



Linear Technology Corporation

Scalable solutions for latest NXP QorIQ Processors

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For NXP use only



Power Solutions for QorIQ Processors

- Overview of recent designs for LayerScape Processors
 - LS1088
 - LS1043
 - T1023
- Solutions from Linear Technology
 - PMBus Regulators and Controllers
 - uModules
 - Silent Switchers
- Design Tools
 - Solutions reference website: www.linear.com/nxp
 - LTpowerplanner
 - LTpowerCAD
 - LTpowerplay

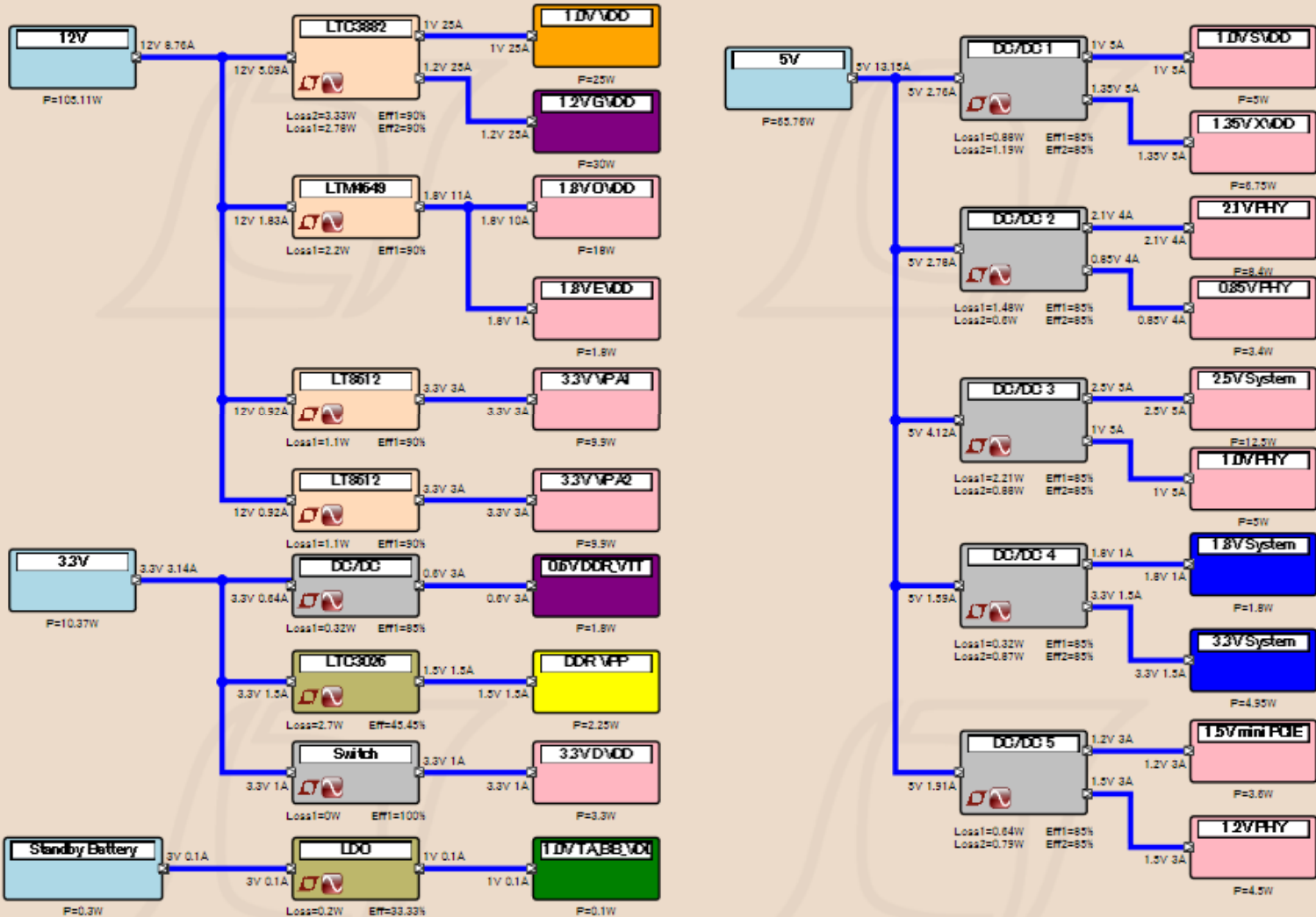
A variety of solutions for NXP QorIQ and T-series processors



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LS1088 (QDS and RDB)

QorIQ LS1088A-RDB

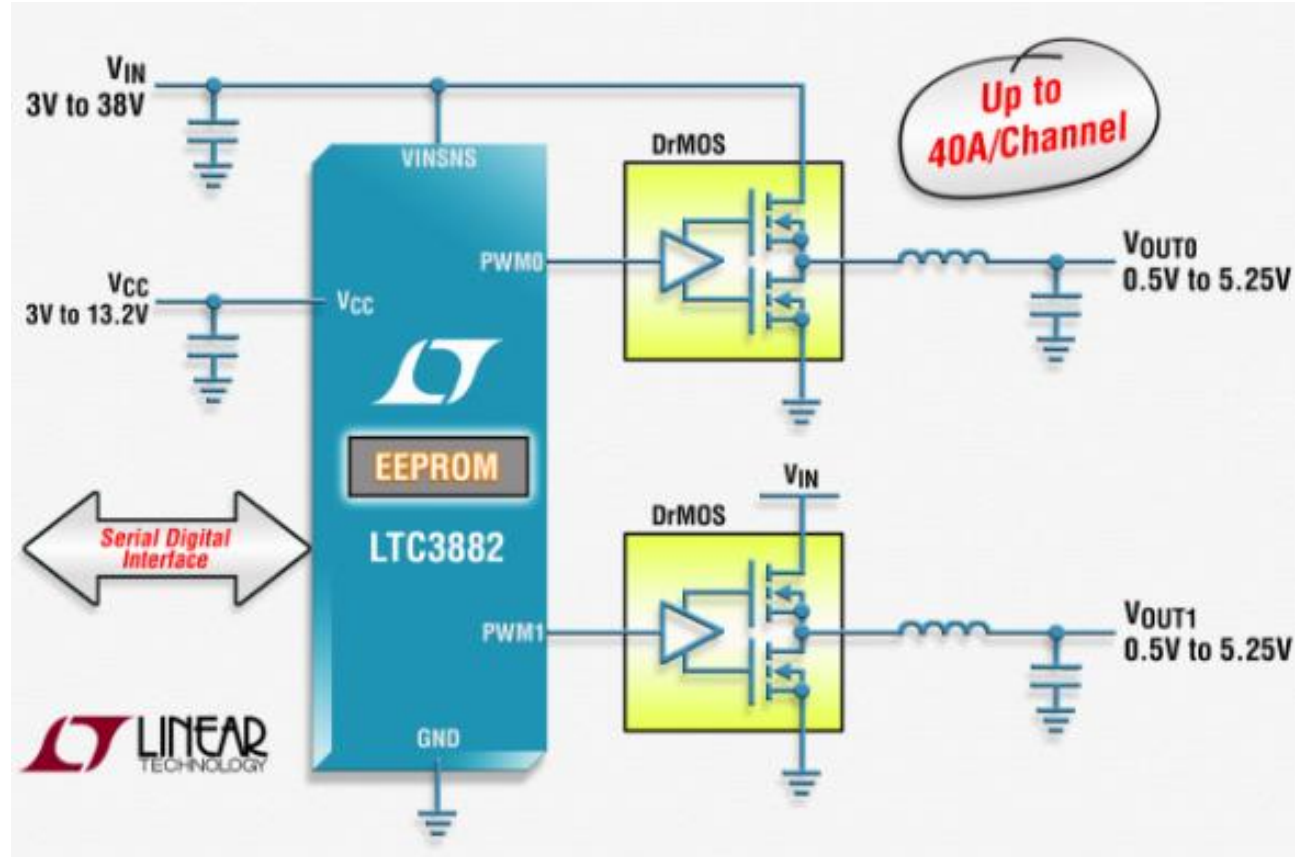


- Start-Up Sequence
1. Green
 2. Blue
 3. Pink
 4. Orange, Yellow
 5. Purple

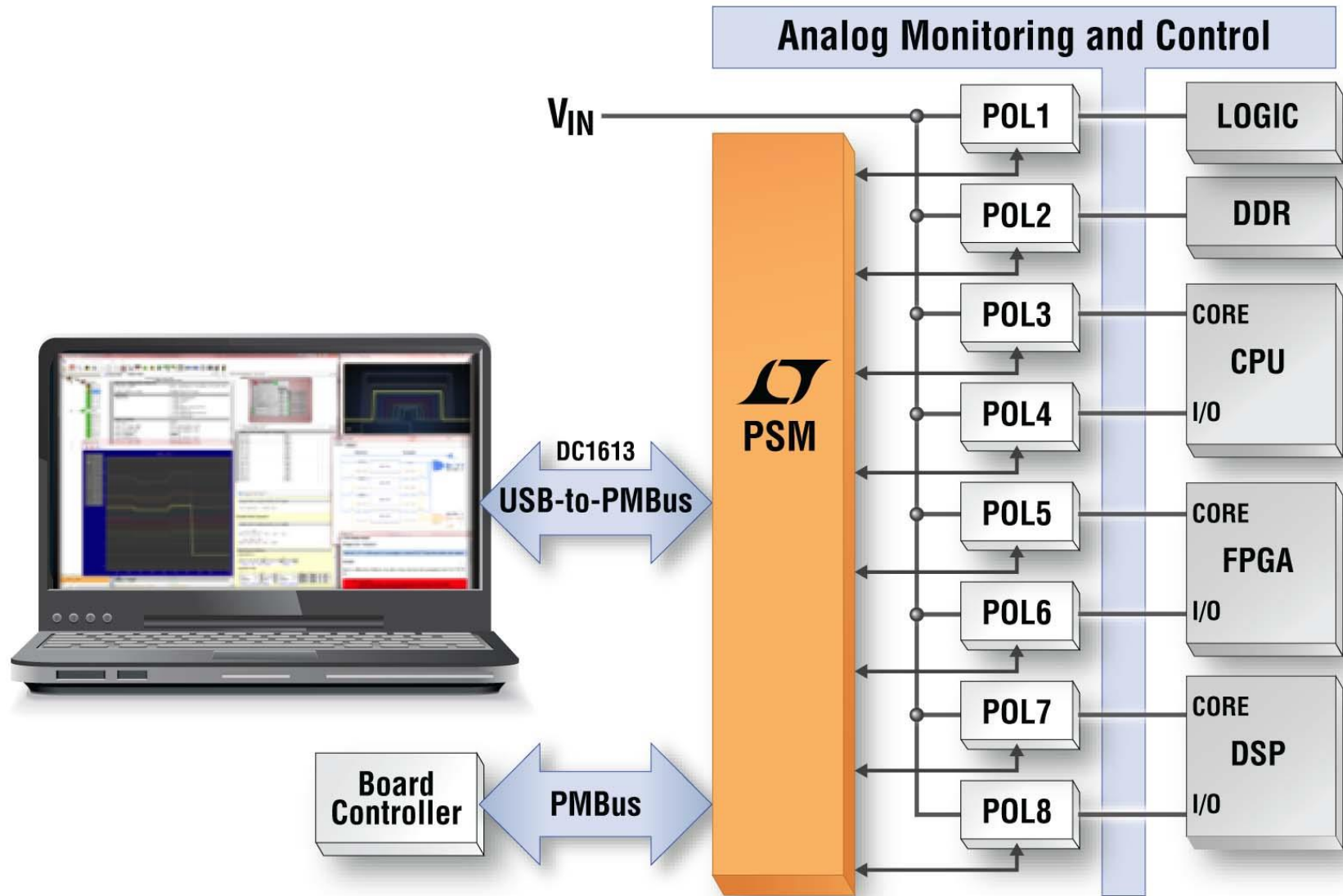
Summary Report
 Total Pin = 181.54W
 Total Pout = 157.95W
 Total Ploss = 23.59W
 Total Efficiency = 87%
 Total Size = 13Units²

LTC3882: Dual Output PolyPhase Step-Down DC/DC Voltage Mode Controller with Digital Power System Management

- PMBus/I2C Compliant Serial Interface
 - Monitor Voltage, Current, Temperature and Faults
 - Digitally Programmable Voltage, Current Limit, Soft-Start/Stop, Sequencing, Margining, AVP, UV/OV Thresholds
- VIN: 3V - 38V
- VOUT: 0.5V - 5.25V
- ±0.5% Output Voltage Accuracy
- Switching Frequency: 250kHz - 1.25MHz
- Accurate PolyPhase® Current Sharing
- Internal EEPROM with Fault Logging
- Optional Resistor Programming for Key Parameters



What is Power System Management (PSM)



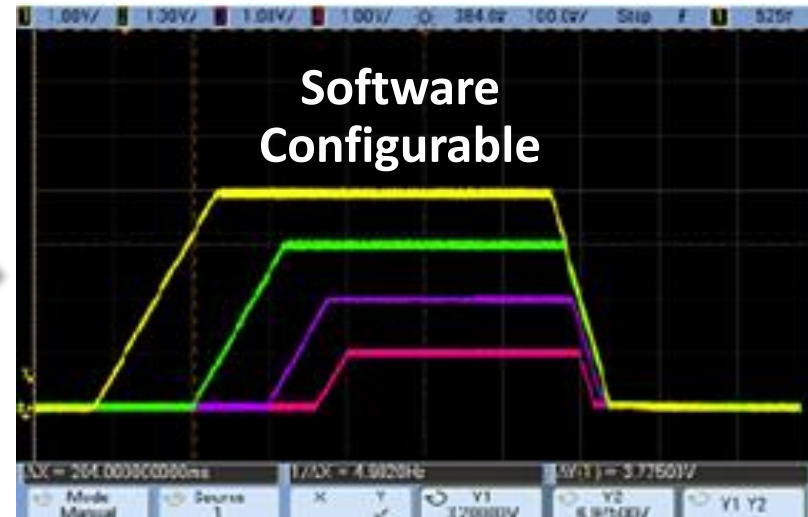
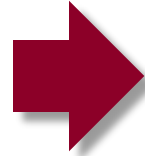
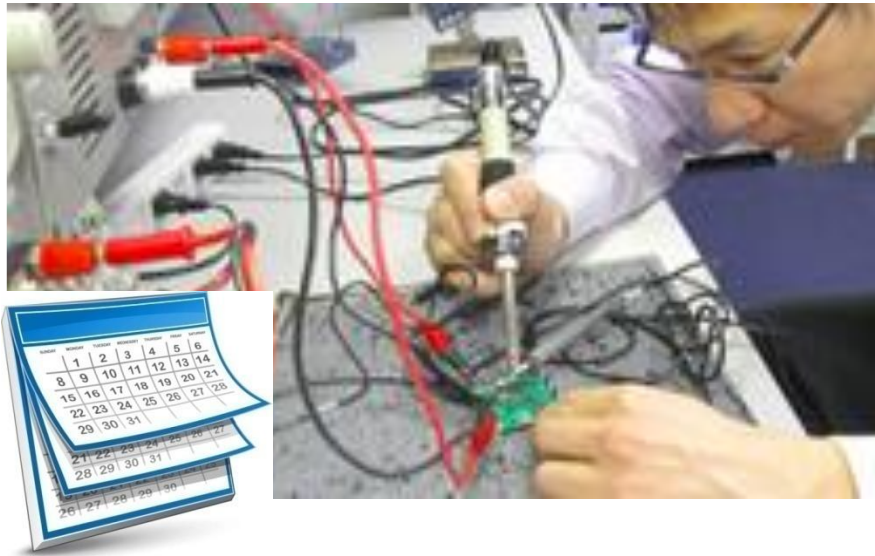
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Digital Board Trends & Challenges



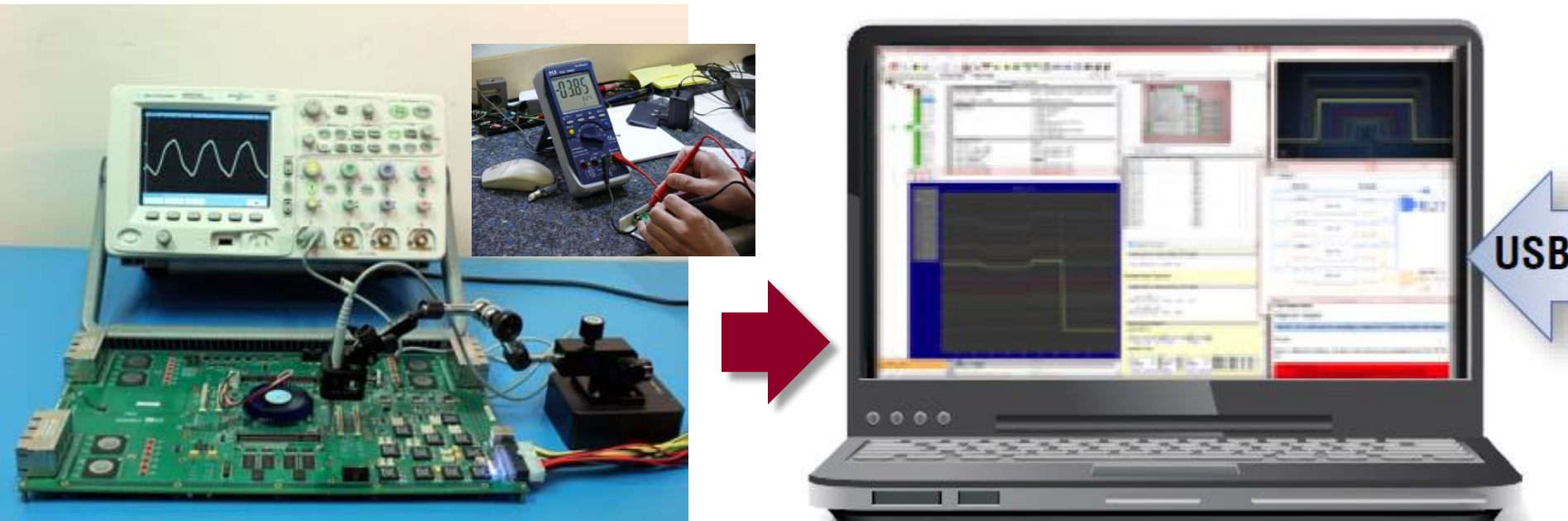
- Nanometer Processes: 20nm → 10nm
 - Supplies: 20 to 50, Sub-1V, 100A+, 1% to 3% Tolerance
- Hotter Boards and Chassis – 100°C
- Shortening Design Cycles and parameters determined empirically
- Complex & Changing Power-Up/Down Sequencing

PSM System Benefit: Reduced Time to Market



- Single IC
- PSM Delivers Software Model of Rapid Prototyping to Hardware
- Easy Last-Minute Tweaks Avoid Board Spins & Project Slips
- Field Upgrades Via Firmware

PSM System Benefit: Insight into Power System



- From Computer Instead of Voltmeters & Oscilloscopes
- Improve Board Reliability
- Correlate Failures to Voltage & Current Patterns
- Monitor and Optimize Energy Consumption

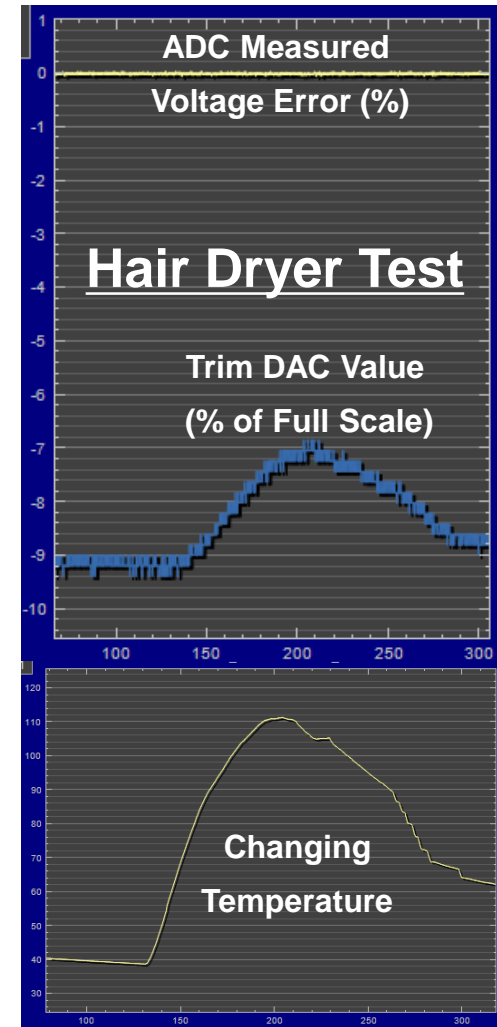
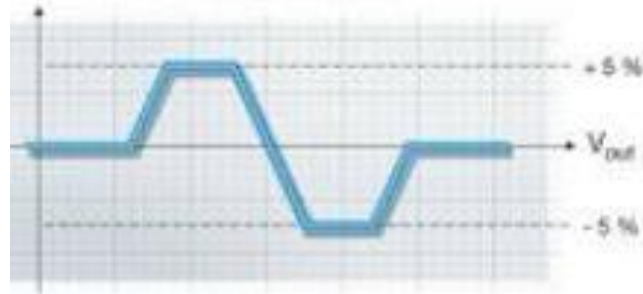
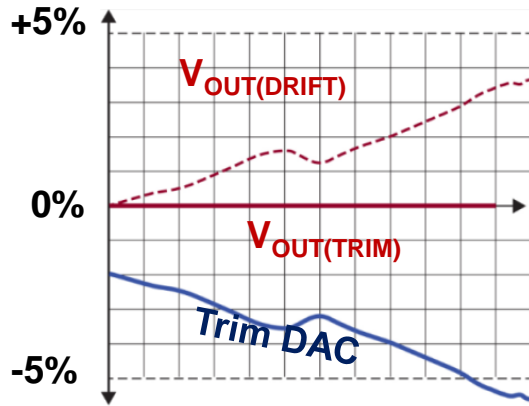
PSM System Benefit: Speed Up Failure Analysis



- EEPROM Black Box Recorder (I/V/Temp)
- Remote Debug

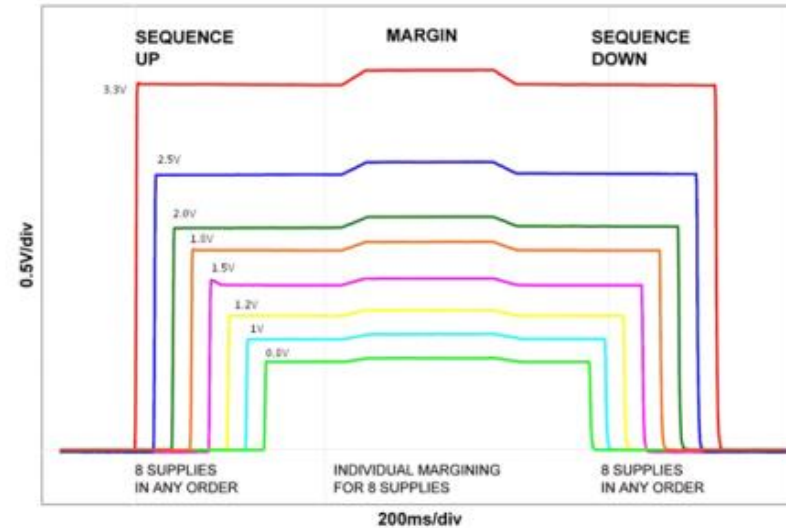
PSM Design Benefits

- Trim/Margin/Monitor Supply to $\pm 0.25\%$ Precision

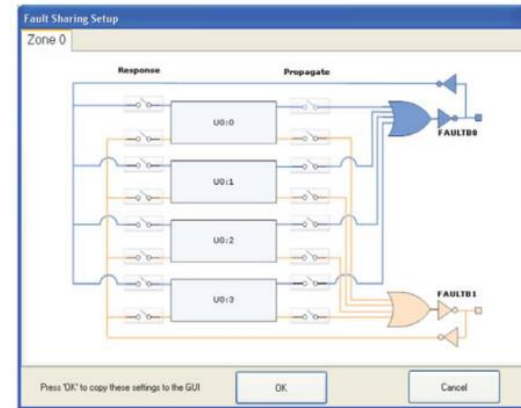


PSM Design Benefits

- Sequence/Track Multiple Rails Easily



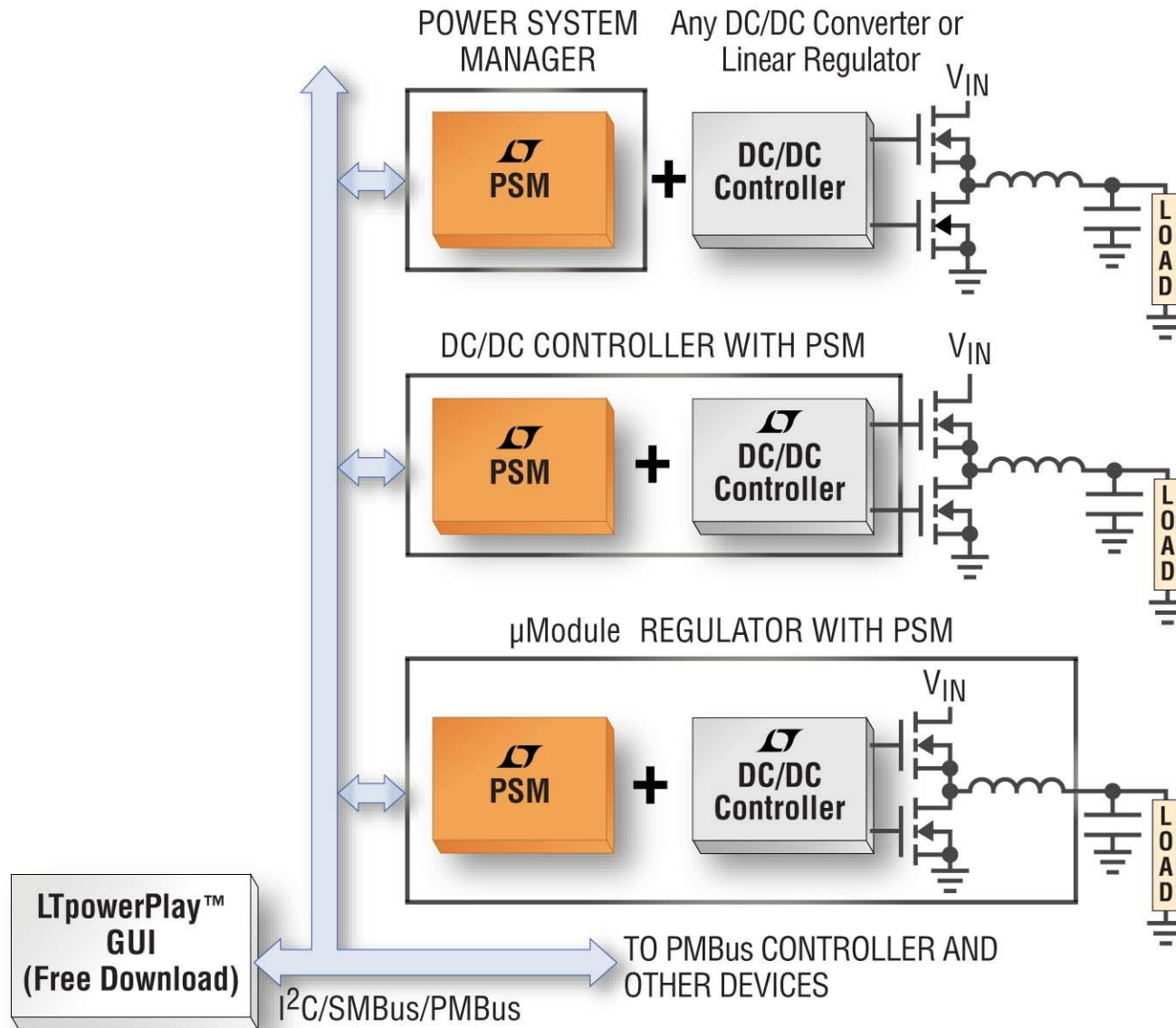
- UV/OV/UC/OC/UT/OT Supervise to Protect Expensive Electronics
- Monitor V_{IN} , I_{IN} , P_{IN} , E_{IN} , V_{OUT} , I_{OUT} , P_{OUT} , Temperature
 - Monitor Board Health, Power Consumption vs Load/Traffic
- Fault Log & Manage
 - Log Faults to EEPROM
 - Response: Ignore, Delayed, Latchoff, Retry 1-6x or ∞
 - Supply Zones for Fault Propagation



LTC PSM Highlights

- Best-in-Class $\pm 0.25\%$ Voltage Accuracy
- Interoperable Products
 - Power System Managers
 - DC/DC Controllers with PSM
 - Fully Integrated μ Module Regulators
- LTpowerPlay GUI: Engineering-Level Development Environment
- PMBus Compliant Commands Over I²C/SMBus Digital Interface
- EEPROM for Configuration and Black Box Fault Logging
- Autonomous Operation—No Software Coding Required
- Coordinate Sequencing and Fault Management Across PSM Devices
- Reduced BOM Cost and Validation Effort

LTC PMBus Solutions



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Power System Management (PSM) Lineup

- Power System Manager Companion IC

- Add Power System Management to any power supply

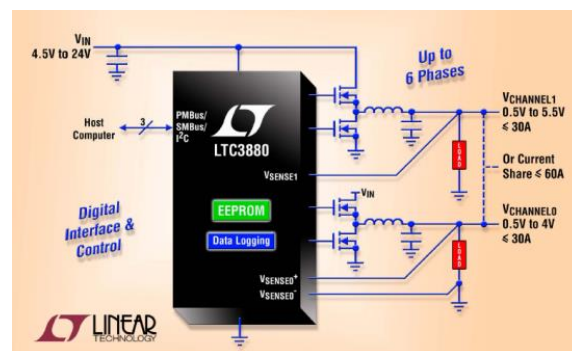
- LTC2977: Octal Power System Manager
- LTC2974: Quad Power System Manager
- LTC2975: Quad Power System Manager with Input Energy Meter
- LTC2980: 16 channel Power System Manager
- LTM2987: 16 Channel Power System Manager with Integrated Filters



- DC/DC Converters with PSM

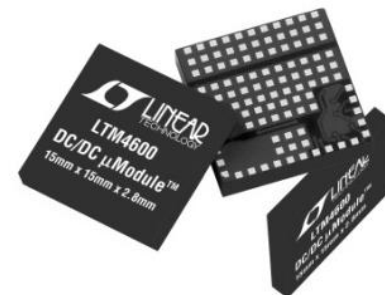
- Analog Control Loop plus Power System Management

- LTC3887: Dual Output Poly-Phase Current Mode DC/DC
- LTC3883: Poly-Phase Current Mode DC/DC
- LTC3882: Dual Output Poly-Phase Voltage Mode DC/DC
- LTC3884: Dual Output Sub-milliohm DCR Current Mode DC/DC



- DC/DC μ Modules with PSM

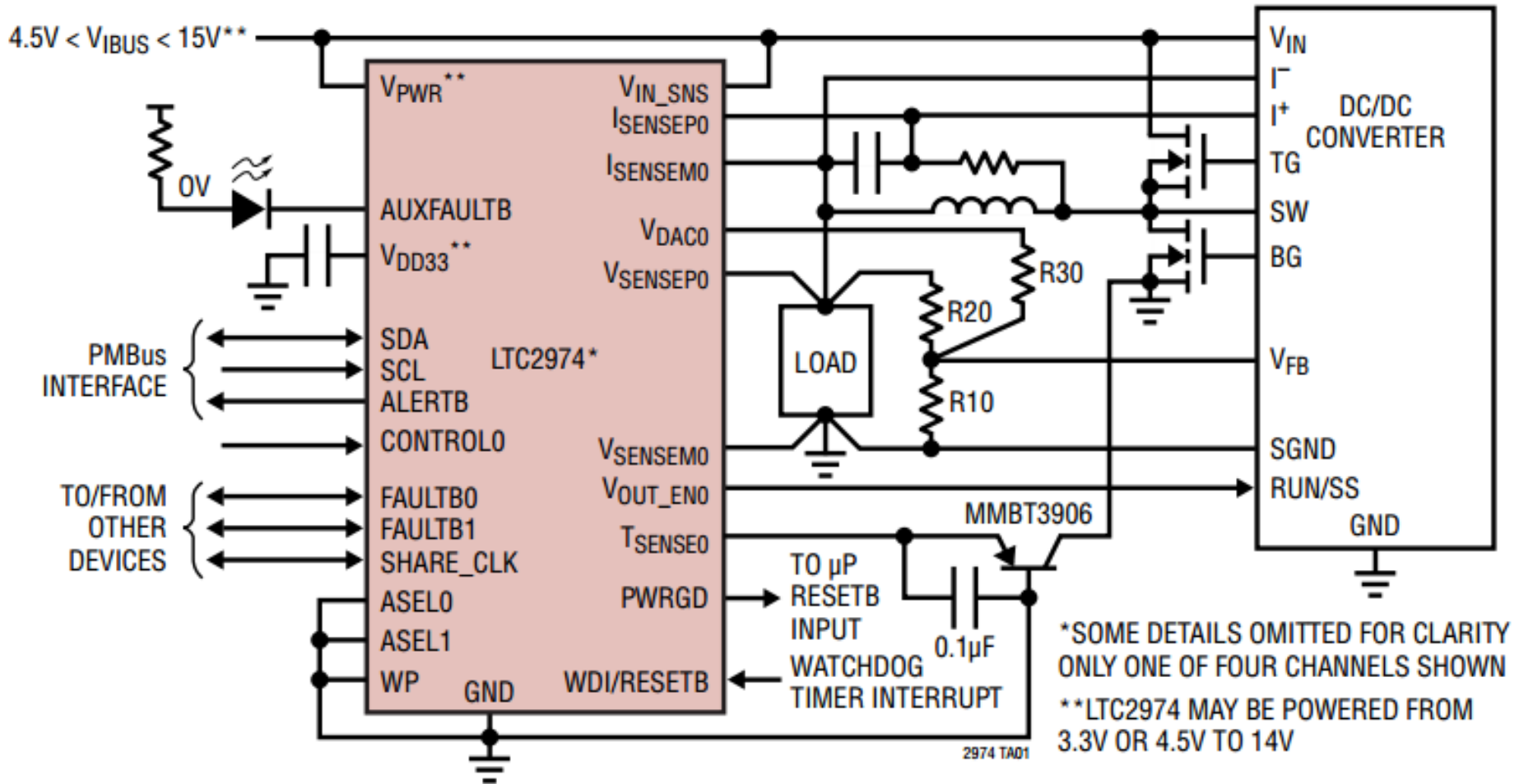
- LTM4675 (Dual 8A Output) in 11.9mmX16mm BGA
- LTM4676 (Dual 13A Output) in 16mmx16mm BGA
- LTM4677 (Dual 18A Output) in 16mmX16mm BGA



PSM Companion IC

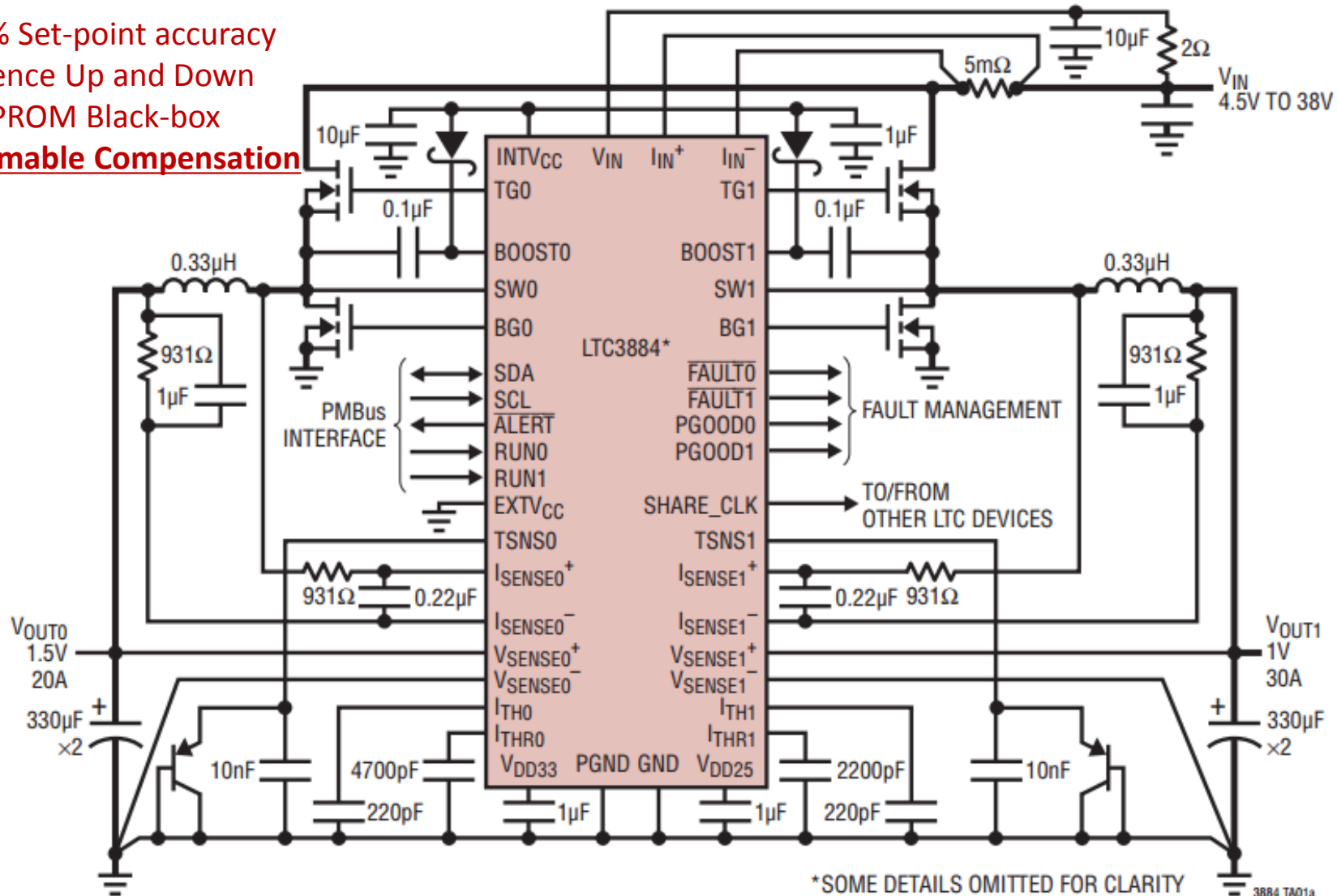
- $\pm 0.25\%$ Set-point accuracy
- Sequence Up and Down
- EEPROM Black-box

4-Channel PMBus Power System Manager



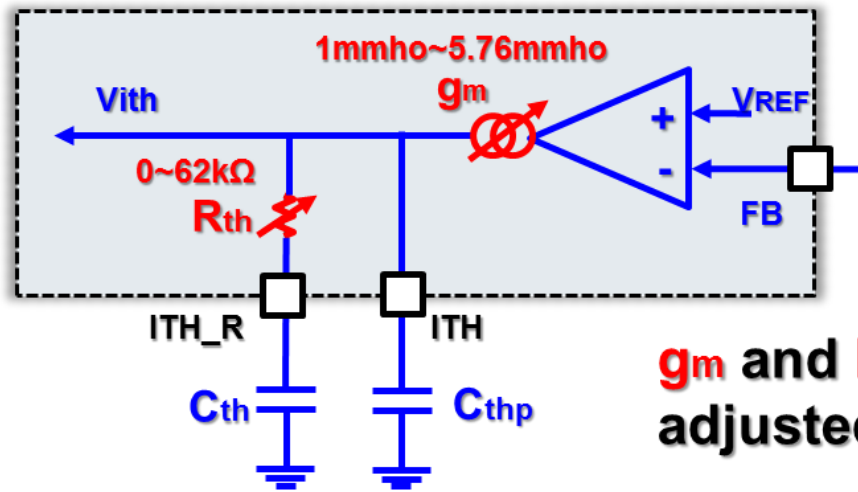
DC/DC Converter with PSM

- $\pm 0.5\%$ Set-point accuracy
- Sequence Up and Down
 - EEPROM Black-box
- **Programmable Compensation**

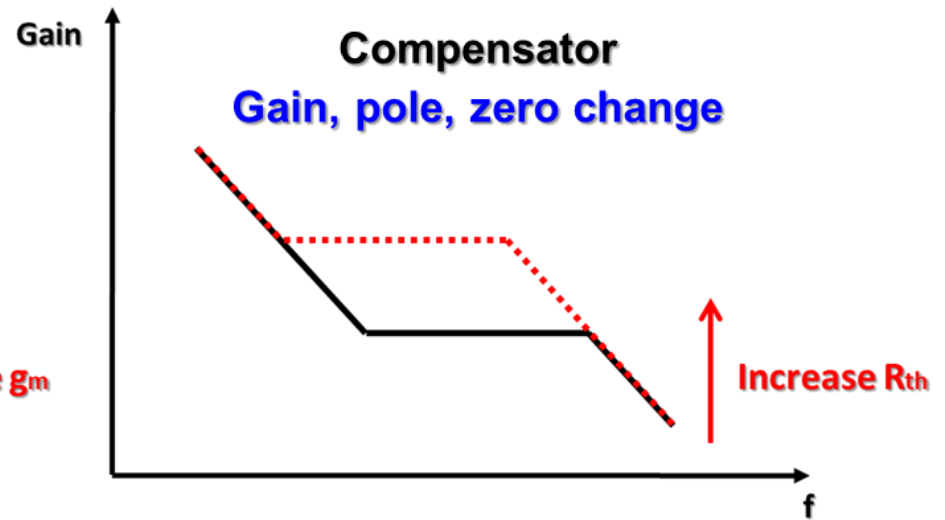
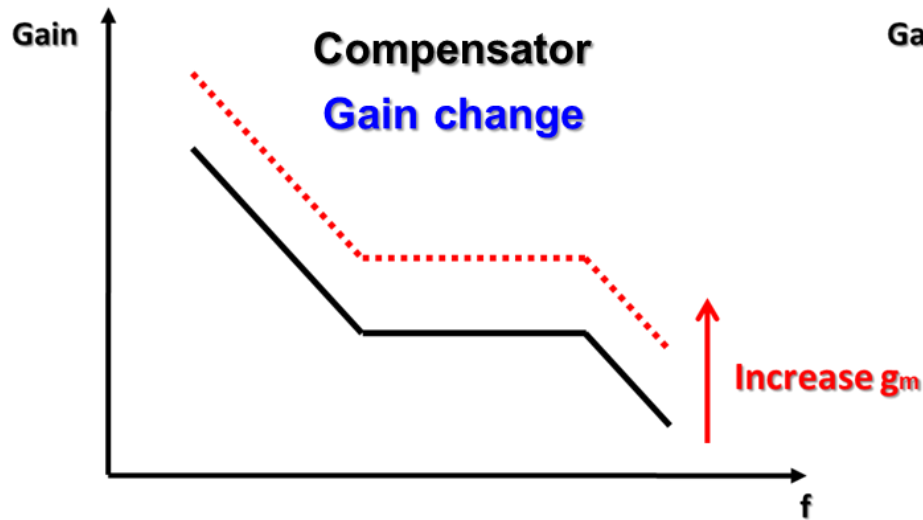


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LTC3884: Programmable Compensation

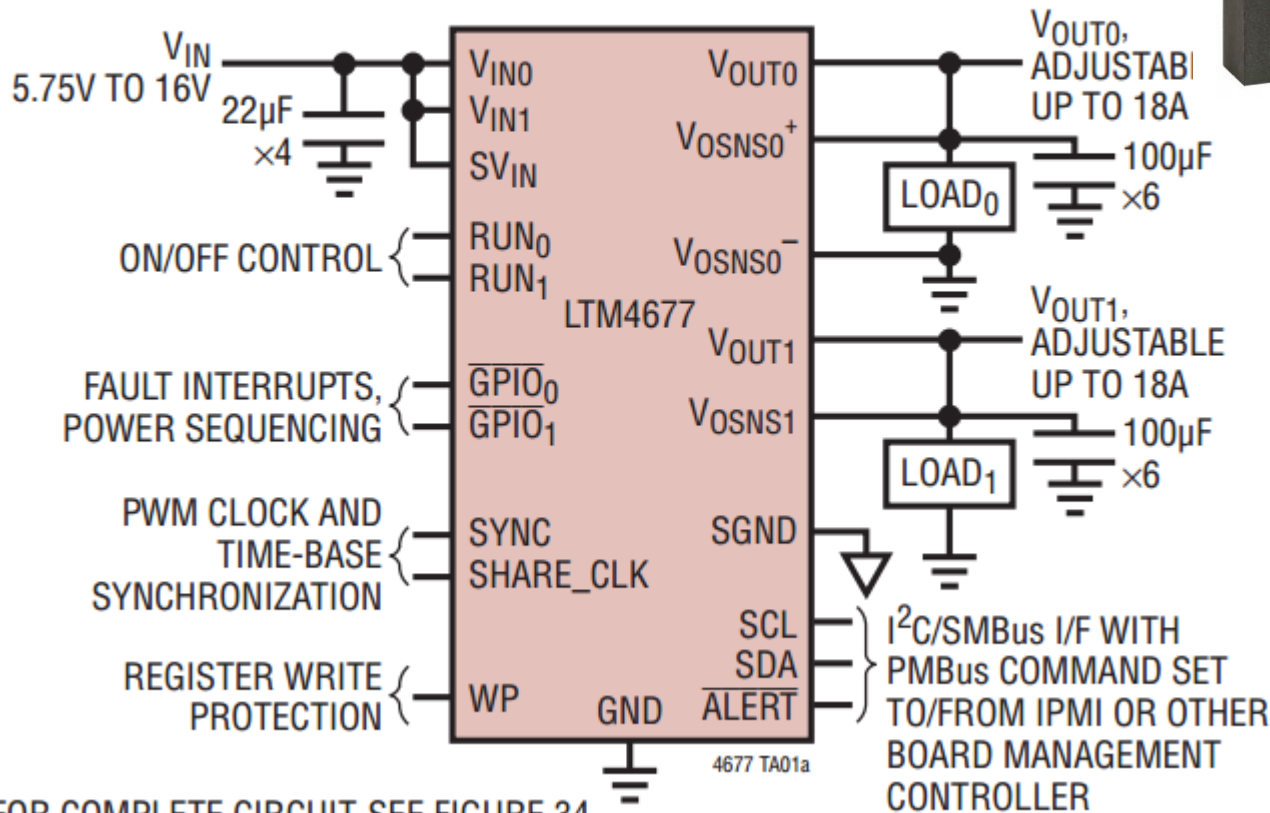
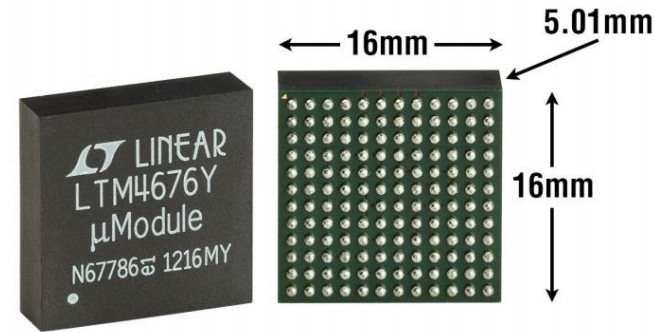


g_m and R_{th} can be adjusted through PMBus



DC/DC Integrated uModule with PSM

Dual 18A μ Module Regulator with Digital Interface for Control and Monitoring*



*FOR COMPLETE CIRCUIT, SEE FIGURE 34

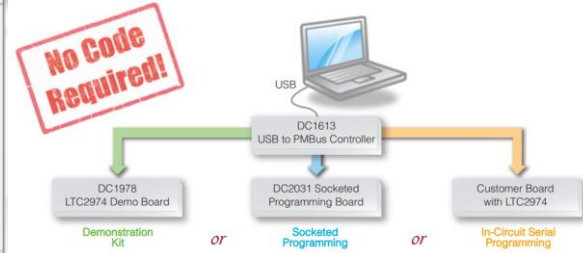
One GUI to rule them all...

The screenshot displays the LTpowerPlay v1.0.150.2 [LTC2974] GUI with several panels open:

- System:** Shows a tree view of chips including U0 (7h5E) and U1 (7h5D).
- PI Config:** Configured for 'bd2-3.3V (Paged-Global)'. Shows 'Output Voltage' settings with VOUT_MAX at 3.800V and VOUT_COMMAND at 3.900V.
- Telemetry:** Displays real-time data for 'bd2-3.3V (Paged-Global)'.

Telemetry - Input Voltage	Value
MFR_VIN_PEAK_LTC2978	12,1250 V
READ_VIN	12,1094 V
MFR_VIN_MIN_LTC2978	12,0938 V
- Chip Dashboard --U1 (7h5D):** Shows 'Ch 0' with 'VOUT' at 0.0000 V and 'IOUT' at 0.00 A. Temperature is 31.91 °C. Other channels show 0.00 V / 0.00 A and 1.20 V / 0.04 A.
- Idealized On/Off Waveforms:** Shows a plot for 'bd2-3.3V' with ON and OFF states.
- Telemetry Plot:** Shows a plot for 'READ_VOUT' with a y-axis from -0.5 to 4 and an x-axis from 650 to 655.
- Register Information:** Shows 'Description: DC/DC converter output voltage (V) read back as measured by the ADC.' and 'Register Info: Command Code: 0x8B'.
- Fault Sharing Setup:** Shows a logic diagram for 'Zone 0' with 'bd-3.3V', 'bd-2.5V', 'bd-1.8V', and 'bd-1.2V' inputs leading to 'FAULTB' and 'FAULTS' outputs.
- Read Protocol sequence:** Shows a sequence of I2C commands: 'write PAGE to 0' and 'read READ_VOUT'.
- [8 rails] READ_VOUT:** Shows a table of output voltages for all rails.

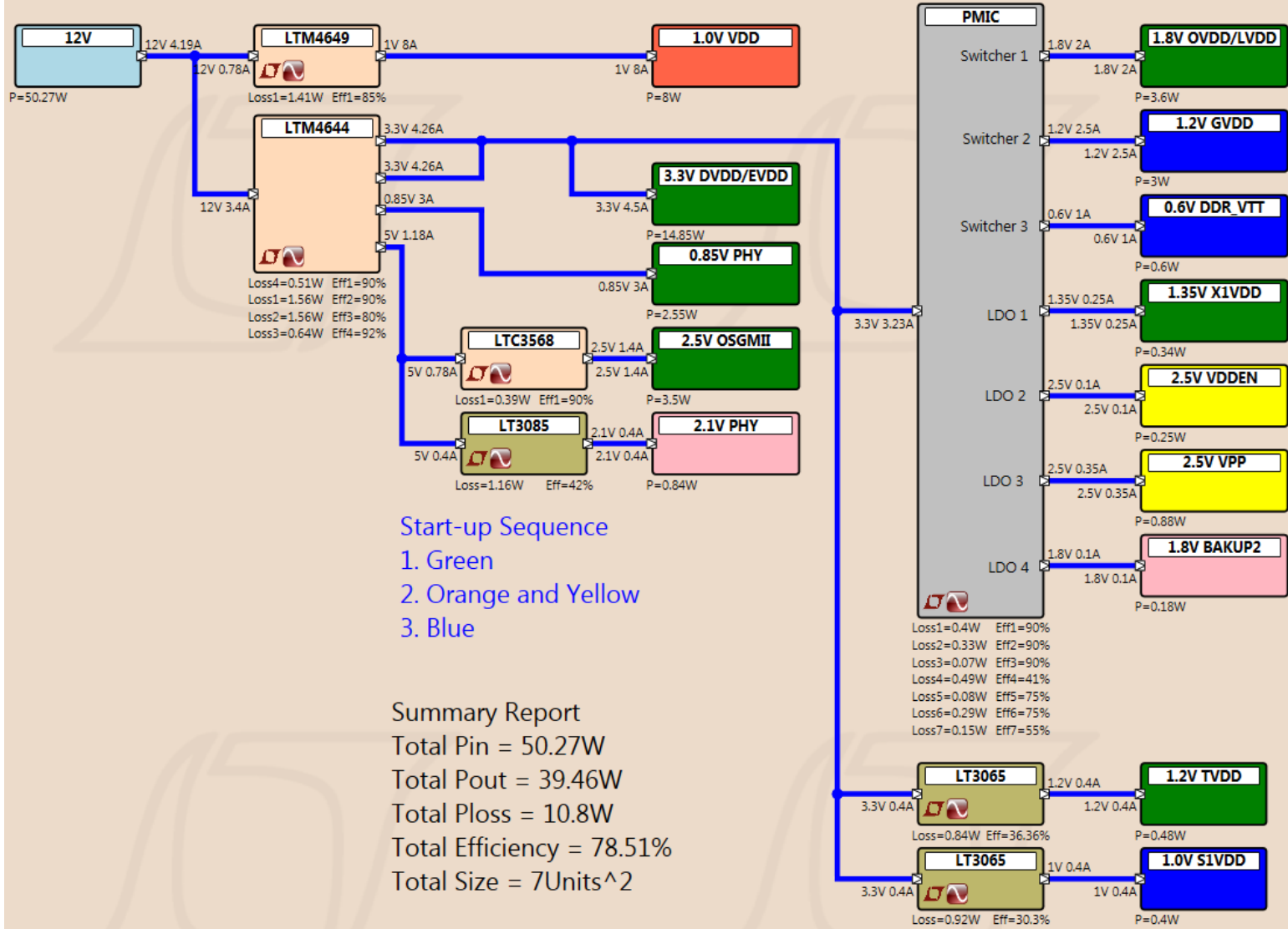
RAIL	READ_VOUT (All Pages in System)
bd1-3.2V	3,1997 V
bd1-2.4V	2,4000 V
bd1-1.7V	1,7009 V
bd1-1.1V	1,0997 V
bd2-3.3V	0,0000 V
bd2-2.5V	0,0000 V
bd2-1.8V	0,0000 V
bd2-1.2V	1,1996 V



- View and change registers for board bring up
- Data log the system for long term testing
- Test sample code and functionality
- **Remote Debugging**

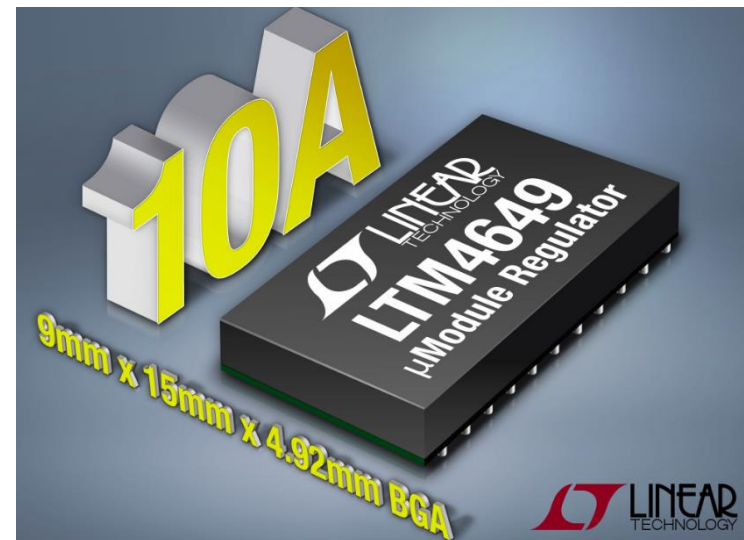
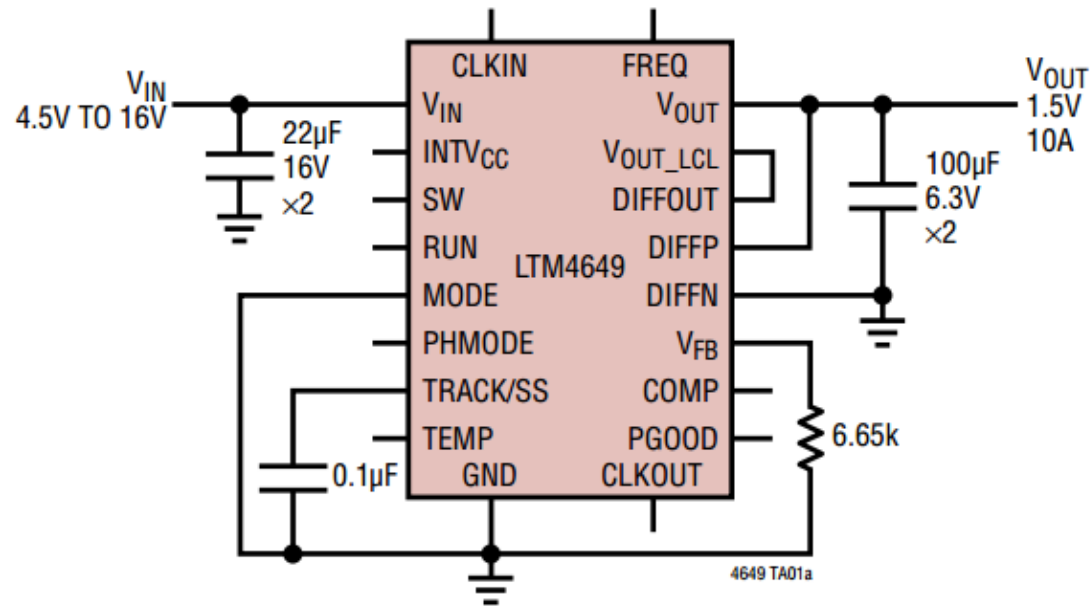
LS1043

QorIQ LS1043A-RDB



LTM4649: 10A Step-Down DC/DC μ Module Regulator

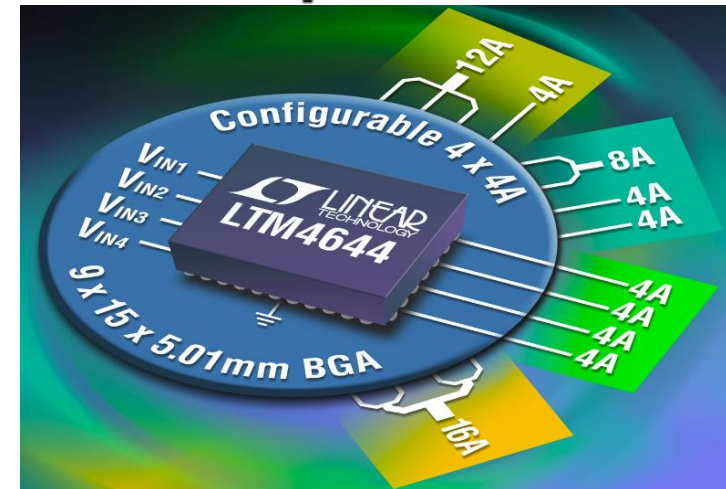
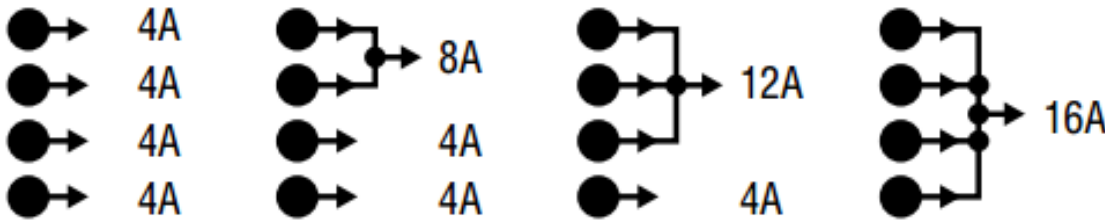
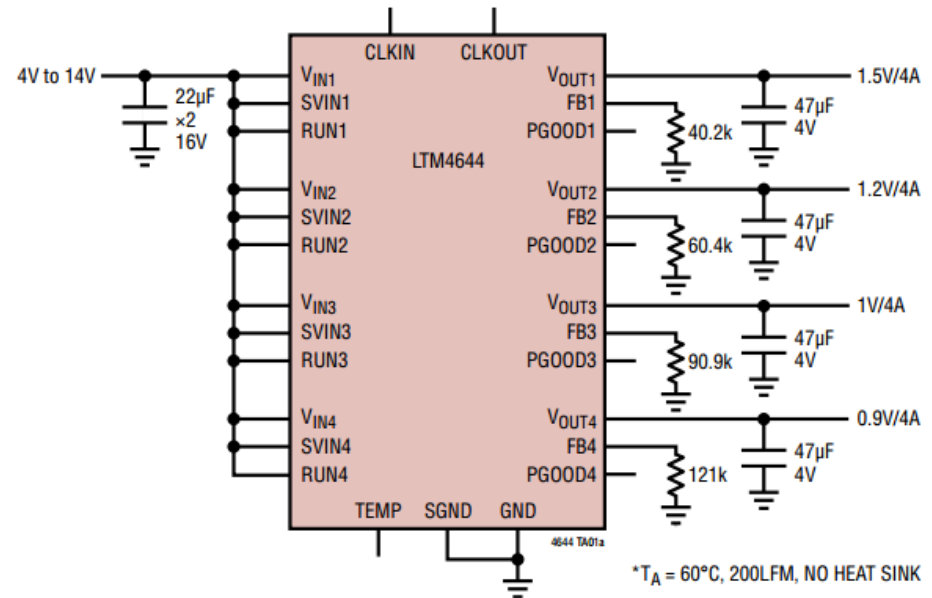
- 10A DC Output Current
- V_{IN} : 4.5V - 16V
- V_{OUT} : 0.6V - 3.3V
- No Heat Sink or Current Derating Up to 85°C Ambient Temperature
- $\pm 1.5\%$ Total DC Voltage Output Error
- Multiphase Operation with Current Sharing
- Remote Sense Amplifier



LTM4644: Quad 4A Step-Down DC/DC μ Module Regulator

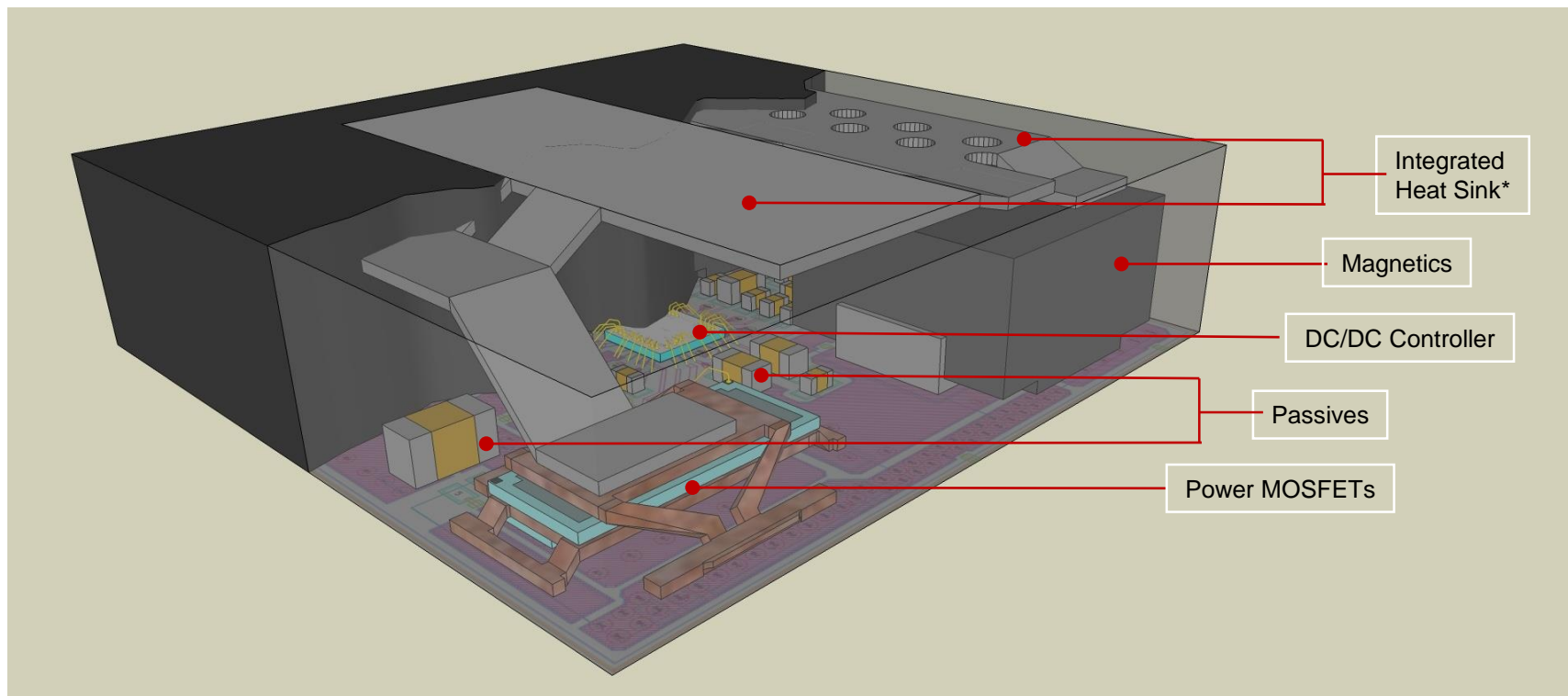
4V to 14V Input, Quad 0.9V, 1V, 1.2V and 1.5V Output DC/DC μ Module Regulator*

- Quad 4A DC Output Current
- VIN: 4V - 14V
- VOUT: 0.6V – 5.5V
- Up to 5.5W Power Dissipation
- $\pm 1.5\%$ Total DC Voltage Output Error
- Multiphase Operation with Current Sharing



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What is a μ Module Power Product?

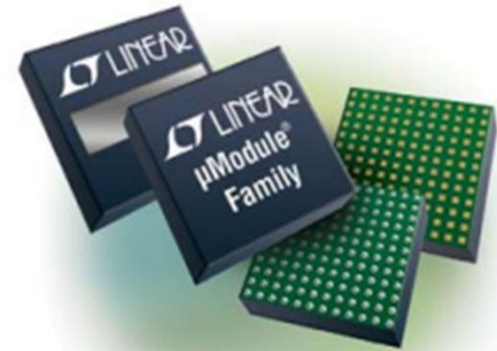
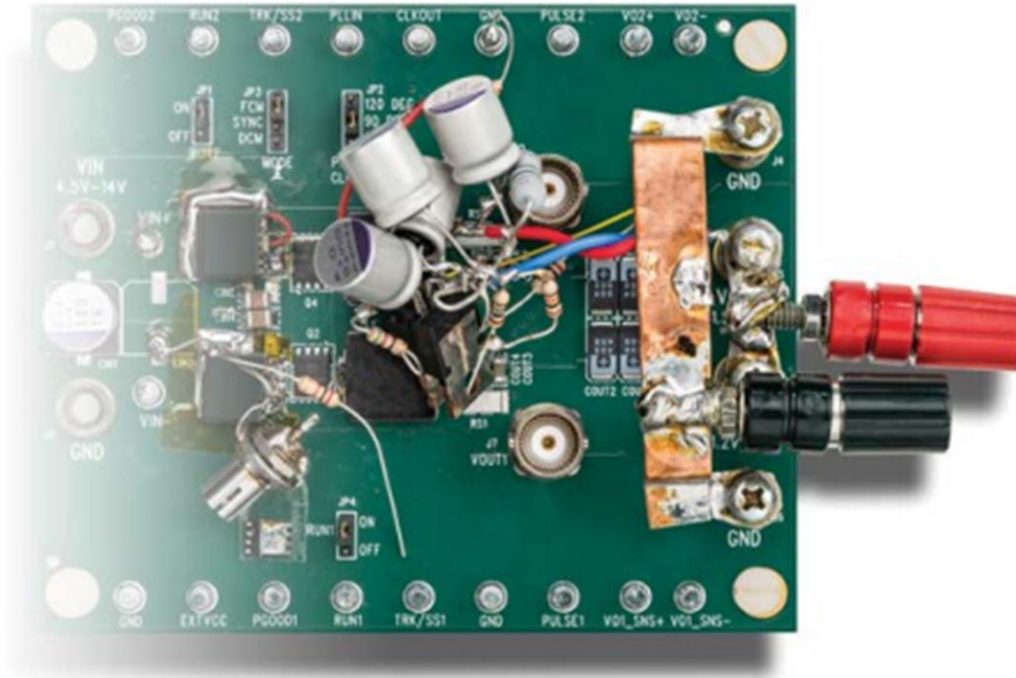


A μ Module[®] Power Product Simplifies Implementation, Verification, and Manufacturing of Complex Power Circuits by Integrating the Power Function in a Compact Molded Plastic Package

* Example: LTM4620, LTM4620A, & LTM4637 step-down μ Module regulators

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Time to market



Complete Power System-in-a-Package

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Reliability

OPERATING LIFE TEST					
PACKAGE TYPE	SAMPLE SIZE	OLDEST DATE CODE	NEWEST DATE CODE	K DEVICE HRS (+125°C) ¹	No. of FAILURES ^{2, 2}
BGA 15X09	75	1228	1228	75	0
BGA 15X15	529	1141	1227	452	0
LGA 15X09	941	0634	1247	903	0
LGA 15X15	2448	0452	1223	2294	0
Totals	3593	-	-	3,727	0

HIGHLY ACCELERATED STRESS TEST AT +131 DEG C /85% RH					
PACKAGE TYPE	SAMPLE SIZE	OLDEST DATE CODE	NEWEST DATE CODE	K DEVICE HRS (+85°C) ⁴	No. of FAILURES
BGA 15X09	304	1213	1300	1839	0
BGA 15X15	304	1235	1316	1927	0
LGA 15X15	1621	0645	1237	10690	0
Totals	2,229	-	-	14,456	0

TEMP CYCLE FROM -55 TO 125 DEG C					
PACKAGE TYPE	SAMPLE SIZE	OLDEST DATE CODE	NEWEST DATE CODE	K DEVICE CYCLES	No. of FAILURES
BGA06X06	154	1245	1306	192	0
BGA 15X09	533	1150	1306	568	0
BGA 11X15	77	1304	1304	77	0
BGA 15X15	1892	1148	1320	1651	0
LGA 15X09	983	0634	1317	1166	0
LGA 11X15	153	1304	1304	153	0
LGA 15X15	9413	0643	1319	11099	0
Totals	13,205	-	-	14,906	0

TEMP CYCLE FROM -65 TO 150 DEG C					
PACKAGE TYPE	SAMPLE SIZE	OLDEST DATE CODE	NEWEST DATE CODE	K DEVICE CYCLES	No. of FAILURES
BGA 15X09	149	1213	1228	259	0
BGA 15X15	1871	1141	1235	1520	0
LGA 06X06	100	0646	0749	55	0
LGA 15X09	5243	0634	1309	2706	0
LGA 15X15	31797	0513	1320	15756	0
Totals	39,160	-	-	20,296	0

THERMAL SHOCK FROM -65 TO 150 DEG C					
PACKAGE TYPE	SAMPLE SIZE	OLDEST DATE CODE	NEWEST DATE CODE	K DEVICE CYCLES	No. of FAILURES
BGA 15X09	228	1213	1306	266	0
BGA 15X15	1434	1141	1235	1068	0
LGA 15X09	4861	0634	1309	2332	0
LGA 15X15	25552	0332	1320	11509	0
Totals	32,075	-	-	15,175	0

- FIT Rate = 0.49
- MTBF = 232k years
- 3.7M Operating Life Device Hours
- 22.2M Power Cycles
- 35.2M Temperature Cycles
- 3.1M Board Mount Temp Cycles
- 29.8M Thermal Shock Cycles
- 43.1M Hours of High Temp Bake
- 14.5M Hours HAST

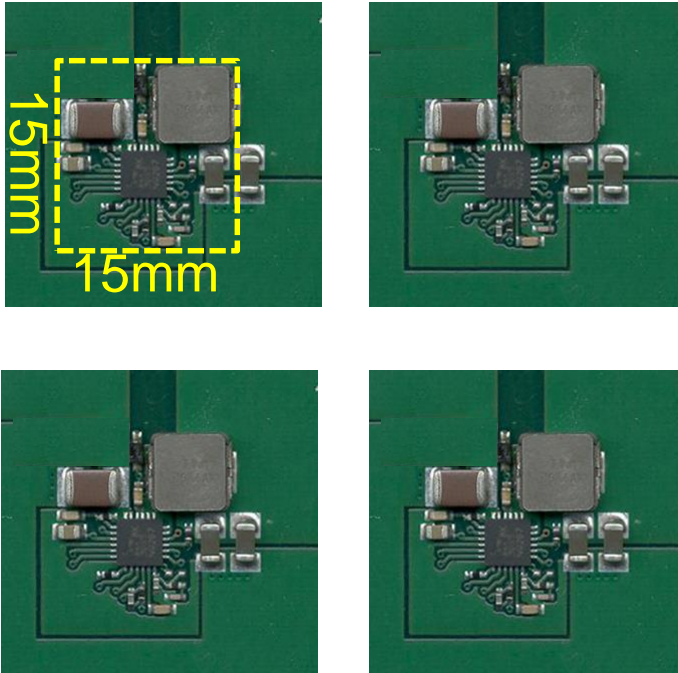
<http://www.linear.com/designtools/packaging/umodule.php#rel>

POWER CYCLE FROM 50 TO 100 DEG C					
PACKAGE TYPE	SAMPLE SIZE	OLDEST DATE CODE	NEWEST DATE CODE	K DEVICE CYCLES	No. of FAILURES
LGA 15X09	117	0712	0730	5850	0
LGA 15X15	347	0513	1048	16325	0
Totals	464	-	-	22,175	0

Board Space

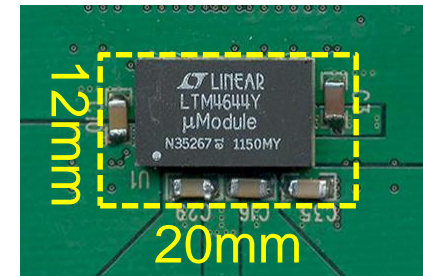
LTC3605 x 4

5A Monolithic Converters



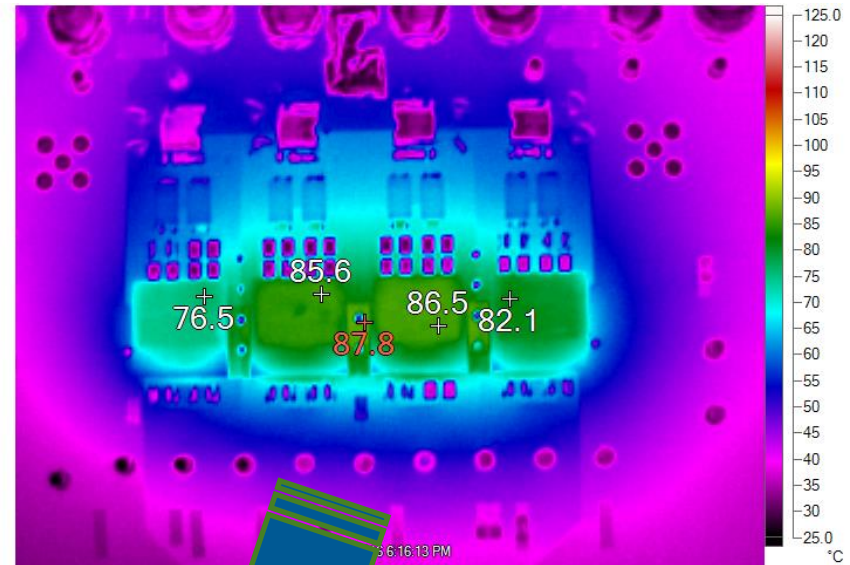
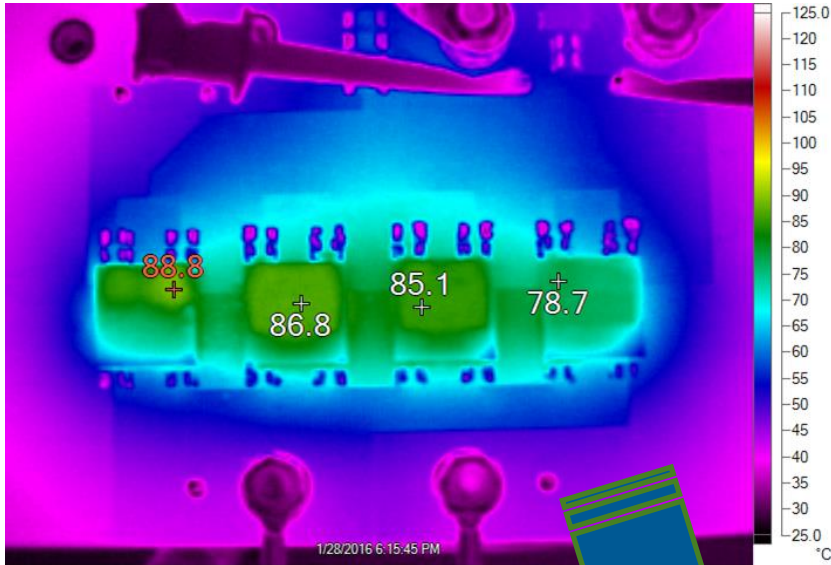
LTM4644

Quad 4A (5A Peak) DC/DC Module



- 900 mm^2 vs. $240 \text{ mm}^2 = 73\%$ reduction

Scalable (386A Design Below)

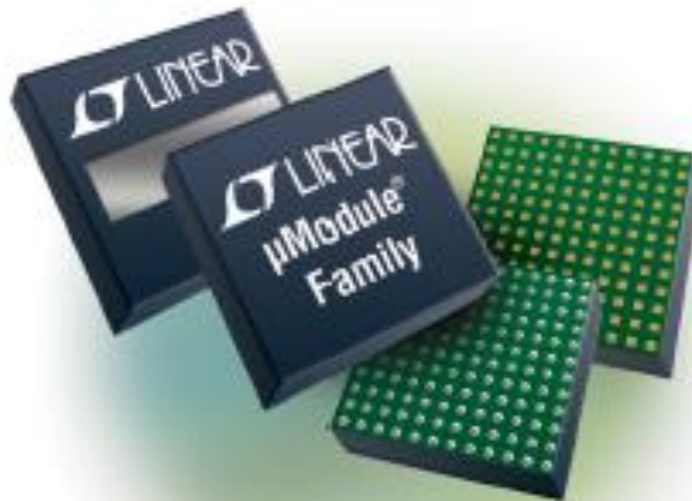


Test Conditions:

- 386A = 7 x LTM4650
50A + LTM4677
36A digital brain
- 12Vin
- 1Vout
- 425kHz switch frequency
- 400-450 LFM
- $T_A = 25^\circ \text{C}$



(top of devices are painted white for better quality thermal imaging)



15 Product Families

100 μ Module Power Products

30 Package Options

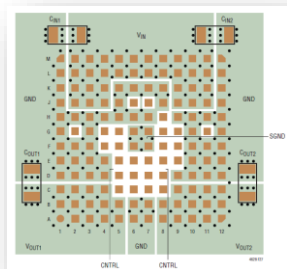
First uModule Introduced in 2004!!

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Recommended Solutions for QorIQ Processors



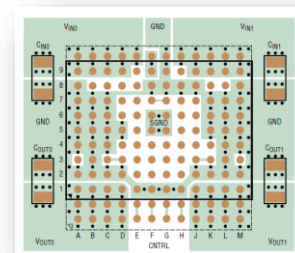
Multiple Output



Multiple Output



Digital Power System Management



<u>Non PMBus</u>	<u>Output</u>	<u>Size</u>		<u>PMBus</u>	<u>Output</u>	<u>Size</u>
LTM4628	Dual 8A, Single 16A	15x15		LTM4675	Dual 9A, Single 18A	16x11.9
LTM4620(A)	Dual 13A, Single 26A	15x15		LTM4676(A)	Dual 13A, Single 26A	16x16
LTM4630(A), LTM4630-1	Dual 18A, Single 36A	16x16		LTM4677	Dual 18A, Single 36A	16x16
LTM4650, LTM4650-1	Dual 25A, Single 50A	16x16		LTM467x (2016/2017)	Dual 25A+, Single 50A+	TBD
Pin Compatible, package sizes may vary				Pin Compatible, package sizes may vary		

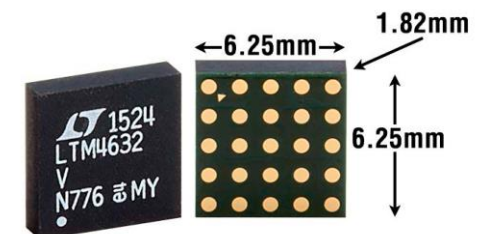
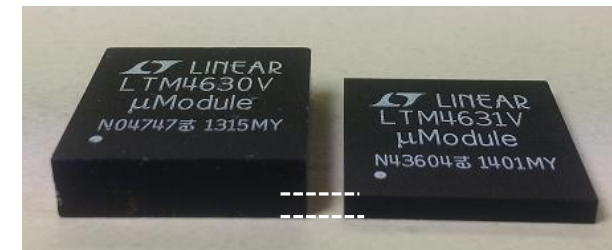
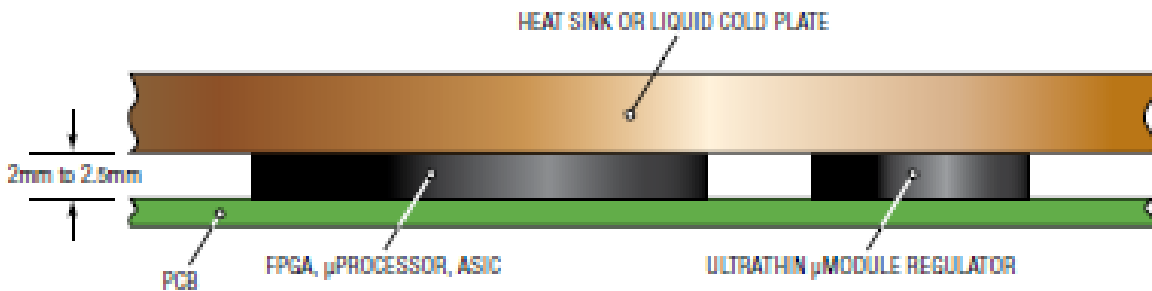
Ultrathin uModules

Ultrathin 1.82mm, 20VIN μ Module Regulators



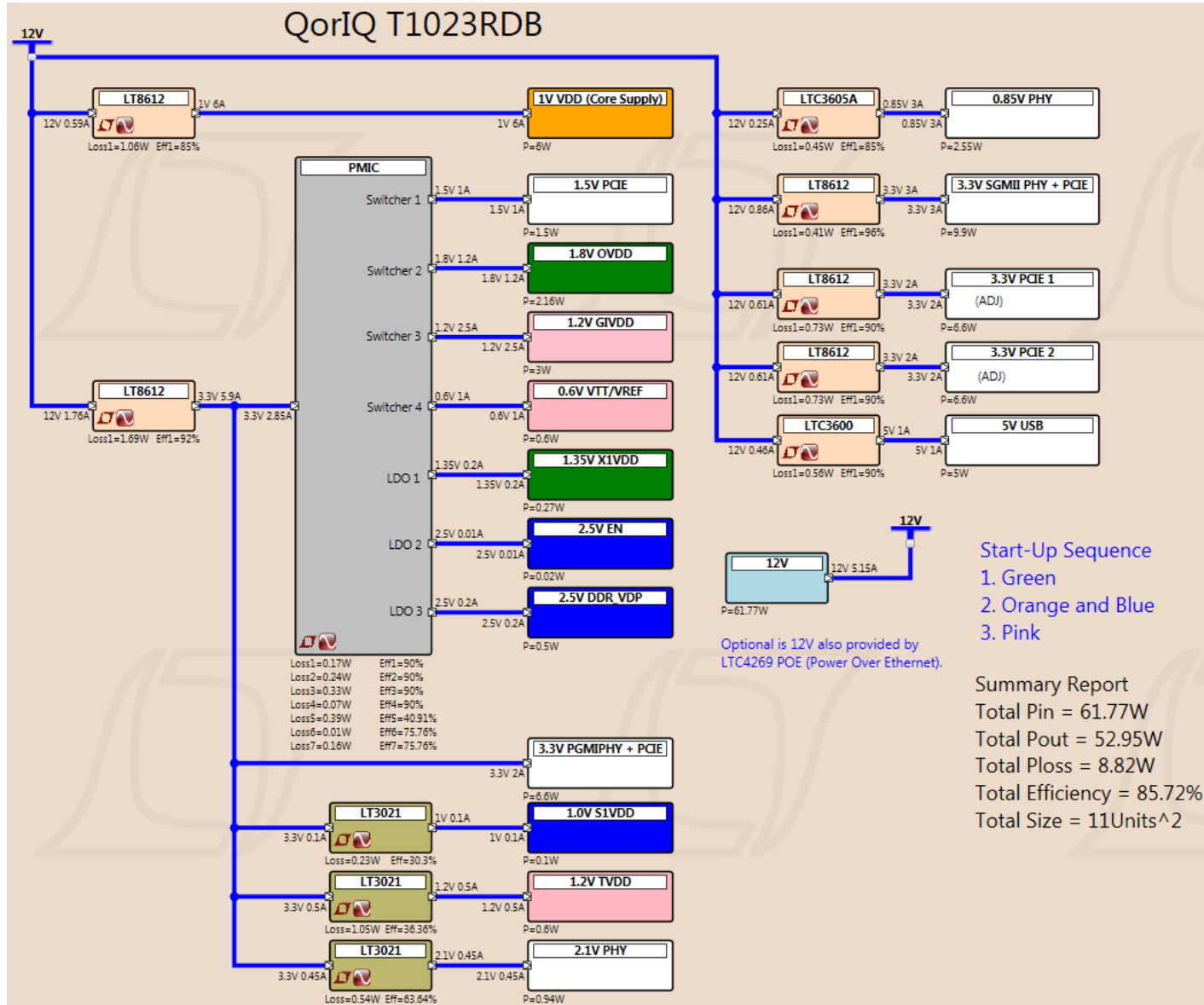
	LTM4622	LTM4623	LTM463x**	LTM4632
	Dual Step-Down	Single Step-Down	Dual Step-Down	For DDQ/QDR
Vin Range	3.6V* to 20V	4V to 20V	4.5V to 15V	3.6V* to 15V
Vout Range	0.6V to 5.5V	0.6V to 5.5V	0.6V to 1.8V	0.6V to 2.5V
Iout	2.5A x 2	3A	10A x 2	$\pm 3A \times 2$ (VDDQ, VTT) 10mA (VREF)
Package Type	LGA (BGA available)	LGA (BGA available)	LGA	LGA
Package Size (mm)	6.25 x 6.25 x 1.82	6.25 x 6.25 x 1.82	16 x 16 x 1.82	6.25 x 6.25 x 1.82

Ultrathin μ Module Regulators Fit Under the FPGA Heat Sink



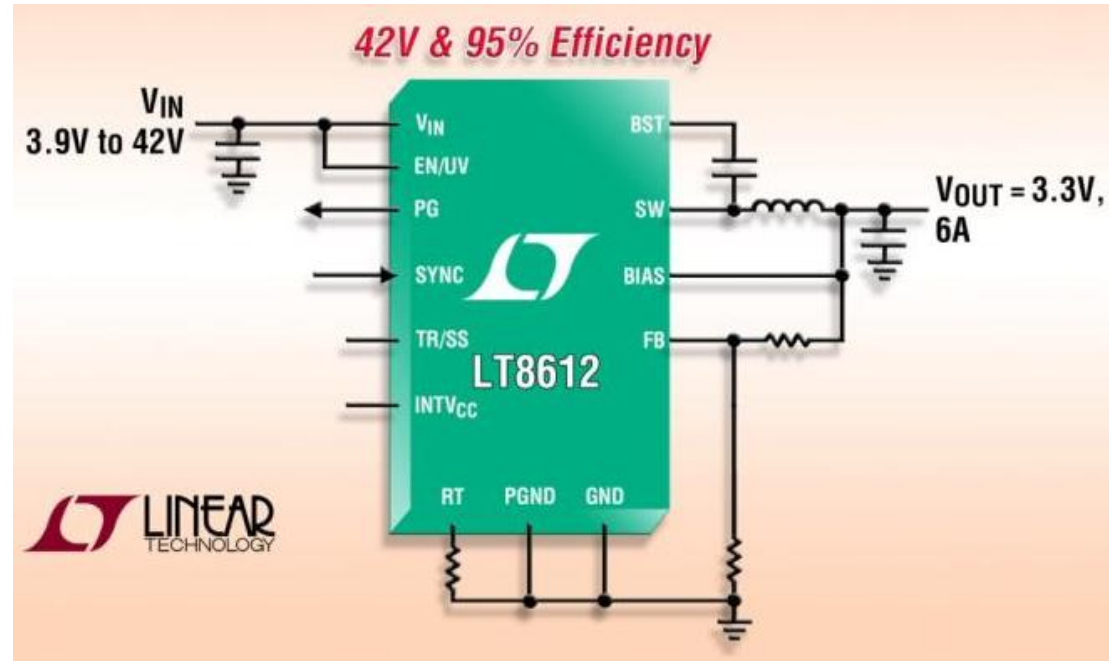
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T1023

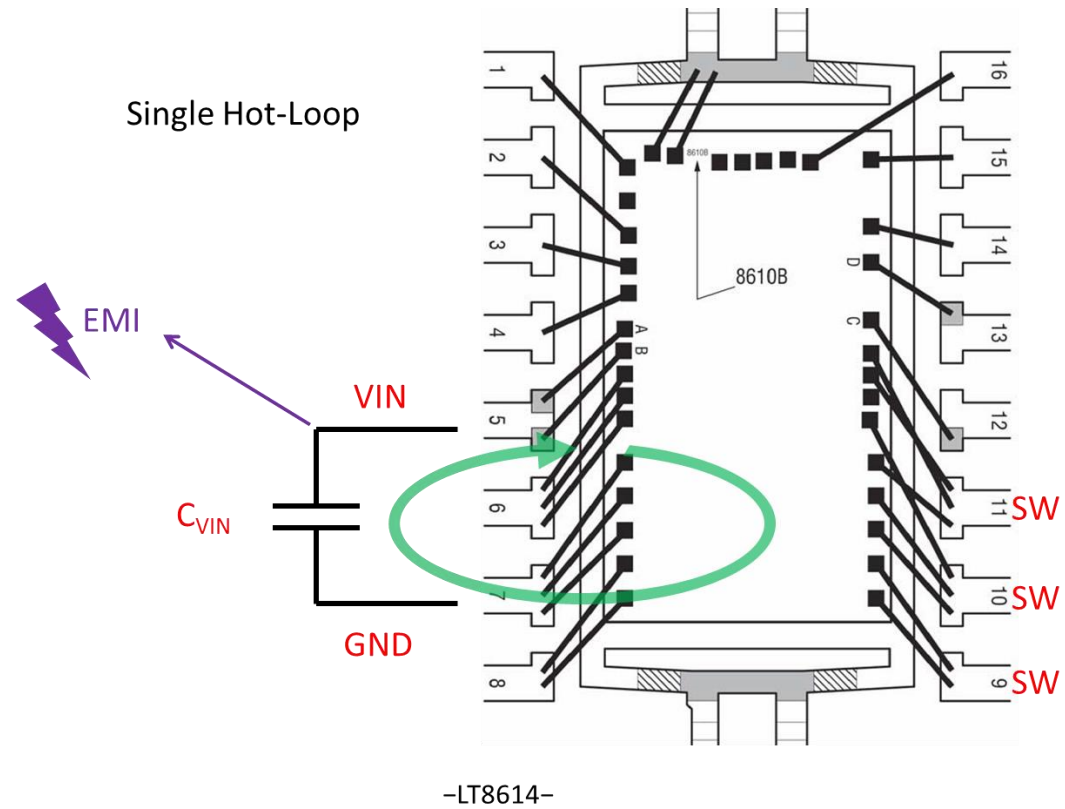


LT8612: 6A Synchronous Monolithic Switching Regulator

- V_{IN} : 3.4V to 42V
- 3 μ A Burst Mode[®] operation
quiescent current with low
<10mVp-p output ripple
- Fast 40ns on-time
- Frequency: 200kHz-2.2MHz
- Low dropout under all
conditions: 250mV at 3A
- Soft-start and output voltage
tracking
- Internal compensation



Traditional Monolithic: LT8610



Silent Switcher Monolithic

Dual Coupled
Hot-Loops

Flip-chip +
copper pillars

Much Lower
Total Inductance
+
Lower EMI

Low-EMI

Low-EMI

C_{VIN}

C_{VIN}

VIN

VIN

GND

GND

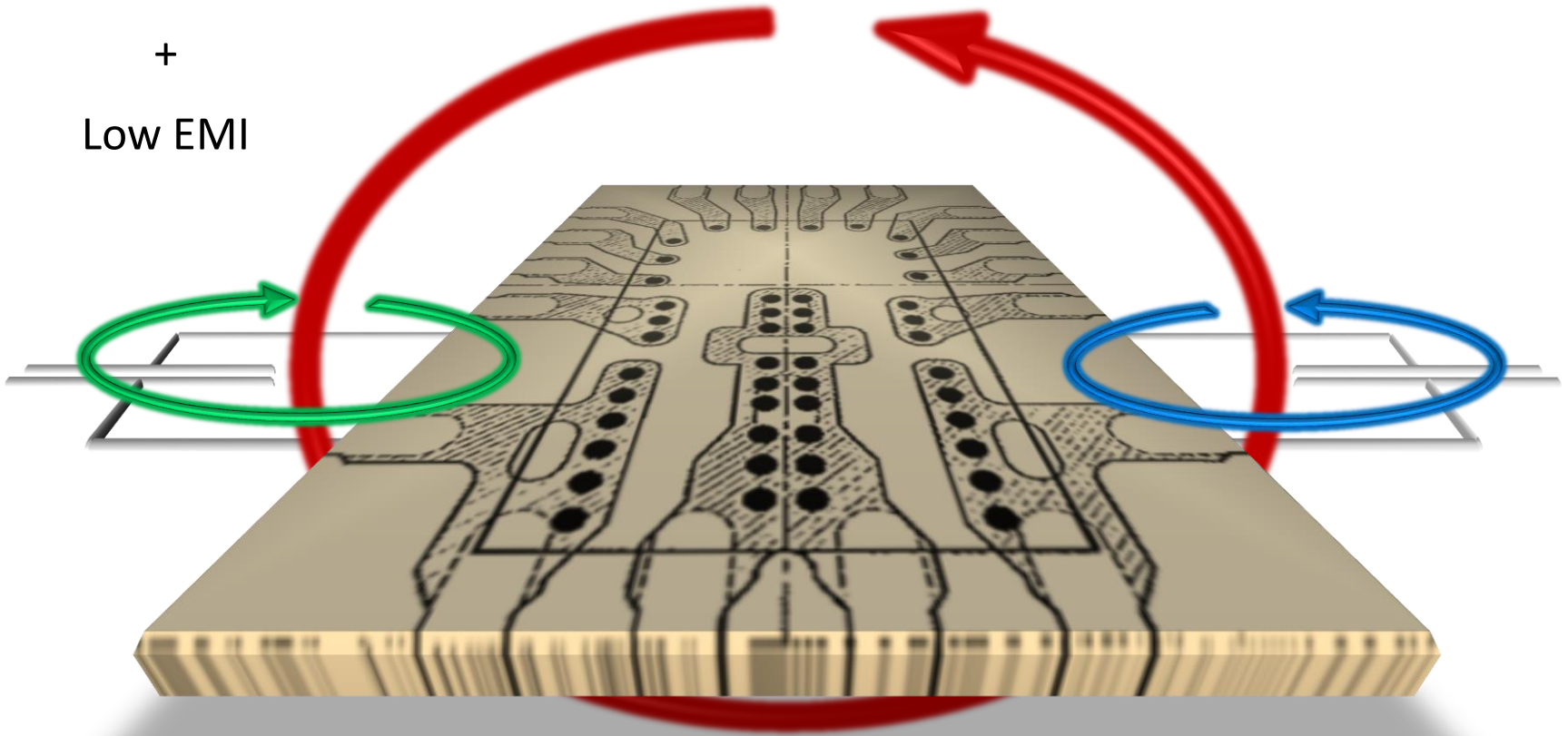
SW

-LT8614-

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Silent Switcher Technology

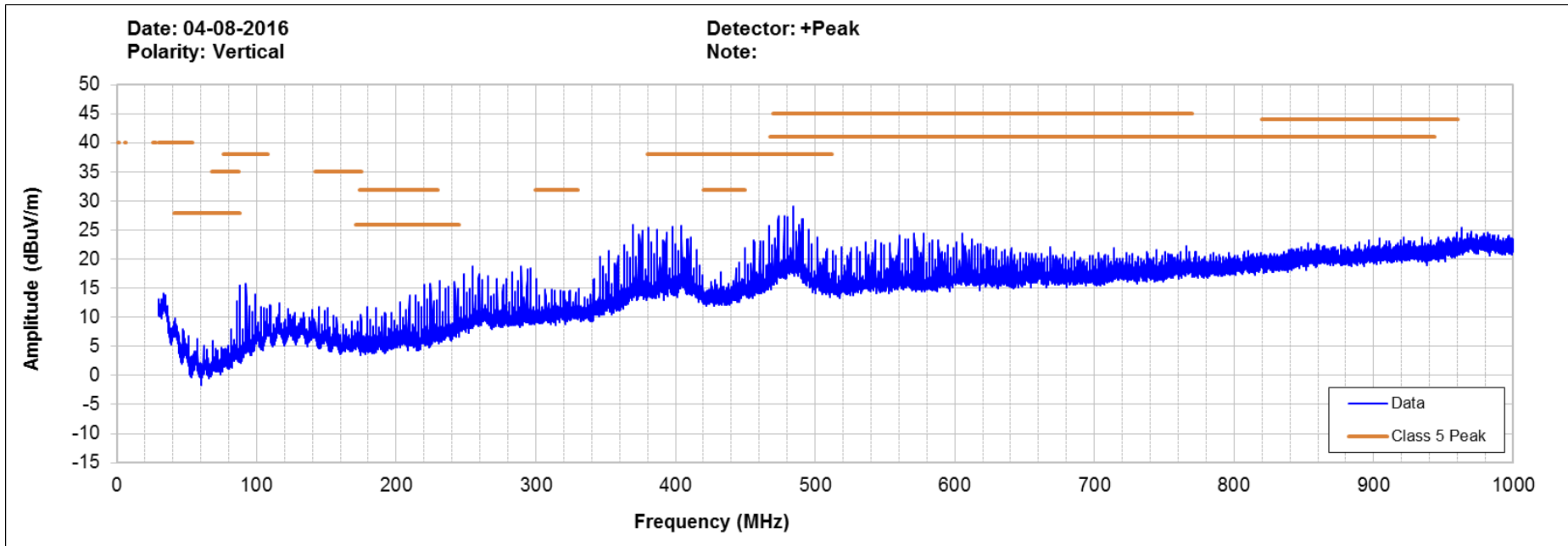
Confined
Magnetic Field
+
Low EMI



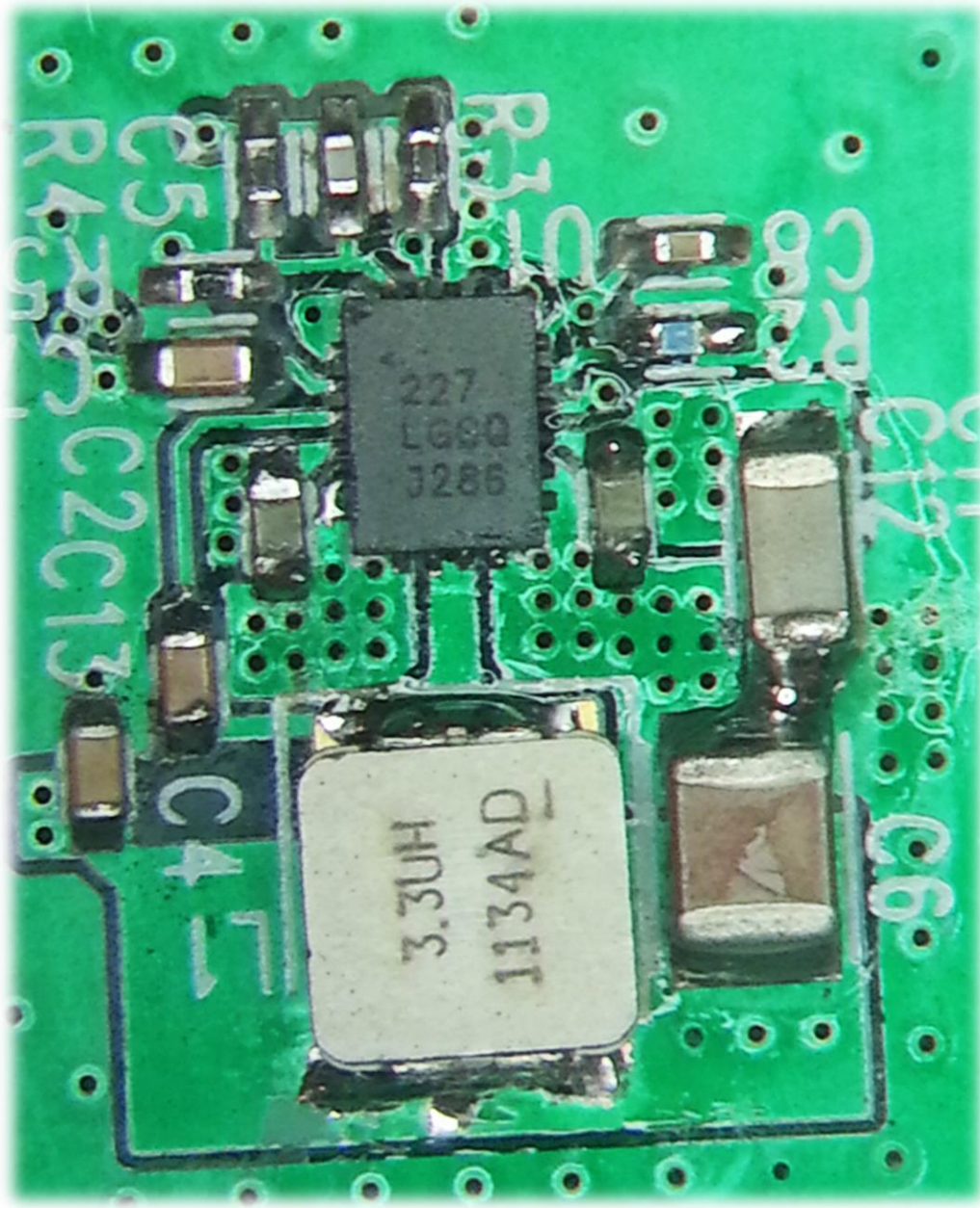
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Low noise switching regulators

CISPR25 Radiated Emission Test with Class 5 Peak Limits



3mmx4mm

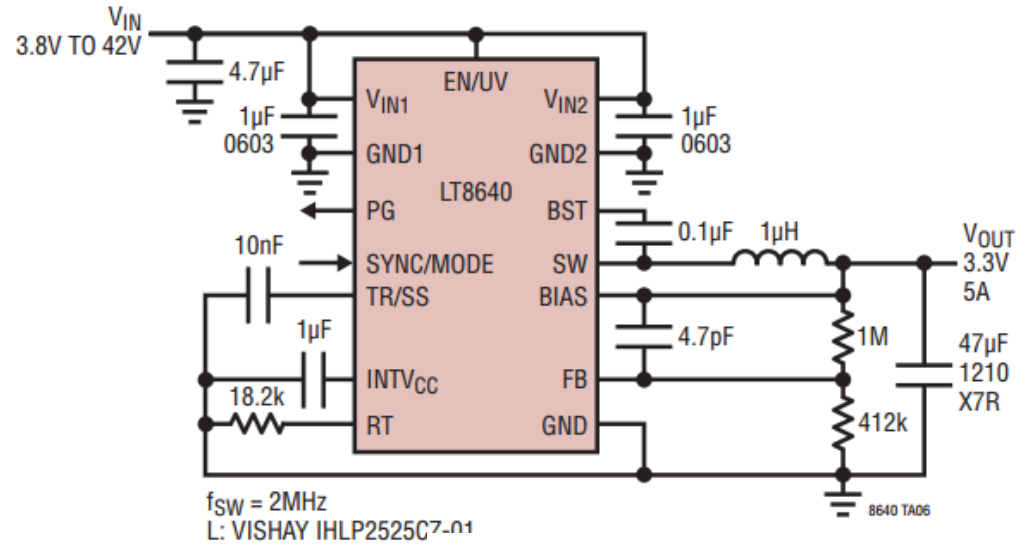


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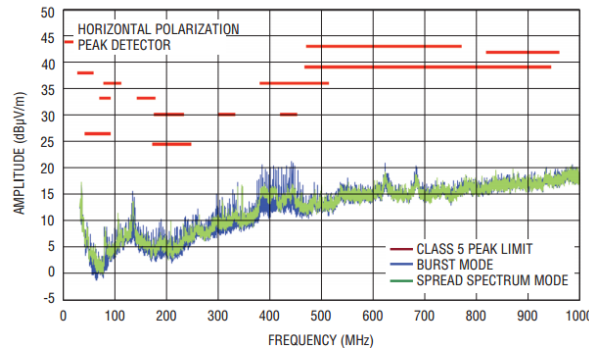
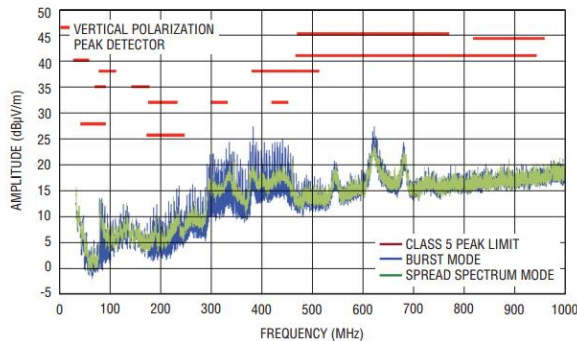
LT8640: 5A Synchronous Step-Down Silent Switcher

- Input: 3.4V to 42V
- Output: 5A, 7A Peak
- **Output Ripple:** < 10mV_{P-P}
- Fast Minimum Switch-On Time: 40ns

2MHz 3.3V, 5A Step-Down Converter



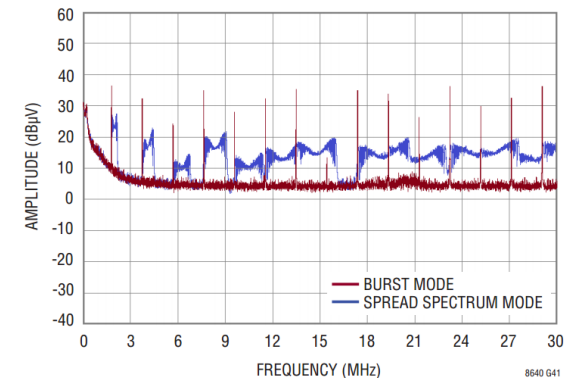
Radiated EMI Performance
(CISPR25 Radiated Emission Test with Class 5 Peak Limits)



DC2202A DEMO BOARD
(WITH EMI FILTER INSTALLED)
14V INPUT TO 5V OUTPUT AT 4A, $f_{SW} = 2\text{MHz}$

8640 G42

Conducted EMI Performance



DC2202A DEMO BOARD
(WITH EMI FILTER INSTALLED)
14V INPUT TO 5V OUTPUT AT 4A, $f_{SW} = 2\text{MHz}$

8640 G41

Linear Technology Confidential

Released Silent Switcher – Stay Tuned!

	LT8641	LT8614	LT8640/-1
V_{IN}	3V to 65V	3.4V – 42V	3.4V to 42V
V_{REF}	0.8V	0.97	0.97
I_{OUT}	3.5A	4A	5A
I_{OUT} (Peak)	5A		7A
Fsw	3MHz	3MHz	3MHz
Iq	2.5 μ A	2.5 μ A	2.5 μ A
Ton min	35ns	30ns	30ns
Note	Silent Switcher! SSFM!	Silent Switcher!	Silent Switcher! SSFM!
Pack	3x4 QFN-18	3x4 QFN-18	3x4 QFN-28

Upcoming:

18V, 10A

18V, Dual 7.5A

20V, 20A

Tools from LTC

- Website: www.linear.com/nxp
- Design Tools:
 - LTpowerPlanner
 - LTpowerCAD
 - LTpowerPlay
 - LTspice

QorIQ		
LayerScape		
Product Name	Power	
	Core	I/O
NXP (Freescale) QorIQ LS1043A-RDB	LTM4649 - 1V @ 8A	2.5V @ 0.1A 2.5V @ 0.35A
NXP (Freescale) QorIQ LS1088A -RDB	LTC3882 - 1V @ 25A	LTC3026 - 2.5V @ 1.5A
T Series		
NXP (Freescale) QorIQ T1023RDB	LT8612 - 1V @ 6A	LT3021 - 2.1V @ 0.45A

i.MX		
i.MX 7		
Product Name	Power	
	Core	I/O
NXP (Freescale) i.MX7 96Board	LTC3589-2 - 1.1V @ 0.5A	LTC3589-2 - 1.8V @ 0.2A

System Planning to Simulation



System Level Power Arch./Plan



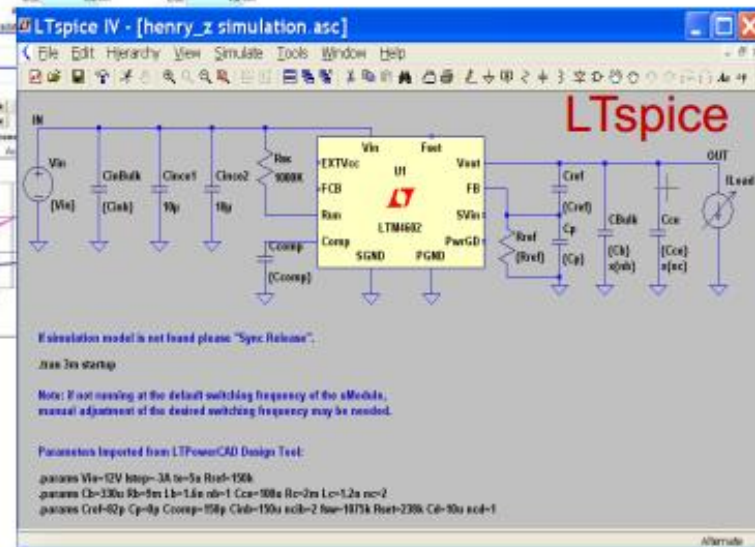
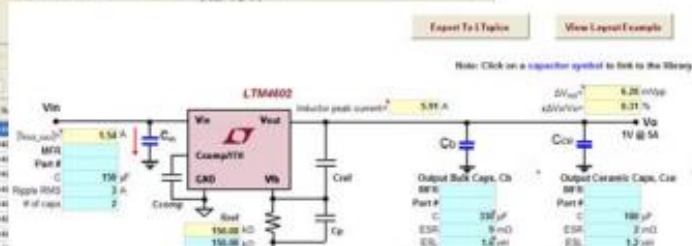
Search/Selection Solution



Circuit Parameter Design



Simulation



Working with PMBus Devices - LTpowerPlay

The screenshot displays the LTpowerPlay v1.2.51.0 software interface. The main window is titled "Config: U0 (7'h40) -LTM4676A". The interface is divided into several panes:

- System Tree:** Shows a hierarchy starting with "System" (Ungrouped), followed by "U0 (7'h40) -LTM4676A", and then "U0:0" and "U0:1".
- Config Pane:** Contains a "Lookup" field and several tabs: "Setup", "All Global", "All Paged", "Addressing/WP", "General Config", "On/Off/Margin", "PWM Configuration", "Voltage", "Current", "Temperature", "Timing", "Fault Responses", "Fault Sharing", and "Scratchpad". The "General Configuration Registers" section is expanded, showing registers like "MFR_CHAN_CONF...", "MFR_RAIL_ADDRES...", "ON/OFF Control and Margining", "PWM Related Configuration", "Fault Responses -- Input Voltage", and "Output Voltage". The "VOUT_COMMAND" register is highlighted, with a description: "(Press F1 for More Detailed Information on this Register) Nominal DC/DC converter output voltage setpoint."
- Telemetry Pane:** Displays "Telemetry: U0:0" and states "No Custom Scaling is Enabled. Telemetry values shown are as reported by the". It includes a link "Click Here to View Custom Scaling Parameters...". The telemetry data is as follows:

Parameter	Value
READ_VOUT	0.0000 V
Telemetry -- Output Voltage (%)	
MFR_VOUT_PEAK_LTC_PE...	-100.00 % above/below...
READ_VOUT_PERCENT	-100.00 % above/below...
Telemetry -- Input Current	
READ_IIN	0.0000 A
MFR_READ_IIN_CHAN_LTC...	0.0000 A
Telemetry -- Output Current	
MFR_IOUT_PEAK_LTC	0.000 A
READ_IOUT	0.000 A
PMBUS_RAIL_CURRENT	0.000 A
TOTAL_RAIL_CURRENT	0.000 A
PHASE_CURRENT_DEVI...	0.000 %
Telemetry -- Temperature	
MFR_TEMPERATURE_1_P...	0.0 °C
READ_TEMPERATURE_1_...	0.0 °C
READ_TEMPERATURE_2	0.0 °C
PHASE_TEMP_DEVIATION	0.000 %
- Realized On/Off Waveform:** Shows a graph titled "U0:0" with a yellow waveform on a black background.
- Telemetry Plot:** Shows a graph titled "READ_VOUT" with a blue background and a white grid. The y-axis ranges from 0 to 1, and the x-axis ranges from 0 to 1.
- Dashboard:** A small window titled "Dashboard --U0 (7'h40) -L" shows a digital display with "Ch 0" and "Ch 1" indicators, and a "99.9" readout.

Questions?