Abstract

The TID testing results of the first radiation hardened analog mixed-signal Power Driver with Rotation and Position Sensing IC, the LX7720, are presented. TID characterizations were performed on all the devices functions, the resolver ADC, floating current sensing, MOSFET drivers, demodulator drivers and supporting circuitry.

TID Testing on Microsemi Integrated Motor Controller LX7720

Power Driver with Rotation and Current Sensing

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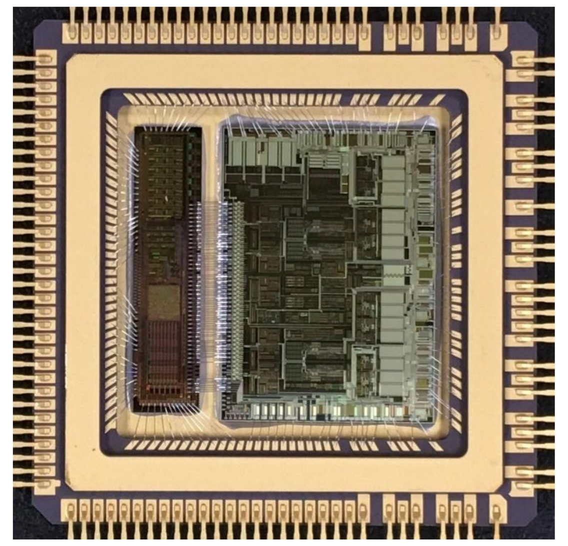
Conclusion

The results exhibit the TID hardening goal for the device. The TID performance at 100krad of the different blocks of this highly integrated device is consistent with the pre-radiation results.

I. INTRODUCTION

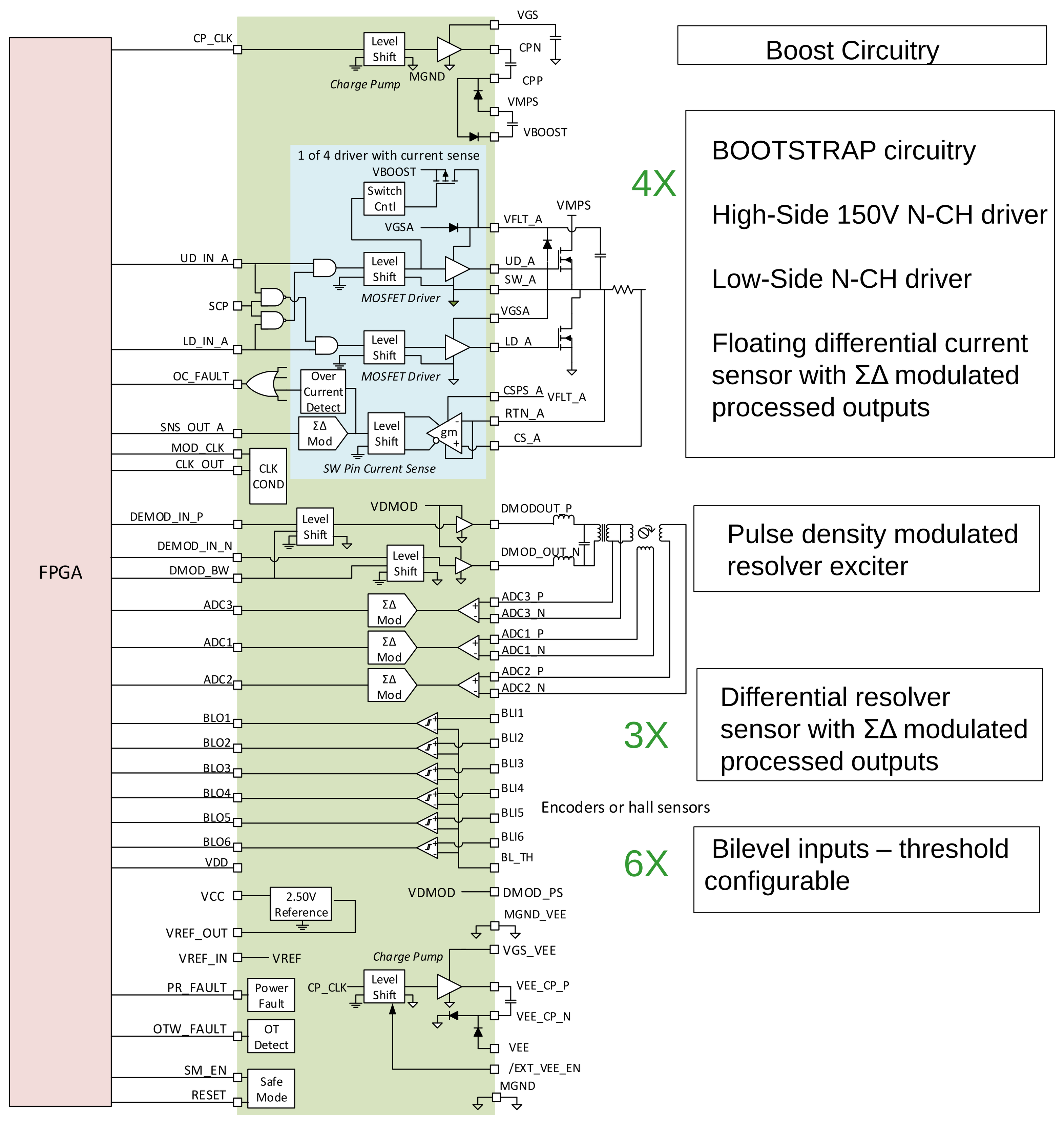
- The LX7720 is a power driver with rotation and position sensing.
- It contains four half-bridge N-CH MOSFET drivers and four floating differential current sensors.
- Also available are: three differential ADC sense inputs, pulse modulated resolver transformer driver and six bi-level logic inputs.
- Can be interfaced with an FPGA, microcontroller or other logic element.
- Manufactured as a dual die MCM solution in a custom 132-pin CQFP package, body 24mm*24mm.
- The LX7720 is designed to achieve the following radiation hardening goals:
  - Total Dose Objective: TID tolerance is greater than 100 krad (S_iO_2) – presented here
  - SEL/SEU Objective: SEL immune at >80 MeV.cm²/mg and 125℃, Strong SEE performance – Testing scheduled July 2018
  - ELDRS sensitivity Objective: tolerance greater than 50krad (S_iO_2) – Testing scheduled for January 2019
- Temperature range: -55℃ to 125℃. High temperature warning flag and thermal shutdown available.
- The LX7720 device is classified under EAR 9a515.e



II. LX7720 – RADIATION TOLERANT BY DESIGN

- The Microsemi hardening solution involves a series of test chips and careful device characterization prior to being used in analog designs. In addition, some primitive devices on a given process or inadequate biasing of devices can yield poor total dose results. Microsemi has developed a series of block design IP and a components library to overcome these issues.
- The LX7720 Controller is designed using two technology processes:
  - BI-CMOS process for analog precision circuitry,
  - Dielectric Isolated technology process capable of high voltage operation up to 350V, which is well beyond the absolute max rated operating voltage of the LX7720 of 150V.
- The design is partitioned to take advantage of both processes in terms of accuracy requirements and high voltage device ratings and radiation performance.
- The device is manufactured as a dual-die solution, co-packaged in a single package with interconnect bonds between the two dice.

LX7720 BLOCK DIAGRAM



III. LX7720 – TID TEST PLAN

- The LX7720 TID testing was performed at 100krad(S_iO_2) dose.
- The TID testing was completed at the Defense Microelectronics Activity (DMEA) Test Facility in McClellan, California, radiation source Co-60.
- The TID testing followed MIL-STD-883J Test Method 1019.9, Condition A with a dose rate of 50rad/s.
- Two devices were used for this test
- The devices used were part of the final samples lot.
- The devices were characterized pre-radiation and post radiation using production test program at Microsemi facility in San Jose

III. LX7720 TID RESULTS SUMMARY

100k TID Test Summary

- The LX7720 performance after 100krad(S_iO_2) exposure is overall very stable and comparable to pre-radiation.
- Results show very good results on all key blocks of the design:
  - Stable supplies currents consumptions.
  - Stable under-voltage detection thresholds.
  - Stable internally regulated voltages.
  - Very small increase (<13%) in drivers impedance.
  - Stable overall ADCs performance with only small THD degradation.
  - Stable overall performance for the floating current sense with only small THD and INL degradation.
- Results also exhibit a few small shifts:
  - The MOSFET drivers delays shift differently based on the bias conditions during irradiation. These shifts can be compensated with adequate dead-time in the driving signals.
  - The demodulator drivers delays shift differently based on the bias conditions during irradiation. Delays asymmetry can be minimized by not driving static opposite signals for very long periods.
  - The floating current Sense offset can vary by up to 1.5%FSR. If necessary, the zero point can be calibrated at system level.
- Thus, we conclude that the performance of the LX7720 is TID tolerant up to 100krad(S_iO_2).
- Below graphs show data on key parameters on 2 tested devices.

	Pre-Radiation Specification				SN172		SN163		
Parameters	**Min**	**Typ**	**Max**	**Units**	**Pre**	**Post 100k**	**Pre**	**Post 100k**	**Comments**
Operating Current									
VCC Current, All ADCs and CS off		15		mA	15.8	15.6	15.8	15.5	Very Stable
VCC Current, All ADCs and CS on		98		mA	98.8	98.2	97.5	96.2	Very Stable
VGS Current, All LD_IN# & UD_IN# high		26		mA	27.3	26.0	26.3	24.7	Very Stable
VEE Current, All UD_IN# & LD_IN# low		-14		mA	-13.8	-13.3	-13.4	-12.8	Very Stable
DMOD_PS Current, DMOD_BW high		10		mA	9.2	7.8	9.6	7.8	Slight Decrease
Internally Regulated Voltages									
VREF regulator	2.48	2.5	2.52	V	2.499	2.500	2.500	2.501	Very Stable
VEE Inv Charge Pump drop		2.7		V	1.95	2.09	1.89	2.06	Slight Increase
VBOOST Charge Pump Drop		1.6		V	1.71	1.73	1.68	1.72	Very Stable
VBOOST-VFLT# switch		0.4		V	0.25-0.26	0.30-0.42	0.25-0.27	0.30-0.42	<0.16V increase
MOSFET Driver									
UD Impedance VFLT# to UD_#	0.85		10.0	Ω	3.4-4.7	3.7-5.1	3.6-4.8	3.8-5.2	<13% increase
UD Impedance UD_# to SW_#	0.85		10.0	Ω	3.7-4.4	4.0-4.7	3.8-4.6	4.1-4.8	<9% increase
LD Impedance VGS# to LD_#	0.85		10.0	Ω	5.4-6.7	5.8-7.1	5.4-6.7	5.8-7.0	<9% increase
LD Impedance LD_# to MGND	0.85		10.0	Ω	5.0-6.4	5.3-6.9	5.0-6.4	5.3-6.8	<8% increase
UD Prop Delay	140	300	500	ns	240-275	228-527	218-304	206-609	Some increase
LD Prop Delay	140	300	500	ns	250-270	243-439	253-276	229-515	Some increase
ADC Converters									
Gain error	-0.8	+/-0.6	0.8	%	-0.09-0.29	-0.08-0.31	-0.46-0.19	-0.43-0.24	Stable
Offset error	-0.29	+/-0.053	0.29	%FSR	-0.02-0.00	-0.05-0.01	-0.03-0.01	-0.05-0.07	<0.07%FSR variation
Integral Non-Linearity (24MHz)	-0.06	+/-0.02	0.06	%FSR	-0.010-0.007	-0.015-0.010	-0.010-0.007	-0.019-0.016	<0.009%FSR increase
SNR 1kHz BW (24MHz)	TBD	100		dB	99.2-100.1	98.0-112	99.3-100.2	98.4-98.8	<1.3dB decrease
THD at 1kHz-1.6Vpp (24MHz)		-78	TBD	dB	-79.6- -78.5	-77.3- -72.0	-79.2- -76.5	-77.7- -68.1	<8dB degradation
Floating Current Sense									
Gain error	-1.3	+/-0.5	1.3	%	-0.35- -0.23	-0.36-0.14	-0.23-0.11	-0.32-0.12	Stable
Offset error	-0.7	+/-0.2	0.7	%FSR	-0.08-0.13	-0.27- 0.8	-0.10-0.11	-1.4- -1.1%	<1.4%FSR variation
Integral Non-Linearity (24MHz)	-0.07	+/-0.03	0.07	%FSR	-0.02-0.04	-0.04-0.06	-0.02-0.03	-0.04-0.06	<0.035%FSR degradation
SNR 4kHz BW (24MHz)	TBD	78		dB	77.0-78.0	75.0-77.7	78.0-78.5	75.5-77.2	<3dB decrease
THD at 1kHz-0.4Vpp (24MHz)		-66	TBD	dB	-66.6- -65.1	-66.0- -61.8	-66.8- -65.2	-66.3- -62.0	<5dB degradation
Demodulator driver									
Impedance DMOD_PS to DMOD_OUT_#	0.89	2	5	Ω	2.2-232	2.3-2.4	2.1-2.2	2.3-2.4	<10% increase
Impedance DMOD_OUT_# to MGND	0.89	2	5	Ω	1.8-2.0	2.0-2.2	1.8-1.9	1.9-2.1	<2% increase
Prop Delay, DMOD_BW High	70		155	ns	98-107	122-175	97-106	117-178	<70ns increase