LP87524B/J/P-Q1 Four 4-MHz Buck Converters for AWR and IWR MMICs

1 Features

- Qualified for Automotive Applications
- AEC-Q100 Qualified With the Following Results:
  - Device Temperature Grade 1: –40°C to +125°C Ambient Operating Temperature
- Input Voltage: 2.8 V to 5.5 V
- Output Voltage: 0.6 V to 3.36 V
- Four High-Efficiency Step-Down DC-DC Converter Cores:
  - Total Output Current Up To 10 A
  - Output Voltage Slew-Rate 3.8 mV/µs
- 4-MHz Switching Frequency
- Spread-Spectrum Mode and Phase Interleaving
- Configurable General Purpose I/O (GPIOs)
- I^2C-Compatible Interface which Supports Standard (100 kHz), Fast (400 kHz), Fast+ (1 MHz), and High-Speed (3.4 MHz) Modes
- Interrupt Function with Programmable Masking
- Programmable Power Good Signal (PGOOD)
- Output Short-Circuit and Overload Protection
- Overtemperature Warning and Protection
- Overvoltage Protection (OVP) and Undervoltage Lockout (UVLO)

2 Applications

Automotive Infotainment, Cluster, Radar, and Camera Power Applications

3 Description

The LP87524B/J/P-Q1 is designed to meet the power management requirements of the latest processors and platforms in various automotive power applications. The device contains four step-down DC-DC converter cores, which are configured as 4 single phase outputs. The device is controlled by an I^2C-compatible serial interface and by enable signals.

The automatic PFM/PWM (AUTO mode) operation maximizes efficiency over a wide output-current range. The LP87524B/J/P-Q1 supports remote voltage sensing to compensate IR drop between the regulator output and the point-of-load (POL) thus improving the accuracy of the output voltage. In addition the switching clock can be forced to PWM mode and also synchronized to an external clock to minimize the disturbances.

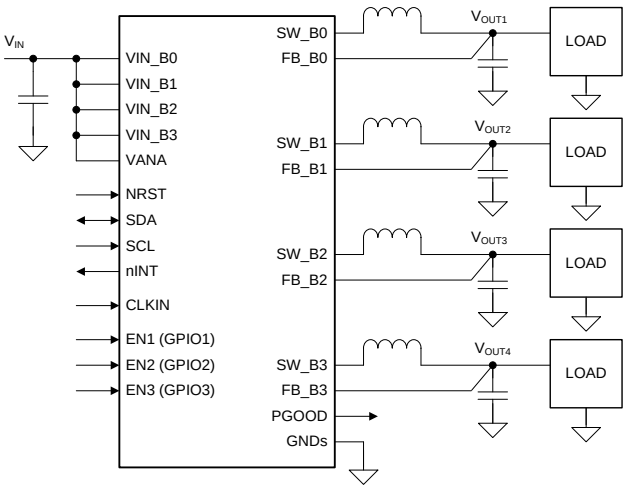
The LP87524B/J/P-Q1 device supports load-current measurement without the addition of external current-sense resistors. In addition, the LP87524B/J/P-Q1 supports programmable start-up and shutdown delays and sequences synchronized to enable signals. The sequences can also include GPIO signals to control external regulators, load switches and processor reset. During start-up and voltage change, the device controls the output slew rate to minimize output voltage overshoot and the in-rush current.

Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
LP87524B-Q1	VQFN-HR (26)	4.50 mm × 4.00 mm
LP87524J-Q1		
LP87524P-Q1		

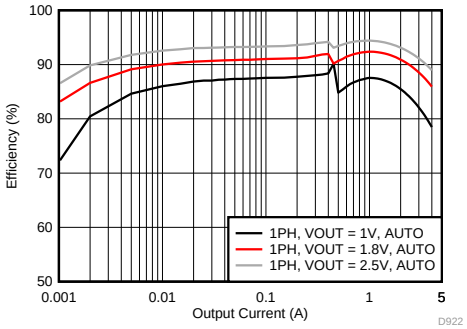
(1) For all available packages, see the orderable addendum at the end of the data sheet.

Simplified Schematic



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Efficiency vs Output Current



An IMPORTANT NOTICE at the end of this data sheet addresses availability, warranty, changes, use in safety-critical applications, intellectual property matters and other important disclaimers. PRODUCTION DATA.

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4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision A (December 2017) to Revision B **Page**

- Added LP87524P-Q1 GPN to SNVSAW2 data sheet ... 1

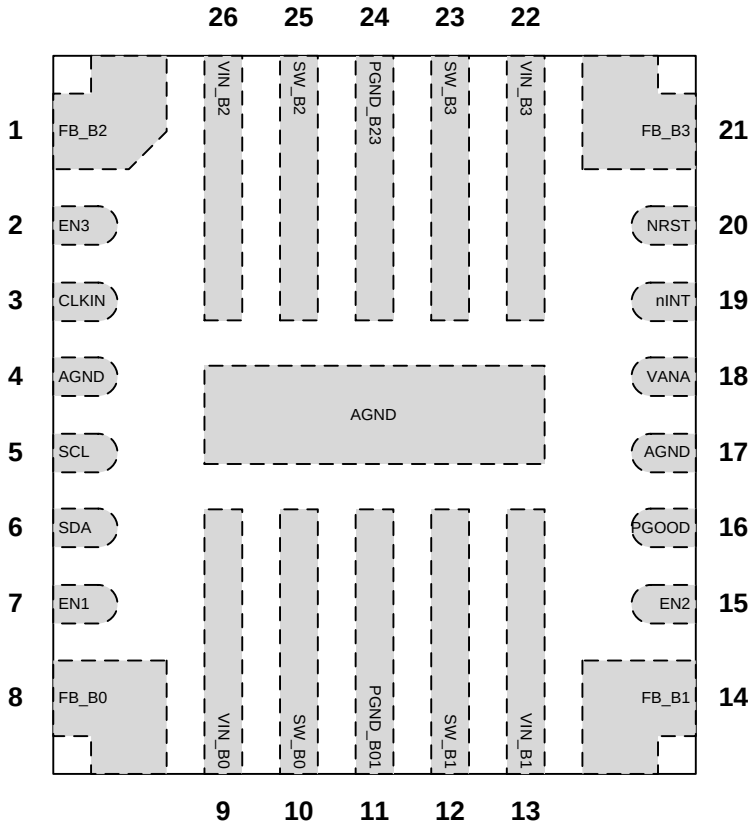
Changes from Original (April 2017) to Revision A **Page**

- Added LP87524J-Q1 GPN to SNVSAW2 data sheet ... 1

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5 Pin Configuration and Functions

RNF Package
26-Pin VQFN With Thermal Pad
Top View



Pin Functions

PIN		TYPE	DESCRIPTION
NUMBER	NAME		
1	FB_B2	A	Output voltage feedback (positive) for Buck2.
2	EN3	D/I/O	Programmable enable signal for buck regulators (can be also configured to select between two buck output voltage levels). Alternative function is GPIO3.
3	CLKIN	D/I	External clock input. Connect to ground if external clock is not used.
4, 17, Thermal Pad	AGND	G	Ground
5	SCL	D/I	Serial interface clock input for I2C access. Connect a pullup resistor.
6	SDA	D/I/O	Serial interface data input and output for I2C access. Connect a pullup resistor.
7	EN1	D/I/O	Programmable Enable signal for buck regulators (can be also configured to select between two buck output voltage levels). Alternative function is GPIO1.
8	FB_B0	A	Output voltage feedback (positive) for Buck0
9	VIN_B0	P	Input for Buck0. The separate power pins VIN_Bx are not connected together internally - VIN_Bx pins must be connected together in the application and be locally bypassed.
10	SW_B0	A	Buck0 switch node
11	PGND_B01	G	Power ground for Buck0 and Buck1
12	SW_B1	A	Buck1 switch node
13	VIN_B1	P	Input for Buck1. The separate power pins VIN_Bx are not connected together internally – VIN_Bx pins must be connected together in the application and be locally bypassed.
14	FB_B1	A	Output voltage feedback (positive) for Buck1.
15	EN2	D/I/O	Programmable enable signal for Buck regulators (can be also configured to select between two buck output voltage levels). Alternative function is GPIO2.
16	PGOOD	D/O	Power Good indication signal
18	VANA	P	Supply voltage for analog and digital blocks. Must be connected to same node as with VIN_Bx.
19	nINT	D/O	Open-drain interrupt output, active LOW
20	NRST	D/I	Reset signal for the device.
21	FB_B3	A	Output voltage feedback (positive) for Buck3.
22	VIN_B3	P	Input for Buck3. The separate power pins VIN_Bx are not connected together internally – VIN_Bx pins must be connected together in the application and be locally bypassed.
23	SW_B3	A	Buck3 switch node
24	PGND_B23	G	Power Ground for Buck2 and Buck3
25	SW_B2	A	Buck2 switch node
26	VIN_B2	P	Input for Buck2. The separate power pins VIN_Bx are not connected together internally – VIN_Bx pins must be connected together in the application and be locally bypassed.
A: Analog Pin, D: Digital Pin, G: Ground Pin, P: Power Pin, I: Input Pin, O: Output Pin			

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6 Specifications

6.1 Absolute Maximum Ratings

Over operating free-air temperature range (unless otherwise noted)(1) (2)

		MIN	MAX	UNIT
Voltage on power connections	VIN_Bx, VANA	–0.3	6	V
Voltage on buck switch nodes	SW_Bx	–0.3	(VIN_Bx + 0.3 V) with 6 V maximum	V
Voltage on buck voltage sense nodes	FB_Bx	–0.3	(VANA + 0.3 V) with 6 V maximum	V
Voltage on NRST input	NRST	–0.3	6	V
Voltage on logic pins (input or output pins)	SDA, SCL, nINT, CLKIN	–0.3	6	V
Voltage on logic pins (input or output pins)	EN1 (GPIO1), EN2 (GPIO2), EN3 (GPIO3), PGOOD	–0.3	(VANA + 0.3 V) with 6 V maximum	V
Junction temperature, T_{J-MAX}		−40	150	°C
Storage temperature, T_{stg}		–65	150	°C
Maximum lead temperature (soldering, 10 sec.)			260	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) All voltage values are with respect to network ground.

6.2 ESD Ratings

				VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per AEC Q100-002(1)		±2000	V
		Charged-device model (CDM), per AEC Q100-011	All pins	±500	
			Corner pins (1, 8, 14 and 21)	±750	

(1) AEC Q100-002 indicates that HBM stressing shall be in accordance with the ANSI/ESDA/JEDEC JS-001 specification.

6.3 Recommended Operating Conditions

Over operating free-air temperature range (unless otherwise noted)

		MIN	MAX	UNIT
INPUT VOLTAGE				
Voltage on power connections	VIN_Bx, VANA	2.8	5.5	V
Voltage on NRST	NRST	1.65	VANA with 5.5 V maximum	V
Voltage on logic pins	nINT, CLKIN	1.65	5.5	V
Voltage on logic pins (input or output pins)	ENx, PGOOD	0	VANA with 5.5 V maximum	V
Voltage on I2C interface, standard (100 kHz), fast (400 khz), fast+ (1 MHz), and high-speed (3.4 MHz) modes	SCL, SDA	1.65	1.95	V
Voltage on I2C interface, standard (100 kHz), fast (400 kHz), and fast+ (1 MHz) modes		3.1	VANA with 3.6 V maximum	V
TEMPERATURE				
Junction temperature, T_J		−40	140	°C
Ambient temperature, T_A		−40	125	°C

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6.4 Thermal Information

THERMAL METRIC(1)		LP875xx-Q1 RNF (VQFN) 26 PINS	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	34.6	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	16.5	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	4.7	°C/W
ψ_{JT}	Junction-to-top characterization parameter	0.6	°C/W
ψ_{JB}	Junction-to-board characterization parameter	4.7	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	1.4	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report.

6.5 Electrical Characteristics

Limits apply over the junction temperature range –40°C ≤ T_J ≤ +140°C, C_{POL} = 22 µF / phase, specified V_{VANA}, V_{VIN_Bx} , V_{NRST}, V_{VOUT_Bx} and I_{OUT} range, unless otherwise noted. Typical values are at T_J = 25°C, V_{VANA} = V_{VIN_Bx} = 3.7 V, and V_{OUT} = 1 V, unless otherwise noted.(1) (2)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
EXTERNAL COMPONENTS						
C_{IN}	Input filtering capacitance	Connected from VIN_Bx to PGND_Bx	1.9	10		µF
C_{OUT}	Output filtering Capacitance, local	Capacitance per phase	10	22		µF
C_{POL}	Point-of-Load (POL) capacitance	Optional POL capacitance per phase		22		µF
$C_{OUT-TOTAL}$	Output capacitance, total (local and POL)	Total output capacitance, 1-phase output			100	µF
ESR_C	Input and output capacitor ESR	[1-10] MHz		2	10	mΩ
L	Inductor	Inductance of the inductor		0.47		µH
			–30%		30%	
DCR_L	Inductor DCR			25		mΩ
BUCK REGULATOR						
V_{VIN_Bx}	Input voltage range		2.8	3.7	5.5	V
V_{VOUT_Bx}	Output voltage	Programmable voltage range, 2.8 V ≤ V_{VIN_Bx} ≤ 4 V	0.6		3.36	V
		Programmable voltage range, 2.8 V ≤ V_{VIN_Bx} ≤ 5.5 V	1.0		3.36	
		Step size, 0.6 V ≤ V_{OUT} < 0.73 V		10		mV
		Step size, 0.73 V ≤ V_{OUT} < 1.4 V		5		
		Step size, 1.4 V ≤ V_{OUT} ≤ 3.36 V		20		
I_{OUT}	Output current, LP87524B/J	Buck0, Buck1			1.5(3)	A
		Buck2: V_{IN} ≥ 3 V			4(3)	
		Buck2: 2.8 V ≤ V_{IN} < 3 V			3(3)	
		Buck3			2.5(3)	
I_{OUT}	Output current, LP87524P	Buck0, Buck2			3(3)	A
		Buck1			1.5(3)	
		Buck3			2.5(3)	

(1) All voltage values are with respect to network ground.
(2) Minimum (Min) and Maximum (Max) limits are specified by design, test, or statistical analysis. Typical (Typ) numbers are not verified, but do represent the most likely norm.
(3) The maximum output current can be limited by the forward current limit $I_{LIM\ FWD}$ and by the junction temperature. The power dissipation inside the die depends on the length of the current pulse and efficiency and the junction temperature may increase to thermal shutdown level if the board and ambient temperatures are high.

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Electrical Characteristics (continued)

Limits apply over the junction temperature range –40°C ≤ T_J ≤ +140°C, C_{POL} = 22 µF / phase, specified V_{VANA}, V_{VIN_Bx} , V_{NRST}, V_{VOUT_Bx} and I_{OUT} range, unless otherwise noted. Typical values are at T_J = 25°C, V_{VANA} = V_{VIN_Bx} = 3.7 V, and V_{OUT} = 1 V, unless otherwise noted.(1) (2)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
	Input and output voltage difference	Minimum voltage between VIN_x and V_{OUT} to fulfill the electrical characteristics	0.5			V
V_{VOUT_DC}	DC output voltage accuracy, includes voltage reference, DC load and line regulations, process and temperature	V_{OUT} < 1 V, PWM mode	–20		20	mV
		V_{OUT} ≥ 1 V, PWM mode	–2%		2%	
		V_{OUT} < 1 V, PFM mode	–20		40	mV
		V_{OUT} ≥ 1 V, PFM mode	–2%		2% + 20 mV	
	Ripple voltage	PWM mode, ESR_C < 2 mΩ, L = 0.47 µH		4		mV_{p-p}
		PFM mode, L = 0.47 µH		14		
DC_{LNR}	DC line regulation	I_{OUT} = $I_{OUT(max)}$		0.1		%/V
DC_{LDR}	DC load regulation in PWM mode	V_{OUT} = 1 V, I_{OUT} from 0 to $I_{OUT(max)}$		0.8%		
T_{LDSR}	Transient load step response	I_{OUT} = 0 A to 2 A, T_R = T_F = 10 µs, PWM mode, C_{OUT} = 22 µF, L = 0.47 µH, C_{POL} = 22 µF	–3%		3%	mV
		I_{OUT} = 0.1 A to 2 A, T_R = T_F = 1 µs, PWM mode, C_{OUT} = 22 µF, L = 0.47 µH, C_{POL} = 22 µF		±40		
T_{LNSR}	Transient line response	V_{VIN_Bx} stepping 3 V ↔ 3.5 V, T_R = T_F = 10 µs, I_{OUT} = $I_{OUT(max)}$		±5		mV
$I_{LIM\ FWD}$	Forward current limit (peak for every switching cycle), LP87524B/J	Buck0, Buck1: V_{VIN_Bx} ≥ 3 V	2.3	2.7	3.0	A
		Buck0, Buck1: 2.8 V ≤ V_{VIN_Bx} < 3 V	2.0	2.7	3.0	
		Buck2: V_{VIN_Bx} ≥ 3 V	4.7	5.4	6.0	
		Buck2: 2.8 V ≤ V_{VIN_Bx} < 3 V	4.0	5.4	6.0	
		Buck3: V_{VIN_Bx} ≥ 3 V	4.2	4.8	5.4	
		Buck3: 2.8 V ≤ V_{VIN_Bx} < 3 V	3.6	4.8	5.4	
$I_{LIM\ FWD}$	Forward current limit (peak for every switching cycle), LP87524P	Buck0, Buck2: V_{VIN_Bx} ≥ 3 V	3.8	4.3	4.8	A
		Buck0, Buck2: 2.8 V ≤ V_{VIN_Bx} < 3 V	3.2	4.3	4.8	
		Buck1: V_{VIN_Bx} ≥ 3 V	2.3	2.7	3.0	
		Buck1: 2.8 V ≤ V_{VIN_Bx} < 3 V	2.0	2.7	3.0	
		Buck3: V_{VIN_Bx} ≥ 3 V	4.2	4.8	5.4	
		Buck3: 2.8 V ≤ V_{VIN_Bx} < 3 V	3.6	4.8	5.4	
$I_{LIM\ NEG}$	Negative current limit / phase (peak for every switching cycle)		1.6	2	2.4	A
$R_{DS(ON)\ HS\ FET}$	On-resistance, high-side FET	Each phase, between VIN_Bx and SW_Bx pins (I = 1 A)		29	65	mΩ
$R_{DS(ON)\ LS\ FET}$	On-resistance, low-side FET	Each phase, between SW_Bx and PGND_Bx pins (I = 1 A)		17	35	mΩ
f_{SW}	Switching frequency, PWM mode	V_{OUT} > 0.8	3.6	4	4.4	MHz
		0.6 < V_{OUT} ≤ 0.8	2.7	3	3.3	
		V_{OUT} = 0.6	1.8	2	2.2	
	Start-up time (soft start)	From ENx to V_{OUT} = 0.35 V (slew-rate control begins), C_{OUT_TOTAL} = 44 µF / phase		200		µs
	Output voltage slew-rate(4)		3.23	3.8	4.4	mV/µs

(4) Output capacitance, forward and negative current limits and load current may limit the maximum and minimum slew rates.

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Electrical Characteristics (continued)

Limits apply over the junction temperature range –40°C ≤ T_J ≤ +140°C, C_{POL} = 22 µF / phase, specified V_{VANA}, V_{VIN_Bx} , V_{NRST}, V_{VOUT_Bx} and I_{OUT} range, unless otherwise noted. Typical values are at T_J = 25°C, V_{VANA} = V_{VIN_Bx} = 3.7 V, and V_{OUT} = 1 V, unless otherwise noted.(1) (2)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$I_{PFM-PWM}$	PFM-to-PWM - current threshold(5)			600		mA
$I_{PWM-PFM}$	PWM-to-PFM - current threshold(5)			200		mA
	Output pulldown resistance	Regulator disabled	160	230	300	Ω
	Output voltage monitoring for PGOOD pin	Overvoltage monitoring (compared to DC output voltage level, V_{VOUT_DC})	39	50	64	mV
		Undervoltage monitoring (compared to DC output voltage level, V_{VOUT_DC})	–53	–40	–29	
		Debounce time during regulator enable PGOOD_SET_DELAY = 0	4		10	µs
		Debounce time during regulator enable PGOOD_SET_DELAY = 1	10	11	13	ms
		Deglitch time during operation and after voltage change	4		10	µs
	Powergood threshold for interrupt BUCKx_PG_INT, difference from final voltage	Rising ramp voltage, enable or voltage change	–20	–14	–8	mV
		Falling ramp voltage, voltage change	8	14	20	
	Powergood threshold for status bit BUCKx_PG_STAT	During operation, status signal is forced to '0' during voltage change	–20	–14	–8	mV
EXTERNAL CLOCK AND PLL						
	External input clock	Nominal frequency	1		24	MHz
		Nominal frequency step size		1		
		Required accuracy from nominal frequency	–30%		10%	
	External clock detection	Delay for missing clock detection			1.8	µs
		Delay and debounce for clock detection			20	
	Clock change delay (internal to external)	Delay from valid clock detection to use of external clock		600		µs
	PLL output clock jitter	Cycle to cycle		300		ps, p-p
PROTECTION FUNCTIONS						
	Thermal warning	Temperature rising, TDIE_WARN_LEVEL = 0	115	125	135	°C
		Temperature rising, TDIE_WARN_LEVEL = 1	127	137	147	
		Hysteresis		20		
	Thermal shutdown	Temperature rising	140	150	160	°C
		Hysteresis		20		
$VANA_{OVP}$	VANA overvoltage	Voltage rising	5.6	5.8	6.1	V
		Voltage falling	5.45	5.73	5.96	
		Hysteresis	40			mV
$VANA_{UVLO}$	VANA undervoltage lockout	Voltage rising	2.51	2.63	2.75	V
		Voltage falling	2.5	2.6	2.7	
LOAD CURRENT MEASUREMENT						

(5) The final PFM-to-PWM and PWM-to-PFM switchover current varies slightly and is dependent on the output voltage, input voltage, and the inductor current level.

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Electrical Characteristics (continued)

Limits apply over the junction temperature range –40°C ≤ T_J ≤ +140°C, C_{POL} = 22 µF / phase, specified V_{VANA}, V_{VIN_Bx} , V_{NRST}, V_{VOUT_Bx} and I_{OUT} range, unless otherwise noted. Typical values are at T_J = 25°C, V_{VANA} = V_{VIN_Bx} = 3.7 V, and V_{OUT} = 1 V, unless otherwise noted.(1) (2)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
	Current measurement range	Output current for maximum code			20.47	A
	Resolution	LSB		20		mA
	Measurement accuracy	I_{OUT} > 1 A		<10%		
	Measurement time	PFM mode (automatically changing to PWM mode for the measurement)		45		µs
		PWM mode		4		
CURRENT CONSUMPTION						
	Shutdown current consumption	From VANA and VIN_Bx pins: NRST = 0 V, VANA = VIN_Bx = 3.7 V		1.4		µA
	Standby current consumption, regulators disabled	From VANA and VIN_Bx pins: NRST = 1.8 V, VANA = VIN_Bx = 3.7 V		6.7		
	Active current consumption in PFM mode, one regulator enabled, internal RC oscillator, PGOOD monitoring enabled	From VANA and VIN_Bx pins: NRST = 1.8 V, VANA = VIN_Bx = 3.7 V, I_{OUT} = 0 mA, not switching		57		µA
	Active current consumption during PWM operation, per phase			19		mA
	PLL and clock detector current consumption	Additional current consumption when internal RC oscillator, clock detector and PLL are enabled		2		mA
DIGITAL INPUT SIGNALS NRST, EN1, EN2, EN3, EN4, SCL, SDA, GPIO1, GPIO2, GPIO3, CLKIN						
V_{IL}	Input low level				0.4	V
V_{IH}	Input high level		1.2			
V_{HYS}	Hysteresis of Schmitt Trigger inputs		10	77	200	mV
	ENx pulldown resistance	ENx_PD = 1		500		kΩ
	NRST pulldown resistance	Always present	650	1150	1700	
DIGITAL OUTPUT SIGNALS nINT						
V_{OL}	Output low level	I_{SOURCE} = 2 mA			0.4	V
R_P	External pullup resistor	To VIO supply		10		kΩ
DIGITAL OUTPUT SIGNALS SDA						
V_{OL}	Output low level	I_{SOURCE} = 10 mA			0.4	V
DIGITAL OUTPUT SIGNALS PGOOD, GPIO1, GPIO2, GPIO3						
V_{OL}	Output low level	I_{SOURCE} = 2 mA			0.4	V
V_{OH}	Output high level, configured to push-pull	I_{SINK} = 2 mA	V_{VANA} – 0.4		V_{VANA}	V
V_{PU}	Supply voltage for external pull-up resistor, configured to open-drain				V_{VANA}	V
R_{PU}	External pullup resistor, configured to open-drain			10		kΩ
ALL DIGITAL INPUTS						

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Electrical Characteristics (continued)

Limits apply over the junction temperature range –40°C ≤ T_J ≤ +140°C, C_{POL} = 22 µF / phase, specified V_{VANA}, V_{VIN_Bx} , V_{NRST}, V_{VOUT_Bx} and I_{OUT} range, unless otherwise noted. Typical values are at T_J = 25°C, V_{VANA} = V_{VIN_Bx} = 3.7 V, and V_{OUT} = 1 V, unless otherwise noted.(1) (2)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{LEAK}	Input current	All logic inputs over pin voltage range (except NRST)	−1		1	µA

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6.6 I2C Serial Bus Timing Requirements

These specifications are ensured by design. Unless otherwise noted, V_{IN_Bx} = 3.7 V.

			MIN	MAX	UNIT
f_{SCL}	Serial clock frequency	Standard mode		100	kHz
		Fast mode		400	
		Fast mode+		1	MHz
		High-speed mode, C_b = 100 pF		3.4	
		High-speed mode, C_b = 400 pF		1.7	
t_{LOW}	SCL low time	Standard mode	4.7		µs
		Fast mode	1.3		
		Fast mode+	0.5		
		High-speed mode, C_b = 100 pF	160		ns
		High-speed mode, C_b = 400 pF	320		
t_{HIGH}	SCL high time	Standard mode	4		µs
		Fast mode	0.6		
		Fast mode+	0.26		
		High-speed mode, C_b = 100 pF	60		ns
		High-speed mode, C_b = 400 pF	120		
$t_{SU;DAT}$	Data setup time	Standard mode	250		ns
		Fast mode	100		
		Fast mode+	50		
		High-speed mode	10		
$t_{HD;DAT}$	Data hold time	Standard mode	10	3450	ns
		Fast mode	10	900	
		Fast mode+	10		
		High-speed mode, C_b = 100 pF	10	70	ns
		High-speed mode, C_b = 400 pF	10	150	
$t_{SU;STA}$	Setup time for a start or a repeated start condition	Standard mode	4.7		µs
		Fast mode	0.6		
		Fast mode+	0.26		
		High-speed mode	160		ns
$t_{HD;STA}$	Hold time for a start or a repeated start condition	Standard mode	4.0		µs
		Fast mode	0.6		
		Fast mode+	0.26		
		High-speed mode	160		ns
t_{BUF}	Bus free time between a stop and start condition	Standard mode	4.7		µs
		Fast mode	1.3		
		Fast mode+	0.5		
$t_{SU;STO}$	Setup time for a stop condition	Standard mode	4		µs
		Fast mode	0.6		
		Fast mode+	0.26		
		High-speed mode	160		ns
t_{rDA}	Rise time of SDA signal	Standard mode		1000	ns
		Fast mode	20	300	
		Fast mode+		120	
		High-speed mode, C_b = 100 pF	10	80	
		High-speed mode, C_b = 400 pF	20	160	

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I2C Serial Bus Timing Requirements (continued)

These specifications are ensured by design. Unless otherwise noted, V_{IN_Bx} = 3.7 V.

			MIN	MAX	UNIT
t_{fDA}	Fall time of SDA signal	Standard mode		300	ns
		Fast mode	20 × (V_{DD} / 5.5 V)	300	
		Fast mode+	20 × (V_{DD} / 5.5 V)	120	
		High-speed mode, C_b = 100 pF	10	80	
		High-speed mode, C_b = 400 pF	30	160	
t_{rCL}	Rise time of SCL signal	Standard mode		1000	ns
		Fast mode	20	300	
		Fast mode+		120	
		High-speed mode, C_b = 100 pF	10	40	
		High-speed mode, C_b = 400 pF	20	80	
t_{rCL1}	Rise time of SCL signal after a repeated start condition and after an acknowledge bit	High-speed mode, C_b = 100 pF	10	80	ns
		High-speed mode, C_b = 400 pF	20	160	
t_{fCL}	Fall time of a SCL signal	Standard mode		300	ns
		Fast mode	20 × (V_{DD} / 5.5 V)	300	
		Fast mode+	20 × (V_{DD} / 5.5 V)	120	
		High-speed mode, C_b = 100 pF	10	40	
		High-speed mode, C_b = 400 pF	20	80	
C_b	Capacitive load for each bus line (SCL and SDA)			400	pF
t_{SP}	Pulse width of spike suppressed (SCL and SDA spikes that are less than the indicated width are suppressed)	Standard mode, fast mode and fast mode+		50	ns
		High-speed mode		10	

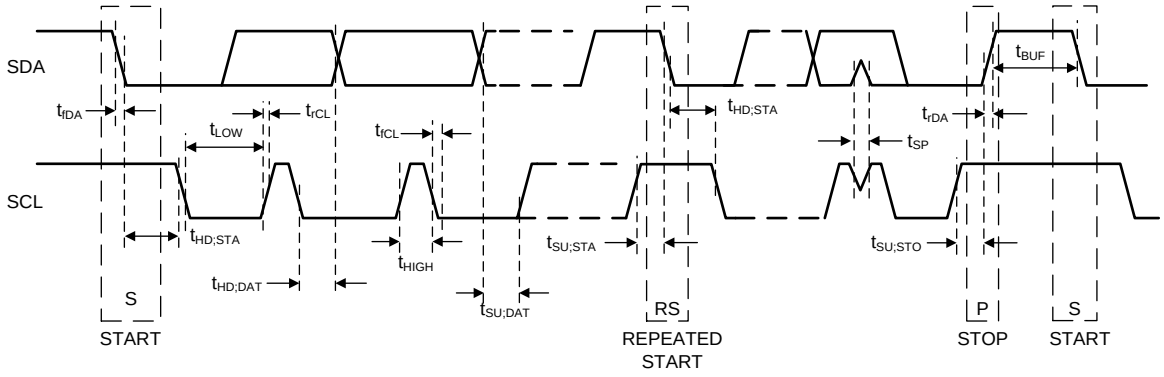
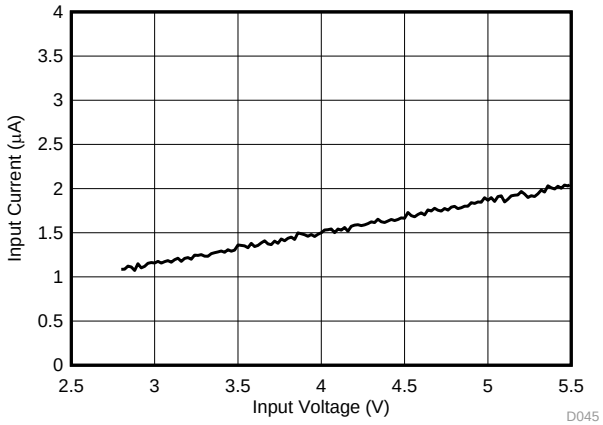


Figure 1. I²C Timing

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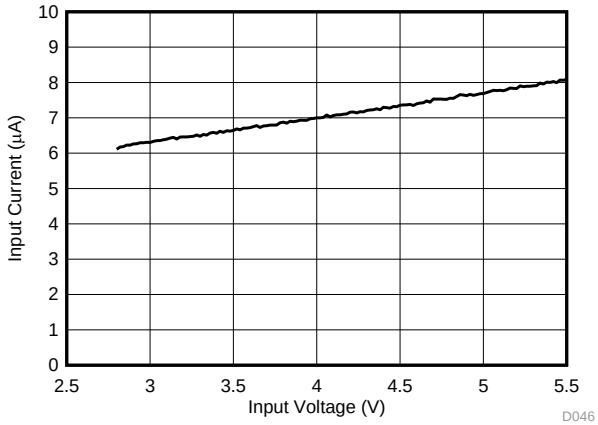
6.7 Typical Characteristics

Unless otherwise specified: T_A = 25°C, V_{IN} = 3.7 V, V_{OUT} = 1 V, $V_{(NRST)}$ = 1.8 V, f_{SW} = 4 MHz, L = 0.47 µH (TOKO DFE252012PD-R47M), C_{OUT} = 22 µF / phase, C_{POL} = 22 µF / phase.



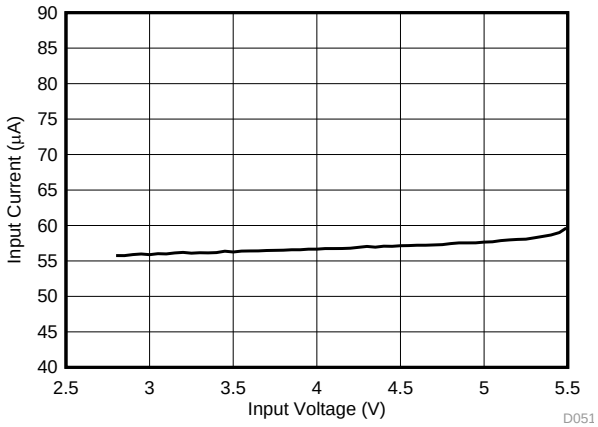
$V_{(NRST)}$ = 0 V

Figure 2. Shutdown Current Consumption vs Input Voltage



$V_{(NRST)}$ = 1.8 V Regulators disabled

Figure 3. Standby Current Consumption vs Input Voltage



$V_{(NRST)}$ = 1.8 V Load = 0 mA

Figure 4. PFM Mode Current Consumption vs Input Voltage, One Regulator Enabled

7 Detailed Description

7.1 Overview

The LP87524B/J/P-Q1 is a high-efficiency, high-performance power supply device with four step-down DC-DC converter cores for automotive applications. Table 1 lists the output characteristics of the regulators.

Table 1. Supply Specification

SUPPLY	OUTPUT		
	V_{OUT} RANGE (V)	RESOLUTION (mV)	I_{MAX} MAXIMUM OUTPUT CURRENT (A)
Buck0	0.6 to 3.36 (V_{IN} = 2.8 V - 4 V) 1.0 to 3.36 (V_{IN} = 2.8 V - 5.5 V)	10 (0.6 V to 0.73 V) 5 (0.73 V to 1.4 V) 20 (1.4 V to 3.36 V)	10 A total
Buck1	0.6 to 3.36 (V_{IN} = 2.8 V - 4 V) 1.0 to 3.36 (V_{IN} = 2.8 V - 5.5 V)	10 (0.6 V to 0.73 V) 5 (0.73 V to 1.4 V) 20 (1.4 V to 3.36 V)	
Buck2	0.6 to 3.36 (V_{IN} = 2.8 V - 4 V) 1.0 to 3.36 (V_{IN} = 2.8 V - 5.5 V)	10 (0.6 V to 0.73 V) 5 (0.73 V to 1.4 V) 20 (1.4 V to 3.36 V)	
Buck3	0.6 to 3.36 (V_{IN} = 2.8 V - 4 V) 1.0 to 3.36 (V_{IN} = 2.8 V - 5.5 V)	10 (0.6 V to 0.73 V) 5 (0.73 V to 1.4 V) 20 (1.4 V to 3.36 V)	
LP87524B-Q1 default settings:	**V_{OUT} (V)**	**I_{MAX} MAXIMUM OUTPUT CURRENT (A)**	**AWR / IWR Rail**
Buck0	3.3 V	1.5 A	IO
Buck1	1.2 V	1.5 A	Digital
Buck2	1.8 V	4 A	RF, with external LDO
Buck3	2.3 V	2.5 A	RF, with external LDO
LP87524J-Q1 default settings:	**V_{OUT} (V)**	**I_{MAX} MAXIMUM OUTPUT CURRENT (A)**	**AWR / IWR Rail**
Buck0	3.3 V	1.5 A	IO
Buck1	1.2 V	1.5 A	Digital
Buck2	1 V	4 A	RF, with ferrite filter
Buck3	1.8 V	2.5 A	RF, with ferrite filter
LP87524P-Q1 default settings:	**V_{OUT} (V)**	**I_{MAX} MAXIMUM OUTPUT CURRENT (A)**	**AWR / IWR Rail**
Buck0	1 V	3 A	RF, with ferrite filter
Buck1	1.2 V	1.5 A	Digital
Buck2	1 V	3 A	RF, with ferrite filter
Buck3	1.8 V	2.5 A	RF, with ferrite filter

The LP87524B/J/P-Q1 also supports switching clock synchronization to an external clock. The nominal frequency of the external clock can be from 1 MHz to 24 MHz with 1-MHz steps.

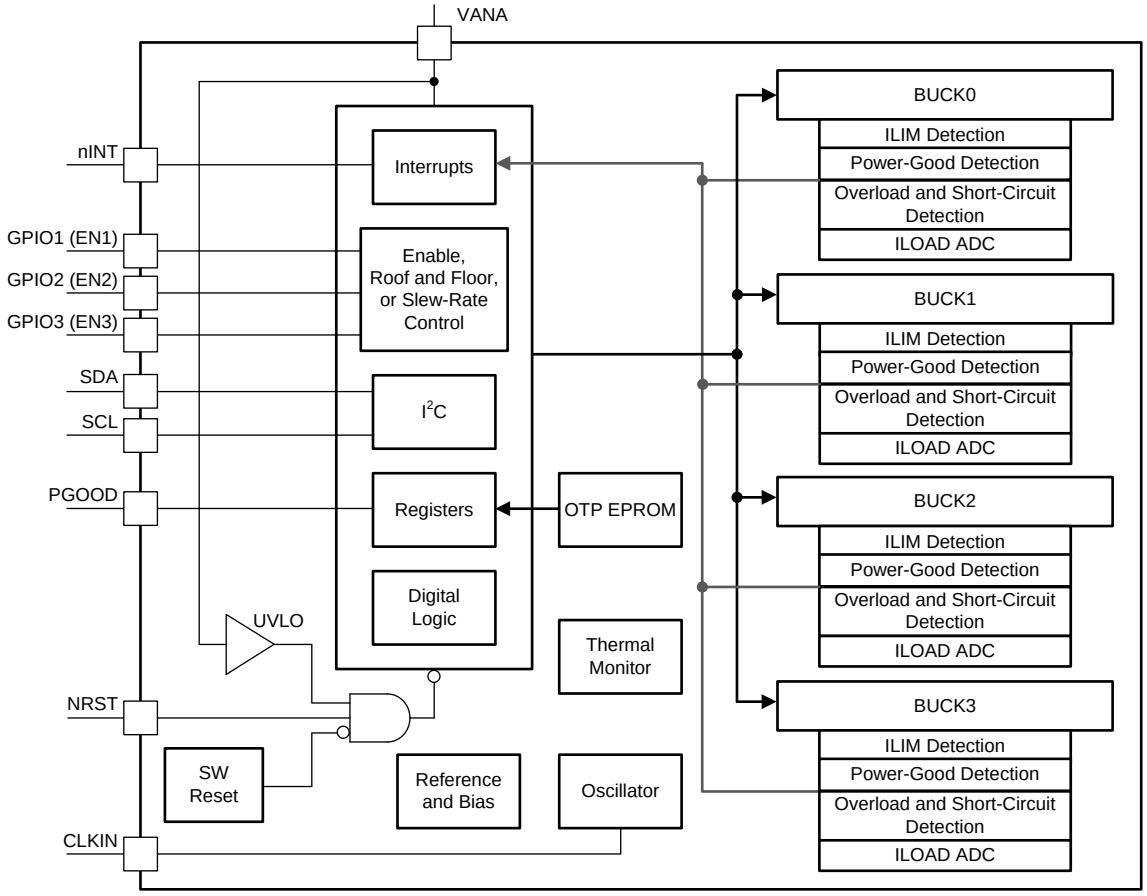
Additional features include:

- Soft start
- Input voltage protection:
  - Undervoltage lockout
  - Overvoltage protection
- Output voltage monitoring and protection:
  - Overvoltage monitoring
  - Undervoltage monitoring
  - Overload protection
- Thermal warning
- Thermal shutdown

Three enable signals can be multiplexed to general purpose I/O (GPIO) signals. The direction and output type (open-drain or push-pull) are programmable for the GPIOs.

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7.2 Functional Block Diagram



7.3 Feature Descriptions

7.3.1 DC-DC Converters

7.3.1.1 Overview

The LP87524B/J/P-Q1 includes four step-down DC-DC converter cores configured for four single-phase outputs. The cores are designed for flexibility; most of the functions are programmable, thus giving a possibility to optimize the regulator operation for each application.

The LP87524B/J/P-Q1 has the following features:

- DVS support
- Automatic mode control based on the loading (PFM or PWM mode)
- Forced-PWM mode operation
- Optional external clock input to minimize crosstalk
- Optional spread spectrum technique to reduce EMI
- Phase control for optimized EMI
- Synchronous rectification
- Current mode loop with PI compensator
- Soft start
- Power Good flag with maskable interrupt
- Power Good signal (PGOOD) with selectable sources
- Average output current sensing (for PFM entry and load current measurement)

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Feature Descriptions (continued)

The following parameters can be programmed via registers:

- Output voltage
- Forced-PWM operation
- Enable and disable delays for regulators and GPIOs controlled by ENx pins

There are two modes of operation for the converter, depending on the output current required: pulse-width modulation (PWM) and pulse-frequency modulation (PFM). The converter operates in PWM mode at high load currents of approximately 600 mA or higher. Lighter output current loads cause the converter to automatically switch into PFM mode for reduced current consumption when forced-PWM mode is disabled.

A multi-phase synchronous buck converter offers several advantages over a single power stage converter. For application processor power delivery, lower ripple on the input and output currents and faster transient response to load steps are the most significant advantages. Also, because the load current is evenly shared among multiple channels in multi-phase output configuration, the heat generated is greatly reduced for each channel due to the fact that power loss is proportional to square of current. The physical size of the output inductor shrinks significantly due to this heat reduction. A block diagram of a single core is shown in Figure 5.

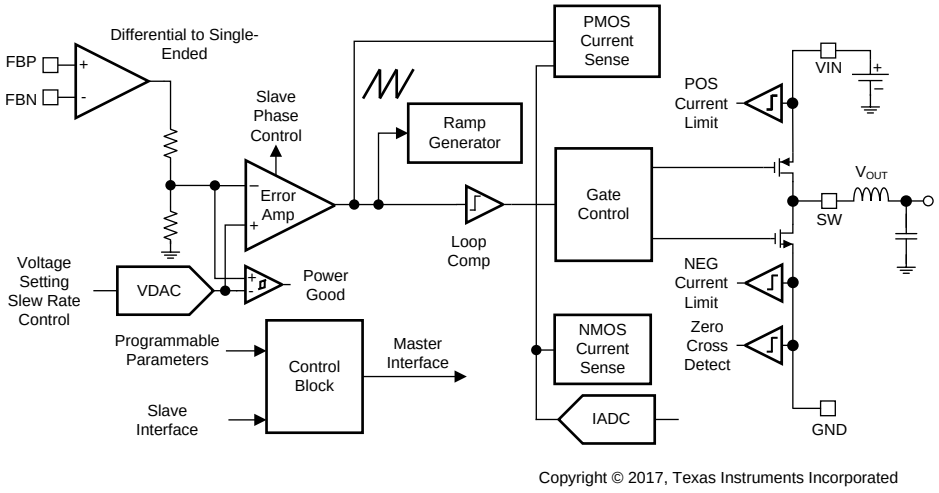


Figure 5. Detailed Block Diagram Showing One Core

7.3.1.2 Transition Between PWM and PFM Modes

The LP87524B/J/P-Q1 converter operates in PWM mode at load current of about 600 mA or higher. At lighter load-current levels the device automatically switches into PFM mode for reduced current consumption when forced-PWM mode is disabled (AUTO-mode operation). By combining the PFM and the PWM modes a high efficiency is achieved over a wide output-load-current range.

7.3.1.3 Buck Converter Load-Current Measurement

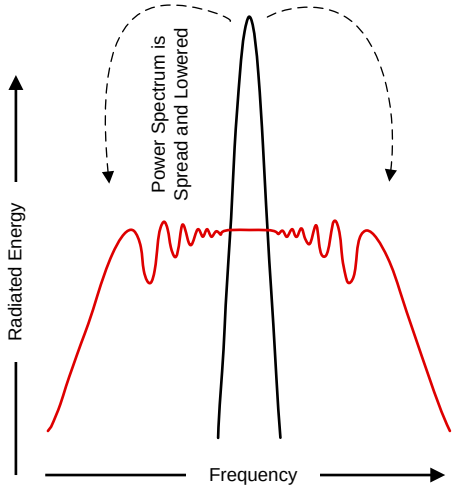
Buck load current can be monitored via I^2C registers. The monitored buck converter is selected with the LOAD_CURRENT_BUCK_SELECT[1:0] bits in SEL_I_LOAD register. A write to this selection register starts a current measurement sequence. The regulator is forced to PWM mode during the measurement. The measurement sequence is 50 µs long, maximum. LP87524B/J/P-Q1 can be configured to give out an interrupt (I_LOAD_READY bit in INT_TOP1 register) after the load current measurement sequence is finished. Load current measurement interrupt can be masked with I_LOAD_READY_MASK bit (TOP_MASK1 register). The measurement result can be read from registers I_LOAD_1 and I_LOAD_2. Register I_LOAD_1 bits BUCK_LOAD_CURRENT[7:0] give out the LSB bits and register I_LOAD_2 bits BUCK_LOAD_CURRENT[9:8] the MSB bits. The measurement result BUCK_LOAD_CURRENT[9:0] LSB is 20 mA, and maximum value of the measurement corresponds to 20.46 A.

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Feature Descriptions (continued)

7.3.1.4 Spread-Spectrum Mode

Systems with periodic switching signals may generate a large amount of switching noise in a set of narrowband frequencies (the switching frequency and its harmonics). The usual solution to reduce noise coupling is to add EMI filters and shields to the boards. The LP87524B/J/P-Q1 device has register selectable spread-spectrum mode which minimizes the need for output filters, ferrite beads, or chokes. In spread-spectrum mode, the switching frequency varies around the center frequency, reducing the EMI emissions radiated by the converter and associated passive components and PCB traces (see Figure 6). This feature is available only when internal RC oscillator is used (PLL_MODE[1:0] = 00 in PLL_CTRL register), and it is enabled with the EN_SPREAD_SPEC bit (PIN_FUNCTION register), and it affects all the buck cores.



Where a fixed-frequency converter exhibits large amounts of spectral energy at the switching frequency, the spread-spectrum architecture of the LP87524B/J/P-Q1 spreads that energy over a large bandwidth.

Figure 6. Spread-Spectrum Modulation

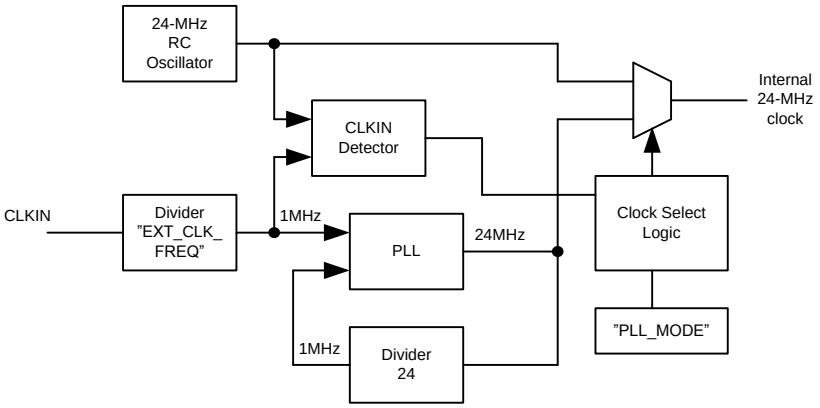
7.3.2 Sync Clock Functionality

The LP87524B/J/P-Q1 device contains a CLKIN input to synchronize switching clock of the buck regulator with the external clock. The block diagram of the clocking and PLL module is shown in Figure 7. Depending on the PLL_MODE[1:0] bits (in PLL_CTRL register) and the external clock availability, the external clock is selected and interrupt is generated as shown in Table 2. The interrupt can be masked with SYNC_CLK_MASK bit in TOP_MASK1 register. The nominal frequency of the external input clock is set by EXT_CLK_FREQ[4:0] bits (in PLL_CTRL register) and it can be from 1 MHz to 24 MHz with 1-MHz steps. The external clock must be inside accuracy limits (–30%/+10%) for valid clock detection.

The NO_SYNC_CLK interrupt (in INT_TOP1 register) is also generated in cases the external clock is expected but it is not available. These cases are start-up (read OTP-to-STANDBY transition) when PLL_MODE[1:0] = 01 and regulator enable (STANDBY-to-ACTIVE transition) when PLL_MODE[1:0] = 10.

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Feature Descriptions (continued)



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Figure 7. Clock and PLL Module

Table 2. PLL Operation

DEVICE OPERATION MODE	PLL_MODE[1:0]	PLL AND CLOCK DETECTOR STATE	INTERRUPT FOR EXTERNAL CLOCK	CLOCK
STANDBY	00	Disabled	No	Internal RC
ACTIVE	00	Disabled	No	Internal RC
STANDBY	01	Enabled	When external clock appears or disappears	Automatic change to external clock when available
ACTIVE	01	Enabled	When external clock appears or disappears	Automatic change to external clock when available
STANDBY	10	Disabled	No	Internal RC
ACTIVE	10	Enabled	When external clock appears or disappears	Automatic change to external clock when available
STANDBY	11	Reserved		
ACTIVE	11	Reserved		

7.3.3 Power-Up

The power-up sequence for the LP87524B/J/P-Q1 is as follows:

- VANA (and VIN_Bx) reach minimum recommended level (V_{VANA} > $VANA_{UVLO}$).
- NRST is set to high level (or shorted to VANA). This initiates power-on-reset (POR), OTP reading and enables the system I/O interface. The I^2C host must allow at least 1.2 ms before writing or reading data to the LP87524B/J/P-Q1.
- Device enters STANDBY-mode.
- The host can change the default register setting by I^2C if needed.
- The regulator(s) can be enabled/disabled by ENx pin(s) and by I^2C interface.

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7.3.4 Regulator Control

7.3.4.1 Enabling and Disabling Regulators

The regulator(s) can be enabled when the device is in STANDBY or ACTIVE state. There are two ways for enable and disable the regulators:

- Using EN_BUCKx bit in BUCKx_CTRL1 register (EN_PIN_CTRLx register bit is 0)
- Using EN1/2/3 control pins (EN_BUCKx bit is 1 **AND** EN_PIN_CTRLx register bit is 1 in BUCKx_CTRL1 register)

If the EN1/2/3 control pins are used for enable and disable then the control pin is selected with BUCKx_EN_PIN_SELECT[1:0] bits (in BUCKx_CTRL1 register). The delay from the control signal rising edge to enabling of the regulator is set by BUCKx_STARTUP_DELAY[3:0] bits and the delay from control signal falling edge to disabling of the regulator is set by BUCKx_SHUTDOWN_DELAY[3:0] bits in BUCKx_DELAY register. The delays are valid only for EN1/2/3 signal control. The control with EN_BUCKx bit is immediate without the delays.

The control of the regulator (with 0-ms delays) is shown in Table 3.

NOTE

The control of the regulator cannot be changed from one ENx pin to a different ENx pin because the control is ENx signal edge sensitive. The control from ENx pin to register bit and back to the original ENx pin can be done during operation.

Table 3. Regulator Control

CONTROL METHOD	EN_BUCKx	EN_PIN_CTRLx	BUCKx_EN_PIN_SELECT[1:0]	EN_ROOF_FLOORx	EN1 PIN	EN2 PIN	EN3 PIN	BUCKx OUTPUT VOLTAGE
Enable/disable control with EN_BUCKx bit	0	Don't Care	Don't Care	Don't Care	Don't Care	Don't Care	Don't Care	Disabled
	1	0	Don't Care	Don't Care	Don't Care	Don't Care	Don't Care	BUCKx_VSET[7:0]
Enable/disable control with EN1 pin	1	1	00	0	Low	Don't Care	Don't Care	Disabled
	1	1	00	0	High	Don't Care	Don't Care	BUCKx_VSET[7:0]
Enable/disable control with EN2 pin	1	1	01	0	Don't Care	Low	Don't Care	Disabled
	1	1	01	0	Don't Care	High	Don't Care	BUCKx_VSET[7:0]
Enable/disable control with EN3 pin	1	1	10	0	Don't Care	Don't Care	Low	Disabled
	1	1	10	0	Don't Care	Don't Care	High	BUCKx_VSET[7:0]
Roof/floor control with EN1 pin	1	1	00	1	Low	Don't Care	Don't Care	BUCKx_FLOOR_VSET[7:0]
	1	1	00	1	High	Don't Care	Don't Care	BUCKx_VSET[7:0]
Roof/floor control with EN2 pin	1	1	01	1	Don't Care	Low	Don't Care	BUCKx_FLOOR_VSET[7:0]
	1	1	01	1	Don't Care	High	Don't Care	BUCKx_VSET[7:0]
Roof/floor control with EN3 pin	1	1	10	1	Don't Care	Don't Care	Low	BUCKx_FLOOR_VSET[7:0]
	1	1	10	1	Don't Care	Don't Care	High	BUCKx_VSET[7:0]

The regulator is enabled by the ENx pin or by I^2C writing as shown in Figure 8. The soft-start circuit limits the in-rush current during start-up. When the output voltage rises to 0.35-V level, the output voltage becomes slew-rate controlled. If there is a short circuit at the output and the output voltage does not increase above 0.35-V level in 1 ms, the regulator is disabled, and interrupt is set. When the output voltage reaches the Power-Good threshold level the BUCKx_PG_INT interrupt flag (in INT_BUCK_x register) is set. The Power-Good interrupt flag can be masked using BUCKx_PG_MASK bit (in BUCKx_MASK register).

The ENx input pins have integrated pulldown resistors. The pulldown resistors are enabled by default, and the host can disable those with ENx_PD bits (in CONFIG register).

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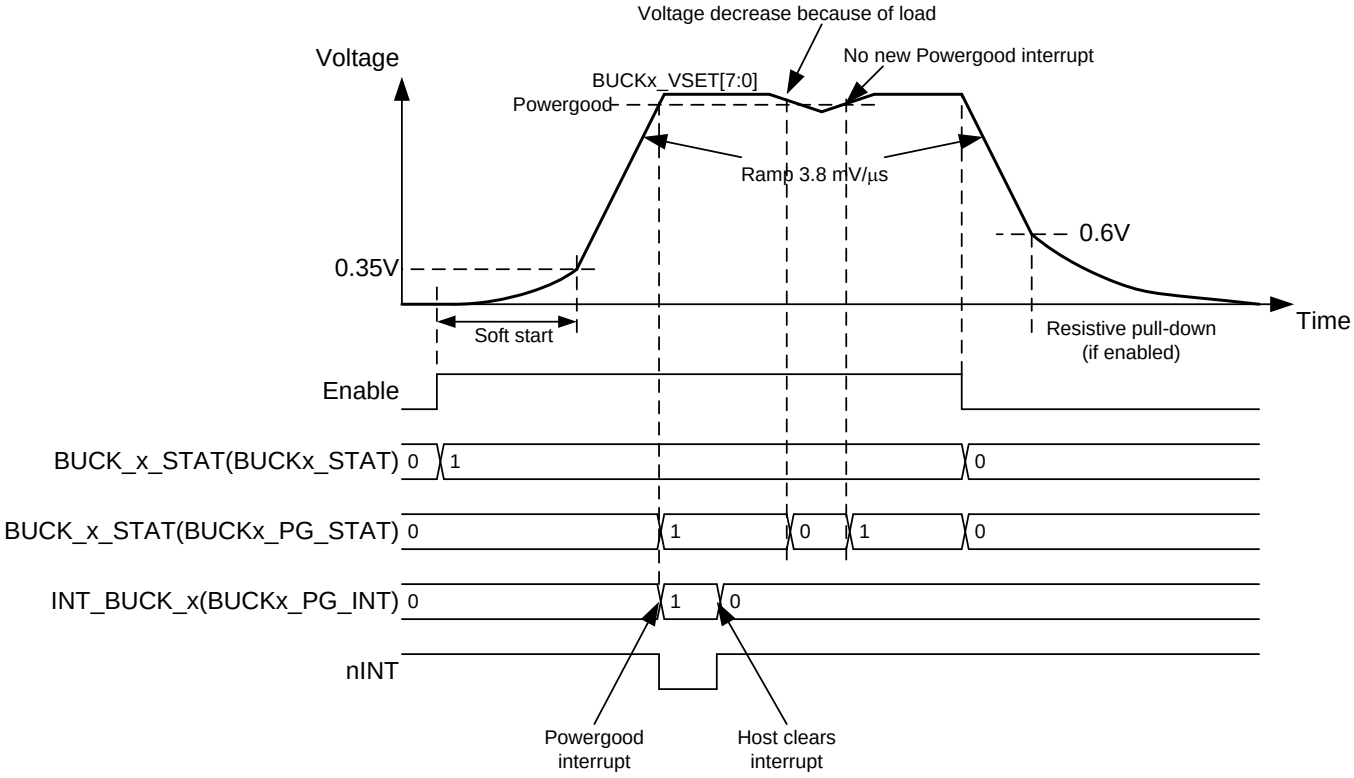


Figure 8. Regulator Enable and Disable

7.3.4.2 Changing Output Voltage

The output voltage of the regulator can be changed by the ENx pin (voltage levels defined by the BUCKx_VOUT and BUCKx_FLOOR_VOUT registers) or by writing to the BUCKx_VOUT and BUCKx_FLOOR_VOUT registers. The voltage change is always slew-rate controlled, 3.8 mV/µs. During voltage change the forced-PWM mode is used automatically. When the programmed output voltage is achieved, the mode becomes the one defined by the load current and the BUCKx_FPWM bit in BUCKx_CTRL1 register.

The Power-Good interrupt is generated when the output voltage reaches the programmed voltage level, as shown in Figure 9.

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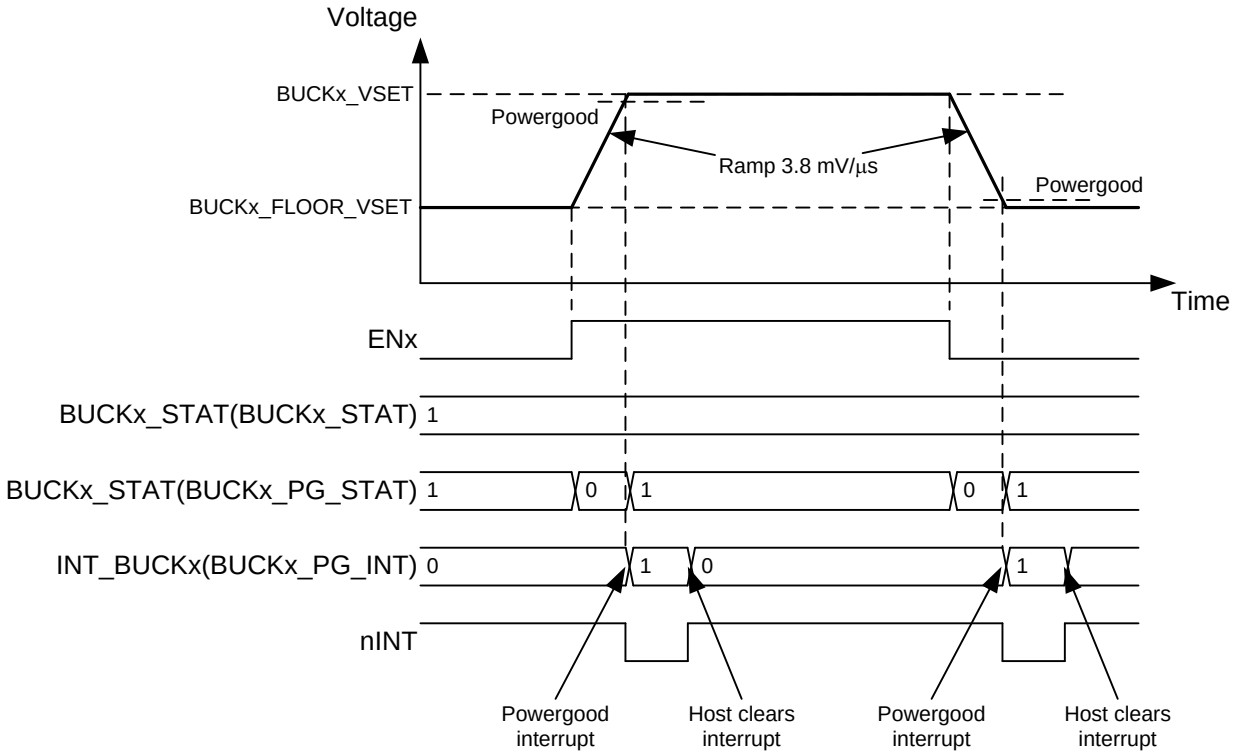


Figure 9. Regulator Output Voltage Change With ENx pin

7.3.5 Enable and Disable Sequences

The LP87524B/J/P-Q1 device supports start-up and shutdown sequencing with programmable delays for different regulator outputs using single EN1/2/3 control signal. The regulator is selected for delayed control with:

- EN_BUCKx = 1 (in BUCKx_CTRL1 register)
- EN_PIN_CTRLx = 1 (in BUCKx_CTRL1 register)
- EN_ROOF_FLOORx = 0 (in BUCKx_CTRL1 register)
- BUCKx_VSET[7:0] = Required voltage when ENx is high (in BUCKx_VOUT register)
- The ENABLE pin for control is selected with BUCKx_EN_PIN_SELECT[1:0] (in BUCKx_CTRL1 register)
- The delay from rising edge of ENx signal to the regulator enable is set by BUCKx_STARTUP_DELAY[3:0] bits (in BUCKx_DELAY register) and
- The delay from falling edge of ENx signal to the regulator disable is set by BUCKx_SHUTDOWN_DELAY[3:0] bits (in BUCKx_DELAY register)

There are four time steps available for start-up and shutdown sequences. The delay times are selected with DOUBLE_DELAY bit in CONFIG register and HALF_DELAY bit in PGOOD_CTRL2 register as shown in Table 4.

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Table 4. Start-up and Shutdown Delays

X_STARTUP_DELAY / X_SHUTDOWN_DELAY	DOUBLE_DELAY = 0 HALF_DELAY = 1	DOUBLE_DELAY = 1 HALF_DELAY = 1	DOUBLE_DELAY = 0 HALF_DELAY = 0	DOUBLE_DELAY = 1 HALF_DELAY = 0
0000	0 ms	0 ms	0 ms	0 ms
0001	0.32 ms	0.64 ms	1 ms	2 ms
0010	0.64 ms	1.28 ms	2 ms	4 ms
0011	0.96 ms	1.92 ms	3 ms	6 ms
0100	1.28 ms	2.56 ms	4 ms	8 ms
0101	1.6 ms	3.2 ms	5 ms	10 ms
0110	1.92 ms	3.84 ms	6 ms	12 ms
0111	2.24 ms	4.48 ms	7 ms	14 ms
1000	2.56 ms	5.12 ms	8 ms	16 ms
1001	2.88 ms	5.76 ms	9 ms	18 ms
1010	3.2 ms	6.4 ms	10 ms	20 ms
1011	3.52 ms	7.04 ms	11 ms	22 ms
1100	3.84 ms	7.68 ms	12 ms	24 ms
1101	4.16 ms	8.32 ms	13 ms	26 ms
1110	4.48 ms	8.96 ms	14 ms	28 ms
1111	4.8 ms	9.6 ms	15 ms	30 ms

An example of start-up and shutdown sequences is shown in Figure 10 and Figure 11. The start-up and shutdown delays for the Buck0/1 regulators are 1 ms and 4 ms and for the Buck2/3 regulators 3 ms and 1 ms. The delay settings are used only for enable/disable control with EN1/2/3 signals, not for Roof/Floor control.

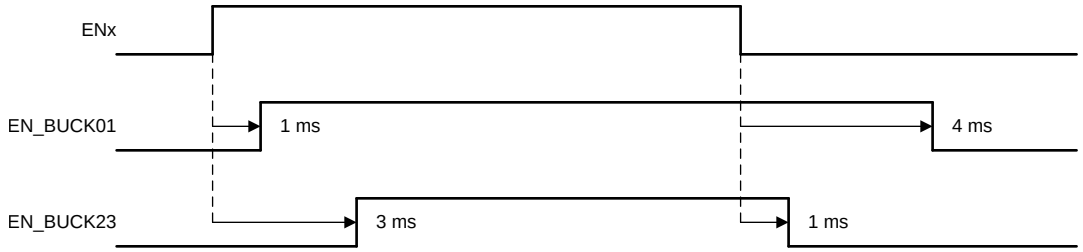


Figure 10. Typical Start-Up and Shutdown Sequencing

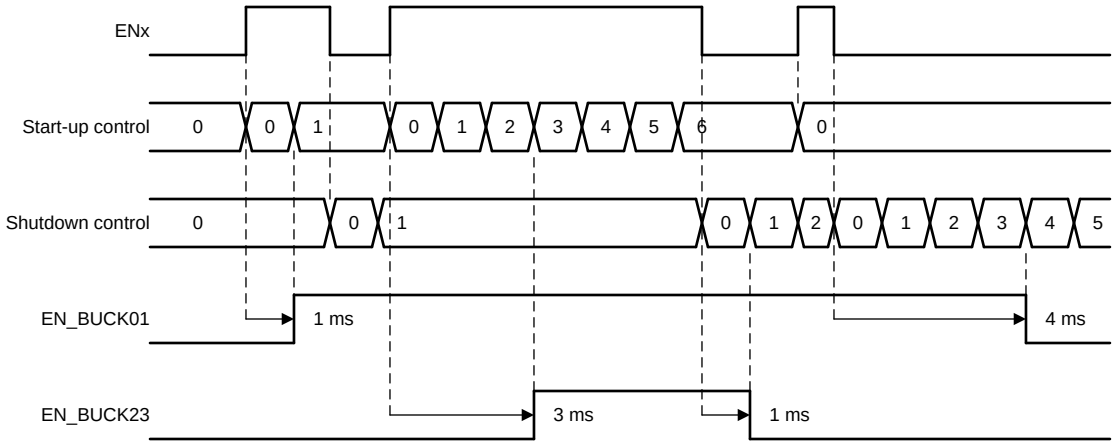


Figure 11. Start-Up and Shutdown Sequencing With Short ENx Low and High Periods

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7.3.6 Device Reset Scenarios

There are three reset methods implemented on the LP87524B/J/P-Q1:

- Software reset with SW_RESET register bit (in RESET register)
- POR from rising edge of NRST signal
- Undervoltage lockout (UVLO) reset from VANA supply

A SW-reset occurs when SW_RESET bit is written 1. The bit is automatically cleared after writing. This event disables all the regulators immediately, resets all the register bits to the default values and OTP bits are loaded (see Figure 15). I^2C interface is not reset during software reset. The host must wait at least 1.2 ms after writing SW reset until making a new I^2C read or write to the device.

If VANA supply voltage falls below UVLO threshold level or NRST signal is set low then all the regulators are disabled immediately, and all the register bits are reset to the default values. When the VANA supply voltage rises above UVLO threshold level **AND** NRST signal rises above threshold level an internal power-on reset (POR) occurs. OTP bits are loaded to the registers and a start-up is initiated according to the register settings. The host must wait at least 1.2 ms after POR until reading or writing to I^2C interface.

7.3.7 Diagnosis and Protection Features

The LP87524B/J/P-Q1 is capable of providing four levels of protection features:

- Information of valid regulator output voltage which sets interrupt or PGOOD signal;
- Warnings for diagnosis which sets interrupt;
- Protection events which are disabling the regulators affected; and
- Faults which are causing the device to shutdown.

The LP87524B/J/P-Q1 sets the flag bits indicating what protection or warning conditions have occurred, and the nINT pin is pulled low. nINT is released again after a clear of flags is complete. The nINT signal stays low until all the pending interrupts are cleared.

When a fault is detected, it is indicated by a RESET_REG interrupt flag (in INT2_TOP register) after next start-up.

Table 5. Summary of Interrupt Signals

EVENT	RESULT	INTERRUPT REGISTER AND BIT	INTERRUPT MASK	STATUS BIT	RECOVERY/INTERRUPT CLEAR
Current limit triggered (20-µs debounce)	Interrupt	INT_BUCKx = 1 BUCKx_ILIM_INT = 1	BUCKx_ILIM_MASK	BUCKx_ILIM_STAT	Write 1 to BUCKx_ILIM_INT bit Interrupt is not cleared if current limit is active
Short circuit (V_{VOUT} < 0.35 V at 1 ms after enable) or overload (V_{VOUT} decreasing below 0.35 V during operation, 1 ms debounce)	Regulator disable and interrupt	INT_BUCKx = 1 BUCKx_SC_INT = 1	N/A	N/A	Write 1 to BUCKx_SC_INT bit
Thermal warning	Interrupt	TDIE_WARN = 1	TDIE_WARN_MASK	TDIE_WARN_STAT	Write 1 to TDIE_WARN bit Interrupt is not cleared if temperature is above thermal warning level
Thermal whutdown	All regulators disabled and Output GPIOx set to low and interrupt	TDIE_SD = 1	N/A	TDIE_SD_STAT	Write 1 to TDIE_SD bit Interrupt is not cleared if temperature is above thermal shutdown level
VANA overvoltage ($VANA_{OVP}$)	All regulators disabled and Output GPIOx set to low and interrupt	INT_OVP	N/A	OVP_STAT	Write 1 to INT_OVP bit Interrupt is not cleared if VANA voltage is above VANA OVP level
Power Good, output voltage reaches the programmed value	Interrupt	INT_BUCKx = 1 BUCKx_PG_INT = 1	BUCKx_PG_MASK	BUCKx_PG_STAT	Write 1 to BUCKx_PG_INT bit
GPIO	Interrupt	INT_GPIO	GPIO_MASK	GPIO_IN register	Write 1 to INT_GPIO bit
External clock appears or disappears	Interrupt	NO_SYNC_CLK(1)	SYNC_CLK_MASK	SYNC_CLK_STAT	Write 1 to NO_SYNC_CLK bit
Load current measurement ready	Interrupt	I_LOAD_READY = 1	I_LOAD_READY_MASK	N/A	Write 1 to I_LOAD_READY bit

(1) Interrupt is generated during clock detector operation and in case clock is not available when clock detector is enabled.

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Table 5. Summary of Interrupt Signals (continued)

EVENT	RESULT	INTERRUPT REGISTER AND BIT	INTERRUPT MASK	STATUS BIT	RECOVERY/INTERRUPT CLEAR
Start-up (NRST rising edge)	Device ready for operation, registers reset to default values and interrupt	RESET_REG = 1	RESET_REG_MASK	N/A	Write 1 to RESET_REG bit
Glitch on supply voltage and UVLO triggered (VANA falling and rising)	Immediate shutdown followed by power up, registers reset to default values and interrupt	RESET_REG = 1	RESET_REG_MASK	N/A	Write 1 to RESET_REG bit
Software requested reset	Immediate shutdown followed by power up, registers reset to default values and interrupt	RESET_REG = 1	RESET_REG_MASK	N/A	Write 1 to RESET_REG bit

7.3.7.1 Power-Good Information (PGOOD pin)

In addition to the interrupt based indication of current limit and Power-Good level the LP87524B/J/P-Q1 device supports the indication with PGOOD signal. Either voltage and current monitoring or a voltage monitoring only can be selected for PGOOD indication. This selection is individual for all buck regulators and is set by PGx_SEL[1:0] bits (in PGOOD_CTRL1 register). When both voltage and current are monitored, PGOOD signal active indicates that regulator output is inside the Power-Good voltage window and that load current is below $I_{LIM\ FWD}$. If only voltage is monitored, then the current monitoring is ignored for the PGOOD signal. When a regulator is disabled, the monitoring is automatically masked to prevent it forcing PGOOD inactive. This allows connecting PGOOD signals from various devices together when open-drain outputs are used. When regulator voltage is transitioning from one target voltage to another, the voltage monitoring PGOOD signal is set inactive. The monitoring from all the output rails are combined, and PGOOD is active only if all the sources shows active status. The status from all the voltage rails are summarized in Table 6.

If the PGOOD signal is inactive or it changes the state to inactive, the source for the state can be read from PGOOD_FLT register. During reading all the PGx_FLT bit are cleared that are not driving the PGOOD inactive. When PGOOD signal goes active, the host must read the PGOOD_FLT register to clear all the bits. The PGOOD signal follows the status of all the monitored outputs.

The PGOOD signal can be also configured so that it maintains inactive state even when the monitored outputs are valid but there are PGx_FLT bits pending clearance in PGOOD_FLT register. This mode of operation is selected by setting EN_PGFLT_STAT bit to 1 (in PGOOD_CTRL2 register).

The type of output voltage monitoring for PGOOD signal is selected by PGOOD_WINDOW bit (in PGOOD_CTRL2 register). If the bit is 0, only undervoltage is monitored; if the bit is 1, both undervoltage and overvoltage are monitored.

The polarity and the output type (push-pull or open-drain) are selected by PGOOD_POL and PGOOD_OD bits in PGOOD_CTRL2 register.

The filtering time for invalid output voltage is always typically 7 µs and for valid output voltage the filtering time is selected with PGOOD_SET_DELAY bit (in PGOOD_CTRL2 register). The Power-Good waveforms are shown in Figure 13.

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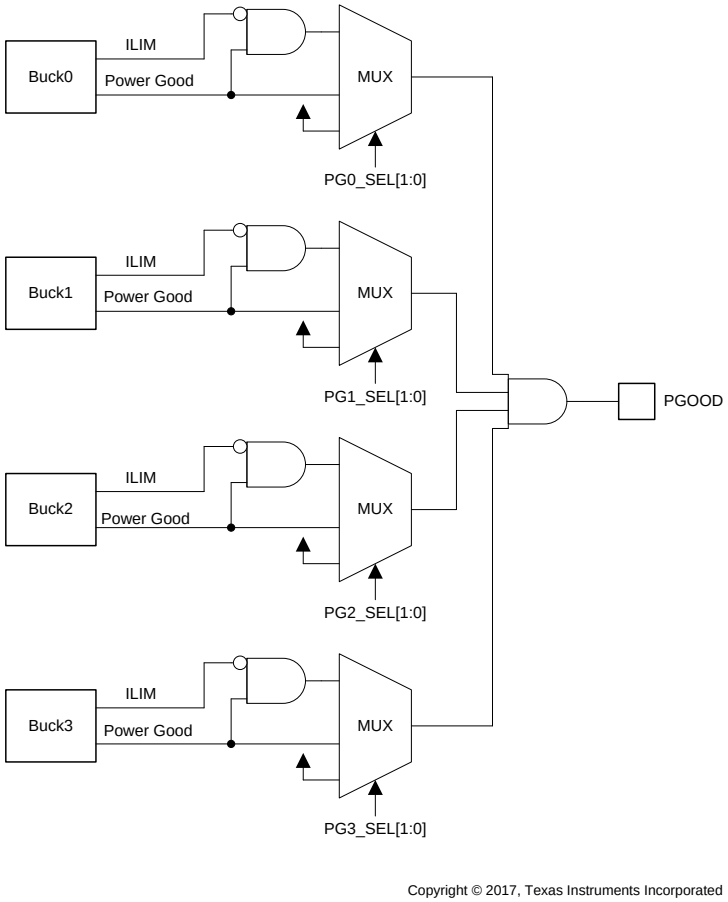


Figure 12. PGOOD Block Diagram

Table 6. PGOOD Operation

STATUS / USE CASE	CONDITION	INPUT TO PGOOD SIGNAL
Buck not selected for PGOOD monitoring	PGx_SEL = 00 (in PGOOD_CTRL1 register)	Active
Buck disabled		Active
BUCK SELECTED FOR PGOOD MONITORING		
Buck start-up delay		Inactive
Buck soft start	V_{OUT} < 0.35 V	Inactive
Buck voltage ramp-up	0.35 V < V_{OUT} < V_{SET}	Inactive
Output voltage within window limits after start-up	Must be inside limits longer than debounce time	Active
Output voltage inside voltage window and current limit active	Current limit active longer than debounce time	Active (if only voltage monitoring selected) Inactive (if also current monitoring selected)
Output voltage spikes (overvoltage or undervoltage)	If spikes are outside voltage window longer than debounce time	Inactive
Voltage setting change, output voltage ramp		Inactive
Output voltage within window limits after voltage change	Must be inside limits longer than debounce time	Active
Buck shutdown delay		Active
Buck output voltage ramp down		Active

Table 6. PGOOD Operation (continued)

STATUS / USE CASE	CONDITION	INPUT TO PGOOD SIGNAL
Buck disabled by thermal shutdown and interrupt pending		Inactive
Buck disabled by overvoltage and interrupt pending		Inactive
Buck disabled by short-circuit detection and interrupt pending		Inactive

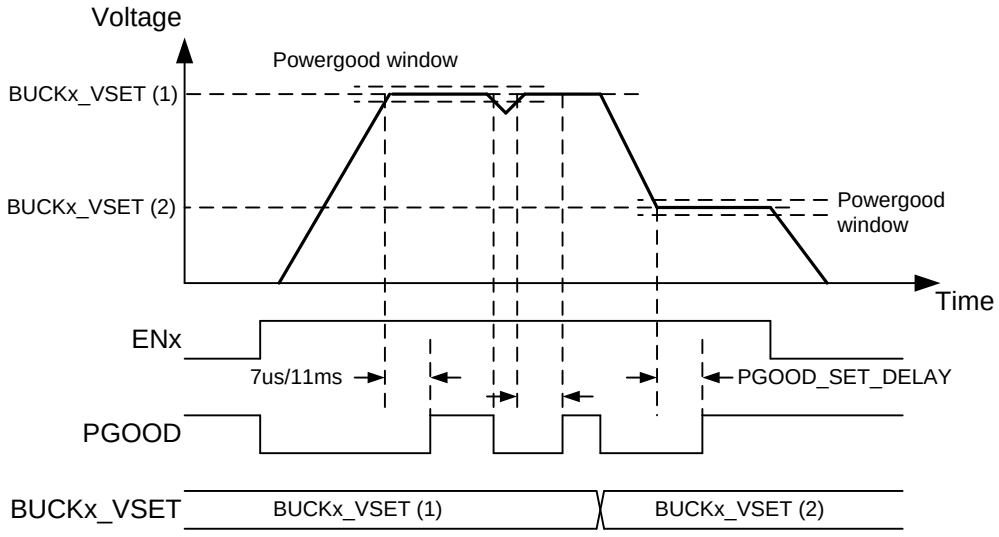


Figure 13. PGOOD Waveforms (PGOOD_POL=0)

7.3.7.2 Warnings for Diagnosis (Interrupt)

7.3.7.2.1 Output Power Limit

The regulators have output peak current limits. The peak current limits are described in *Specifications*. If the load current is increased so that the current limit is triggered, the regulator continues to regulate to the limit current level (current peak regulation, peak on every switching cycle). The voltage may decrease if the load current is higher than the average output current. If the current regulation continues for 20 µs, the LP87524B/J/P-Q1 device sets the BUCKx_ILIM_INT bit (in INT_BUCKx register) and pulls the nINT pin low. The host processor can read BUCKx_ILIM_STAT bits (in BUCKx_STAT register) to see if the regulator is still in peak current regulation mode.

If the load is so high that the output voltage decreases below a 350-mV level, the LP87524B/J/P-Q1 device disables the regulator and sets the BUCKx_SC_INT bit (in INT_BUCKx register). In addition the BUCKx_STAT bit (in BUCKx_STAT register) is set to 0. The interrupt is cleared when the host processor writes 1 to BUCKx_SC_INT bit. The overload situation is shown in Figure 14.

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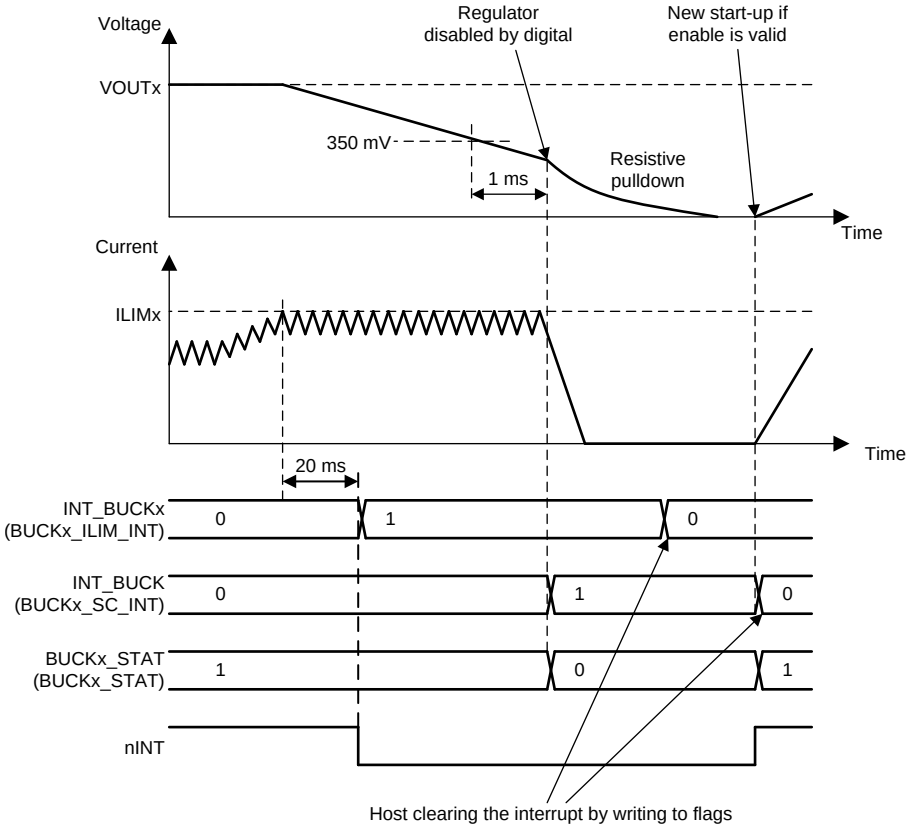


Figure 14. Overload Situation

7.3.7.2.2 Thermal Warning

The LP87524B/J/P-Q1 device includes a monitoring feature against overtemperature by setting an interrupt for host processor. The threshold level of the thermal warning is selected with TDIE_WARN_LEVEL bit (in CONFIG register).

If the LP87524B/J/P-Q1 device temperature increases above thermal warning level the device sets TDIE_WARN bit (in INT_TOP1 register) and pulls nINT pin low. The status of the thermal warning can be read from TDIE_WARN_STAT bit (in TOP_STAT register), and the interrupt is cleared by writing 1 to TDIE_WARN bit.

7.3.7.3 Protection (Regulator Disable)

If the regulator is disabled because of protection or fault (short-circuit protection, overload protection, thermal shutdown, overvoltage protection, or UVLO), the output power FETs are set to high-impedance mode, and the output pulldown resistor is enabled (if enabled with EN_RDISx bits in BUCKx_CTRL1 register). The turnoff time of the output voltage is defined by the output capacitance, load current, and the resistance of the integrated pulldown resistor. The pulldown resistors are active as long as VANA voltage is above approximately a 1.2-V level.

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7.3.7.3.1 Short-Circuit and Overload Protection

A short-circuit protection feature allows the LP87524B/J/P-Q1 to protect itself and external components against short circuit at the output or against overload during start-up. The fault threshold is 350 mV, the protection is triggered, and the regulator is disabled if the output voltage is below the threshold level 1 ms after the regulator is enabled.

In a similar way the overload situation is protected during normal operation. If the voltage on the feedback pin of the regulator falls below 0.35 V and remains below the threshold level for 1 ms, the regulator is disabled.

In the short-circuit and overload situations the BUCKx_SC_INT (in INT_BUCKx register) and the INT_BUCKx bits (in INT_TOP1 register) are set to 1, the BUCKx_STAT bit (in BUCKx_STAT register) is set to 0, and the nINT signal is pulled low. The host processor clears the interrupt by writing 1 to the BUCKx_SC_INT bit. Upon clearing the interrupt the regulator makes a new start-up attempt if the regulator is in enabled state.

7.3.7.3.2 Overvoltage Protection

The LP87524B/J/P-Q1 device monitors the input voltage from the VANA pin in standby and active operation modes. If the input voltage rises above $VANA_{OVP}$ voltage level, all the regulators are disabled, pulldown resistors discharge the output voltages (if EN_RDISx = 1 in BUCKx_CTRL1 register), GPIOs that are configured to outputs are set to logic low level, nINT signal is pulled low, INT_OVP bit (in INT_TOP1 register) is set to 1, and BUCKx_STAT bits (in BUCK_x_STAT register) are set to 0. The host processor clears the interrupt by writing 1 to the INT_OVP bit. If the input voltage is above the overvoltage detection level the interrupt is not cleared. The host can read the status of the overvoltage from the OVP_STAT bit (in TOP_STAT register). Regulators cannot be enabled as long as the input voltage is above overvoltage detection level or the overvoltage interrupt is pending.

7.3.7.3.3 Thermal Shutdown

The LP87524B/J/P-Q1 has an overtemperature protection function that operates to protect the device from short-term misuse and overload conditions. When the junction temperature exceeds around 150°C, the regulators are disabled, the TDIE_SD bit (in INT_TOP1 register) is set to 1, the nINT signal is pulled low, and the device enters STANDBY. nINT is cleared by writing 1 to the TDIE_SD bit. If the temperature is above thermal shutdown level the interrupt is not cleared. The host can read the status of the thermal shutdown from the TDIE_SD_STAT bit (in TOP_STAT register). Regulators cannot be enabled as long as the junction temperature is above thermal shutdown level or the thermal shutdown interrupt is pending.

7.3.7.4 Fault (Power Down)

7.3.7.4.1 Undervoltage Lockout

When the input voltage falls below $VANA_{UVLO}$ at the VANA pin, the buck converters are disabled immediately, and the output capacitors are discharged using the pulldown resistor, and the LP87524B/J/P-Q1 device enters SHUTDOWN. When VANA voltage is above UVLO threshold level and NRST signal is high, the device powers up to STANDBY state.

If the reset interrupt is unmasked by default (RESET_REG_MASK = 0 in TOP_MASK2 register) the RESET_REG interrupt (in INT_TOP2 register) indicates that the device has been in SHUTDOWN. The host processor must clear the interrupt by writing 1 to the RESET_REG bit. If the host processor reads the RESET_REG flag after detecting an nINT low signal, it knows that the input supply voltage has been below UVLO level (or the host has requested reset), and the registers are reset to default values.

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7.3.8 GPIO Signal Operation

The LP87524B/J/P-Q1 device supports up to 3 GPIO signals. The GPIO signals are multiplexed with enable signals. The selection between enable and GPIO function is set with GPIOx_SEL bits in PIN_FUNCTION register. The GPIOs are mapped to EN signals so that:

- EN1 is multiplexed with GPIO1
- EN2 is multiplexed with GPIO2
- EN3 is multiplexed with GPIO3

When the pin is selected for GPIO function, additional bits defines how the GPIO operates:

- GPIOx_DIR defines the direction of the GPIO, input or output (GPIO_CONFIG register)
- GPIOx_OD defines the type of the output when the GPIO is set to output, either push-pull with VANA level or open-drain (GPIO_CONFIG register)

When the GPIOx is defined as output, the logic level of the pin is set by GPIOx_OUT bit (in GPIO_OUT register).

When the GPIOx is defined as input, the logic level of the pin can be read from GPIOx_IN bit (in GPIO_IN register).

The control of the GPIOs configured to outputs can be included to start-up and shutdown sequences. The GPIO control for a sequence with ENx signal is selected by EN_PIN_CTRL_GPIOx and EN_PIN_SELECT_GPIOx bits (in PIN_FUNCTION register). The delays during start-up and shutdown are set by GPIOx_STARTUP_DELAY[3:0] and GPIOx_SHUTDOWN_DELAY[3:0] bits (in GPIOx_DELAY register) in the same way as control of the regulators.

The GPIOx signals have a selectable pulldown resistor. The pulldown resistors are selected by ENx_PD bits (in CONFIG register).

NOTE

The control of the GPIOx pin cannot be changed from one ENx pin to a different ENx pin because the control is ENx signal edge sensitive. The control from ENx pin to register bit and back to the original ENx pin can be done during operation.

7.3.9 Digital Signal Filtering

The digital signals have a debounce filtering. The signal/supply is sampled with a clock signal and a counter. This results as an accuracy of one clock period for the debounce window.

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Table 7. Digital Signal Filtering

EVENT	SIGNAL/SUPPLY	RISING EDGE DEBOUNCE TIME	FALLING EDGE DEBOUNCE TIME
Enable/disable/voltage select for Buckx	EN1	3 µs (1)	3 µs (1)
Enable/disable/voltage select for Buckx	EN2	3 µs (1)	3 µs (1)
Enable/disable/voltage select for Buckx	EN3	3 µs (1)	3 µs (1)
VANA UVLO	VANA	20 µs (VANA voltage rising)	Immediate (VANA voltage falling)
VANA overvoltage	VANA	20 µs (VANA voltage rising)	20 µs (VANA voltage falling)
Thermal warning	TDIE_WARN	20 µs	20 µs
Thermal shutdown	TDIE_SD	20 µs	20 µs
Current limit	VOUTx_ILIM	20 µs	20 µs
Overload	FB_B0, FB_B1, FB_B2, FB_F3	1 ms	20 µs
Power-Good interrupt	FB_B0, FB_B1, FB_B2, FB_F3	20 µs	20 µs
PGOOD pin (voltage monitoring)	PGOOD / FB_B0, FB_B1, FB_B2, FB_F3	4-8 µs (start-up debounce time during start-up)	4 to 8 µs
PGOOD pin (current monitoring)	PGOOD	20 µs	20 µs

(1) No glitch filtering, only synchronization.

7.4 Device Functional Modes

7.4.1 Modes of Operation

SHUTDOWN: The NRST voltage is below threshold level. All switch, reference, control, and bias circuitry of the LP87524B/J/P-Q1 device are turned off.

READ OTP: The main supply voltage VANA is above $VANA_{UVLO}$ level and NRST voltage is above threshold level. The regulators are disabled and the reference and bias circuitry of the LP87524B/J/P-Q1 are enabled. The OTP bits are loaded to registers.

STANDBY: The main supply voltage VANA is above $VANA_{UVLO}$ level and NRST voltage is above threshold level. The regulators are disabled and the reference, control and bias circuitry of the LP87524B/J/P-Q1 are enabled. All registers can be read or written by the host processor via the system serial interface. The regulators can be enabled if needed.

ACTIVE: The main supply voltage VANA is above $VANA_{UVLO}$ level and NRST voltage is above threshold level. At least one regulated DC-DC converter is enabled. All registers can be read or written by the host processor via the system serial interface.

The operating modes and transitions between the modes are shown in Figure 15.

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Device Functional Modes (continued)

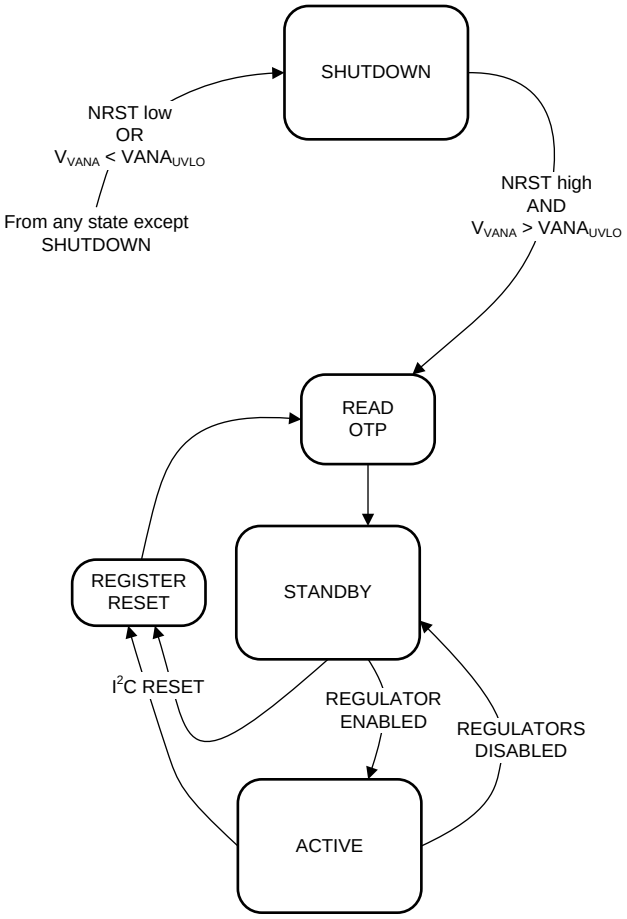


Figure 15. Device Operation Modes

7.5 Programming

7.5.1 I²C-Compatible Interface

The I²C-compatible synchronous serial interface provides access to the programmable functions and registers on the device. This protocol uses a two-wire interface for bidirectional communications between the devices connected to the bus. The two interface lines are the serial data line (SDA), and the serial clock line (SCL). Every device on the bus is assigned a unique address and acts as either a master or a slave depending on whether it generates or receives the serial clock SCL. The SCL and SDA lines must each have a pullup resistor placed somewhere on the line and remain HIGH even when the bus is idle. Note: CLK pin is not used for serial bus data transfer. The LP87524B/J/P-Q1 supports standard mode (100 kHz), fast mode (400 kHz), fast mode+ (1 MHz), and high-speed mode (3.4 MHz).

7.5.1.1 Data Validity

The data on the SDA line must be stable during the HIGH period of the clock signal (SCL). In other words, the state of the data line can only be changed when clock signal is LOW.

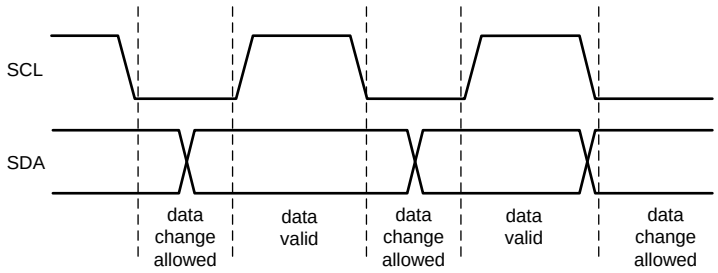


Figure 16. Data Validity Diagram

7.5.1.2 Start and Stop Conditions

The LP87524B/J/P-Q1 is controlled via an I²C-compatible interface. START and STOP conditions classify the beginning and end of the I²C session. A START condition is defined as SDA transitions from HIGH to LOW while SCL is HIGH. A STOP condition is defined as SDA transition from LOW to HIGH while SCL is HIGH. The I²C master always generates the START and STOP conditions.

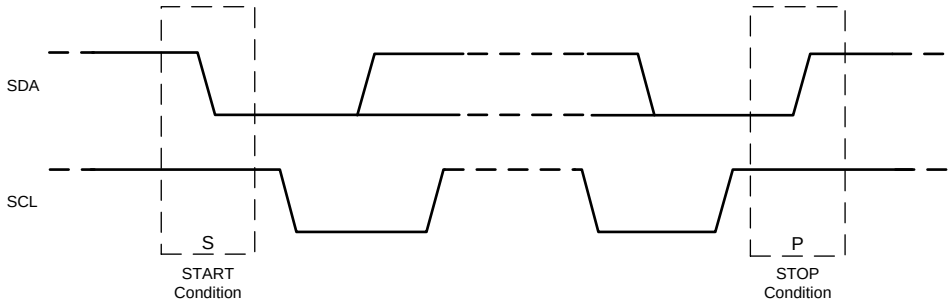


Figure 17. Start and Stop Sequences

The I²C bus is considered busy after a START condition and free after a STOP condition. During data transmission the I²C master can generate repeated START conditions. A START and a repeated START condition are equivalent function-wise. The data on SDA must be stable during the HIGH period of the clock signal (SCL). In other words, the state of SDA can only be changed when SCL is LOW. Figure 18 shows the SDA and SCL signal timing for the I²C-compatible bus. See the Figure 1 for timing values.

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Programming (continued)

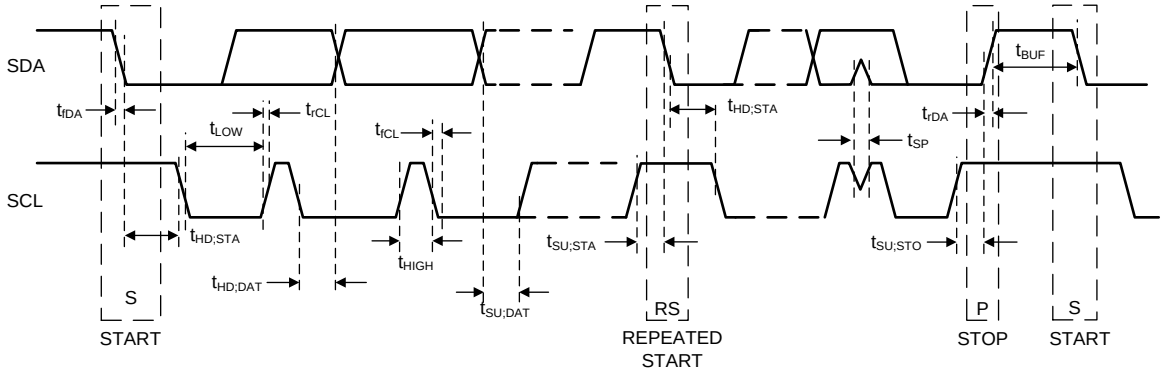


Figure 18. I²C-Compatible Timing

7.5.1.3 Transferring Data

Every byte put on the SDA line must be eight bits long, with the most significant bit (MSB) being transferred first. Each byte of data has to be followed by an acknowledge bit. The acknowledge related clock pulse is generated by the master. The master releases the SDA line (HIGH) during the acknowledge clock pulse. The LP87524B/J/P-Q1 pulls down the SDA line during the 9th clock pulse, signifying an acknowledge. The LP87524B/J/P-Q1 generates an acknowledge after each byte has been received.

There is one exception to the *acknowledge after every byte* rule. When the master is the receiver, it must indicate to the transmitter an end of data by not-acknowledging (*negative acknowledge*) the last byte clocked out of the slave. This *negative acknowledge* still includes the acknowledge clock pulse (generated by the master), but the SDA line is not pulled down.

NOTE

If the NRST signal is low during I²C communication the LP87524B/J/P-Q1 device does not drive SDA line. The ACK signal and data transfer to the master is disabled at that time.

After the START condition, the bus master sends a chip address. This address is seven bits long followed by an eighth bit which is a data direction bit (READ or WRITE). For the eighth bit, a 0 indicates a WRITE and a 1 indicates a READ. The second byte selects the register to which the data will be written. The third byte contains data to write to the selected register.

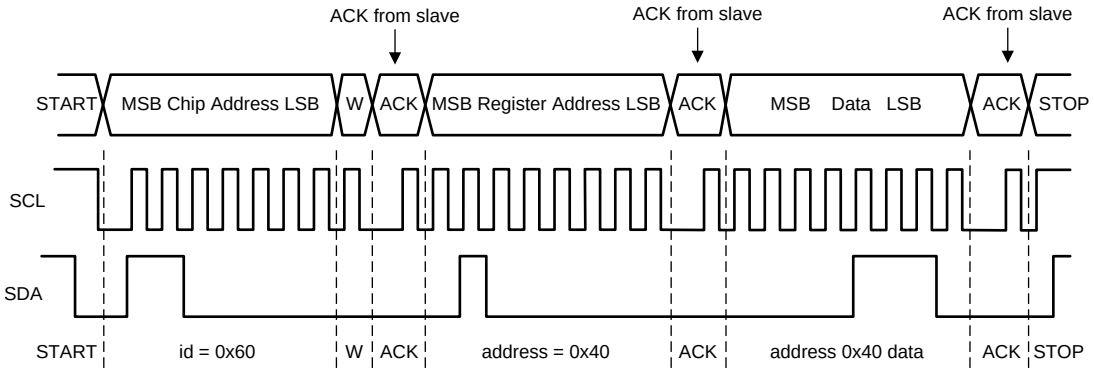
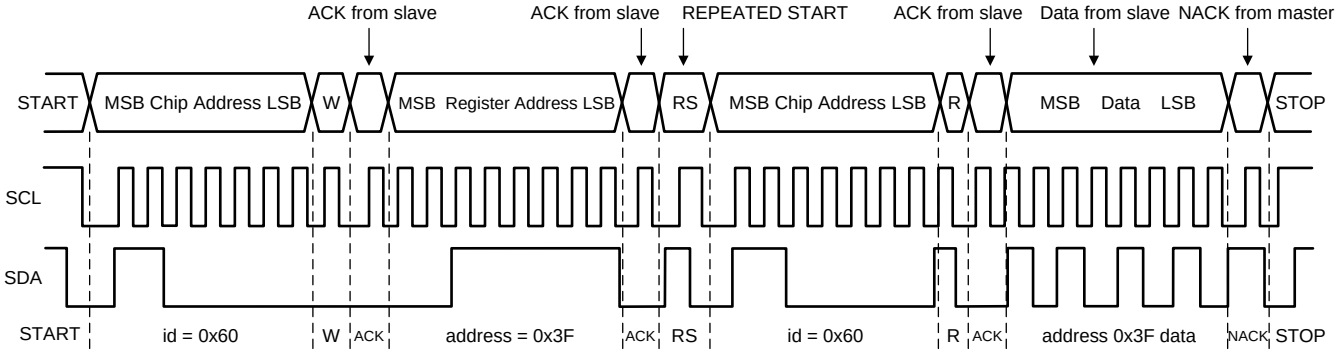


Figure 19. Write Cycle (w = write; SDA = 0), id = Device Address = 0x60 for LP87524B/J/P-Q1

Programming (continued)



When READ function is to be accomplished, a WRITE function must precede the READ function as shown above.

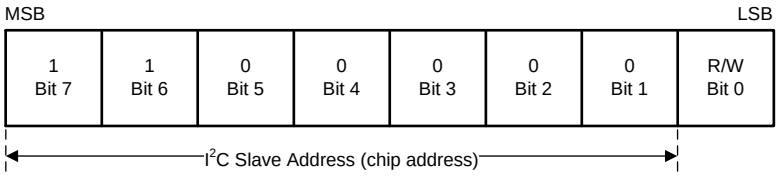
Figure 20. Read Cycle (r = read; SDA = 1), id = Device Address = 0x60 for LP87524B/J/P-Q1

7.5.1.4 I^2C-Compatible Chip Address

NOTE

The device address for the LP87524B/J/P-Q1 is 0x60

After the START condition, the I^2C master sends the 7-bit address followed by an eighth bit, read or write (R/W). R/W = 0 indicates a WRITE and R/W = 1 indicates a READ. The second byte following the device address selects the register address to which the data will be written. The third byte contains the data for the selected register.



A. Here device address is 1100000Bin = 60Hex.

Figure 21. Example Device Address

7.5.1.5 Auto-Increment Feature

The auto-increment feature allows writing several consecutive registers within one transmission. Every time an 8-bit word is sent to the device, the internal address index counter is incremented by one and the next register is written. Table 8 below shows writing sequence to two consecutive registers. Note that auto increment feature does not work for read.

Table 8. Auto-Increment Example

MASTER ACTION	START	DEVICE ADDRESS = 0x60	WRITE		REGISTER ADDRESS		DATA		DATA		STOP
LP87524B/J/P-Q1				ACK		ACK		ACK		ACK	

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7.6 Register Maps

7.6.1 Register Descriptions

The LP87524B/J/P-Q1 is controlled by a set of registers through the I^2C-compatible interface. The device registers, their addresses, and their abbreviations are listed in Table 9. A more detailed description is given in the *OTP_REV* to *GPIO_OUT* sections.

The asterisk (*) marking indicates register bits which are updated from OTP memory during READ OTP state.

NOTE

This register map describes the default values read from OTP memory for a device with orderable code of LP87524BRNFRQ1, LP87524JRNFRQ1 and LP87524PRNFRQ1. For other LP8752x versions the default values read from OTP memory can be different.

Table 9. Summary of LP87524B/J/P-Q1 Control Registers

Addr	Register	Read / Write	D7	D6	D5	D4	D3	D2	D1	D0
0x01	OTP_REV	R	OTP_ID[7:0]							
0x02	BUCK0_CTRL1	R/W	EN_BUCK0	EN_PIN_CTRL0	BUCK0_EN_PIN SELECT[1:0]		EN_ROOF_FLOOR0	EN_RDIS0	BUCK0_FPWM	Reserved
0x04	BUCK1_CTRL1	R/W	EN_BUCK1	EN_PIN_CTRL1	BUCK1_EN_PIN SELECT[1:0]		EN_ROOF_FLOOR1	EN_RDIS1	BUCK1_FPWM	Reserved
0x06	BUCK2_CTRL1	R/W	EN_BUCK2	EN_PIN_CTRL2	BUCK2_EN_PIN SELECT[1:0]		EN_ROOF_FLOOR2	EN_RDIS2	BUCK2_FPWM	Reserved
0x08	BUCK3_CTRL1	R/W	EN_BUCK3	EN_PIN_CTRL3	BUCK3_EN_PIN SELECT[1:0]		EN_ROOF_FLOOR3	EN_RDIS3	BUCK3_FPWM	Reserved
0x0A	BUCK0_VOUT	R/W	BUCK0_VSET[7:0]							
0x0B	BUCK0_FLOOR_VOUT	R/W	BUCK0_FLOOR_VSET[7:0]							
0x0C	BUCK1_VOUT	R/W	BUCK1_VSET[7:0]							
0x0D	BUCK1_FLOOR_VOUT	R/W	BUCK1_FLOOR_VSET[7:0]							
0x0E	BUCK2_VOUT	R/W	BUCK2_VSET[7:0]							
0x0F	BUCK2_FLOOR_VOUT	R/W	BUCK2_FLOOR_VSET[7:0]							
0x10	BUCK3_VOUT	R/W	BUCK3_VSET[7:0]							
0x11	BUCK3_FLOOR_VOUT	R/W	BUCK3_FLOOR_VSET[7:0]							
0x12	BUCK0_DELAY	R/W	BUCK0_SHUTDOWN_DELAY[3:0]				BUCK0_STARTUP_DELAY[3:0]			
0x13	BUCK1_DELAY	R/W	BUCK1_SHUTDOWN_DELAY[3:0]				BUCK1_STARTUP_DELAY[3:0]			
0x14	BUCK2_DELAY	R/W	BUCK2_SHUTDOWN_DELAY[3:0]				BUCK2_STARTUP_DELAY[3:0]			
0x15	BUCK3_DELAY	R/W	BUCK3_SHUTDOWN_DELAY[3:0]				BUCK3_STARTUP_DELAY[3:0]			
0x16	GPIO2_DELAY	R/W	GPIO2_SHUTDOWN_DELAY[3:0]				GPIO2_STARTUP_DELAY[3:0]			
0x17	GPIO3_DELAY	R/W	GPIO3_SHUTDOWN_DELAY[3:0]				GPIO3_STARTUP_DELAY[3:0]			
0x18	RESET	R/W	Reserved							SW_RESET

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Register Maps (continued)

Table 9. Summary of LP87524B/J/P-Q1 Control Registers (continued)

Addr	Register	Read / Write	D7	D6	D5	D4	D3	D2	D1	D0
0x19	CONFIG	R/W	DOUBLE_DELAY	CLKIN_PD	Reserved	EN3_PD	TDIE_WARN_LEVEL	EN2_PD	EN1_PD	Reserved
0x1A	INT_TOP1	R/W	Reserved	INT_BUCK23	INT_BUCK01	NO_SYNC_CLK	TDIE_SD	TDIE_WARN	INT_OVP	I_LOAD_READY
0x1B	INT_TOP2	R/W	Reserved							RESET_REG
0x1C	INT_BUCK_0_1	R/W	Reserved	BUCK1_PG_INT	BUCK1_SC_INT	BUCK1_ILIM_INT	Reserved	BUCK0_PG_INT	BUCK0_SC_INT	BUCK0_ILIM_INT
0x1D	INT_BUCK_2_3	R/W	Reserved	BUCK3_PG_INT	BUCK3_SC_INT	BUCK3_ILIM_INT	Reserved	BUCK2_PG_INT	BUCK2_SC_INT	BUCK2_ILIM_INT
0x1E	TOP_STAT	R	Reserved			SYNC_CLK_STAT	TDIE_SD_STAT	TDIE_WARN_STAT	OVP_STAT	Reserved
0x1F	BUCK_0_1_STAT	R	BUCK1_STAT	BUCK1_PG_STAT	Reserved	BUCK1_ILIM_STAT	BUCK0_STAT	BUCK0_PG_STAT	Reserved	BUCK0_ILIM_STAT
0x20	BUCK_2_3_STAT	R	BUCK3_STAT	BUCK3_PG_STAT	Reserved	BUCK3_ILIM_STAT	BUCK2_STAT	BUCK2_PG_STAT	Reserved	BUCK2_ILIM_STAT
0x21	TOP_MASK1	R/W	Reserved	Reserved		SYNC_CLK_MASK	Reserved	TDIE_WARN_MASK	Reserved	I_LOAD_READY_MASK
0x22	TOP_MASK2	R/W	Reserved							RESET_REG_MASK
0x23	BUCK_0_1_MASK	R/W	Reserved	BUCK1_PG_MASK	Reserved	BUCK1_ILIM_MASK	Reserved	BUCK0_PG_MASK	Reserved	BUCK0_ILIM_MASK
0x24	BUCK_2_3_MASK	R/W	Reserved	BUCK3_PG_MASK	Reserved	BUCK3_ILIM_MASK	Reserved	BUCK2_PG_MASK	Reserved	BUCK2_ILIM_MASK
0x25	SEL_I_LOAD	R/W	Reserved						LOAD_CURRENT_BUCK_SELECT[1:0]	
0x26	I_LOAD_2	R	Reserved						BUCK_LOAD_CURRENT[9:8]	
0x27	I_LOAD_1	R	BUCK_LOAD_CURRENT[7:0]							
0x28	PGOOD_CTRL1	R/W	PG3_SEL[1:0]		PG2_SEL[1:0]		PG1_SEL[1:0]		PG0_SEL[1:0]	
0x29	PGOOD_CTRL2	R/W	HALF_DELAY	EN_PG0_NINT	PGOOD_SET_DELAY	EN_PGFLT_STAT	Reserved	PGOOD_WINDOW	PGOOD_OD	PGOOD_POL
0x2A	PGOOD_FLT	R					PG3_FLT	PG2_FLT	PG1_FLT	PG0_FLT
0x2B	PLL_CTRL	R/W	PLL_MODE[1:0]		Reserved	EXT_CLK_FREQ[4:0]				
0x2C	PIN_FUNCTION	R/W	EN_SPREAD_SPEC	EN_PIN_CTRL_GPIO3	EN_PIN_SELECT_GPIO3	EN_PIN_CTRL_GPIO2	EN_PIN_SELECT_GPIO2	GPIO3_SEL	GPIO2_SEL	GPIO1_SEL
0x2D	GPIO_CONFIG	R/W	Reserved	GPIO3_OD	GPIO2_OD	GPIO1_OD	Reserved	GPIO3_DIR	GPIO2_DIR	GPIO1_DIR
0x2E	GPIO_IN	R	Reserved					GPIO3_IN	GPIO2_IN	GPIO1_IN
0x2F	GPIO_OUT	R/W	Reserved					GPIO3_OUT	GPIO2_OUT	GPIO1_OUT

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7.6.1.1 OTP_REV

Address: 0x01

D7	D6	D5	D4	D3	D2	D1	D0
OTP_ID[7:0]							

Bits	Field	Type	Default	Description
7:0	OTP_ID[7:0]	R	0x71 for LP87524B, 0x72 for LP87524J, 0x3B for LP87524P *	Identification code of the OTP EPROM version

7.6.1.2 BUCK0_CTRL1

Address: 0x02

D7	D6	D5	D4	D3	D2	D1	D0
EN_BUCK0	EN_PIN_CTRL0	BUCK0_EN_PIN_SELECT[1:0]		EN_ROOF_FLOOR0	EN_RDIS0	BUCK0_FPWM	Reserved

Bits	Field	Type	Default	Description
7	EN_BUCK0	R/W	1 *	Enable Buck0 regulator: 0 - Buck0 regulator is disabled 1 - Buck0 regulator is enabled
6	EN_PIN_CTRL0	R/W	1 *	Enable EN1/2/3 pin control for Buck0: 0 - Only the EN_BUCK0 bit controls Buck0 1 - EN_BUCK0 bit AND ENx pin control Buck0
5:4	BUCK0_EN_PIN_SELECT[1:0]	R/W	0x0*	Enable EN1/2/3 pin control for Buck0: 0x0 - EN_BUCK0 bit AND EN1 pin control Buck0 0x1 - EN_BUCK0 bit AND EN2 pin control Buck0 0x2 - EN_BUCK0 bit AND EN3 pin control Buck0 0x3 - Reserved
3	EN_ROOF_FLOOR0	R/W	0	Enable Roof/Floor control of EN1/2/3 pin if EN_PIN_CTRL0 = 1: 0 - Enable/disable (1/0) control 1 - Roof/floor (1/0) control
2	EN_RDIS0	R/W	1	Enable output discharge resistor when Buck0 is disabled: 0 - Discharge resistor disabled 1 - Discharge resistor enabled
1	BUCK0_FPWM	R/W	0 for LP87524B, LP87524J, 1 for LP87524P *	Forces the Buck0 regulator to operate in PWM mode: 0 - Automatic transitions between PFM and PWM modes (AUTO mode). 1 - Forced to PWM operation
0	Reserved	R/W	0 *	

7.6.1.3 BUCK1_CTRL1

Address: 0x04

D7	D6	D5	D4	D3	D2	D1	D0
EN_BUCK1	EN_PIN_CTRL1	BUCK1_EN_PIN_SELECT[1:0]		EN_ROOF_FLOOR1	EN_RDIS1	BUCK1_FPWM	Reserved

Bits	Field	Type	Default	Description
7	EN_BUCK1	R/W	1 *	Enable Buck1 regulator: 0 - Buck1 regulator is disabled 1 - Buck1 regulator is enabled
6	EN_PIN_CTRL1	R/W	1 *	Enable EN1/2/3 pin control for Buck1: 0 - Only EN_BUCK1 bit controls Buck1 1 - EN_BUCK1 bit AND ENx pin control Buck1
5:4	BUCK1_EN_PIN_SELECT[1:0]	R/W	0x0*	Enable EN1/2/3 pin control for Buck1: 0x0 - EN_BUCK1 bit AND EN1 pin control Buck1 0x1 - EN_BUCK1 bit AND EN2 pin control Buck1 0x2 - EN_BUCK1 bit AND EN3 pin control Buck1 0x3 - Reserved
3	EN_ROOF_FLOOR1	R/W	0	Enable Roof/Floor control of EN1/2/3 pin if EN_PIN_CTRL1 = 1: 0 - Enable/Disable (1/0) control 1 - Roof/Floor (1/0) control
2	EN_RDIS1	R/W	1	Enable output discharge resistor when Buck1 is disabled: 0 - Discharge resistor disabled 1 - Discharge resistor enabled
1	BUCK1_FPWM	R/W	0 for LP87524B, LP87524J, 1 for LP87524P *	Forces the Buck1 regulator to operate in PWM mode: 0 - Automatic transitions between PFM and PWM modes (AUTO mode). 1 - Forced to PWM operation
0	Reserved	R/W	0	

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7.6.1.4 BUCK2_CTRL1

Address: 0x06

D7	D6	D5	D4	D3	D2	D1	D0
EN_BUCK2	EN_PIN_CTRL2	BUCK2_EN_PIN_SELECT[1:0]		EN_ROOF_FLOOR2	EN_RDIS2	BUCK2_FPWM	Reserved

Bits	Field	Type	Default	Description
7	EN_BUCK2	R/W	1 *	Enable Buck2 regulator: 0 - Buck2 regulator is disabled 1 - Buck2 regulator is enabled
6	EN_PIN_CTRL2	R/W	1 *	Enable EN1/2/3 pin control for Buck2: 0 - Only EN_BUCK2 bit controls Buck2 1 - EN_BUCK2 bit AND ENx pin control Buck2
5:4	BUCK2_EN_PIN_SELECT[1:0]	R/W	0x0*	Enable EN1/2/3 pin control for Buck2: 0x0 - EN_BUCK2 bit AND EN1 pin control Buck2 0x1 - EN_BUCK2 bit AND EN2 pin control Buck2 0x2 - EN_BUCK2 bit AND EN3 pin control Buck2 0x3 - Reserved
3	EN_ROOF_FLOOR2	R/W	0	Enable Roof/Floor control of EN1/2/3 pin if EN_PIN_CTRL2 = 1: 0 - Enable/Disable (1/0) control 1 - Roof/Floor (1/0) control
2	EN_RDIS2	R/W	1	Enable output discharge resistor when Buck2 is disabled: 0 - Discharge resistor disabled 1 - Discharge resistor enabled
1	BUCK2_FPWM	R/W	1 *	Forces the Buck2 regulator to operate in PWM mode: 0 - Automatic transitions between PFM and PWM modes (AUTO mode) 1 - Forced to PWM operation
0	Reserved	R/W	0 *	

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7.6.1.5 BUCK3_CTRL1

Address: 0x08

D7	D6	D5	D4	D3	D2	D1	D0
EN_BUCK3	EN_PIN_CTRL3	BUCK3_EN_PIN_SELECT[1:0]		EN_ROOF_FLOOR3	EN_RDIS3	BUCK3_FPWM	Reserved

Bits	Field	Type	Default	Description
7	EN_BUCK3	R/W	1 *	Enable Buck3 regulator: 0 - Buck3 regulator is disabled 1 - Buck3 regulator is enabled
6	EN_PIN_CTRL3	R/W	1 *	Enable EN1/2/3 pin control for Buck3: 0 - Only EN_BUCK3 bit controls Buck3 1 - EN_BUCK3 bit AND ENx pin control Buck3
5:4	BUCK3_EN_PIN_SELECT[1:0]	R/W	0x0*	Enable EN1/2/3 pin control for Buck3: 0x0 - EN_BUCK3 bit AND EN1 pin control Buck3 0x1 - EN_BUCK3 bit AND EN2 pin control Buck3 0x2 - EN_BUCK3 bit AND EN3 pin control Buck3 0x3 - Reserved
3	EN_ROOF_FLOOR3	R/W	0	Enable Roof/Floor control of EN1/2/3 pin if EN_PIN_CTRL3 = 1: 0 - Enable/Disable (1/0) control 1 - Roof/Floor (1/0) control
2	EN_RDIS3	R/W	1	Enable output discharge resistor when Buck3 is disabled: 0 - Discharge resistor disabled 1 - Discharge resistor enabled
1	BUCK3_FPWM	R/W	1 *	Forces the Buck3 regulator to operate in PWM mode: 0 - Automatic transitions between PFM and PWM modes (AUTO mode) 1 - Forced to PWM operation
0	Reserved	R/W	0	

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7.6.1.6 BUCK0_VOUT

Address: 0x0A

D7	D6	D5	D4	D3	D2	D1	D0
BUCK0_VSET[7:0]							

Bits	Field	Type	Default	Description
7:0	BUCK0_VSET[7:0]	R/W	0xFC for LP87524B, LP87524J, 0x4D for LP87524P *	Sets the output voltage of Buck0 regulator **Reserved, DO NOT USE** 0x00...0x09 **0.6 V - 0.73 V, 10 mV steps** 0x0A - 0.6 V ... 0x17 - 0.73 V **0.73 V - 1.4 V, 5 mV steps** 0x18 - 0.735 V ... 0x9D - 1.4 V **1.4 V - 3.36 V, 20 mV steps** 0x9E - 1.42 V ... 0xFF - 3.36 V **If the input voltage is above 4 V, do not use output voltages below 1.0 V.**

7.6.1.7 BUCK0_FLOOR_VOUT

Address: 0x0B

D7	D6	D5	D4	D3	D2	D1	D0
BUCK0_FLOOR_VSET[7:0]							

Bits	Field	Type	Default	Description
7:0	BUCK0_FLOOR_VSET[7:0]	R/W	0x00	Sets the output voltage of Buck0 regulator when floor state is used: **Reserved, DO NOT USE** 0x00...0x09 **0.6 V - 0.73 V, 10 mV steps** 0x0A - 0.6 V ... 0x17 - 0.73 V **0.73 V - 1.4 V, 5 mV steps** 0x18 - 0.735 V ... 0x9D - 1.4 V **1.4 V - 3.36 V, 20 mV steps** 0x9E - 1.42 V ... 0xFF - 3.36 V **If the input voltage is above 4 V, do not use output voltages below 1.0 V.**

7.6.1.8 BUCK1_VOUT

Address: 0x0C

D7	D6	D5	D4	D3	D2	D1	D0
BUCK1_VSET[7:0]							

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Bits	Field	Type	Default	Description
7:0	BUCK1_VSET[7:0]	R/W	0x75*	Sets the output voltage of Buck1 regulator: **Reserved, DO NOT USE** 0x00...0x09 **0.6 V - 0.73 V, 10 mV steps** 0x0A - 0.6 V ... 0x17 - 0.73 V **0.73 V - 1.4 V, 5 mV steps** 0x18 - 0.735 V ... 0x9D - 1.4 V **1.4 V - 3.36 V, 20 mV steps** 0x9E - 1.42 V ... 0xFF - 3.36 V **If the input voltage is above 4 V, do not use output voltages below 1.0 V.**

7.6.1.9 BUCK1_FLOOR_VOUT

Address: 0x0D

D7	D6	D5	D4	D3	D2	D1	D0
BUCK1_FLOOR_VSET[7:0]							

Bits	Field	Type	Default	Description
7:0	BUCK1_FLOOR_VSET[7:0]	R/W	0x00	Sets the output voltage of Buck1 regulator when floor state is used: **Reserved, DO NOT USE** 0x00...0x09 **0.6 V - 0.73 V, 10 mV steps** 0x0A - 0.6 V ... 0x17 - 0.73 V **0.73 V - 1.4 V, 5 mV steps** 0x18 - 0.735 V ... 0x9D - 1.4 V **1.4 V - 3.36 V, 20 mV steps** 0x9E - 1.42 V ... 0xFF - 3.36 V **If the input voltage is above 4 V, do not use output voltages below 1.0 V.**

7.6.1.10 BUCK2_VOUT

Address: 0x0E

D7	D6	D5	D4	D3	D2	D1	D0
BUCK2_VSET[7:0]							

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Bits	Field	Type	Default	Description
7:0	BUCK2_VSET[7:0]	R/W	0xB1 for LP87524B, 0x4D for LP87524J, LP87524P *	Sets the output voltage of Buck2 regulator: **Reserved, DO NOT USE** 0x00...0x09 **0.6 V - 0.73 V, 10 mV steps** 0x0A - 0.6V ... 0x17 - 0.73 V **0.73 V - 1.4 V, 5 mV steps** 0x18 - 0.735 V ... 0x9D - 1.4 V **1.4 V - 3.36 V, 20 mV steps** 0x9E - 1.42 V ... 0xFF - 3.36 V **If the input voltage is above 4 V, do not use output voltages below 1.0 V.**

7.6.1.11 BUCK2_FLOOR_VOUT

Address: 0x0F

D7	D6	D5	D4	D3	D2	D1	D0
BUCK2_FLOOR_VSET[7:0]							

Bits	Field	Type	Default	Description
7:0	BUCK2_FLOOR_VSET[7:0]	R/W	0x00	Sets the output voltage of Buck2 regulator when floor state is used: **Reserved, DO NOT USE** 0x00...0x09 **0.6 V - 0.73 V, 10 mV steps** 0x0A - 0.6 V ... 0x17 - 0.73 V **0.73 V - 1.4 V, 5 mV steps** 0x18 - 0.735 V ... 0x9D - 1.4 V **1.4 V - 3.36 V, 20 mV steps** 0x9E - 1.42 V ... 0xFF - 3.36 V **If the input voltage is above 4 V, do not use output voltages below 1.0 V.**

7.6.1.12 BUCK3_VOUT

Address: 0x10

D7	D6	D5	D4	D3	D2	D1	D0
BUCK3_VSET[7:0]							

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Bits	Field	Type	Default	Description
7:0	BUCK3_VSET[7:0]	R/W	0xCA for LP87524B, LP87524J, 0xB1 for LP87524P *	Sets the output voltage of Buck3 regulator: **Reserved, DO NOT USE** 0x00...0x09 **0.6 V - 0.73 V, 10 mV steps** 0x0A - 0.6 V ... 0x17 - 0.73 V **0.73 V - 1.4 V, 5 mV steps** 0x18 - 0.735 V ... 0x9D - 1.4 V **1.4 V - 3.36 V, 20 mV steps** 0x9E - 1.42 V ... 0xFF - 3.36 V **If the input voltage is above 4 V, do not use output voltages below 1.0 V.**

7.6.1.13 BUCK3_FLOOR_VOUT

Address: 0x11

D7	D6	D5	D4	D3	D2	D1	D0
BUCK3_FLOOR_VSET[7:0]							

Bits	Field	Type	Default	Description
7:0	BUCK3_FLOOR_VSET[7:0]	R/W	0x00	Sets the output voltage of Buck3 regulator when Floor state is used: **Reserved, DO NOT USE** 0x00...0x09 **0.6 V - 0.73 V, 10 mV steps** 0x0A - 0.6 V ... 0x17 - 0.73 V **0.73 V - 1.4 V, 5 mV steps** 0x18 - 0.735 V ... 0x9D - 1.4 V **1.4 V - 3.36 V, 20 mV steps** 0x9E - 1.42 V ... 0xFF - 3.36 V **If the input voltage is above 4 V, do not use output voltages below 1.0 V.**

7.6.1.14 BUCK0_DELAY

Address: 0x12

D7	D6	D5	D4	D3	D2	D1	D0
BUCK0_SHUTDOWN_DELAY[3:0]				BUCK0_STARTUP_DELAY[3:0]			

Bits	Field	Type	Default	Description
7:4	BUCK0_SHUTDOWN_DELAY[3:0]	R/W	0x0 for LP87524B, LP87524J, 0x1 for LP87524P *	Shutdown delay of Buck0 from falling edge of ENx signal (DOUBLE_DELAY = 0 in CONTROL register and HALF_DELAY = 0 in PGOOD_CTRL2 register. See other delay options in Table 4): 0x0 - 0 ms 0x1 - 1 ms ... 0xF - 15 ms
3:0	BUCK0_STARTUP_DELAY[3:0]	R/W	0x5 for LP87524B, LP87524J, 0x3 for LP87524P *	Start-up delay of Buck0 from rising edge of ENx signal (DOUBLE_DELAY = 0 in CONTROL register and HALF_DELAY = 0 in PGOOD_CTRL2 register. See other delay options in Table 4): 0x0 - 0 ms 0x1 - 1 ms ... 0xF - 15 ms

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7.6.1.15 BUCK1_DELAY

Address: 0x13

D7	D6	D5	D4	D3	D2	D1	D0
BUCK1_SHUTDOWN_DELAY[3:0]				BUCK1_STARTUP_DELAY[3:0]			

Bits	Field	Type	Default	Description
7:4	BUCK1_ SHUTDOWN_ DELAY[3:0]	R/W	0x0 for LP87524B, LP87524J, 0x1 for LP87524P *	Shutdown delay of Buck1 from falling edge of ENx signal (DOUBLE_DELAY = 0 in CONTROL register and HALF_DELAY = 0 in PGOOD_CTRL2 register. See other delay options in Table 4): 0x0 - 0 ms 0x1 - 1 ms ... 0xF - 15 ms
3:0	BUCK1_ STARTUP_ DELAY[3:0]	R/W	0x5 for LP87524B, LP87524J, 0x7 for LP87524P *	start-up delay of Buck1 from rising edge of ENx signal (DOUBLE_DELAY = 0 in CONTROL register and HALF_DELAY = 0 in PGOOD_CTRL2 register. See other delay options in Table 4): 0x0 - 0 ms 0x1 - 1 ms ... 0xF - 15 ms

7.6.1.16 BUCK2_DELAY

Address: 0x14

D7	D6	D5	D4	D3	D2	D1	D0
BUCK2_SHUTDOWN_DELAY[3:0]				BUCK2_STARTUP_DELAY[3:0]			

Bits	Field	Type	Default	Description
7:4	BUCK2_ SHUTDOWN_ DELAY[3:0]	R/W	0x0 for LP87524B, LP87524J, 0x1 for LP87524P *	Shutdown delay of Buck2 from falling edge of ENx signal (DOUBLE_DELAY = 0 in CONTROL register and HALF_DELAY = 0 in PGOOD_CTRL2 register. See other delay options in Table 4): 0x0 - 0 ms 0x1 - 1 ms ... 0xF - 15 ms
3:0	BUCK2_ STARTUP_ DELAY[3:0]	R/W	0x2 for LP87524B, LP87524J, 0x5 for LP87524P *	start-up delay of Buck2 from rising edge of ENx signal (DOUBLE_DELAY = 0 in CONTROL register and HALF_DELAY = 0 in PGOOD_CTRL2 register. See other delay options in Table 4): 0x0 - 0 ms 0x1 - 1 ms ... 0xF - 15 ms

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7.6.1.17 BUCK3_DELAY

Address: 0x15

D7	D6	D5	D4	D3	D2	D1	D0
BUCK3_SHUTDOWN_DELAY[3:0]				BUCK3_start-up_DELAY[3:0]			

Bits	Field	Type	Default	Description
7:4	BUCK3_ SHUTDOWN_ DELAY[3:0]	R/W	0x1*	Shutdown delay of Buck3 from falling edge of ENx signal (DOUBLE_DELAY = 0 in CONTROL register and HALF_DELAY = 0 in PGOOD_CTRL2 register. See other delay options in Table 4): 0x0 - 0 ms 0x1 - 1 ms ... 0xF - 15 ms
3:0	BUCK3_ STARTUP_ DELAY[3:0]	R/W	0x0*	Startup delay of Buck3 from rising edge of ENx signal (DOUBLE_DELAY = 0 in CONTROL register and HALF_DELAY = 0 in PGOOD_CTRL2 register. See other delay options in Table 4): 0x0 - 0 ms 0x1 - 1 ms ... 0xF - 15 ms

7.6.1.18 GPIO2_DELAY

Address: 0x16

D7	D6	D5	D4	D3	D2	D1	D0
GPIO2_SHUTDOWN_DELAY[3:0]				GPIO2_STARTUP_DELAY[3:0]			

Bits	Field	Type	Default	Description
7:4	GPIO2_ SHUTDOWN_ DELAY[3:0]	R/W	0x0 for LP87524B, LP87524J, 0x1 for LP87524P *	Delay for GPIO2 falling edge from falling edge of ENx signal (DOUBLE_DELAY = 0 in CONTROL register and HALF_DELAY = 0 in PGOOD_CTRL2 register. See other delay options in Table 4): 0x0 - 0 ms 0x1 - 1 ms ... 0xF - 15 ms
3:0	GPIO2_ STARTUP_ DELAY[3:0]	R/W	0x5 for LP87524B, LP87524J, 0x9 for LP87524P *	Delay for GPIO2 rising edge from rising edge of ENx signal (DOUBLE_DELAY = 0 in CONTROL register and HALF_DELAY = 0 in PGOOD_CTRL2 register. See other delay options in Table 4): 0x0 - 0 ms 0x1 - 1 ms ... 0xF - 15 ms

7.6.1.19 GPIO3_DELAY

Address: 0x17

D7	D6	D5	D4	D3	D2	D1	D0
GPIO3_SHUTDOWN_DELAY[3:0]				GPIO3_STARTUP_DELAY[3:0]			

Bits	Field	Type	Default	Description
7:4	GPIO3_ SHUTDOWN_ DELAY[3:0]	R/W	0x0 *	Delay for GPIO3 falling edge from falling edge of ENx signal (DOUBLE_DELAY = 0 in CONTROL register and HALF_DELAY = 0 in PGOOD_CTRL2 register. See other delay options in Table 4): 0x0 - 0 ms 0x1 - 1 ms ... 0xF - 15 ms

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Bits	Field	Type	Default	Description
3:0	GPIO3_ STARTUP_ DELAY[3:0]	R/W	0x3 for LP87524B, LP87524J, 0xD for LP87524P *	Delay for GPIO3 rising edge from rising edge of ENx signal (DOUBLE_DELAY = 0 in CONTROL register and HALF_DELAY = 0 in PGOOD_CTRL2 register. See other delay options in Table 4): 0x0 - 0 ms 0x1 - 1 ms ... 0xF - 15 ms

7.6.1.20 RESET

Address: 0x18

D7	D6	D5	D4	D3	D2	D1	D0
Reserved							SW_RESET

Bits	Field	Type	Default	Description
7:1	Reserved	R/W	0x00	
0	SW_RESET	R/W	0	Software commanded reset. When written to 1, the registers are reset to default values, OTP memory is read, and the I^2C interface is reset. The bit is automatically cleared.

7.6.1.21 CONFIG

Address: 0x19

D7	D6	D5	D4	D3	D2	D1	D0
DOUBLE_DEL AY	CLKIN_PD	EN4_PD	EN3_PD	TDIE_WARN_ LEVEL	EN2_PD	EN1_PD	Reserved

Bits	Field	Type	Default	Description
7	DOUBLE_DELAY	R/W	0 *	Start-up and shutdown delays from ENx signals: 0 - 0 ms - 15 ms with 1-ms steps 1 - 0 ms - 30 ms with 2-ms steps
6	CLKIN_PD	R/W	1 *	Selects the pulldown resistor on the CLKIN input pin: 0 - Pulldown resistor is disabled. 1 - Pulldown resistor is enabled.
5	Reserved	R/W	0 *	
4	EN3_PD	R/W	0 *	Selects the pulldown resistor on the EN3 (GPIO3) input pin: 0 - Pulldown resistor is disabled. 1 - Pulldown resistor is enabled.
3	TDIE_WARN_ LEVEL	R/W	1 for LP87524B, LP87524J, 0 for LP87524P *	Thermal warning threshold level: 0 - 125°C 1 - 137°C.
2	EN2_PD	R/W	0 *	Selects the pull down resistor on the EN2 (GPIO2) input pin: 0 - Pulldown resistor is disabled. 1 - Pull-down resistor is enabled.
1	EN1_PD	R/W	1 *	Selects the pull down resistor on the EN1 (GPIO1) input pin: 0 - Pulldown resistor is disabled. 1 - Pulldown resistor is enabled.
0	Reserved	R/W	0	

7.6.1.22 INT_TOP1

Address: 0x1A

D7	D6	D5	D4	D3	D2	D1	D0
Reserved	INT_BUCK23	INT_BUCK01	NO_SYNC_CL K	TDIE_SD	TDIE_WARN	INT_OVP	I_LOAD_ READY

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Bits	Field	Type	Default	Description
7	Reserved	R/W	0	
6	INT_BUCK23	R	0	Interrupt indicating that output Buck3 and/or Buck2 have a pending interrupt. The reason for the interrupt is indicated in INT_BUCK_2_3 register. This bit is cleared automatically when INT_BUCK_2_3 register is cleared to 0x00.
5	INT_BUCK01	R	0	Interrupt indicating that output Buck1 and/or Buck0 have a pending interrupt. The reason for the interrupt is indicated in INT_BUCK_0_1 register. This bit is cleared automatically when INT_BUCK_0_1 register is cleared to 0x00.
4	NO_SYNC_CLK	R/W	0	Latched status bit indicating that the external clock is not valid. Write 1 to clear interrupt.
3	TDIE_SD	R/W	0	Latched status bit indicating that the die junction temperature has exceeded the thermal shutdown level. The regulators have been disabled if they were enabled. The regulators cannot be enabled if this bit is active. The actual status of the thermal warning is indicated by TDIE_SD_STAT bit in TOP_STAT register. Write 1 to clear interrupt.
2	TDIE_WARN	R/W	0	Latched status bit indicating that the die junction temperature has exceeded the thermal warning level. The actual status of the thermal warning is indicated by TDIE_WARN_STAT bit in TOP_STAT register. Write 1 to clear interrupt.
1	INT_OVP	R/W	0	Latched status bit indicating that the input voltage has exceeded the overvoltage detection level. The actual status of the overvoltage is indicated by OVP_STAT bit in TOP_STAT register. Write 1 to clear interrupt.
0	I_LOAD_READY	R/W	0	Latched status bit indicating that the load current measurement result is available in I_LOAD_1 and I_LOAD_2 registers. Write 1 to clear interrupt.

7.6.1.23 INT_TOP2

Address: 0x1B

D7	D6	D5	D4	D3	D2	D1	D0
Reserved							RESET_REG

Bits	Field	Type	Default	Description
7:1	Reserved	R/W	0x00	
0	RESET_REG	R/W	0	Latched status bit indicating that either start-up (NRST rising edge) is done, VANA supply voltage has been below undervoltage threshold level, or the host has requested a reset (SW_RESET bit in RESET register). The regulators have been disabled, and registers are reset to default values and the normal start-up procedure is done. Write 1 to clear interrupt.

7.6.1.24 INT_BUCK_0_1

Address: 0x1C

D7	D6	D5	D4	D3	D2	D1	D0
Reserved	BUCK1_PG_INT	BUCK1_SC_INT	BUCK1_ILIM_INT	Reserved	BUCK0_PG_INT	BUCK0_SC_INT	BUCK0_ILIM_INT

Bits	Field	Type	Default	Description
7	Reserved	R/W	0	
6	BUCK1_PG_INT	R/W	0	Latched status bit indicating that Buck1 output voltage has reached Power-Good-threshold level. Write 1 to clear.
5	BUCK1_SC_INT	R/W	0	Latched status bit indicating that the Buck1 output voltage has fallen below 0.35-V level during operation or Buck1 output did not reach 0.35-V level in 1 ms from enable. Write 1 to clear.
4	BUCK1_ILIM_INT	R/W	0	Latched status bit indicating that output current limit has been active. Write 1 to clear.
3	Reserved	R/W	0	

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Bits	Field	Type	Default	Description
2	BUCK0_PG_INT	R/W	0	Latched status bit indicating that Buck0 output voltage has reached Power-Good-threshold level. Write 1 to clear.
1	BUCK0_SC_INT	R/W	0	Latched status bit indicating that the Buck0 output voltage has fallen below 0.35-V level during operation or Buck0 output did not reach 0.35-V level in 1 ms from enable. Write 1 to clear.
0	BUCK0_ILIM_INT	R/W	0	Latched status bit indicating that output current limit has been active. Write 1 to clear.

7.6.1.25 INT_BUCK_2_3

Address: 0x1D

D7	D6	D5	D4	D3	D2	D1	D0
Reserved	BUCK3_PG_INT	BUCK3_SC_INT	BUCK3_ILIM_INT	Reserved	BUCK2_PG_INT	BUCK2_SC_INT	BUCK2_ILIM_INT

Bits	Field	Type	Default	Description
7	Reserved	R/W	0	
6	BUCK3_PG_INT	R/W	0	Latched status bit indicating that Buck3 output voltage has reached Power-Good-threshold level. Write 1 to clear.
5	BUCK3_SC_INT	R/W	0	Latched status bit indicating that the Buck3 output voltage has fallen below 0.35-V level during operation or Buck3 output did not reach 0.35-V level in 1 ms from enable. Write 1 to clear.
4	BUCK3_ILIM_INT	R/W	0	Latched status bit indicating that output current limit has been active. Write 1 to clear.
3	Reserved	R/W	0	
2	BUCK2_PG_INT	R/W	0	Latched status bit indicating that Buck2 output voltage has reached Power-Good-threshold level. Write 1 to clear.
1	BUCK2_SC_INT	R/W	0	Latched status bit indicating that the Buck2 output voltage has fallen below 0.35-V level during operation or Buck2 output did not reach 0.35-V level in 1 ms from enable. Write 1 to clear.
0	BUCK2_ILIM_INT	R/W	0	Latched status bit indicating that output current limit has been active. Write 1 to clear.

7.6.1.26 TOP_STAT

Address: 0x1E

D7	D6	D5	D4	D3	D2	D1	D0
Reserved			SYNC_CLK_STAT	TDIE_SD_STAT	TDIE_WARN_STAT	OVP_STAT	Reserved

Bits	Field	Type	Default	Description
7:5	Reserved	R	0x0	
4	SYNC_CLK_STAT	R	0	Status bit indicating the status of external clock (CLKIN): 0 - External clock frequency is valid 1 - External clock frequency is not valid
3	TDIE_SD_STAT	R	0	Status bit indicating the status of thermal shutdown: 0 - Die temperature below thermal shutdown level 1 - Die temperature above thermal shutdown level
2	TDIE_WARN_STAT	R	0	Status bit indicating the status of thermal warning: 0 - Die temperature below thermal warning level 1 - Die temperature above thermal warning level
1	OVP_STAT	R	0	Status bit indicating the status of input overvoltage monitoring: 0 - Input voltage below overvoltage threshold level 1 - Input voltage above overvoltage threshold level
0	Reserved	R	0	

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7.6.1.27 BUCK_0_1_STAT

Address: 0x1F

D7	D6	D5	D4	D3	D2	D1	D0
BUCK1_STAT	BUCK1_PG_STAT	Reserved	BUCK1_ILIM_STAT	BUCK0_STAT	BUCK0_PG_STAT	Reserved	BUCK0_ILIM_STAT

Bits	Field	Type	Default	Description
7	BUCK1_STAT	R	0	Status bit indicating the enable/disable status of Buck1: 0 - Buck1 regulator is disabled 1 - Buck1 regulator is enabled
6	BUCK1_PG_STAT	R	0	Status bit indicating Buck1 output voltage validity (raw status) 0 - Buck1 output is below Power-Good-threshold level 1 - Buck1 output is above Power-Good-threshold level
5	Reserved	R	0	
4	BUCK1_ILIM_STAT	R	0	Status bit indicating Buck1 current limit status (raw status) 0 - Buck1 output current is below current limit level 1 - Buck1 output current limit is active
3	BUCK0_STAT	R	0	Status bit indicating the enable/disable status of Buck0: 0 - Buck0 regulator is disabled 1 - Buck0 regulator is enabled
2	BUCK0_PG_STAT	R	0	Status bit indicating Buck0 output voltage validity (raw status): 0 - Buck0 output is below Power-Good-threshold level 1 - Buck0 output is above Power-Good-threshold level
1	Reserved	R	0	
0	BUCK0_ILIM_STAT	R	0	Status bit indicating Buck0 current limit status (raw status): 0 - Buck0 output current is below current limit level 1 - Buck0 output current limit is active

7.6.1.28 BUCK_2_3_STAT

Address: 0x20

D7	D6	D5	D4	D3	D2	D1	D0
BUCK3_STAT	BUCK3_PG_STAT	Reserved	BUCK3_ILIM_STAT	BUCK2_STAT	BUCK2_PG_STAT	Reserved	BUCK2_ILIM_STAT

Bits	Field	Type	Default	Description
7	BUCK3_STAT	R	0	Status bit indicating the enable/disable status of Buck3: 0 - Buck3 regulator is disabled 1 - Buck3 regulator is enabled
6	BUCK3_PG_STAT	R	0	Status bit indicating Buck3 output voltage validity (raw status): 0 - Buck3 output is below Power-Good-threshold level 1 - Buck3 output is above Power-Good-threshold level
5	Reserved	R	0	
4	BUCK3_ILIM_STAT	R	0	Status bit indicating Buck3 current limit status (raw status): 0 - Buck3 output current is below current limit level 1 - Buck3 output current limit is active
3	BUCK2_STAT	R	0	Status bit indicating the enable/disable status of Buck2: 0 - Buck2 regulator is disabled 1 - Buck2 regulator is enabled
2	BUCK2_PG_STAT	R	0	Status bit indicating Buck2 output voltage validity (raw status): 0 - Buck2 output is below Power-Good-threshold level 1 - Buck2 output is above Power-Good-threshold level
1	Reserved	R	0	
0	BUCK2_ILIM_STAT	R	0	Status bit indicating Buck2 current limit status (raw status): 0 - Buck2 output current is below current limit level 1 - Buck2 output current limit is active

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7.6.1.29 TOP_MASK1

Address: 0x21

D7	D6	D5	D4	D3	D2	D1	D0
Reserved	Reserved		SYNC_CLK _MASK	Reserved	TDIE_WARN _MASK	Reserved	I_LOAD_ READY_MASK

Bits	Field	Type	Default	Description
7	Reserved	R/W	1 *	
6:5	Reserved	R/W	0x0	
4	SYNC_CLK _MASK	R/W	0 *	Masking for external clock detection interrupt (NO_SYNC_CLK in INT_TOP1 register): 0 - Interrupt generated 1 - Interrupt not generated
3	Reserved	R/W	0	
2	TDIE_WARN _MASK	R/W	0 *	Masking for thermal warning interrupt (TDIE_WARN in INT_TOP1 register): 0 - Interrupt generated 1 - Interrupt not generated This bit does not affect TDIE_WARN_STAT status bit in TOP_STAT register.
1	Reserved	R/W	0	
0	I_LOAD_ READY_MASK	R/W	1 *	Masking for load current measurement ready interrupt (I_LOAD_READY in INT_TOP register). 0 - Interrupt generated 1 - Interrupt not generated

7.6.1.30 TOP_MASK2

Address: 0x22

D7	D6	D5	D4	D3	D2	D1	D0
Reserved							RESET_REG _MASK

Bits	Field	Type	Default	Description
7:1	Reserved	R/W	0x00	
0	RESET_REG _MASK	R/W	1 *	Masking for register reset interrupt (RESET_REG in INT_TOP2 register): 0 - Interrupt generated 1 - Interrupt not generated

7.6.1.31 BUCK_0_1_MASK

Address: 0x23

D7	D6	D5	D4	D3	D2	D1	D0
Reserved	BUCK1_PG _MASK	Reserved	BUCK1_ILIM _MASK	Reserved	BUCK0_PG _MASK	Reserved	BUCK0_ILIM _MASK

Bits	Field	Type	Default	Description
7	Reserved	R/W	0	
6	BUCK1_PG_MASK	R/W	1 *	Masking for Buck1 Power-Good interrupt (BUCK1_PG_INT in INT_BUCK_0_1 register): 0 - Interrupt generated 1 - Interrupt not generated This bit does not affect BUCK1_PG_STAT status bit in BUCK_0_1_STAT register.
5	Reserved	R	0	
4	BUCK1_ILIM _MASK	R/W	1 *	Masking for Buck1 current-limit-detection interrupt (BUCK1_ILIM_INT in INT_BUCK_0_1 register): 0 - Interrupt generated 1 - Interrupt not generated This bit does not affect BUCK1_ILIM_STAT status bit in BUCK_0_1_STAT register.
3	Reserved	R/W	0	

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Bits	Field	Type	Default	Description
2	BUCK0_PG_MASK	R/W	1 *	Masking for Buck0 Power-Good interrupt (BUCK0_PG_INT in INT_BUCK_0_1 register): 0 - Interrupt generated 1 - Interrupt not generated This bit does not affect BUCK0_PG_STAT status bit in BUCK_0_1_STAT register.
1	Reserved	R	0	
0	BUCK0_ILIM _MASK	R/W	1 *	Masking for Buck0 current-limit-detection interrupt (BUCK0_ILIM_INT in INT_BUCK_0_1 register): 0 - Interrupt generated 1 - Interrupt not generated This bit does not affect BUCK0_ILIM_STAT status bit in BUCK_0_1_STAT register.

7.6.1.32 BUCK_2_3_MASK

Address: 0x24

D7	D6	D5	D4	D3	D2	D1	D0
Reserved	BUCK3_PG _MASK	Reserved	BUCK3_ILIM _MASK	Reserved	BUCK2_PG _MASK	Reserved	BUCK2_ILIM _MASK

Bits	Field	Type	Default	Description
7	Reserved	R/W	0	
6	BUCK3_PG_MASK	R/W	1 *	Masking for Buck3 Power-Good interrupt (BUCK3_PG_INT in INT_BUCK_2_3 register): 0 - Interrupt generated 1 - Interrupt not generated This bit does not affect BUCK3_PG_STAT status bit in BUCK_2_3_STAT register.
5	Reserved	R	0	
4	BUCK3_ILIM _MASK	R/W	1 *	Masking for Buck3 current-limit-detection interrupt (BUCK3_ILIM_INT in INT_BUCK_2_3 register): 0 - Interrupt generated 1 - Interrupt not generated This bit does not affect BUCK3_ILIM_STAT status bit in BUCK_2_3_STAT register.
3	Reserved	R/W	0	
2	BUCK2_PG_MASK	R/W	1 *	Masking for Buck2 Power-Good interrupt (BUCK2_PG_INT in INT_BUCK_2_3 register): 0 - Interrupt generated 1 - Interrupt not generated This bit does not affect BUCK2_PG_STAT status bit in BUCK_2_3_STAT register.
1	Reserved	R	0	
0	BUCK2_ILIM _MASK	R/W	1 *	Masking for Buck2 current limit-detection interrupt (BUCK2_ILIM_INT in INT_BUCK_2_3 register): 0 - Interrupt generated 1 - Interrupt not generated This bit does not affect BUCK2_ILIM_STAT status bit in BUCK_2_3_STAT register.

7.6.1.33 SEL_I_LOAD

Address: 0x25

D7	D6	D5	D4	D3	D2	D1	D0
Reserved						LOAD_CURRENT_BUCK _SELECT[1:0]	

Bits	Field	Type	Default	Description
7:2	Reserved	R/W	0x00	
1:0	LOAD_CURRENT_ BUCK_SELECT [1:0]	R/W	0x0	Start the current measurement on the selected regulator: 0x0 - Buck0 0x1 - Buck1 0x2 - Buck2 0x3 - Buck3 A single measurement is started when register is written.

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7.6.1.34 I_LOAD_2

Address: 0x26

D7	D6	D5	D4	D3	D2	D1	D0
Reserved						BUCK_LOAD_CURRENT[9:8]	

Bits	Field	Type	Default	Description
7:2	Reserved	R	0x00	
1:0	BUCK_LOAD_CURRENT[9:8]	R	0x0	This register describes 3 MSB bits of the average load current on selected regulator with a resolution of 20 mA per LSB and max code corresponding to 20.47-A current.

7.6.1.35 I_LOAD_1

Address: 0x27

D7	D6	D5	D4	D3	D2	D1	D0
BUCK_LOAD_CURRENT[7:0]							

Bits	Field	Type	Default	Description
7:0	BUCK_LOAD_CURRENT[7:0]	R	0x00	This register describes 8 LSB bits of the average load current on selected regulator with a resolution of 20 mA per LSB and max code corresponding to a 20.47-A current.

7.6.1.36 PGOOD_CTRL1

Address: 0x28

D7	D6	D5	D4	D3	D2	D1	D0
PG3_SEL[1:0]		PG2_SEL[1:0]		PG1_SEL[1:0]		PG0_SEL[1:0]	

Bits	Field	Type	Default	Description
7:6	PG3_SEL[1:0]	R/W	0x1*	PGOOD signal source control from Buck3 0x0 - Masked 0x1 - Power-Good-threshold voltage 0x2 - Reserved, do not use 0x3 - Power-Good-threshold voltage AND current limit
5:4	PG2_SEL[1:0]	R/W	0x1*	PGOOD signal source control from Buck2 0x0 - Masked 0x1 - Power-Good-threshold voltage 0x2 - Reserved, do not use 0x3 - Power-Good threshold voltage AND current limit
3:2	PG1_SEL[1:0]	R/W	0x1*	PGOOD signal source control from Buck1 0x0 - Masked 0x1 - Power-Good-threshold voltage 0x2 - Reserved, do not use 0x3 - Power-Good-threshold voltage AND current limit
1:0	PG0_SEL[1:0]	R/W	0x1*	PGOOD signal source control from Buck0 0x0 - Masked 0x1 - Power-Good-threshold voltage 0x2 - Reserved, do not use 0x3 - Power-Good-threshold voltage AND current limit

7.6.1.37 PGOOD_CTRL2

Address: 0x29

D7	D6	D5	D4	D3	D2	D1	D0
HALF_DELAY	EN_PG0_NINT	PGOOD_SET_DELAY	EN_PGFLT_STAT	Reserved	PGOOD_WINDOW	PGOOD_OD	PGOOD_POL

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Bits	Field	Type	Default	Description
7	HALF_DELAY	R/W	0 for LP87524B, LP87524J, 1 for LP87524P *	Select the time step for start-up and shutdown delays: 0 - Start-up and shutdown delays have 0.5-ms or 1-ms time steps, based on DOUBLE_DELAY bit in CONFIG register. 1 - Start-up and shutdown delays have 0.32-ms or 0.64-ms time steps, based on DOUBLE_DELAY bit in CONFIG register.
6	EN_PG0_NINT	R/W	0 *	Combine Buck0 PGOOD signal to nINT signal: 0 - Buck0 PGOOD signal not included to nINT signal 1 - Buck0 PGOOD signal included to nINT signal. If nINT OR Buck0 PGOOD is low then nINT signal is low.
5	PGOOD_SET_DELAY	R/W	1 *	Debounce time of output voltage monitoring for PGOOD signal (only when PGOOD signal goes valid): 0 - 4-10 µs 1 - 11 ms
4	EN_PGFLT_STAT	R/W	0 *	Operation mode for PGOOD signal: 0 - Indicates live status of monitored voltage outputs. 1 - Indicates status of PGOOD_FLT register, inactive if at least one of PGx_FLT bit is inactive.
3	Reserved	R/W	0	
2	PGOOD_WINDOW	R/W	1 *	Voltage monitoring method for PGOOD signal: 0 - Only undervoltage monitoring 1 - Overvoltage and undervoltage monitoring
1	PGOOD_OD	R/W	1 *	PGOOD signal type: 0 - Push-pull output (VANA level) 1 - Open-drain output
0	PGOOD_POL	R/W	0 *	PGOOD signal polarity: 0 - PGOOD signal high when monitored outputs are valid 1 - PGOOD signal low when monitored outputs are valid

7.6.1.38 PGOOD_FLT

Address: 0x2A

D7	D6	D5	D4	D3	D2	D1	D0
Reserved				PG3_FLT	PG2_FLT	PG1_FLT	PG0_FLT

Bits	Field	Type	Default	Description
7:4	Reserved	R/W	0x0	
3	PG3_FLT	R	0	Source for PGOOD inactive signal: 0 - Buck3 has not set PGOOD signal inactive. 1 - Buck3 has set PGOOD signal inactive. This bit can be cleared by reading this register when Buck3 output is valid.
2	PG2_FLT	R	0	Source for PGOOD inactive signal: 0 - Buck2 has not set PGOOD signal inactive. 1 - Buck2 has set PGOOD signal inactive. This bit can be cleared by reading this register when Buck2 output is valid.
1	PG1_FLT	R	0	Source for PGOOD inactive signal: 0 - Buck1 has not set PGOOD signal inactive. 1 - Buck1 has set PGOOD signal inactive. This bit can be cleared by reading this register when Buck1 output is valid.
0	PG0_FLT	R	0	Source for PGOOD inactive signal: 0 - Buck0 has not set PGOOD signal inactive. 1 - Buck0 has set PGOOD signal inactive. This bit can be cleared by reading this register when Buck0 output is valid.

7.6.1.39 PLL_CTRL

Address: 0x2B

D7	D6	D5	D4	D3	D2	D1	D0
PLL_MODE[1:0]		Reserved		EXT_CLK_FREQ[4:0]			

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Bits	Field	Type	Default	Description
7:6	PLL_MODE[1:0]	R/W	0x2*	Selection of external clock and PLL operation: 0x0 - Forced to internal RC oscillator — PLL disabled. 0x1 - PLL is enabled in STANDBY and ACTIVE modes. Automatic external clock use when available, interrupt generated if external clock appears or disappears. 0x2 - PLL is enabled only in ACTIVE mode. Automatic external clock use when available, interrupt generated if external clock appears or disappears. 0x3 - Reserved
5	Reserved	R/W	0	
4:0	EXT_CLK_FREQ[4:0]	R/W	0x01*	Frequency of the external clock (CLKIN): 0x00 - 1 MHz 0x01 - 2 MHz 0x02 - 3 MHz ... 0x16 - 23 MHz 0x17 - 24 MHz 0x18...0x1F - Reserved See *Specifications* for input clock frequency tolerance.

7.6.1.40 PIN_FUNCTION

Address: 0x2C

D7	D6	D5	D4	D3	D2	D1	D0
EN_SPREAD_SPEC	EN_PIN_CTRL_GPIO3	EN_PIN_SELECT_GPIO3	EN_PIN_CTRL_GPIO2	EN_PIN_SELECT_GPIO2	GPIO3_SEL	GPIO2_SEL	GPIO1_SEL

Bits	Field	Type	Default	Description
7	EN_SPREAD_SPEC	R/W	0 *	Enable spread-spectrum feature: 0 - Disabled 1 - Enabled
6	EN_PIN_CTRL_GPIO3	R/W	1 *	Enable EN1/2 pin control for GPIO3 (GPIO3_SEL=1 AND GPIO3_DIR=1): 0 - Only GPIO3_OUT bit controls GPIO3. 1 - GPIO3_OUT bit AND ENx pin control GPIO3
5	EN_PIN_SELECT_GPIO3	R/W	0 *	Enable EN1/2 pin control for GPIO3: 0 - GPIO3_SEL bit AND EN1 pin control GPIO3 1 - GPIO3_SEL bit AND EN2 pin control GPIO3
4	EN_PIN_CTRL_GPIO2	R/W	1 *	Enable EN1/3 pin control for GPIO2 (GPIO2_SEL=1 AND GPIO2_DIR=1): 0 - Only GPIO2_OUT bit controls GPIO2. 1 - GPIO2_OUT bit AND ENx pin control GPIO2
3	EN_PIN_SELECT_GPIO2	R/W	0 *	Enable EN1/3 pin control for GPIO2: 0 - GPIO2_SEL bit AND EN1 pin control GPIO2 1 - GPIO2_SEL bit AND EN3 pin control GPIO2
2	GPIO3_SEL	R/W	1 *	EN3 pin function: 0 - EN3 1 - GPIO3
1	GPIO2_SEL	R/W	1 *	EN2 pin function: 0 - EN2 1 - GPIO2
0	GPIO1_SEL	R/W	0 *	EN1 pin function: 0 - EN1 1 - GPIO1

7.6.1.41 GPIO_CONFIG

Address: 0x2D

D7	D6	D5	D4	D3	D2	D1	D0
Reserved	GPIO3_OD	GPIO2_OD	GPIO1_OD	Reserved	GPIO3_DIR	GPIO2_DIR	GPIO1_DIR

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Bits	Field	Type	Default	Description
7	Reserved	R	0	
6	GPIO3_OD	R/W	1 *	GPIO3 signal type when configured to output: 0 - Push-pull output (VANA level) 1 - Open-drain output
5	GPIO2_OD	R/W	1 *	GPIO2 signal type when configured to output: 0 - Push-pull output (VANA level) 1 - Open-drain output
4	GPIO1_OD	R/W	0 *	GPIO1 signal type when configured to output: 0 - Push-pull output (VANA level) 1 - Open-drain output
3	Reserved	R	0	
2	GPIO3_DIR	R/W	1 *	GPIO3 signal direction: 0 - Input 1 - Output
1	GPIO2_DIR	R/W	1 *	GPIO2 signal direction: 0 - Input 1 - Output
0	GPIO1_DIR	R/W	0 *	GPIO1 signal direction: 0 - Input 1 - Output

7.6.1.42 GPIO_IN

Address: 0x2E

D7	D6	D5	D4	D3	D2	D1	D0
Reserved					GPIO3_IN	GPIO2_IN	GPIO1_IN

Bits	Field	Type	Default	Description
7:3	Reserved	R	0x00	
2	GPIO3_IN	R	0	State of GPIO3 signal: 0 - Logic low level 1 - Logic high level
1	GPIO2_IN	R	0	State of GPIO2 signal: 0 - Logic low level 1 - Logic high level
0	GPIO1_IN	R	0	State of GPIO1 signal: 0 - Logic low level 1 - Logic high level

7.6.1.43 GPIO_OUT

Address: 0x2F

D7	D6	D5	D4	D3	D2	D1	D0
Reserved					GPIO3_OUT	GPIO2_OUT	GPIO1_OUT

Bits	Field	Type	Default	Description
7:3	Reserved	R/W	0x00	
2	GPIO3_OUT	R/W	1 *	Control for GPIO3 signal when configured to GPIO Output: 0 - Logic low level 1 - Logic high level
1	GPIO2_OUT	R/W	1 *	Control for GPIO2 signal when configured to GPIO Output: 0 - Logic low level 1 - Logic high level
0	GPIO1_OUT	R/W	0	Control for GPIO1 signal when configured to GPIO Output: 0 - Logic low level 1 - Logic high level

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8 Application and Implementation

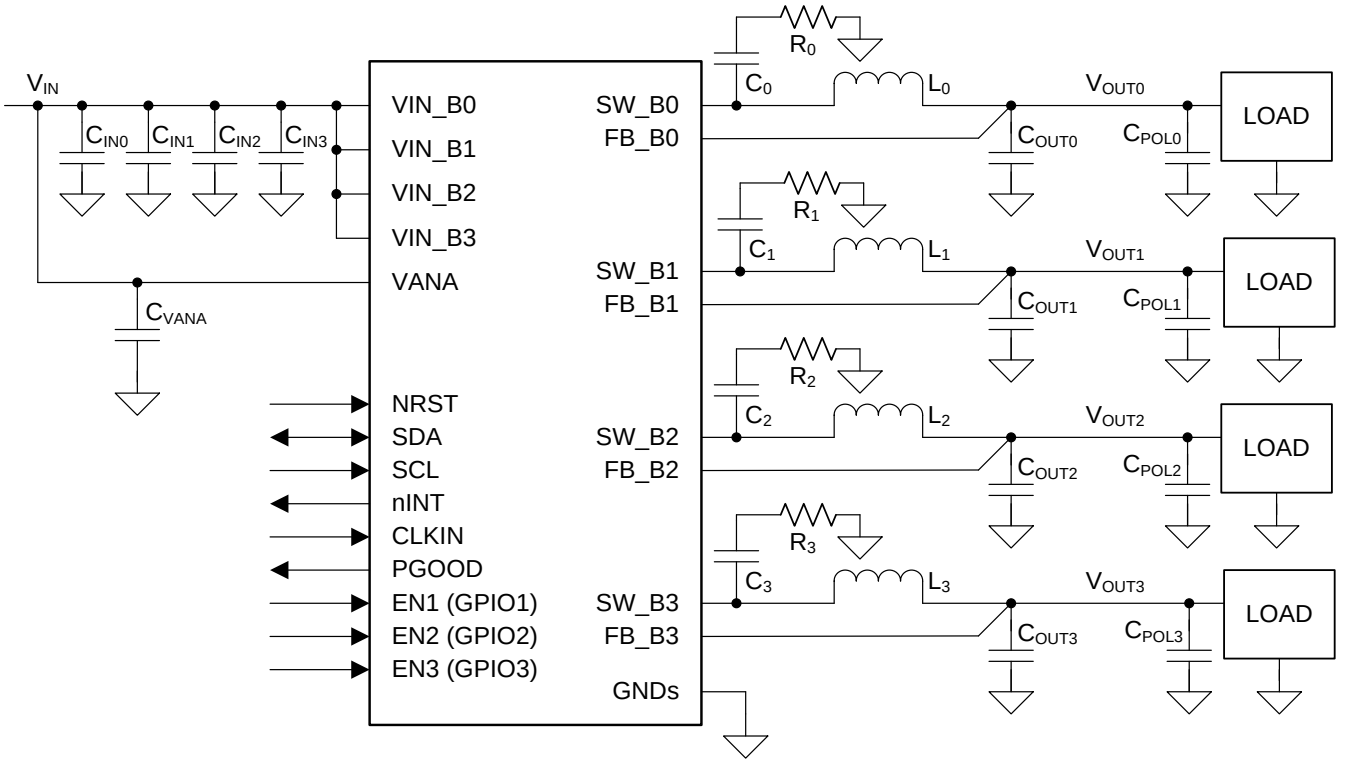
NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

8.1 Application Information

The LP87524B/J/P-Q1 is a multi-phase step-down converter with four switcher cores, which are configured to four one-phase regulators configuration.

8.2 Typical Application



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Figure 22. Four 1-Phase Configuration

8.2.1 Design Requirements

8.2.1.1 Inductor Selection

The inductors are L_0, L_1, L_2, and L_3 are shown in the *Typical Application*. The inductance and DCR of the inductor affects the control loop of the buck regulator. TI recommends using inductors similar to those listed in Table 10. Pay attention to the saturation current and temperature rise current of the inductor. Check that the saturation current is higher than the peak current limit and the temperature rise current is higher than the maximum expected rms output current. Minimum effective inductance to ensure good performance is 0.22 µH at maximum peak output current over the operating temperature range. DC resistance of the inductor must be less than 0.05 Ω for good efficiency at high-current condition. The inductor AC loss (resistance) also affects conversion efficiency. Higher Q factor at switching frequency usually gives better efficiency at light load to middle load. Shielded inductors are preferred as they radiate less noise.

Typical Application (continued)

Table 10. Recommended Inductors

MANUFACTURER	PART NUMBER	VALUE	DIMENSIONS L × W × H (mm)	RATED DC CURRENT, I_{SAT} maximum (typical) / I_{TEMP} maximum (typical) (A)	DCR typical / maximum (mΩ)
TOKO	DFE252012PD-R47M	0.47 µH (20%)	2.5 × 2 × 1.2	5.2 (–) / 4 (–)(1)	- / 27
Vishay	IHLP1616AB-1A	0.47 µH (20%)	4.1 × 4.5 × 1.2	– (6) / – (6)(1)	19 / 21

(1) Operating temperature range is up to 125°C including self temperature rise.

8.2.1.2 Input Capacitor Selection

The input capacitors C_{IN0}, C_{IN1}, C_{IN2}, and C_{IN3} are shown in the *Typical Application*. A ceramic input bypass capacitor of 10 µF is required for each phase of the regulator. Place the input capacitor as close as possible to the VIN_Bx pin and PGND_Bx pin of the device. A larger value or higher voltage rating improves the input voltage filtering. Use X7R type of capacitors, not Y5V or F. DC bias characteristics capacitors must be considered, minimum effective input capacitance to ensure good performance is 1.9 µF per buck input at maximum input voltage including tolerances and ambient temperature range, assuming that there are at least 22 µF of additional capacitance common for all the power input pins on the system power rail. See Table 11.

The input filter capacitor supplies current to the high-side FET switch in the first half of each cycle and reduces voltage ripple imposed on the input power source. A ceramic capacitor's low ESR provides the best noise filtering of the input voltage spikes due to this rapidly changing current. Select an input filter capacitor with sufficient ripple current rating. In addition ferrite can be used in front of the input capacitor to reduce the EMI.

Table 11. Recommended Input Capacitors (X7R Dielectric)

MANUFACTURER	PART NUMBER	VALUE	CASE SIZE	DIMENSIONS L × W × H (mm)	VOLTAGE RATING (V)
Murata	GCM21BR71A106KE22	10 µF (10%)	0805	2 × 1.25 × 1.25	10 V

8.2.1.3 Output Capacitor Selection

The output capacitors C_{OUT0}, C_{OUT1}, C_{OUT2}, and C_{OUT3} are shown in Typical Application. A ceramic local output capacitor of 22 µF is required per phase. Use ceramic capacitors, X7R or X7T types; do not use Y5V or F. DC bias voltage characteristics of ceramic capacitors must be considered. The output filter capacitor smooths out current flow from the inductor to the load, helps maintain a steady output voltage during transient load changes and reduces output voltage ripple. These capacitors must be selected with sufficient capacitance and sufficiently low ESR and ESL to perform these functions. Minimum effective output capacitance to ensure good performance is 10 µF per phase including the DC voltage roll-off, tolerances, aging and temperature effects.

The output voltage ripple is caused by the charging and discharging of the output capacitor and also due to its R_{ESR}. The R_{ESR} is frequency dependent (as well as temperature dependent); make sure the value used for selection process is at the switching frequency of the part. See Table 12.

POL capacitors (C_{POL0}, C_{POL1}, C_{POL2}, C_{POL3}) can be used to improve load transient performance and to decrease the ripple voltage. A higher output capacitance improves the load step behavior and reduces the output voltage ripple as well as decreases the PFM switching frequency. However, output capacitance higher than 100 µF per phase is not necessarily of any benefit. Note that the output capacitor may be the limiting factor in the output voltage ramp and the maximum total output capacitance listed in electrical characteristics must not be exceeded. At shutdown the output voltage is discharged to 0.6 V level using forced-PWM operation. This can increase the input voltage if the load current is small and the output capacitor is large. Below 0.6 V level the output capacitor is discharged by the internal discharge resistor and with large capacitor more time is required to settle V_{OUT} down as a consequence of the increased time constant.

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Table 12. Recommended Output Capacitors (X7R or X7T Dielectric)

MANUFACTURER	PART NUMBER	VALUE	CASE SIZE	DIMENSIONS L × W × H (mm)	VOLTAGE RATING (V)
Murata	GCM31CR71A226KE02	22 µF (10%)	1206	3.2 × 1.6 × 1.6	10

8.2.1.4 Snubber Components

If the input voltage for the regulators is above 4 V, snubber components are needed at the switching nodes to decrease voltage spiking in the switching node and to improve EMI. The snubber capacitors C_0, C_1, C_2, and C_3 and the snubber resistors R_0, R_1, R_2, and R_3 are shown in Figure 22. The recommended components are shown in Table 13 and these component values give good performance on LP87524B/J/P-Q1 EVM. The optimal resistance and capacitance values finally depend on the PCB layout.

Table 13. Recommended Snubber Components

MANUFACTURER	PART NUMBER	VALUE	CASE SIZE	DIMENSIONS L × W x H (mm)	VOLTAGE / POWER RATING
Vishay-Dale	CRCW04023R90JNED	3.9 Ω (5%)	0402	1 × 0.5 × 0.4	62 mW
Murata	GCM1555C1H391JA16	390 pF (5%)	0402	1 × 0.5 × 0.5	50 V

8.2.1.5 Supply Filtering Components

The VANA input is used to supply analog and digital circuits in the device. See Table 14 for recommended components for VANA input supply filtering.

Table 14. Recommended Supply Filtering Components

MANUFACTURER	PART NUMBER	VALUE	CASE SIZE	DIMENSIONS L × W × H (mm)	VOLTAGE RATING (V)
Murata	GCM155R71C104KA55	100 nF (10%)	0402	1.0 × 0.5 × 0.5	16
Murata	GCM188R71C104KA37	100 nF (10%)	0603	1.6 × 0.8 × 0.8	16

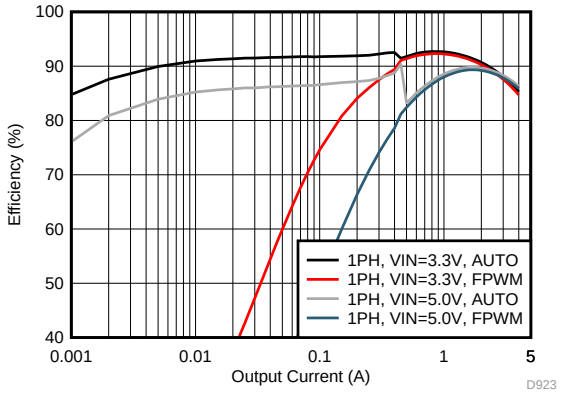
8.2.2 Detailed Design Procedure

The performance of the LP87524B/J/P-Q1 device depends greatly on the care taken in designing the printed circuit board (PCB). The use of low-inductance and low serial-resistance ceramic capacitors is strongly recommended, while proper grounding is crucial. Attention must be given to decoupling the power supplies. Decoupling capacitors must be connected close to the device and between the power and ground pins to support high peak currents being drawn from system power rail during turnon of the switching MOSFETs. Keep input and output traces as short as possible, because trace inductance, resistance, and capacitance can easily become the performance limiting items. The separate power pins VIN_Bx are not connected together internally. Connect the VIN_Bx power connections together outside the package using power plane construction.

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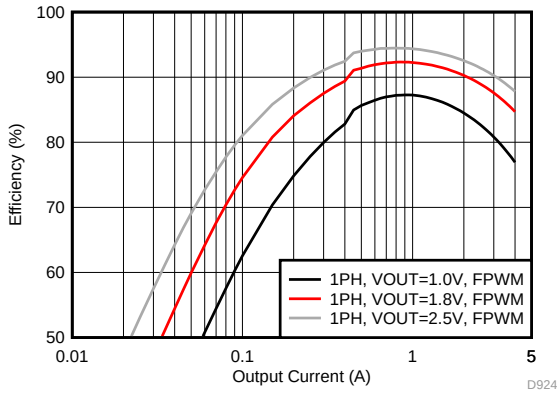
8.2.3 Application Curves

Measurements are done using typical application set up with connections shown in Figure 22 (snubber components included when V_{IN} > 4 V). Graphs may not reflect the OTP default settings. Unless otherwise specified: V_{IN} = 3.7 V, V_{OUT} = 1 V, $V_{(NRST)}$ = 1.8 V, T_A = 25°C, f_{SW} = 4 MHz, L = 0.47 µH (TOKO DFE252012PD-R47M), C_{OUT} = 22 µF / phase, and C_{POL} = 22 µF / phase. Measurements are done using connections in the *Typical Application*.



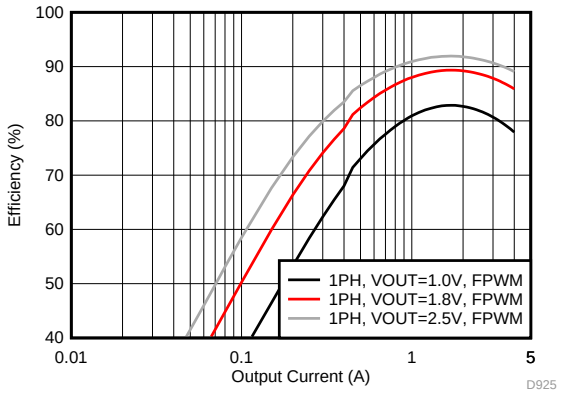
V_{OUT} = 1.8 V

Figure 23. Efficiency in PFM/PWM Mode



V_{IN} = 3.3 V

Figure 24. Efficiency in Forced-PWM Mode



V_{IN} = 5 V

Figure 25. Efficiency in Forced-PWM Mode

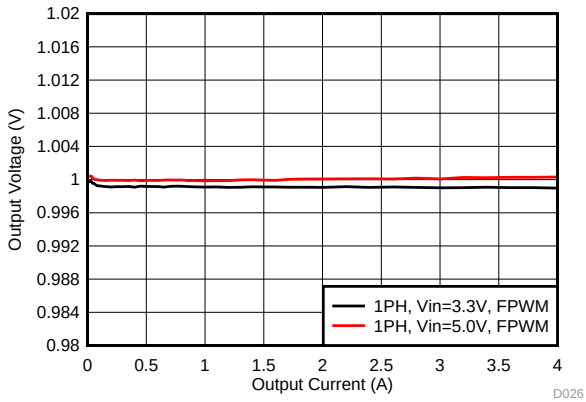


Figure 26. Output Voltage vs Load Current in Forced-PWM Mode

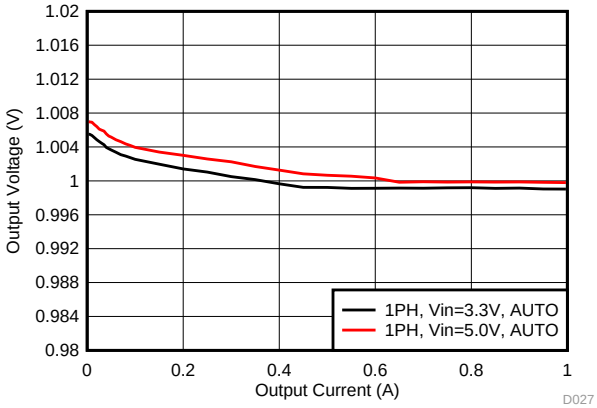
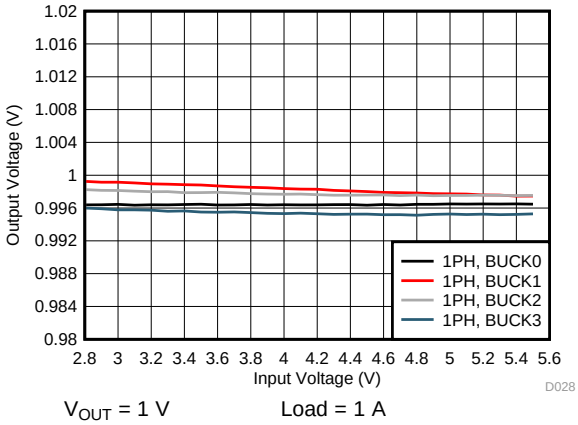


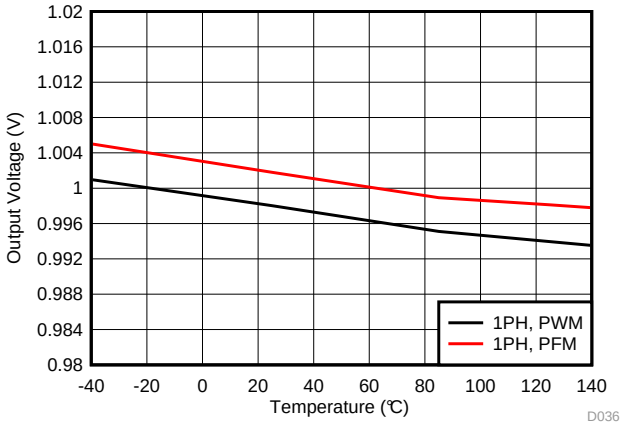
Figure 27. Output Voltage vs Load Current in PFM/PWM Mode



V_{OUT} = 1 V Load = 1 A

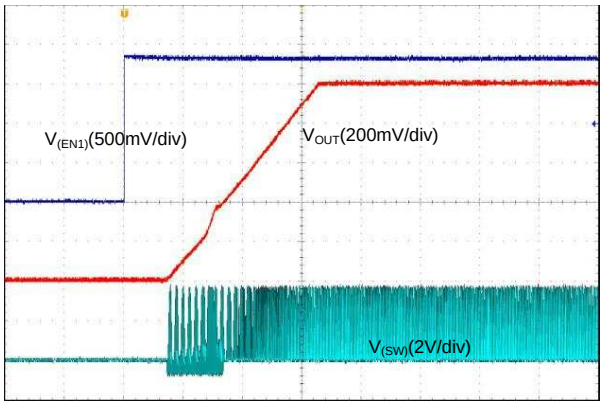
Figure 28. Output Voltage vs Input Voltage in PWM Mode

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Load = 1 A (PWM) and 0.1 A (PFM)

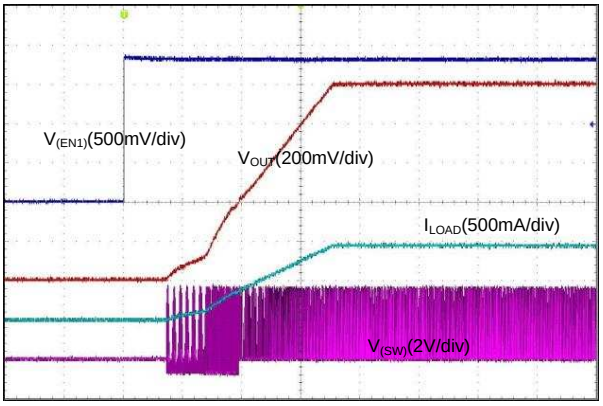
Figure 29. Output Voltage vs Temperature



Time (100 µs/div)

I_{OUT} = 0 A

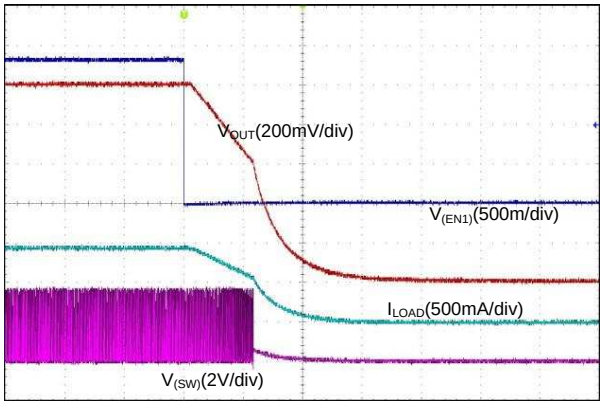
Figure 30. Start-Up With EN1, Forced PWM



Time (100 µs/div)

R_{LOAD} = 1 Ω

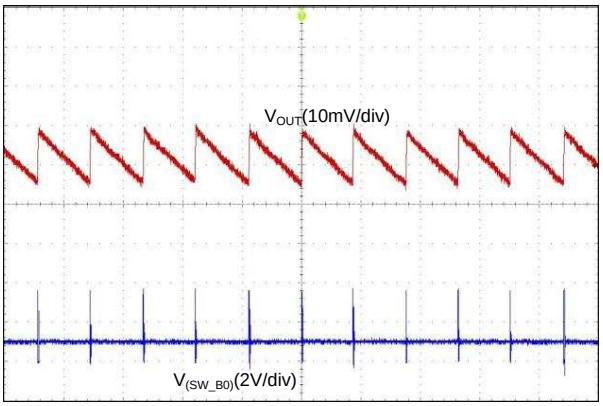
Figure 31. Start-Up With EN1, Forced PWM (1-Phase Output)



Time (100 µs/div)

R_{LOAD} = 1 Ω

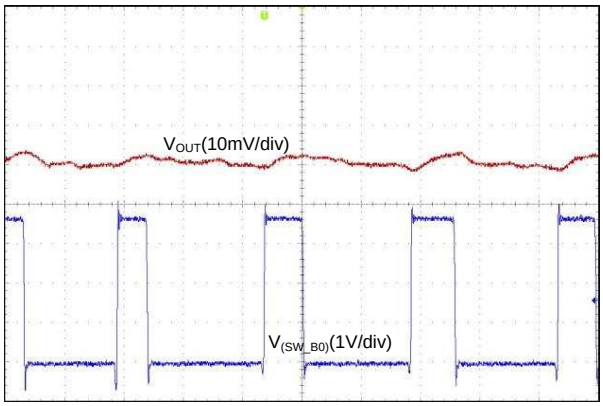
Figure 32. Shutdown With EN1, Forced PWM (1-Phase Output)



Time (40 µs/div)

I_{OUT} = 10 mA

Figure 33. Output Voltage Ripple, PFM Mode (1-Phase Output)

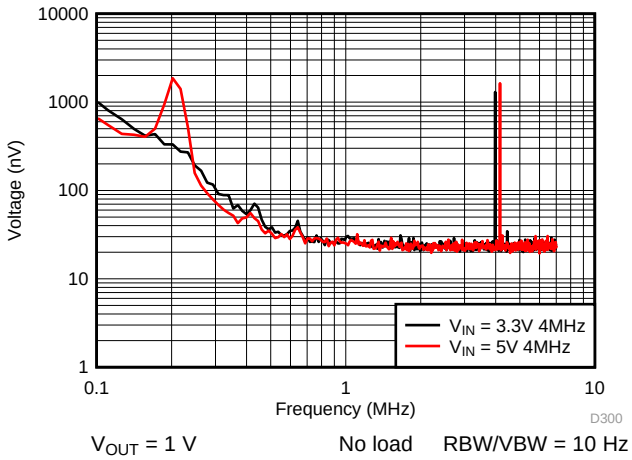


Time (100 ns/div)

I_{OUT} = 200 mA

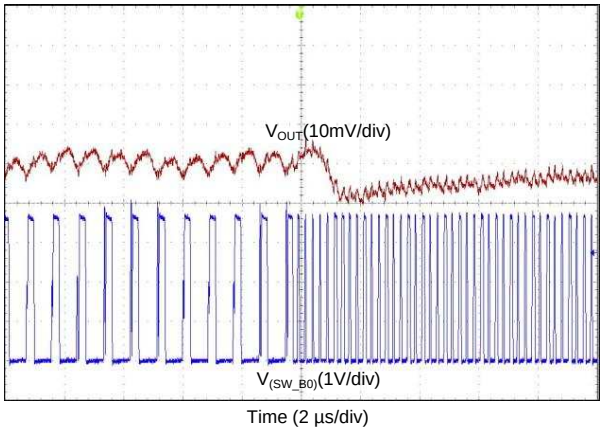
Figure 34. Output Voltage Ripple, Forced-PWM Mode (1-Phase Output)

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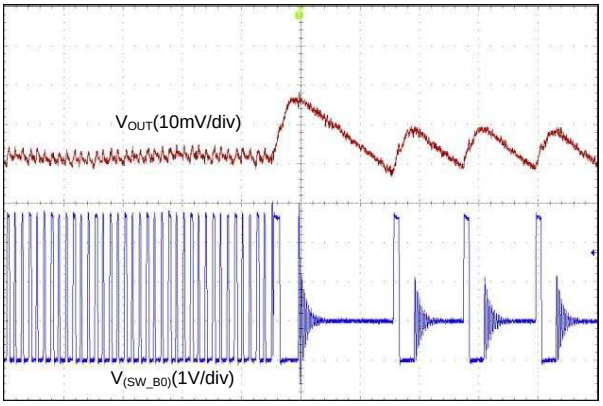
V_{OUT} = 1 V No load RBW/VBW = 10 Hz

Figure 35. Output Voltage Ripple Spectrum, Forced-PWM Mode. C_{OUT} = 22 µF, ferrite BLM18KG121TH1D, C_{POL} = 10 µF + 0.22 µF.



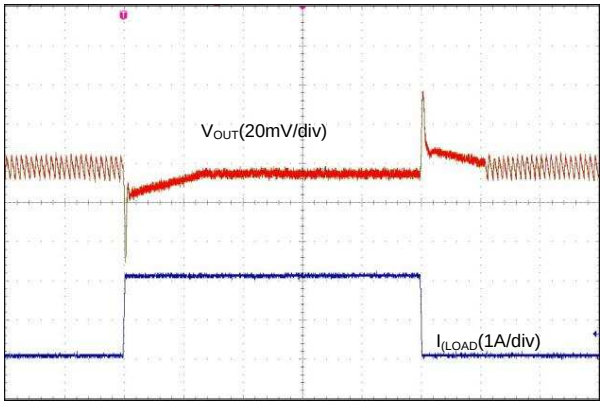
Time (2 µs/div)

Figure 36. Transient from PFM-to-PWM Mode (1-Phase Output)



Time (2 µs/div)

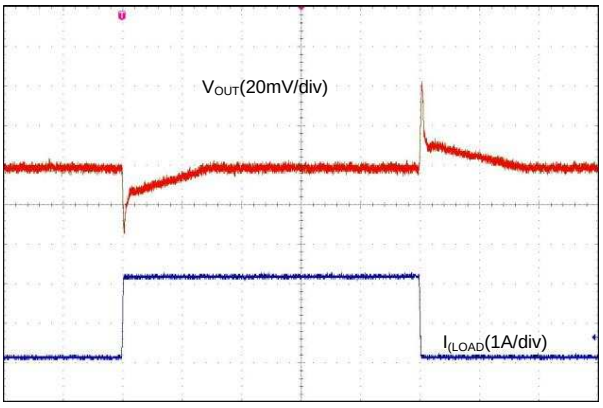
Figure 37. Transient from PWM-to-PFM Mode (1-Phase Output)



Time (40 µs/div)

I_{OUT} = 0.1 A → 2 A → 0.1 A $T_R = T_F$ = 1 µs

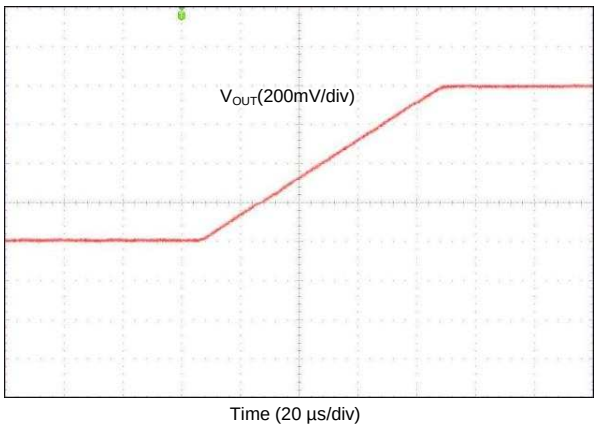
Figure 38. Transient Load Step Response, AUTO Mode (1-Phase Output)



Time (40 µs/div)

I_{OUT} = 0.1 A → 2 A → 0.1 A $T_R = T_F$ = 1 µs

Figure 39. Transient Load Step Response, Forced-PWM Mode (1-Phase Output)



Time (20 µs/div)

Figure 40. V_{OUT} Transition from 0.6 V to 1.4 V

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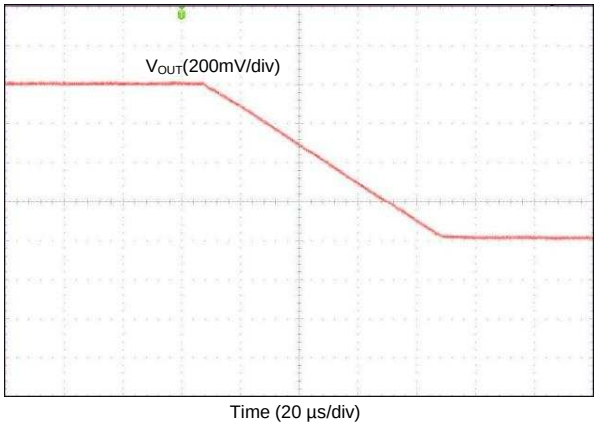


Figure 41. V_{OUT} Transition from 1.4 V to 0.6 V

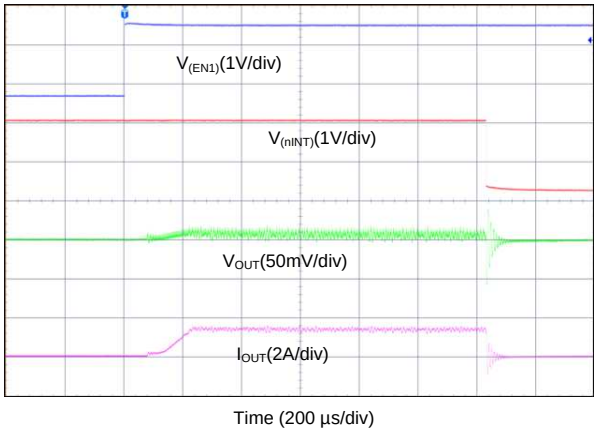


Figure 42. Start-up With Short on Output (1-Phase Output)

9 Power Supply Recommendations

The device is designed to operate from an input voltage supply range from 2.8 V and 5.5 V. This input supply must be well regulated and able to withstand maximum input current and maintain stable voltage without voltage drop even at load transition condition. The resistance of the input supply rail must be low enough that the input current transient does not cause too high drop in the LP87524B/J/P-Q1 supply voltage that can cause false UVLO fault triggering. If the input supply is located more than a few inches from the LP87524B/J/P-Q1 additional bulk capacitance may be required in addition to the ceramic bypass capacitors.

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10 Layout

10.1 Layout Guidelines

The high frequency and large switching currents of the LP87524B/J/P-Q1 make the choice of layout important. Good power supply results only occur when care is given to proper design and layout. Layout affects noise pickup and generation and can cause a good design to perform with less-than-expected results. With a range of output currents from milliamps to 10 A, good power supply layout is much more difficult than most general PCB design. Use the following steps as a reference to ensure the device is stable and maintains proper voltage and current regulation across its intended operating voltage and current range.

1. Place C_{IN} as close as possible to the VIN_Bx pin and the PGND_Bxx pin. Route the V_{IN} trace wide and thick to avoid IR drops. The trace between the positive node of the input capacitor and the VIN_Bx pin(s) of LP87524B/J/P-Q1, as well as the trace between the negative node of the input capacitor and power PGND_Bxx pin(s), must be kept as short as possible. The input capacitance provides a low-impedance voltage source for the switching converter. The inductance of the connection is the most important parameter of a local decoupling capacitor — parasitic inductance on these traces must be kept as small as possible for proper device operation. The parasitic inductance can be reduced by using a ground plane as close as possible to top layer by using thin dielectric layer between top layer and ground plane.
2. The output filter, consisting of COUT and L, converts the switching signal at SW_Bx to the noiseless output voltage. It must be placed as close as possible to the device keeping the switch node small, for best EMI behavior. Route the traces between the LP87524B/J/P-Q1 output capacitors and the load direct and wide to avoid losses due to the IR drop.
3. Input for analog blocks (VANA and AGND) must be isolated from noisy signals. Connect VANA directly to a quiet system voltage node and AGND to a quiet ground point where no IR drop occurs. Place the decoupling capacitor as close as possible to the VANA pin.
4. If the processor load supports remote voltage sensing, connect the feedback pins FB_Bx of the LP87524B/J/P-Q1 device to the respective sense pins on the processor. The sense lines are susceptible to noise. They must be kept away from noisy signals such as PGND_Bxx, VIN_Bx, and SW_Bx, as well as high bandwidth signals such as the I^2C. Avoid both capacitive and inductive coupling by keeping the sense lines short, direct, and close to each other. Run the lines in a quiet layer. Isolate them from noisy signals by a voltage or ground plane if possible. If series resistors are used for load current measurement, place them after connection of the voltage feedback.
5. PGND_Bxx, VIN_Bx and SW_Bx must be routed on thick layers. They must not surround inner signal layers, which are not able to withstand interference from noisy PGND_Bxx, VIN_Bx and SW_Bx.
6. If the input voltage is above 4 V, place snubber components (capacitor and resistor) between SW_Bx and ground on all four phases. The components can be also placed to the other side of the board if there are area limitations and the routing traces can be kept short.

Due to the small package of this converter and the overall small solution size, the thermal performance of the PCB layout is important. Many system-dependent parameters such as thermal coupling, airflow, added heat sinks and convection surfaces, and the presence of other heat-generating components affect the power dissipation limits of a given component. Proper PCB layout, focusing on thermal performance, results in lower die temperatures. Wide and thick power traces come with the ability to sink dissipated heat. This can be improved further on multi-layer PCB designs with vias to different planes. This results in reduced junction-to-ambient ($R_{\theta JA}$) and junction-to-board ($R_{\theta JB}$) thermal resistances and thereby reduces the device junction temperature, T_J. TI strongly recommends to perform of a careful system-level 2D or full 3D dynamic thermal analysis at the beginning product design process, by using a thermal modeling analysis software.

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10.2 Layout Example

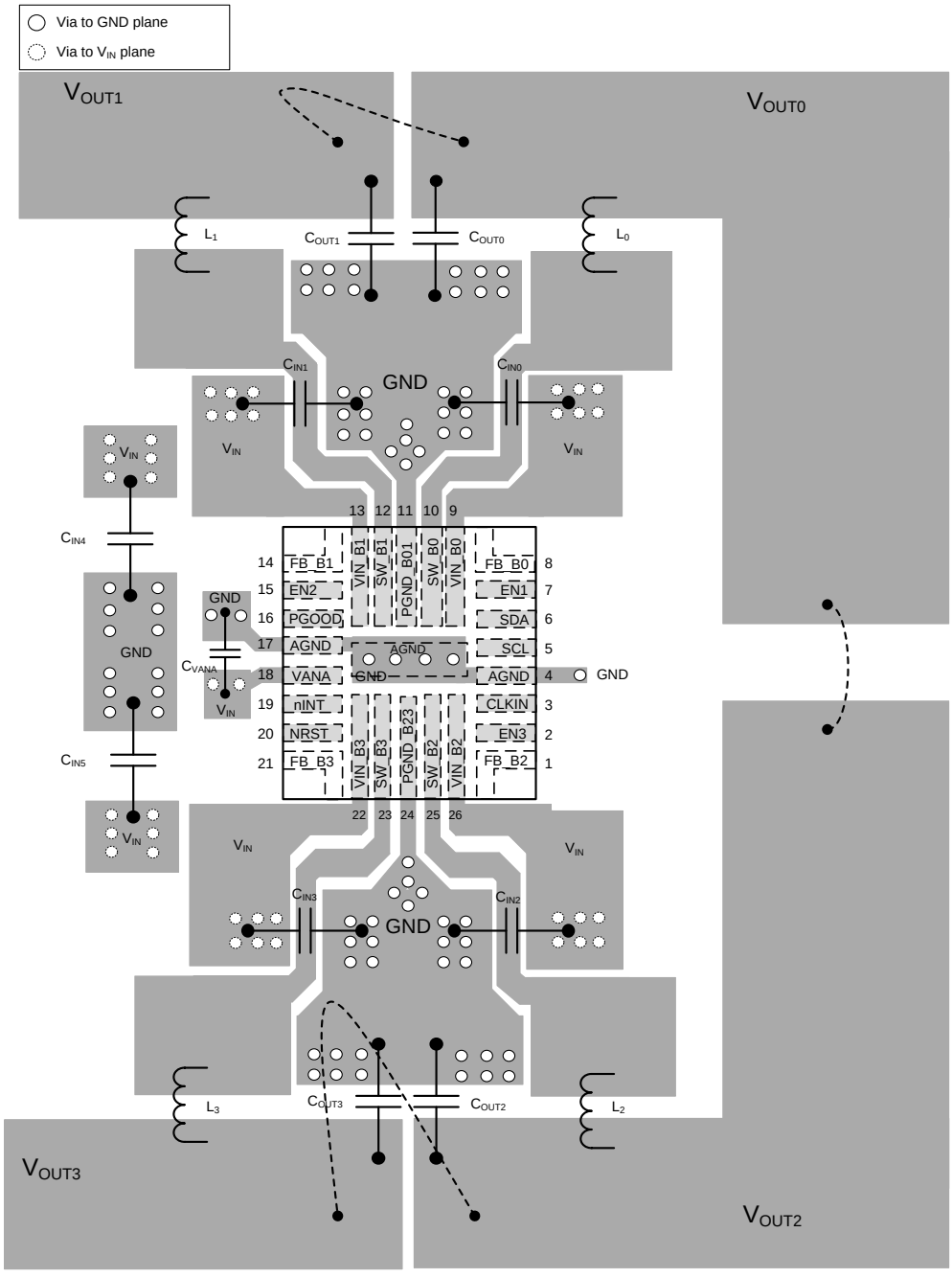


Figure 43. LP87524B/J/P-Q1 Board Layout

The output voltage rails are shorted together based on the configuration as shown in *Typical Application*.

11 Device and Documentation Support

11.1 Device Support

11.1.1 Third-Party Products Disclaimer

TI'S PUBLICATION OF INFORMATION REGARDING THIRD-PARTY PRODUCTS OR SERVICES DOES NOT CONSTITUTE AN ENDORSEMENT REGARDING THE SUITABILITY OF SUCH PRODUCTS OR SERVICES OR A WARRANTY, REPRESENTATION OR ENDORSEMENT OF SUCH PRODUCTS OR SERVICES, EITHER ALONE OR IN COMBINATION WITH ANY TI PRODUCT OR SERVICE.

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To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on *Alert me* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

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The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

TI E2E™ Online Community ***TI's Engineer-to-Engineer (E2E) Community.*** Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

Design Support ***TI's Design Support*** Quickly find helpful E2E forums along with design support tools and contact information for technical support.

11.4 Trademarks

E2E is a trademark of Texas Instruments.
All other trademarks are the property of their respective owners.

11.5 Electrostatic Discharge Caution



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

11.6 Glossary

SLYZ022 — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

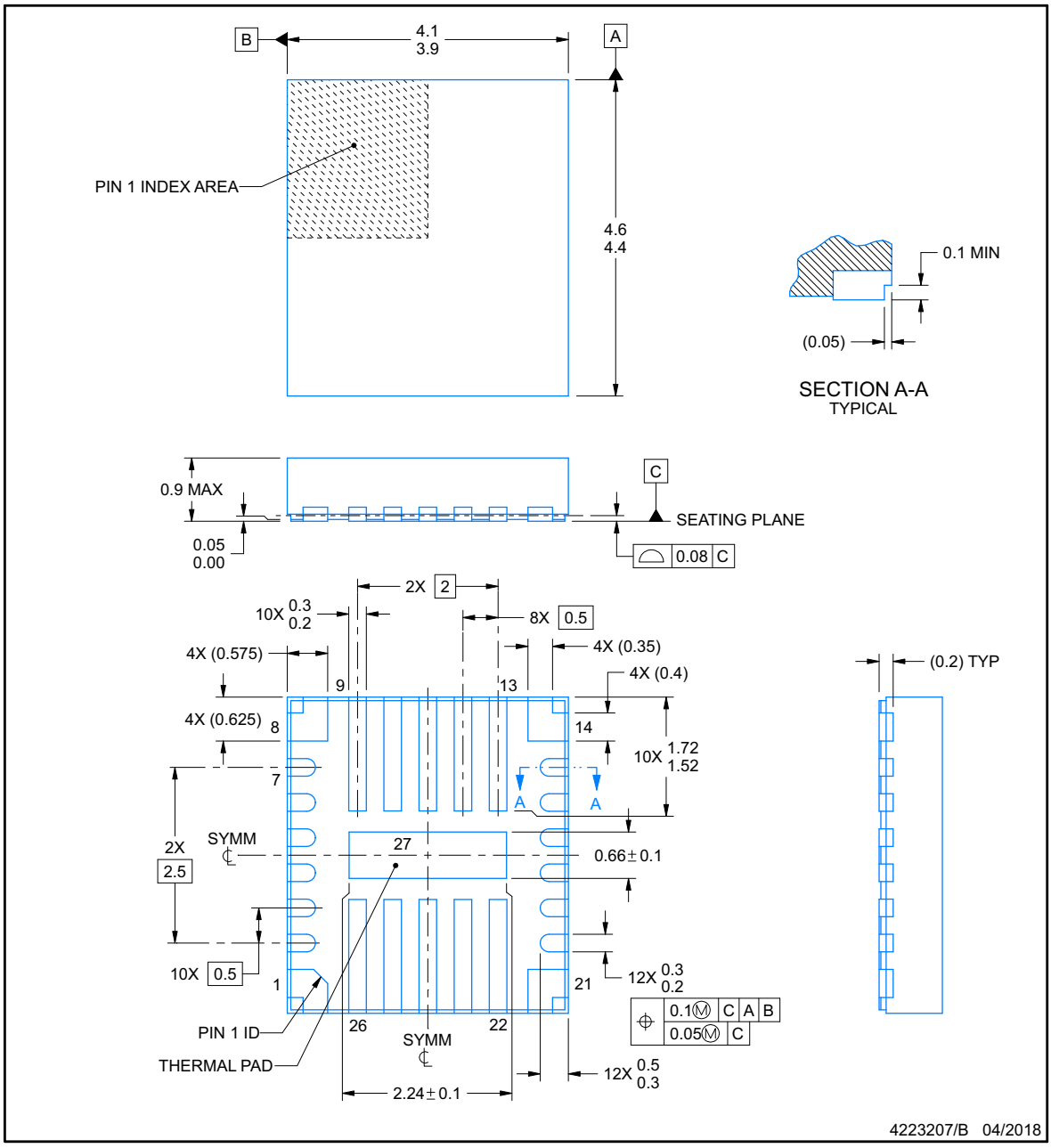
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PACKAGE OUTLINE

RNF0026C

VQFN-HR - 0.9 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



NOTES:

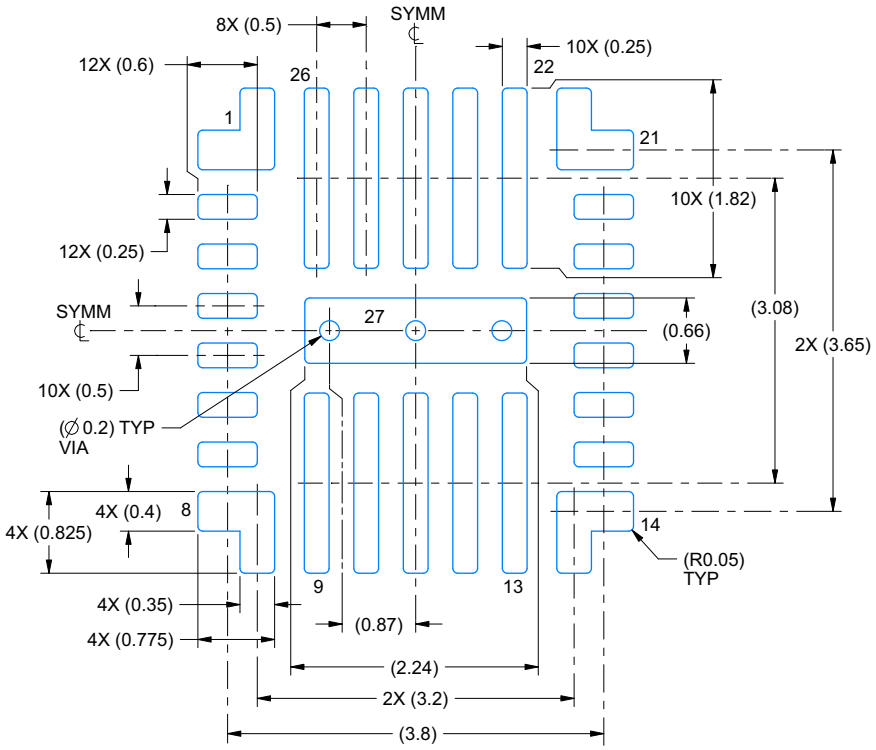
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.

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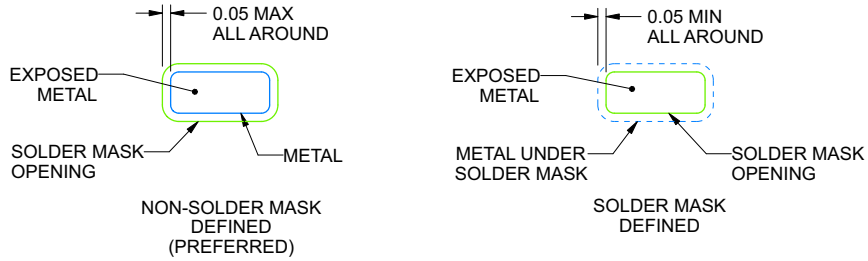
EXAMPLE BOARD LAYOUT

RNF0026C — **VQFN-HR - 0.9 mm max height**

PLASTIC QUAD FLATPACK - NO LEAD



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:15X



SOLDER MASK DETAIL
NOT TO SCALE

4223207/B 04/2018

NOTES: (continued)

4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/slua271).
5. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.

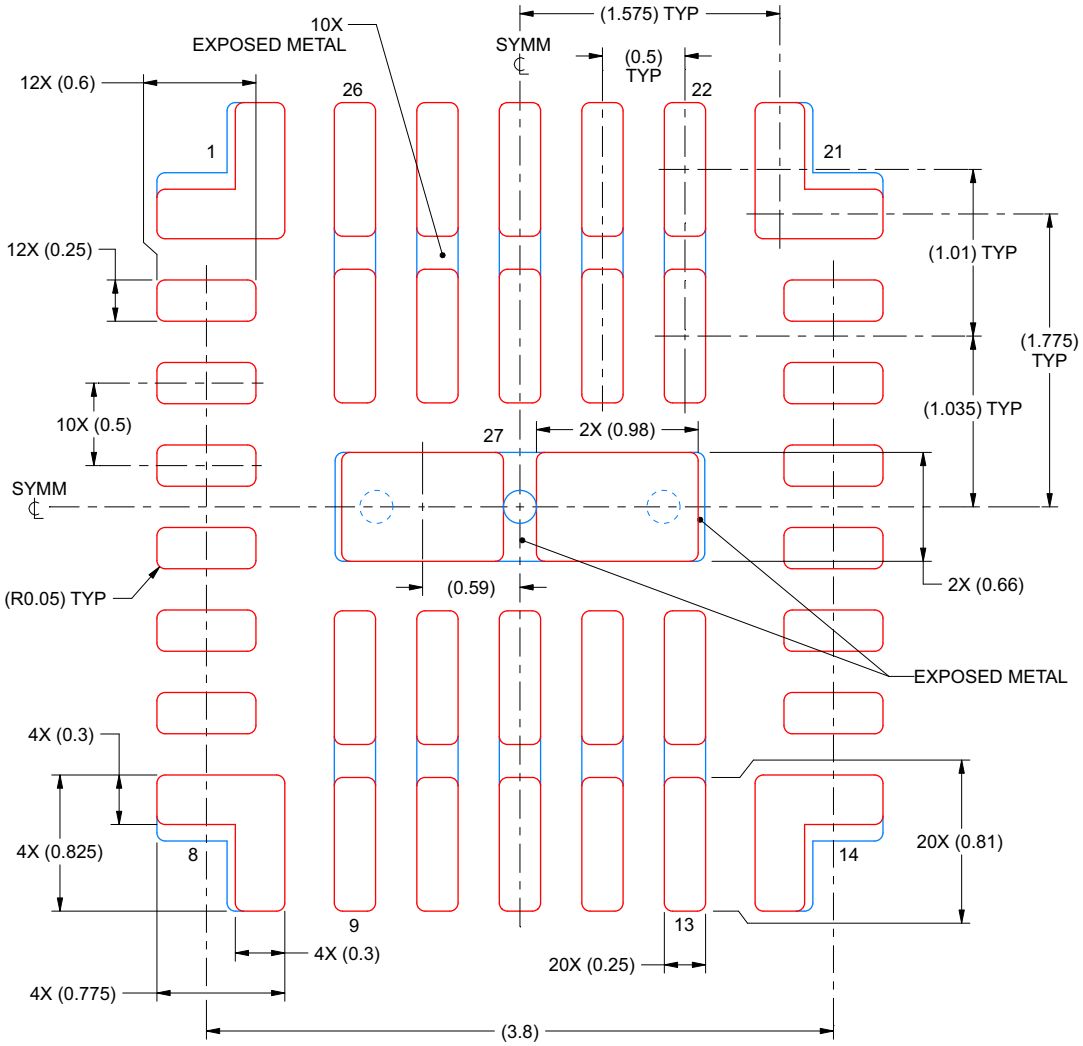
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EXAMPLE STENCIL DESIGN

RNF0026C

VQFN-HR - 0.9 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL

PRINTED SOLDER COVERAGE BY AREA UNDER PACKAGE
PADS 1, 8, 14 & 21: 87% - PADS 9-13 & 22-26: 88% - THERMAL PAD 27: 87%
SCALE:25X

4223207/B 04/2018

NOTES: (continued)

6. For alternate stencil design recommendations, see IPC-7525 or board assembly site preference.

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PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
LP87524BRNFRQ1	ACTIVE	VQFN-HR	RNF	26	3000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	LP8752 4B-Q1	Samples
LP87524BRNFTQ1	ACTIVE	VQFN-HR	RNF	26	250	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	LP8752 4B-Q1	Samples
LP87524JRNFRQ1	ACTIVE	VQFN-HR	RNF	26	3000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	LP8752 4J-Q1	Samples
LP87524JRNFTQ1	ACTIVE	VQFN-HR	RNF	26	250	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	LP8752 4J-Q1	Samples
LP87524PRNFRQ1	ACTIVE	VQFN-HR	RNF	26	3000	Pb-Free (RoHS Exempt)	CU SN	Level-1-260C-UNLIM	-40 to 125	LP8752 4P-Q1	Samples
LP87524PRNFTQ1	ACTIVE	VQFN-HR	RNF	26	250	Pb-Free (RoHS Exempt)	CU SN	Level-1-260C-UNLIM	-40 to 125	LP8752 4P-Q1	Samples

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

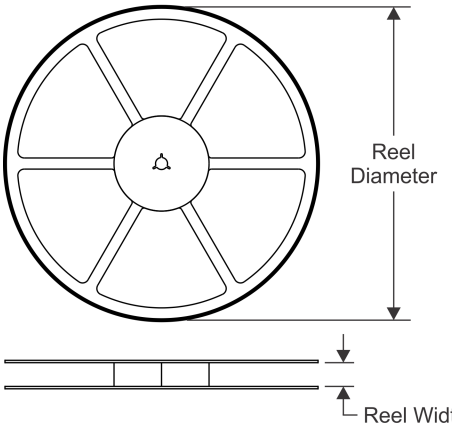
(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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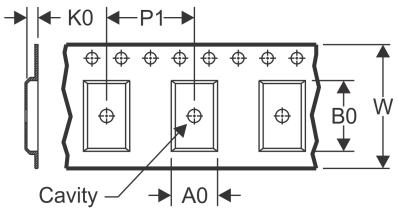
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TAPE AND REEL INFORMATION

REEL DIMENSIONS

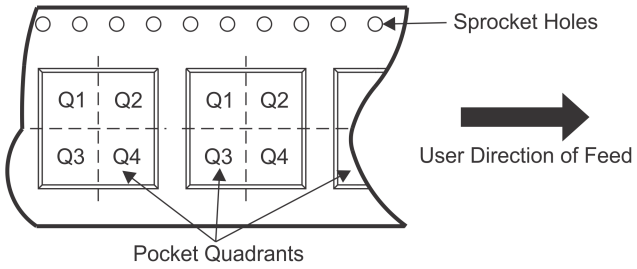


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

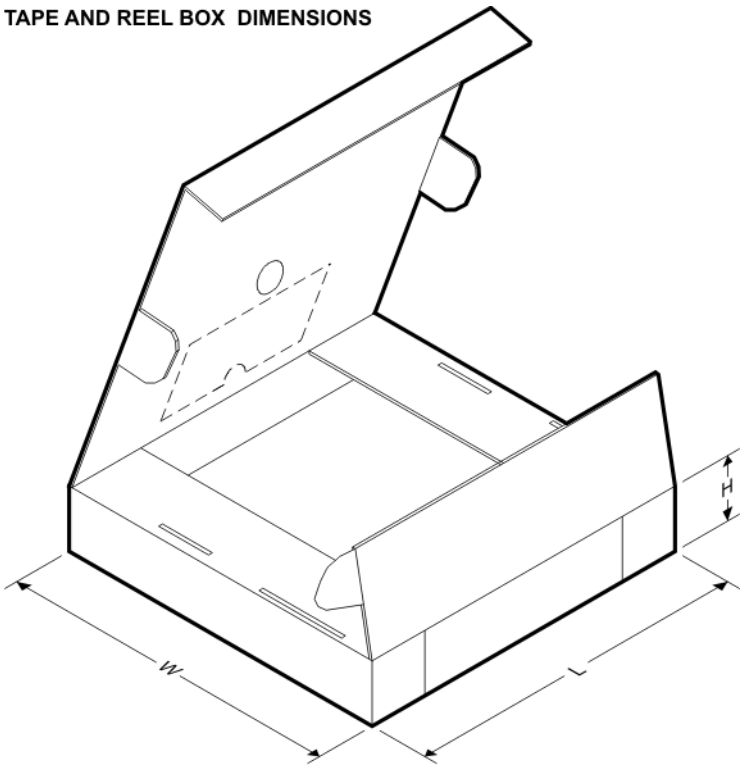
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
LP87524BRNFRQ1	VQFN-HR	RNF	26	3000	330.0	12.4	4.25	4.75	1.2	8.0	12.0	Q1
LP87524BRNFTQ1	VQFN-HR	RNF	26	250	180.0	12.4	4.25	4.75	1.2	8.0	12.0	Q1
LP87524JRNFRQ1	VQFN-HR	RNF	26	3000	330.0	12.4	4.25	4.75	1.2	8.0	12.0	Q1
LP87524JRNFTQ1	VQFN-HR	RNF	26	250	180.0	12.4	4.25	4.75	1.2	8.0	12.0	Q1
LP87524PRNFRQ1	VQFN-HR	RNF	26	3000	330.0	12.4	4.25	4.75	1.2	8.0	12.0	Q1
LP87524PRNFTQ1	VQFN-HR	RNF	26	250	180.0	12.4	4.25	4.75	1.2	8.0	12.0	Q1

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LP87524BRNFRQ1	VQFN-HR	RNF	26	3000	346.0	346.0	35.0
LP87524BRNFTQ1	VQFN-HR	RNF	26	250	203.0	203.0	35.0
LP87524JRNFRQ1	VQFN-HR	RNF	26	3000	346.0	346.0	35.0
LP87524JRNFTQ1	VQFN-HR	RNF	26	250	203.0	203.0	35.0
LP87524PRNFRQ1	VQFN-HR	RNF	26	3000	346.0	346.0	35.0
LP87524PRNFTQ1	VQFN-HR	RNF	26	250	203.0	203.0	35.0

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