at BNL and our irradiation plan

- **At BNL**
  - LTM 4619 module has been tested under gamma irradiation, with **200 Gy/h** dose rate and 26 V input: this module **did not survive 150 Gy**
  - A second LTM 4619 irradiated at **90 Gy/h survived up to 2000 Gy**
  - A third LTM 4619 was tested at **14 Gy/h, surviving up to 3500 Gy**

  No further info available.

- **At Calliope we tested in July two LTM 4619 at 22 Gy/h, and the boards survived up to 2000 Gy**

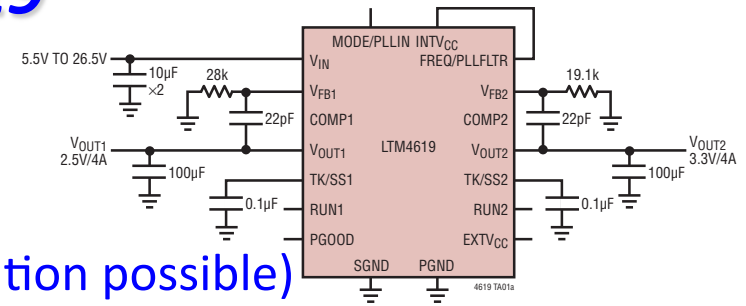
- **At Calliope** the current test is using lower dose rates and V_{in}, V_{out} monitoring to verify the behaviour of different DC-DC converters at low dose rate

Gamma Irradiation test setup

The irradiation campaign **started on Nov. 21st at Calliope** ϒ irradiation facility (ENEA Casaccia) and is still ongoing:

- **Two LTM 8033 and two LTM 4619** demo boards (Linear), **one POL** manufactured by PD-INFN
- Dose rate: **5 Gy/h (Si)** specific position selected, dedicated dosimetry
- **Monitored values: V_{in}, I_{in}, V_{out}** (V monitoring thanks to A. Lanza data logger)
- Monitoring time intervals: 30 min
- Maximum irradiation interruption: 2h (ESA standards), devices always powered up

Linear LTM 4619



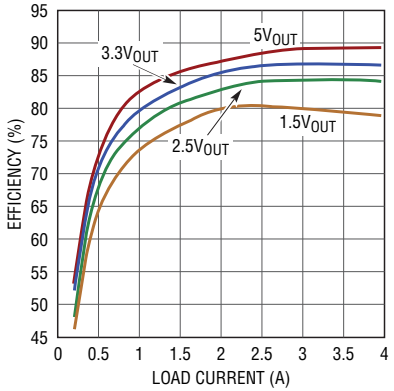
- Dual Output step-down module
- 4.5 ÷ 26.5 V input , 0.8 ÷ 5 V output
- 4A output (5A peak) per module (sync'd combination possible)

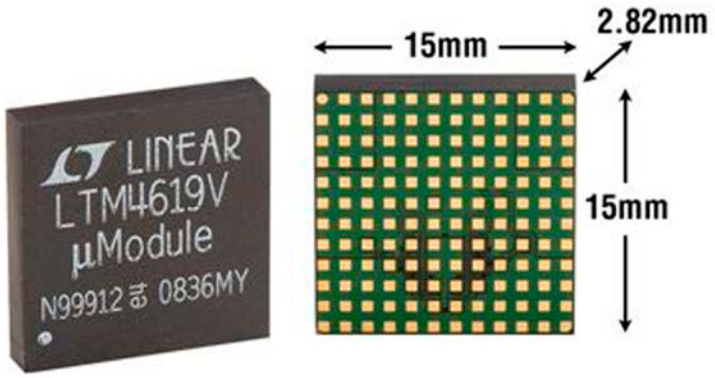
Already tested in July with 22 Gy/h ϒ

Output Specifications

$I_{OUT1, 2(DC)}$	Output Continuous Current Range	V_{IN} = 12V, V_{OUT} = 2.5V (Note 5)		0	4	A
$\frac{\Delta V_{OUT1(LINE)}}{V_{OUT(NOM)}}$	Line Regulation Accuracy	V_{OUT} = 2.5V, V_{IN} from 6V to 26.5V I_{OUT} = 0A For Each Output	 ●	0.15 0.25	0.3 0.5	% %
$\frac{\Delta V_{OUT2(LINE)}}{V_{OUT(NOM)}}$	Line Regulation Accuracy	V_{OUT} = 2.5V, V_{IN} from 6V to 26.5V I_{OUT} = 0A For Each Output	 ●	0.15 0.25	0.3 0.5	% %
$\frac{\Delta V_{OUT1(LOAD)}}{V_{OUT1(NOM)}}$	Load Regulation Accuracy	For Each Output, V_{OUT} = 2.5V, 0A to 4A (Note 5) V_{IN} = 12V	●	0.6	0.8	±%
$\frac{\Delta V_{OUT2(LOAD)}}{V_{OUT2(NOM)}}$	Load Regulation Accuracy	For Each Output, V_{OUT} = 2.5V, 0A to 4A (Note 5) V_{IN} = 12V	●	0.6	0.8	±%
$V_{OUT1, 2(AC)}$	Output Ripple Voltage	I_{OUT} = 0A, C_{OUT} = 100µF X5R Ceramic V_{IN} = 12V, V_{OUT} = 2.5V V_{IN} = 26.5V, V_{OUT} = 2.5V		 20 25		 mV mV

Efficiency vs Load Current with $24V_{IN}$ (f = 500kHz for $1.5V_{OUT}$)





Linear LTM 4619: demo board setup

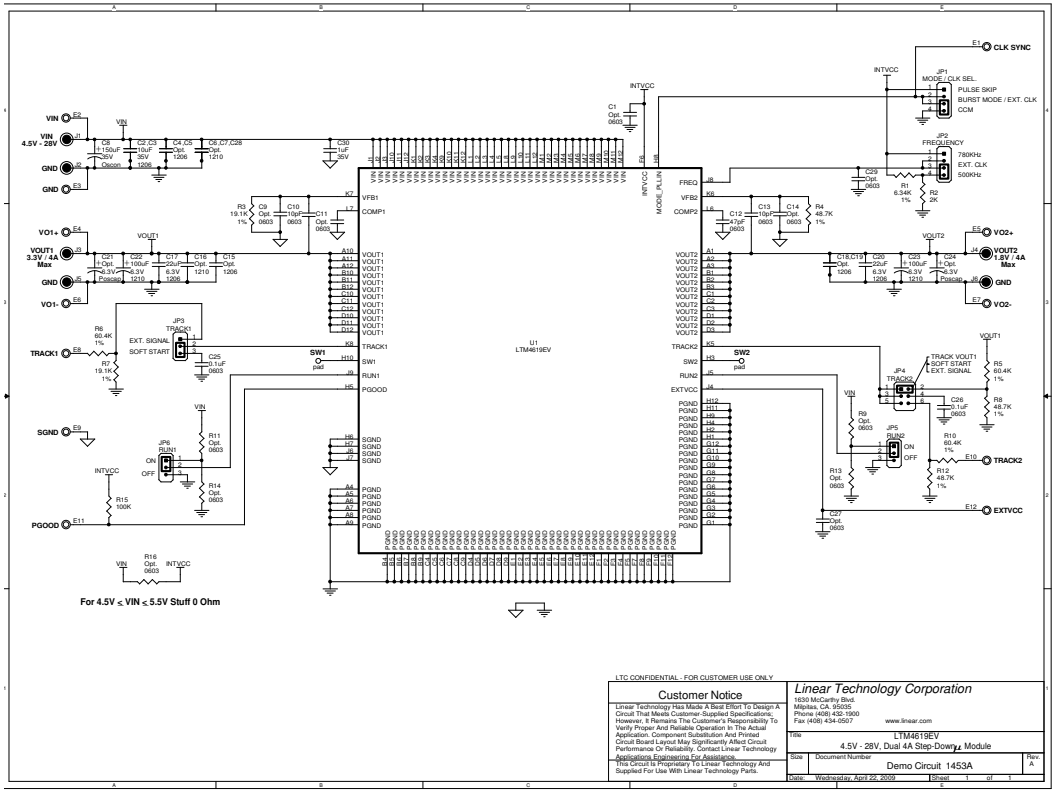
Two demo boards provided by PV-INFN

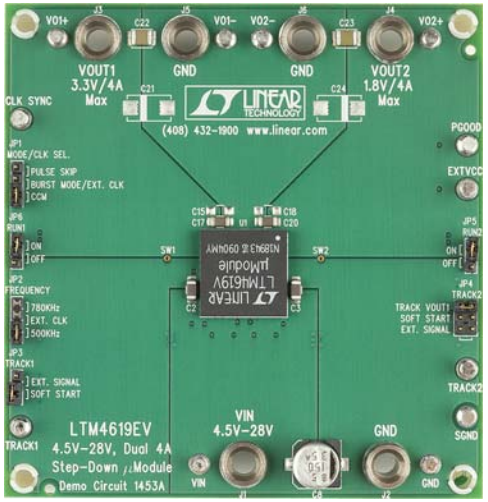
Each board has 1.8 V and 3.3 V outputs original configuration

V_{in}: 24 V

I_{out}: 3.1 A on 1.8 V, 3.6 A on 3.3 V test initial settings

Irradiation with with 5 Gy/h (Si)

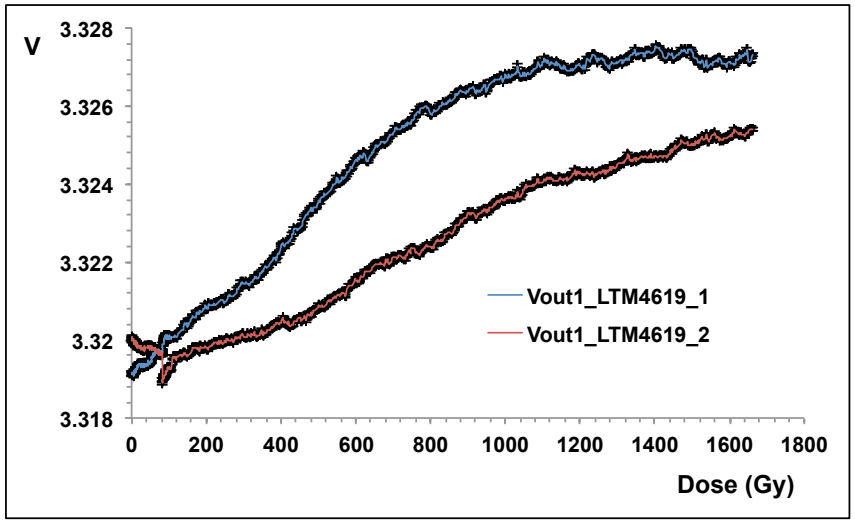


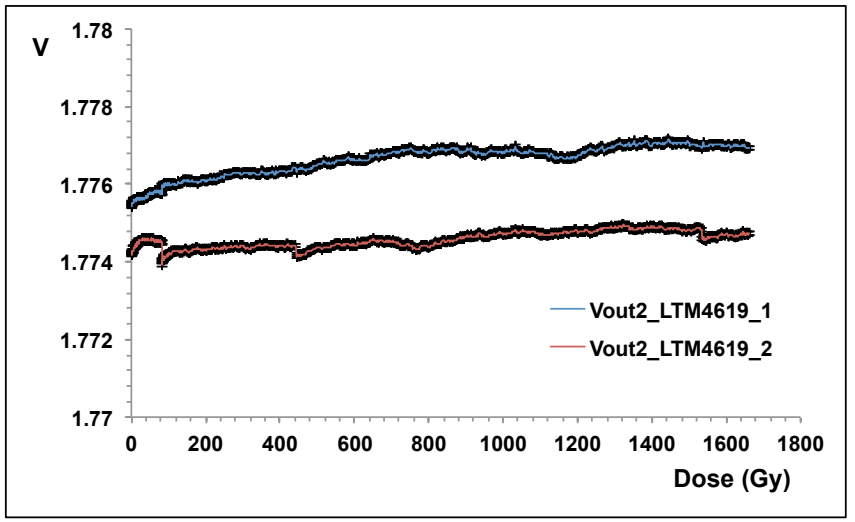


Linear LTM 4619: performances under ϒ

Irradiation results after **14 days and 1700 Gy**:

- Both LTM 4619 modules have very stable performances:
- **Efficiency ε and V_{out} constant**
- ε = 0.68 ± 0.01 for both boards

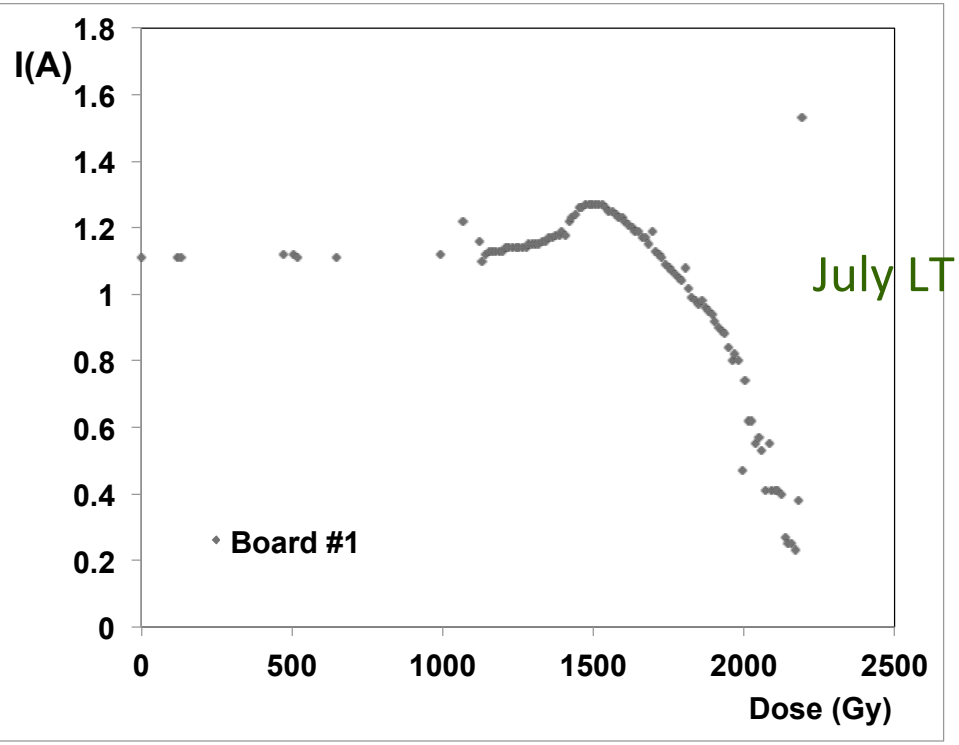




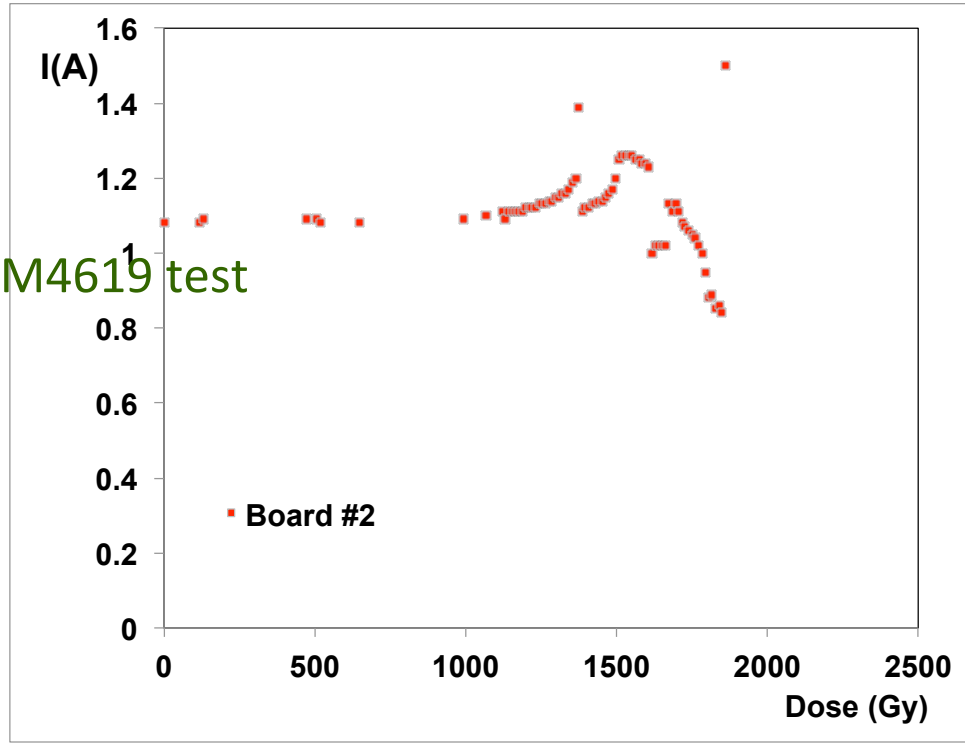
Linear LTM 4619: Present vs July test

In July a 22 Gy/h dose rate was used:
I_{out} variations after 1000 Gy interpreted as efficiency decrease (no V_{out} monitoring)

Now with present test we are at 1800 Gy and no effect on I_{out} is observed



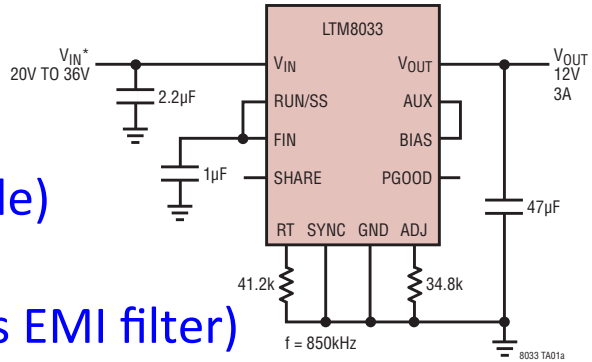
July LTM4619 test



Linear LTM 8033

- Single Output step-down module
- 3.6 ÷ 36 V input , 0.8 ÷ 24 V output
- 3A output max per module (sync'd combination possible)
- 11 x 15 x 4.3 mm^3 , smaller than LTM 4619

Compliance with EMI EN55022 class B is stressed (contains EMI filter)

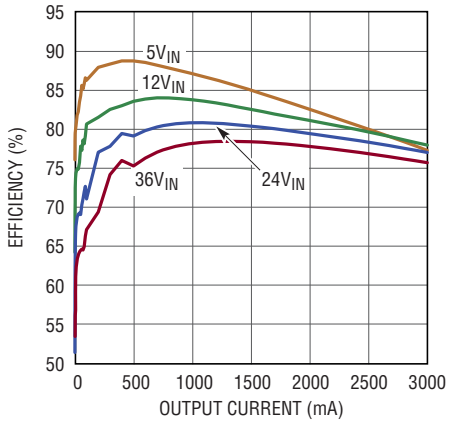


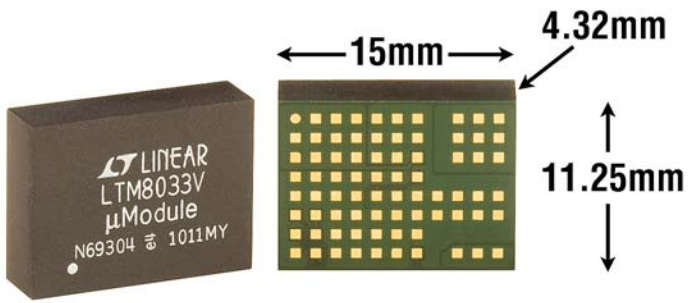
ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. V_{IN} = 12V, RUN/SS = 12V unless otherwise noted (Note 2).

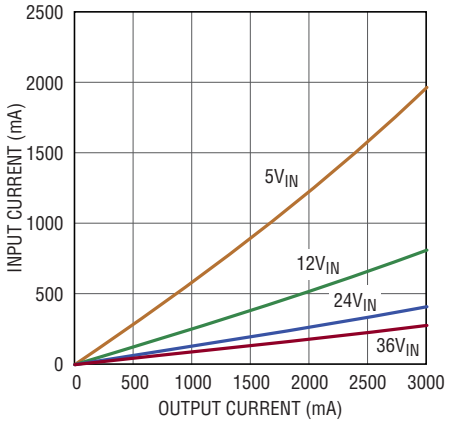
PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Output RMS Voltage Ripple	V_{IN} = 24V, 0A < I_{OUT} < 3A			5		mV
Switching Frequency	R_T = 45.3k			780		kHz
Voltage at ADJ Pin		●	775	790	805	mV
Current Out of ADJ Pin	ADJ = 1V, V_{OUT} = 0V			2		µA
Minimum BIAS Voltage for Proper Operation				2	2.8	V

2.5V_{OUT} Efficiency





Input Current vs Output Current 2.5V_{OUT}

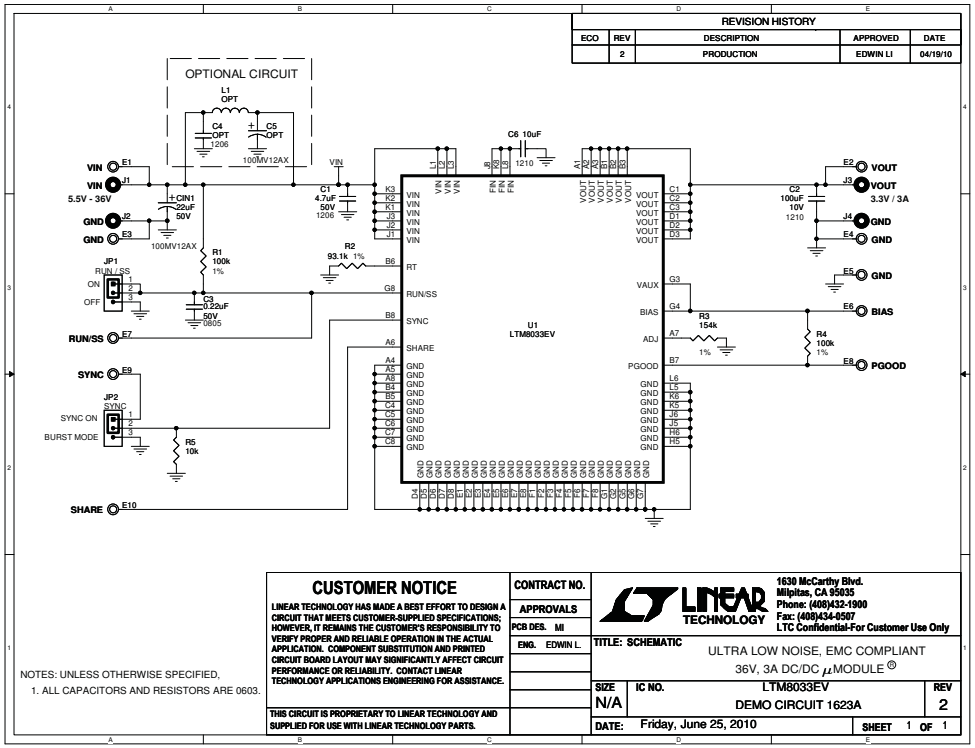


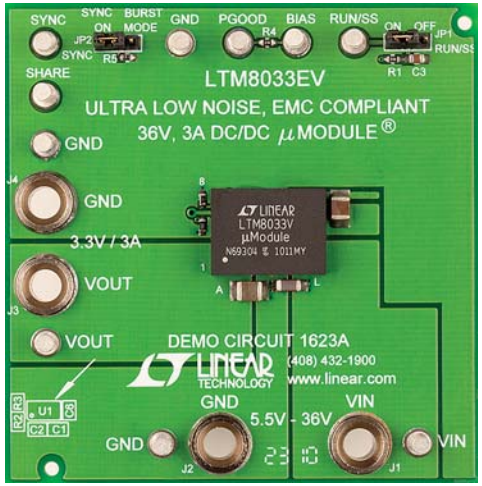
Linear LTM 8033: demo board setup

Two demo boards provided by MI-PV:

- Board 1 has been modified by MI (S. Latorre) to provide 1.5 V_{out}
- Board 2 has original 3.3 V_{out}

V_{in}: 24 V , I_{out}: 2 A intended as test initial setting (1,78 A on 1.5 V, 1.93 A on 3.3 V)
Irradiation with 5 Gy/h ϒ

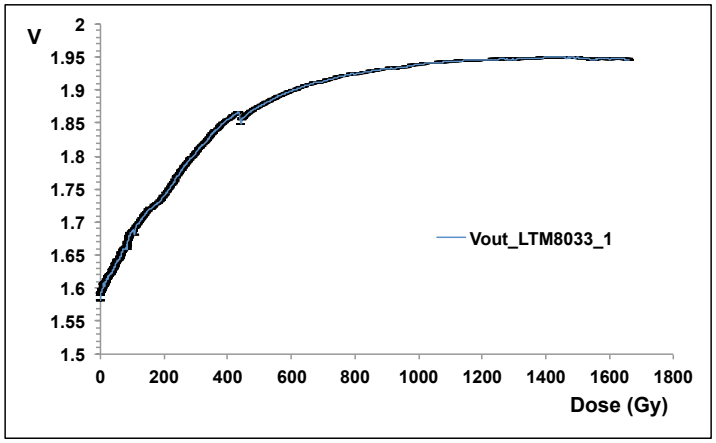


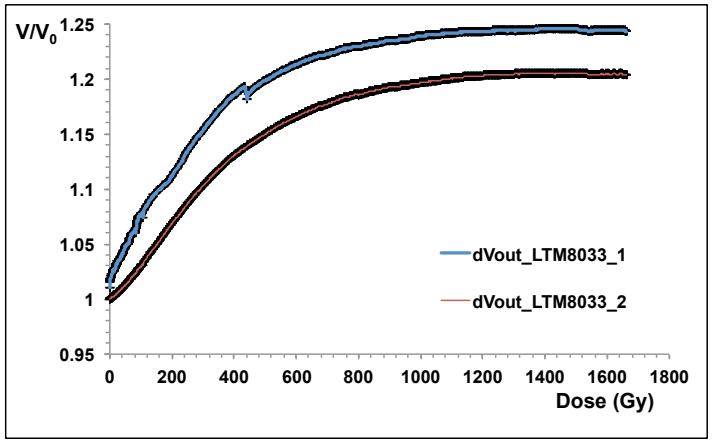


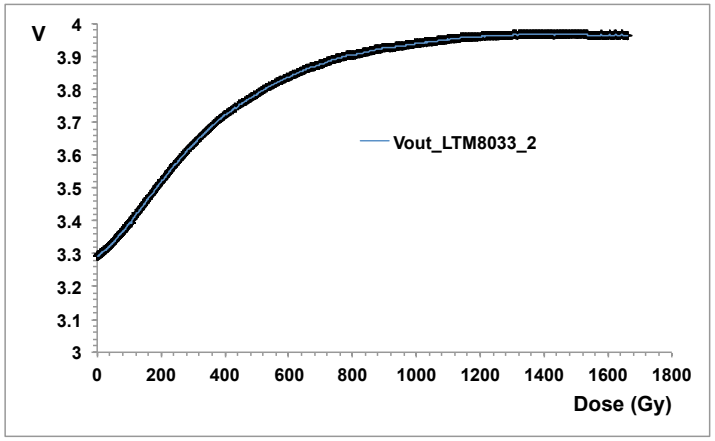
Linear LTM 8033: performances under ϒ

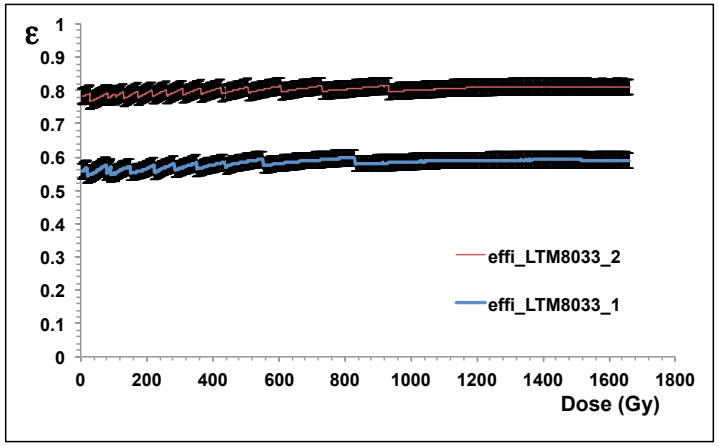
Irradiation results after 14 days and 1700 Gy :

- **Both LTM 8033 modules have increased their V_{out}** up to a plateau of about **+20%** with respect to test initial value
- **Efficiency is stable** at 0.80±0.03 for board 1 and 0.58±0.04 for board 2 (taking into account V_{out} variation)









POL converter by PD-INFN

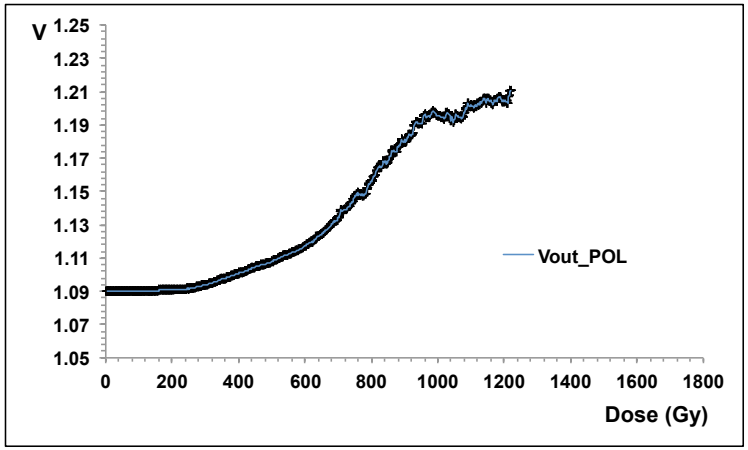
Single Output step-down module
12 V input, 1.2 V output, 6A
More details from PD colleagues

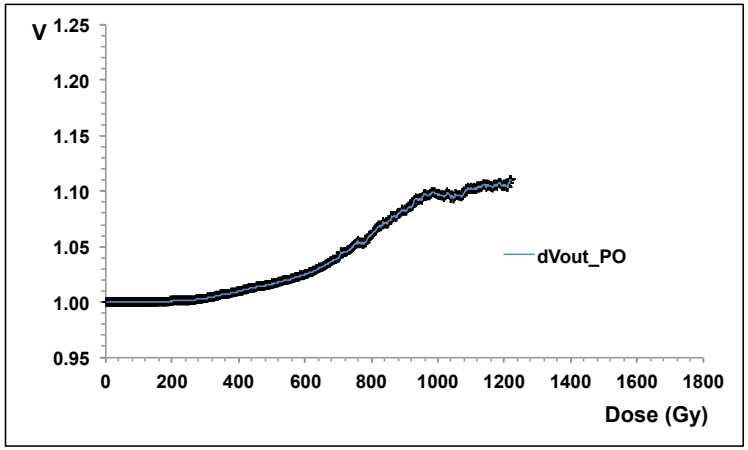
One board provided with resistive load
V_{in}: 12V, I_{out} 6A test initial settings
Irradiation at 5 Gy/h

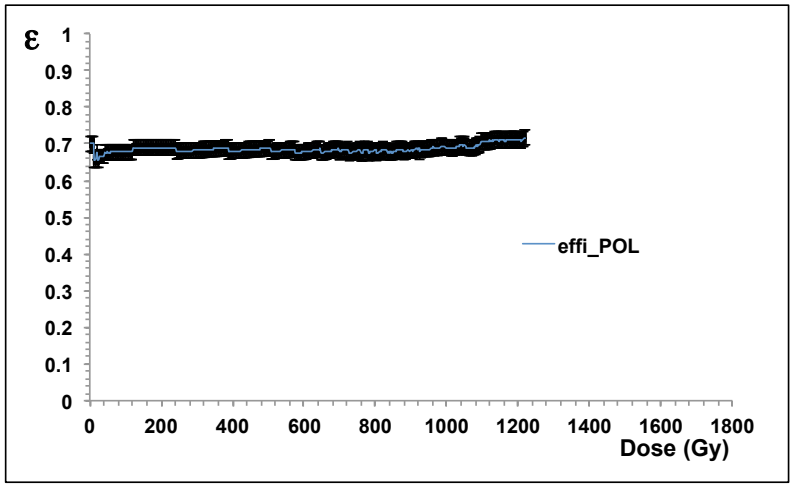
POL-PD performances under ϒ

Irradiation results after 10 days and 1300 Gy :

- POL module has **increased slightly its V_{out}** up to +10% with respect to test initial setting, better than LTM 8033 but still sensitive to TID
- **Efficiency is stable** at 0.68±0.02 (taking into account V_{out} variation)







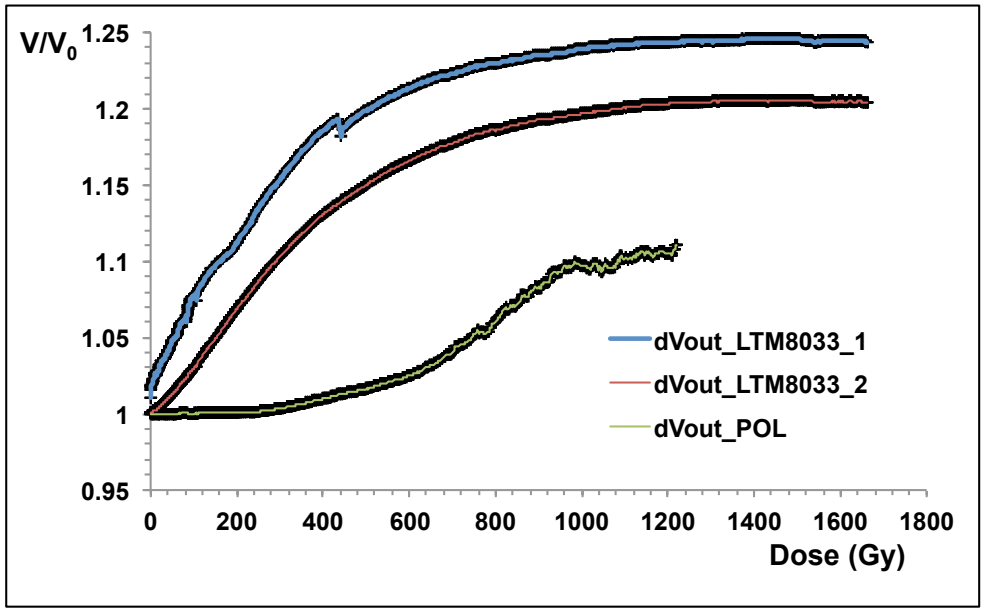
Comparison of TID radiation effects

Efficiencies are stable up to 1800 Gy for all modules

TID effect is an increase of V_{out}: a possible explanation is a **gate oxide damage** of the MOSFETs integrated in the step-down modules, with consequent increase of the leakage current resulting in higher V_{out}

Significant differences in V/V_0:

- LTM 4619 is stable at per-mil level
- LTM 8033 increases V outputs of 20% after 1400 Gy
- POL-PD increased V_{out} of 10% after 1000 Gy, different trend: GaN MOSFETs ?



New boards from U. Michighan

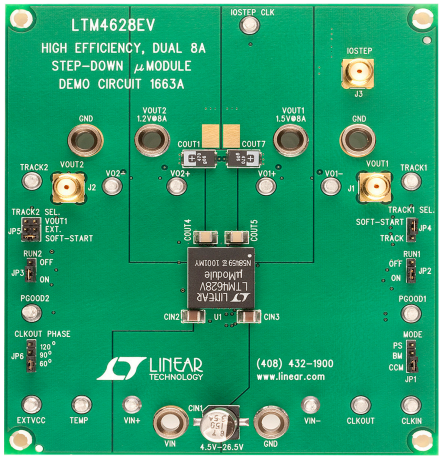
- Agostino managed to have from D. Amidei (U. Michighan) two new modules manufactured by Linear: LT 8610 and LTM 4628
- We received the boards in Casaccia, but LTM 4628 malfunctioned right after powering it up due to wrong output modification by Michighan
- Presently only LT 8610 is under irradiation at 10 Gy/h, we will try to repair the other board tomorrow.

LTM4628

Dual 8A or Single 16A DC/DC µModule Regulator

FEATURES

- Complete Standalone Dual Power Supply
- Single 16A or Dual 8A Output
- Wide Input Voltage Range: 4.5V to 26.5V
- Output Voltage Range: 0.6V to 5.5V

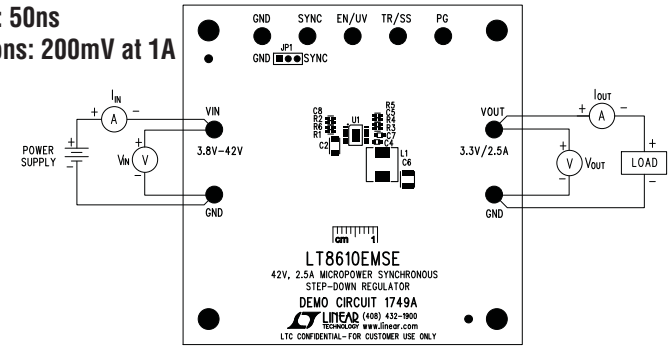


LT8610

42V, 2.5A Synchronous Step-Down Regulator with 2.5µA Quiescent Current

FEATURES

- Wide Input Voltage Range: 3.4V to 42V
- Ultralow Quiescent Current Burst Mode® Operation:
  - 2.5µA I_Q Regulating $12V_{IN}$ to $3.3V_{OUT}$
  - Output Ripple < $10mV_{P-P}$
- High Efficiency Synchronous Operation:
  - 96% Efficiency at 1A, $5V_{OUT}$ from $12V_{IN}$
  - 94% Efficiency at 1A, $3.3V_{OUT}$ from $12V_{IN}$
- Fast Minimum Switch-On Time: 50ns
- Low Dropout Under All Conditions: 200mV at 1A
- Allows Use Of Small Inductors



Conclusions and outlook

- ✓ **LTM 4619 seems the less sensitive to TID**
- ✓ LTM 8033 is sensitive to few tens of Gy: V_{out} regulation impaired
- ✓ POL-PD has a different behaviour, but still sensitive to hundreds of Gy
- ✓ New boards from U. Michighan have just started the test

But:

- Irradiation at 5 Gy/h is still ongoing:
- **goal is 3500 Gy for Linear LTM 8033 and 4619**
- **POL-PD will take 3000 Gy**
- New Linear Michighan boards will reach 3500 and 1500 Gy at 10 Gy/h

Results will be discussed in January after the end of the test