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Tel: +86-755-8981 8866 Fax: +86-755-8427 6832
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Data Sheet

MxL7704

Five Output Universal PMIC

General Description

The MxL7704 is a five output Universal PMIC optimized for powering low power FPGAs, DSPs, and microprocessors from 5V inputs. Four synchronous step down buck regulators range from 1.5A system power to 4A core power. A 100mA LDO provides a clean 1.5V to 3.6V power for auxiliary devices. All outputs support ±10% margining and the two highest power outputs support dynamic voltage control to support processors that can utilize this function to save power. Through a 400kHz I²C interface, the customer can monitor an input voltage flag and PGOOD flags for each output. The I²C port can also be used to modify power up and down sequencing options, assign PGOOD outputs to the PGOOD pins, enable outputs and select switching frequency.

High switching frequency and a current mode architecture with internal compensation enable a very fast transient response to line and load changes without sacrificing stability and keeping board space to a minimum.

Fault protection features include input undervoltage lockout, overcurrent protection, and thermal protection. The MxL7704 is offered in a 5mm x 5mm QFN package.

Features

- Input voltage range: 4.0V to 5.5V
- 4 Synchronous Buck Regulators
  - Internally compensated current mode
  - 1MHz to 2.1MHz switching frequency
  - Buck 1: 3.0V to 3.6V, 20mV step, 1.5A
  - Buck 2: 1.3V to 1.92V, 20mV step, 1.5A
  - Buck 3: 0.8V to 1.6V, 6.25mV step, 2.5A
  - Buck 4: 0.6V to 1.4V, 6.25mV step, 4A
- 100mA LDO 1.5V to 3.6V, 20mV step
- ±2% maximum total dc output error over line, load and temperature
- 3.3V/5V 400kHz I²C interface
  - Dynamic voltage scaling
  - Status monitoring by channel
  - Sequencing control
  - Input voltage status register
- Highly flexible conditional sequencing engine with external input
- 2 configurable PGOOD outputs
- Adjustable switching frequency
- 5mm x 5mm 32-pin QFN package

Applications

- Low power processor, ASIC and FPGA power
- Industrial control
- Test equipment
- POS terminals

Ordering Information - Back Page

Revision History

Revision	Release Date	Change Description
1A	02/28/18	Initial Release

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MxL7704 Specifications

Absolute Maximum Ratings

Important! The stresses above what is listed under Table 1 may cause permanent damage to the device. This is a stress rating only—functional operation of the device above what is listed under Table 1 or any other conditions beyond what MaxLinear recommends is not implied. Exposure to conditions above what is listed under Table 3 for extended periods of time may affect device reliability. Solder reflow profile is specified in the IPC/JEDEC J-STD-020C standard.

Table 1: Absolute Maximum Ratings

Parameter	Minimum	Maximum	Units
V_{IN}, V_{IN1}, V_{IN2}, V_{IN3}, V_{IN4}, 5VSYS	–0.3	6	V
SDA, SCL, VDDIO	–0.3	6	V
AN0, AN1	–0.3	6	V
PG1, PG2, GLOBAL EN, SEQ EN	–0.3	6	V
LDO	–0.3	6	V
V_{OUT1}, V_{OUT2}, V_{OUT3}, V_{OUT4}	–0.3	V_{INx} - 0.3V(1)	V
Storage Temperature Range	-55	150	°C
Peak Package Body Temperature		260	°C

NOTE:
1. x = Buck number

ESD Rating

Table 2: ESD Rating

Parameter	Minimum	Maximum	Units
HBM (Human Body Model)		2k	V

Operating Conditions

Table 3: Operating Conditions

Parameter	Minimum	Maximum	Units
V_{IN}, V_{IN1}, V_{IN2}, V_{IN3}, V_{IN4}, 5VSYS	4.0	5.5	V
SDA, SCL, VDDIO	3.3	5.5	V
AN0, AN1	0	3	V
PG1, PG2, GLOBAL EN, SEQ EN	0	5.5	V
LDO	0	V_{IN} - 0.3V(1)	V
LX1, LX2, LX3, LX4	-1	5.5(2)	V
Switching Frequency	1000	2100	kHz
Junction Temperature Range (T_J)	-40	125	°C
Package Power Dissipation Max at 25°C		3.65	W
Package Thermal Resistance Θ_{JA}		27	°C/W

NOTES:
1. LDO set to 3.3V.
2. LX pin's DC range is -1V for less than 50ns.

Electrical Characteristics

Specifications are for Operating Junction Temperature of T_J = 25°C only; limits applying over the full Operating Junction Temperature range are denoted by a "•". Typical values represent the most likely parametric norm at T_J = 25°C, and are provided for reference purposes only. Unless otherwise indicated, V_{IN} = 5VSYS = 5.0V.

Table 4: Electrical Characteristics

Symbol	Parameter	Conditions	•	Min	Typ	Max	Units
DC Specifications							
V_{IN}	Input DC voltage		•	4.0	5.0	5.5	V
UVLO	Under Voltage Lockout	Rising				3.9	V
	Under Voltage Lockout Hysteresis	Falling			210		mV
$I_{Q\_SHUTDOWN}$	Shutdown Quiescent Current	GLOBAL EN = logic LOW, All outputs <20% of set point or initial power applied.			10		µA
$I_{Q\_OPERATING\_5VSYS}$	5VSYS Operating Quiescent Current	GLOBAL EN = logic HIGH, All outputs in regulation no load. f_{OSC} = 1.5MHz			8		mA
T_{SD}	Thermal Shutdown Threshold	Temperature rising			145		°C
T_{SDH}	Thermal Shutdown Hysteresis	Temperature falling			20		°C
Buck Regulators 1 – 4							
V_{IN}	Operational Voltage Range		•	4.0		5.5	V
V_{OUT} Accuracy	Output Voltage Accuracy at Factory Programmed Initial Set Point	Load current = 10mA to full load V_{IN} = 5VSYS = 4.0V to 5.5V	•	-2		+2	%
V_{OUT} Initial Accuracy	Output Voltage Accuracy at Factory Programmed Initial Set Point	Load current = 10mA V_{IN} =5VSYS = 4.5V to 5.5V		-0.5		+0.5	%
Buck 1 V_{OUT} Range	Output Voltage Set Point Range	20mV resolution, 8 bit		3.0		3.6	V
Buck 2 V_{OUT} Range	Output Voltage Set Point Range	20mV resolution, 8 bit		1.30		1.92	V
Buck 3 V_{OUT} Range	Output Voltage Set Point Range	6.25mV resolution, 8 bit		0.800(1)		1.59375	V
Buck 4 V_{OUT} Range	Output Voltage Set Point Range	6.25mV resolution, 8 bit		0.600(1)		1.39375	V
V_{OUT_DYN}	Dynamic Output Slew Rate	Closed loop controlled			10		V/ms
V_{OUT_SS} V_{OUT_SO}	Soft Start Slew Rate, and Soft Off Slew Rate	Closed loop controlled			1		V/ms

NOTE:
1. Limited by minimum t_{ON}. See Table 6 for Minimum Permissible V_{OUT} versus frequency.

Electrical Characteristics (continued)

Specifications are for Operating Junction Temperature of T_J = 25°C only; limits applying over the full Operating Junction Temperature range are denoted by a "•". Typical values represent the most likely parametric norm at T_J = 25°C, and are provided for reference purposes only. Unless otherwise indicated, V_{IN} = 5VSYS = 5.0V.

Table 4: Electrical Characteristics (continued)

Symbol	Parameter	Conditions	•	Min	Typ	Max	Units
Buck Regulators 1 – 4 (continued)							
$V_{OUT\_DISCHARGE}$	Pre-Bias Discharge Threshold	Output falling			200		mV
R_{AD}	Output Active Discharge Resistance	Converter disabled and option selected			78		Ω
I_{OUT}	Full Load Rated Current	Buck 1	•	1.5			A
		Buck 2	•	1.5			A
		Buck 3	•	2.5			A
		Buck 4	•	4.0			A
I_{CLIM}	Peak Current Limit These current limits help define maximum inductor ripple and to protect the internal power switches from an EOS event.	Buck 1	•	2.5	3.4	4.5	A
		Buck 2	•	2.5	3.4	4.5	A
		Buck 3	•	3.5	4.5	5.5	A
		Buck 4	•	5.5	6.5	9.0	A
V_{UVP}	Under Voltage Protection Threshold	Soft start completed, DVS inactive			70		%
	UVP Deglitch				10		µs
f_{OSC_RANGE}	Switching Frequency Programmable Range	See Figure 8		1000		2000	kHz
f_{OSC}	Default Switching Frequency	Default 1001 -AQB			1500		kHz
		Default 0100 -XQB			1000		kHz
	Oscillator Accuracy	At factory programmed set point	•	-10		10	%
t_{ON-MIN}	Minimum Controllable On-Time	Full load			92	120	ns
R_{DSON} (P)	Pin to Pin Resistance PFET High Side MOSFET	Buck 1			146		mΩ
		Buck 2			146		mΩ
		Buck 3			67		mΩ
		Buck 4			60		mΩ
R_{DSON} (N)	Pin To Pin Resistance NFET Low Side MOSFET	Buck 1			103		mΩ
		Buck 2			103		mΩ
		Buck 3			32		mΩ
		Buck 4			27		mΩ

Electrical Characteristics (continued)

Specifications are for Operating Junction Temperature of T_J = 25°C only; limits applying over the full Operating Junction Temperature range are denoted by a "•". Typical values represent the most likely parametric norm at T_J = 25°C, and are provided for reference purposes only. Unless otherwise indicated, V_{IN} = 5VSYS = 5.0V.

Table 4: Electrical Characteristics (continued)

Symbol	Parameter	Conditions	•	Min	Typ	Max	Units
Low Dropout Regulator, LDO							
V_{IN}	Operational Voltage Range		•	4.0		5.5	V
V_{OUT} Accuracy	Output Voltage Accuracy at Factory Programmed Initial Set Point	Load current = 1mA to 100mA V_{IN} = 4.0V to 5.5V	•	-2		+2	%
V_{OUT} Range	Output Voltage Set Point Range	20mV resolution, 8 bit		1.5		3.6	V
V_{OUT} Default	Default Set Point				3.3		V
V_{OUT_DYN}	Dynamic Output Slew Rate	Closed loop controlled, load = 25mA			10		V/ms
V_{OUT_SS}	Soft Start Slew Rate	Closed loop controlled			1		V/ms
I_{SC}	Short Circuit Current Limit	3V3LDO = 0V	•	120	230	260	mA
V_{DO}	Dropout Voltage (defined as a drop of 2% from initial value)	Load current = 10mA	•		11	30	mV
		Load current = 100mA	•		210	300	mV
PSRR	Power Supply Rejection Ratio	f = 1kHz, I_{OUT} = 10mA, V_{IN} = 4.3V, V_{OUT} = 3.3V			56		dB
		f = 10kHz, I_{OUT} = 10mA V_{IN} = 4.3V, V_{OUT} = 3.3V			40		dB
C_{OUT}	Output Capacitor (ceramic)	Capacitance (effective capacitance)		0.68	1.0		µF
		ESR		1		100	mΩ
θ_n	Supply Output Noise	10 Hz ≤ f ≤ 100 kHz, V_{IN} = 4.3V, V_{OUT} = 3.3V			470		µVrms
R_{AD}	Output Active Discharge Resistance	Converter disabled and option selected			78		Ω

Electrical Characteristics (continued)

Specifications are for Operating Junction Temperature of T_J = 25°C only; limits applying over the full Operating Junction Temperature range are denoted by a "•". Typical values represent the most likely parametric norm at T_J = 25°C, and are provided for reference purposes only. Unless otherwise indicated, V_{IN} = 5VSYS = 5.0V.

Table 4: Electrical Characteristics (continued)

Symbol	Parameter	Conditions	•	Min	Typ	Max	Units
Power Good Outputs							
	Power Good Threshold	V_{OUT} rising, at default V_{OUT} set points	•	85	90	95	%
	Power Good Hysteresis Buck 1 and LDO	V_{OUT} falling			122		mV
	Power Good Hysteresis Buck 3 and Buck 4	V_{OUT} falling			38		mV
	Power Good Hysteresis Buck 2	V_{OUT} falling			67		mV
	Power Good Assertion Delay, FB Rising				2		ms
	Power Good De-Assertion Delay, FB Falling				65		µs
V_{OL}	Output Level Low	I_{SINK} = 1mA	•			0.4	V
GLOBAL EN and SEQ EN Input							
V_{IL}	Input low level					0.8	V
V_{IH}	Input High Level			2.0			V
	GLOBAL EN Input Current	GLOBAL EN = 5.5V			4	30	µA
	SEQ EN Input Current	SEQ EN = 5.5V			4	30	µA
Input Voltage Monitor Flag							
V_{TH_RISING}	Input Voltage Good Threshold	Voltage rising		4.59	4.63	4.7	V
$V_{TH\_FALLING}$	Input Voltage Good Threshold	Voltage falling		4.52	4.57	4.65	V

Electrical Characteristics (continued)

Specifications are for Operating Junction Temperature of T_J = 25°C only; limits applying over the full Operating Junction Temperature range are denoted by a "•". Typical values represent the most likely parametric norm at T_J = 25°C, and are provided for reference purposes only. Unless otherwise indicated, V_{IN} = 5VSYS = 5.0V.

Table 4: Electrical Characteristics (continued)

Symbol	Parameter	Conditions	•	Min	Typ	Max	Units
ADC, Temperature Monitoring							
	Input range	5VSYS ≥ 4.2V	•	0		2.55 + offset(1)	V
	Input range	5VSYS = 4.0V	•	0		2.35	V
	Nominal Resolution	8 bit			10		mV/ LSB
	INL					±2	LSB
	DNL, Differential nonlinearity					±1	LSB
	Full Scale Error					±2	LSB
	Zero Error (offset)				+1		LSB
	Full Scale Error Temperature Coefficient				±0.03	±0.05	%/°C
	ADC Conversion Frequency				5.56		kHz
	Input capacitance				4		pF
	AN0/1 DC Input Impedance				10		MΩ
T_{RANGE}	Temperature Monitoring Range			-40		Thermal Shutdown	°C
T_{RES}	Temperature Monitoring Resolution				1.06		°C
$T_{ACCURACY}$	Temperature Monitoring Accuracy	25°C (h'5F)		-2		2	°C
		105°C (h'B4)		-7		7	°C

NOTE:
1. Zero error (offset) specification shown below.

Electrical Characteristics (continued)

Specifications are for Operating Junction Temperature of T_J = 25°C only; limits applying over the full Operating Junction Temperature range are denoted by a "•". Typical values represent the most likely parametric norm at T_J = 25°C, and are provided for reference purposes only. Unless otherwise indicated, V_{IN} = 5VSYS = 5.0V.

Table 4: Electrical Characteristics (continued)

Symbol	Parameter	Conditions	•	Min	Typ	Max	Units
I²C Interface – Default Address 7'b0101101 (0x2D), see Table 10							
V_{IL}	Input Low Level					0.8	V
V_{IH}	Input High Level			2.0			V
V_L	VDDIO Supply Voltage			3.0		5.5	V
V_{OL_I2C}	SDA Logic Output Low Voltage	3mA sink current	•			0.8	V
f_{SCL}	SCL Clock Frequency		•	0		400	kHz
t_{SCL_H}	SCL Clock High Period		•	0.6			µs
t_{SCL_L}	SCL Clock Low Period		•	1.3			µs
t_{SP}	I²C Spike Rejection Filter Pulse Width1		•	0		50	ns
t_{SU_DAT}	I²C Data Setup Time		•	100			ns
t_{HD_DAT}	I²C Data Hold Time		•	0		900	ns
t_{R_I2C}	SDA, SCL Rise Time	C_B = total capacitance of bus line in pF	•		20 + 0.1*C_B	300	ns
t_{F_I2C}	SDA, SCL Fall Time	C_B = total capacitance of bus line in pF	•		20 + 0.1*C_B	300	ns
t_{BUF}	I²C Bus Free Time Between Stop and Start		•	1.3			µs
t_{SU_STA}	I²C Repeated Start Condition Setup Time		•	0.6			µs
t_{HD_STA}	I²C Repeated Start Condition Hold Time		•	0.6			µs
t_{SU_STO}	I²C Stop Condition Setup Time		•	0.6			µs
C_B	I²C Bus Capacitive Load		•			400	pF
C_{SDA}	SDA Input Capacitance		•			10	pF
C_{SCL}	SCL Input Capacitance		•			10	pF

Electrical Characteristics (continued)

Specifications are for Operating Junction Temperature of T_J = 25°C only; limits applying over the full Operating Junction Temperature range are denoted by a "•". Typical values represent the most likely parametric norm at T_J = 25°C, and are provided for reference purposes only. Unless otherwise indicated, V_{IN} = 5VSYS = 5.0V.

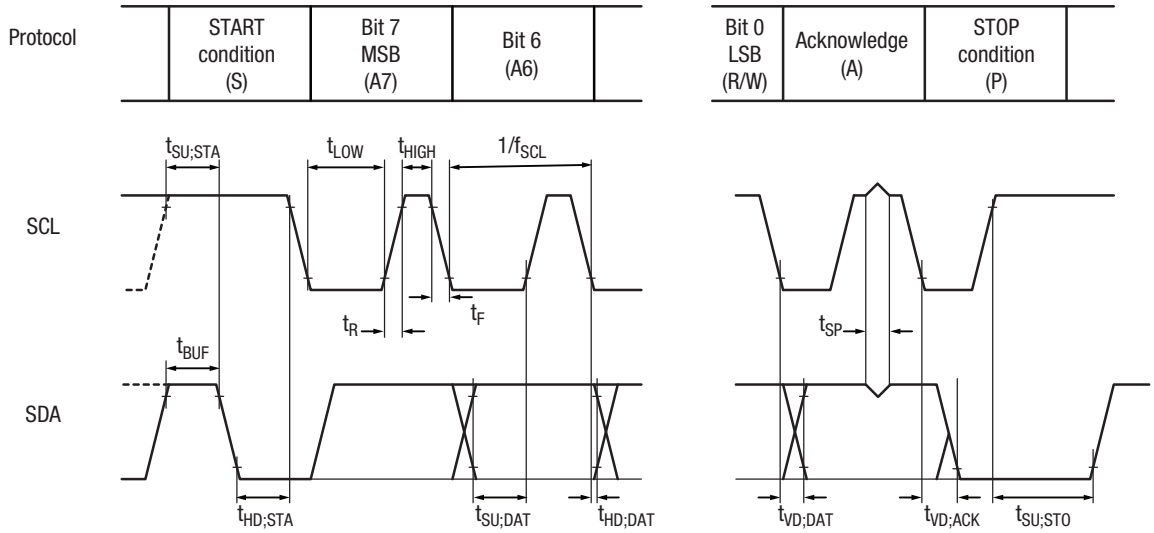

Figure 1: I²C Bus Timing Diagram

Pin Information

Pin Configuration

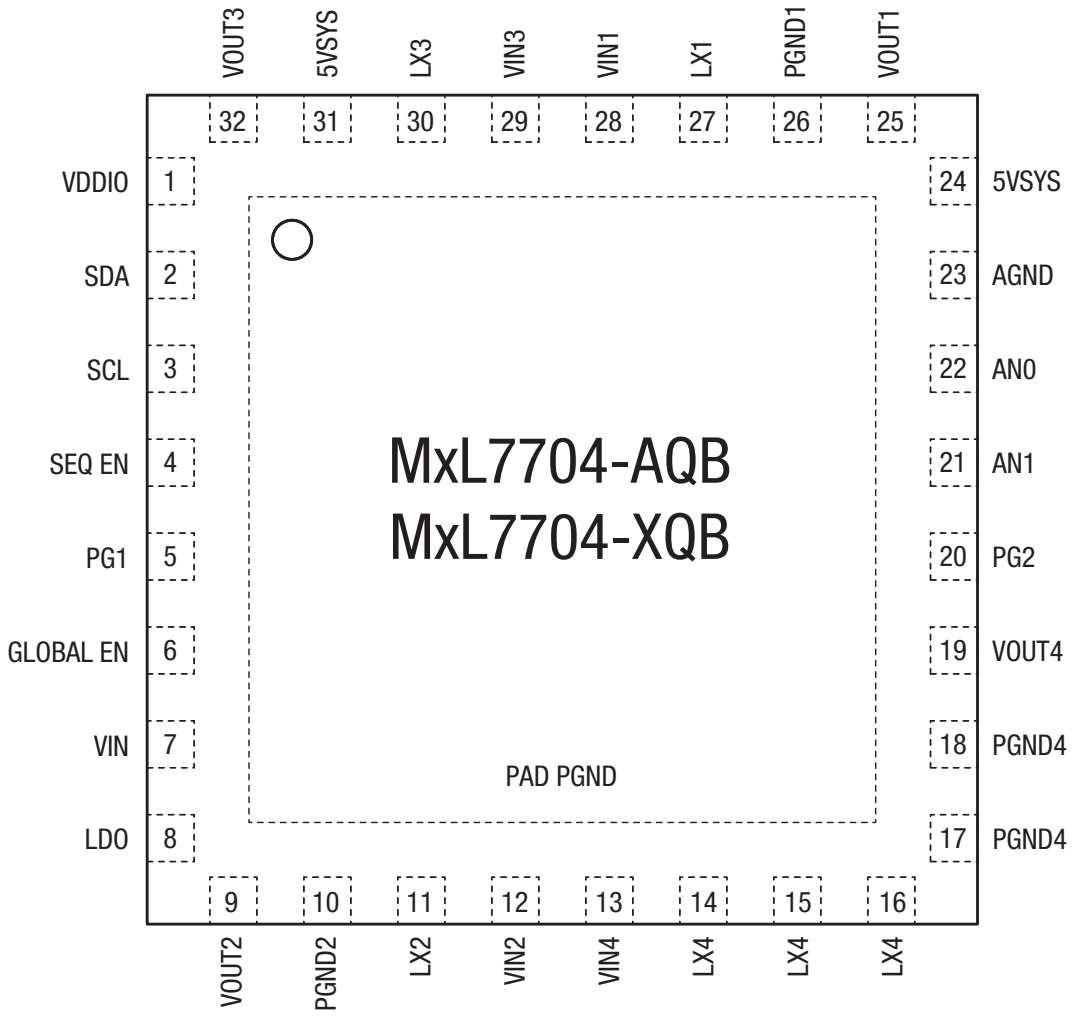

Figure 2: Pin Configuration (Top View)

Pin Description

***Table 5:* Pin Names and Descriptions**

Pin Number	Pin Name	Description
1	VDDIO	Supply for I²C Interface, 3.3V to 5V nominal.
2	SDA	I²C Data
3	SCL	I²C Clock
4	SEQ EN	Sequence enable. Input which can be added as an external gate to the power up sequencing. Is effectively ANDed to the power up sequencing. As such, has no effect on power down sequencing. See register map. If not used, tie to 5VSYS pin.
5	PG1	Power Good output 1. May consist of any ANDed output of all 5 regulators. See register map.
6	GLOBAL EN	Chip enable. When pulled low, shuts down entire chip after power down sequencing complete.
7	VIN	Input supply to the LDO
8	LDO	Output of the 100mA LDO. May be programmed from 1.5V to 3.6V in 20mV steps.
9	VOUT2	Feedback pin for Buck 2. Buck 2 can be programmed from 1.3V to 1.92V in 20mV steps.
10	PGND2	Power Ground. Source of the low side MOSFET for Buck 2.
11	LX2	Switch node of Buck 2. Connect to output inductor.
12	VIN2	Input supply to Buck 2. Bypass to PGND.
13	VIN4	Input supply to Buck 4. Bypass to PGND.
14, 15,16	LX4	Switch node of Buck 4. Connect to output inductor.
17,18	PGND4	Power Ground. Source of the low side MOSFET for Buck 4.
19	VOUT4	Feedback pin for Buck 4. Buck 4 can be programmed from 0.6V to 1.39375V in 6.25mV steps
20	PG2	Power Good output 2. May consist of any ANDed output of all 5 regulators.
21	AN1	Input to ADC. If not used, tie to AGND.
22	AN0	Input to ADC. If not used, tie to AGND.
23	AGND	Signal Analog Ground. Connect to system ground.
24	5VSYS	Filtered from VIN through a RC to provide internal circuits with clean 5V. Place a 100nF capacitor between this pin and AGND as close as possible to the IC.
25	VOUT1	Feedback pin for Buck 1. Buck 1 can be programmed from 3.0V to 3.6V in 20mV steps.
26	PGND1	Power Ground. Source of the low side MOSFET for Buck 1.
27	LX1	Switch node of Buck 1. Connect to output inductor.
28	VIN1	Input supply to Buck 1. Bypass to PGND.
29	VIN3	Input supply to Buck 3. Bypass to PGND.
30	LX3	Switch node of Buck 3. Connect to output inductor.
31	5VSYS	Connect to 5V input. Unlike Pin 24, bypassing is unimportant.
32	VOUT3	Feedback pin for Buck 3. Buck 3 can be programmed from 0.8V to 1.59375V in 6.25mV steps.
PAD	PGND	Package central pad. Connect to PGND.

Typical Performance Characteristics

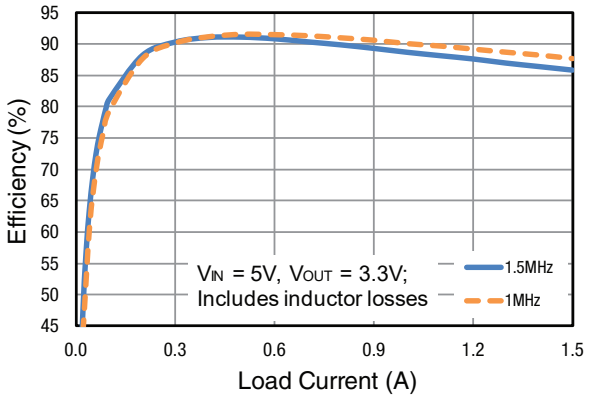

Figure 3: Buck 1 Efficiency

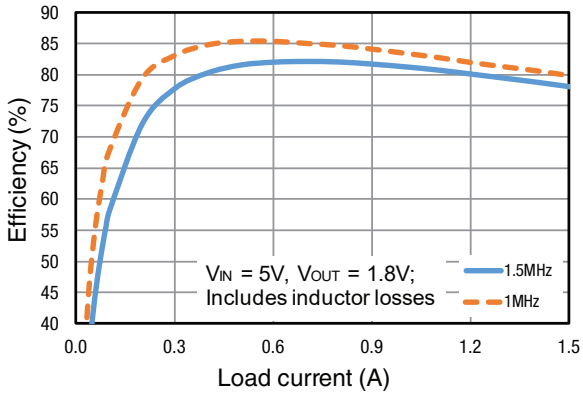

Figure 4: Buck 2 Efficiency

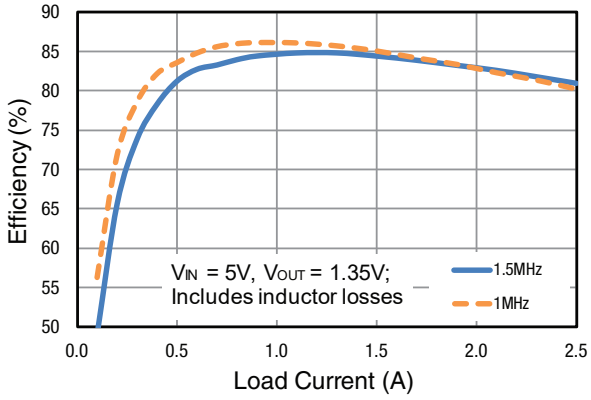

Figure 5: Buck 3 Efficiency

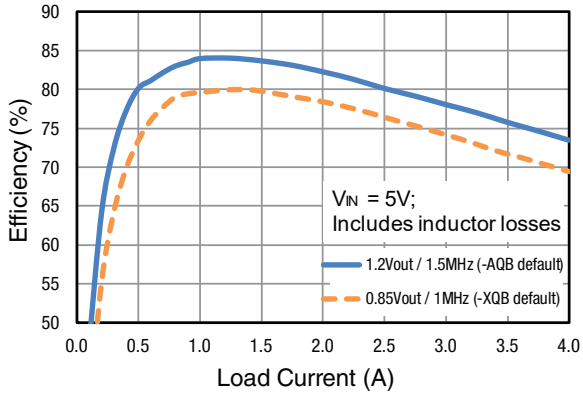

Figure 6: Buck 4 Efficiency

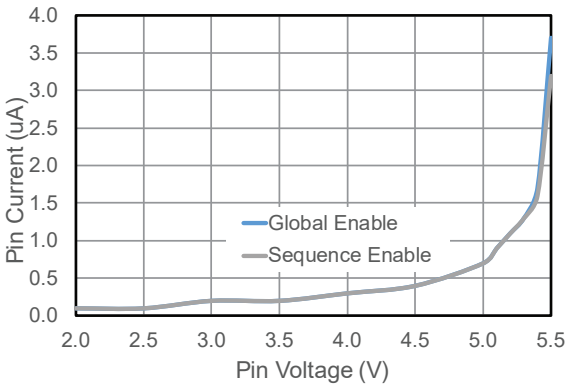

Figure 7: GLOBAL EN and SEQ EN Input Current vs Voltage

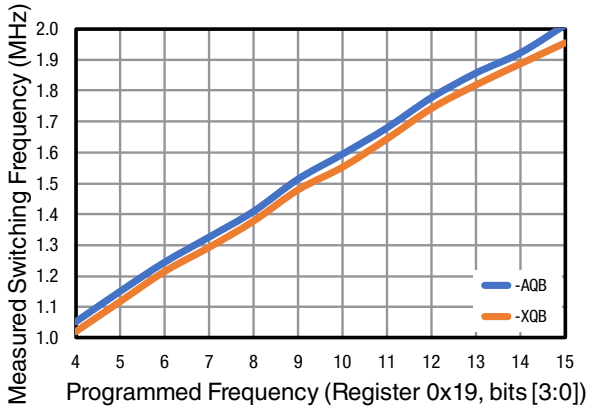

Figure 8: Measured vs Programmed Frequency

Typical Performance Characteristics (Continued)

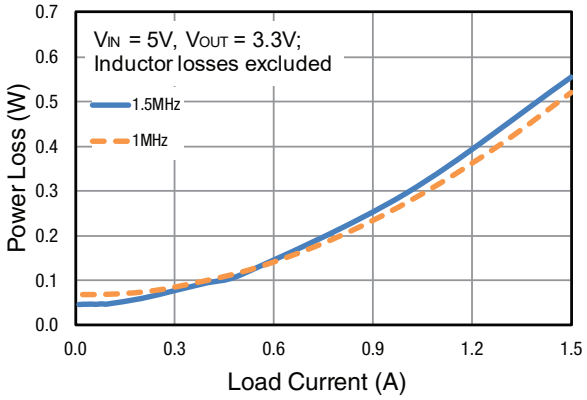

Figure 9: Buck 1 Power Loss

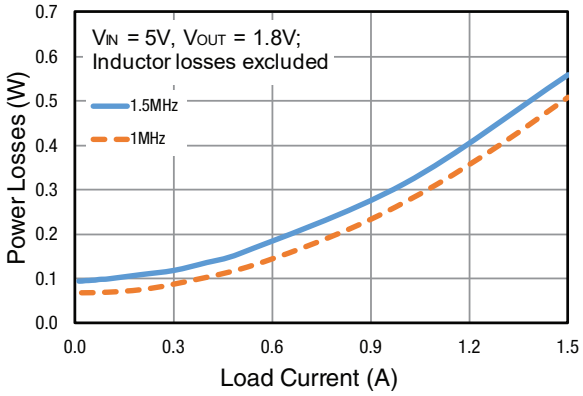

Figure 10: Buck 2 Power Loss

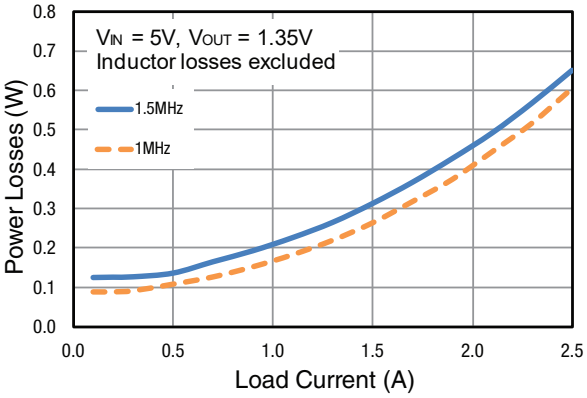

Figure 11: Buck 3 Power Loss

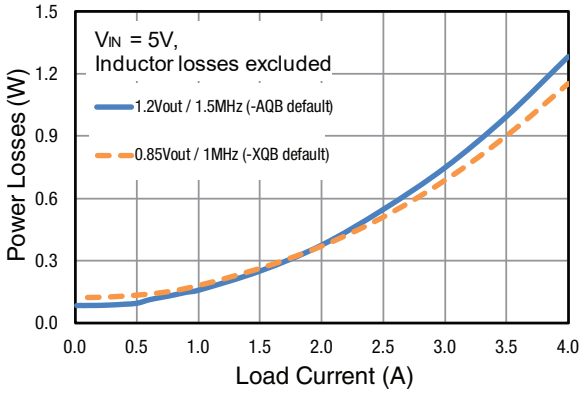

Figure 12: Buck 4 Power Loss

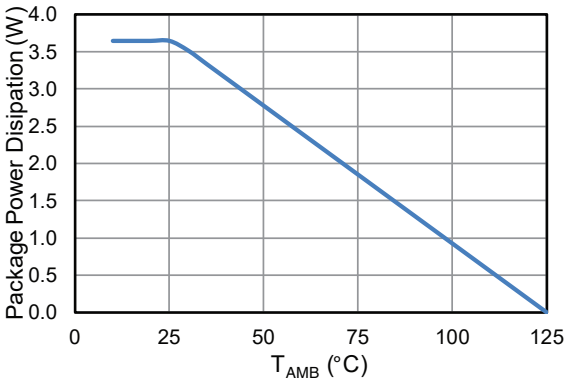

Figure 13: Package Derating

Typical Performance Characteristics (Continued)

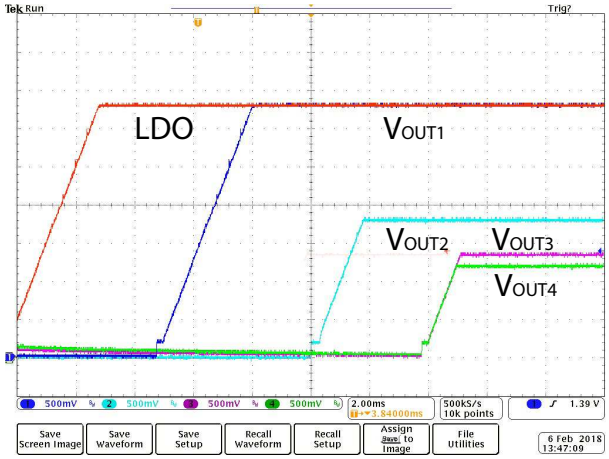

Figure 14: MxL7704-AQB Power-Up Sequencing

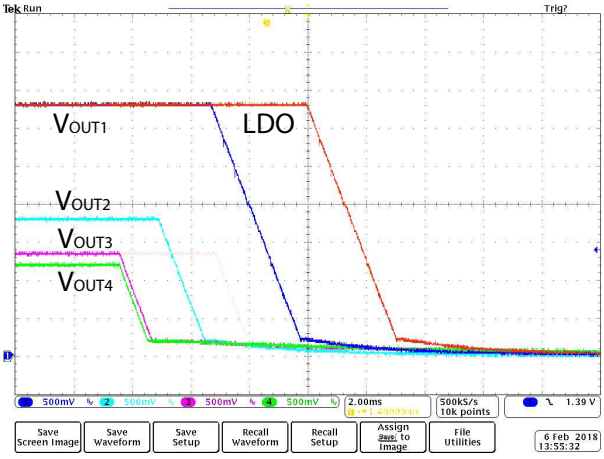

Figure 15: MxL7704-AQB Power-Down Sequencing

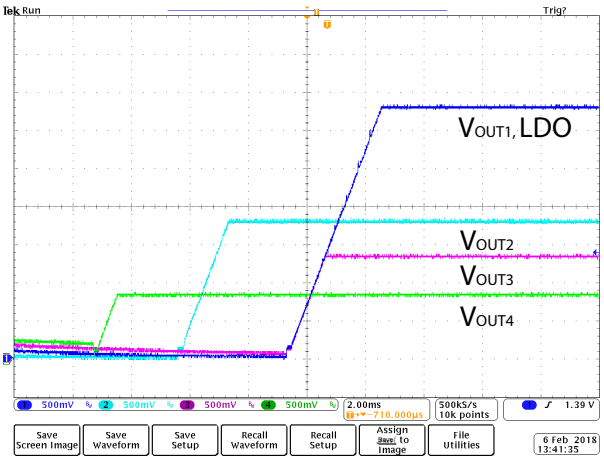

Figure 16: MxL7704-XQB Power-Up Sequencing

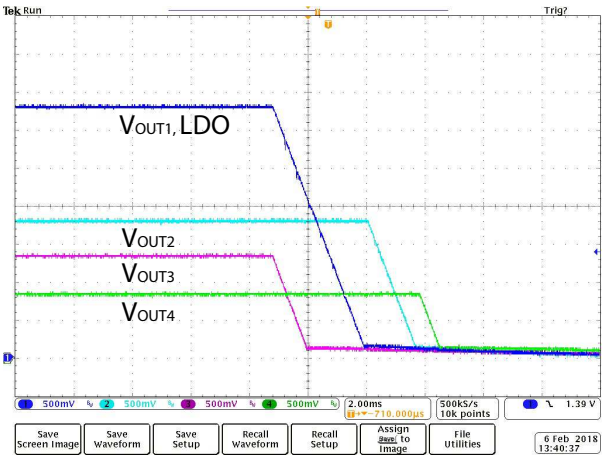

Figure 17: MxL7704-XQB Power-Down Sequencing

Functional Block Diagram

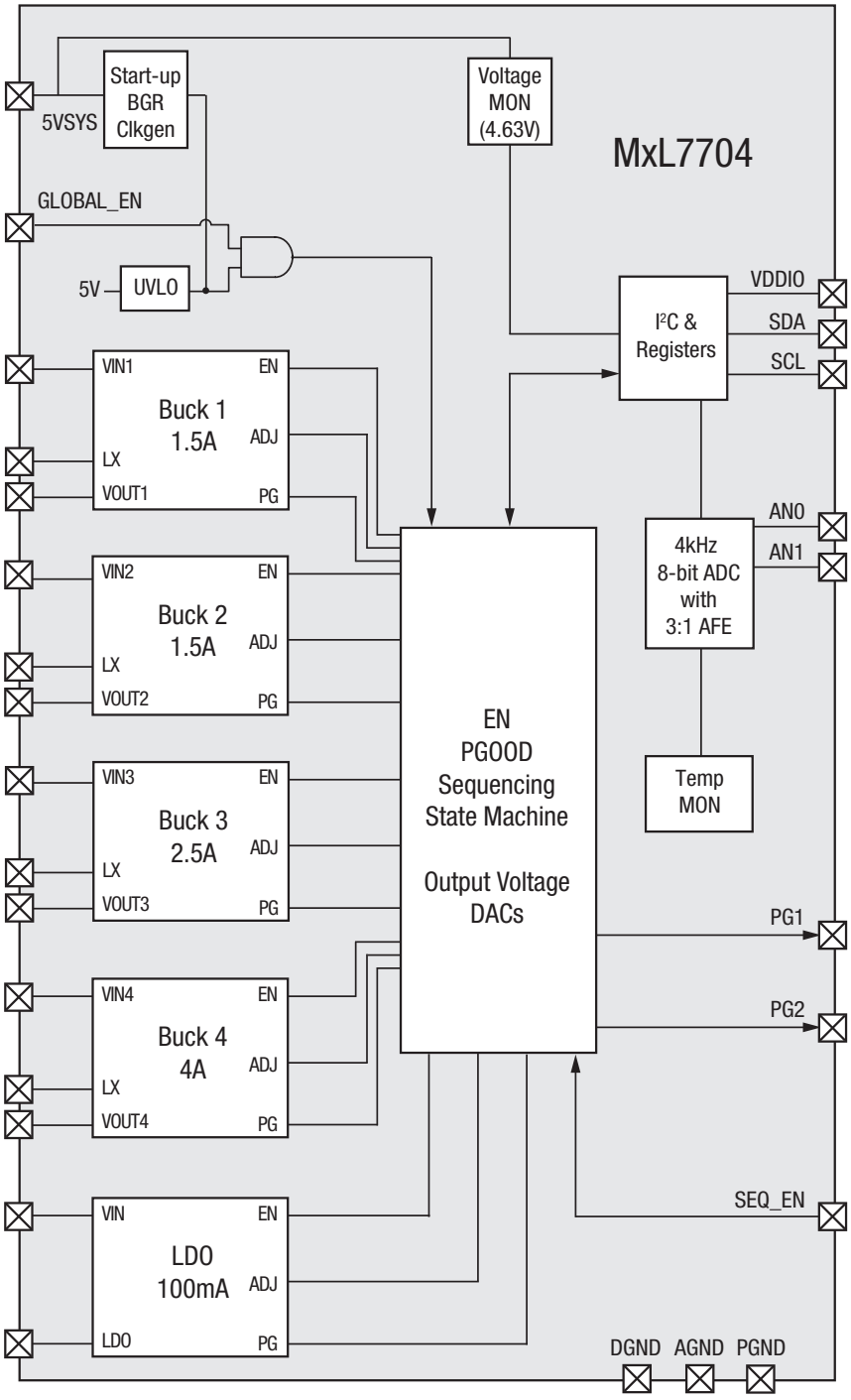

Figure 18: Functional Block Diagram

Applications Information

Operation

MxL7704 is a 5 output Universal PMIC optimized for powering low power FPGAs, DSPs and microprocessors from a 5V input. Four independent buck regulators provide load currents of 1.5A for system power, 1.5A for I/O, 2.5A for memory and 4A for core power. A 100mA LDO provides a clean 1.5V to 3.6V power for auxiliary devices. All outputs support margining where the initial set point can be changed by an 8-bit code. All outputs also support Dynamic Voltage Scaling (DVS) where the output voltage can be dynamically ramped up or down at a preset rate to support processors that can utilize this function to save power.

The I^2C interface allows the customer to monitor an input voltage flag and PGOOD flags for each output. The I^2C port can also be used to modify the power up and power down sequencing options, assign power good outputs to PG1 and PG2 pins, enable the PMIC outputs and select the switching frequency.

All buck regulators employ peak current mode control architecture with internal compensation and high switching frequency. This provides fast transient response to load and line changes without sacrificing stability and keeping small component sizes on board.

Fault protection features include input undervoltage lockout (UVLO), output overcurrent protection (OCP), undervoltage protection (UVP) and over temperature (OTP) or thermal protection.

Two Power Good outputs are available (PG1, PG2). The default configuration leaves these outputs unassigned to be selected by the engineer to do their initial design.

Each channel has a soft start, soft stop function and a Dynamic Voltage Scaling Function (DVS).

Output Voltage Scaling

All outputs support margining where the initial set point can be changed by an 8-bit code. The channel 1 range is from 3.0V to 3.6V with 20mV resolution. Note that the channel 1 regulation will be limited by duty cycle. The channel 2 dynamic range is from 1.3V to 1.92V with 20mV resolution, the channel 3 from 0.8V to 1.6V with 6.25mV resolution, and the channel 4 from 0.6V to 1.4V with 6.25mV resolution. The channel 3 and 4 lower regulation range will be limited by the minimum on time of 120ns. LDO dynamic range is from 1.5V to 3.6V with 20mV resolution. Rather than change the voltage divider resistances in the feedback path, the error amplifier reference is changed. This ensures that the gain of the control loop remains unchanged as the voltage is changed. When a voltage change is commanded, the output will slew at 10V/ms which minimizes latency when moving from low power states to high power states.

Although the 8-bit register will accept values outside those within the ranges listed above, the accuracy of the output is not guaranteed.

Sequencing

Power up and power down sequencing is controlled by setting registers 0x15, 0x16, 0x17 and 0x19. Each channel (BUCK or LDO) can be assigned to be in any of four groups (GROUP 0 thru 3) by programing register 0x15 and 0x16 (each of them has a 2-bit group register that assigns them to each of the four groups). When enabled through GLOBAL EN or the input voltage rising above the UVLO point, all outputs will be discharged by enabling the 78Ω discharge resistors. This ensures proper sequencing after an input voltage glitch.

The sequencing state machine starts with GROUP 0 and looks for any channels if assigned to it by their respective 2-bit group settings. If any channels are assigned to GROUP 0, the state machine starts them up at the same time, provided 5VSYS Under Voltage Lock-out (UVLO) has cleared and the outputs assigned to GROUP 0 have been discharged by the 78Ω resistor to <200mV. Once all GROUP 0 channels are up (all PGOODs are found with the 2ms blanking time added), the sequencing state machine moves to GROUP 1 and repeats the same process, omitting the wait of the output to be discharged to <200mV. It continues to GROUP2 and then GROUP 3. If one group is not up (at least one channel in the group is at fault or disabled thru register setting 0x16), all subsequent groups won't be started. If a group does not have any channels, it will be ignored and the sequencing state machine will move to the next one.

Power Down Sequencing of Channels

After a normal power up sequence is completed, the power down sequencing can be controlled by pulling GLOBAL EN LOW. Power down sequencing of channels follows the reverse order of power up sequencing of channels (GROUP 3 thru 0). All channels will be sequenced down in one of the two methods, depending on the Soft Off Enable Setting (bit 6 of 0x19):

- Soft Off is enabled: Dynamically slewed down for Xms (where X = Vout) then discharged through the 78Ω resistor (default).
- Soft Off is disabled: All channels will be immediately tri-stated and will be discharged by the 78Ω active discharge resistance.

If an output is not dynamically slewed down, the system will consider down sequencing complete for that channel immediately and the next channel in the sequence will begin its power down. For example, if all outputs are chosen to only have 78Ω discharge without dynamic soft-off, all regulators would effectively turn off at the same time (within limits of the state machine).

LDO by default has no ability to slew negative and thus will immediately be considered soft-off complete.

The MxL7704 uses a digitally controlled soft start and soft off. Each output, including the LDO, has an 8 bit Reference DAC feeding the error amplifier input. Although the registers will accept a value across the entire DAC range, the outputs are optimized for the output voltage ranges specified in the electrical table.

Note that after all channels are sequencing down by pulling GLOBAL EN LOW, the IC will be in a hard-reset mode.

When the IC is shut down via Thermal Shutdown (TSD), the channels will be immediately tri-stated and discharged by the 78Ω active discharge resistance. Bit 6 at register address 0x19 will be ignored.

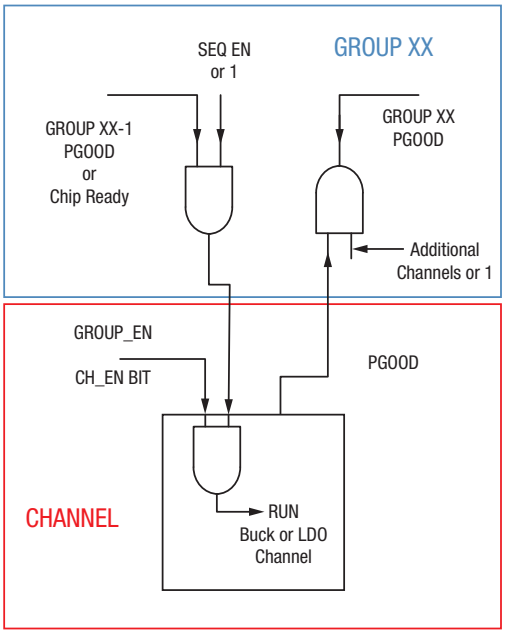

Figure 19: Sequencing

SEQ EN and Channel Enable Bits

The SEQ EN pin input can be assigned to any of the sequence groups to allow an external signal to gate sequencing. This is accomplished by setting bits [7:6] of register 0x17, which will act as an enable to that group and all other subsequently higher groups. Given that each channel has its own channel enable (bits [4:0] of register 0x16), group enable needs to be enabled as well to effectively enable a channel. Having SEQ EN LOW at start will then gate the startup of the group that is assigned to it, and hence all other subsequent higher groups. Having SEQ EN HIGH at startup will void its effect (all group enables will be ON) on the Soft Start Sequencing.

One can always use SEQ EN (pulling HIGH/LOW) to turn on/off multiple groups/channels at any time by moving/setting SEQ EN Group Assign (bit [7:6] of register 0x17). If SEQ EN is pulled LOW, the group / channel(s) assigned to the SEQ EN will be shut down according to the Soft Off Enable setting (bit 6 of 0x19) without any power down sequencing. If SEQ EN is logic HIGH when GLOBAL EN is driven low it does not gate the sequential power down of the sequencing groups.

One can always use channel enable bits (bits [4:0] of the register 0x16) to gate sequencing through the I^2C interface. However once power up sequencing is completed, the channel enable bits can only turn on or off particular channels.

Changing Sequencing Registers While Operating

Sequencing registers may be changed while in operation to allow one to change the power down behavior vs the startup behavior. However, it is not recommended to write to these registers when the chip is powering up or down.

PGOOD

The state of the PGOOD of each channel will gate power up of subsequent higher groups. The state of the PGOOD signals are reported in the status register 0x1A bits [4:0].

At the end of the soft start, PGOOD goes high after the 2ms PGOOD assertion delay. If a channel goes out of the regulation window for more than 65us during regulation, PGOOD will go low. It will assert again after the 2ms assertion delay, assuming the channel is back into the regulation window. If the glitch is faster than 65µs, PGOOD will not record it.

During DVS, PGOOD will be blanked and held HIGH. Once DVS is done, PGOOD will be re-evaluated and an effective PGOOD will be updated.

In the event of a fault, PGOOD will be pulled low immediately.

The registers 0x17 and 0x18 are used to route PGOOD signals from all channels to PG1 and PG2 outputs respectively. Multiple channels can be assigned and PG1 or PG2 signals will be logic function AND of the selected PGOOD signals.

Input Voltage Monitor Flag

The device is continually monitoring voltage at the 5VSYS pin. The status of this pin will be kept in register 0x1A (bit [6:5]). Bit 5 provides the current status of this pin while bit 6 is “sticky” set once the 5VSYS pin is above 4.63V. If the voltage at the 5VSYS pin is above 4.63V, bit 5 will be set or vice versa. The host can poll these two bits to check the status of this pin. Bit 6 can only be cleared by the host writing “1” to it.

Hot Start

If chip fault action is selected and a fault occurs, start up sequencing varies from a cold start where Global EN or UVLO enables the device.

Instead of discharging all outputs in all sequencing groups to <200mV, only the outputs in sequencing group 0 will be discharged. For example if there is no load on the outputs and the down sequencing actions soft-off and 78Ω discharge are not selected, when one channel is faulted all other outputs will float at their set point. When the chip initiates the startup sequence, the 4 buck regulators will drive the outputs down as a natural function of the commanded output voltage. This is also true when using SEQ EN to turn groups on and off. An example of startup after a fault on buck 4 is shown in Figure 20.

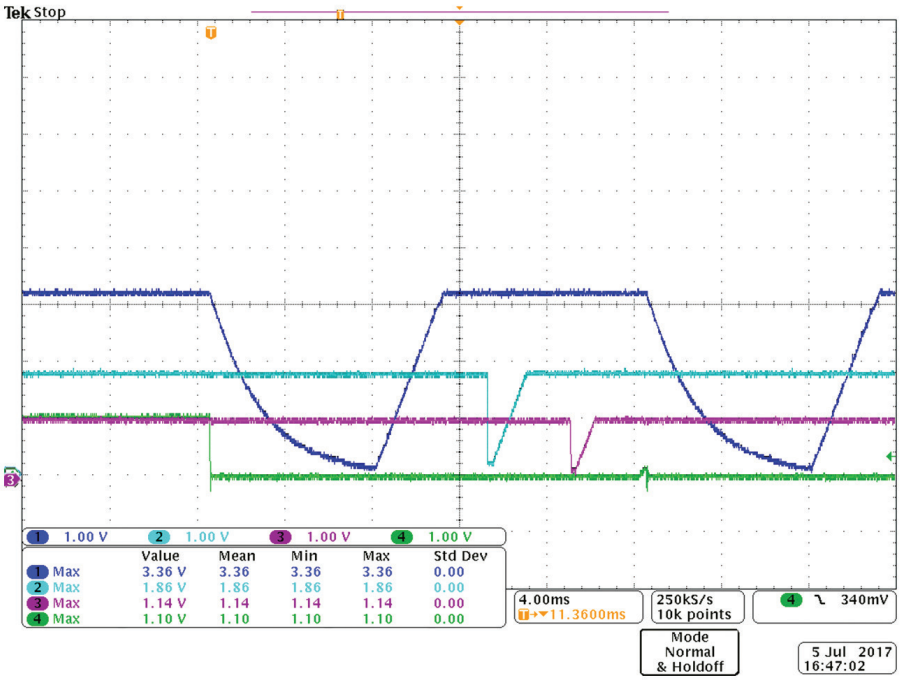

Figure 20: Example of Startup, After a Buck 4 Fault

Figure 20 was generated on an evaluation board with no external load and the 78Ω discharge disabled. The default state is to have the 78Ω discharge enabled from the factory.