

LP8728-Q1 Quad-Output Step-Down DC/DC Converter

Check for Samples: [LP8728-Q1](#)

FEATURES

- LP8728-Q1 is an Automotive Grade Product that is AECQ-100 Grade 1 Qualified
- Four High Efficiency Step-Down DC/DC Converters:
 - 93% Peak Efficiency ($V_{IN} = 5.0V$, $V_{OUT} = 3.3V$)
 - Max Output Current 1.0A
 - Forced PWM Operation
 - Soft-Start Control
 - $V_{OUT1} = 3.3V$
 - $V_{OUT2} = 1.25V$
 - $V_{OUT3} = 1.8V$ or $2.65V$ (pin selectable)
 - $V_{OUT4} = 1.8V$
- Separate Enable Inputs for each Converter Control
- Separate Power Good Outputs for each Converter
- Output Over-Current and Input Over-Voltage Protection
- Over-Temperature Protection
- Under-Voltage Lockout (UVLO)
- 28-pin 0.5 mm Pitch QFN Package

APPLICATIONS

- FPGA, DSP Core Power
- Processor Power for Mobile Devices
- Peripheral I/O Power
- Automotive Safety Cameras
- Automotive Infotainment

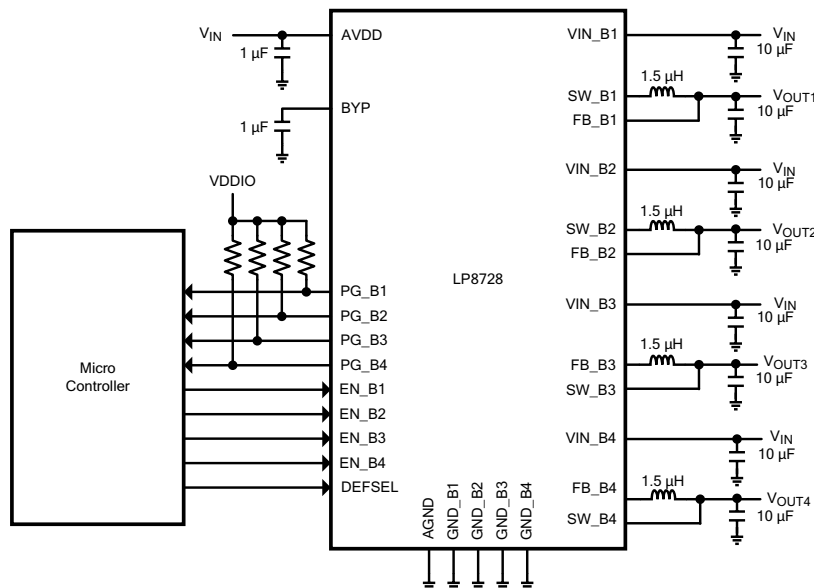
DESCRIPTION

The LP8728-Q1 is a quad-output Power Management Unit, optimized for low-power FPGAs, microprocessors, and DSPs. This device integrates four highly efficient step-down DC/DC converters into one package. All the converters operate above the AM band with a fixed 3.2 MHz switching frequency. Each buck converter's high-side switch turn-on time is phase shifted to minimize input current spikes.

The protection features include output short-circuit protection, switch current limits, input over-voltage protection, input under-voltage lockout, and thermal shutdown functions. During startup, the device controls the output slew rate to minimize output voltage overshoot and the input inrush current.

The device comes in a 5 x 5 x 0.8 mm 28-pin QFN package with 0.5 mm pitch.

TYPICAL APPLICATION CIRCUIT



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

ABSOLUTE MAXIMUM RATINGS⁽¹⁾⁽²⁾

Over operating ambient temperature range (unless otherwise noted).

PARAMETER		VALUE	UNIT
V _{IN}	Voltage on power pins (AVDD, VIN_Bx)	–0.3 to 6.0	V
V _{FB}	Voltage on feedback pins (FB_Bx)	–0.3 to 6.0	V
V _{SW}	Voltage on buck converter switch pins (SW_Bx)	(GND_Bx – 0.2 V) to (VIN_Bx + 0.2 V) with 6.0V max	V
V _{DIG}	Voltage on digital pins (PG_Bx, EN_Bx, DEFSEL)	(AGND – 0.2V) to (AVDD + 0.2 V) with 6.0 max	V
V _{BYP}	Voltage on BYP pin	–0.3 to 2.0	V
T _{J(MAX)}	Maximum operating junction temperature ⁽³⁾	+150	°C
T _{STG}	Storage temperature range	–65 to +150	°C
Electrostatic discharge (HBM)		2000	V
Electrostatic discharge (CDM)		750	V

- (1) Stresses beyond those listed under *absolute maximum ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *recommended operating conditions* is not implied. Exposure to absolute–maximum–rated conditions for extended periods may affect device reliability.
- (2) All voltage values are with respect to network ground terminal.
- (3) Internal thermal shutdown circuitry protects the device from permanent damage. Thermal shutdown engages at T_J = 150°C (typ.) and disengages at T_J = 130°C (typ.).

THERMAL PROPERTIES

QFN-28 package thermal properties

PARAMETER		VALUE	UNIT
θ _{JA}	Junction-to-Ambient Thermal Resistance ⁽¹⁾	36.3	°C/W

- (1) Calculated using 4-layer standard JEDEC thermal test board with 5 thermal vias between the die attach pad in the first copper layer and second copper layer.

RECOMMENDED OPERATING CONDITIONS⁽¹⁾

Over operating ambient temperature range (unless otherwise noted).

PARAMETER		MIN	NOM	MAX	UNIT
V _{IN}	Input Voltage on AVDD, VIN_B1, VIN_B2, VIN_B3 and VIN_B4 Pins	4.5	5.0	5.5	V
T _A	Operating ambient temperature range ⁽²⁾	–40		+125	°C
C _{OUT}	Effective output capacitance during operation. Min value over T _A –40°C to 125°C.	5.0	10	12	μF
C _{IN}	Effective input capacitance during operation. 4.5V ≤ V _{IN_Bx} ≤ 5.5V. Min value over T _A –40°C to 125°C.	2.5	10		μF
L	Effective inductance during operation Min value over T _A –40°C to 125°C.	0.47	1.5	2	μH

- (1) All voltage values are with respect to network ground terminal.
- (2) In applications where high power dissipation and/or poor package thermal resistance is present, the maximum ambient temperature may have to be derated. Maximum ambient temperature [T_{A(max)}] is dependent on the maximum operating junction temperature [T_{J(max)}], the maximum power dissipation of the device in the application [P_{D(max)}], and the junction-to-ambient thermal resistance of the part/package in the application (θ_{JA}), as given by the following equation: T_{A(max)} = T_{J(max)} – (θ_{JA} × P_{D(max)})

ELECTRICAL CHARACTERISTICS⁽¹⁾⁽²⁾

Typical values and limits appearing in normal type apply for $T_A = 25^\circ\text{C}$. Unless otherwise noted, $V_{IN} = 5.0\text{ V}$. Limits appearing in **boldface** type apply over junction temperature range, $T_J = -40^\circ\text{C}$ to 125°C .

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{SHDN}	Shutdown Supply Current into Power Connections	$EN_Bx = 0V$		1.0	6	μA
I_{OP}	Operating Current	All buck-converters active, $I_{OUT} = 0\text{mA}$		20		mA
LOGIC INPUTS (EN_Bx, DEFSEL)						
V_{IL}	Input Low Level				0.4	V
V_{IH}	Input High Level		1.6			V
R_{PD_DI}	EN_Bx and DEFSEL Internal Pull-down Resistance		300	520	820	$\text{k}\Omega$
T_{H_MIN}	Minimum EN_Bx High Time			1		ms
T_{L_MIN}	Minimum EN_Bx Low Time			10		μs
LOGIC OUTPUTS (PG_Bx)						
V_{OL}	Output Low Level	$I_{SINK} = 3\text{mA}$			0.4	V
R_{PU}	Recommended Pull-up Resistor			10		$\text{k}\Omega$
BUCK CONVERTERS						
V_{OUT1}	Output Voltage for Buck 1	Fixed voltage		3.3		V
V_{OUT2}	Output Voltage for Buck 2	Fixed voltage		1.25		V
V_{OUT3}	Output Voltage for Buck 3	DEFSEL = 1		2.65		V
		DEFSEL = 0		1.8		
V_{OUT4}	Output Voltage for Buck 4	Fixed voltage		1.8		V
V_{FB_Bx}	Output voltage accuracy		-3		3	%
ΔV_{OUT}	Line Regulation	$4.5\text{ V} \leq V_{IN_Bx} \leq 5.5\text{ V}$ $I_{LOAD} = 10\text{ mA}$		3		mV
	Load Regulation	$V_{IN} = 5.0\text{ V}$ $100\text{ mA} \leq I_{LOAD} \leq 900\text{ mA}$		3		mV
I_{OUT}	Output Current	DC load			1000	mA
F_{SW}	Switching Frequency		3.03	3.2	3.37	MHz
GBW	Gain Bandwidth			300		kHz
I_{LIMITP}	High Side Switch Current Limit		1200	1500	1800	mA
I_{LIMITN}	Low Side Switch Current Limit	Reverse current		500		mA
$R_{DS(ON)P}$	Pin-Pin Resistance for PFET	$I_{OUT} = 200\text{ mA}$		210	300	$\text{m}\Omega$
$R_{DS(ON)N}$	Pin-Pin Resistance for NFET	$I_{OUT} = 200\text{ mA}$		140	240	$\text{m}\Omega$
I_{LK_SW}	Switch Pin Leakage Current	$V_{OUT} = 1.8\text{V}$			1	μA
R_{PD_FB}	Pull-down Resistor from FB_Bx pin to GND	Only active when converter disabled.	40	70	100	Ω
K_{RAMP}	Slew Rate Control	DEFSEL from 0 to 1		10		$\text{mV}/\mu\text{s}$
T_{START}	Startup Time	Time from first EN_Bx high to start of switching		420		μs
K_{START}	Soft-Start VOUT Slew Rate			18		$\text{mV}/\mu\text{s}$
VOLTAGE MONITORING						
V_{PG}	Power Good Threshold Voltage	Power good threshold for voltage rising	93.5	96	98	%
		Power good threshold for voltage falling	91	93	95	%
V_{OVP}	Input Over-voltage Protection Trigger Point	Voltage monitored on AVDD Pin, voltage rising	5.5	5.7	5.9	V
		Hysteresis		80		mV
V_{UVLO}	Input Under-voltage Lockout (UVLO) turn-on threshold.	Voltage monitored on AVDD Pin, voltage falling		4.35		V
		Hysteresis		80		mV

(1) All voltage values are with respect to network ground terminal.

(2) Min and Max limits are specified by design, test, or statistical analysis. Typical (Typ) numbers are not verified, but do represent the most likely norm. Unless otherwise specified, conditions for Typ specifications are: $V_{IN} = 5.0\text{ V}$ and $T_J = 25^\circ\text{C}$.

ELECTRICAL CHARACTERISTICS⁽¹⁾⁽²⁾ (continued)

Typical values and limits appearing in normal type apply for $T_A = 25^\circ\text{C}$. Unless otherwise noted, $V_{IN} = 5.0\text{ V}$. Limits appearing in **boldface** type apply over junction temperature range, $T_J = -40^\circ\text{C}$ to 125°C .

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
THERMAL SHUTDOWN AND MONITORING						
TSD	Thermal Shutdown	Threshold, Temperature rising		150		$^\circ\text{C}$
		Hysteresis		20		

SYSTEM CHARACTERISTICS⁽¹⁾⁽²⁾⁽³⁾

Typical values and limits appearing in normal type apply for $T_A = 25^\circ\text{C}$. Unless otherwise noted, $V_{IN} = 5.0\text{ V}$. Limits appearing in **boldface** type apply over junction temperature range, $T_J = -40^\circ\text{C}$ to 125°C .

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
ΔV_{OUT}	Load Transient Response	I_{OUT} 10% max load $\rightarrow$ 90% max load, $1\mu\text{s}$ load step		70		mV
		I_{OUT} 90% max load $\rightarrow$ 10% max load, $1\mu\text{s}$ load step		70		mV
	Line Transient Response	V_{IN_BX} stepping $4.5\text{V} \leftrightarrow 5.5\text{V}$ $t_r = t_f = 10\mu\text{s}$, $I_{OUT} = 400\text{ mA}$		20		mV
V_{RIPPLE}	Output voltage ripple	C_{OUT} ESR = $10\text{ m}\Omega$, $I_{OUT} = 200\text{ mA}$		10		mV _{PP}
η	Efficiency	$V_{OUT} = 3.3\text{V}$, $I_{OUT} = 300\text{ mA}$		94		%
		$V_{OUT} = 2.65\text{V}$, $I_{OUT} = 300\text{ mA}$		92		
		$V_{OUT} = 1.8\text{V}$, $I_{OUT} = 300\text{ mA}$		89		
		$V_{OUT} = 1.2\text{V}$, $I_{OUT} = 300\text{ mA}$		85		

- (1) All voltage values are with respect to network ground terminal.
- (2) Min and Max limits are specified by design, test, or statistical analysis. Typical (Typ) numbers are not verified, but do represent the most likely norm. Unless otherwise specified, conditions for Typ specifications are: $V_{IN} = 5.0\text{ V}$ and $T_J = 25^\circ\text{C}$.
- (3) System Characteristics are highly dependent on external components and pcb layout. System Characteristics are verified using inductor type: TOKO MDT2520-CN1R5M, input and output capacitor type: MuRata GRM21BR71A106KE51L.

PIN ASSIGNMENTS

TOP VIEW

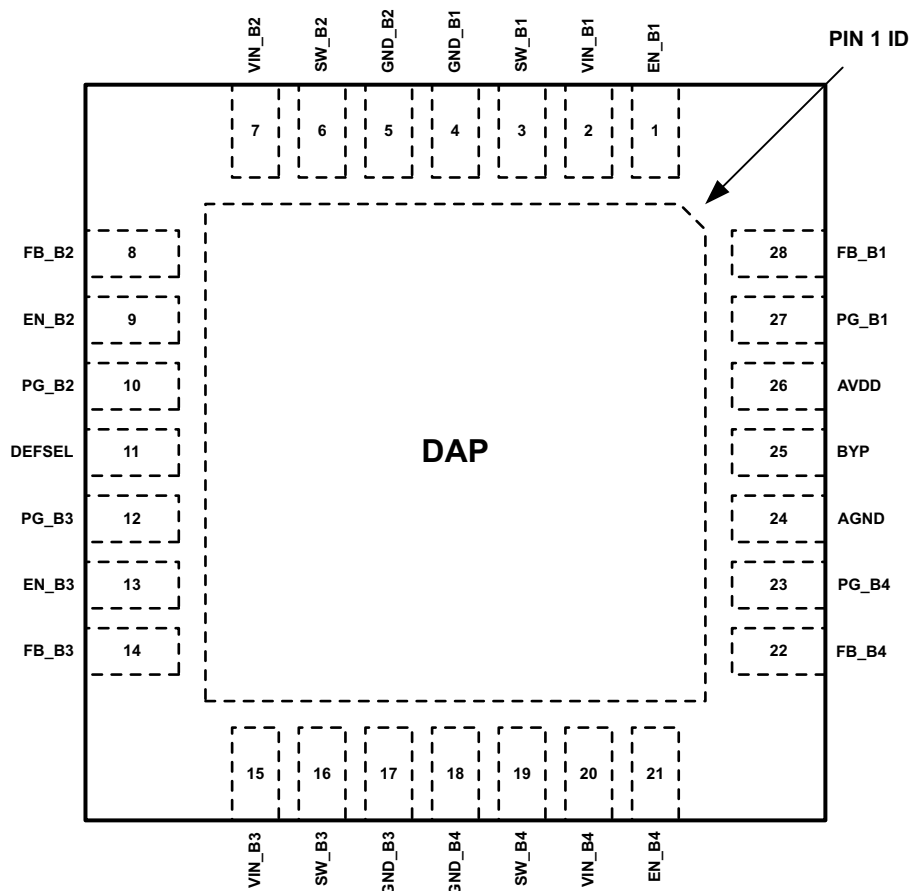
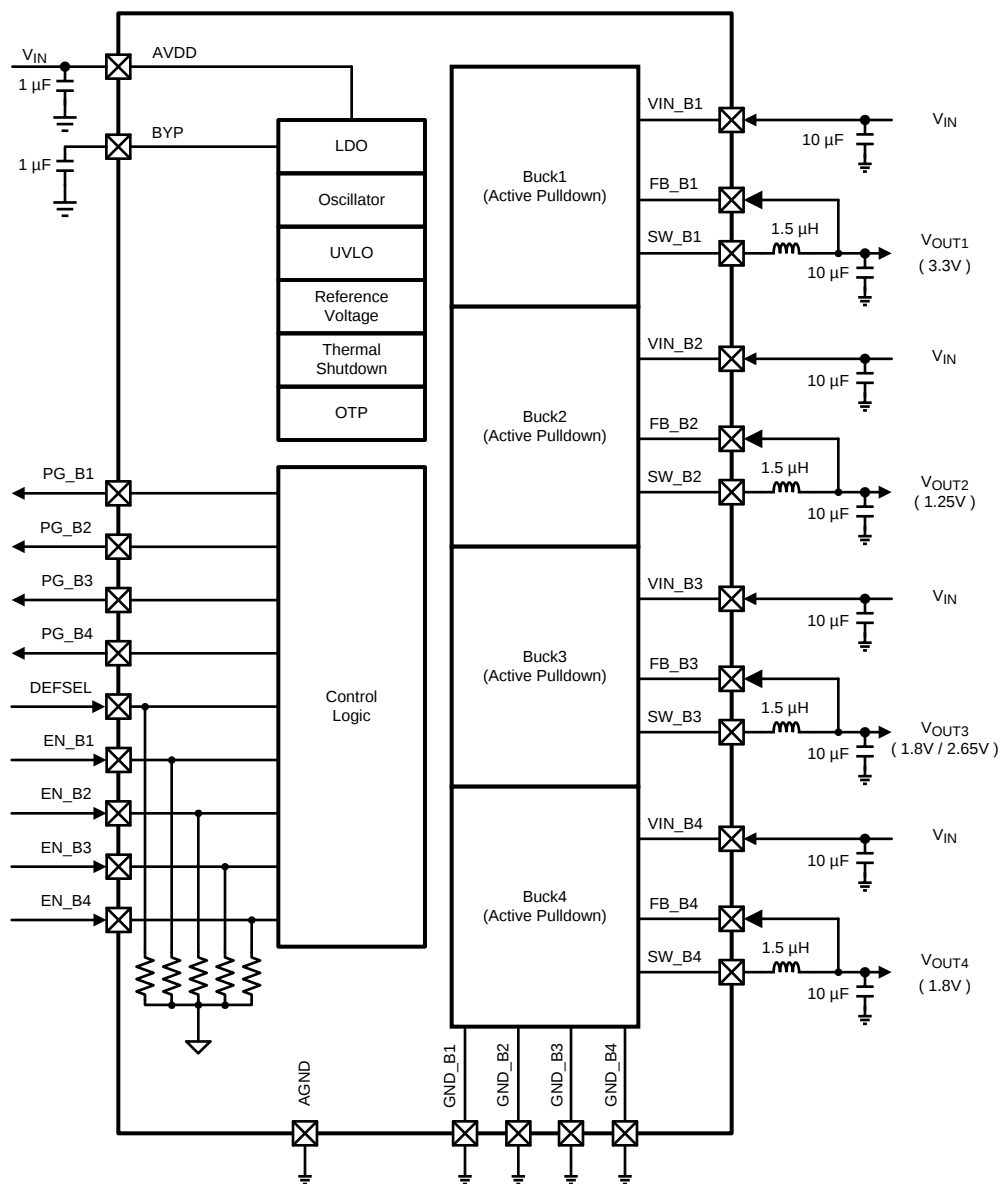


Figure 1. Connection Diagram

Table 1. PIN DESCRIPTIONS

PIN #	PIN NAME	TYPE	DESCRIPTION
1	EN_B1	D/I	Enable buck 1
2	VIN_B1	P	Positive power supply input for Buck 1
3	SW_B1	P	Switch node for Buck 1
4	GND_B1	G	Power ground for Buck 1
5	GND_B2	G	Power ground for Buck 2
6	SW_B2	P	Switch node for Buck 2
7	VIN_B2	P	Positive power supply input for Buck 2
8	FB_B2	A	Feedback pin for Buck 2. Referenced against AGND.
9	EN_B2	D/I	Enable Buck 2
10	PG_B2	D/O	Open-drain Power Good output for Buck 2
11	DEFSEL	D/I	Buck 3 output voltage selection pin
12	PG_B3	D/O	Open-drain Power Good output for Buck 3
13	EN_B3	D/I	Enable buck 3
14	FB_B3	A	Feedback pin for Buck 3. Referenced against AGND.
15	VIN_B3	P	Positive power supply input for Buck 3
16	SW_B3	P	Switch node for Buck 3
17	GND_B3	G	Power ground for Buck 3
18	GND_B4	G	Power ground for Buck 4
19	SW_B4	P	Switch node for Buck 4
20	VIN_B4	P	Positive power supply input for Buck 4
21	EN_B4	D/I	Enable Buck 4
22	FB_B4	A	Feedback pin for Buck 4. Referenced against AGND.
23	PG_B4	D/O	Open-drain Power Good output for Buck 4
24	AGND	G	Analog ground
25	BYP	A	Internal 1.8V supply voltage capacitor pin. A ceramic low ESR 1.0 μ F capacitor should be connected from this pin to AGND. The BYP voltage is generated internally, do not supply or load this pin externally.
26	AVDD	P	Analog positive power supply pin (VIN level)
27	PG_B1	D/O	Open-drain Power Good output for Buck 1
28	FB_B1	A	Feedback pin for Buck 1. Referenced against AGND.
DAP	Die Attachment Pad		Exposed die attachment pad should to be connected to GND plane with thermal vias to improve the thermal performance of the system.

FUNCTIONAL BLOCK DIAGRAM



TYPICAL CHARACTERISTICS

Unless otherwise noted, $V_{IN} = 5.0V$, $T_A = +25^\circ C$

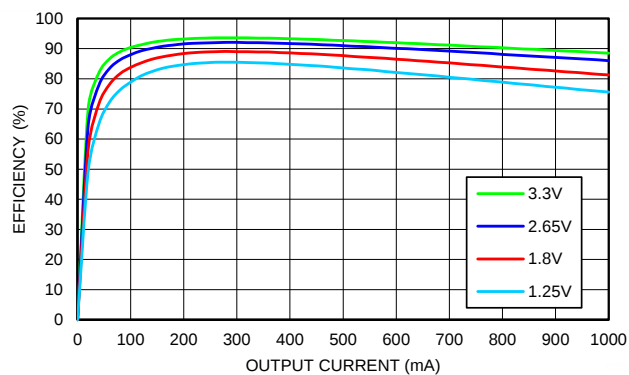


Figure 2. EFFICIENCY vs OUTPUT CURRENT

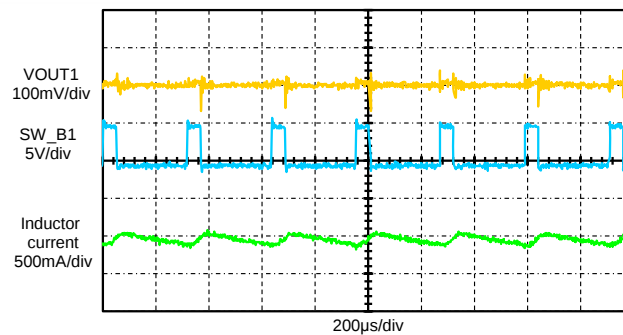


Figure 3. SHORT-CIRCUIT WAVEFORMS

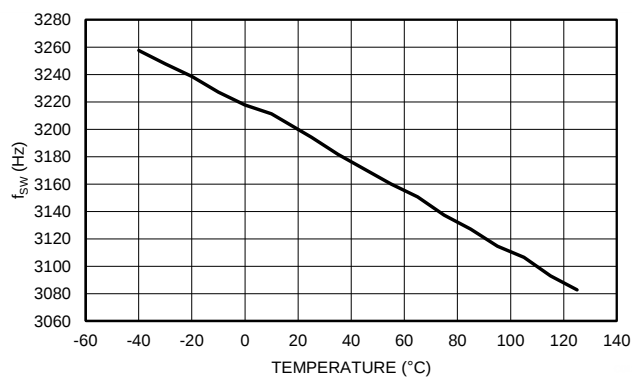


Figure 4. SWITCHING FREQUENCY vs TEMPERATURE

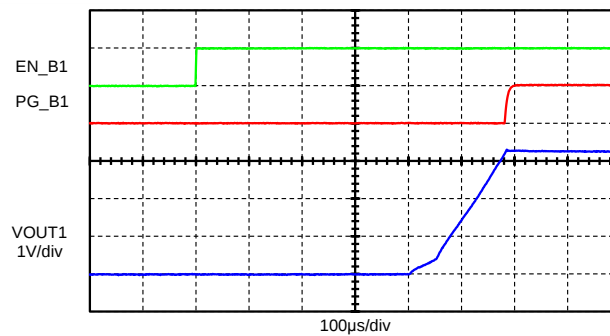


Figure 5. STARTUP DELAY

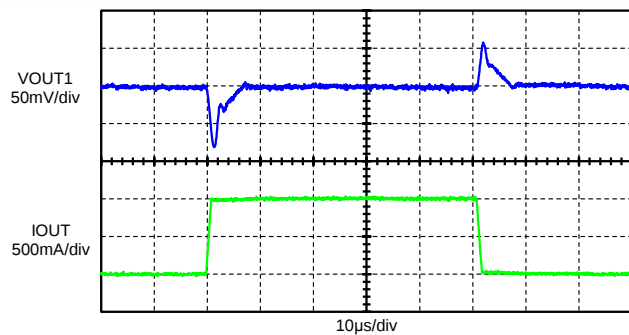


Figure 6. LOAD TRANSIENT RESPONSE,
 I_{OUT} from 0mA to 1A

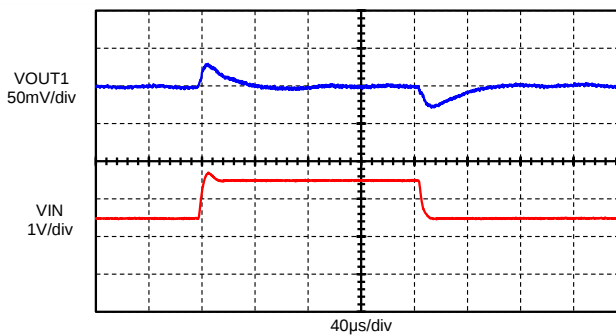


Figure 7. LINE TRANSIENT RESPONSE,
 V_{IN} from 4.5V to 5.5V

TYPICAL CHARACTERISTICS (continued)

Unless otherwise noted, $V_{IN} = 5.0V$, $T_A = +25^\circ C$

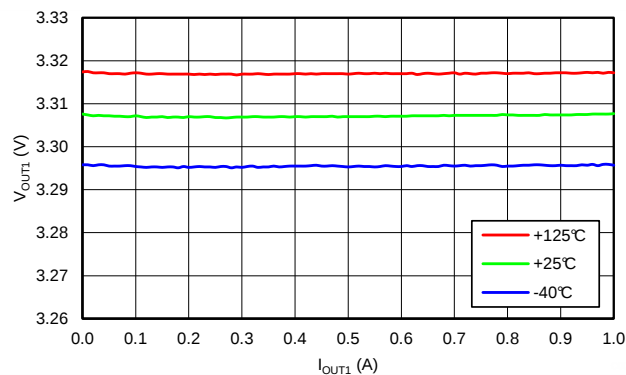


Figure 8. BUCK1 LOAD REGULATION

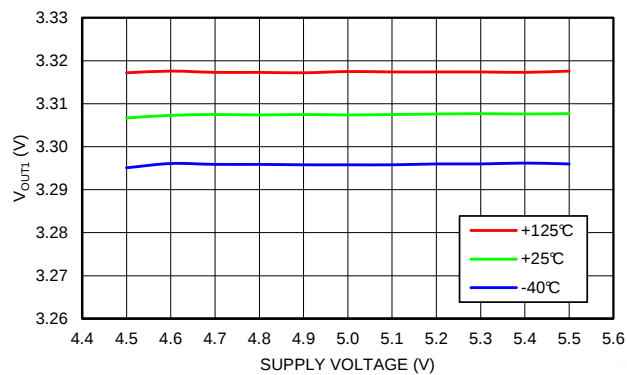


Figure 9. BUCK1 LINE REGULATION

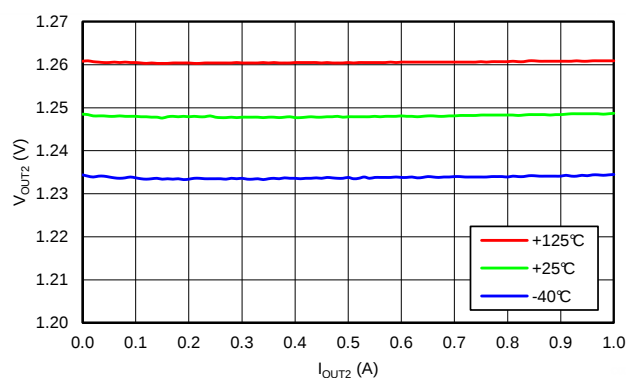


Figure 10. BUCK2 LOAD REGULATION

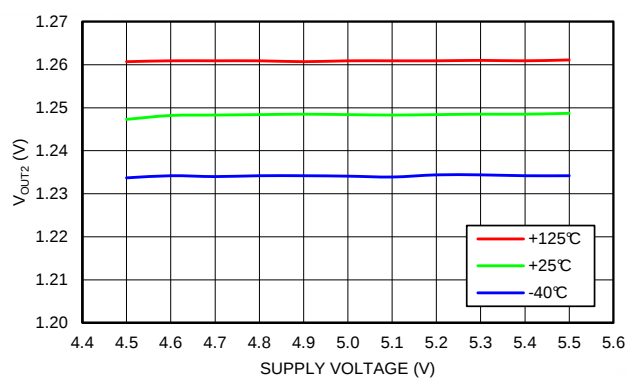


Figure 11. BUCK2 LINE REGULATION

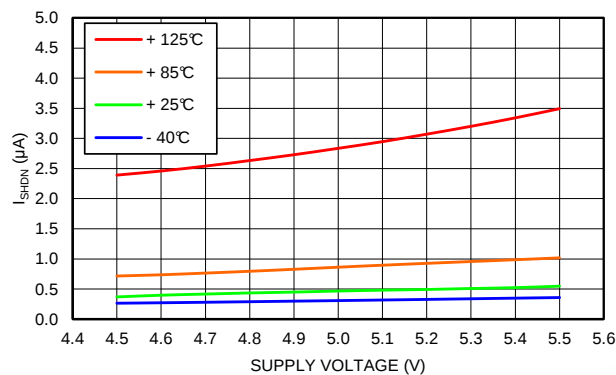
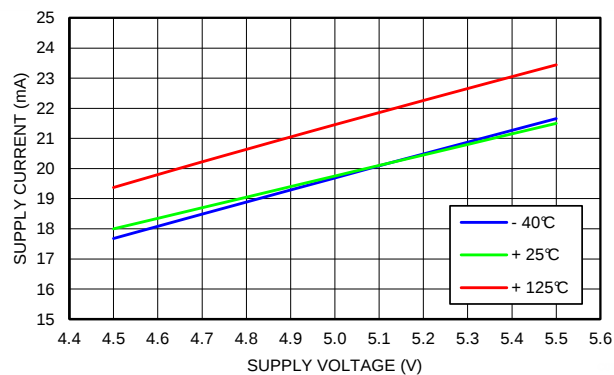


Figure 12. SHUTDOWN CURRENT CONSUMPTION



**Figure 13. ACTIVE MODE CURRENT CONSUMPTION
(ALL BUCKS ACTIVE)**

TYPICAL CHARACTERISTICS (continued)

Unless otherwise noted, $V_{IN} = 5.0V$, $T_A = +25^\circ C$

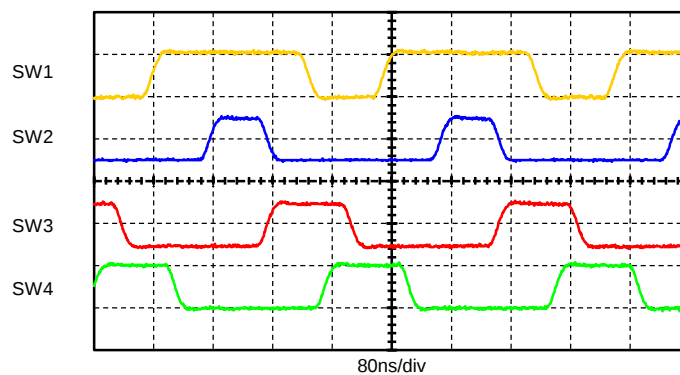


Figure 14. SWITCH TURN ON PHASE SHIFTING

OPERATION DESCRIPTION

The LP8728 has four integrated high-efficiency buck converters. Each buck converter has individual enable input and power good output pins. When the first enable pin is pulled high there is a 420- μ s startup delay when the device wakes up from shutdown mode and all internal reference blocks are started up. Once reference blocks have settled, the corresponding buck converter turns on. Buck cores utilize the soft-start feature to limit the inrush current during startup. Once a buck output reaches 96% (typ.) of the desired output voltage, the power-good pin is pulled high (see Figure 15). When at least one buck core is active, the remaining buck converters will start up without any startup delay.

If the output voltage drops below 93% (typ.) of desired voltage due to, for example, an overload condition, the corresponding power-good pin is pulled low. The power-good signal is always held low for at least 50 ms. When the enable pin is pulled low, the corresponding buck converter's power good signals are set low, and the buck converter is instantly shut down. An output capacitor is then discharged through an internal 70 Ω (typ.) pull-down resistor. The pull-down resistor is connected between buck feedback pin and ground and is only active when the enable pin is set low. When all enable signals are pulled low, the LP8728-Q1 enters a low-current shutdown mode.

Buck Information

The buck converters are operated in forced PWM mode. Even with light load a minimum switching pulse is generated with every switching cycle. Each buck converter's high-side switch turn-on time is phase shifted to minimize the input current ripple (see Figure 14).

Features

The following features are supported for all converters:

- Synchronous rectification
- Current mode feedback loop with PI compensator
- Forced PWM operation
- Soft start
- Power-good output
- Over-voltage comparator

In addition to the aforementioned features, buck3 output voltage can be selected with the DEFSEL pin. If the DEFSEL pin is pulled low, V_{OUT3} is set to 1.8 V. If DEFSEL is pulled high, V_{OUT3} is set to 2.65V.

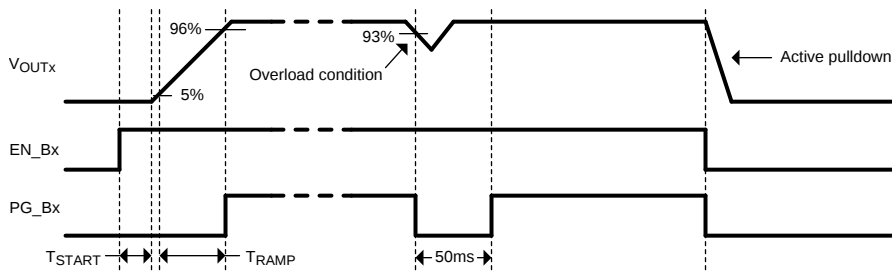


Figure 15. Buck Converter Startup and Shutdown

Thermal Shutdown (TSD)

Thermal shutdown function shuts down all buck regulators if the device's junction temperature T_J rises above 150°C (typ.). All power-good signals are pulled low 5 ms before buck regulators are shut down. Once T_J falls below 130°C (typ.), the LP8728 will automatically start up the buck regulators. There is a 2-second safety delay included in the restart function. Buck regulators are not restarted until 2 seconds have elapsed after T_J falls below 130°C (typ.). To minimize the inrush current during restarting, regulators are started in a buck1 → buck2 → buck3 → buck4 sequence. A 500- μ s delay is included between each buck startup.

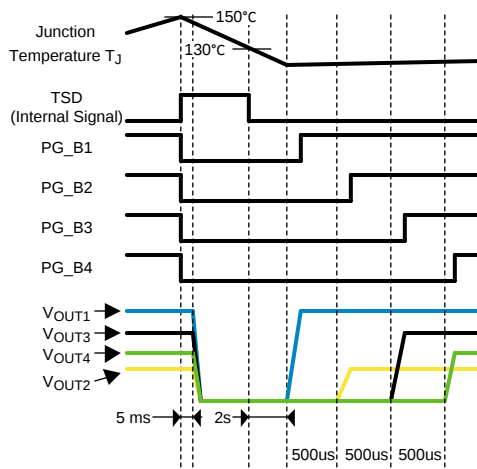


Figure 16. TSD Timing Diagram

Under-Voltage Lockout (UVLO)

Under-voltage lockout pulls the PG_Bx pins low if the input voltage drops below 4.35V (typ.) (Figure 17). PG_Bx pins are always held low for at least 50 ms. Once an under-voltage condition has lasted for 5 ms, all buck converters are shut down. Buck converters are restarted once the input voltage rises above UVLO level.

If an under-voltage condition has lasted more than 5 ms, but less than 50 ms, PG_Bx pins are released high once 50 ms has elapsed and corresponding output voltage has settled. If an over-voltage condition has lasted more than 50 ms, power-good signals are released high once corresponding output voltage has settled. If an under-voltage condition lasts less than 5 ms, the buck converters are not shut down. Even in this case PG_Bx pins are held low for 50 ms.

Regulators are always restarted in a buck1 → buck2 → buck3 → buck4 sequence. A 500-μs delay is included between each buck startup.

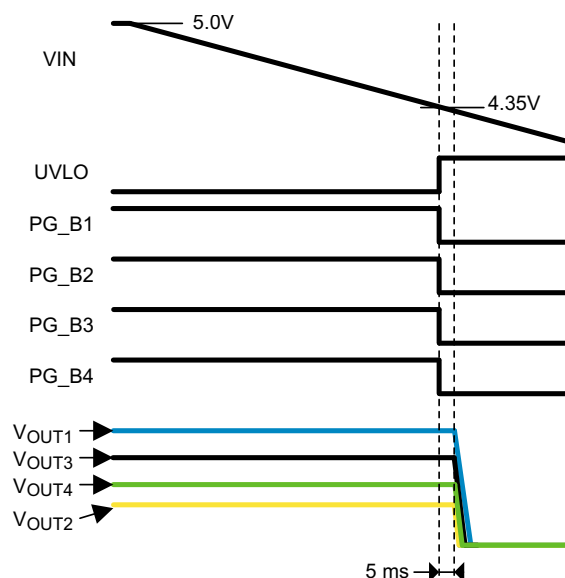


Figure 17. UVLO Operation

Over-Voltage Protection (OVP)

Over-voltage protection protects the device in case of an over-voltage condition. If input voltage exceeds 5.7V (typ.), all PG_Bx pins are pulled low. PG_Bx pins are always held low for at least 50 ms. Once the PG_Bx pins are pulled low, the system has 5 ms time to power down. After over-voltage condition has lasted for 5 ms, all buck converters are shut down. Buck converters are restarted once input voltage falls below 5.62V (typ). Regulators are started in a buck1 → buck2 → buck3 → buck4 sequence. A 500-μs delay is included between each buck startup.

If an over-voltage condition lasted more than 5 ms, but less than 50 ms, the PG_Bx pins are released high once 50 ms has elapsed and corresponding output voltage has settled (Figure 18).

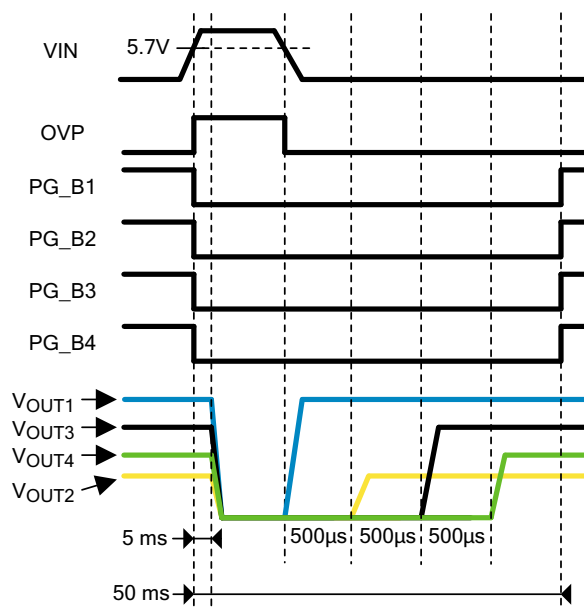
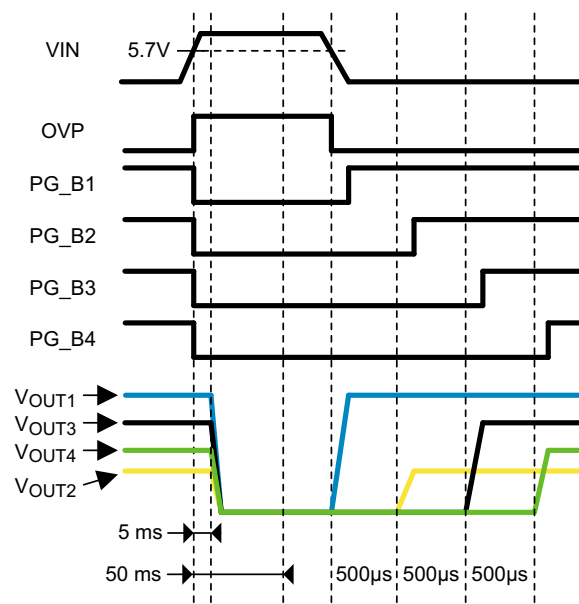


Figure 18. OVP Duration less than 50 ms

If an over-voltage condition has lasted more than 50 ms, power-good signals are released high once corresponding output voltage has settled. Regulators are started in a buck1 → buck2 → buck3 → buck4 sequence. A 500-μs delay is included between each buck startup (Figure 19). If an over-voltage condition has lasted less than 5 ms, buck converters are not shut down. Even in this case the PG_Bx pins are held low for 50 ms. Note: Since regulators are allowed to operate for 5 ms during over-voltage condition it is the system designer's responsibility to verify that input voltage doesn't exceed limits stated in the [ABSOLUTE MAXIMUM RATINGS](#)⁽¹⁾⁽²⁾ table. Exceeding these limits may cause permanent damage to the device.

(1) Stresses beyond those listed under *absolute maximum ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *recommended operating conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

(2) All voltage values are with respect to network ground terminal.

**Figure 19. OVP Duration more than 50 ms**

APPLICATION INFORMATION

Inductor

The four converters operate with 1.5 μH inductors. The selected inductor has to be rated for its dc resistance and saturation current. The dc resistance of the inductor directly influences the efficiency of the converter. Therefore, an inductor with the lowest dc resistance should be selected for the highest efficiency. The inductor should have a saturation current rating equal or higher than the high-side switch current limit (1500 mA) to minimize radiated noise use shielded inductor. The inductor should be connected to the SW pin as close to the IC as possible.

Input and Output Capacitors

Because buck converters have a discontinuous input current, a low ESR input capacitor is required for best input-voltage filtering and minimizing interference with other circuits caused by high input voltage spikes. Each dcdc converter requires a 10- μF ceramic input capacitor on its input pin VIN_Bx. The input capacitor can be increased without any limit for better input voltage filtering. A small 100-nF capacitor can be used in parallel to minimize high-frequency interferences. Input capacitors should be placed as close to VIN_Bx pins as possible. Routing from input capacitor to VIN_Bx pins should be done on top layer without using any vias.

An output capacitor with a typical value of 10 μF is recommended for each converter. Ceramic capacitors with low ESR value have lowest output voltage ripple and are recommended.

Some ceramic capacitors, especially those in small packages, exhibit a strong capacitance reduction with the increased applied DC voltage (DC bias effect). The capacitance value can fall below half of the nominal capacitance. This needs to be taken into consideration and, if necessary, use a capacitor with higher value or higher voltage rating.

Table 2. Recommended External Components

Component	Description	Value	Type	Example
C _{IN_B1,2,3,4}	Buck regulator input capacitor	10 μF	Ceramic, 10V, X7R	MuRata, GRM21BR71A106KE51L
C _{OUT_B1,2,3,4}	Buck regulator output capacitor	10 μF	Ceramic, 10V, X7R	MuRata, GRM21BR71A106KE51L
C _{AVDD}	AVDD pin input capacitor	1 μF	Ceramic, 10V, X7R	MuRata, GRM188R71A105KA61D
C _{BYP}	Internal LDO bypass capacitor	1 μF	Ceramic, 10V, X7R	MuRata, GRM188R71A105KA61D
L _{SW1,2,3,4}	Buck regulator inductor	1.5 μH	ISAT>1.5A, DCR<100m Ω	TOKO MDT2520-CN1R5M

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
LP8728QSQE-A/NOPB	ACTIVE	WQFN	RSG	28	250	Green (RoHS & no Sb/Br)	SN	Level-1-260C-UNLIM	-40 to 125	8728Q-A	Samples
LP8728QSQX-A/NOPB	ACTIVE	WQFN	RSG	28	4500	Green (RoHS & no Sb/Br)	SN	Level-1-260C-UNLIM	-40 to 125	8728Q-A	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) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

TBD: The Pb-Free/Green conversion plan has not been defined.

Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

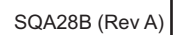
(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(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.

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