MPQ4324

36V, 0.5A to 4A Peak, Ultra-Compact, Low-I_Q, Synchronous Step-Down Converter, AEC-Q100 Qualified

DESCRIPTION

The MPQ4324 is a family of configurable-frequency (350kHz to 2.5MHz) converters. The MPQ4324 is a synchronous, step-down switching regulator with integrated internal high-side and low-side power MOSFETs (HS-FETs and LS-FETs, respectively). The family provides 0.5A to 3A of continuous output current (I_{OUT}) and 4A of highly efficient peak I_{OUT} with peak current mode control.

The wide 3.3V to 36V input voltage (V_{IN}) range and 42V load dump tolerance accommodate a variety of step-down applications in automotive input environments. A 1μA shutdown mode quiescent current (I_Q) allows the device to be used in battery-powered applications.

High power conversion efficiency across a wide load range is achieved by scaling down the switching frequency (f_{SW}) under light-load conditions to reduce the switching and gate driving losses.

An open-drain power good (PG) signal indicates whether the output is within 94.5% to 105.5% of its nominal voltage.

Frequency foldback helps prevent inductor current runaway during start-up. Thermal shutdown provides reliable, fault-tolerant operation.

A high duty cycle and low-dropout mode are provided for automotive cold-crank conditions.

The MPQ4324 is available in QFN-12 (2mmx3mm), QFN-12 (3mmx4mm), and QFN-14 (2.5mmx3.5mm) packages. It is available in AEC-Q100 Grade 1.

FEATURES

- Designed for Automotive Applications
  - Survives 42V Load Dump
  - Continuous Operation Up to 36V
  - Supports Cold Crank Down to 3.1V
  - Low-Dropout (LDO) Mode with Soft Recovery
  - 0.5A to 3A Continuous and 4A Peak Output Current (I_{OUT}) Version in Pin-Compatible Family
  - 65ns Minimum On Time and 50ns Minimum Off Time
  - Available in AEC-Q100 Grade 1
- Increases Battery Life
  - 1μA Shutdown Supply Current
  - 20μA Sleep Mode Quiescent Current (I_Q)
  - Advanced Asynchronous Modulation (AAM) Mode Increases Efficiency under Light Loads
  - Integrated 70mΩ High-Side MOSFET (HS-FET) and 50mΩ Low-Side MOSFET (LS-FET)
- Optimized for EMC/EMI
  - CISPR 25 Class 5 Compliant
  - Configurable 350kHz to 2.5MHz Switching Frequency (f_{SW})
  - Frequency Spread Spectrum (FSS) Modulation
  - Symmetric VIN Pinout
  - MeshConnect™ Flip-Chip Package
- Available Packages with Wettable Flanks
  - QFN-12 (2mmx3mm)
  - QFN-12 (3mmx4mm)
  - QFN-14 (2.5mmx3.5mm)
- Additional Features
  - Power Good (PG) Output
  - Over-Current Protection (OCP) with Hiccup Mode
  - Fixed Output Voltage (V_{OUT}) Options (1): 1V, 1.8V, 2.5V, 3.0V, 3.3V, 3.8V, 5V

FEATURES *(continued)*

- Functional Safety System Design Capability
  - Documents Available for MPSafe™ QM System Design

APPLICATIONS

- Automotive Infotainment
- Automotive Clusters
- Advanced Driver-Assistance Systems (ADAS)
- Industrial Power Systems

Note:

1) See the Ordering Information section on page 4 for the exact availability of each fixed output version. Additional output voltages may be available. Contact MPS for details.

TYPICAL APPLICATIONS

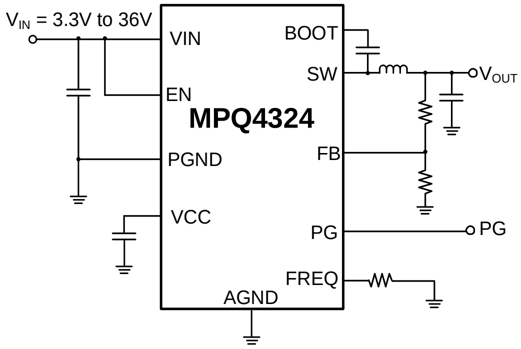
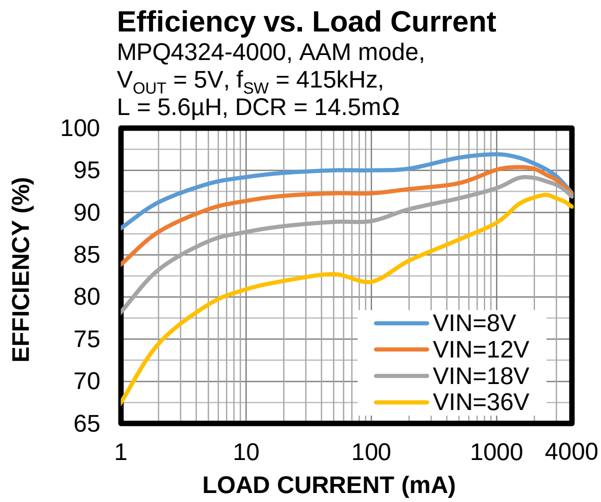


Figure 1: Typical Application (Adjustable Output)



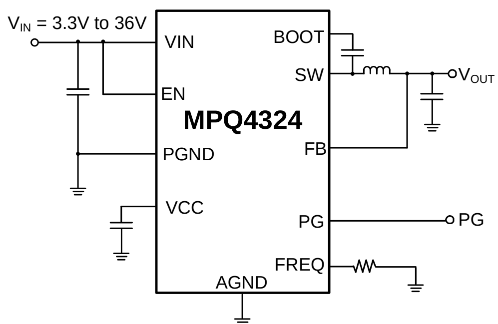
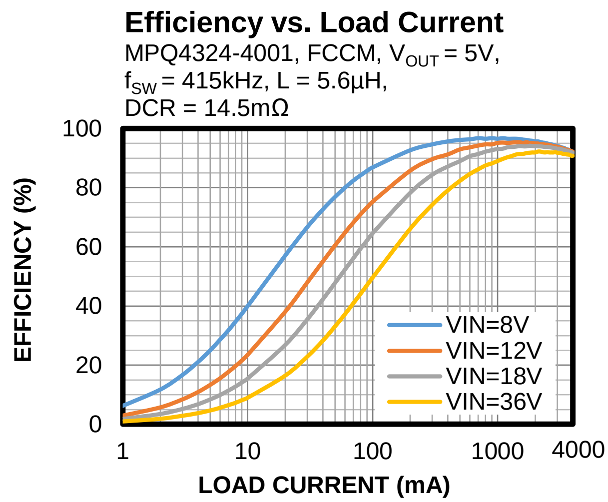


Figure 2: Typical Application (Fixed Output)



ORDERING INFORMATION

Part Number (2) (3)*	Package	Top Marking	MSL Rating**
MPQ4324GDE-xxxx-AEC1 ***	QFN-12 (2mmx3mm)	*See Below*	1
MPQ4324GLE-xxxx-AEC1 ***	QFN-12 (3mmx4mm)	*See Below*	1
MPQ4324GRHE-xxxx-AEC1 ***	QFN-14 (2.5mmx3.5mm)	*See Below*	1

* For Tape & Reel, add suffix -Z (e.g. MPQ4324GDE-xxxx-AEC1-Z).

**Moisture Sensitivity Level Rating

***Wettable flank

Notes:

2) Part numbers following the Table 1 naming rule, but not included in the Ordering Information section, may also be available. Contact MPS for details.
3) The part number can be marked as MPQ4324-XXYZ. Table 1 shows the naming rules.

Table 1: Part Number Digit Code Naming Rule

Digit Code	Naming Rule
XX: Defines the supported load current	05: 0.5A
	10: 1A
	15: 1.5A
	20: 2A
	30: 3A
	40: 4A (4A peak, 3A continuous)
Y: Defines the output voltage	0: Adjustable output
	1: 1V fixed output
	2: 2.5V fixed output
	3: 3.3V fixed output
	4: 3.8V fixed output
	5: 5V fixed output
	B: 1.8V fixed output
	C: 3V fixed output
Z: Defines the control Mode	0: AAM mode with FSS
	1: FCCM with FSS
	2: AAM mode without FSS
	3: FCCM without FSS
	4: AAM mode with FSS, low-dropout with soft recovery
	5: FCCM with FSS, low-dropout with soft recovery
	6: AAM mode without FSS, low-dropout with soft recovery
	7: FCCM without FSS, low-dropout with soft recovery

TOP MARKING (MPQ4324GDE-xxxx-AEC1)

BRL
YWW
LLLL

BRL: Product code
Y: Year code
WW: Week code
LLLL: Lot number

TOP MARKING (MPQ4324GLE-xxxx-AEC1)

MPYW
4324
LLL
E

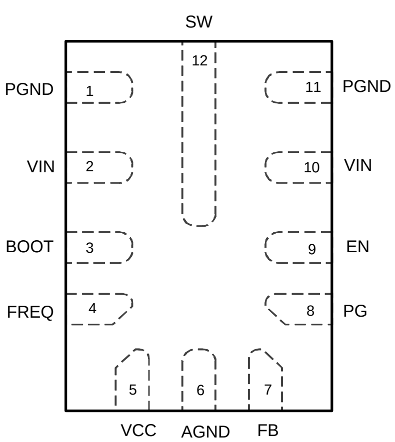
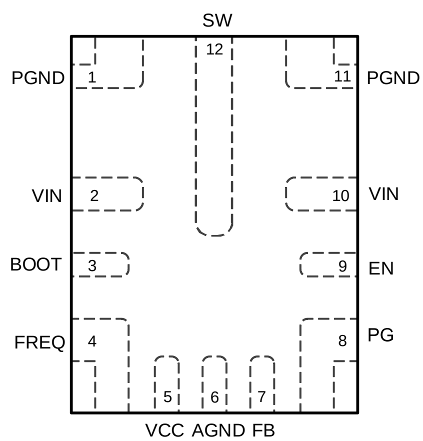
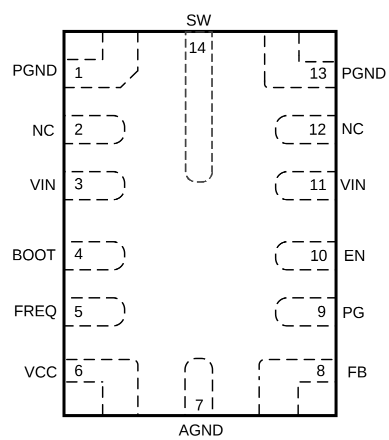
MP: MPS prefix
Y: Year code
W: Week code
4324: Part number
LLL: Lot number
E: Wettable flank

TOP MARKING (MPQ4324GRHE-xxxx-AEC1)

CCL
YWW
LLL

CCL: Product code
Y: Year code
WW: Week code
LLL: Lot number

PACKAGE REFERENCE

TOP VIEW	TOP VIEW	TOP VIEW
		
QFN-12 (2mmx3mm)	**QFN-12 (3mmx4mm)**	**QFN-14 (2.5mmx3.5mm)**

PIN FUNCTIONS

Pin #		Name	Description
QFN-12	QFN-14		
1, 11	1, 13	PGND	**Power ground.** Connect PGND to a large GND plane to ensure good heat dissipation.
2, 10	3, 11	VIN	**Input supply.** The VIN pin supplies power to all the internal control circuitry and the power switch connected to SW. The two VIN pins are connected internally. Connect a decoupling capacitor from each VIN pin to ground, and as close as possible to the VIN pin, to minimize switching spikes and improve EMI performance.
3	4	BOOT	**Bootstrap.** The BOOT pin is the positive power supply for the high-side MOSFET (HS-FET) driver connected to SW. Connect a bypass capacitor between BOOT and SW.
4	5	FREQ	**Switching frequency configuration.** Connect a resistor from the FREQ pin to ground to set the switching frequency (f_{SW}). Table 3 on page 68 shows the detailed relationship between the FREQ resistor and f_{SW}.
5	6	VCC	**Bias supply.** The VCC pin is the output of the internal regulator that supplies power to the internal control circuit and gate drivers. Connect a minimum 1µF decoupling capacitor from VCC to ground, and place it as close as possible to the VCC pin.
6	7	AGND	**Analog ground.** Connect the AGND pin close to the VCC capacitor.
7	8	FB	**Feedback input.** The FB pin is the negative input of the error amplifier. For a fixed output, connect this pin directly to the output voltage. For an adjustable output, connect this pin to the middle point of the external feedback divider, which is between the output and AGND. This sets the output voltage. The FB divider should be close to the FB pin.
8	9	PG	**Power good output.** The output of the PG pin is an open drain. If PG is used, it must be connected to a power source through a pull-up resistor. PG goes high if the output voltage is within 94.5% to 105.5% of the nominal voltage; PG goes low if the output voltage exceeds 107% or is below 93% of the nominal voltage. Float the PG pin if it is not used.
9	10	EN	**Enable.** Pull the EN pin below the specified threshold (about 0.85V) to shut down the chip. Pull EN above the specified threshold (about 1.02V) to enable the chip. The EN pin does not have an internal pull-up or pull-down resistor. Do not float the EN pin.
12	14	SW	**Switch node.** The SW pin is the source of the HS-FET and the drain of the low-side MOSFET (LS-FET).
N/A	2, 12	NC	**Not connected.** The NC pin can be tied to PGND.

ABSOLUTE MAXIMUM RATINGS [4]

VIN, EN……… 42V for automotive load dump [5]
VIN, EN…………………..............-0.3V to +40V
SW……………………… -0.3V to $V_{IN(MAX)}$ + 0.3V
BOOT…………………………........... V_{SW} + 5.5V
FREQ, VCC…………………………………..….5.5V
All other pins…………… ....-0.3V to +6V
Continuous power dissipation (T_A = 25°C) [6]
QFN-12 (2mmx3mm) …………… .... 3.5W [10]
QFN-12 (3mmx4mm) …………… .... 3.6W [11]
QFN-14 (2.5mmx3.5mm)...……………..…3.7W [12]
Operating junction temperature (T_J)..........150°C
Lead temperature……………..................260°C
Storage temperature…………... -65°C to +150°C

ESD Ratings

Human body model (HBM) ……..……..Class 2 [7]
Charged-device model (CDM)........ Class C2b [8]

Recommended Operating Conditions

Supply voltage (V_{IN})…………………3.3V to 36V
Minimum V_{IN} for start-up ……………………3.9V
Minimum V_{IN} after start-up …….……….......3.1V
Output voltage (V_{OUT})…….......0.8V to 0.95 x V_{IN}
Operating junction temp (T_J)….-40°C to +150°C

Thermal Resistance θ_JA θ_JC

	θ_{JA}	θ_{JC}	
QFN-12 (2mmx3mm)			
JESD51-7	60	7.3	°C/W [9]
EVQ4324-D-00A	35.5		°C/W [10]
QFN-12 (3mmx4mm)			
JESD51-7	50	7.5	°C/W [9]
EVQ4324-L-00A	34.3		°C/W [11]
QFN-14 (2.5mmx3.5mm)			
JESD51-7	48.6	7.4	°C/W [9]
EVQ4324-RH-00A	33.6		°C/W [12]

	Ψ_{JT}	
QFN-12 (2mmx3mm)		
JESD51-7	1.1	°C/W [9]
EVQ4324-D-00A	3.5	°C/W [10]
QFN-12 (3mmx4mm)		
JESD51-7	1.2	°C/W [9]
EVQ4324-L-00A	3.7	°C/W [11]
QFN-14 (2.5mmx3.5mm)		
JESD51-7	1.6	°C/W [9]
EVQ4324-RH-00A	3.6	°C/W [12]

Notes:

4) Absolute maximum ratings are rated under room temperature, unless otherwise noted. Exceeding these ratings may damage the device.
5) Refer to ISO16750-2.
6) The maximum allowable power dissipation is a function of the maximum junction temperature, T_J (MAX), the junction-to-ambient thermal resistance, θ_{JA}, and the ambient temperature, T_A. The maximum allowable continuous power dissipation at any ambient temperature is calculated by P_D (MAX) = (T_J (MAX) - T_A) / θ_{JA}. Exceeding the maximum allowable power dissipation can cause excessive die temperature, and the device may go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.
7) Per AEC-Q100-002.
8) Per AEC-Q100-011.
9) Obtained based on a JESD51-7, 4-layer PCB. The values given in this table are only valid for comparison with other packages and cannot be used for design purposes. These values were calculated in accordance with JESD51-7, and simulated on a specified JEDEC board. They do not represent the performance obtained in an actual application. The value of θ_{JC} shows the thermal resistance from the junction-to-case bottom, and the value of Ψ_{JT} shows the characterization parameter from junction-to-case top
10) Measured on MPS's MPQ4324GDE-xxxx-AEC1 standard EVB, 8.3cmx8.3cm, 2oz copper thickness, 4-layer PCB. The value of Ψ_{JT} shows the characterization parameter from junction-to-case top.
11) Measured on MPS's MPQ4324GLE-xxxx-AEC1 standard EVB, 8.3cmx8.3cm, 2oz copper thickness, 4-layer PCB. The value of Ψ_{JT} shows the characterization parameter from junction-to-case top.
12) Measured on MPS's MPQ4324GRHE-xxxx-AEC1 standard EVB, 8.3cmx8.3cm, 2oz copper thickness, 4-layer PCB. The value of Ψ_{JT} shows the characterization parameter from junction-to-case top.

ELECTRICAL CHARACTERISTICS

V_{IN} = 12V, V_{EN} = 2V, T_J = -40°C to +150°C, typical values are at T_J = 25°C, unless otherwise noted.

Parameter	Symbol	Condition	Min	Typ	Max	Units
Input Supply						
Input voltage (V_{IN}) under-voltage lockout (UVLO) rising threshold	V_{INUVLO_RISING}		3.4	3.65	3.9	V
V_{IN} UVLO falling threshold	$V_{INUVLO\_FALLING}$		2.6	2.9	3.1	V
V_{IN} UVLO hysteresis	V_{INUVLO_HYS}			750		mV
VIN quiescent current	I_Q	V_{FB} = 0.85V, AAM mode, no load, T_J = 25°C		20	28	µA
		V_{FB} = 0.85V, AAM mode, no load, T_J = -40°C to +125°C (13)			34	µA
		V_{FB} = 0.85V, AAM mode, no load, T_J = -40°C to +150°C			80	µA
VIN quiescent current (switching) (13)	$I_{Q\_SWITCHING}$	AAM mode, switching, R_{FB1} = 1MΩ, R_{FB2} = 191kΩ, no load		25		µA
VIN active current (switching) (13)	I_{Q_ACTIVE}	FCCM, no load		1200		µA
VIN shutdown current	I_{SHDN}	V_{EN} = 0V		1	10	µA
V_{IN} over-voltage protection (OVP) rising threshold	V_{INOVP_RISING}		35.5	37.5	40	V
V_{IN} OVP falling threshold	$V_{INOVP\_FALLING}$		34.5	36.5	39	V
V_{IN} OVP hysteresis	V_{INOVP_HYS}			1		V
Switches and Frequency						
Switching frequency without frequency spread spectrum (FSS)	f_{SW}	R_{FREQ} = 86.6kΩ	332	415	498	kHz
		R_{FREQ} = 34.8kΩ	900	1000	1100	kHz
		R_{FREQ} = 15kΩ	1980	2200	2420	kHz
FSS span				±10		%
FSS modulation frequency				15		kHz
Minimum on time (13)	t_{ON_MIN}			65	80	ns
Minimum off time (13)	t_{OFF_MIN}			50	70	ns
Maximum duty cycle	D_{MAX}		98	99.5		%
Switch leakage current	I_{SW_LKG}	V_{EN} = 0V, V_{SW} = V_{BOOT} = 0V or V_{IN} (T_J = 25°C)		0.01	1	µA
		V_{EN} = 0V, V_{SW} = V_{BOOT} = 0V or V_{IN} (T_J = -40°C to +150°C)		0.01	5	µA
High-side (HS) switch on resistance	R_{ON_HS}	V_{BOOT} - V_{SW} = 5V		70	130	mΩ
Low-side (LS) switch on resistance	R_{ON_LS}	V_{CC} = 5V		50	90	mΩ

ELECTRICAL CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{EN} = 2V, T_J = -40°C to +150°C, typical values are at T_J = 25°C, unless otherwise noted.

Parameter	Symbol	Condition	Min	Typ	Max	Units
Output and Regulation						
FB voltage (adjustable output version)	V_{FB}	T_J = 25°C	0.794	0.8	0.806	V
		T_J = -40°C to +150°C	0.790	0.8	0.810	V
FB input current	I_{FB}	Adjustable output version		0	100	nA
		Fixed output		3.8		µA
VOUT discharge current	$I_{DISCHARGE}$	V_{EN} = 0V, V_{OUT} = 0.3V	2	4		mA
Output voltage accuracy of 3.3V fixed output version	$V_{OUT\_3.3V}$	T_J = 25°C	3250	3300	3350	mV
		T_J = -40°C to +150°C	3234	3300	3366	mV
Output voltage accuracy of 3.8V fixed output version	$V_{OUT\_3.8V}$	T_J = 25°C	3743	3800	3857	mV
		T_J = -40°C to +150°C	3724	3800	3876	mV
Output voltage accuracy of 5V fixed output version	V_{OUT_5V}	T_J = 25°C	4925	5000	5075	mV
		T_J = -40°C to +150°C	4900	5000	5100	mV
BOOT						
BOOT - SW refresh rising	V_{BOOT_RISING}			2.5	2.9	V
BOOT - SW refresh falling	$V_{BOOT\_FALLING}$			2.3	2.7	V
BOOT - SW refresh hysteresis	V_{BOOT_HYS}			0.2		V
Enable (EN)						
EN rising threshold	V_{EN_RISING}		0.97	1.02	1.07	V
EN falling threshold	$V_{EN\_FALLING}$		0.8	0.85	0.9	V
EN threshold hysteresis	V_{EN_HYS}			170		mV
Soft Start and VCC						
Soft-start time	t_{SS}	EN high to SS finishes	3	5	7	ms
VCC voltage	V_{CC}	I_{VCC} = 0	4.7	5	5.3	V
VCC regulation		I_{VCC} = 30mA		1		%
VCC current Limit	I_{LIMIT_VCC}	V_{CC} = 4V	50	70		mA
Power Good (PG)						
PG rising threshold (adjustable output)	PG_{VTH_RISING}	V_{OUT} rising, V_{FB} / V_{REF}	93	94.5	96	% of V_{REF}
		V_{OUT} falling, V_{FB} / V_{REF}	104	105.5	107	
PG rising threshold (fixed output)	PG_{VTH_RISING}	V_{OUT} rising, V_{FB} / V_{OUT}	93	94.5	96.5	% of V_{OUT}
		V_{OUT} falling, V_{FB} / V_{OUT}	104	105.5	108	
PG falling threshold (adjustable output)	$PG_{VTH\_FALLING}$	V_{OUT} falling, V_{FB} / V_{REF}	91.5	93	94.5	% of V_{REF}
		V_{OUT} rising, V_{FB} / V_{REF}	105.5	107	108.5	
PG falling threshold (fixed output)	$PG_{VTH\_FALLING}$	V_{OUT} rising, V_{FB} / V_{OUT}	91.5	93	95	% of V_{OUT}
		V_{OUT} falling, V_{FB} / V_{OUT}	105.5	107	109.5	
PG threshold hysteresis	PG_{VTH_HYS}	V_{FB} / V_{REF}		1.5		% of V_{REF}
PG output voltage low	V_{PG_LOW}	I_{SINK} = 1mA		0.1	0.3	V
PG rising deglitch time	t_{PG_R}			160		µs
PG falling deglitch time	t_{PG_F}			160		µs

ELECTRICAL CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{EN} = 2V, T_J = -40°C to +150°C, typical values are at T_J = 25°C, unless otherwise noted.

Parameter	Symbol	Condition	Min	Typ	Max	Units
Protections						
HS peak current limit	I_{LIMIT_HS}	Duty cycle = 30%, 0.5A version	0.8	1.35	2	A
		Duty cycle = 30%, 1A version	1.5	2	2.6	A
		Duty cycle = 30%, 1.5A version	2.0	2.6	3.1	A
		Duty cycle = 30%, 2A version	2.7	3.4	4.6	A
		Duty cycle = 30%, 3A version	4.3	5.8	7.3	A
		Duty cycle = 30%, 4A version	4.9	6.5	7.9	A
LS valley current limit	I_{LIMIT_LS}	0.5A version	0.5	1	1.5	A
		1A version	1	1.5	2	A
		1.5A version	1.4	2	2.7	A
		2A version	2	2.7	3.8	A
		3A version	3	4.4	5.7	A
		4A version	3.8	5	6.8	A
Zero-current detection (ZCD) current	I_{ZCD}	AAM mode	-0.1	+0.05	+0.2	A
LS reverse current limit	$I_{LIMIT\_REVERSE}$			2		A
Thermal shutdown (13)	T_{SD}		160	175	185	°C
Thermal shutdown hysteresis (13)	T_{SD_HYS}			20		°C

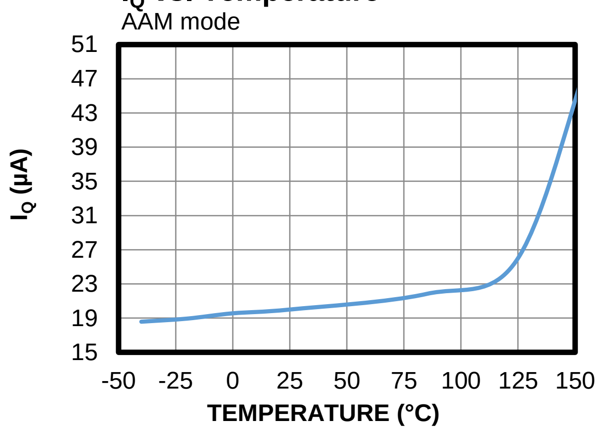
Note:

13) Not tested in production. Guaranteed by design and characterization.

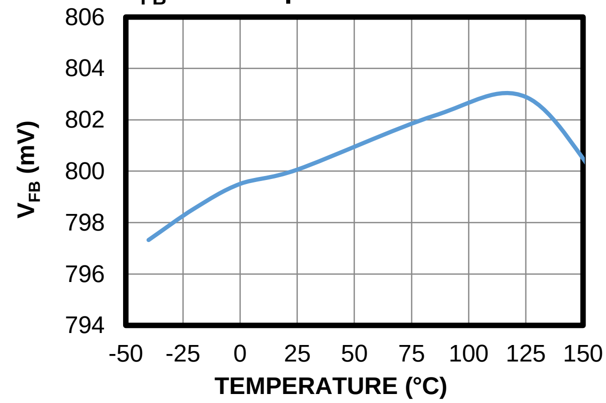
TYPICAL CHARACTERISTICS

V_{IN} = 12V, unless otherwise noted.

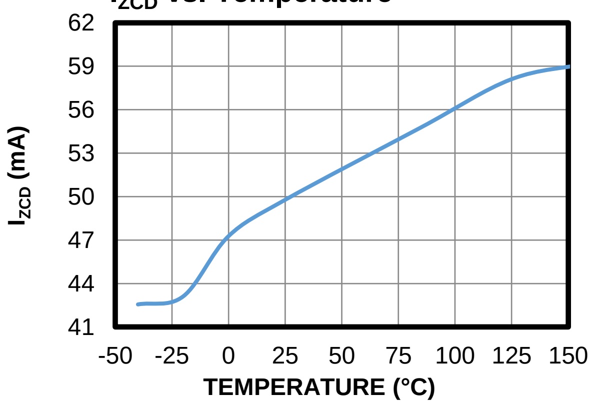
I_Q vs. Temperature



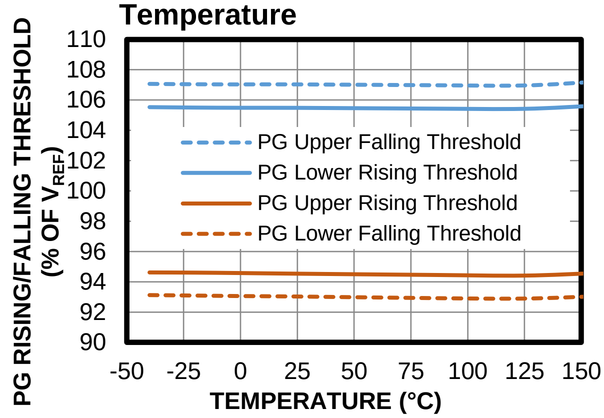
V_{FB} vs. Temperature



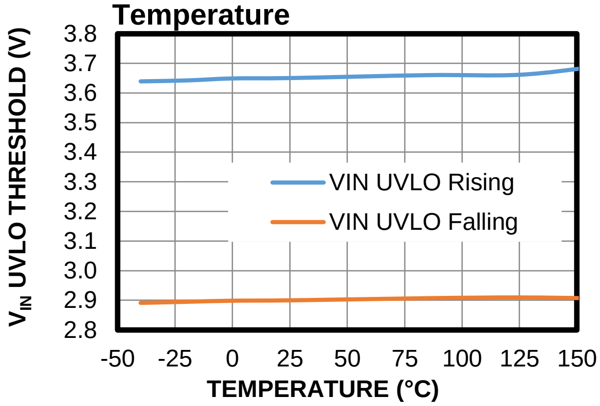
I_{ZCD} vs. Temperature



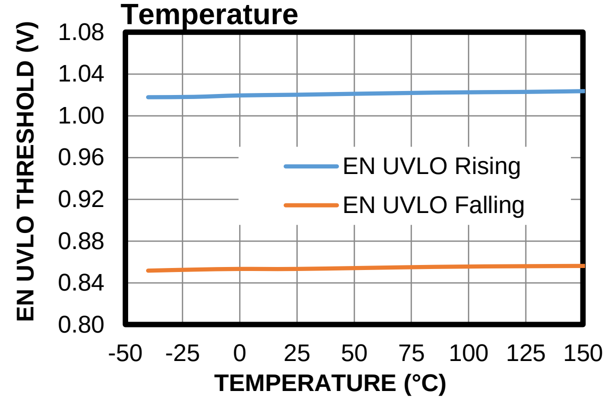
PG Rising/Falling Threshold vs. Temperature



V_{IN} UVLO Threshold vs. Temperature

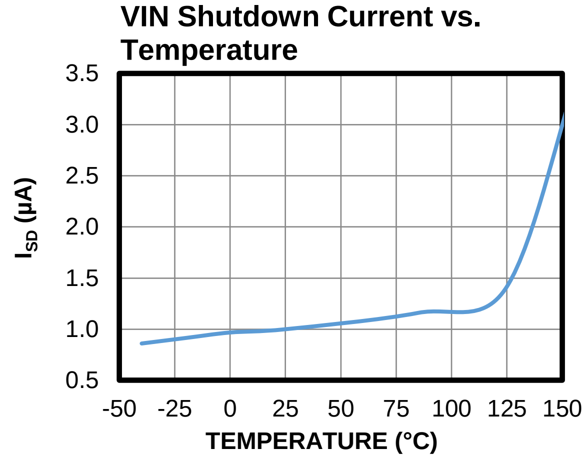


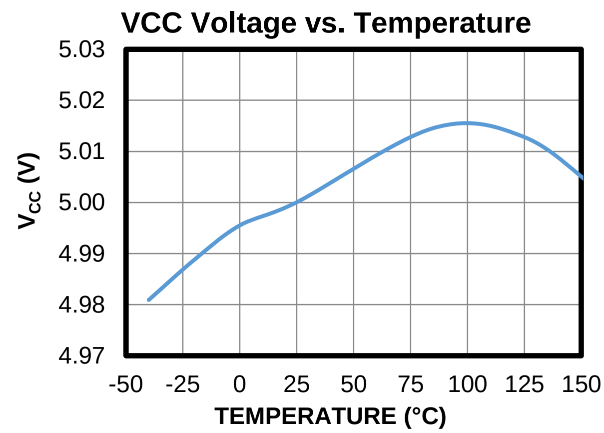
EN UVLO Threshold vs. Temperature

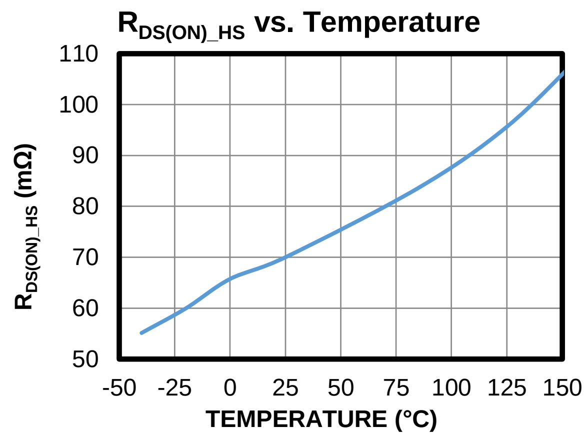


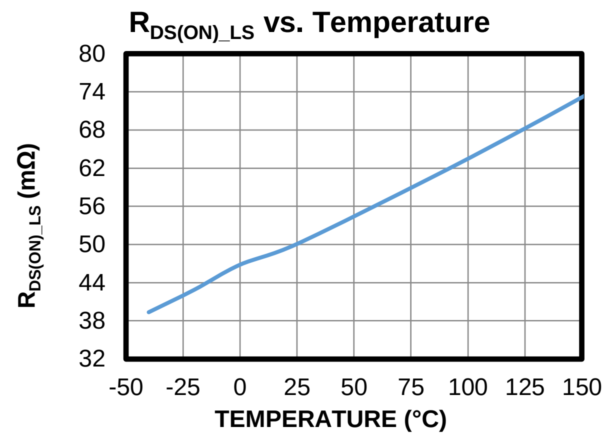
TYPICAL CHARACTERISTICS *(continued)*

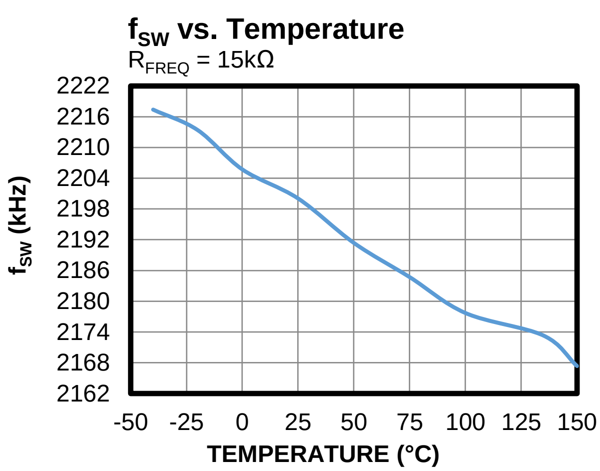
V_{IN} = 12V, unless otherwise noted.

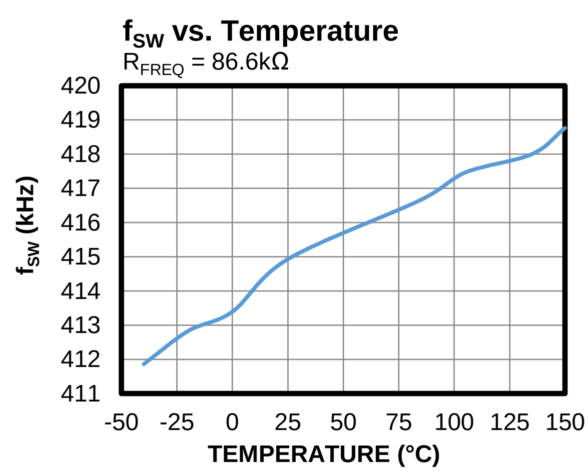








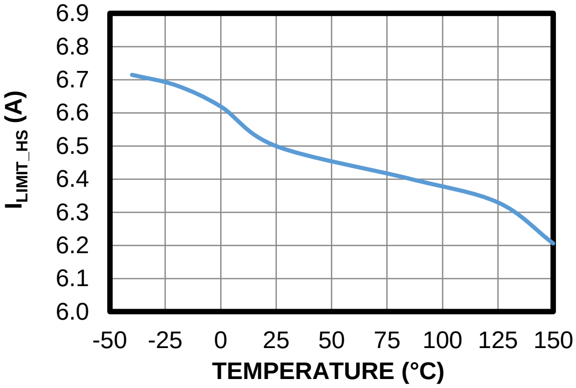




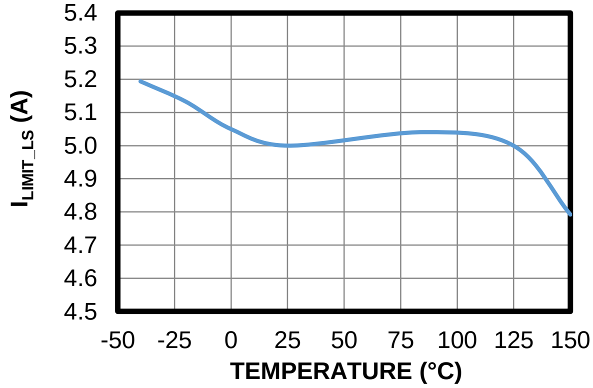
TYPICAL CHARACTERISTICS *(continued)*

V_{IN} = 12V, unless otherwise noted.

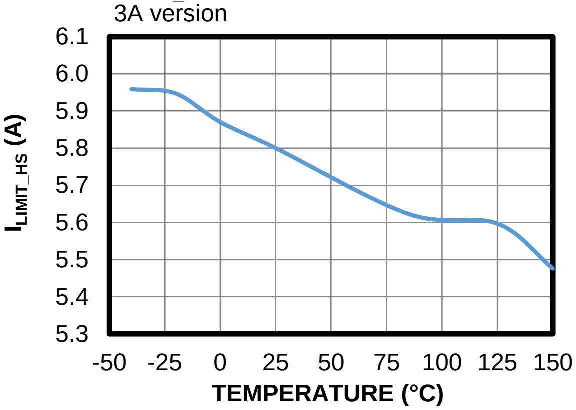
I_{LIMIT_HS} vs. Temperature
4A version



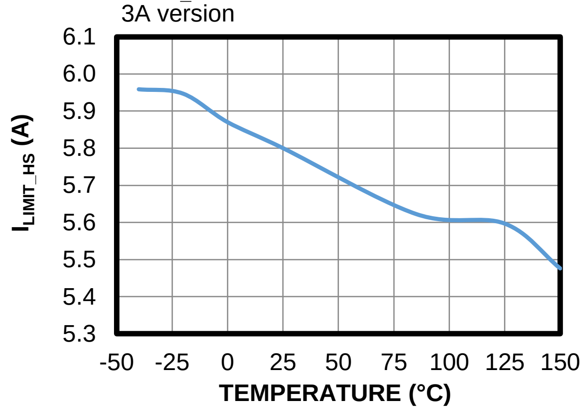
I_{LIMIT_LS} vs. Temperature
4A version



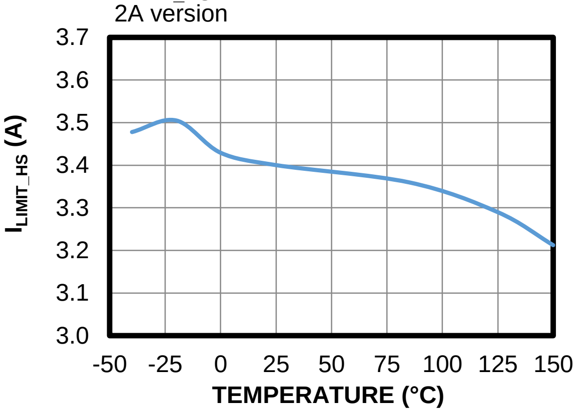
I_{LIMIT_HS} vs. Temperature
3A version



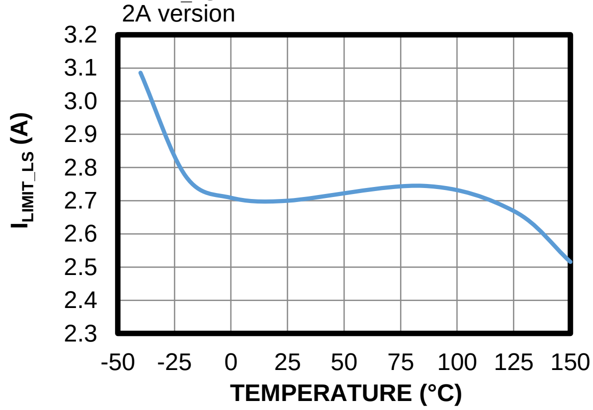
I_{LIMIT_HS} vs. Temperature
3A version



I_{LIMIT_HS} vs. Temperature
2A version

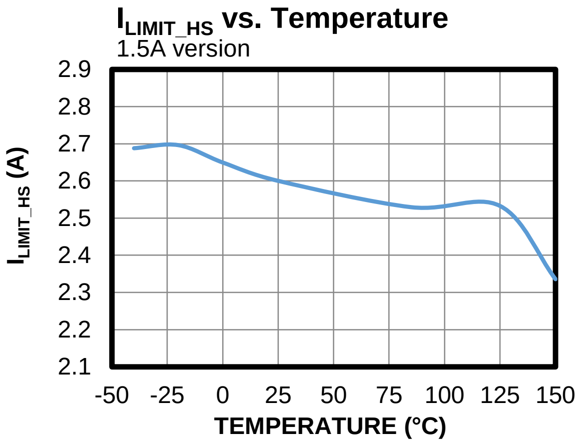


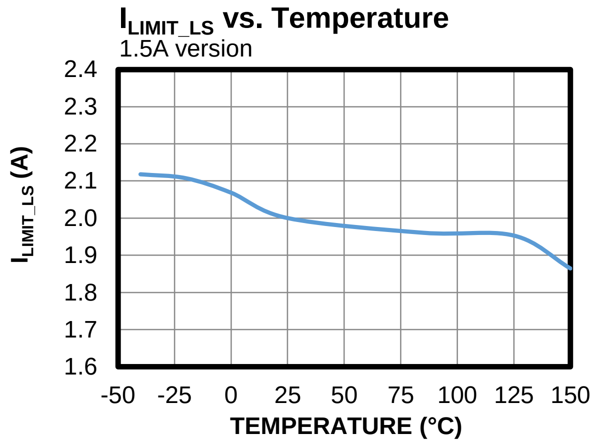
I_{LIMIT_LS} vs. Temperature
2A version

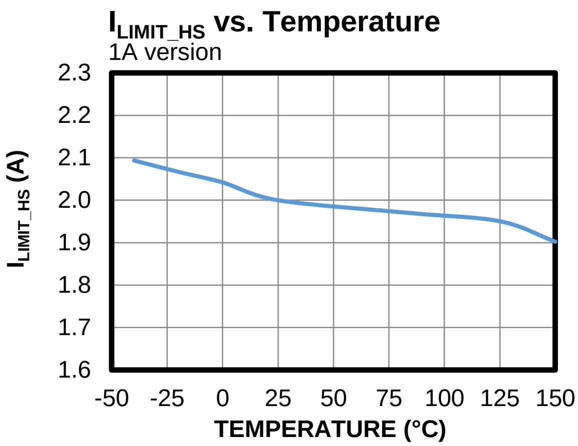


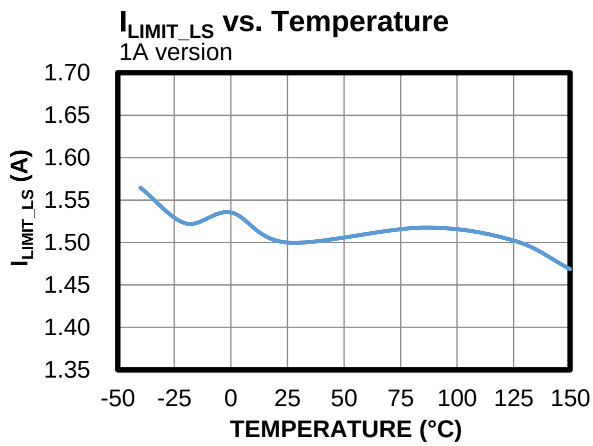
TYPICAL CHARACTERISTICS *(continued)*

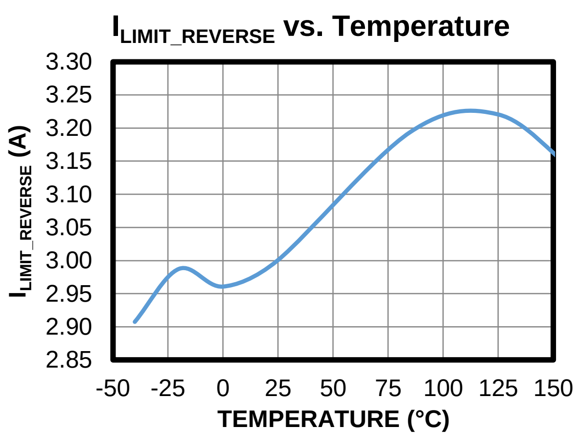
V_{IN} = 12V, unless otherwise noted.







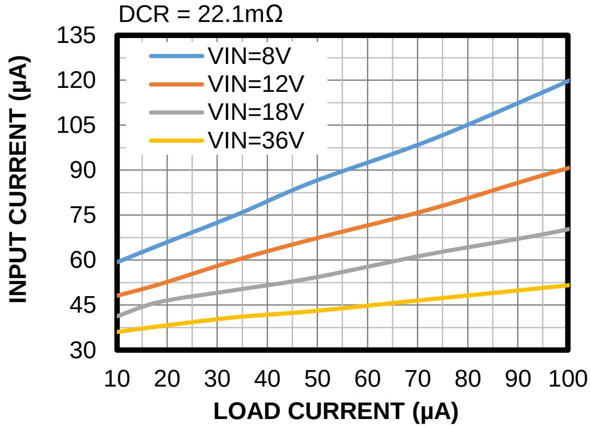




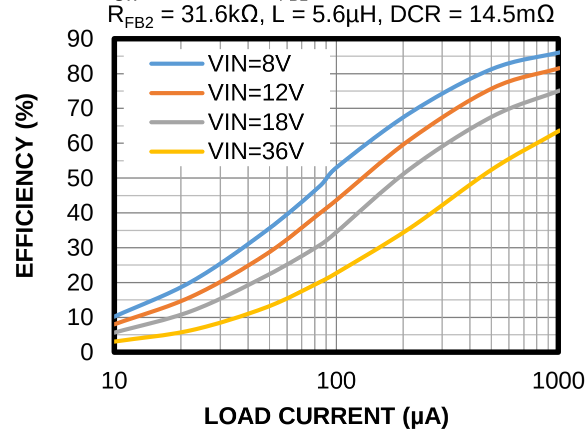
TYPICAL PERFORMANCE CHARACTERISTICS

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

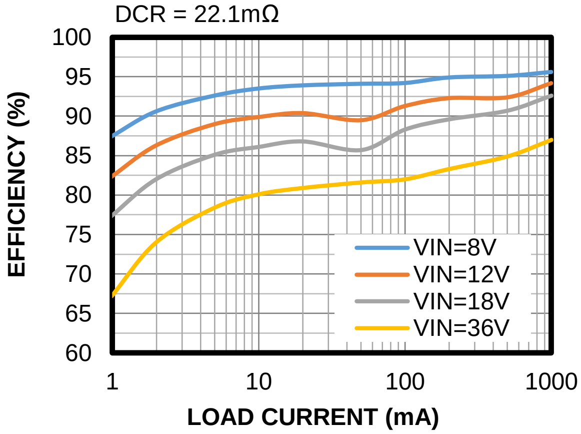
Input Current vs. Load Current
MPQ4324-4000/3000, AAM mode,
R_{FB1} = 100kΩ, R_{FB2} = 19.1kΩ,
DCR = 22.1mΩ



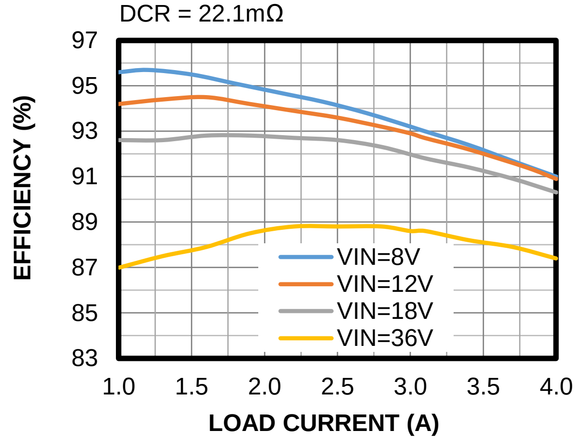
Efficiency vs. Load Current
MPQ4324-4000/3000, V_{OUT} = 3.3V,
f_{SW} = 415kHz, R_{FB1} = 100kΩ,
R_{FB2} = 31.6kΩ, L = 5.6µH, DCR = 14.5mΩ



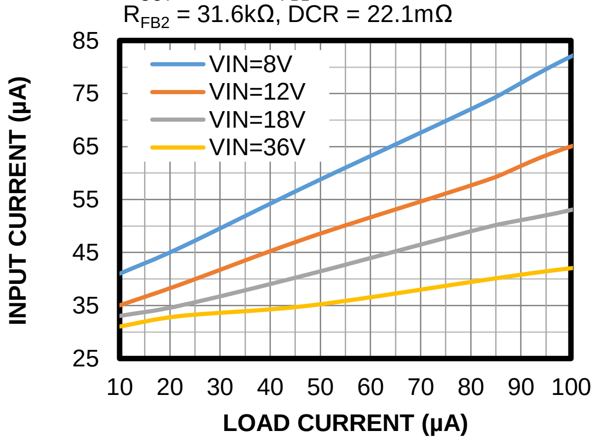
Efficiency vs. Load Current
MPQ4324-4000/3000, AAM mode,
DCR = 22.1mΩ



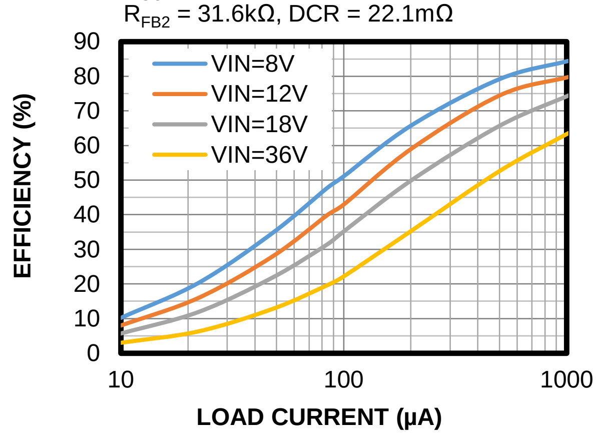
Efficiency vs. Load Current
MPQ4324-4000/3000, AAM mode,
DCR = 22.1mΩ



Input Current vs. Load Current
MPQ4324-4000/3000, AAM mode,
V_{OUT} = 3.3V, R_{FB1} = 100kΩ,
R_{FB2} = 31.6kΩ, DCR = 22.1mΩ



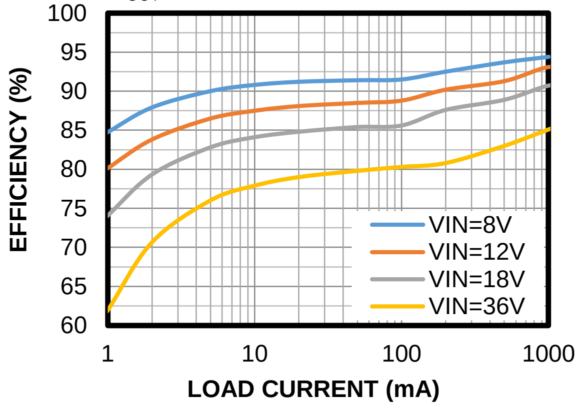
Efficiency vs. Load Current
MPQ4324-4000/3000, AAM mode,
V_{OUT} = 3.3V, R_{FB1} = 100kΩ,
R_{FB2} = 31.6kΩ, DCR = 22.1mΩ



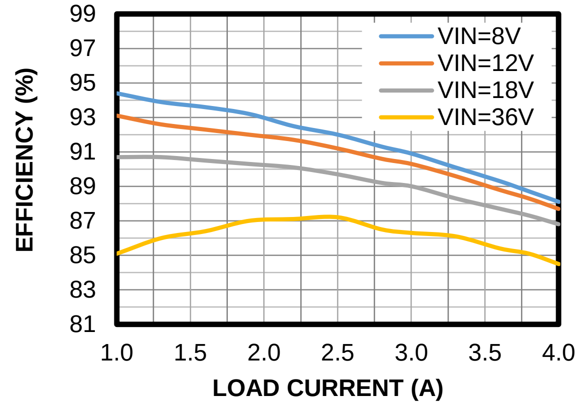
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

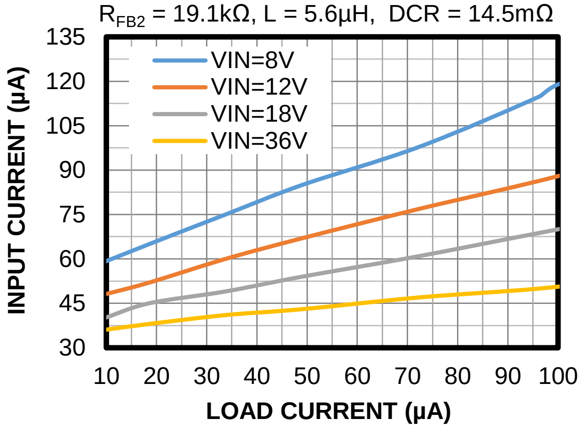
Efficiency vs. Load Current
MPQ4324-4000/3000, AAM mode,
V_{OUT} = 3.3V, DCR = 22.1mΩ



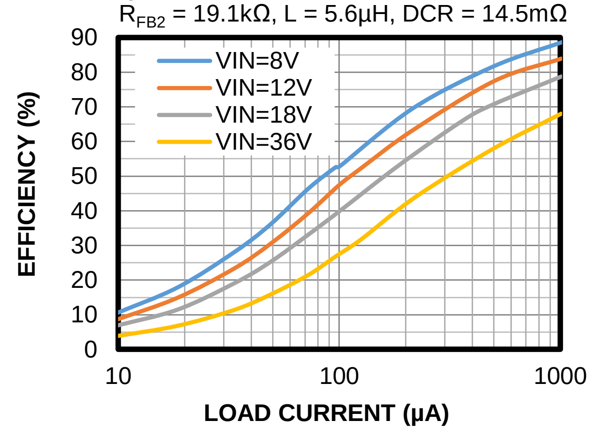
Efficiency vs. Load Current
MPQ4324-4000/3000, AAM mode,
V_{OUT} = 3.3V, DCR = 22.1mΩ



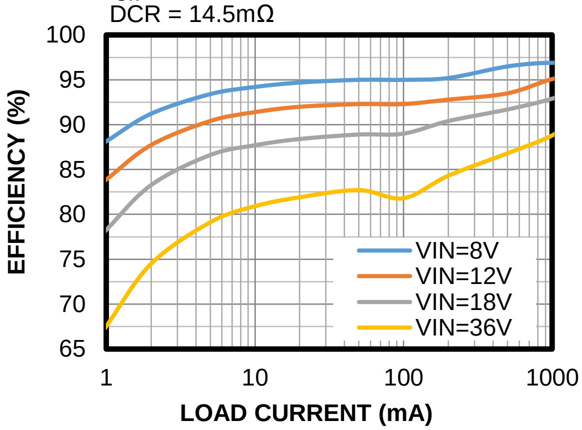
Input Current vs. Load Current
MPQ4324-4000/3000, AAM mode,
f_{SW} = 415kHz, R_{FB1} = 100kΩ,
R_{FB2} = 19.1kΩ, L = 5.6µH, DCR = 14.5mΩ



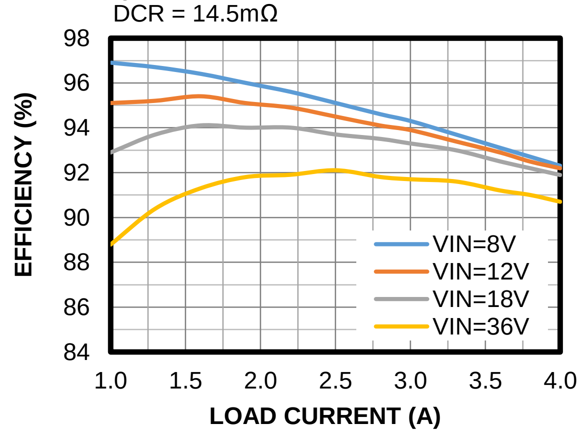
Efficiency vs. Load Current
MPQ4324-4000/3000, AAM mode,
f_{SW} = 415kHz, R_{FB1} = 100kΩ,
R_{FB2} = 19.1kΩ, L = 5.6µH, DCR = 14.5mΩ



Efficiency vs. Load Current
MPQ4324-4000/3000, AAM mode,
f_{SW} = 415kHz, L = 5.6µH,
DCR = 14.5mΩ



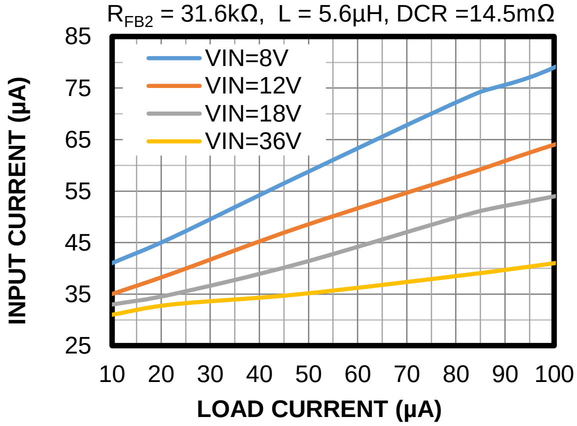
Efficiency vs. Load Current
MPQ4324-4000/3000, AAM mode,
f_{SW} = 415kHz, L = 5.6µH,
DCR = 14.5mΩ



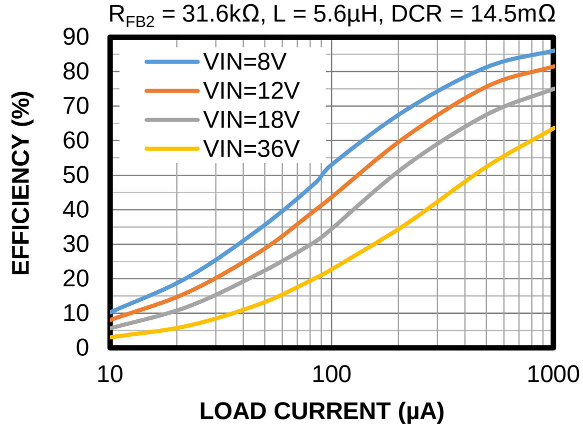
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

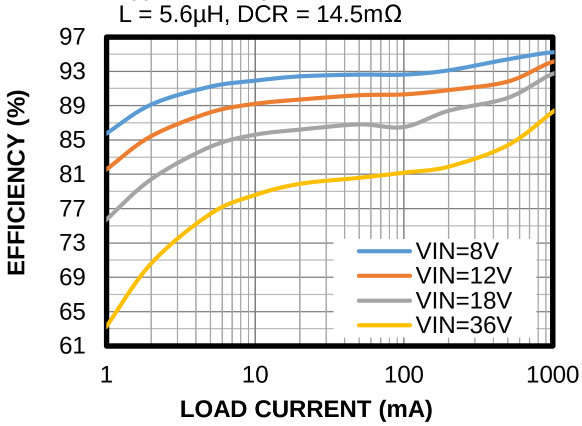
Input Current vs. Load Current
MPQ4324-4000/3000, V_{OUT} = 3.3V, f_{SW} = 415kHz, R_{FB1} = 100kΩ, R_{FB2} = 31.6kΩ, L = 5.6µH, DCR =14.5mΩ



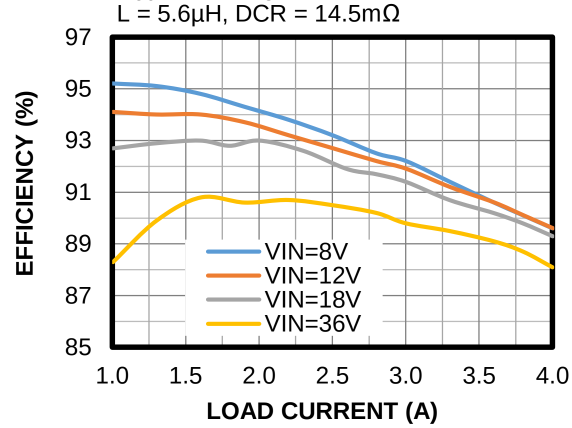
Efficiency vs. Load Current
MPQ4324-4000/3000, V_{OUT} = 3.3V, f_{SW} = 415kHz, R_{FB1} = 100kΩ, R_{FB2} = 31.6kΩ, L = 5.6µH, DCR = 14.5mΩ



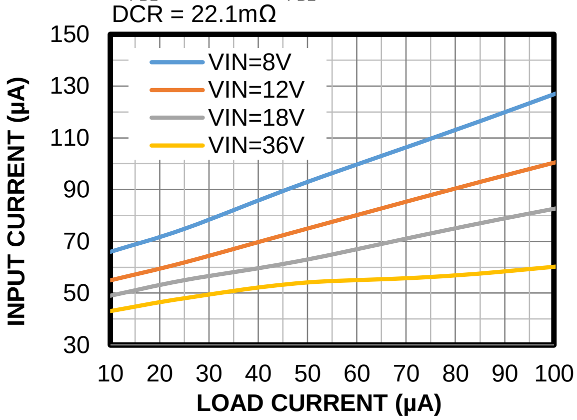
Efficiency vs. Load Current
MPQ4324-4000/3000, AAM mode, V_{OUT} = 3.3V, f_{SW} = 415kHz, L = 5.6µH, DCR = 14.5mΩ



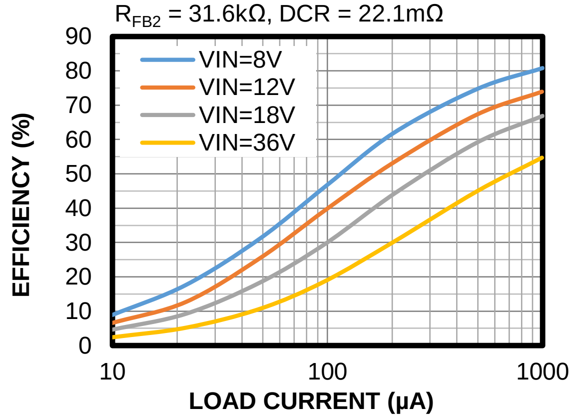
Efficiency vs. Load Current
MPQ4324-4000/3000, AAM mode, V_{OUT} = 3.3V, f_{SW} = 415kHz, L = 5.6µH, DCR = 14.5mΩ



Input Current vs. Load Current
MPQ4324-2000/1500, AAM mode, R_{FB1} = 100kΩ, R_{FB2} = 19.1kΩ, DCR = 22.1mΩ



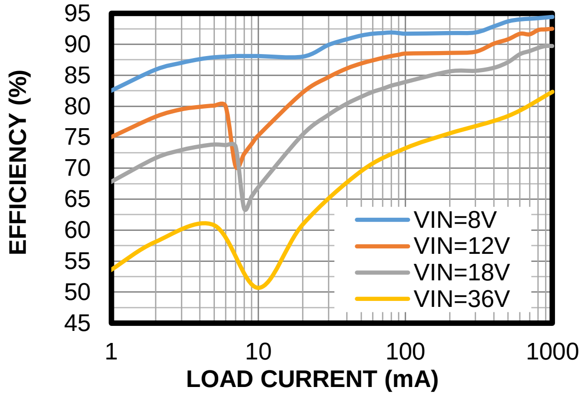
Efficiency vs. Load Current
MPQ4324-2000/1500, AAM mode, V_{OUT} = 3.3V, R_{FB1} = 100kΩ, R_{FB2} = 31.6kΩ, DCR = 22.1mΩ



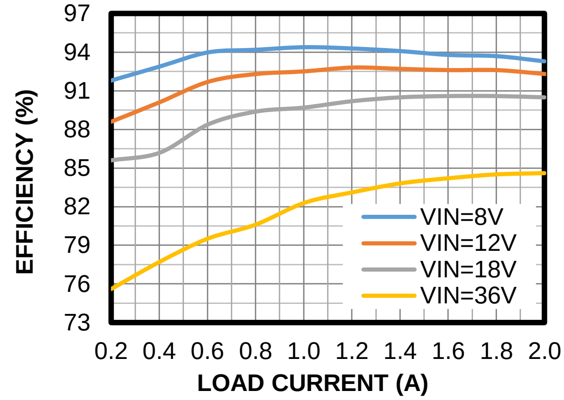
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

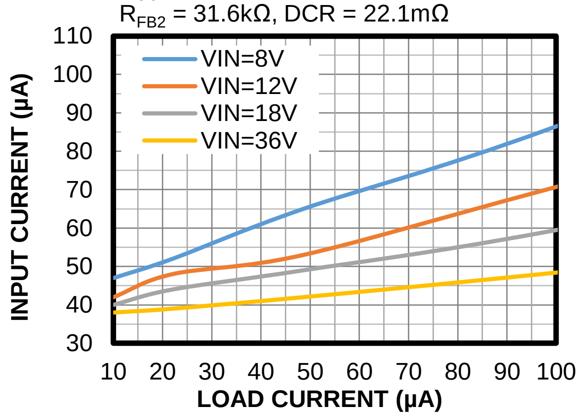
Efficiency vs. Load Current
MPQ4324-2000/1500, AAM mode,
DCR = 22.1mΩ



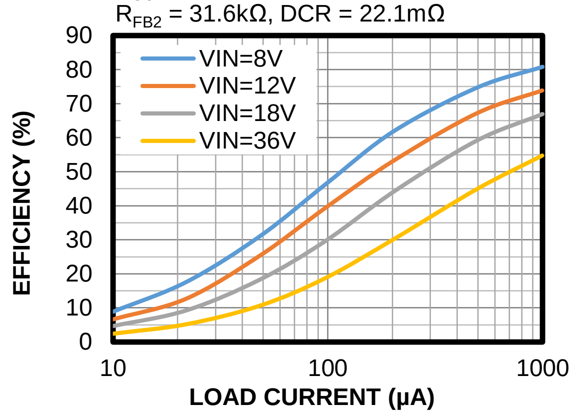
Efficiency vs. Load Current
MPQ4324-2000/1500, AAM mode,
DCR = 22.1mΩ



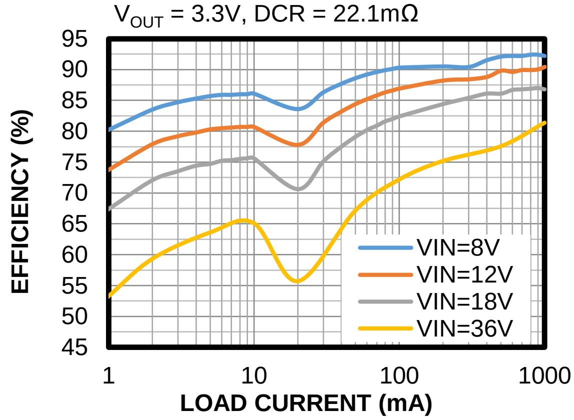
Input Current vs. Load Current
MPQ4324-2000/1500, AAM mode,
V_{OUT} = 3.3V, R_{FB1} = 100kΩ,
R_{FB2} = 31.6kΩ, DCR = 22.1mΩ



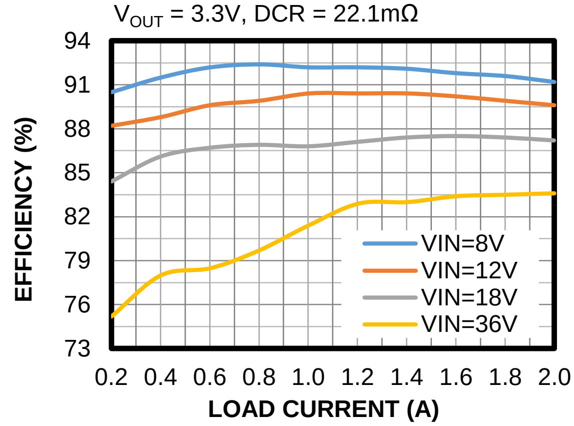
Efficiency vs. Load Current
MPQ4324-2000/1500, AAM mode,
V_{OUT} = 3.3V, R_{FB1} = 100kΩ,
R_{FB2} = 31.6kΩ, DCR = 22.1mΩ



Efficiency vs. Load Current
MPQ4324-2000/1500, AAM mode,
V_{OUT} = 3.3V, DCR = 22.1mΩ



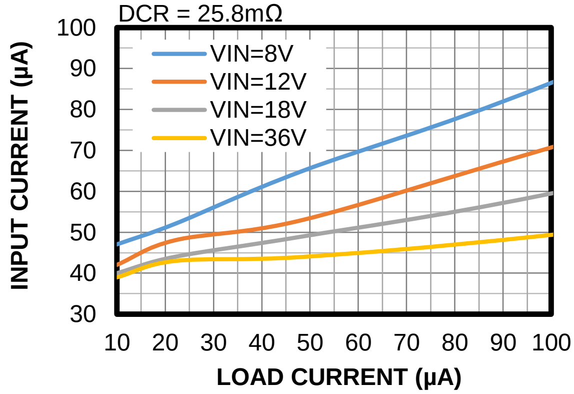
Efficiency vs. Load Current
MPQ4324-2000/1500, AAM mode,
V_{OUT} = 3.3V, DCR = 22.1mΩ



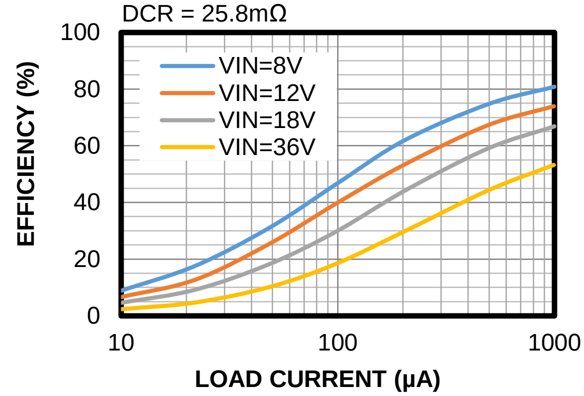
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

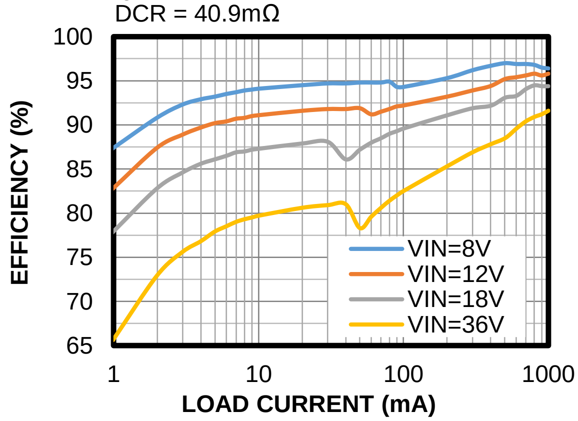
Input Current vs. Load Current
MPQ4324-1000, AAM mode,
V_{OUT} = 3.3V, R_{FB1} = 100kΩ,
R_{FB2} = 31.6kΩ, L = 5.6µH,
DCR = 25.8mΩ



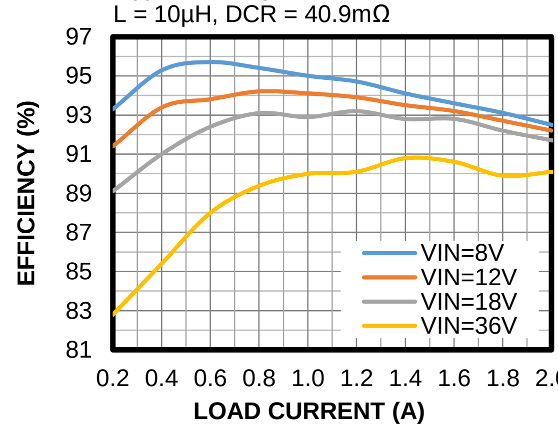
Efficiency vs. Load Current
MPQ4324-1000, AAM mode,
V_{OUT} = 3.3V, R_{FB1} = 100kΩ,
R_{FB2} = 31.6kΩ, L = 5.6µH,
DCR = 25.8mΩ



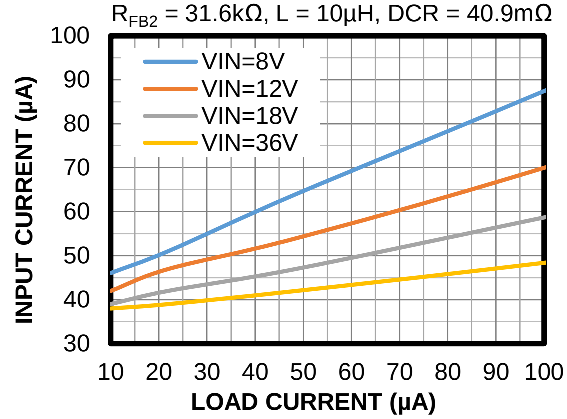
Efficiency vs. Load Current
MPQ4324-2000/1500, AAM mode,
f_{SW} = 415kHz, L = 10µH,
DCR = 40.9mΩ



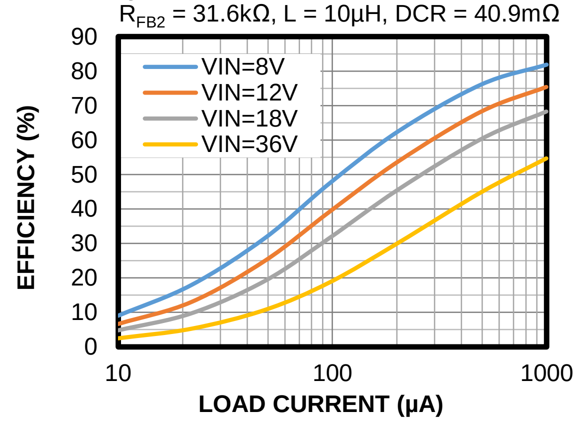
Efficiency vs. Load Current
MPQ4324-2000/1500, AAM mode,
V_{OUT} = 3.3V, f_{SW} = 415kHz,
L = 10µH, DCR = 40.9mΩ



Input Current vs. Load Current
MPQ4324-2000/1500, V_{OUT} = 3.3V,
f_{SW} = 415kHz,R_{FB1} = 100kΩ,
R_{FB2} = 31.6kΩ, L = 10µH, DCR = 40.9mΩ



Efficiency vs. Load Current
MPQ4324-2000/1500, V_{OUT} = 3.3V,
f_{SW} = 415kHz, R_{FB1} = 100kΩ,
R_{FB2} = 31.6kΩ, L = 10µH, DCR = 40.9mΩ

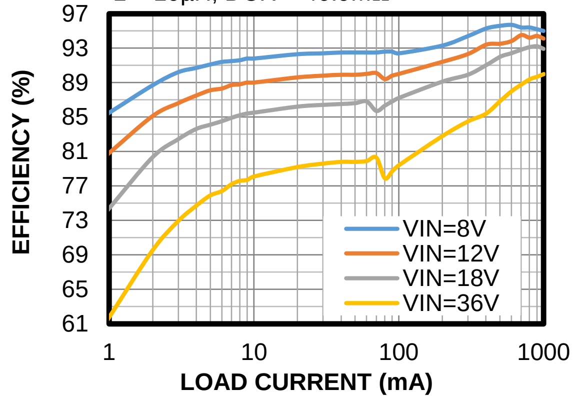


TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

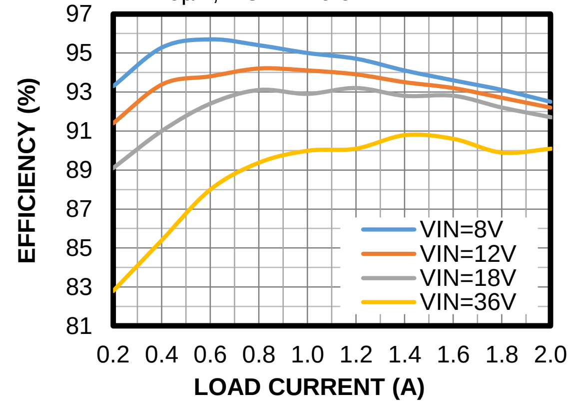
Efficiency vs. Load Current

MPQ4324-2000/1500, AAM mode, V_{OUT} = 3.3V, f_{SW} = 415kHz, L = 10µH, DCR = 40.9mΩ



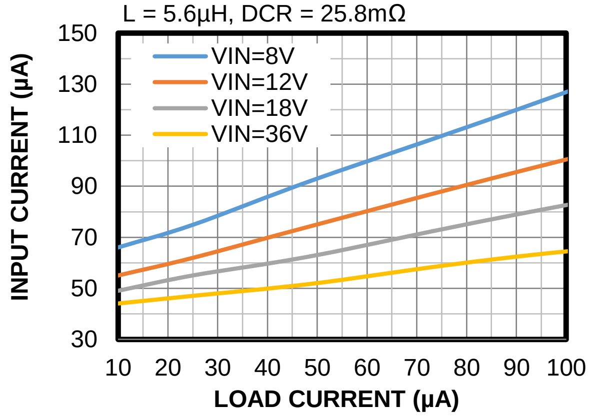
Efficiency vs. Load Current

MPQ4324-2000/1500, AAM mode, V_{OUT} = 3.3V, f_{SW} = 415kHz, L = 10µH, DCR = 40.9mΩ



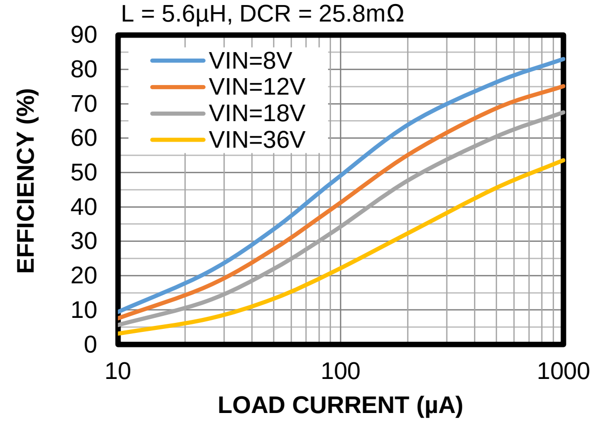
Input Current vs. Load Current

MPQ4324-1000, AAM mode, R_{FB1} = 100kΩ, R_{FB2} = 19.1kΩ, L = 5.6µH, DCR = 25.8mΩ



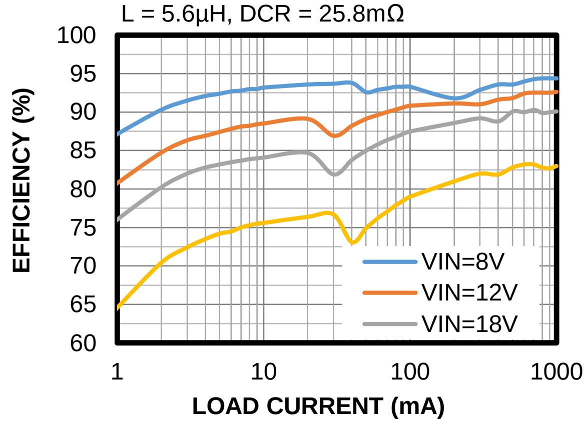
Efficiency vs. Load Current

MPQ4324-1000, AAM mode, R_{FB1} = 100kΩ, R_{FB2} = 19.1kΩ, L = 5.6µH, DCR = 25.8mΩ



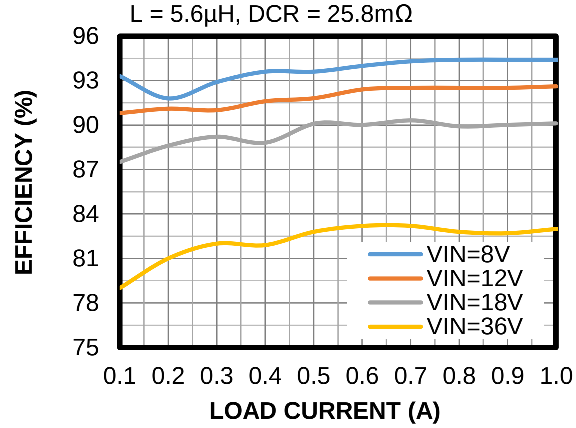
Efficiency vs. Load Current

MPQ4324-1000, AAM mode, L = 5.6µH, DCR = 25.8mΩ



Efficiency vs. Load Current

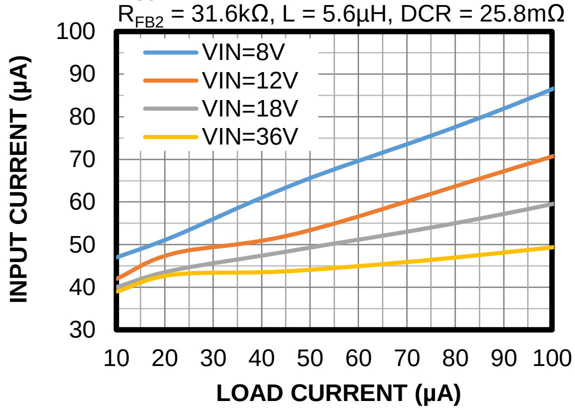
MPQ4324-1000, AAM mode, L = 5.6µH, DCR = 25.8mΩ



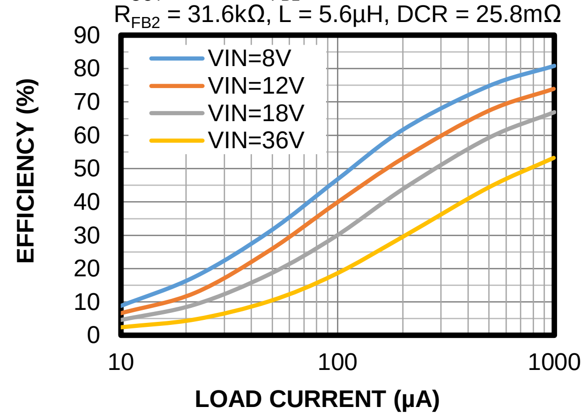
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

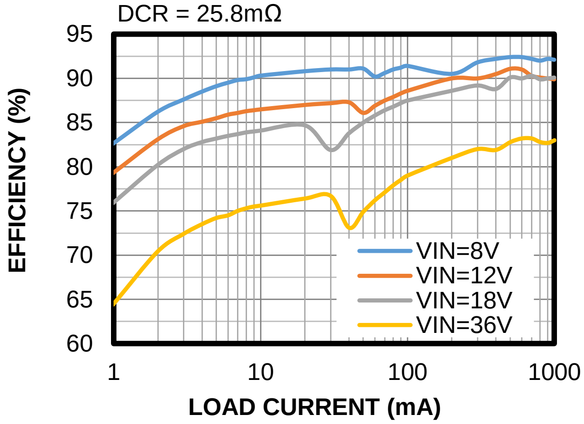
Input Current vs. Load Current
MPQ4324-1000, AAM mode,
V_{OUT} = 3.3V, R_{FB1} = 100kΩ,
R_{FB2} = 31.6kΩ, L = 5.6µH, DCR = 25.8mΩ



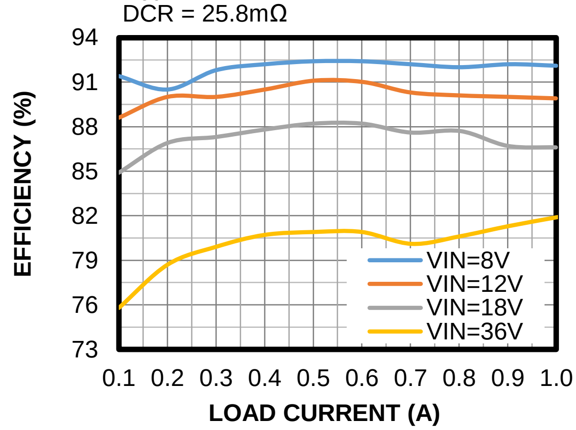
Efficiency vs. Load Current
MPQ4324-1000, AAM mode,
V_{OUT} = 3.3V, R_{FB1} = 100kΩ,
R_{FB2} = 31.6kΩ, L = 5.6µH, DCR = 25.8mΩ



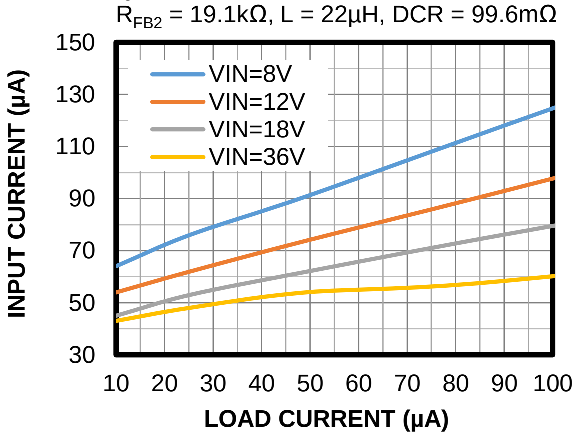
Efficiency vs. Load Current
MPQ4324-1000, AAM mode,
V_{OUT} = 3.3V, L = 5.6µH,
DCR = 25.8mΩ



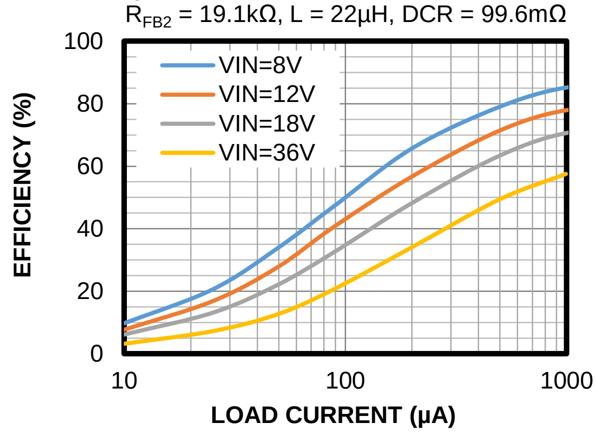
Efficiency vs. Load Current
MPQ4324-1000, AAM mode,
V_{OUT} = 3.3V, L = 5.6µH,
DCR = 25.8mΩ



Input Current vs. Load Current
MPQ4324-1000, AAM mode,
f_{SW} = 415kHz, R_{FB1} = 100kΩ,
R_{FB2} = 19.1kΩ, L = 22µH, DCR = 99.6mΩ



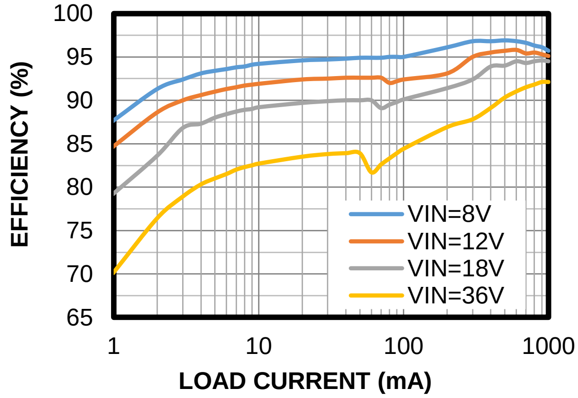
Efficiency vs. Load Current
MPQ4324-1000, AAM mode,
f_{SW} = 415kHz, R_{FB1} = 100kΩ,
R_{FB2} = 19.1kΩ, L = 22µH, DCR = 99.6mΩ



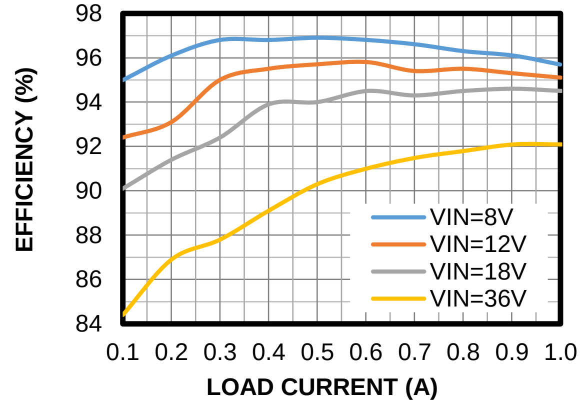
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

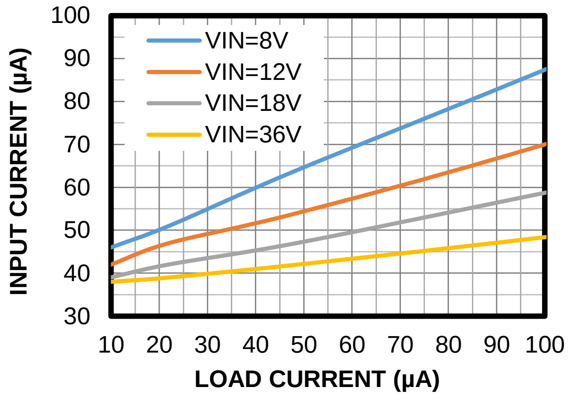
Efficiency vs. Load Current
MPQ4324-1000, AAM mode,
f_{SW} = 415kHz, L = 22µH,
DCR = 99.6mΩ



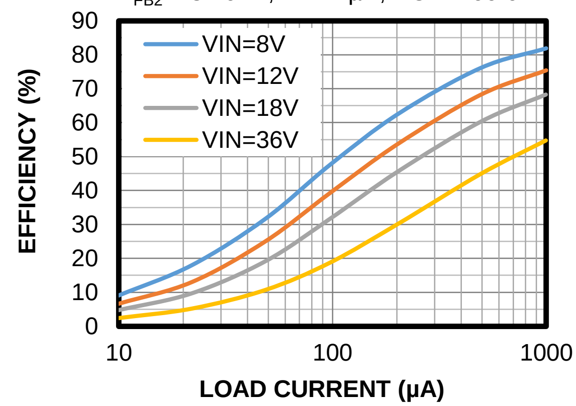
Efficiency vs. Load Current
MPQ4324-1000, AAM mode,
f_{SW} = 415kHz, L = 22µH,
DCR = 99.6mΩ



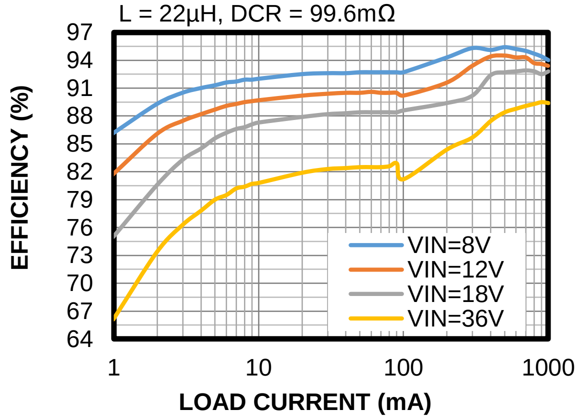
Input Current vs. Load Current
MPQ4324-1000, V_{OUT} = 3.3V,
f_{SW} = 415kHz, R_{FB1} = 100kΩ,
R_{FB2} = 31.6kΩ, L = 22µH, DCR = 99.6mΩ



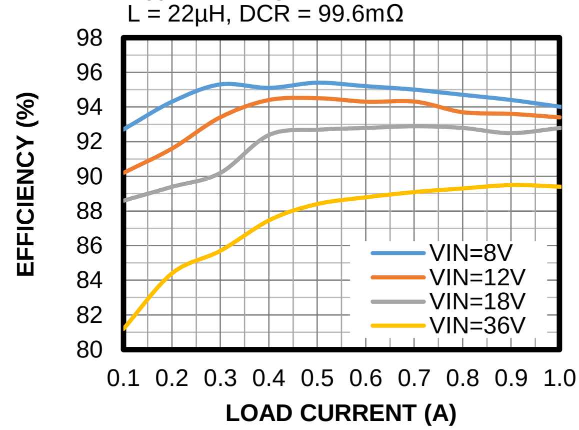
Efficiency vs. Load Current
MPQ4324-1000, V_{OUT} = 3.3V,
f_{SW} = 415kHz, R_{FB1} = 100kΩ,
R_{FB2} = 31.6kΩ, L = 22µH, DCR = 99.6mΩ



Efficiency vs. Load Current
MPQ4324-1000, AAM mode,
V_{OUT} = 3.3V, f_{SW} = 415kHz,
L = 22µH, DCR = 99.6mΩ



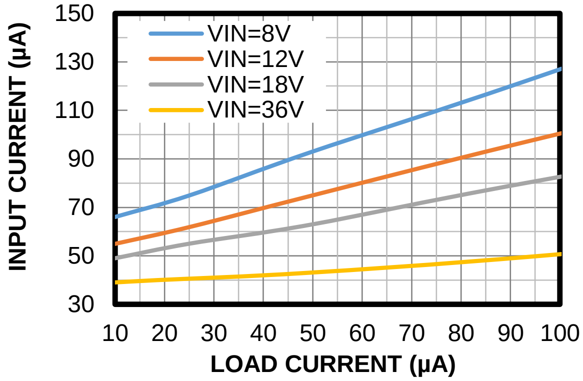
Efficiency vs. Load Current
MPQ4324-1000, AAM mode,
V_{OUT} = 3.3V, f_{SW} = 415kHz,
L = 22µH, DCR = 99.6mΩ



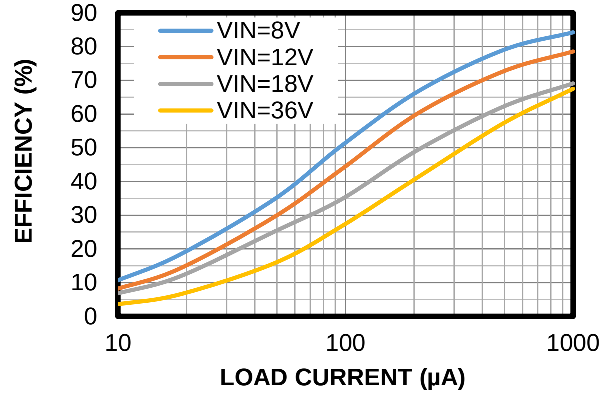
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

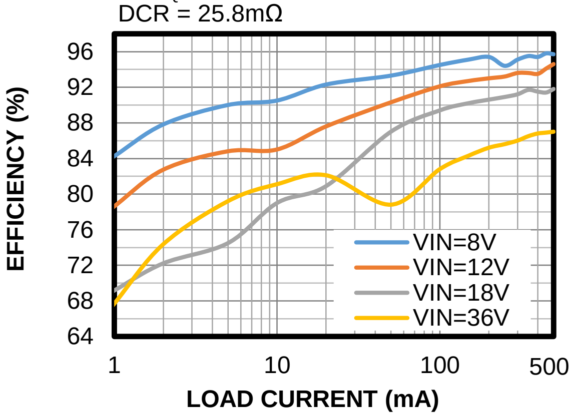
Input Current vs. Load Current
MPQ4324-0500, AAM mode,
R_{FREQ}= 15kΩ, R_{FB1} = 100kΩ,
R_{FB2} = 19.1kΩ, L = 5.6µH, DCR = 25.8mΩ



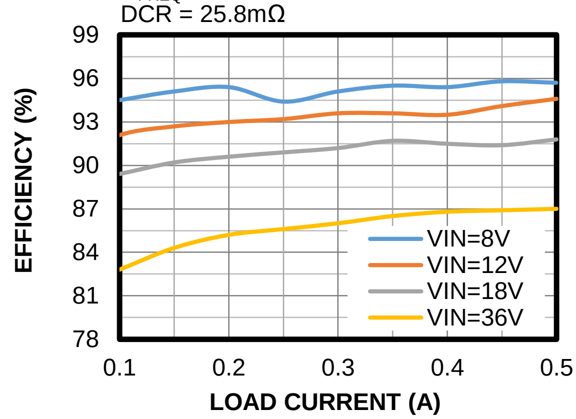
Efficiency vs. Load Current
MPQ4324-0500, AAM mode,
R_{FREQ}= 15kΩ, R_{FB1} = 100kΩ,
R_{FB2} = 19.1kΩ, L = 5.6µH, DCR = 25.8mΩ



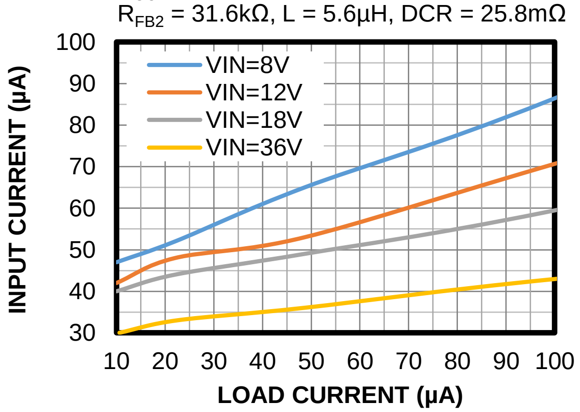
Efficiency vs. Load Current
MPQ4324-0500, AAM mode,
R_{FREQ}= 15kΩ, L = 5.6µH,
DCR = 25.8mΩ



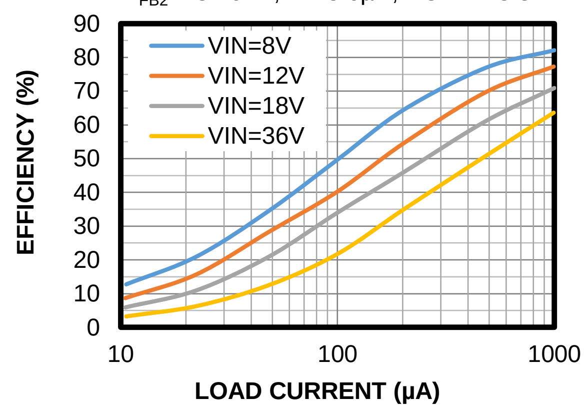
Efficiency vs. Load Current
MPQ4324-0500, AAM mode,
R_{FREQ}= 15kΩ, L = 5.6µH,
DCR = 25.8mΩ



Input Current vs. Load Current
MPQ4324-0500, AAM mode,
V_{OUT} = 3.3V, R_{FB1} = 100kΩ,
R_{FB2} = 31.6kΩ, L = 5.6µH, DCR = 25.8mΩ



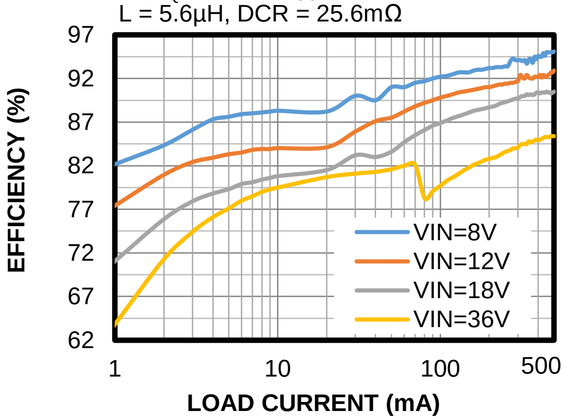
Efficiency vs. Load Current
MPQ4324-0500, AAM mode,
V_{OUT} = 3.3V, R_{FB1} = 100kΩ,
R_{FB2} = 31.6kΩ, L = 5.6µH, DCR = 25.8mΩ



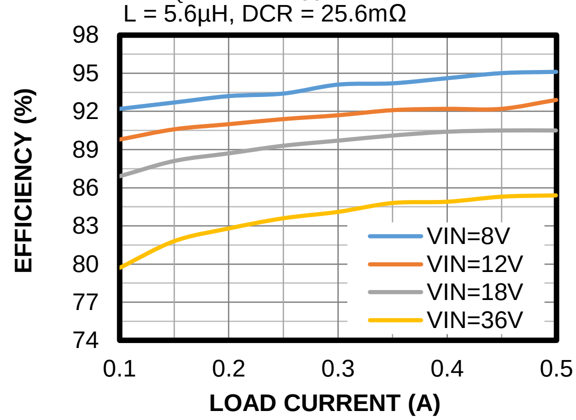
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

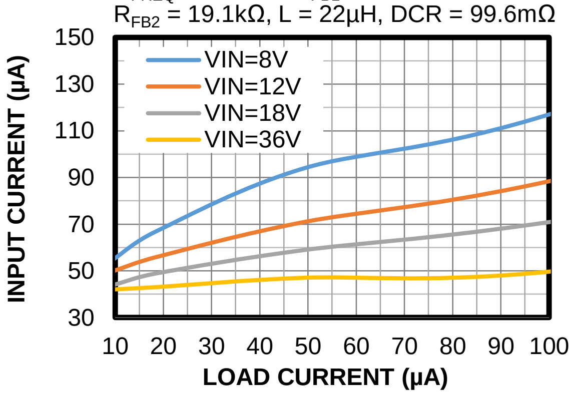
Efficiency vs. Load Current
MPQ4324-0500, AAM mode,
R_{FREQ} = 15kΩ, V_{OUT} = 3.3V,
L = 5.6µH, DCR = 25.6mΩ



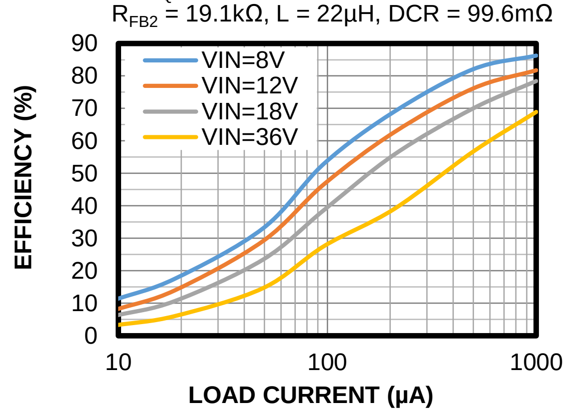
Efficiency vs. Load Current
MPQ4324-0500, AAM mode,
R_{FREQ} = 15kΩ, V_{OUT} = 3.3V,
L = 5.6µH, DCR = 25.6mΩ



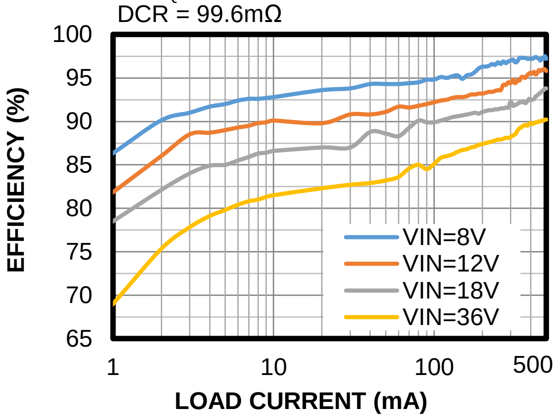
Input Current vs. Load Current
MPQ4324-0500, AAM mode,
R_{FREQ} = 86.6kΩ, R_{FB1} = 100kΩ,
R_{FB2} = 19.1kΩ, L = 22µH, DCR = 99.6mΩ



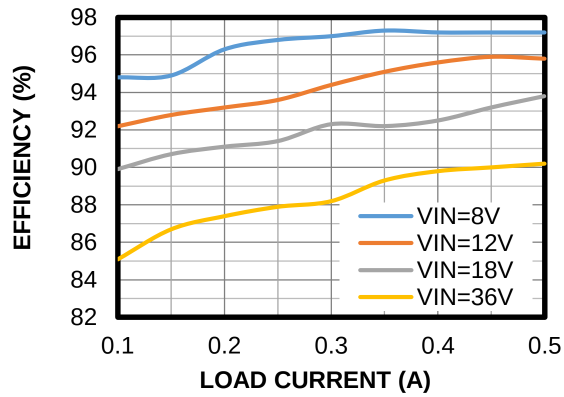
Efficiency vs. Load Current
MPQ4324-0500, AAM mode,
R_{FREQ} = 86.6kΩ, R_{FB1} = 100kΩ,
R_{FB2} = 19.1kΩ, L = 22µH, DCR = 99.6mΩ



Efficiency vs. Load Current
MPQ4324-0500, AAM mode,
R_{FREQ} = 86.6kΩ, L = 22µH,
DCR = 99.6mΩ



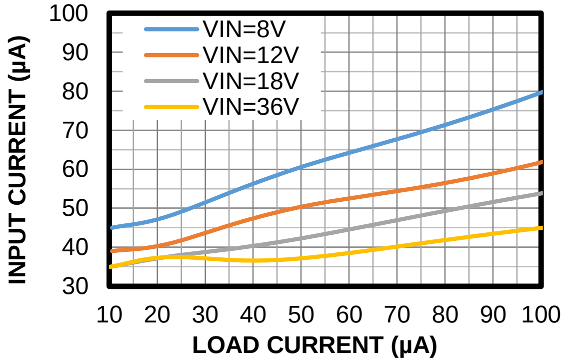
Efficiency vs. Load Current
MPQ4324-0500, AAM mode,
R_{FREQ} = 86.6kΩ, L = 22µH,
DCR = 99.6mΩ



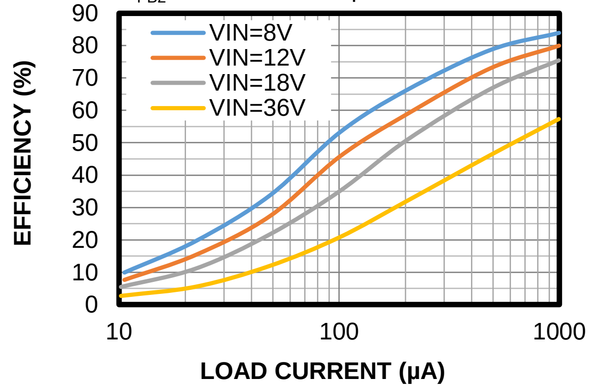
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

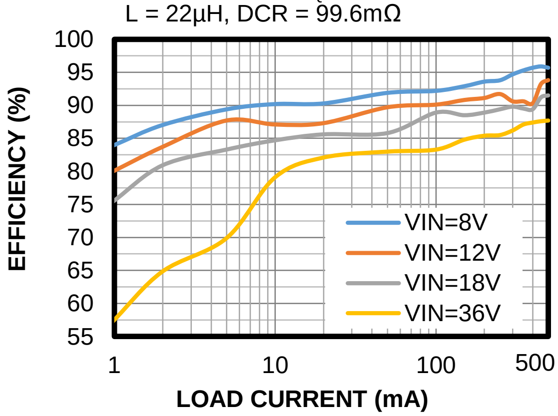
Input Current vs. Load Current
MPQ4324-0500, V_{OUT} = 3.3V,
R_{FREQ} = 86.6kΩ, R_{FB1} = 100kΩ,
R_{FB2} = 31.6kΩ, L = 22µH, DCR = 99.6mΩ



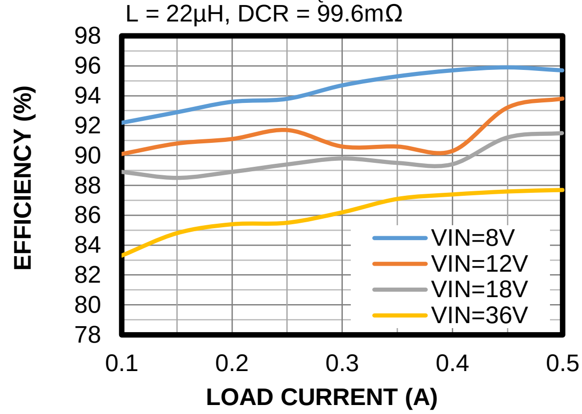
Efficiency vs. Load Current
MPQ4324-0500, V_{OUT} = 3.3V,
R_{FREQ} = 86.6kΩ, R_{FB1} = 100kΩ,
R_{FB2} = 31.6kΩ, L = 22µH, DCR = 99.6mΩ



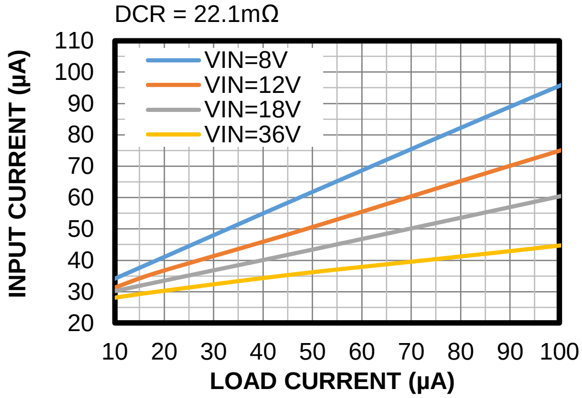
Efficiency vs. Load Current
MPQ4324-0500, AAM mode,
V_{OUT} = 3.3V, R_{FREQ} = 86.6kΩ,
L = 22µH, DCR = 99.6mΩ



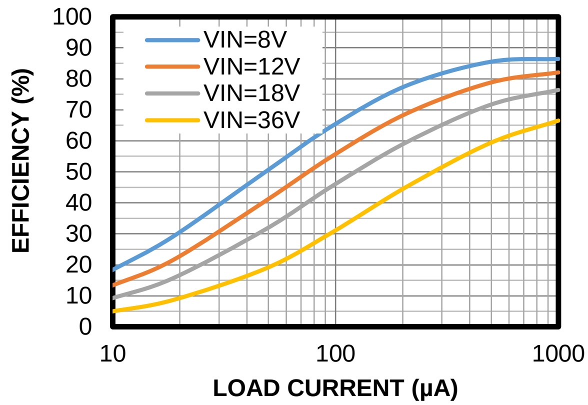
Efficiency vs. Load Current
MPQ4324-0500, AAM mode,
V_{OUT} = 3.3V, R_{FREQ} = 86.6kΩ,
L = 22µH, DCR = 99.6mΩ



Input Current vs. Load Current
MPQ4324-4050/3050, AAM mode,
DCR = 22.1mΩ



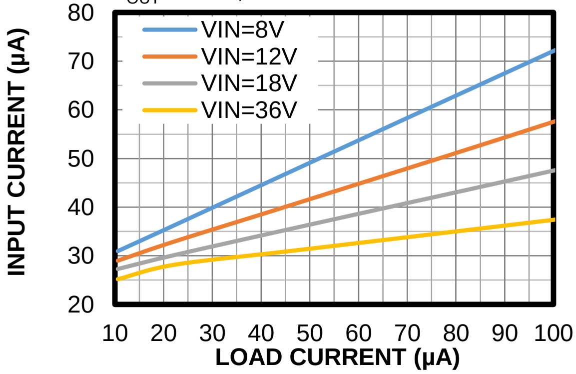
Efficiency vs. Load Current
MPQ4324-4050/3050, AAM mode,
DCR = 22.1mΩ



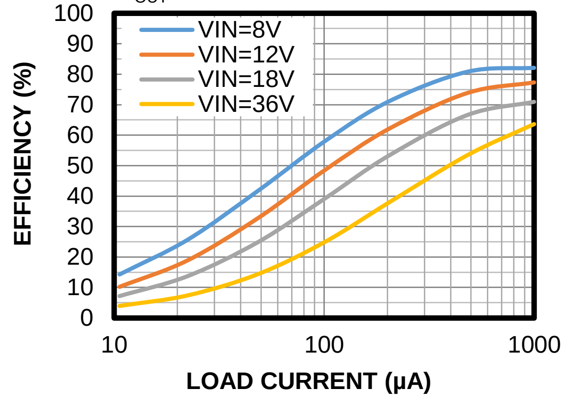
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

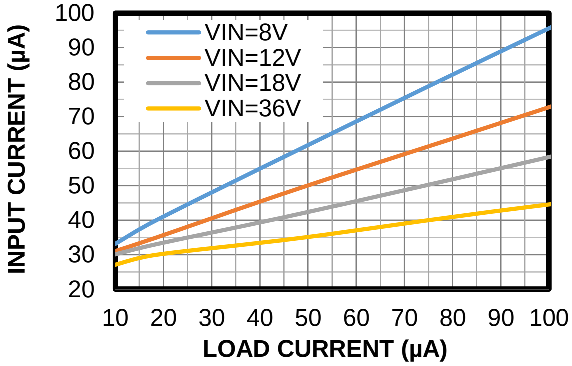
Input Current vs. Load Current
MPQ4324-4030/3030, AAM mode,
V_{OUT} = 3.3V, DCR = 22.1mΩ



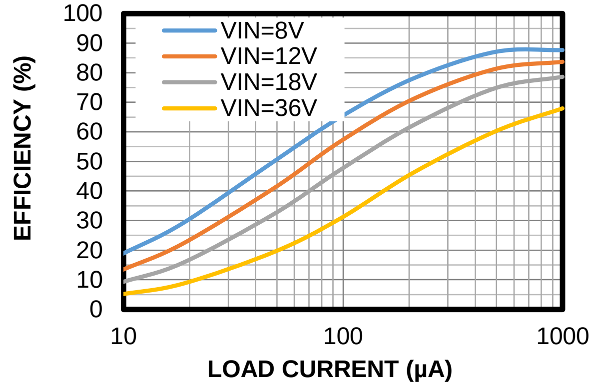
Efficiency vs. Load Current
MPQ4324-4030/3030, AAM mode,
V_{OUT} = 3.3V, DCR = 22.1mΩ



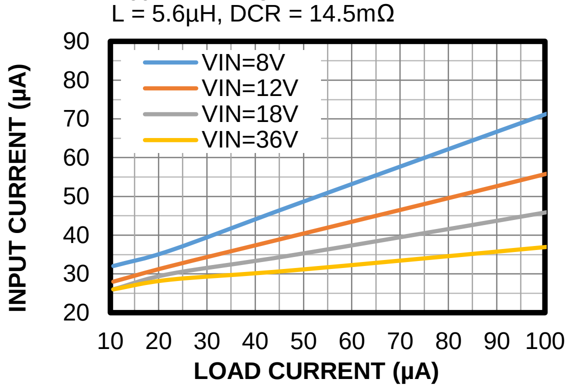
Input Current vs. Load Current
MPQ4324-4050/3050, AAM mode,
f_{SW} = 415kHz, L = 5.6µH,
DCR = 14.5mΩ



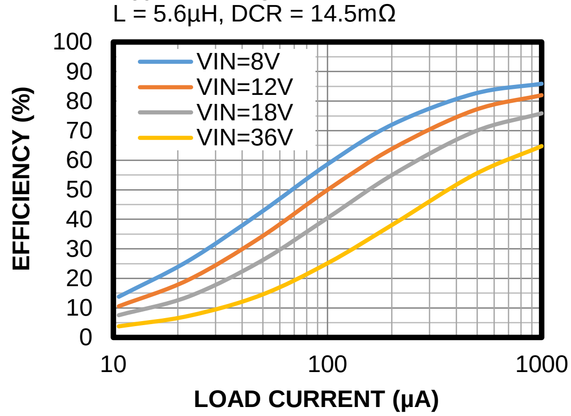
Efficiency vs. Load Current
MPQ4324-4050/3050, AAM mode,
f_{SW} = 415kHz, L = 5.6µH,
DCR = 14.5mΩ



Input Current vs. Load Current
MPQ4324-4030/3030, AAM mode,
V_{OUT} = 3.3V, f_{SW} = 415kHz,
L = 5.6µH, DCR = 14.5mΩ



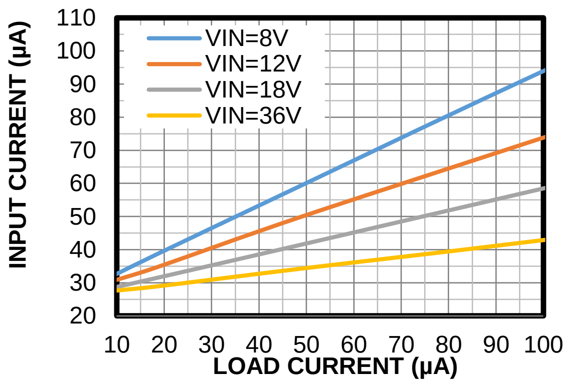
Efficiency vs. Load Current
MPQ4324-4030/3030, AAM mode,
V_{OUT} = 3.3V, f_{SW} = 415kHz,
L = 5.6µH, DCR = 14.5mΩ



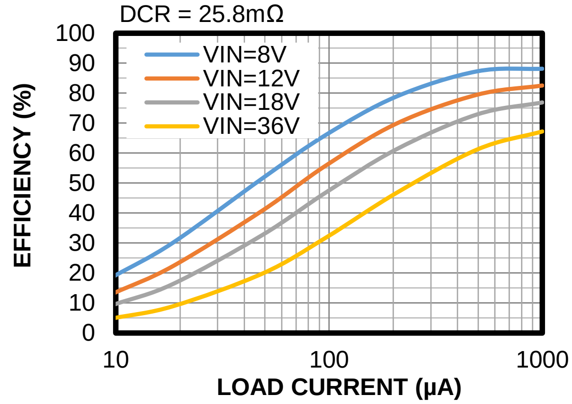
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

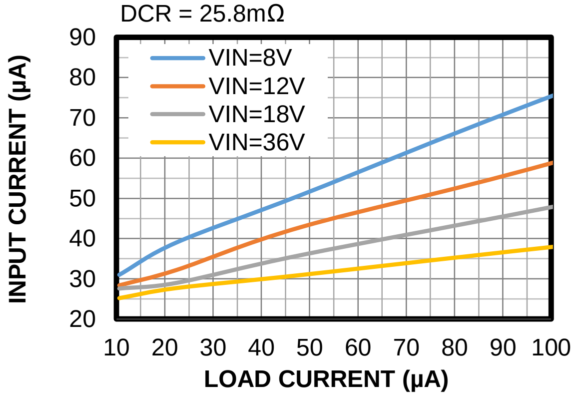
Input Current vs. Load Current
MPQ4324-2050/1550/1050,
AAM mode, L = 5.6µH, DCR = 25.8mΩ



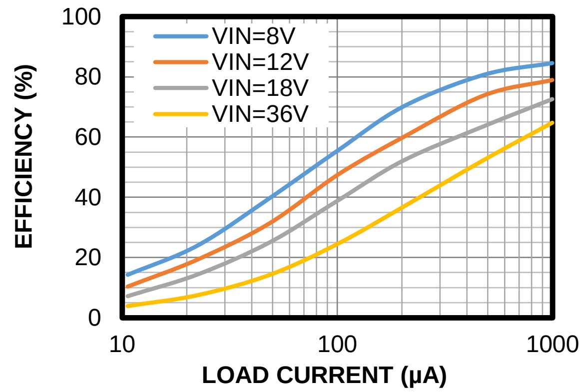
Efficiency vs. Load Current
MPQ4324-2050/1550/1050,
AAM mode, L = 5.6µH,
DCR = 25.8mΩ



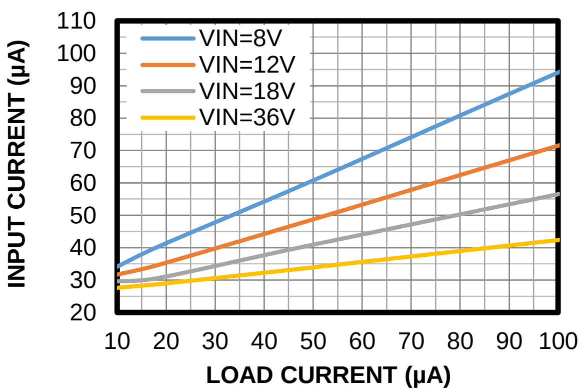
Input Current vs. Load Current
MPQ4324-2030/1530/1030,
AAM mode, V_{OUT} = 3.3V, L = 5.6µH,
DCR = 25.8mΩ



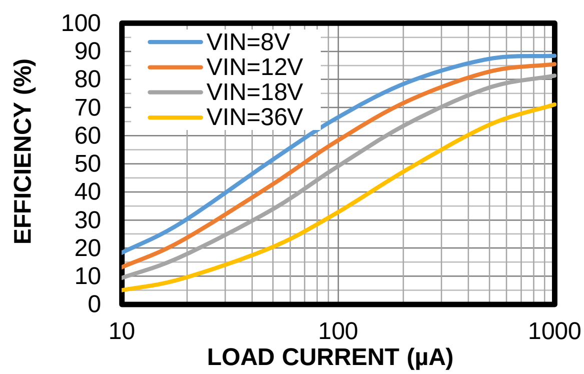
Efficiency vs. Load Current
MPQ4324-2030/1530/1030,
AAM mode, V_{OUT} = 3.3V, L = 5.6µH,
DCR = 25.8mΩ



Input Current vs. Load Current
MPQ4324-2050/1550/1050,
AAM mode, f_{SW} = 415kHz, L = 22µH,
DCR = 99.6mΩ



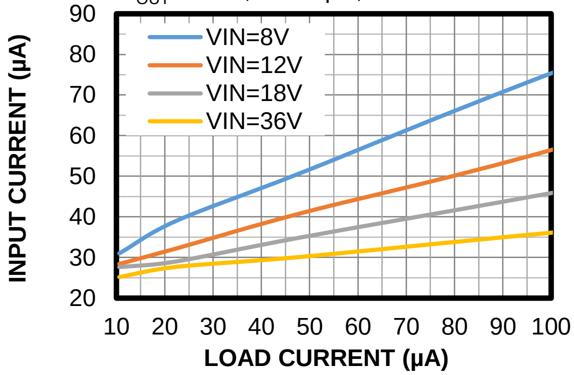
Efficiency vs. Load Current
MPQ4324-2050/1550/1050,
AAM mode, f_{SW} = 415kHz, L = 22µH,
DCR = 99.6mΩ



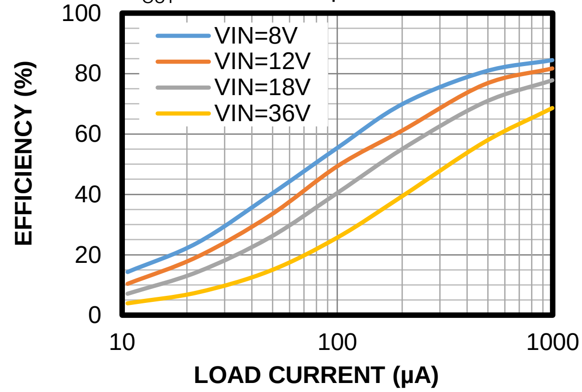
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

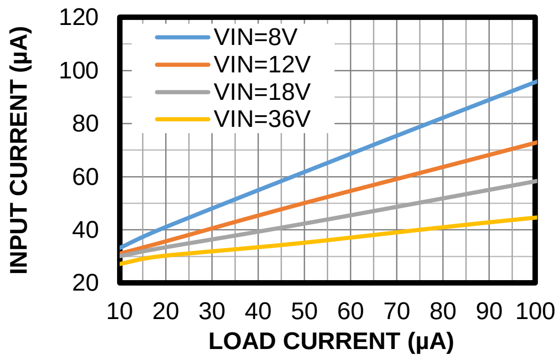
Input Current vs. Load Current
MPQ4324-2030/1530/1030,
AAM mode, f_{SW} = 415kHz,
V_{OUT} = 3.3V, L = 22µH, DCR = 99.6mΩ



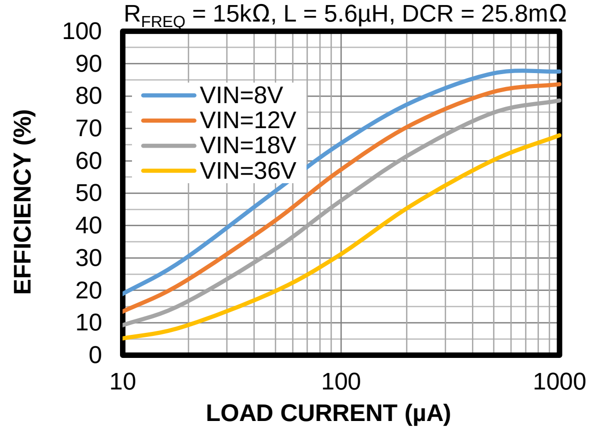
Efficiency vs. Load Current
MPQ4324-2030/1530/1030,
AAM mode, f_{SW} = 415kHz,
V_{OUT} = 3.3V, L = 22µH, DCR = 99.6mΩ



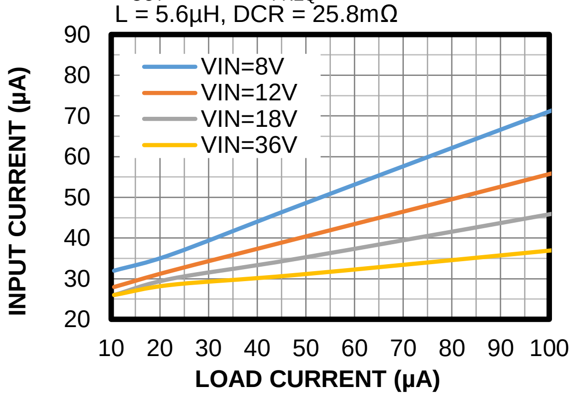
Input Current vs. Load Current
MPQ4324-0550, AAM mode,
R_{FREQ} = 15kΩ, L = 5.6µH,
DCR = 25.8mΩ



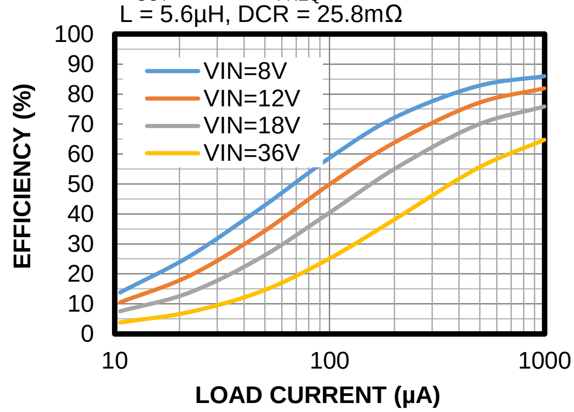
Efficiency vs. Load Current
MPQ4324-0550, AAM mode,
R_{FREQ} = 15kΩ, L = 5.6µH, DCR = 25.8mΩ



Input Current vs. Load Current
MPQ4324-0530, AAM mode,
V_{OUT} = 3.3V, R_{FREQ} = 15kΩ,
L = 5.6µH, DCR = 25.8mΩ



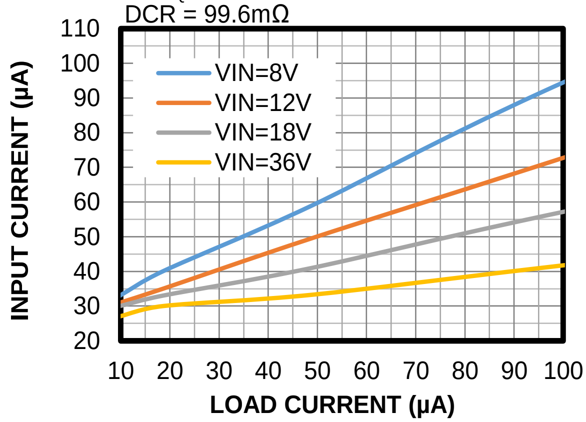
Efficiency vs. Load Current
MPQ4324-0530, AAM mode,
V_{OUT} = 3.3V, R_{FREQ} = 15kΩ,
L = 5.6µH, DCR = 25.8mΩ



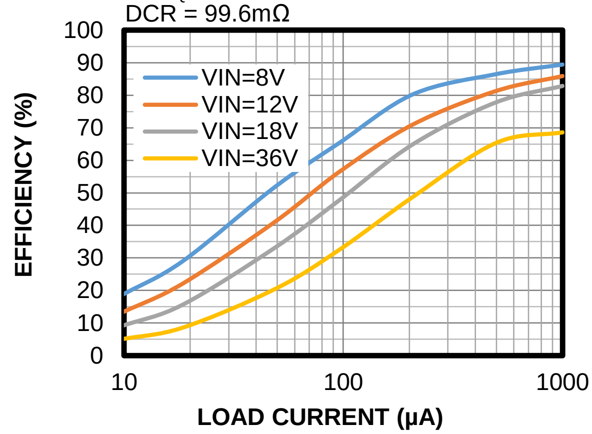
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

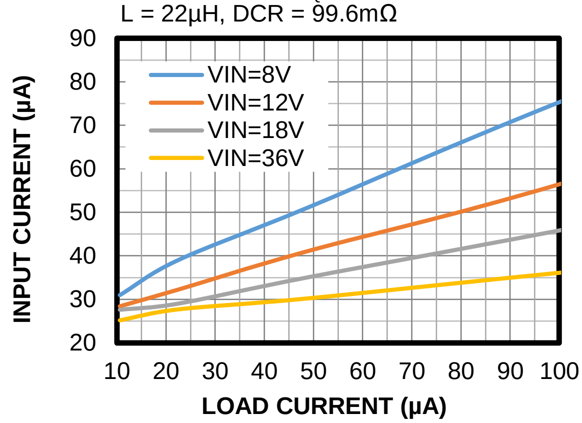
Input Current vs. Load Current
MPQ4324-0550, AAM mode,
R_{FREQ} = 86.6kΩ, L = 22µH,
DCR = 99.6mΩ



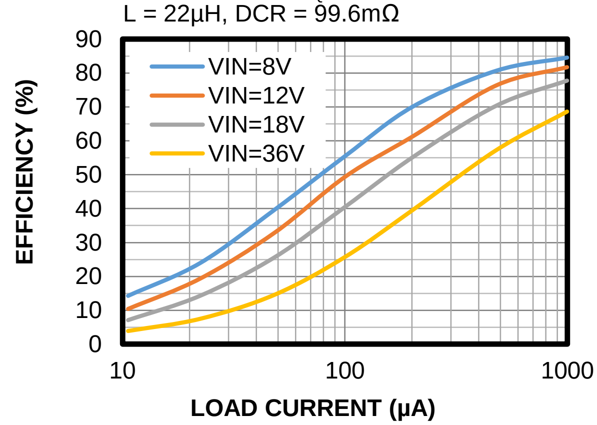
Efficiency vs. Load Current
MPQ4324-0550, AAM mode,
R_{FREQ} = 86.6kΩ, L = 22µH,
DCR = 99.6mΩ



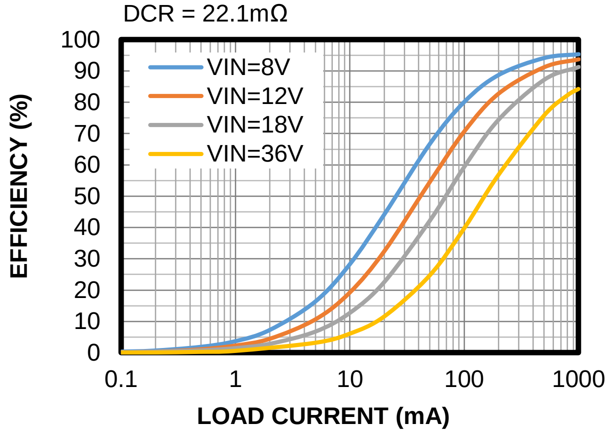
Input Current vs. Load Current
MPQ4324-0530, AAM mode,
V_{OUT} = 3.3V, R_{FREQ} = 86.6kΩ,
L = 22µH, DCR = 99.6mΩ



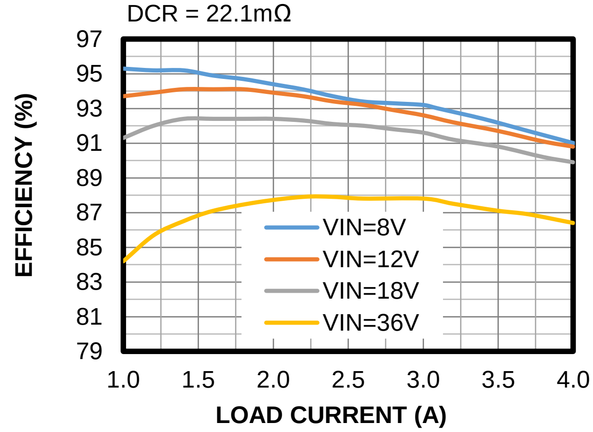
Efficiency vs. Load Current
MPQ4324-0530, AAM mode,
V_{OUT} = 3.3V, R_{FREQ} = 86.6kΩ,
L = 22µH, DCR = 99.6mΩ



Efficiency vs. Load Current
MPQ4324-4001/3001, FCCM,
DCR = 22.1mΩ



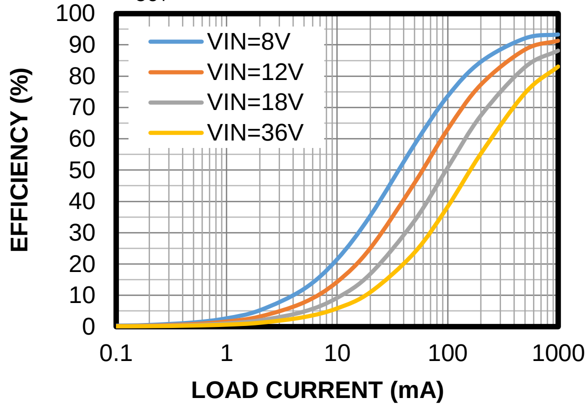
Efficiency vs. Load Current
MPQ4324-4001/3001, FCCM,
DCR = 22.1mΩ



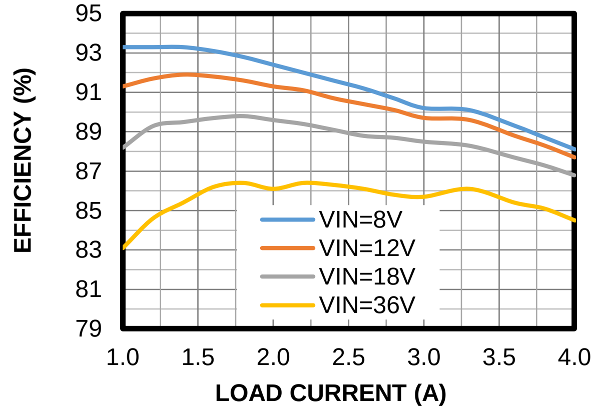
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

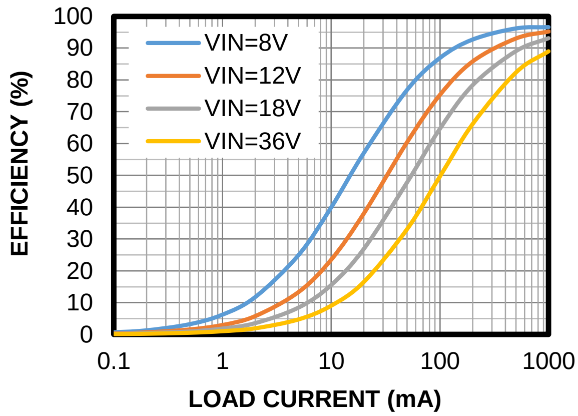
Efficiency vs. Load Current
MPQ4324-4001/3001, FCCM,
V_{OUT} = 3.3V, DCR = 22.1mΩ



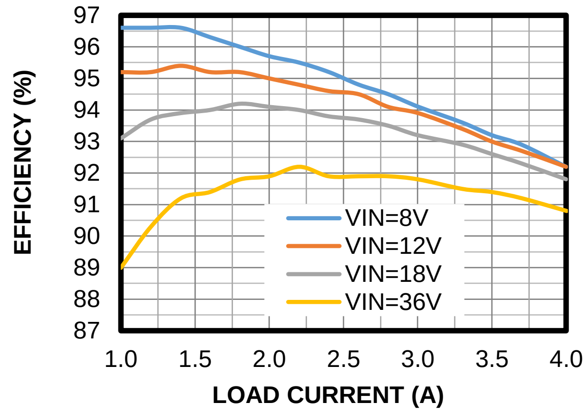
Efficiency vs. Load Current
MPQ4324-4001/3001, FCCM,
V_{OUT} = 3.3V, DCR = 22.1mΩ



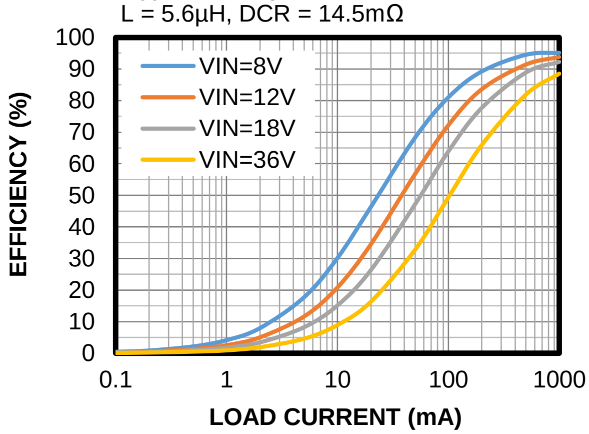
Efficiency vs. Load Current
MPQ4324-4001/3001, FCCM,
f_{SW} = 415kHz, L = 5.6µH,
DCR = 14.5mΩ



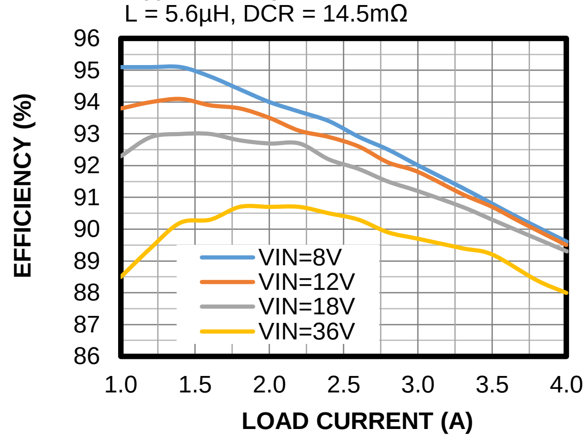
Efficiency vs. Load Current
MPQ4324-4001/3001, FCCM,
f_{SW} = 415kHz, L = 5.6µH,
DCR = 14.5mΩ



Efficiency vs. Load Current
MPQ4324-4001/3001, FCCM,
V_{OUT} = 3.3V, f_{SW} = 415kHz,
L = 5.6µH, DCR = 14.5mΩ



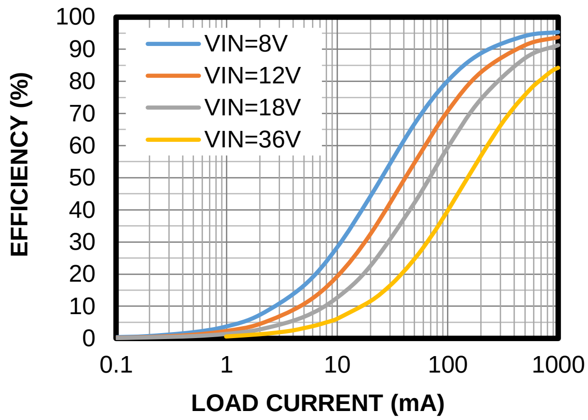
Efficiency vs. Load Current
MPQ4324-4001/3001, FCCM,
V_{OUT} = 3.3V, f_{SW} = 415kHz,
L = 5.6µH, DCR = 14.5mΩ



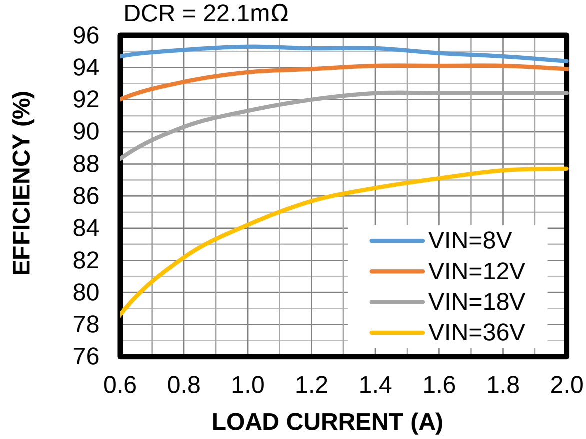
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

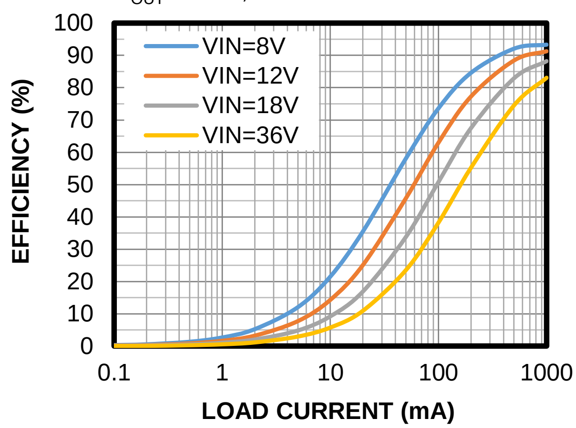
Efficiency vs. Load Current
MPQ4324-2001/1501, FCCM,
DCR = 22.1mΩ



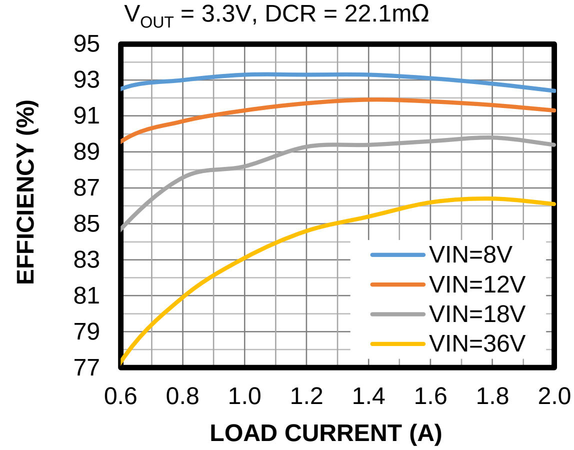
Efficiency vs. Load Current
MPQ4324-2001/1501, FCCM,
DCR = 22.1mΩ



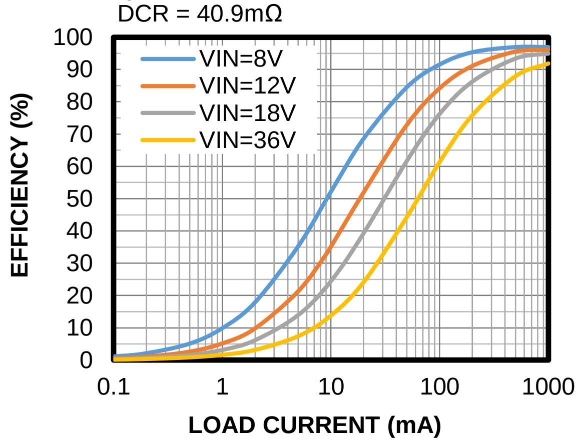
Efficiency vs. Load Current
MPQ4324-2001/1501, FCCM,
V_{OUT} = 3.3V, DCR = 22.1mΩ



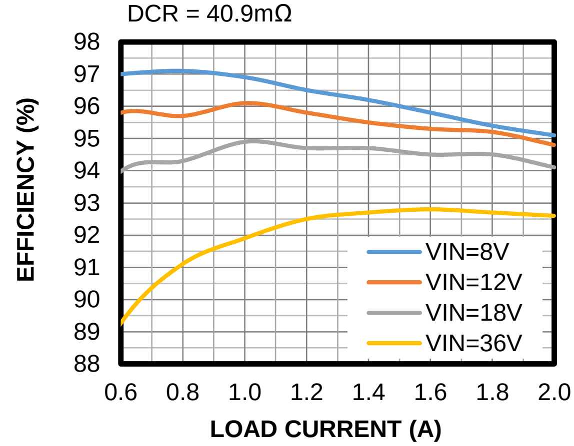
Efficiency vs. Load Current
MPQ4324-2001/1501, FCCM,
V_{OUT} = 3.3V, DCR = 22.1mΩ



Efficiency vs. Load Current
MPQ4324-2001/1501, FCCM,
f_{SW} = 415kHz, L = 10µH,
DCR = 40.9mΩ



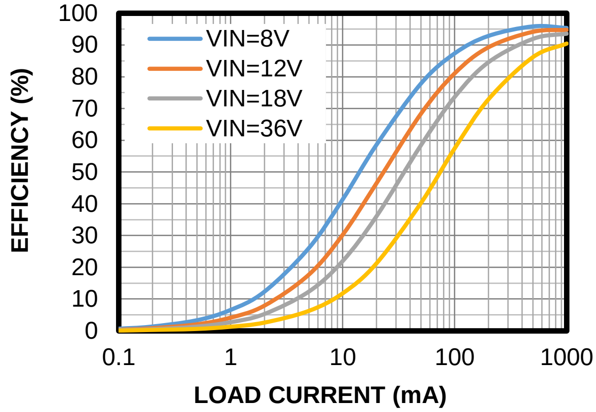
Efficiency vs. Load Current
MPQ4324-2001/1501, FCCM,
f_{SW} = 415kHz, L = 10µH,
DCR = 40.9mΩ



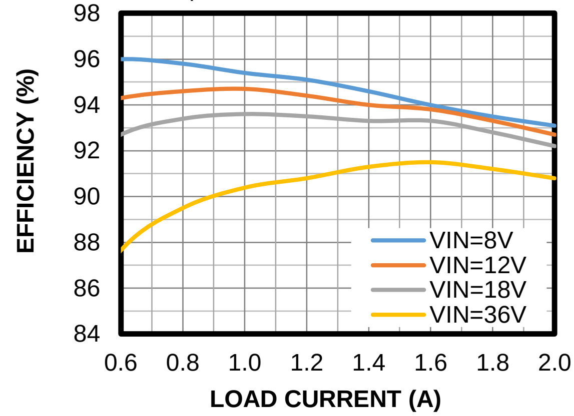
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

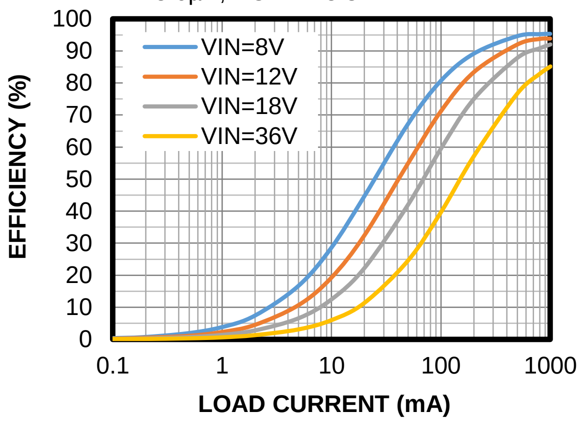
Efficiency vs. Load Current
MPQ4324-2001/1501, FCCM,
V_{OUT} = 3.3V, f_{SW} = 415kHz,
L = 10µH, DCR = 40.9mΩ



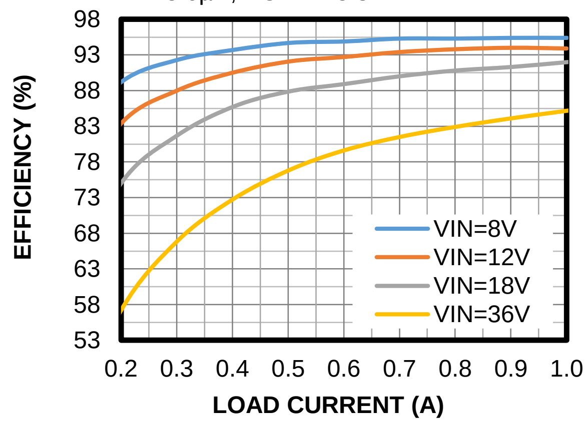
Efficiency vs. Load Current
MPQ4324-2001/1501, FCCM,
V_{OUT} = 3.3V, f_{SW} = 415kHz,
L = 10µH, DCR = 40.9mΩ



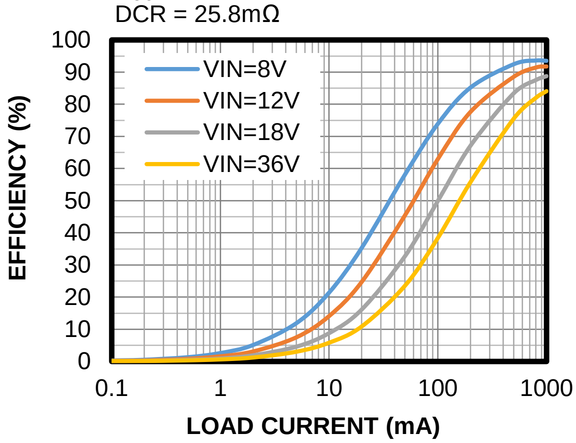
Efficiency vs. Load Current
MPQ4324-1001/0501, FCCM,
L = 5.6µH, DCR = 25.8mΩ



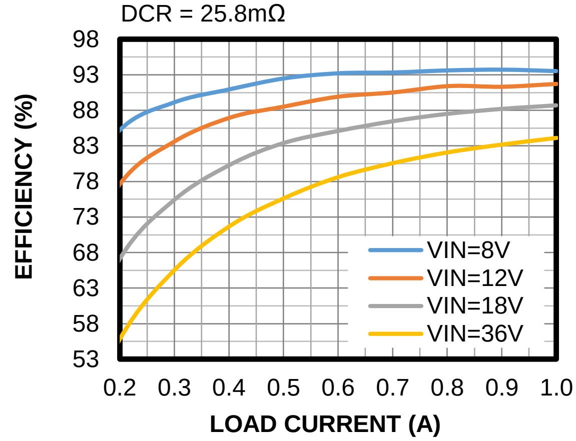
Efficiency vs. Load Current
MPQ4324-1001/0501, FCCM,
L = 5.6µH, DCR = 25.8mΩ



Efficiency vs. Load Current
MPQ4324-1001/0501, FCCM,
V_{OUT} = 3.3V, L = 5.6µH,
DCR = 25.8mΩ



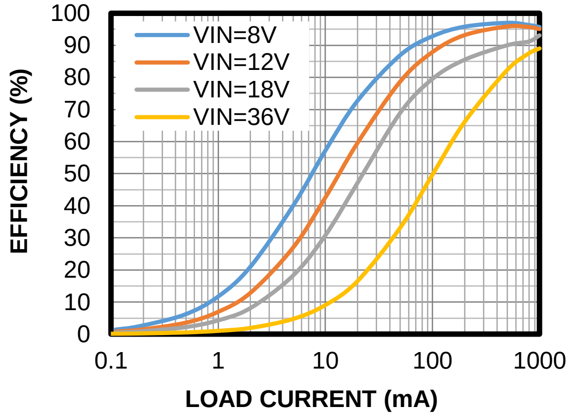
Efficiency vs. Load Current
MPQ4324-1001/0501, FCCM,
V_{OUT} = 3.3V, L = 5.6µH,
DCR = 25.8mΩ



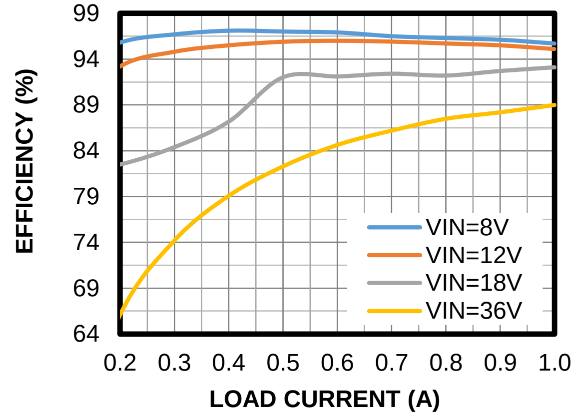
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

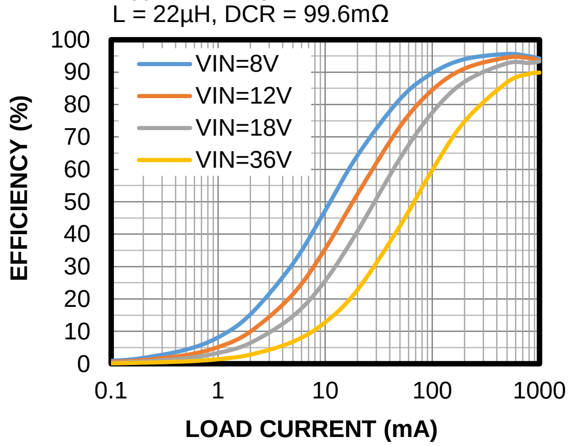
Efficiency vs. Load Current
MPQ4324-1001/0501, FCCM,
f_{SW} = 415kHz, L = 22µH,
DCR = 99.6mΩ



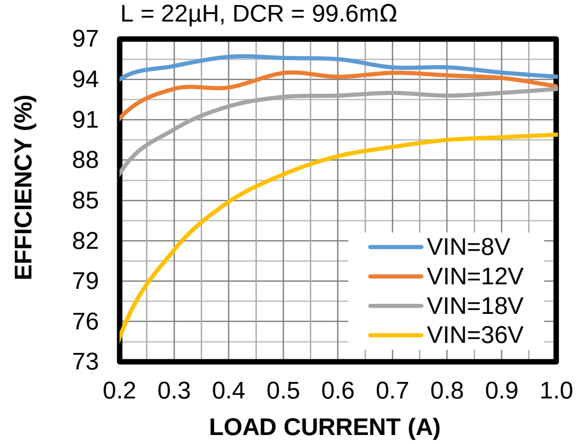
Efficiency vs. Load Current
MPQ4324-1001/0501, FCCM,
f_{SW} = 415kHz, L = 22µH,
DCR = 99.6mΩ



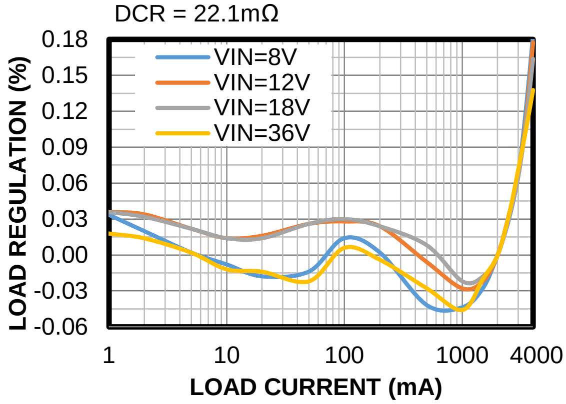
Efficiency vs. Load Current
MPQ4324-1001/0501, FCCM,
V_{OUT} = 3.3V, f_{SW} = 415kHz,
L = 22µH, DCR = 99.6mΩ



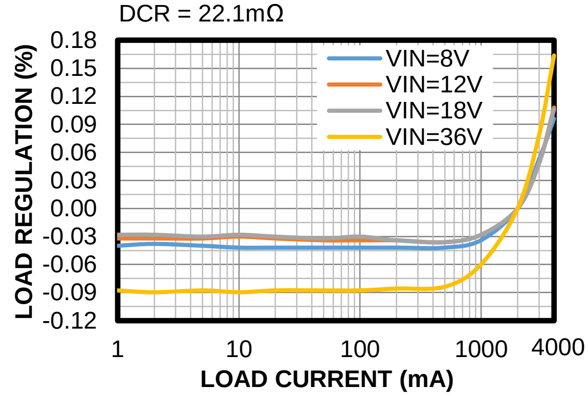
Efficiency vs. Load Current
MPQ4324-1001/0501, FCCM,
V_{OUT} = 3.3V, f_{SW} = 415kHz,
L = 22µH, DCR = 99.6mΩ



Load Regulation
MPQ4324-4000, AAM mode,
DCR = 22.1mΩ



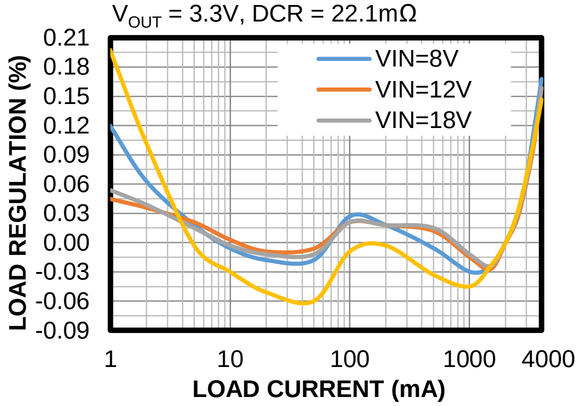
Load Regulation
MPQ4324-4001, FCCM,
DCR = 22.1mΩ



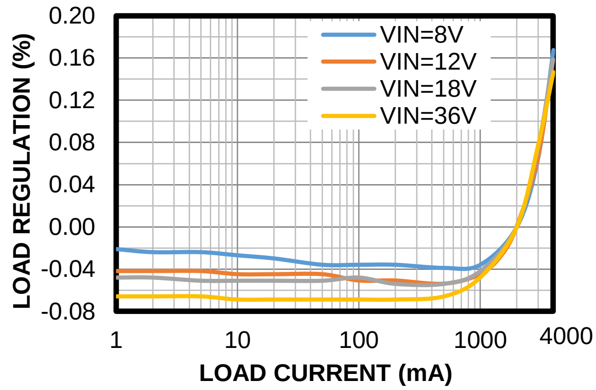
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

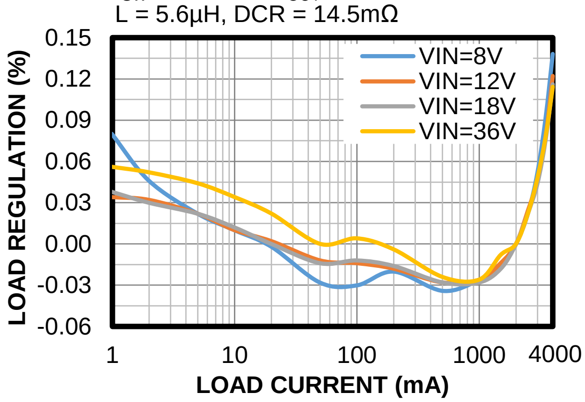
Load Regulation
MPQ4324-4000, AAM mode,
V_{OUT} = 3.3V, DCR = 22.1mΩ



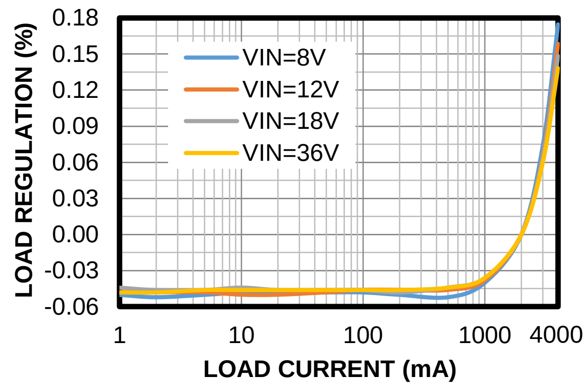
Load Regulation
MPQ4324-4001, FCCM, V_{OUT} = 3.3V,
DCR = 22.1mΩ



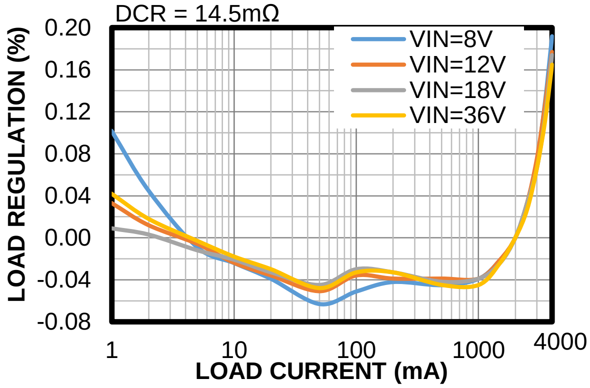
Load Regulation
MPQ4324-4000, AAM mode,
f_{SW} = 415kHz, C_{OUT} = 47µF x 2,
L = 5.6µH, DCR = 14.5mΩ



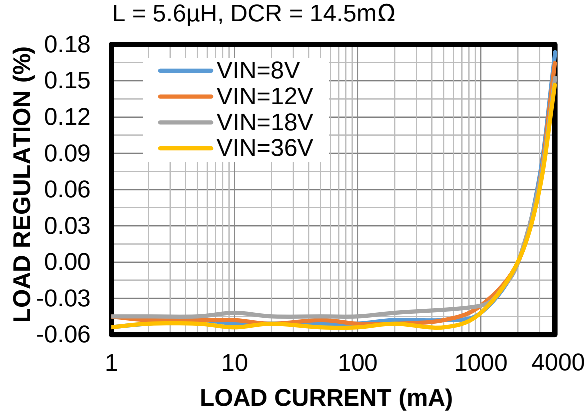
Load Regulation
MPQ4324-4001, FCCM, f_{SW} = 415kHz,
C_{OUT} = 47µF x 2, L = 5.6µH,
DCR = 14.5mΩ



Load Regulation
MPQ4324-4000, AAM mode,
V_{OUT} = 3.3V, f_{SW} = 415kHz,
C_{OUT} = 47µF x 2, L = 5.6µH,
DCR = 14.5mΩ



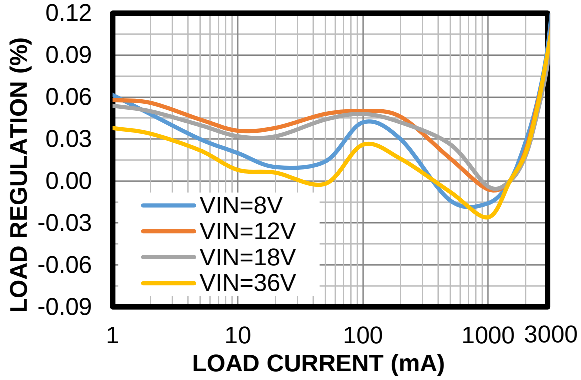
Load Regulation
MPQ4324-4001, FCCM, V_{OUT} = 3.3V,
f_{SW} = 415kHz, C_{OUT} = 47µF x 2,
L = 5.6µH, DCR = 14.5mΩ



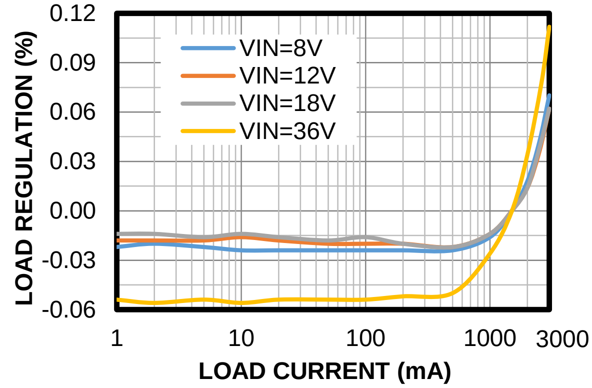
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

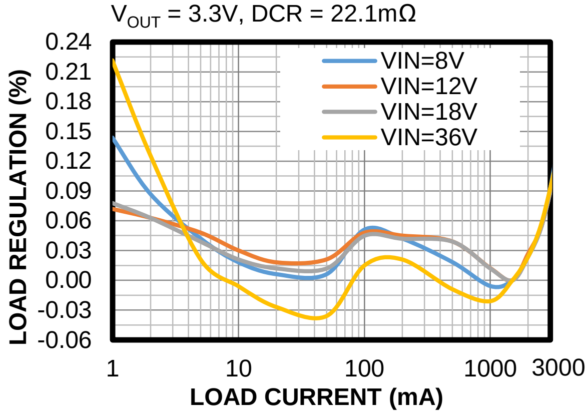
Load Regulation
MPQ4324-3000, AAM mode,
DCR = 22.1mΩ



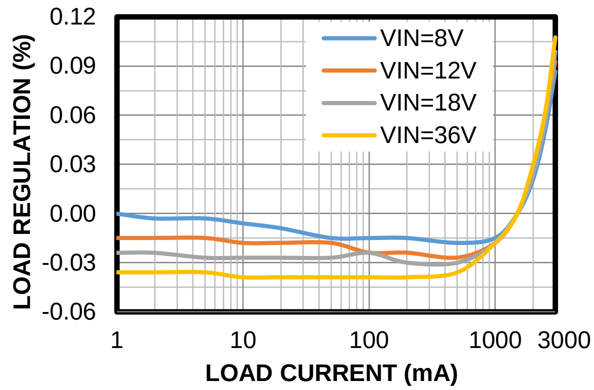
Load Regulation
MPQ4324-3001, FCCM,
DCR = 22.1mΩ



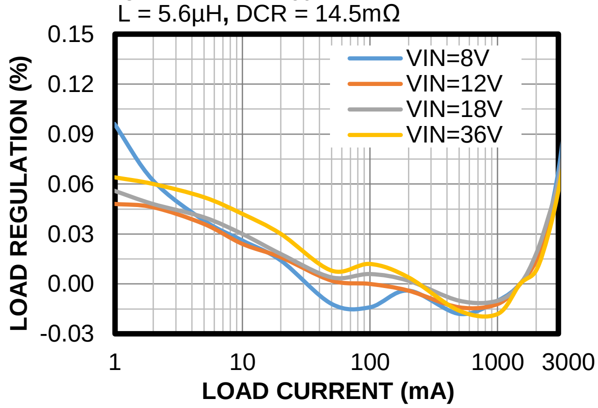
Load Regulation
MPQ4324-3000, AAM mode,
V_{OUT} = 3.3V, DCR = 22.1mΩ



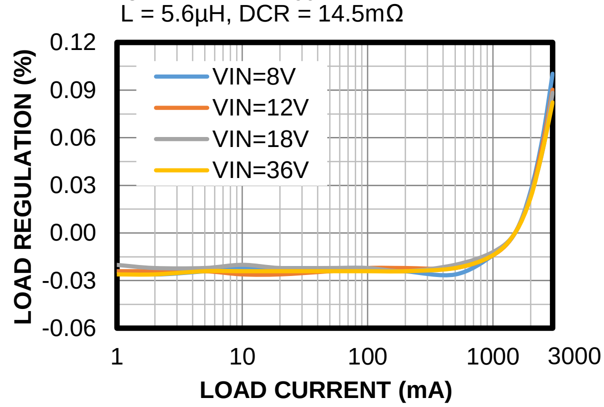
Load Regulation
MPQ4324-3001, FCCM, V_{OUT} = 3.3V,
DCR = 22.1mΩ



Load Regulation
MPQ4324-3000, AAM mode,
f_{SW} = 415kHz, C_{OUT} = 47µF x 2,
L = 5.6µH, DCR = 14.5mΩ



Load Regulation
MPQ4324-3001, FCCM,
f_{SW} = 415kHz, C_{OUT} = 47µF x 2,
L = 5.6µH, DCR = 14.5mΩ

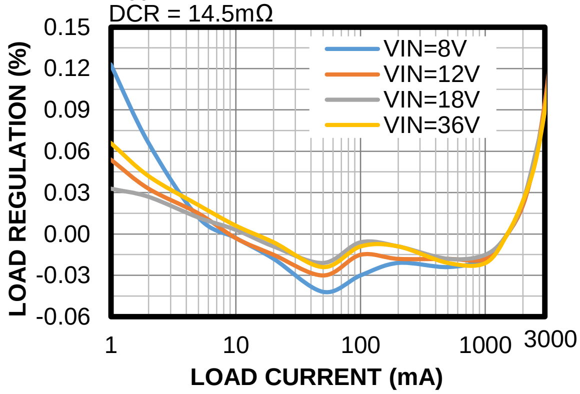


TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

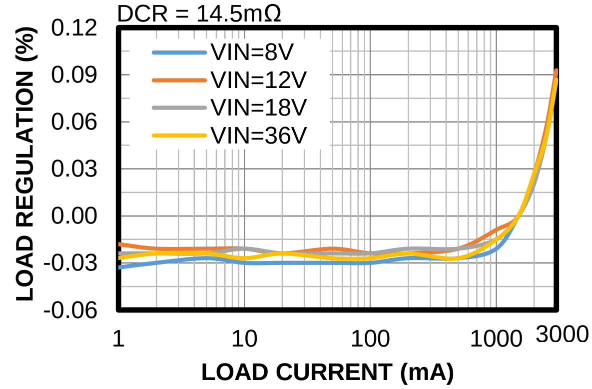
Load Regulation

MPQ4324-3000, AAM mode,
V_{OUT} = 3.3V, f_{SW} = 415kHz,
C_{OUT}= 47µF x 2, L = 5.6µH,
DCR = 14.5mΩ



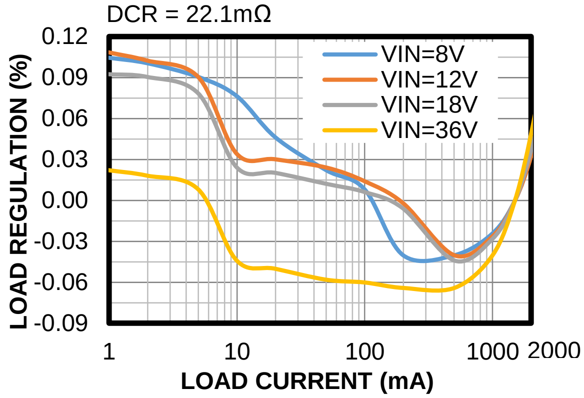
Load Regulation

MPQ4324-3001, FCCM,
V_{OUT} = 3.3V, f_{SW} = 415kHz,
C_{OUT}= 47µF x 2, L = 5.6µH,
DCR = 14.5mΩ



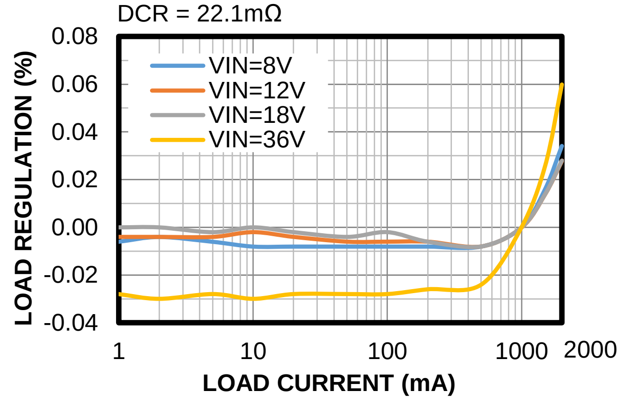
Load Regulation

MPQ4324-2000, AAM mode,
DCR = 22.1mΩ



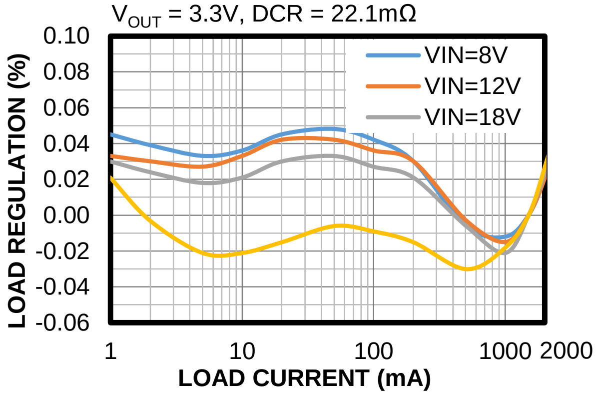
Load Regulation

MPQ4324-2001, FCCM,
DCR = 22.1mΩ



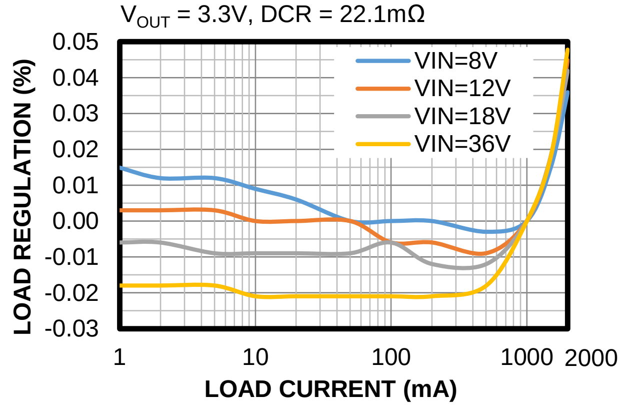
Load Regulation

MPQ4324-2000, AAM mode,
V_{OUT} = 3.3V, DCR = 22.1mΩ



Load Regulation

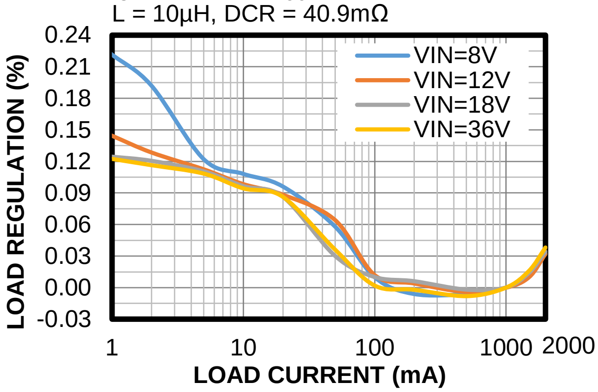
MPQ4324-2001, FCCM,
V_{OUT} = 3.3V, DCR = 22.1mΩ



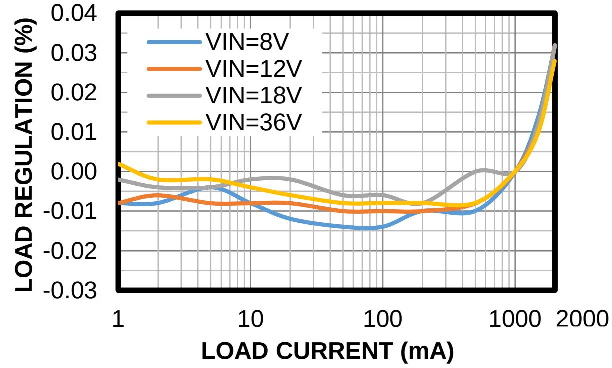
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

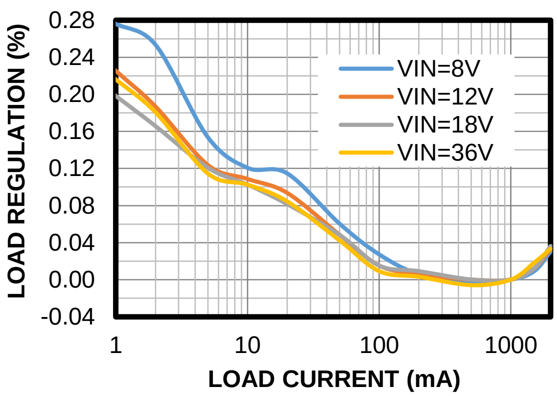
Load Regulation
MPQ4324-2000, AAM mode,
f_{SW} = 415kHz, C_{OUT} = 47µF x 2,
L = 10µH, DCR = 40.9mΩ



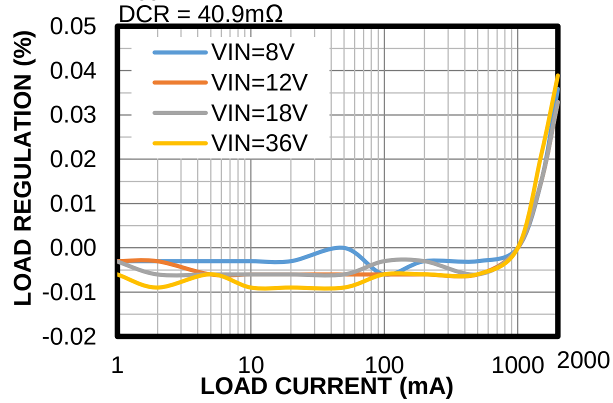
Load Regulation
MPQ4324-2001, FCCM,
f_{SW} = 415kHz, C_{OUT} = 47µF x 2,
L = 10µH, DCR = 40.9mΩ



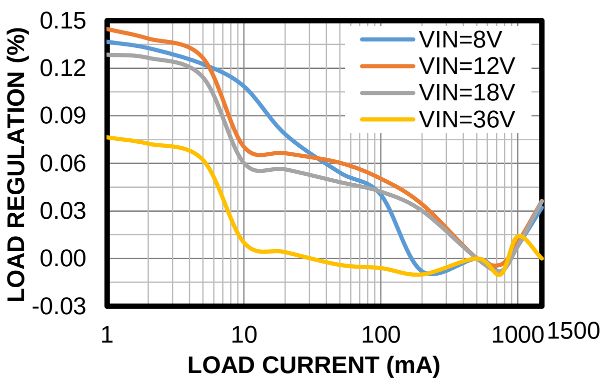
Load Regulation
MPQ4324-2000, AAM mode,
V_{OUT} = 3.3V, f_{SW} = 415kHz,
C_{OUT} = 47µF x 2, L = 10µH,
DCR = 40.9mΩ



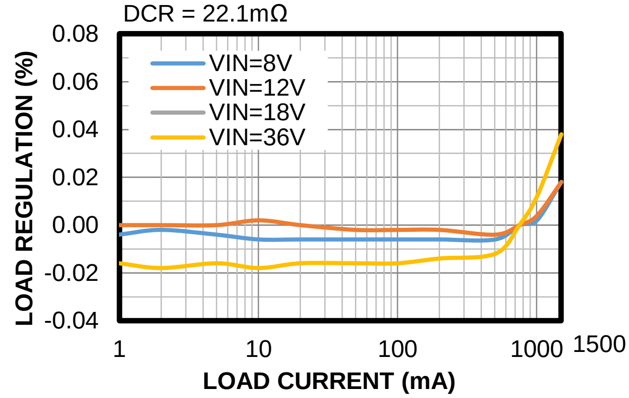
Load Regulation
MPQ4324-2001, FCCM,
V_{OUT} = 3.3V, f_{SW} = 415kHz,
C_{OUT} = 47µF x 2, L = 10µH,
DCR = 40.9mΩ



Load Regulation
MPQ4324-1500, AAM mode,
DCR = 22.1mΩ



Load Regulation
MPQ4324-1501, FCCM,
DCR = 22.1mΩ

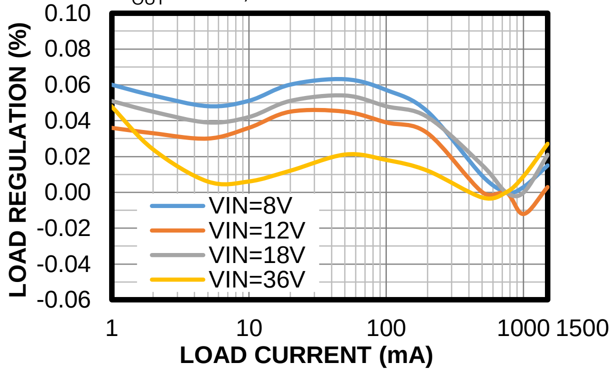


TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

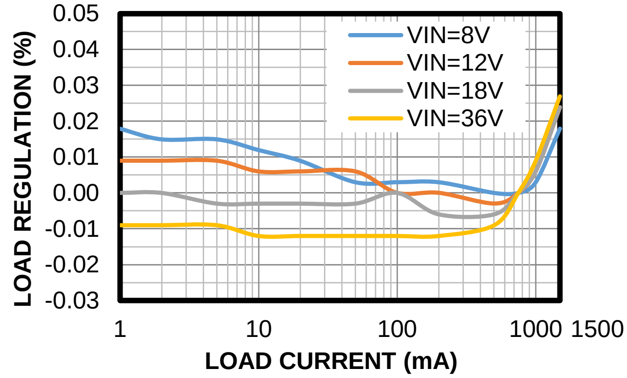
Load Regulation

MPQ4324-1500, AAM mode,
V_{OUT} = 3.3V, DCR = 22.1mΩ



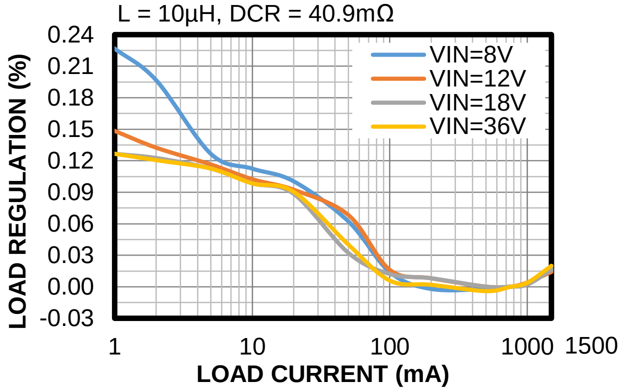
Load Regulation

MPQ4324-1501, FCCM,
V_{OUT} = 3.3V, DCR = 22.1mΩ



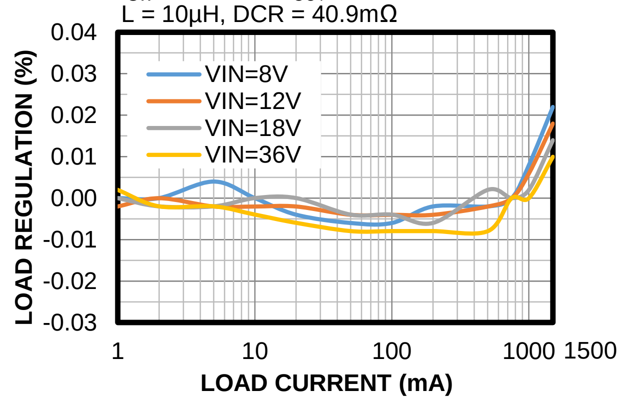
Load Regulation

MPQ4324-1500, AAM mode,
f_{SW} = 415kHz, C_{OUT} = 47µF x 2,
L = 10µH, DCR = 40.9mΩ



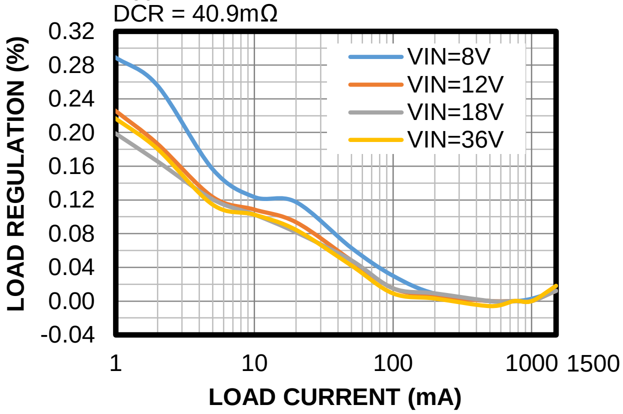
Load Regulation

MPQ4324-1501, FCCM,
f_{SW} = 415kHz, C_{OUT} = 47µF x 2,
L = 10µH, DCR = 40.9mΩ



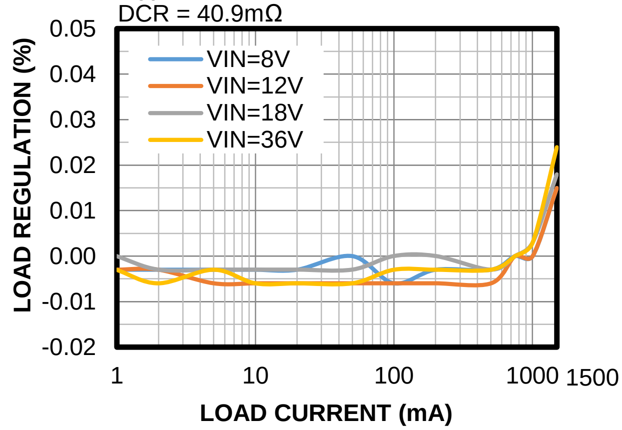
Load Regulation

MPQ4324-1500, AAM mode,
V_{OUT} = 3.3V, f_{SW} = 415kHz,
C_{OUT} = 47µF x 2, L = 10µH,
DCR = 40.9mΩ



Load Regulation

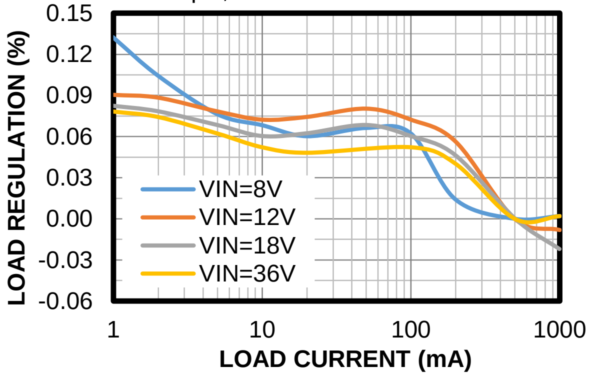
MPQ4324-1501, FCCM,
V_{OUT} = 3.3V, f_{SW} = 415kHz,
C_{OUT} = 47µF x 2, L = 10µH,
DCR = 40.9mΩ



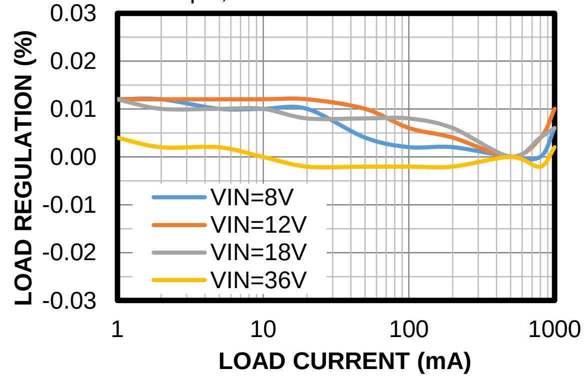
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

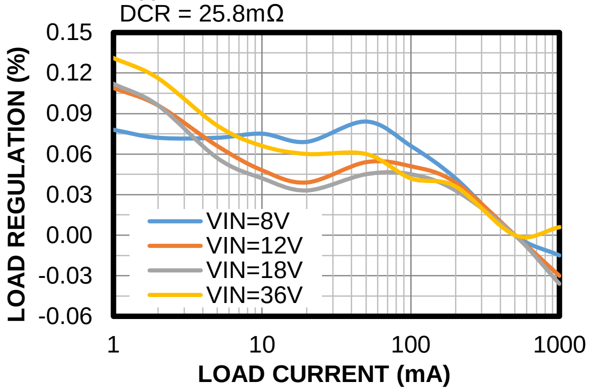
Load Regulation
MPQ4324-1000, AAM mode,
L = 5.6µH, DCR = 25.8mΩ



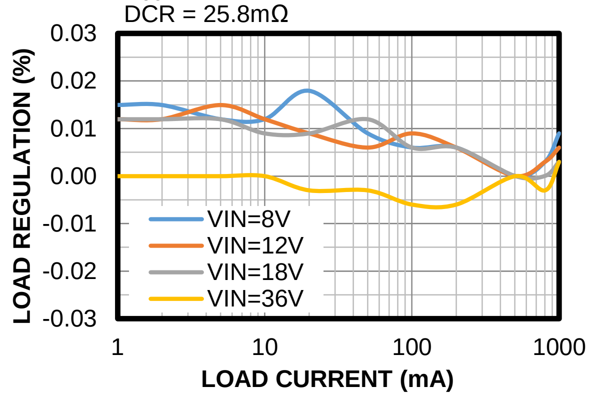
Load Regulation
MPQ4324-1001, FCCM,
L = 5.6µH, DCR = 25.8mΩ



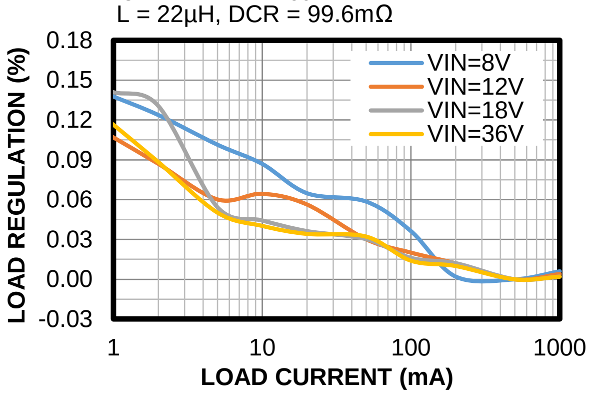
Load Regulation
MPQ4324-1000, AAM mode,
V_{OUT} = 3.3V, L = 5.6µH,
DCR = 25.8mΩ



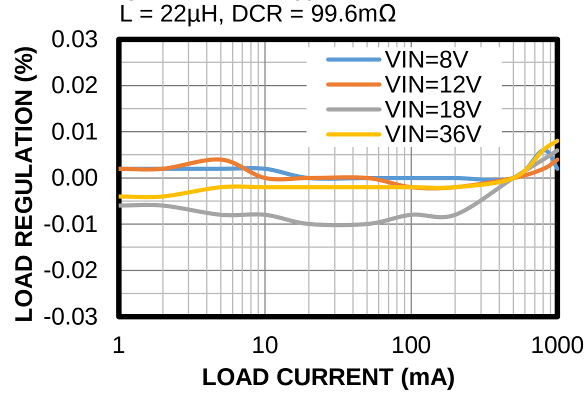
Load Regulation
MPQ4324-1001, FCCM,
V_{OUT} = 3.3V, L = 5.6µH,
DCR = 25.8mΩ



Load Regulation
MPQ4324-1000, AAM mode,
f_{SW} = 415kHz, C_{OUT} = 47µF x 2,
L = 22µH, DCR = 99.6mΩ



Load Regulation
MPQ4324-1001, FCCM,
f_{SW} = 415kHz, C_{OUT} = 47µF x 2,
L = 22µH, DCR = 99.6mΩ

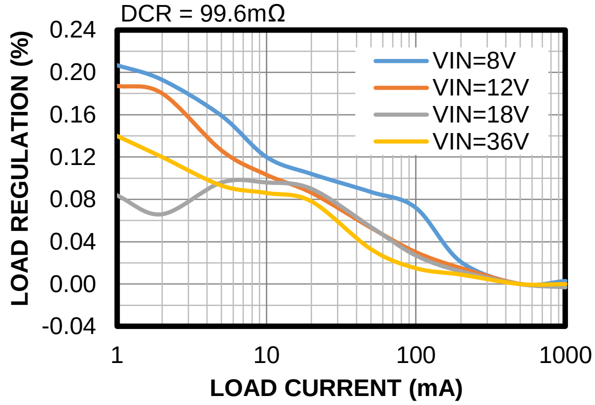


TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

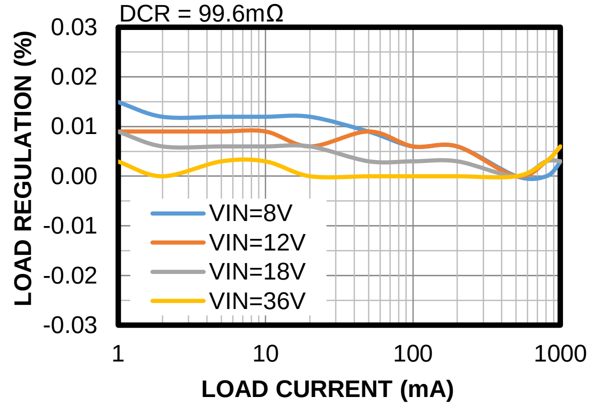
Load Regulation

MPQ4324-1000, AAM mode,
V_{OUT} = 3.3V, f_{SW} = 415kHz,
C_{OUT} = 47µF x 2, L = 22µH,
DCR = 99.6mΩ



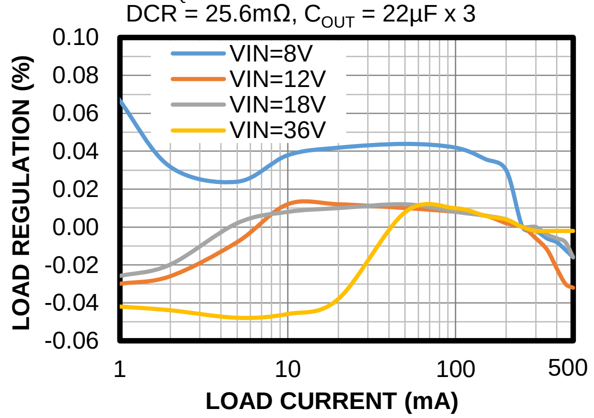
Load Regulation

MPQ4324-1001, FCCM,
V_{OUT} = 3.3V, f_{SW} = 415kHz,
C_{OUT} = 47µF x 2, L = 22µH,
DCR = 99.6mΩ



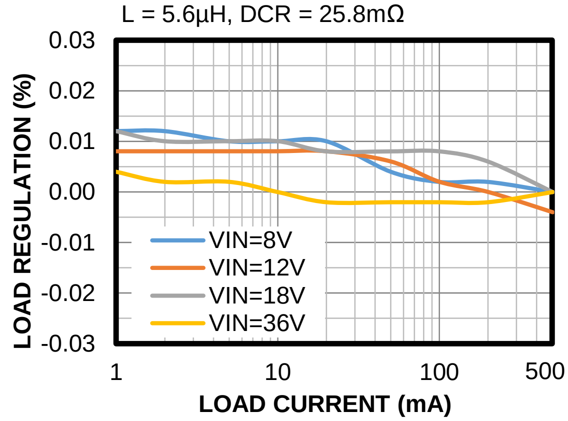
Load Regulation

MPQ4324-0500, AAM mode,
R_{FREQ} = 15kΩ, L = 5.6µH,
DCR = 25.6mΩ, C_{OUT} = 22µF x 3



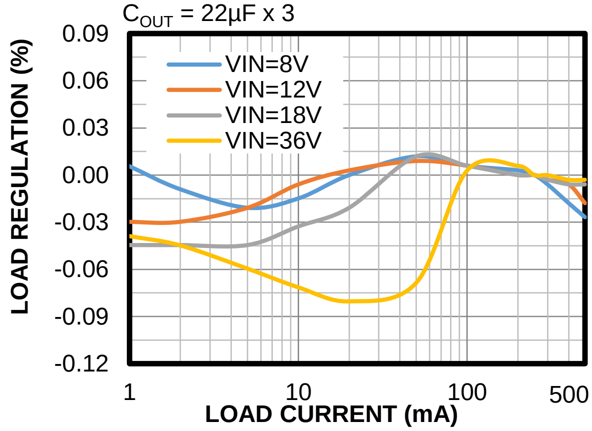
Load Regulation

MPQ4324-0501, FCCM,
L = 5.6µH, DCR = 25.8mΩ



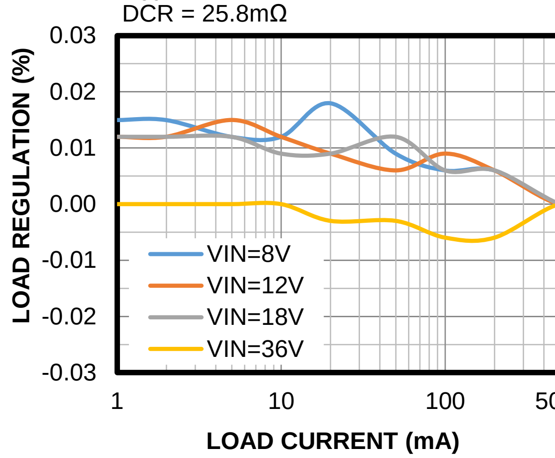
Load Regulation

MPQ4324-0500, AAM mode,
R_{FREQ} = 15kΩ, V_{OUT} = 3.3V,
L = 5.6µH, DCR = 25.6mΩ,
C_{OUT} = 22µF x 3



Load Regulation

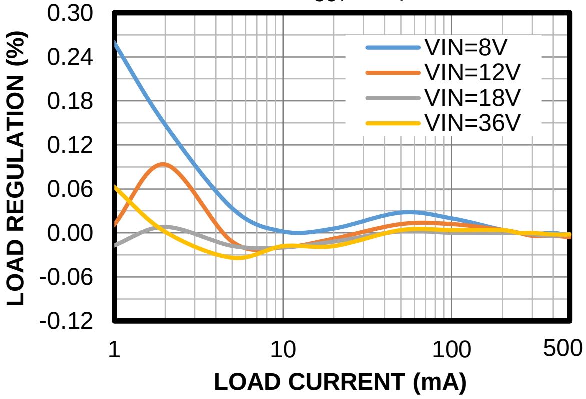
MPQ4324-0501, FCCM,
V_{OUT} = 3.3V, L = 5.6µH,
DCR = 25.8mΩ



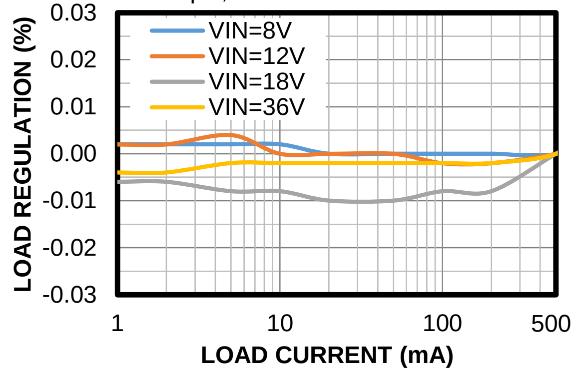
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

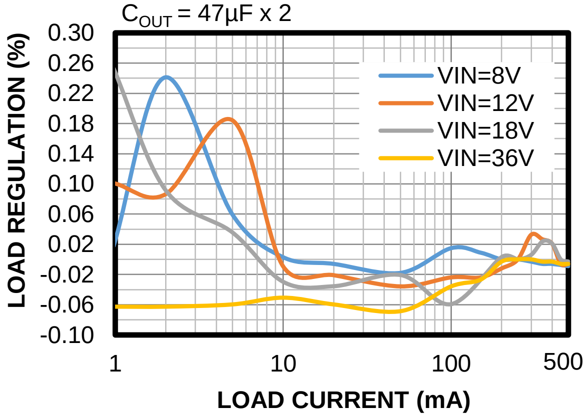
Load Regulation
MPQ4324-0500, AAM mode,
R_{FREQ} = 86.6kΩ, L = 22µH,
DCR = 99.6mΩ, C_{OUT} = 47µF x 2



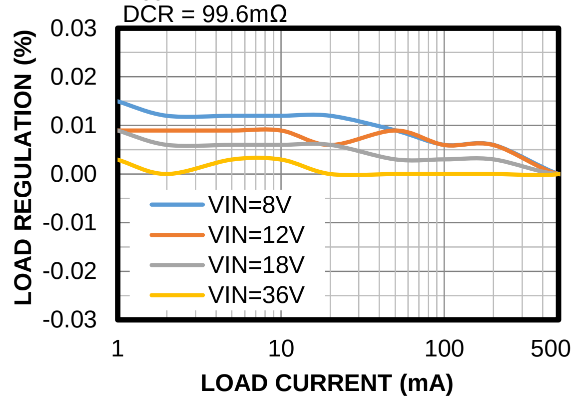
Load Regulation
MPQ4324-0501, FCCM,
f_{SW} = 415kHz, C_{OUT} = 47µF x 2,
L = 22µH, DCR = 99.6mΩ



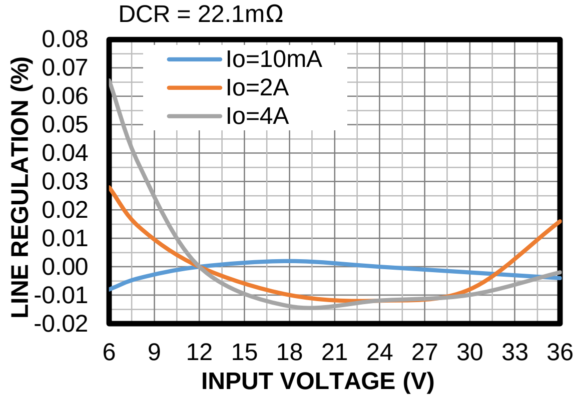
Load Regulation
MPQ4324-0500, AAM mode,
V_{OUT} = 3.3V, R_{FREQ} = 86.6kΩ,
L = 22µH, DCR = 99.6mΩ,
C_{OUT} = 47µF x 2



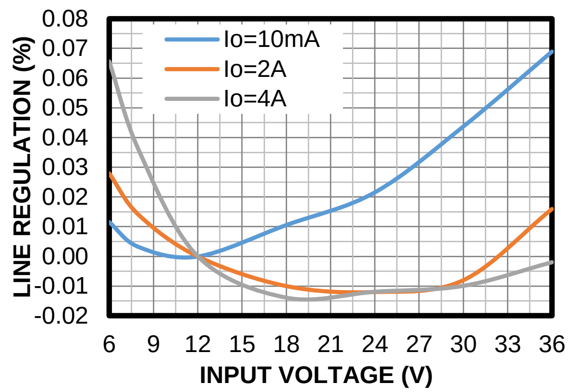
Load Regulation
MPQ4324-0501, FCCM,
V_{OUT} = 3.3V, f_{SW} = 415kHz,
C_{OUT} = 47µF x 2, L = 22µH,
DCR = 99.6mΩ



Line Regulation
MPQ4324-4000, AAM mode,
DCR = 22.1mΩ



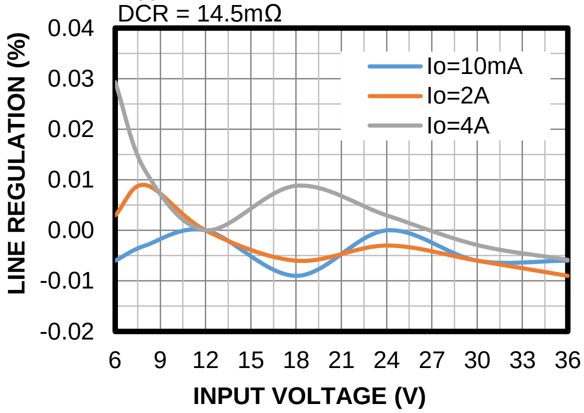
Line Regulation
MPQ4324-4001, FCCM,
DCR = 22.1mΩ



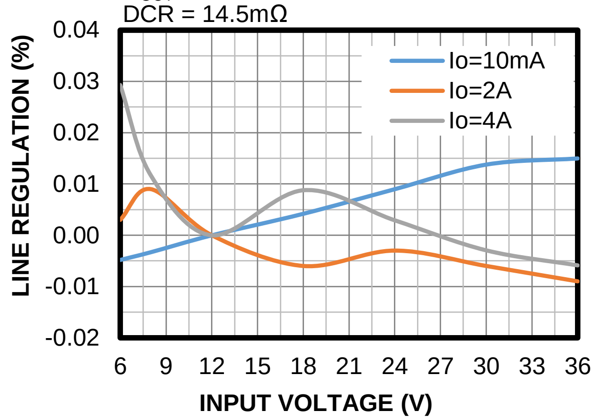
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

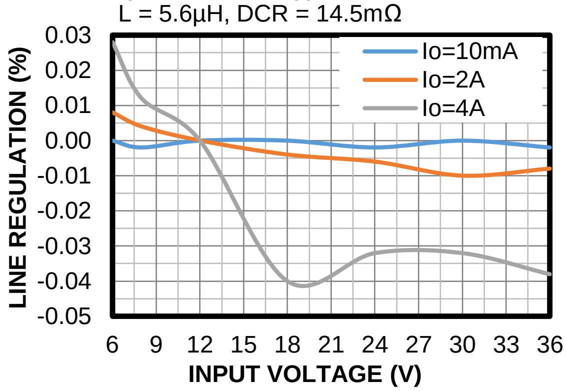
Line Regulation
MPQ4324-4000, AAM mode,
V_{OUT} = 3.3V, f_{SW} = 415kHz,
C_{OUT} = 47µFx 2, L = 5.6µH,
DCR = 14.5mΩ



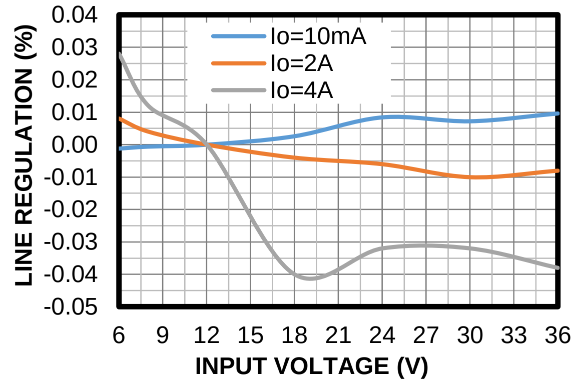
Line Regulation
MPQ4324-4001, FCCM,
V_{OUT} = 3.3V, f_{SW} = 415kHz,
C_{OUT}= 47µF x 2, L = 5.6µH,
DCR = 14.5mΩ



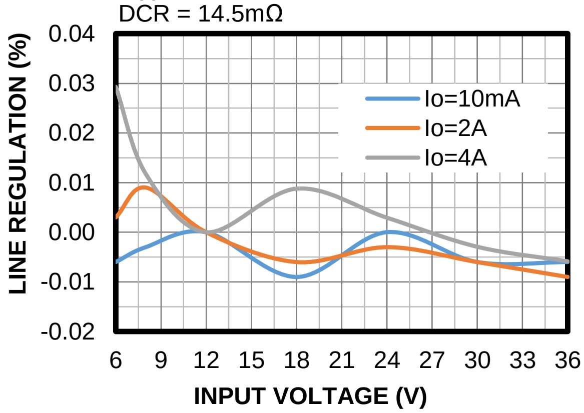
Line Regulation
MPQ4324-4000, AAM mode,
f_{SW} = 415kHz, C_{OUT} = 47µF x 2,
L = 5.6µH, DCR = 14.5mΩ



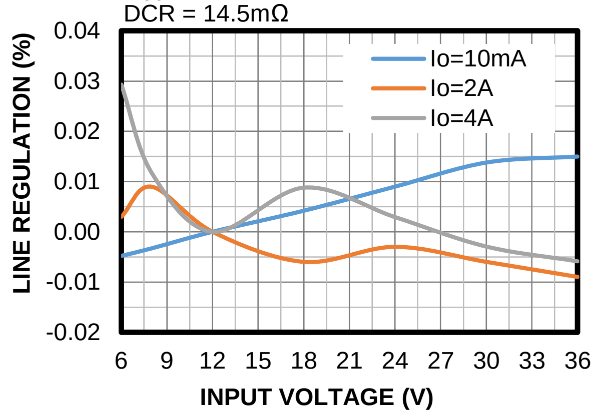
Line Regulation
MPQ4324-4001, FCCM,
f_{SW} = 415kHz, C_{OUT} = 47µF x 2,
L = 5.6µH, DCR = 14.5mΩ



Line Regulation
MPQ4324-4000, AAM mode,
V_{OUT} = 3.3V, f_{SW} = 415kHz,
C_{OUT} = 47µFx 2, L = 5.6µH,
DCR = 14.5mΩ



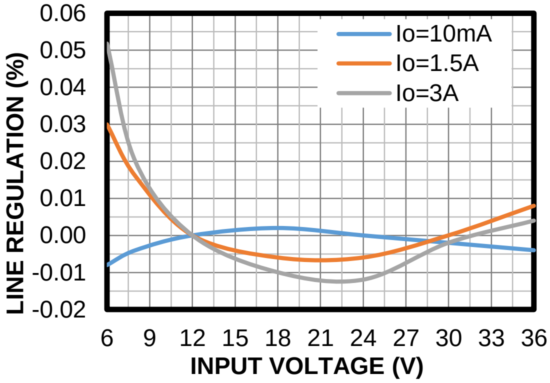
Line Regulation
MPQ4324-4001, FCCM,
V_{OUT} = 3.3V, f_{SW} = 415kHz,
C_{OUT}= 47µF x 2, L = 5.6µH,
DCR = 14.5mΩ



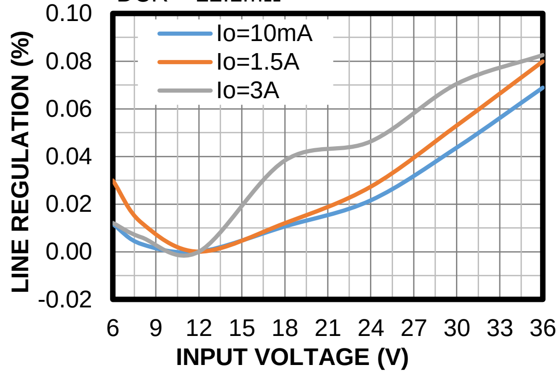
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

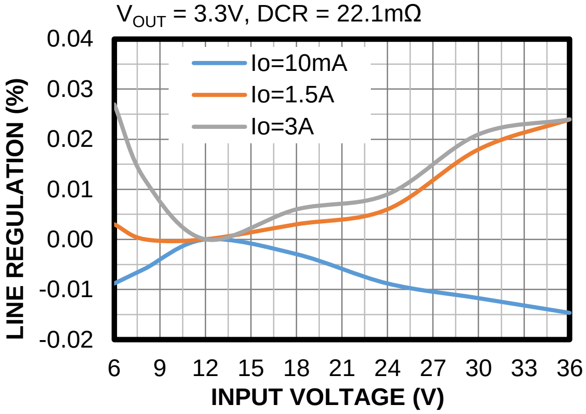
Line Regulation
MPQ4324-3000, AAM mode,
DCR = 22.1mΩ



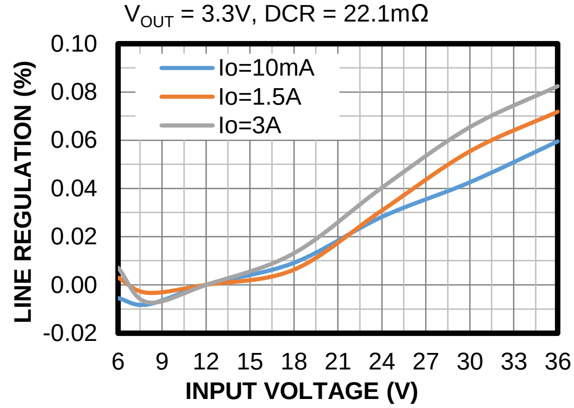
Line Regulation
MPQ4324-3001, FCCM,
DCR = 22.1mΩ



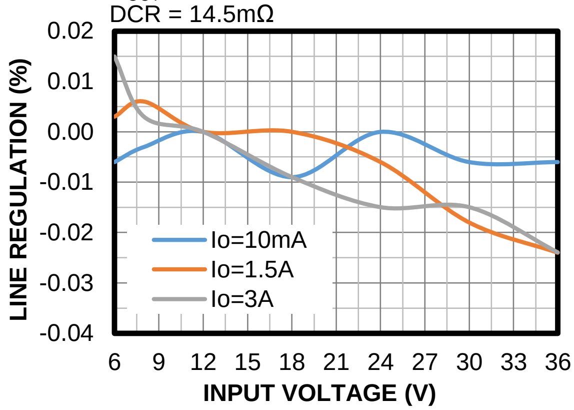
Line Regulation
MPQ4324-3000, AAM mode,
V_{OUT} = 3.3V, DCR = 22.1mΩ



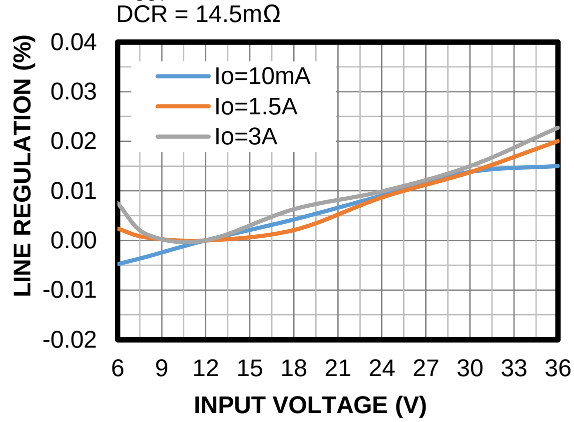
Line Regulation
MPQ4324-3001, FCCM,
V_{OUT} = 3.3V, DCR = 22.1mΩ



Line Regulation
MPQ4324-3000, AAM mode,
V_{OUT} = 3.3V, f_{SW} = 415kHz,
C_{OUT}= 47µF x 2, L = 5.6µH,
DCR = 14.5mΩ



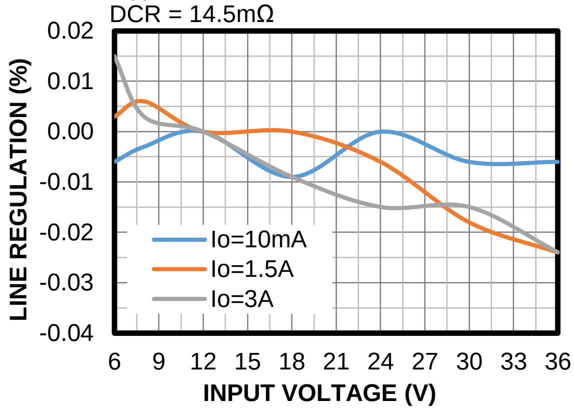
Line Regulation
MPQ4324-3001, FCCM,
V_{OUT} = 3.3V, f_{SW} = 415kHz,
C_{OUT} = 47µF x 2, L = 5.6µH,
DCR = 14.5mΩ



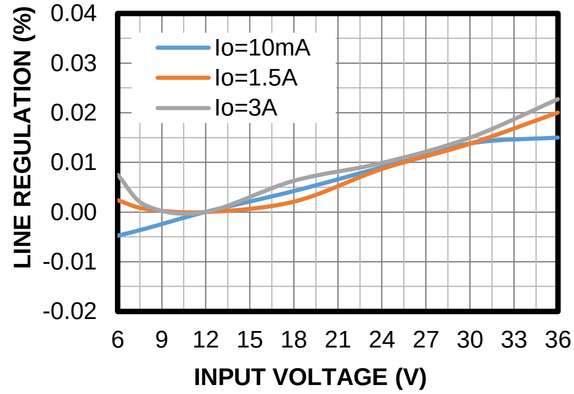
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2μH, C_{OUT} = 22μF x 2, T_A = 25°C, unless otherwise noted.

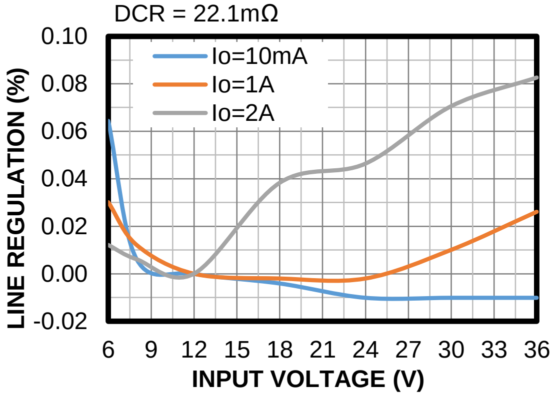
Line Regulation
MPQ4324-3000, AAM mode,
V_{OUT} = 3.3V, f_{SW} = 415kHz,
C_{OUT}= 47μF x 2, L = 5.6μH,
DCR = 14.5mΩ



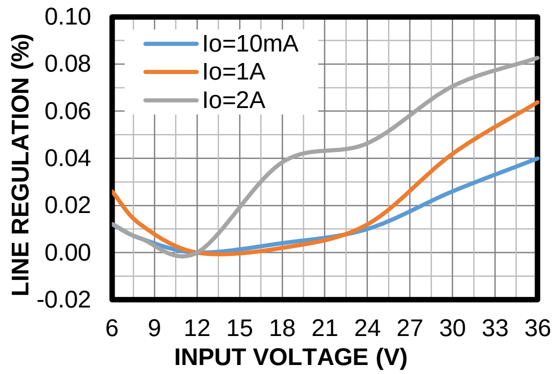
Line Regulation
MPQ4324-3001, FCCM,
V_{OUT} = 3.3V, f_{SW} = 415kHz,
C_{OUT} = 47μF x 2, L = 5.6μH,
DCR = 14.5mΩ



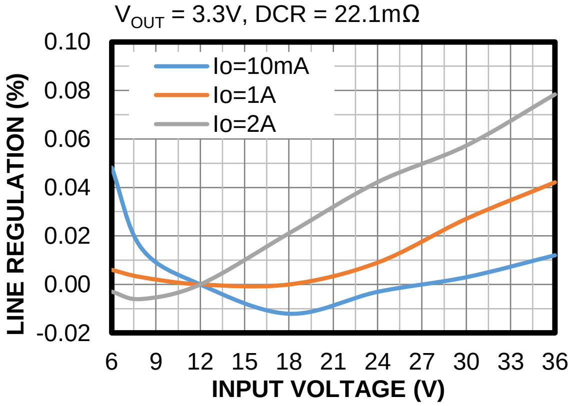
Line Regulation
MPQ4324-2000, AAM mode,
DCR = 22.1mΩ



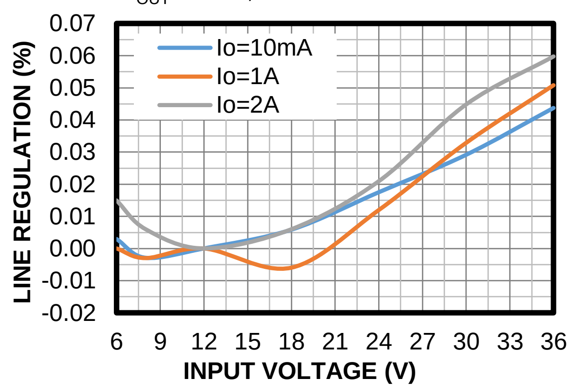
Line Regulation
MPQ4324-2001, FCCM,
DCR = 22.1mΩ



Line Regulation
MPQ4324-2000, AAM mode,
V_{OUT} = 3.3V, DCR = 22.1mΩ



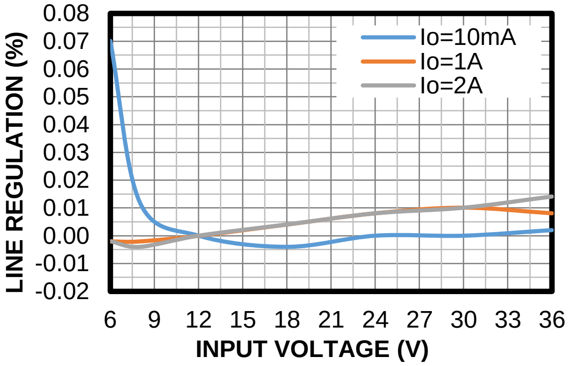
Line Regulation
MPQ4324-2001, FCCM,
V_{OUT} = 3.3V, DCR = 22.1mΩ



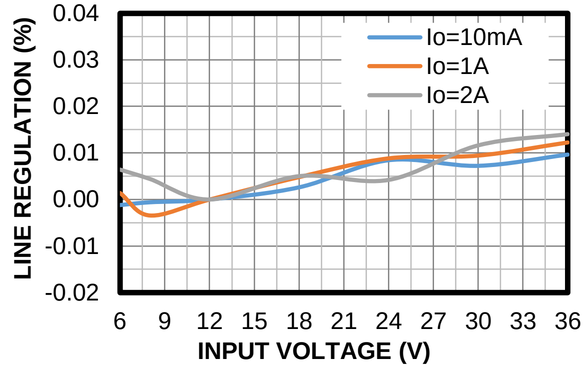
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

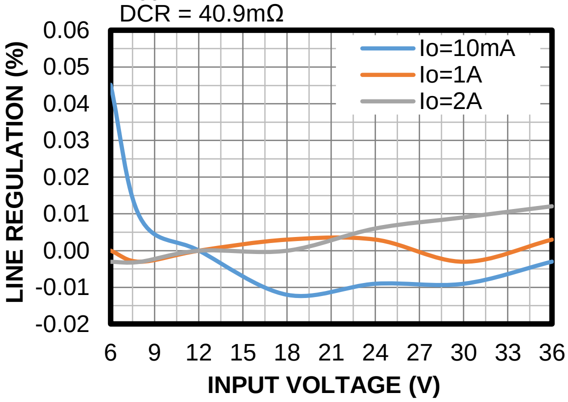
Line Regulation
MPQ4324-2000, AAM mode,
f_{SW} = 415kHz, C_{OUT} = 47µF x 2,
L = 10µH, DCR = 40.9mΩ



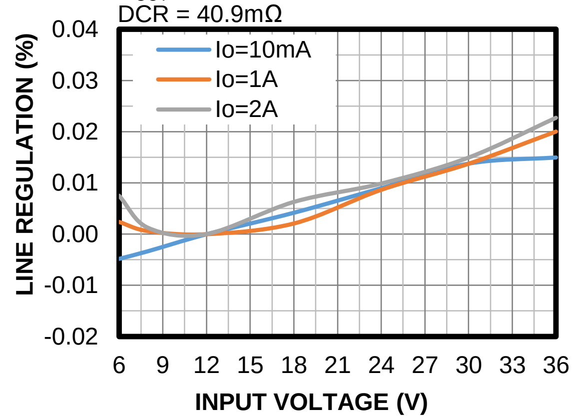
Line Regulation
MPQ4324-2001, FCCM,
f_{SW} = 415kHz, C_{OUT} = 47µF x 2,
L = 10µH, DCR = 40.9mΩ



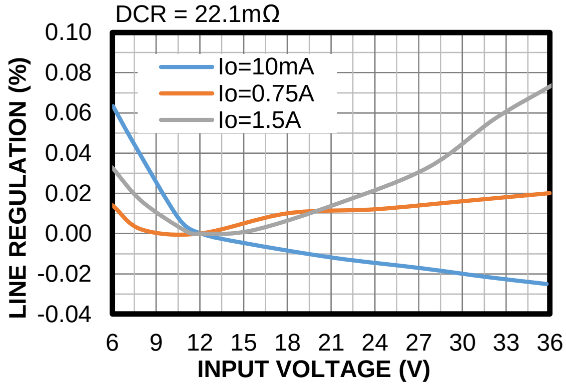
Line Regulation
MPQ4324-2000, AAM mode,
V_{OUT} = 3.3V, f_{SW} = 415kHz,
C_{OUT} = 47µF x 2, L = 10µH,
DCR = 40.9mΩ



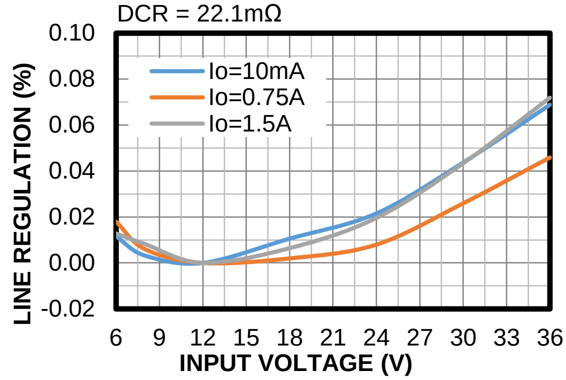
Line Regulation
MPQ4324-2001, FCCM,
V_{OUT} = 3.3V, f_{SW} = 415kHz,
C_{OUT} = 47µF x 2, L = 10µH,
DCR = 40.9mΩ



Line Regulation
MPQ4324-1500, AAM mode,
DCR = 22.1mΩ



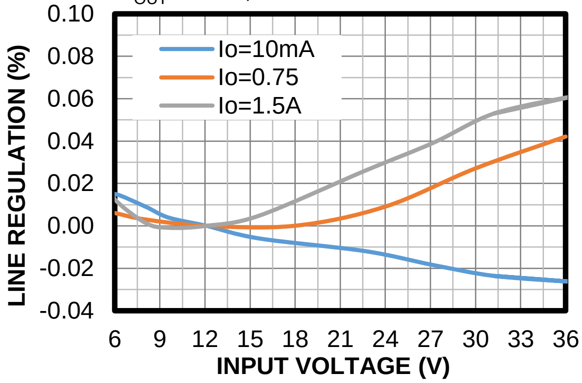
Line Regulation
MPQ4324-1501, FCCM,
DCR = 22.1mΩ



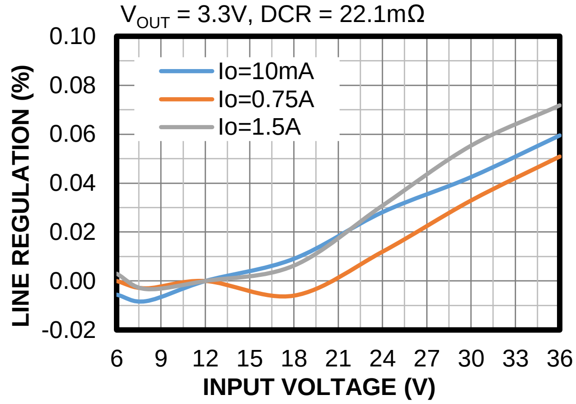
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

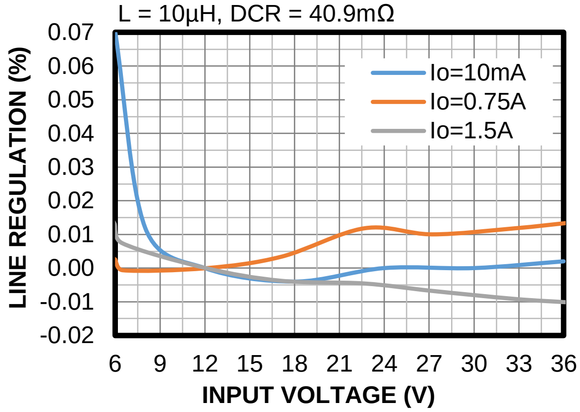
Line Regulation
MPQ4324-1500, AAM mode,
V_{OUT} = 3.3V, DCR = 22.1mΩ



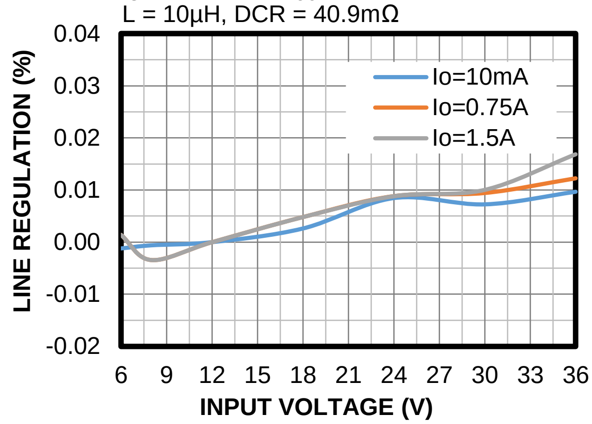
Line Regulation
MPQ4324-1501, FCCM,
V_{OUT} = 3.3V, DCR = 22.1mΩ



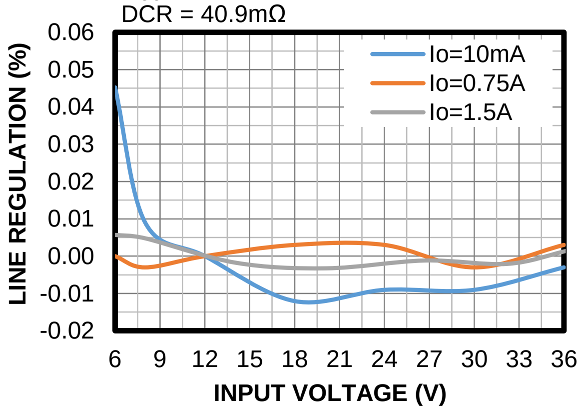
Line Regulation
MPQ4324-1500, AAM mode,
f_{SW} = 415kHz, C_{OUT} = 47µF x 2,
L = 10µH, DCR = 40.9mΩ



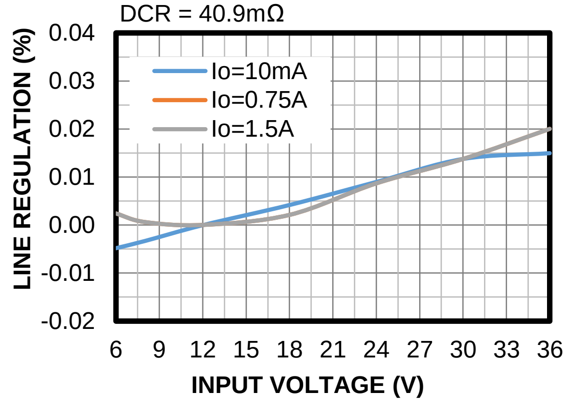
Line Regulation
MPQ4324-1501, FCCM,
f_{SW} = 415kHz, C_{OUT} = 47µF x 2,
L = 10µH, DCR = 40.9mΩ



Line Regulation
MPQ4324-1500, AAM mode,
V_{OUT} = 3.3V, f_{SW} = 415kHz,
C_{OUT} = 47µF x 2, L = 10µH,
DCR = 40.9mΩ



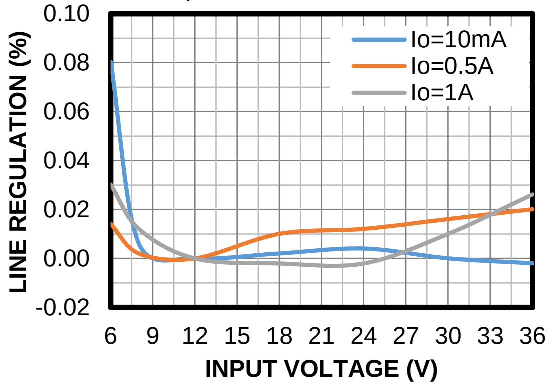
Line Regulation
MPQ4324-1501, FCCM,
V_{OUT} = 3.3V, f_{SW} = 415kHz,
C_{OUT} = 47µF x 2, L = 10µH,
DCR = 40.9mΩ



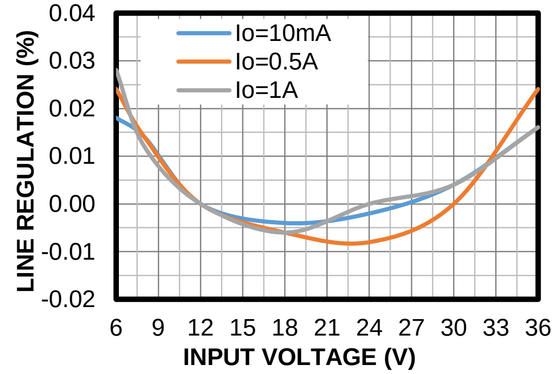
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

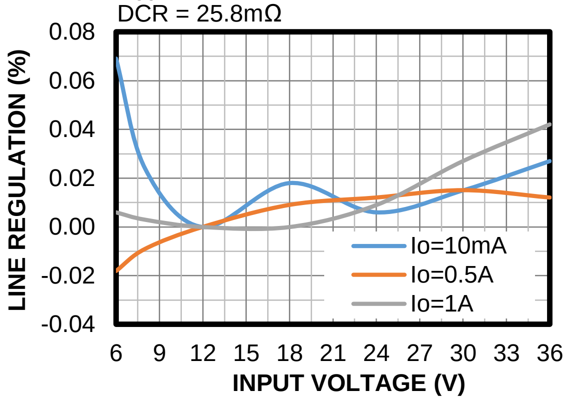
Line Regulation
MPQ4324-1000, AAM mode,
L = 5.6µH, DCR = 25.8mΩ



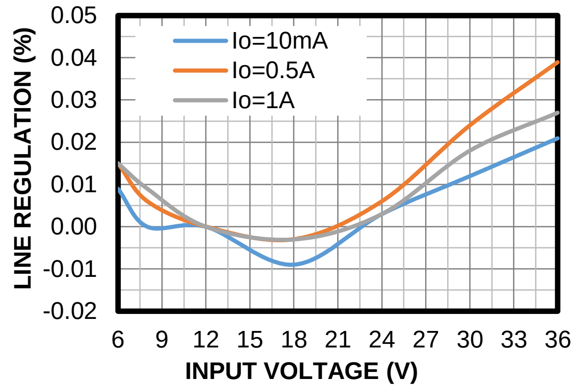
Line Regulation
MPQ4324-1001, FCCM, L = 5.6µH,
DCR = 25.8mΩ



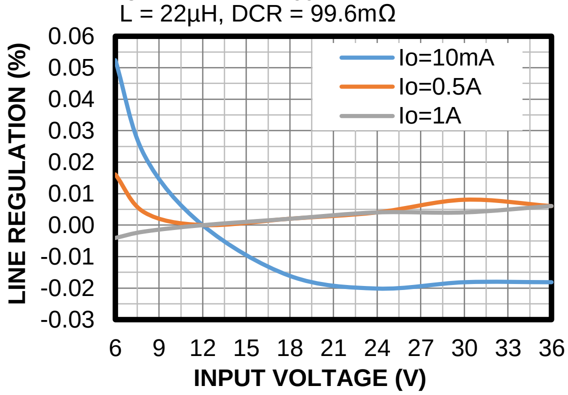
Line Regulation
MPQ4324-1000, AAM mode,
V_{OUT} = 3.3V, L = 5.6µH,
DCR = 25.8mΩ



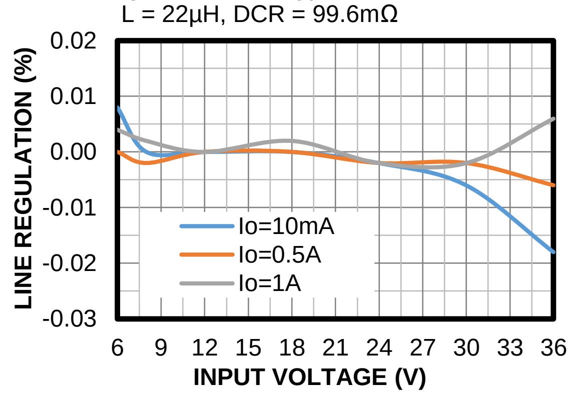
Line Regulation
MPQ4324-1001, FCCM,
V_{OUT} = 3.3V, L = 5.6µH,
DCR = 25.8mΩ



Line Regulation
MPQ4324-1000, AAM mode,
f_{SW} = 415kHz, C_{OUT} = 47µF x 2,
L = 22µH, DCR = 99.6mΩ



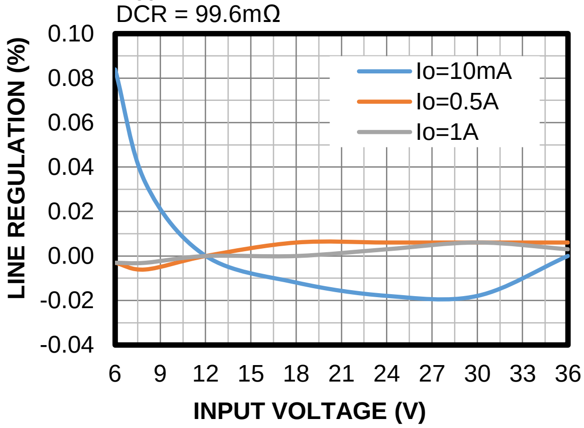
Line Regulation
MPQ4324-1001, FCCM,
f_{SW} = 415kHz, C_{OUT} = 47µF x 2,
L = 22µH, DCR = 99.6mΩ



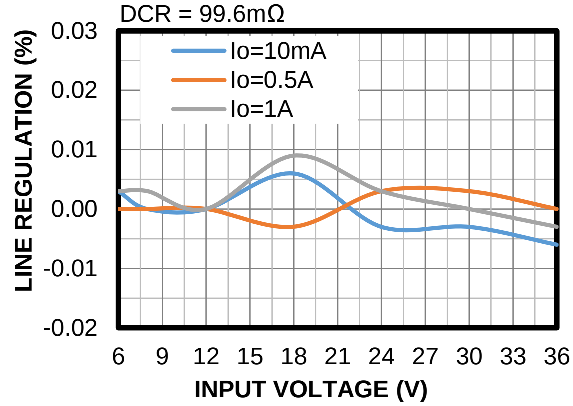
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

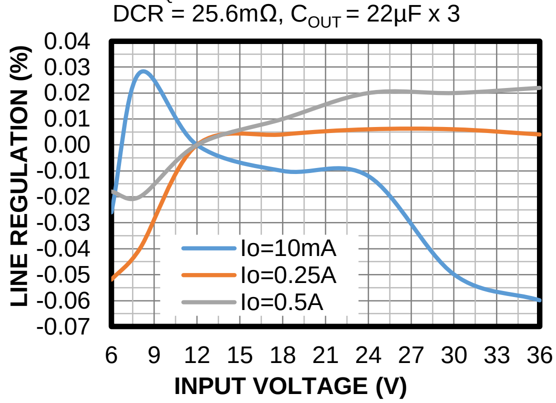
Line Regulation
MPQ4324-1000, AAM mode,
V_{OUT} = 3.3V, f_{SW} = 415kHz,
C_{OUT} = 47µF x 2, L = 22µH,
DCR = 99.6mΩ



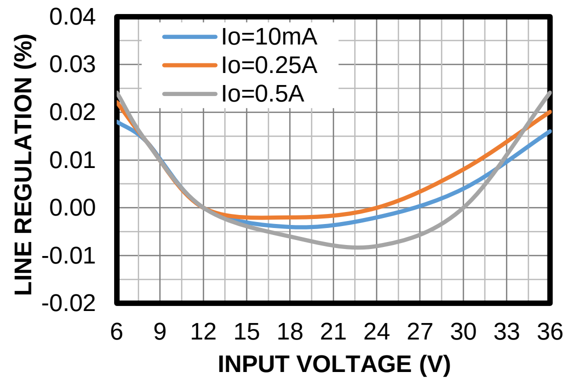
Line Regulation
MPQ4324-1001, FCCM,
V_{OUT} = 3.3V, f_{SW} = 415kHz,
C_{OUT} = 47µF x 2, L = 22µH,
DCR = 99.6mΩ



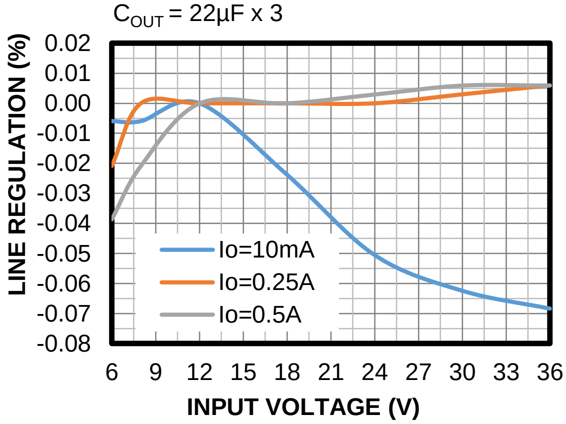
Line Regulation
MPQ4324-0500, AAM mode,
R_{FREQ} = 15kΩ, L = 5.6µH,
DCR = 25.6mΩ, C_{OUT} = 22µF x 3



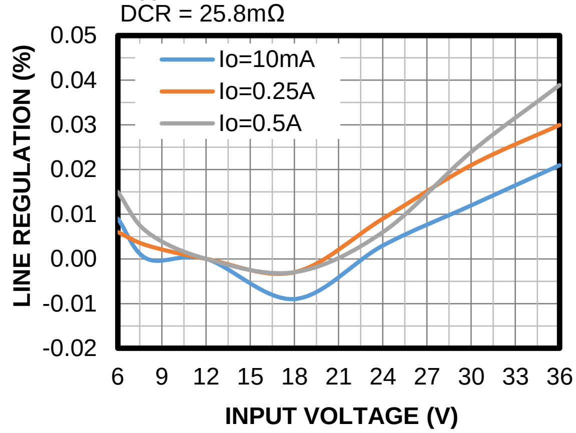
Line Regulation
MPQ4324-0501, FCCM, L = 5.6µH,
DCR = 25.8mΩ



Line Regulation
MPQ4324-0500, AAM mode,
R_{FREQ} = 15kΩ, V_{OUT} = 3.3V,
L = 5.6µH, DCR = 25.6mΩ,
C_{OUT} = 22µF x 3



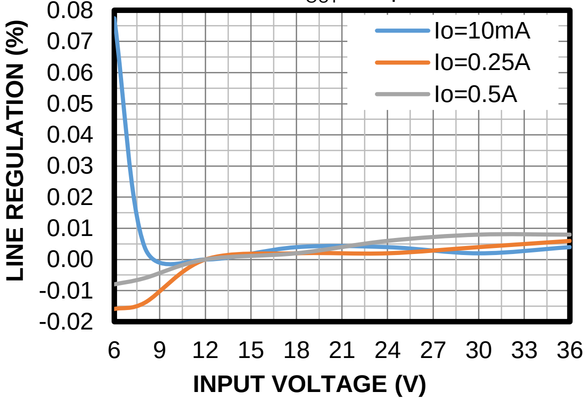
Line Regulation
MPQ4324-0501, FCCM,
V_{OUT} = 3.3V, L = 5.6µH,
DCR = 25.8mΩ



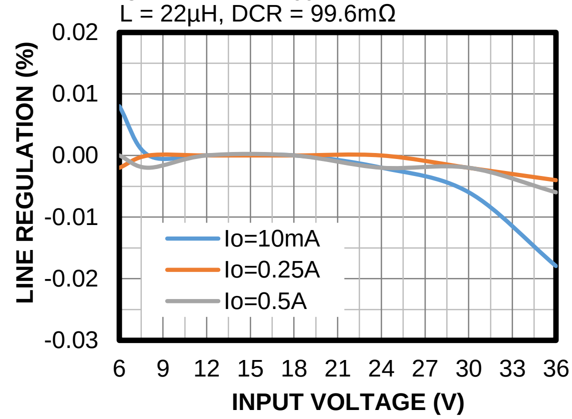
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

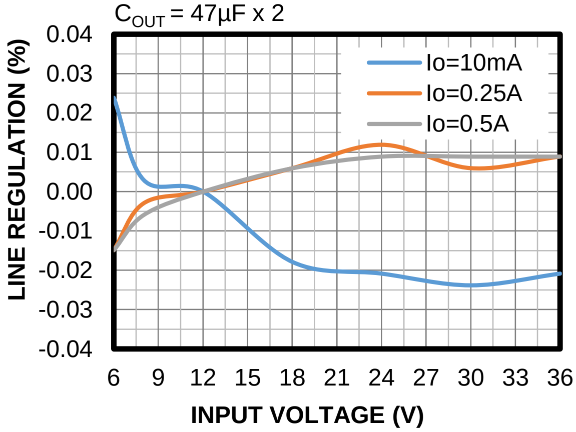
Line Regulation
MPQ4324-0500, AAM mode,
R_{FREQ} = 86.6kΩ, L = 22µH,
DCR = 99.6mΩ, C_{OUT} = 47µF x 2



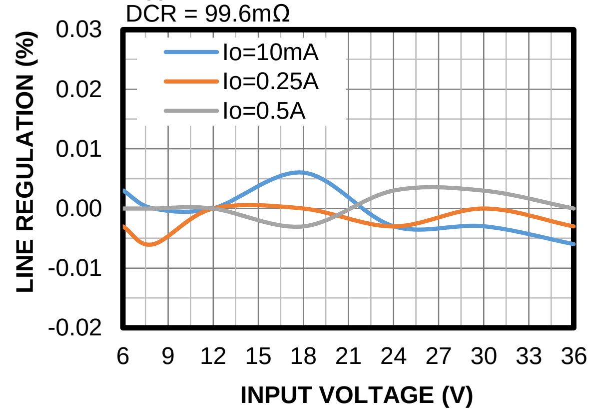
Line Regulation
MPQ4324-0501, FCCM,
f_{SW} = 415kHz, C_{OUT} = 47µF x 2,
L = 22µH, DCR = 99.6mΩ



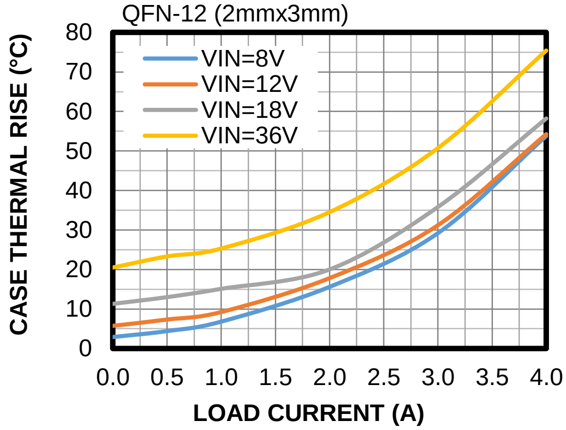
Line Regulation
MPQ4324-0500, AAM mode,
V_{OUT} = 3.3V, R_{FREQ} = 86.6kΩ,
L = 22µH, DCR = 99.6mΩ,
C_{OUT} = 47µF x 2



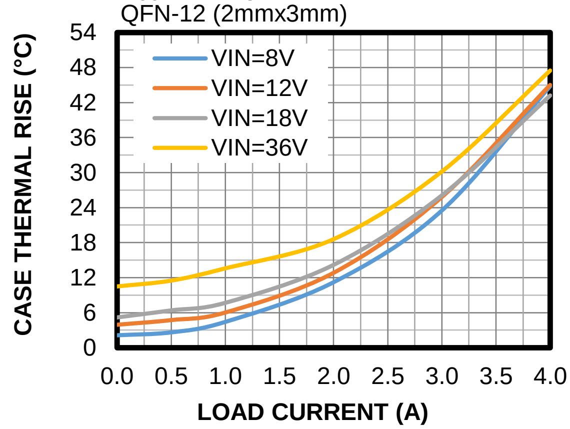
Line Regulation
MPQ4324-0501, FCCM,
V_{OUT} = 3.3V, f_{SW} = 415kHz,
C_{OUT} = 47µF x 2, L = 22µH,
DCR = 99.6mΩ



Case Thermal Rise
V_{OUT} = 5V, f_{SW} = 2.2MHz, FCCM,
QFN-12 (2mmx3mm)

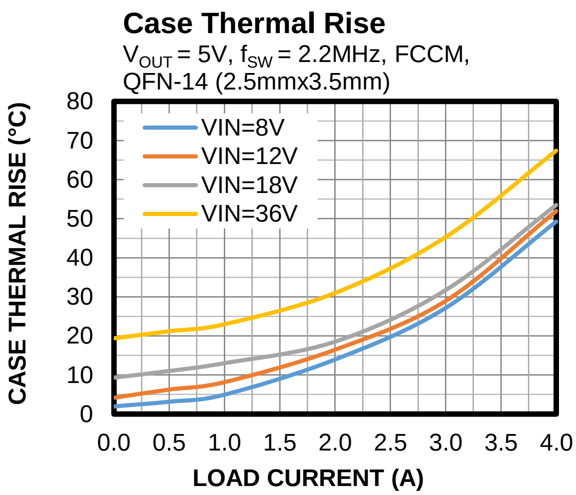


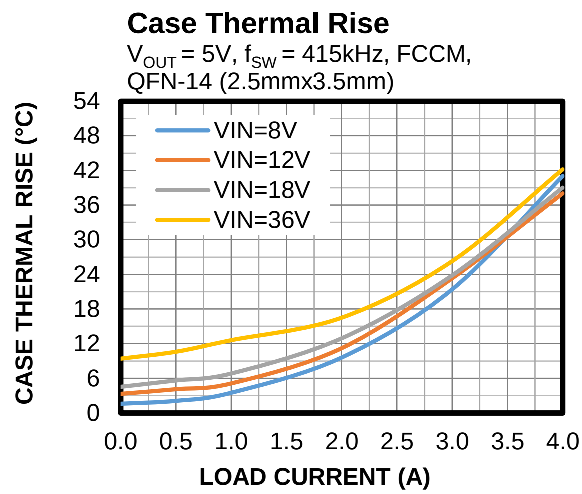
Case Thermal Rise
V_{OUT} = 5V, f_{SW} = 415kHz, FCCM,
QFN-12 (2mmx3mm)

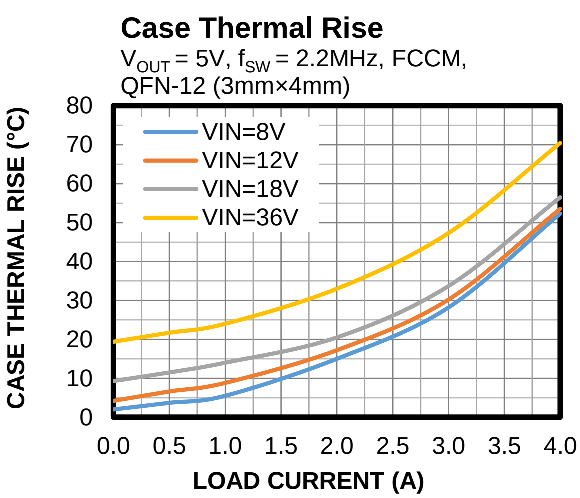


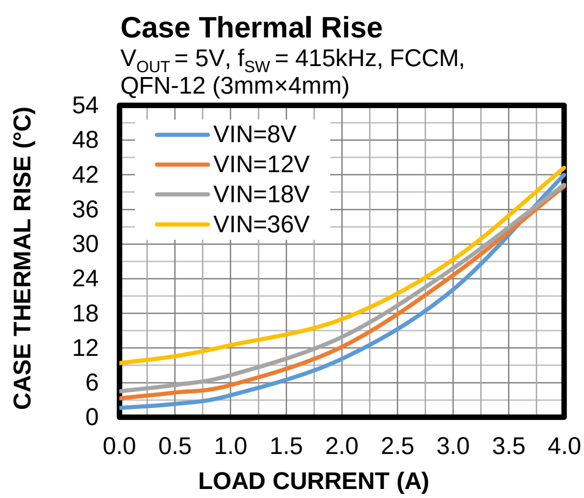
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

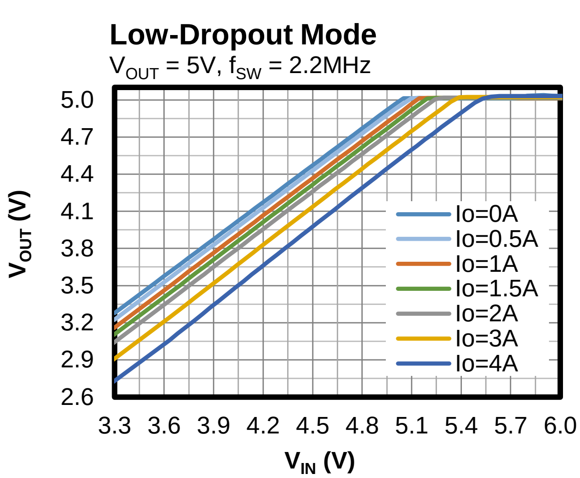
V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

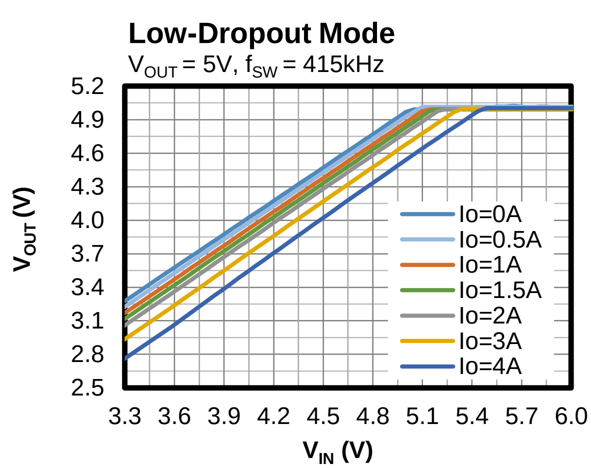






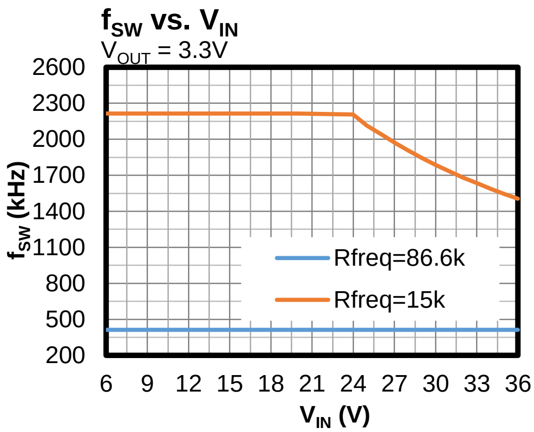


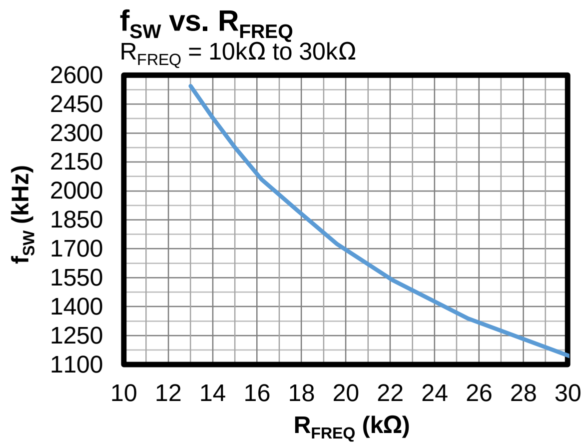


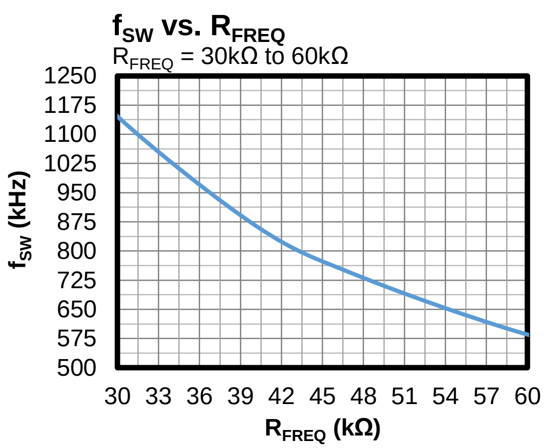


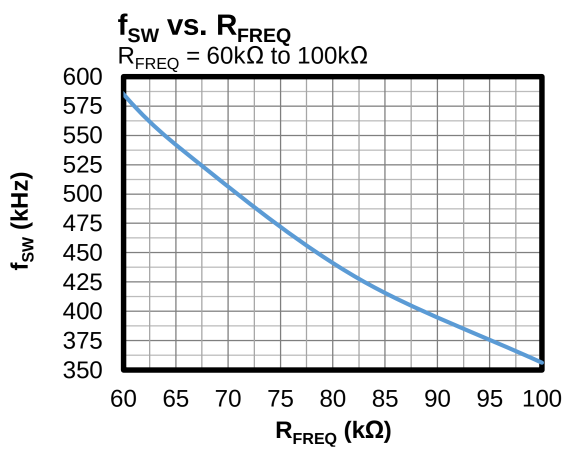
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

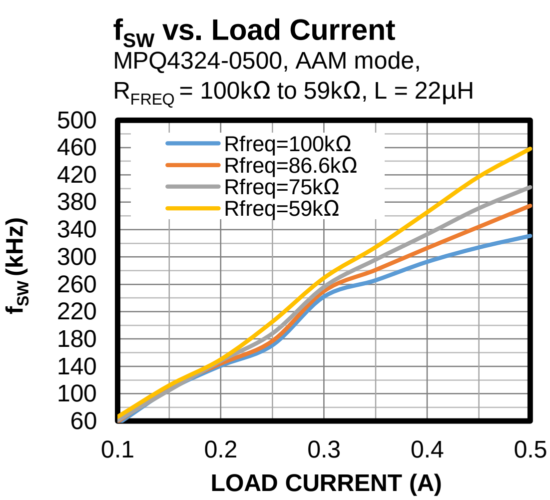
V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

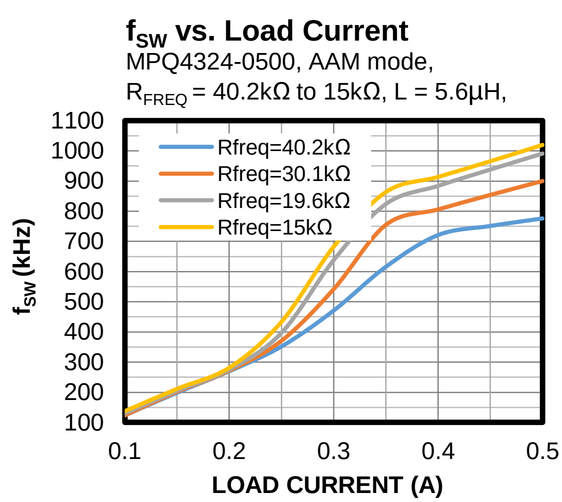






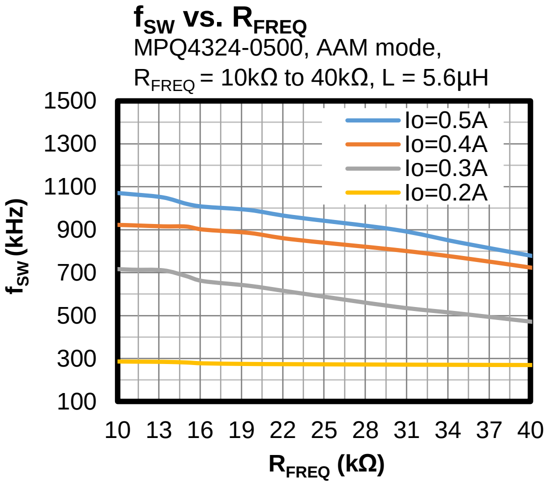


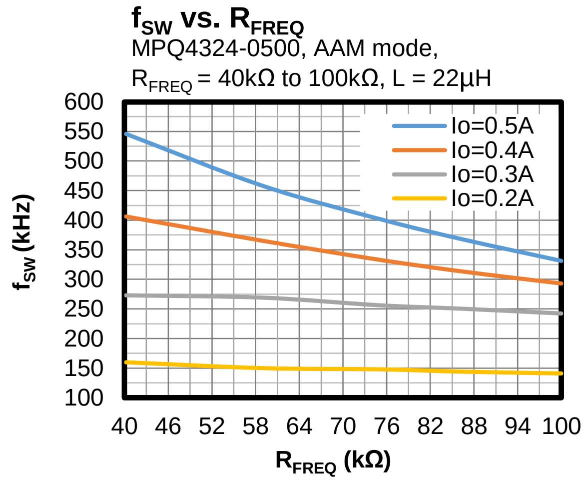




TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

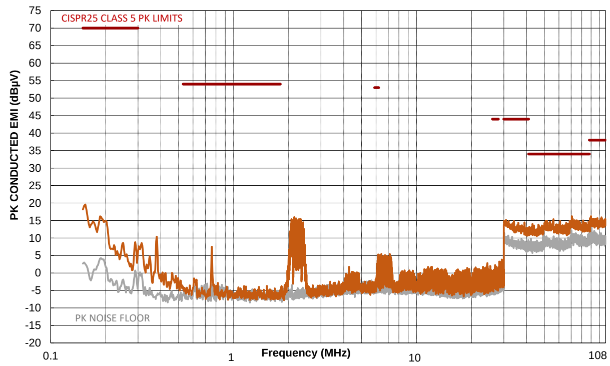




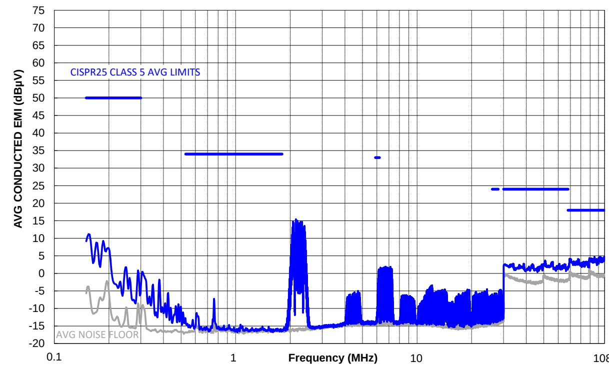
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.
(14)

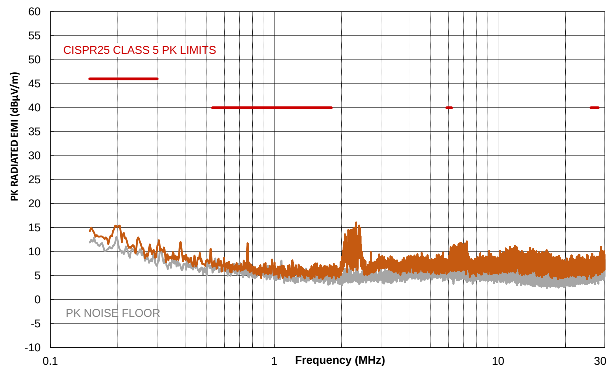
CISPR25 Class 5 Peak Conducted Emissions
150kHz to 108MHz



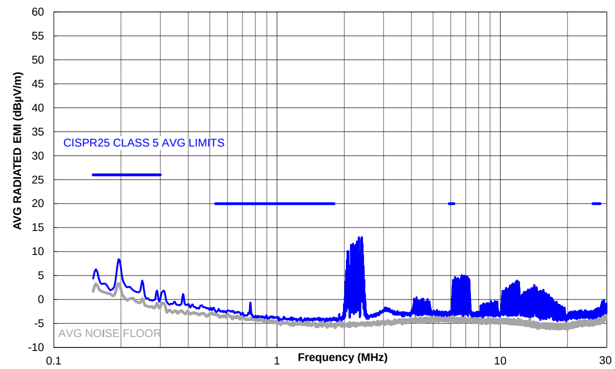
CISPR25 Class 5 Average Conducted Emissions
150kHz to 108MHz



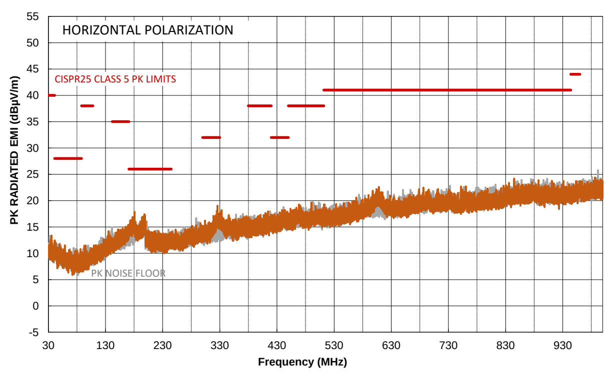
CISPR25 Class 5 Peak Radiated Emissions
150kHz to 30MHz



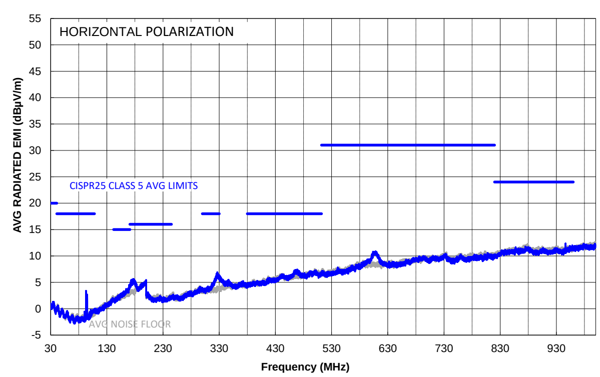
CISPR25 Class 5 Average Radiated Emissions
150kHz to 30MHz



CISPR25 Class 5 Peak Radiated Emissions
Horizontal, 30MHz to 1GHz



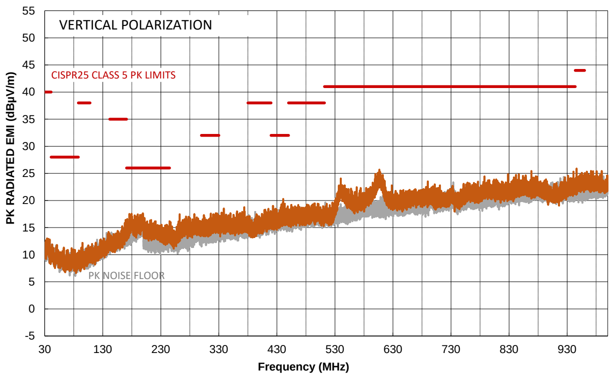
CISPR25 Class 5 Average Radiated Emissions
Horizontal, 30MHz to 1GHz



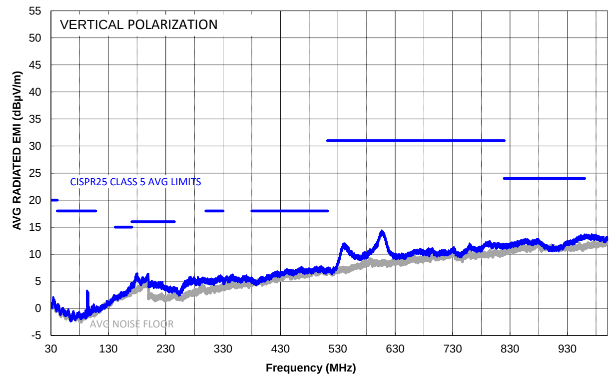
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted. (14)

CISPR25 Class 5 Peak Radiated Emissions
Vertical, 30MHz to 1GHz



CISPR25 Class 5 Average Radiated Emissions
Vertical, 30MHz to 1GHz



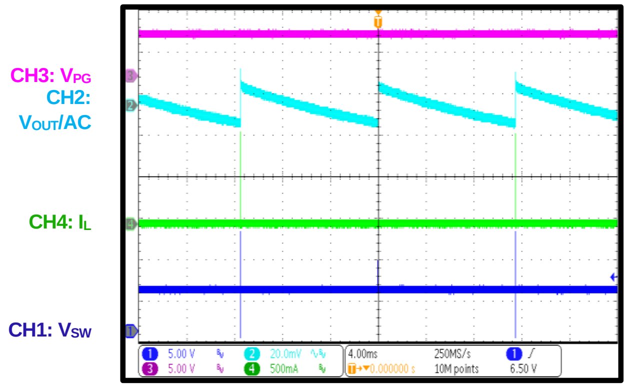
Note:

14) The EMC test results are based on the application circuit with EMI filters (see Figure 34 on page 83).

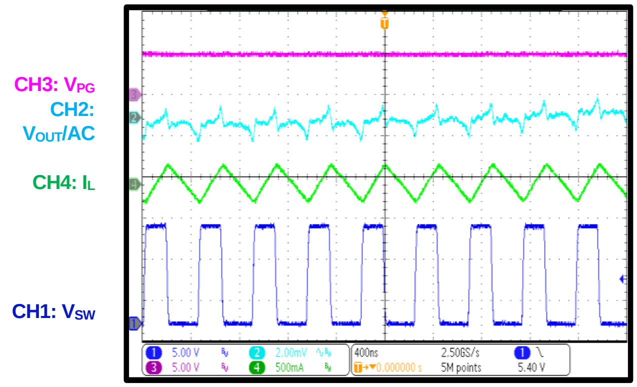
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

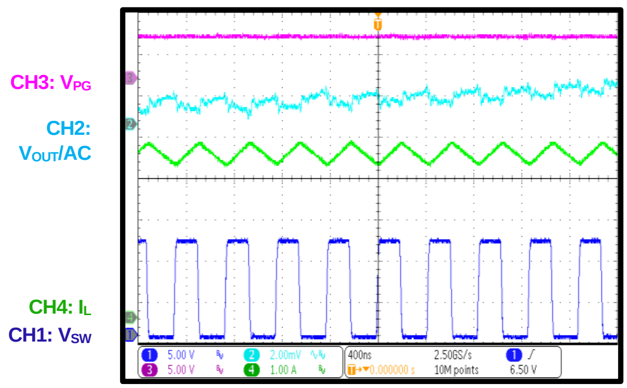
Steady State
AAM mode, I_{OUT} = 0A



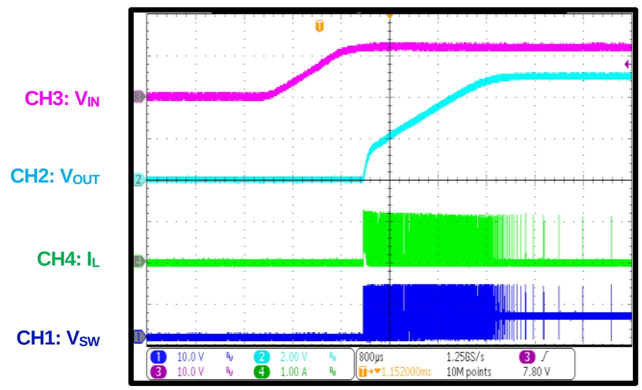
Steady State
FCCM, I_{OUT} = 0A



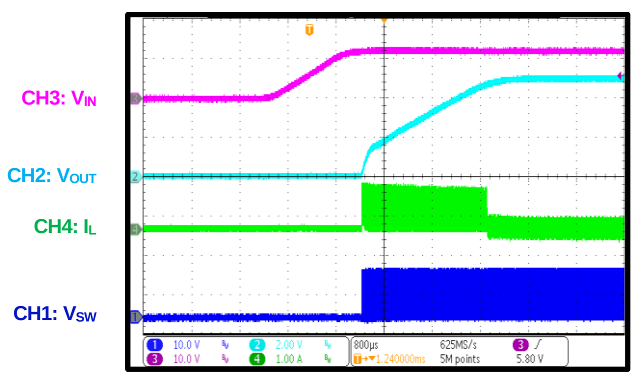
Steady State
I_{OUT} = 4A



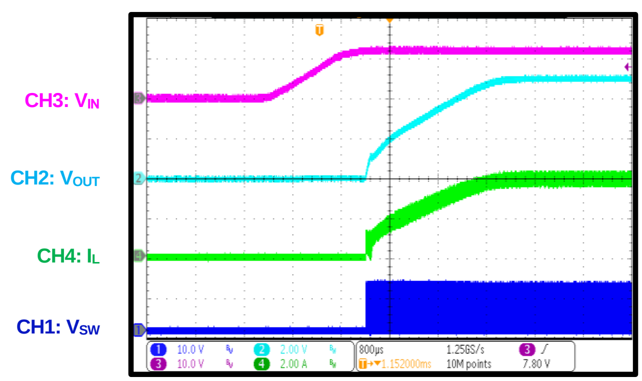
Start-Up through VIN
AAM mode, I_{OUT} = 0A



Start-Up through VIN
FCCM, I_{OUT} = 0A



Start-Up through VIN
I_{OUT} = 4A

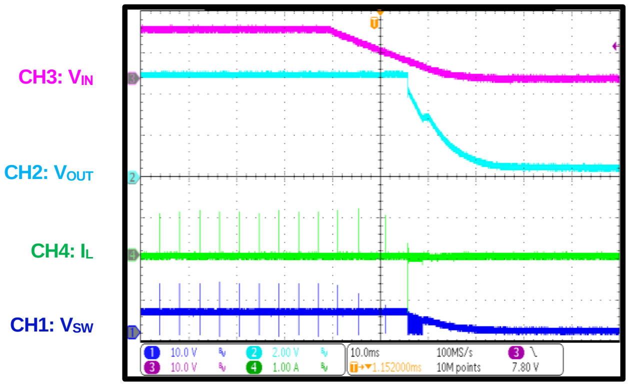


TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

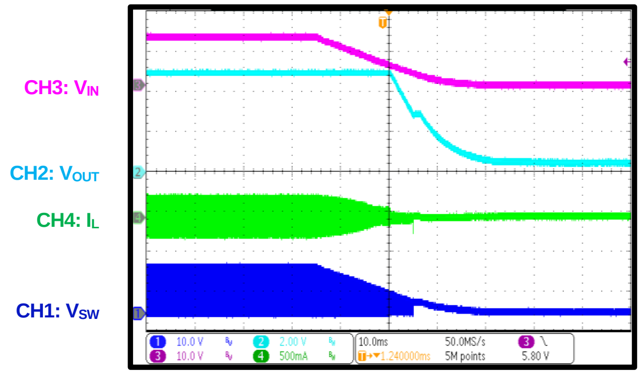
Shutdown through VIN

AAM mode, I_{OUT} = 0A



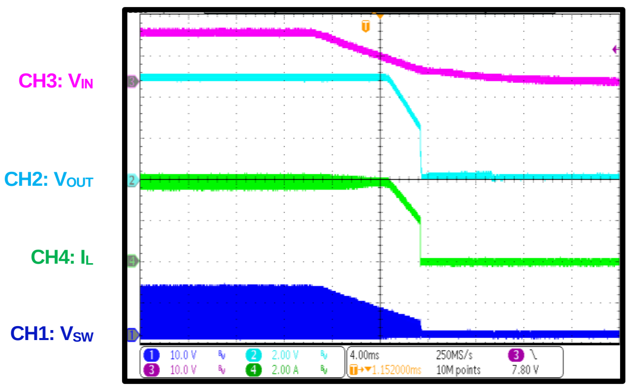
Shutdown through VIN

FCCM, I_{OUT} = 0A



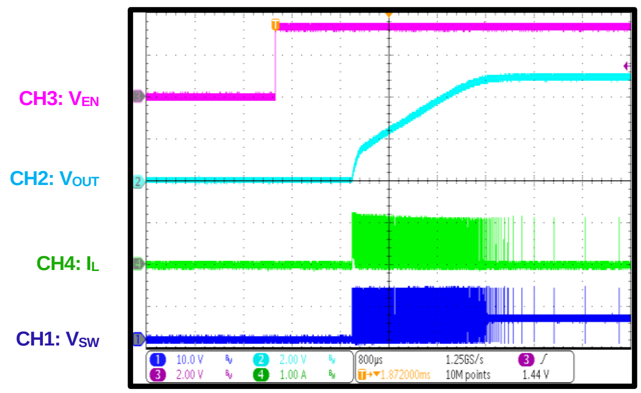
Shutdown through VIN

I_{OUT} = 4A



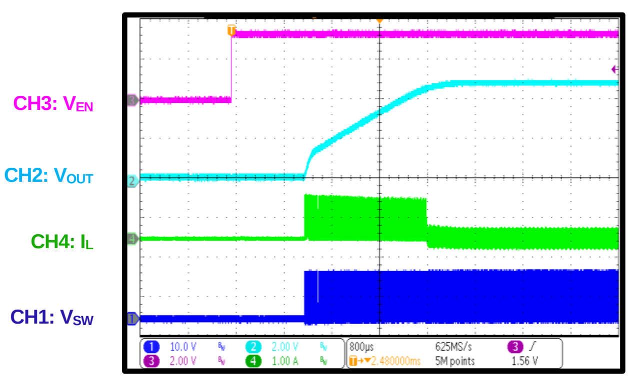
Start-Up through EN

AAM mode, I_{OUT} = 0A



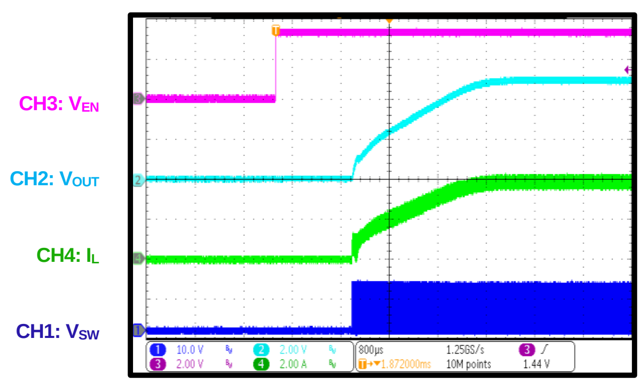
Start-Up through EN

FCCM, I_{OUT} = 0A



Start-Up through EN

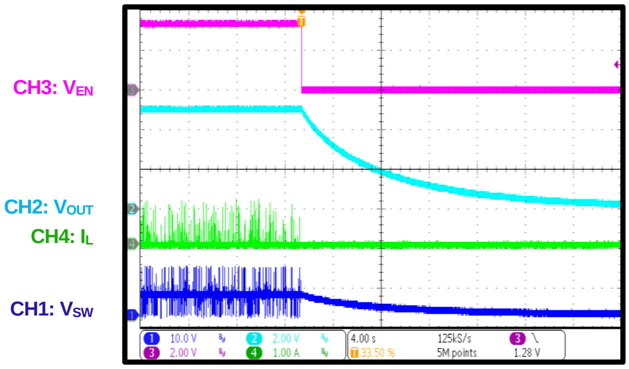
I_{OUT} = 4A



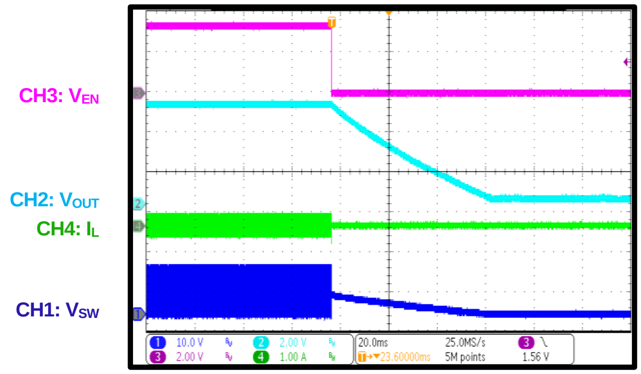
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

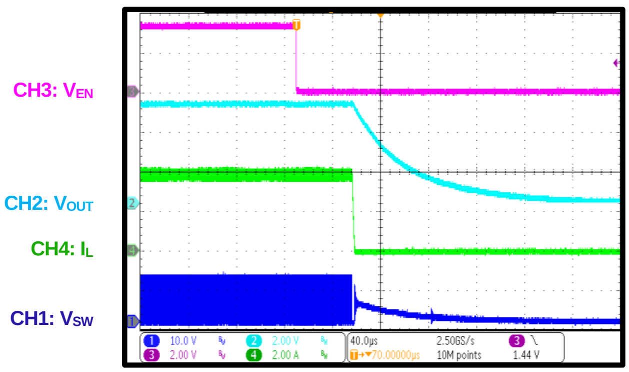
Shutdown through EN
AAM mode, I_{OUT} = 0A



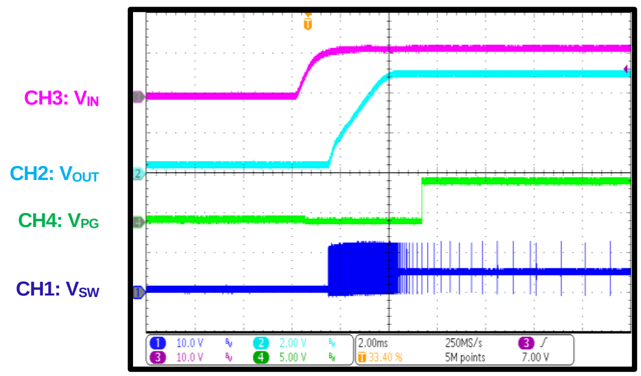
Shutdown through EN
FCCM, I_{OUT} = 0A



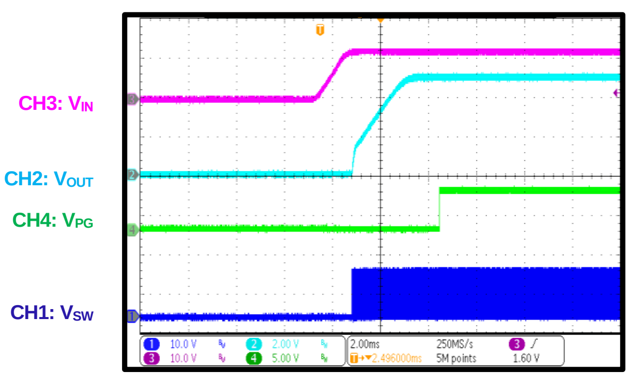
Shutdown through EN
I_{OUT} = 4A



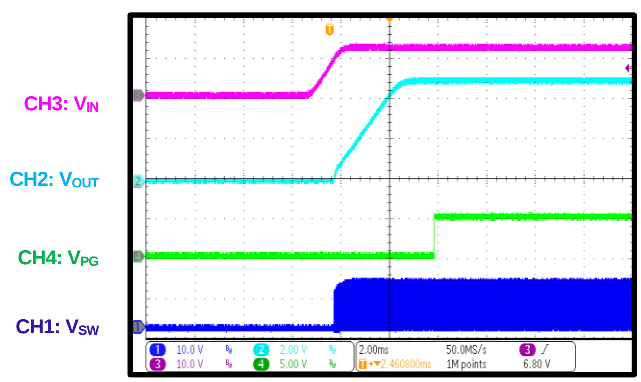
PG Start-Up through VIN
AAM, I_{OUT} = 0A



PG Start-Up through VIN
FCCM, I_{OUT} = 0A



PG Start-Up through VIN
I_{OUT} = 4A

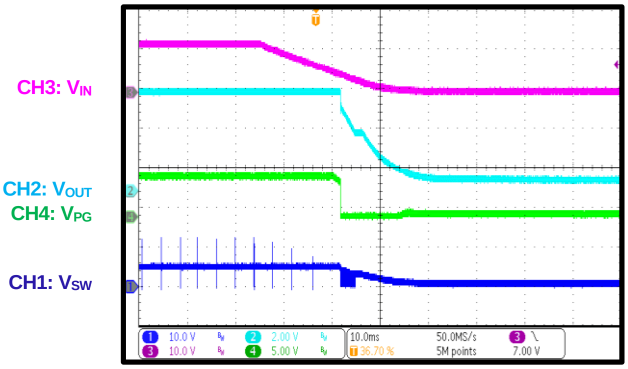


TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

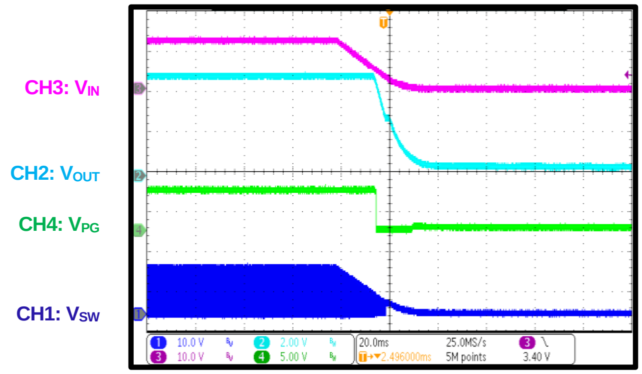
PG Shutdown through VIN

AAM mode, I_{OUT} = 0A



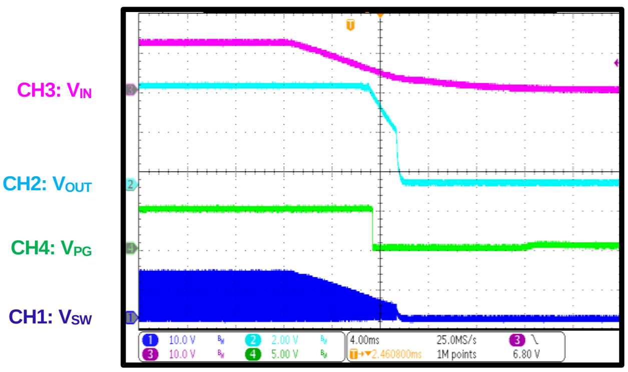
PG Shutdown through VIN

FCCM, I_{OUT} = 0A



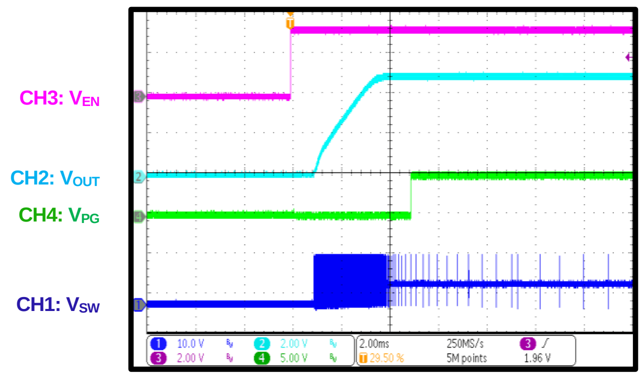
PG Shutdown through VIN

I_{OUT} = 4A



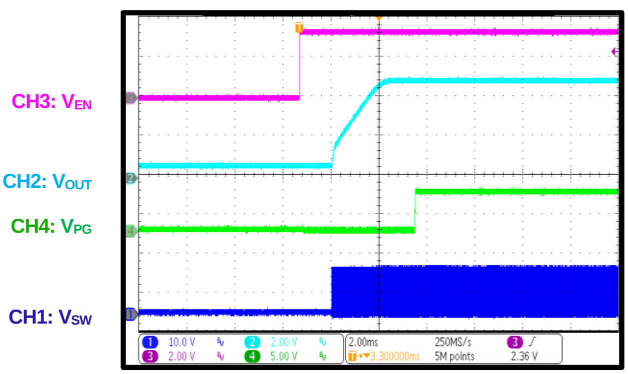
PG Start-Up through EN

AAM mode, I_{OUT} = 0A



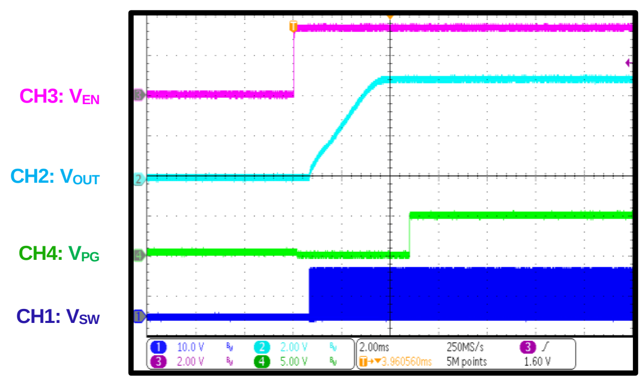
PG Start-Up through EN

FCCM, I_{OUT} = 0A



PG Start-Up through EN

I_{OUT} = 4A

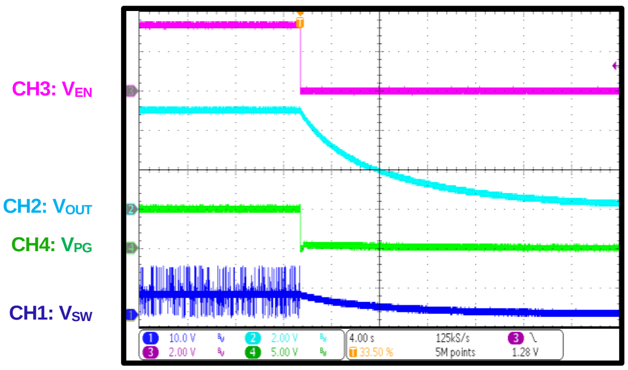


TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

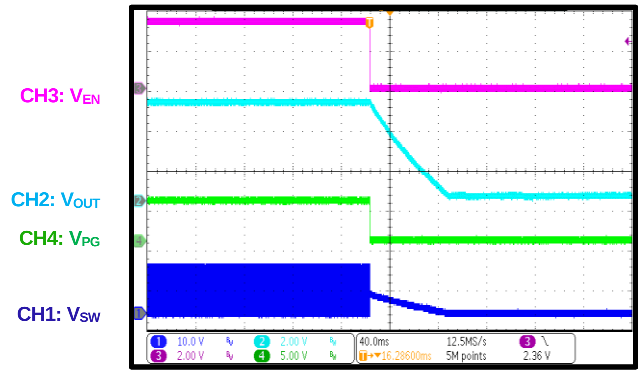
PG Shutdown through EN

AAM mode, I_{OUT} = 0A



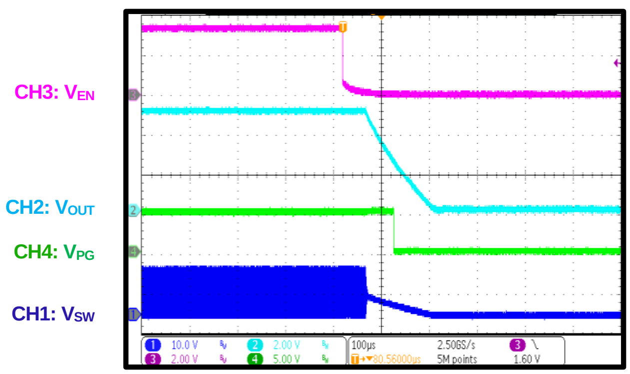
PG Shutdown through EN

FCCM, I_{OUT} = 0A



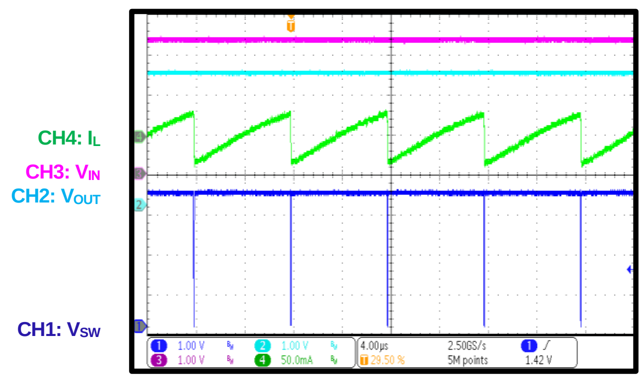
PG Shutdown through EN

I_{OUT} = 4A



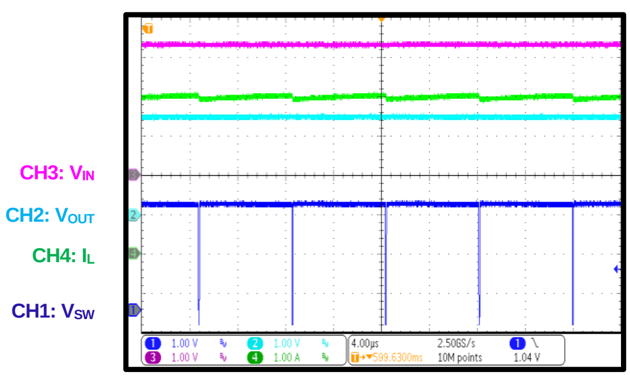
Low-Dropout Mode

I_{OUT} = 0A, V_{IN} = 3.3V



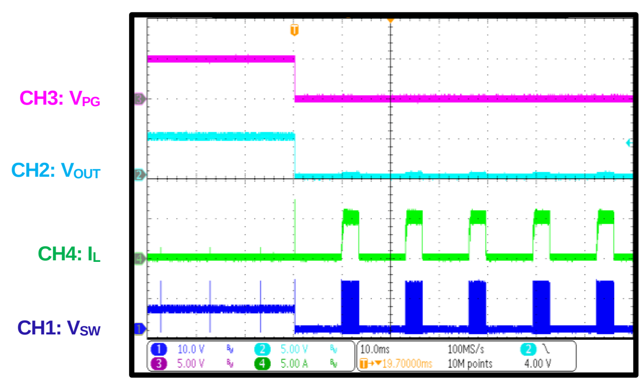
Low-Dropout Mode

I_{OUT} = 4A, V_{IN} = 3.3V



SCP Entry

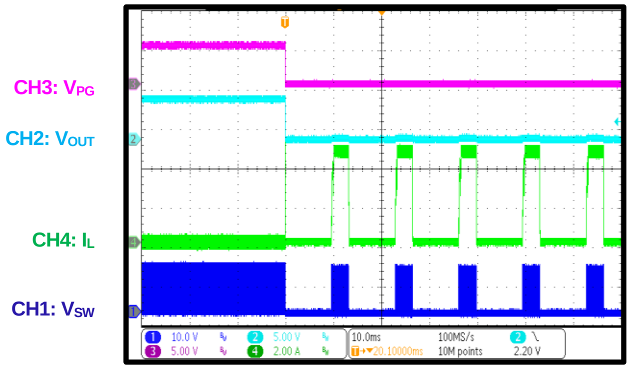
AAM mode, I_{OUT} = 0A



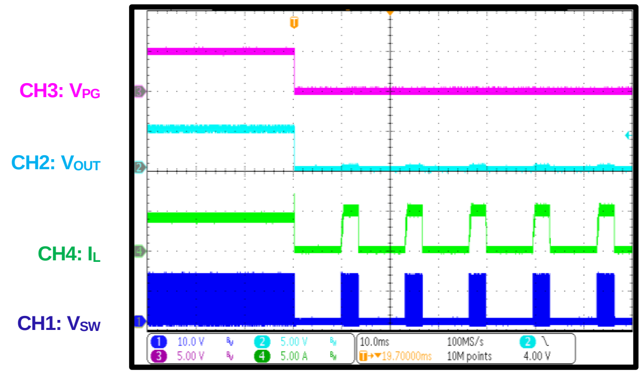
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

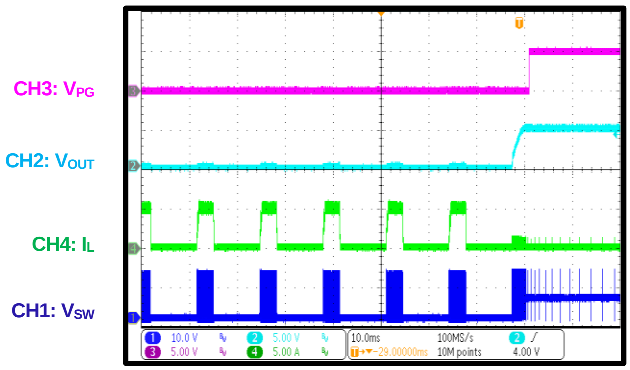
SCP Entry
FCCM, I_{OUT} = 0A



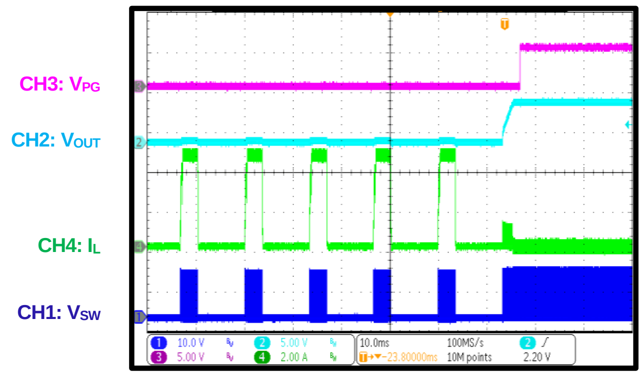
SCP Entry
I_{OUT} = 4A



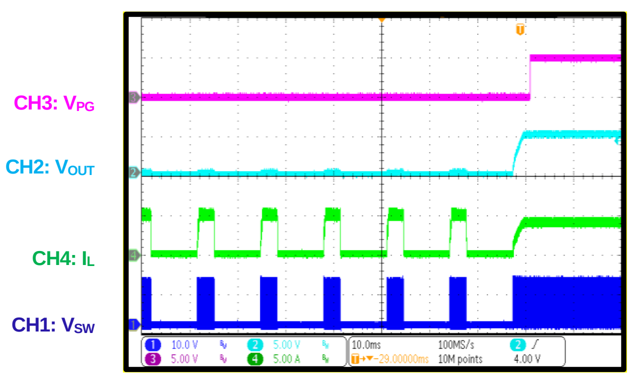
SCP Recovery
AAM mode, I_{OUT} = 0A



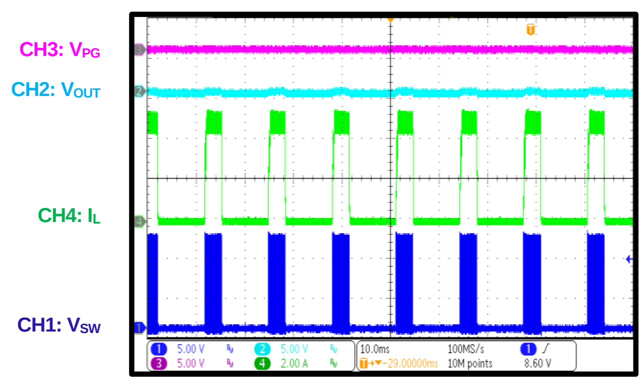
SCP Recovery
FCCM, I_{OUT} = 0A



SCP Recovery
I_{OUT} = 4A



SCP Steady State
I_{OUT} = 0A

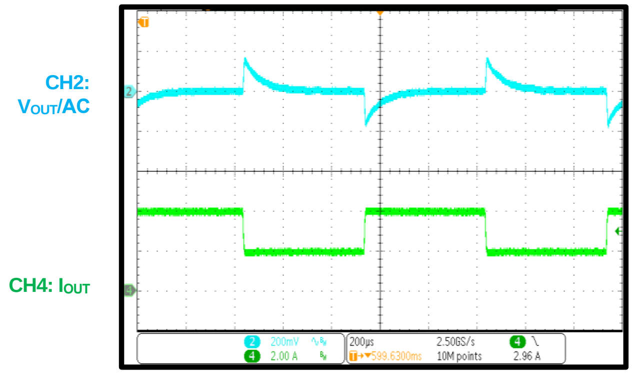


TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

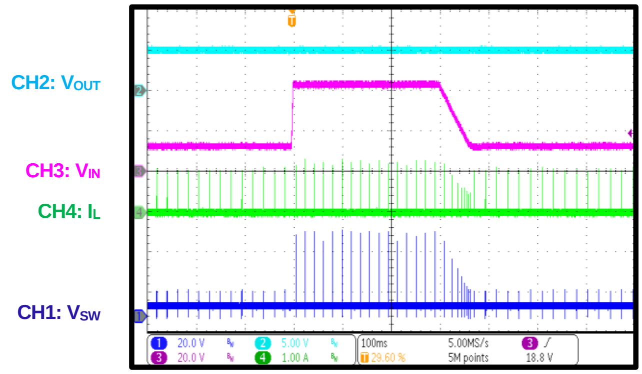
Load Transient Response

I_{OUT} = 2A to 4A, 1.6A/µs



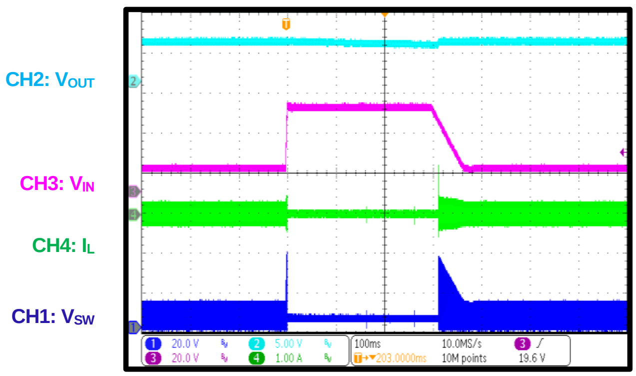
Load Dump

V_{IN}= 12V to 42V, AAM, I_{OUT} = 0A



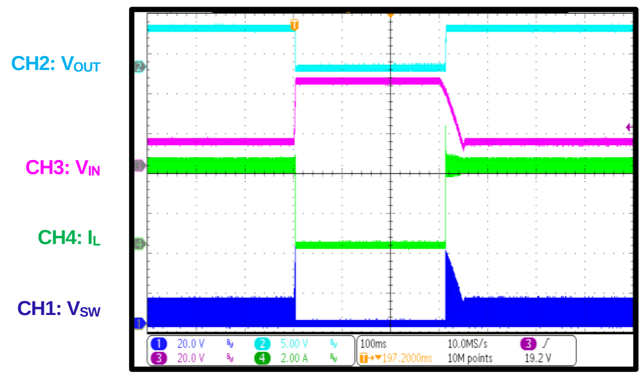
Load Dump

V_{IN}= 12V to 42V, FCCM, I_{OUT} = 0A



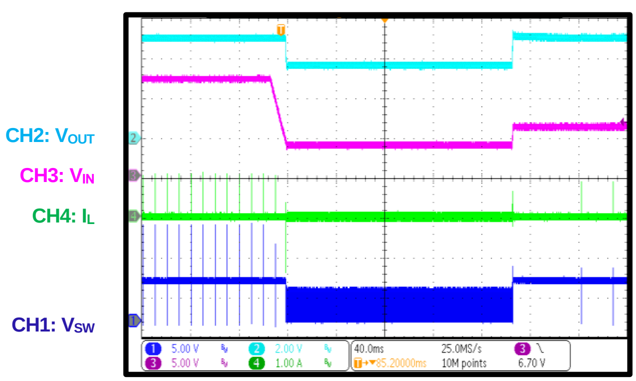
Load Dump

V_{IN}= 12V to 42V, I_{OUT} = 4A



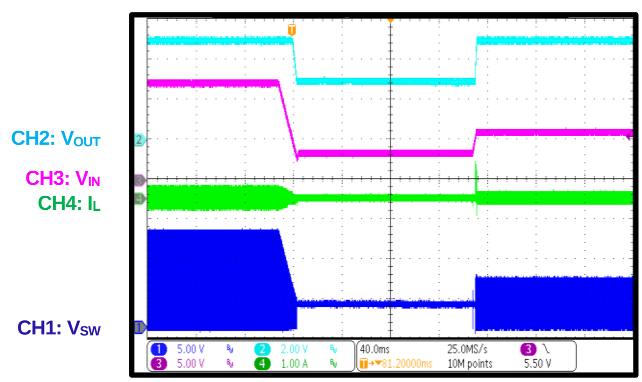
Cold Crank

V_{IN} = 12V to 3.3V to 6V, AAM mode, I_{OUT} = 0A



Cold Crank

V_{IN} = 12V to 3.3V to 6V, FCCM, I_{OUT} = 0A

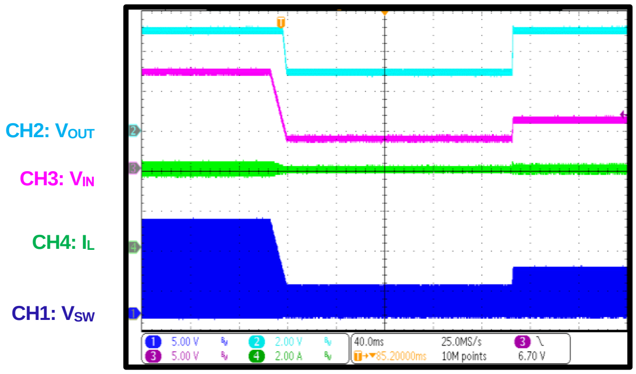


TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 12V, V_{OUT} = 5V, f_{SW} = 2.2MHz, L = 2.2µH, C_{OUT} = 22µF x 2, T_A = 25°C, unless otherwise noted.

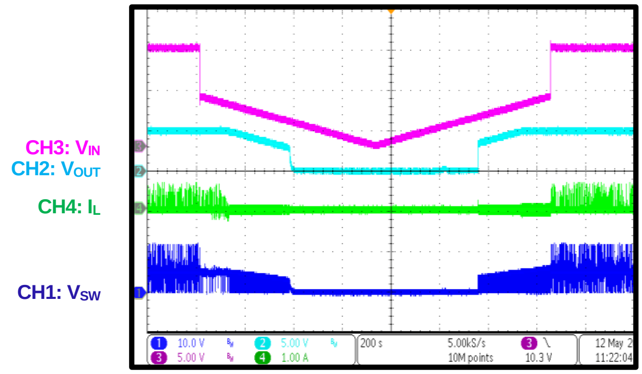
Cold Crank

V_{IN} = 12V to 3.3V to 6V, I_{OUT} = 4A



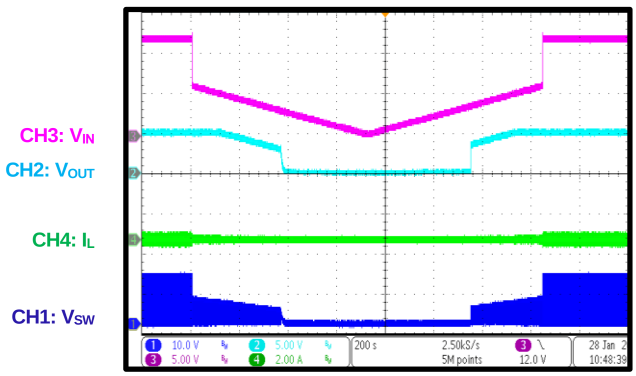
V_{IN} Ramps Down and Up

V_{IN} = 6V to 0V, 0.5V/min, AAM mode, I_{OUT} = 0A



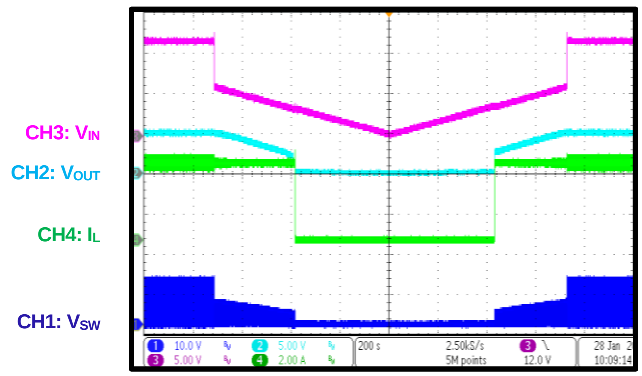
V_{IN} Ramps Down and Up

V_{IN} = 6V to 0V, 0.5V/min, FCCM, I_{OUT} = 0A



V_{IN} Ramps Down and Up

V_{IN} = 6V to 0V, 0.5V/min, I_{OUT} = 4A



FUNCTIONAL BLOCK DIAGRAM

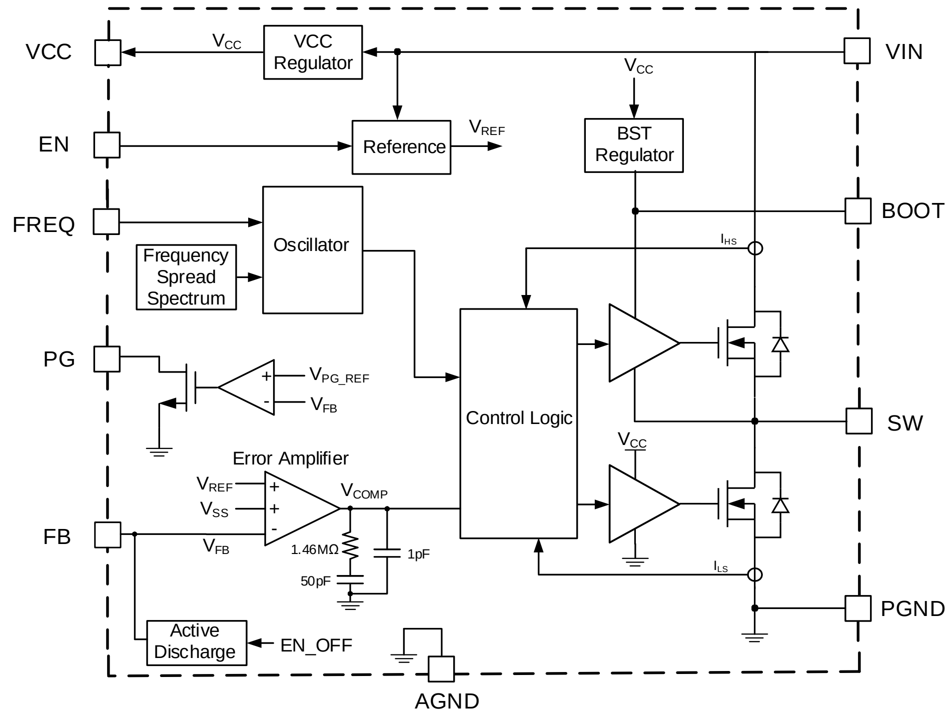


Figure 3: Functional Block Diagram (Adjustable Output)

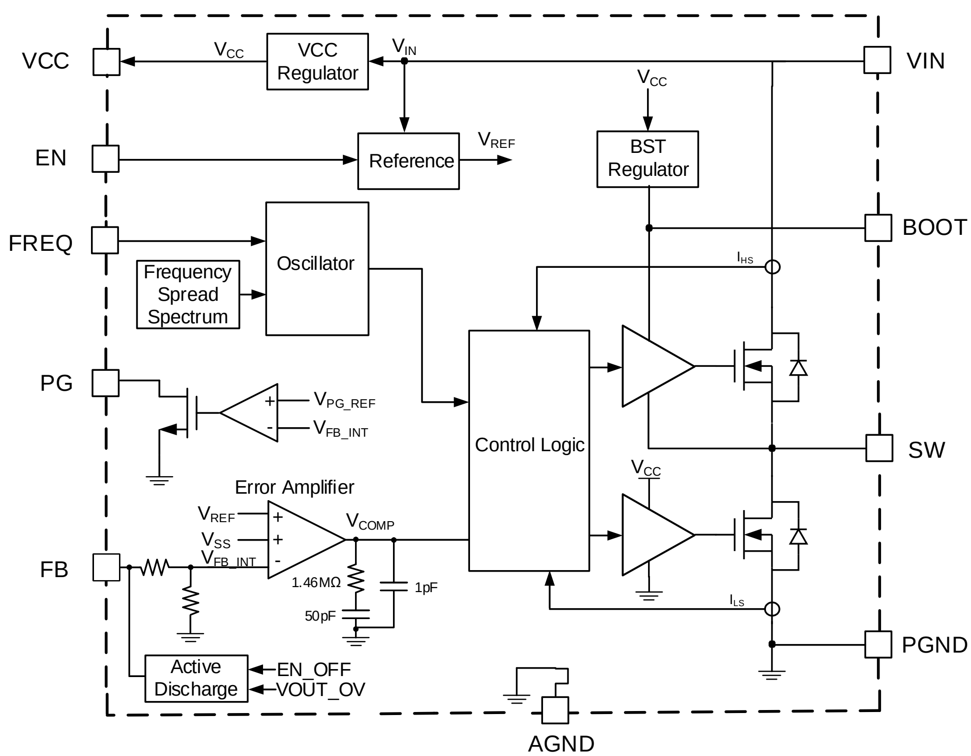


Figure 4: Functional Block Diagram (Fixed Output)

OPERATION

The MPQ4324 is a synchronous, step-down switching regulator with integrated, internal high-side and low-side power MOSFETs (HS-FETs and LS-FETs, respectively). The device provides 0.5A to 3A of continuous output current (I_{OUT}) and 4A of highly efficient peak I_{OUT} with peak current mode control.

The device features a wide input voltage (V_{IN}) range, configurable 350kHz to 2.5MHz switching frequency (f_{SW}), internal soft start (SS), and precision current limiting. The MPQ4324's low operational quiescent current (I_Q) makes it well-suited for battery-powered applications.

Pulse-Width Modulation (PWM) Control

At moderate to high output currents, the MPQ4324 operates with fixed-frequency, peak current mode control to regulate the output voltage (V_{OUT}). A pulse-width modulation (PWM) cycle is initiated by the internal clock. At the rising edge of the clock, the HS-FET turns on and remains on until the control signal reaches the value set by the internal COMP voltage (V_{COMP}). If the control signal reaches V_{COMP} within 65ns, the HS-FET remains on for at least 65ns due to the minimum on time.

When the HS-FET is off, the LS-FET turns on immediately. When the part works in FCCM, the LS-FET stays on until the next cycle starts. When the part is configured for advanced asynchronous modulation (AAM) mode, the LS-FET also turns off once the inductor current (I_L) drops below the zero-current detection (ZCD) threshold. The LS-FET remains on for at least the minimum off time (50ns) before the next cycle starts.

If the current in the HS-FET cannot reach the value set by COMP within one PWM period, the HS-FET remains on and skips a turn-off operation. The HS-FET is forced off until it reaches the value set by COMP, or its 7µs maximum on time is reached. This operation mode extends the duty cycle, which achieves a low dropout when V_{IN} is almost equal to V_{OUT}.

Advanced Asynchronous Modulation (AAM) Mode and Forced Continuous Conduction Mode (FCCM)

When the "Z" in the four-digit code "XXYZ" is configured as "0", "2", "4", or "6", the MPQ4324 works in AAM mode to optimize efficiency under light-load and no-load conditions (see Table 1 on Page 4).

When the inductor current approaches 0A under light loads, the MPQ4324 first initiates asynchronous operation. If the load is further decreased, and V_{COMP} drops below the set value, the MPQ4324 enters AAM mode (see Figure 5).

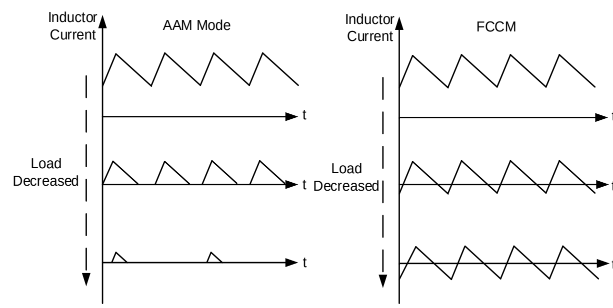


Figure 5: AAM Mode and FCCM

In AAM mode, the internal clock is reset every time V_{COMP} crosses the set value, and the crossover time is used as a benchmark for the next clock. When the load increases and V_{COMP} exceeds the set value, the device operates in continuous conduction mode (CCM) or discontinuous conduction mode (DCM) with a constant f_{SW}.

When the "Z" in the four-digit code "XXYZ" is configured as "1", "3", "5", or "7", the MPQ4324 works in forced continuous conduction mode (FCCM) (see Table 1 on Page 4). The device works with a fixed frequency across the no-load to full-load range (see Figure 5). The advantages of FCCM are its controllable frequency and lower output voltage ripple under light loads.

Error Amplifier (EA)

The error amplifier compares the FB pin's voltage (V_{FB}) with the internal reference (0.8V) and outputs a current proportional to the difference between the two values. This output current is then used to charge the compensation network to form V_{COMP}, which controls the power MOSFET's duty cycle.

During normal operation, the minimum V_{COMP} is clamped to 0.5V, and the maximum V_{COMP} is clamped to 2.5V. The COMP node is internally pulled down to GND in shutdown mode.

Low-Dropout (LDO) Operation

To improve dropout, the MPQ4324 is designed to operate at close to 100% duty cycle when the BOOT-to-SW voltage exceeds 2.5V.

When the device works in low-dropout (LDO) mode, V_{COMP} is clamped to a maximum of 2.5V. When V_{IN} suddenly increases from a lower voltage, the chip recovers from LDO mode. Due to the speed of the loop response, V_{COMP} cannot change rapidly accordingly. This may cause V_{OUT} to potentially overshoot.

The MPQ4324 has a mechanism to reduce this overshoot when the control mode “Z” in the four-digit code is configured as “4”, “5”, “6”, or “7” (see Table 1 on Page 4). Once the device exits LDO mode under this mechanism, it initiates SS and V_{COMP} to reduce the HS-FET’s conduction duty cycle. Even if V_{IN} rapidly increases, the V_{OUT} overshoot is also be minimized. Due to SS re-start, V_{OUT} experiences a drop during this period until SS reaches the set value again.

Spread Spectrum

The MPQ4324 uses a 15kHz modulation frequency with a maximum 128-step triangular profile to spread the internal oscillator frequency across a 20% (±10%) window. The steps vary with the set oscillator frequency to ensure that the exact switching frequency steps cycle by cycle (see Figure 6).

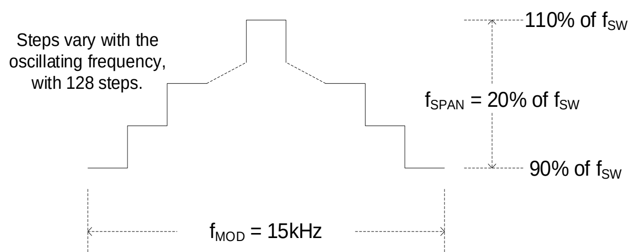


Figure 6: Spread Spectrum

Side bands are created by modulating the switching frequency with the triangle modulation waveform. The emission power of the fundamental switching frequency and its harmonics is reduced. This significantly reduces the peak EMI noise.

This function can also be configured on or off by the control mode “Z” in the four-digit code "WXYZ” (see Table 1 on Page 4).

Soft Start (SS)

Soft start is implemented to prevent the converter’s V_{OUT} from overshooting during start-up. The soft-start time is fixed internally.

When the soft-start period starts, the soft-start voltage (V_{SS}) rises from 0V to 1.2V with a specific slew rate. When V_{SS} is below the internal 0.8V reference voltage (V_{REF}), V_{SS} overrides V_{REF}, and the error amplifier uses V_{SS} as the reference. When V_{SS} exceeds V_{REF}, the error amplifier uses V_{REF} as the reference.

When the chip is enabled by EN, the first pulse comes after 830µs. During this period, V_{CC} is regulated, and the internal bias and charging of the compensator network are completed. After another 2.9ms, V_{OUT} ramps up and reaches the set value. Then the entire soft-start process is completed after 1.5ms. PG also pulls high after a 70µs delay.

Start-Up and Shutdown

If both V_{IN} and EN exceed their appropriate thresholds, the chip starts up. The reference block starts first, generating a stable reference voltage and currents, and then the internal regulator is enabled. The regulator provides a stable supply for the remaining circuitries.

When the internal supply rail is up, the internal circuits start to work. If BOOT does not reach its refresh rising threshold (about 2.5V), the LS-FET turns on to charge BOOT. The HS-FET stays off during this time. When the soft-start block is enabled, V_{OUT} starts to ramp up slowly. V_{OUT} smoothly reaches its target within 5ms.

Three events shut down the chip: EN going low, V_{IN} falling below its UVLO threshold, and thermal shutdown. During shutdown, the signaling path is blocked first to avoid any fault triggering. Then V_{COMP} pulls down, and the floating driver works to disable the HS-FET.

Bootstrap Charging

The voltage between BOOT and SW ($V_{BOOT-SW}$) is regulated to about 5V by the dedicated internal bootstrap regulator. When $V_{BOOT-SW}$ is below its regulated value, an N-channel MOSFET pass transistor connected from VCC to BOOT turns on to charge the bootstrap capacitor (C_{BOOT}). The external circuit should provide enough voltage headroom to facilitate the charging. When the HS-FET is on, the BOOT voltage exceeds V_{CC}, so the bootstrap capacitor cannot be charged.

Under conditions with higher duty cycles, the time available for bootstrap charging is shorter, so the bootstrap capacitor may not be charged sufficiently. In this scenario, the external circuit has insufficient voltage and time to charge the bootstrap capacitor. External circuitry can be used to ensure that the bootstrap voltage remains in the normal operation region.

If the bootstrap voltage reaches its under-voltage lockout (UVLO) threshold, the HS-FET turns off, and the LS-FET turns on with a minimum off time to refresh the bootstrap voltage with the set f_{SW}.

Pre-Biased Start-Up

If V_{FB} exceeds V_{SS} during start-up, this means that the output has a pre-biased voltage. Neither the HS-FET nor LS-FET turn on until V_{SS} exceeds V_{FB}.

Peak and Valley Current Limit

Both the HS-FET and LS-FET have cycle-by-cycle current-limit protection. When the inductor current (I_L) reaches the high-side peak current limit while the HS-FET is on, the HS-FET is forced off immediately to prevent the current from rising further. Then, the LS-FET is on until I_L drops below the valley current limit.

When the LS-FET is on, the next clock's rising edge is held until I_L drops below the low-side valley current limit. Then I_L can drop to a sufficiently low value when the HS-FET turns on again. This current limit scheme prevents current runaway if an overload or short-circuit event occurs.

Reverse Current Limit

The reverse current direction is from the SW-to-GND node. The reverse current limit ($I_{LIMIT\_REVERSE}$) threshold is 2A. Once I_L reaches the current limit, the LS-FET immediately turns off and the HS-FET turns on. After the control signal reaches V_{COMP}, the HS-FET turns off and the LS-FET turns on again. The current limit prevents the negative current from dropping too low and potentially damaging the components.

Short-Circuit Protection (SCP)

If the output is shorted to ground, and V_{OUT} drops below 70% of its nominal output, the MPQ4324 stops switching and begins discharging V_{SS}. The device restarts with a full soft start when V_{SS} is fully discharged. This hiccup process is repeated until the fault is removed.

V_{IN} Over-Voltage Protection (OVP)

The MPQ4324 stops switching when V_{IN} exceeds its over-voltage (OV) rising threshold (typically 37.5V). The device resumes normal regulation and switching when V_{IN} drops below the OV falling threshold (typically 36.5V).

Output Over-Voltage Protection (OVP) and Discharge

In AAM mode, the MPQ4324 stops switching when V_{OUT} exceeds its nominal output voltage.

In FCCM, the MPQ4324 stops switching if V_{OUT} exceeds 130% of its nominal regulation value.

When V_{OUT} exceeds 130% of its nominal regulation value, then an internal 270Ω discharge path (with a 4mA saturation current) from FB to GND is activated to discharge V_{OUT}. This discharge path can only be activated for the fixed-output version. For FCCM, the part resumes switching when V_{OUT} drops back to 125% of its nominal value, and then the discharge path is disabled. For AAM mode, the discharge path is also disabled when V_{OUT} drops back to 125% of its nominal value, but resumes switching only when V_{OUT} drops below its nominal value.

The V_{OUT} discharge path is also activated if an EN shutdown occurs, whether the device is a fixed-output version or an adjustable-output version.

Thermal Shutdown

Thermal shutdown is implemented to prevent the chip from thermal runaway. If the silicon die temperature exceeds its upper threshold (about 175°C), the device shuts down the power MOSFETs. If the temperature drops below its lower threshold (about 155°C), the thermal shutdown condition is removed, and the chip is enabled again.

APPLICATION INFORMATION

Figure 7 shows the MPQ4324's typical application circuit.

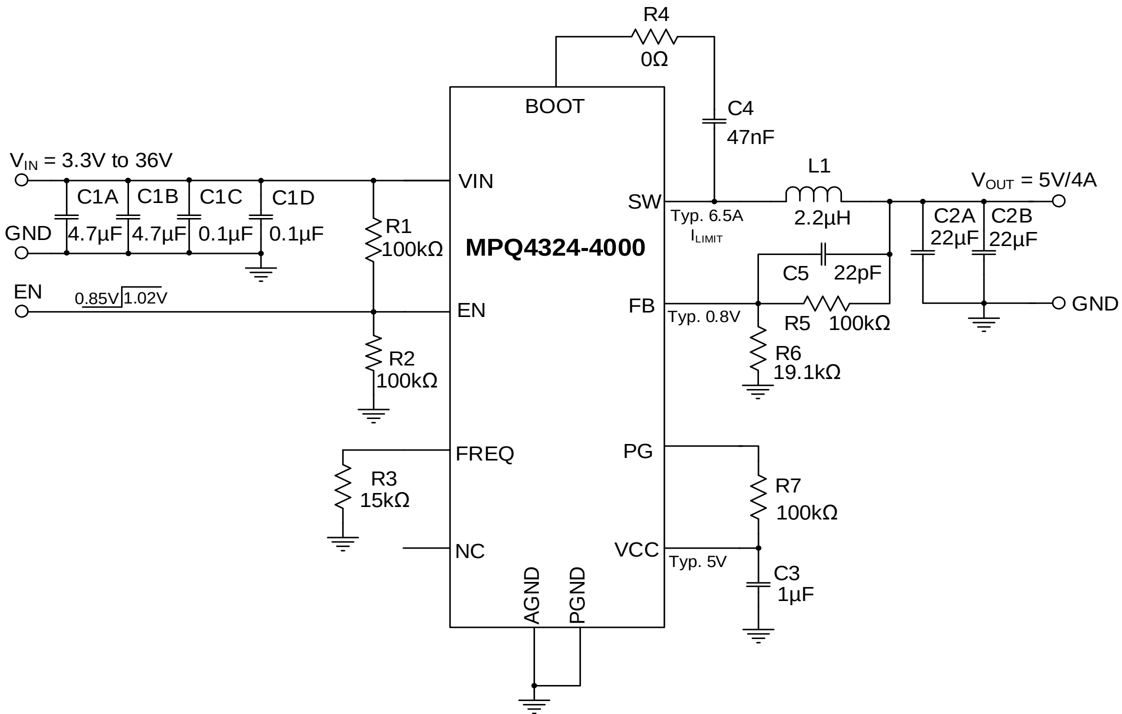


Figure 7: Typical Application Circuit (V_{OUT} = 5V, f_{SW} = 2.2MHz, 4A Version)

Table 2: Design Guide Index

Pin #		Pin Name	Component	Design Guide Index
QFN-12	QFN-14			
2, 10	3, 11	VIN	C1A, C1B, C1C, C1D	Selecting the Input Capacitors (VIN, Pins 2 and 10)
3	4	BOOT	R4, C4	Floating Driver and Bootstrap Charging (BOOT, Pin 3)
4	5	FREQ	R3	Setting the Switching Frequency (FREQ, Pin 4)
5	6	VCC	C3	Internal VCC (VCC, Pin 5)
7	8	FB	R5, R6, C5	Feedback (FB, Pin 7)
8	9	PG	R7	Power Good Indicator (PG, Pin 8)
9	10	EN	R1, R2	Enable and Under-Voltage Lockout (UVLO) (EN Pin 9)
12	14	SW	L1, C2A, C2B	Selecting the Inductor and Output Capacitors (SW, Pin 12)
1, 11	1, 13	PGND	-	GND Connection
6	7	AGND	-	GND Connection
-	2, 12	NC	-	No connection

Selecting the Input Capacitors (VIN, Pins 2 and 10)

The step-down converter has a discontinuous input current, and requires a capacitor to supply AC current to the converter while maintaining the DC input voltage. For the best performance, use low-ESR capacitors. Ceramic capacitors with X5R or X7R dielectrics are highly recommended because of their low ESR and small temperature coefficients.

For most applications, use a 4.7µF to 10µF capacitor. It is strongly recommended to use an additional lower-value capacitor (e.g. 0.1µF) with a small package size (0603) to absorb high-frequency switching noise. Place the smaller capacitor as close to VIN and GND as possible.

Since the input capacitor (C_{IN}) absorbs the input switching current, it requires an adequate ripple current rating. The RMS current in the input capacitor can be estimated with Equation (1):

$$I_{CIN} = I_{LOAD} \times \sqrt{\frac{V_{OUT}}{V_{IN}} \times (1 - \frac{V_{OUT}}{V_{IN}})} \quad (1)$$

The worst-case condition occurs at V_{IN} = 2 x V_{OUT}, calculated with Equation (2):

$$I_{CIN} = \frac{I_{LOAD}}{2} \quad (2)$$

For simplification, choose an input capacitor with an RMS current rating greater than half of the maximum load current. The input capacitor can be electrolytic, tantalum, or ceramic. When using electrolytic or tantalum capacitors, add a small, high-quality ceramic capacitor (e.g. 0.1µF) as close to the IC as possible. When using ceramic capacitors, ensure that they have enough capacitance to provide a sufficient charge to prevent excessive voltage ripple at the input. The input voltage ripple caused by the capacitance can be estimated with Equation (3):

$$\Delta V_{IN} = \frac{I_{LOAD}}{f_{SW} \times C_{IN}} \times \frac{V_{OUT}}{V_{IN}} \times (1 - \frac{V_{OUT}}{V_{IN}}) \quad (3)$$

Floating Driver and Bootstrap Charging (BOOT, Pin 3)

The BOOT capacitor (C4) is recommended to be between 22nF to 100nF**.**

It is not recommended to place a resistor (R_{BOOT}) in series with the BOOT capacitor, unless there is a strict EMI requirement. R_{BOOT} helps enhance EMI performance and reduce voltage stress at high input voltages, but also generates additional power consumption and reduces efficiency. When R_{BOOT} is necessary, it should be below 4Ω.

Setting the Switching Frequency (FREQ, Pin 4)

A resistor (R3) can set the switching frequency (see Table 3 and the f_{SW} vs. R_{FREQ} curves starting on page 51).

The MPQ4324's oscillating frequency can be configured by an external resistor (R_{FREQ}) connected from the FREQ pin to ground. The frequency resistor should be located between the FREQ pin and GND, placed as close as possible to the device. Table 3 shows the relationship between f_{SW} and R_{FREQ}.

Table 3: f_{SW} vs. R_{FREQ}

R_{FREQ} (kΩ)	f_{SW} (kHz)	R_{FREQ} (kΩ)	f_{SW} (kHz)
100	355	30.1	1150
93.1	385	26.1	1300
86.6	415	22.6	1450
80.6	450	20.5	1600
75	480	19.6	1750
68.1	520	17.8	1900
59	600	16.2	2050
51.1	700	15	2200
40.2	850	14.3	2350
34.8	1000	13.3	2500

For the MPQ4324-05x0, the device works in AAM mode to optimize efficiency under light loads. In addition, the real switching frequency also depends on the depth of its AAM mode. The depth of AAM mode is related to inductance and load. The curves starting on page 51 show the detailed relationship between f_{SW} and R_{FREQ} under different loads and inductances.

It is not possible to have both a high f_{SW} and V_{IN} due to the HS-FET's limited minimum on time. The MPQ4324's control loop automatically sets the maximum possible f_{SW} to the set frequency, which also reduces excessive power loss. V_{OUT} is regulated by varying the duration of the HS-FET's switch-off time, which automatically reduces f_{SW}.

The device is guaranteed to comply with the HS-FET's minimum on time. An advantage of this method is that the device works at the target f_{SW} for as long as possible, and f_{SW} only changes when the device operates at high input voltages. For more details, see the f_{SW} vs. V_{IN} curve on page 51. In this scenario, R_{FREQ} = 15kΩ, and V_{OUT} = 3.3V.

Internal VCC (VCC, Pin 5)

The VCC capacitor (C3) is recommended to be 1µF.

Most of the internal circuitry is powered by the internal 5V VCC regulator. This regulator uses VIN as its input and operates across the full V_{IN} range. When V_{IN} exceeds 5V, VCC is in full regulation. When V_{IN} drops below 5V, the VCC output degrades.

Feedback (FB, Pin 7)

For the adjustable-output version, the feedback voltage is typically 0.8V. The external resistor divider connected to FB sets the output voltage (see Figure 8).

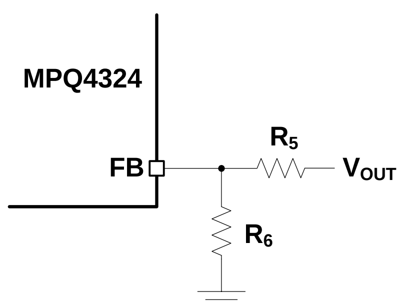


Figure 8: Feedback Divider Network with Adjustable Output

Calculate R_6 with Equation (4):

$$R_6 = \frac{R_5}{\frac{V_{OUT}}{0.8V} - 1} \quad (4)$$

For a fixed output, the FB resistor divider is integrated internally. This means that FB should be directly connected to the output to set the output voltage. The following fixed outputs can be selected: 1V, 1.8V, 2.5V, 3.0V, 3.3V, 3.8V, and 5V (see Figure 9).

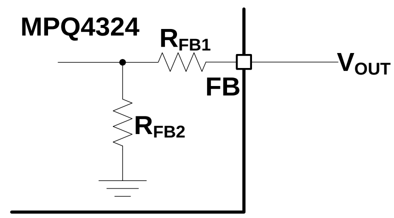


Figure 9: Feedback Divider Network of Fixed Output Version

Table 4 shows the relationship between the internal R_{FB} and V_{OUT}.

Table 4: R_{FB} vs. V_{OUT}

V_{OUT} (V)	R_{FB1} (kΩ)	R_{FB2} (kΩ)
1	64	256
1.8	320	256
2.5	544	256
3.0	704	256
3.3	800	256
3.8	960	256
5	1344	256

A feed-forward capacitor (C5) improves the phase margin and transient response of circuits that have output capacitors with a low ESR.

Power Good Indicator (PG, Pin 8)

The PG resistor (R7 or R_{PG}) should have a resistance that is about 100kΩ. The MPQ4324 includes an open-drain power good (PG) output that indicates whether the regulator's output is within the specific window of its nominal value.

If using PG, connect it to a logic high level power source (e.g. 3.3V) via a pull-up resistor. PG goes high if the output voltage is within 94.5% to 105.5% of the nominal voltage; PG goes low if the output voltage is above 107% or below 93% of the nominal voltage. Float PG if it is not used.

Enable and Under-Voltage Lockout (UVLO) (EN, Pin 9)

EN is a digital control pin that turns the regulator on and off.

Enabled by External Logic High/Low Signal

When the EN voltage reaches 0.7V, the bandgap (BG) does not turn on until V_{IN} exceeds 2.7V. BG then provides an accurate reference voltage for the EN threshold. Forcing EN above its rising threshold (about 1.02V) turns the device on.

Turn the device off by driving EN below 0.85V. There is no internal pull-up or pull-down resistor connected to the EN pin, so do not float EN. An external pull-up or pull-down resistor is required if the control signal cannot give an accurate high or low logic.

Configurable V_{IN} Under-Voltage Lockout (UVLO)

The MPQ4324 has an internal, fixed under-voltage lockout (UVLO) threshold. The rising threshold is 3.65V, while the falling threshold is about 2.9V. For applications that require a higher UVLO point, an external resistor divider can be placed between VIN and EN to achieve a higher equivalent UVLO threshold (see Figure 10).

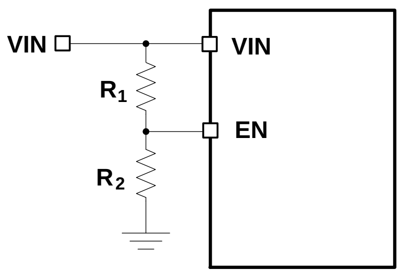


Figure 10: Adjustable UVLO Using EN Divider

The UVLO rising and falling thresholds can be calculated with Equation (5) and Equation (6), respectively:

$$V_{INUVRISING} = (1 + \frac{R_1}{R_2}) \times V_{EN\_RISING} \tag{5}$$

$$V_{INUVFALLING} = (1 + \frac{R_1}{R_2}) \times V_{EN\_FALLING} \tag{6}$$

Where V_{EN_RISING} is 1.02V, and $V_{EN\_FALLING}$ is 0.85V.

If EN is not used to control when the device turns on and off, connect EN to a high voltage source (e.g. VIN) to turn the device on by default.

Selecting the Inductor and Output Capacitors (SW, Pin 12)

The inductance (L_1) can be estimated with Equation (7):

$$L_1 = \frac{V_{OUT}}{f_{SW} \times \Delta I_L} \times (1 - \frac{V_{OUT}}{V_{IN}}) \tag{7}$$

Where ΔI_L is the peak-to-peak inductor ripple current.

A 1µH to 10µH inductor with a DC current rating at least 25% higher than the maximum load current is recommended for most applications. For higher efficiency, choose an inductor with a lower DC resistance. A larger-value inductor results in less ripple current and a lower output ripple voltage, but also has a larger physical size, higher series resistance, and lower saturation current. A good rule to determine the inductor value is to allow the inductor ripple current to be approximately 30% of the maximum load current.

The peak inductor current (I_{LP}) can be calculated with Equation (8)

$$I_{LP} = I_{LOAD} + \frac{V_{OUT}}{2 \times f_{SW} \times L} \times (1 - \frac{V_{OUT}}{V_{IN}}) \tag{8}$$

Choose an inductor that does not saturate under the peak inductor current.

The output voltage ripple can be estimated with Equation (9):

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_{SW} \times L} \times (1 - \frac{V_{OUT}}{V_{IN}}) \times (R_{ESR} + \frac{1}{8 \times f_{SW} \times C_{OUT}}) \tag{9}$$

Where L is the inductance, and R_{ESR} is the output capacitor's equivalent series resistance (ESR). The output capacitor (C_{OUT}) maintains the DC output voltage. Use ceramic, tantalum, or low-ESR electrolytic capacitors. For the best results, use low-ESR capacitors to keep the output voltage ripple low.

For ceramic capacitors**,** the capacitance dominates the impedance at the switching frequency and causes the majority of the output voltage ripple. For simplification, the output voltage ripple can be calculated with Equation (10):

$$\Delta V_{OUT} = \frac{V_{OUT}}{8 \times f_{SW}^2 \times L \times C_{OUT}} \times (1 - \frac{V_{OUT}}{V_{IN}}) \tag{10}$$

For tantalum or electrolytic capacitors, the ESR dominates the impedance at the switching frequency. For simplification, the output voltage ripple can be estimated with Equation (11):

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_{SW} \times L} \times (1 - \frac{V_{OUT}}{V_{IN}}) \times R_{ESR} \tag{11}$$

When selecting an output capacitor, consider the allowable overshoot in V_{OUT} if the load is suddenly removed. In this scenario, energy stored in the inductor is transferred to C_{OUT}, causing its voltage to rise. To achieve an optimal overshoot relative to the regulated voltage, the output capacitance can be estimated with Equation (12):

$$C_{OUT} = \frac{I_{OUT}^2 \times L}{V_{OUT}^2 \times ((V_{OUTMAX} / V_{OUT})^2 - 1)} \quad (12)$$

Where V_{OUTMAX}/V_{OUT} is the allowable maximum overshoot.

After calculating the capacitance that meets both the ripple and overshoot requirements, choose the greater capacitance value.

The characteristics of the output capacitor also affect the stability of the regulation system. The MPQ4324 can be optimized for a wide range of capacitance and ESR values.

GND Connection (GND, Pins 1, 6, and 11; AGND, Pin 12)

See the PCB Layout Guidelines on page 72 for more details.

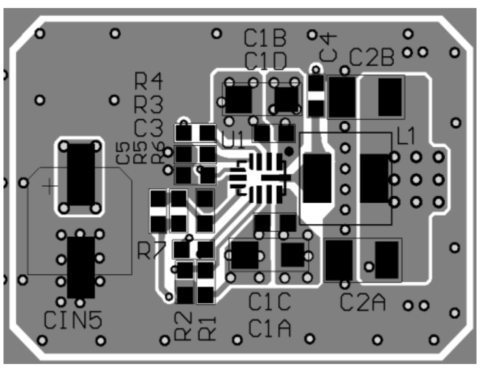
PCB Layout Guidelines [15]

Efficient PCB layout, especially for input capacitor placement, is critical for stable operation. A 4-layer layout is strongly recommended to improve thermal performance. For the best results, refer to Figure 11 and follow the guidelines below:

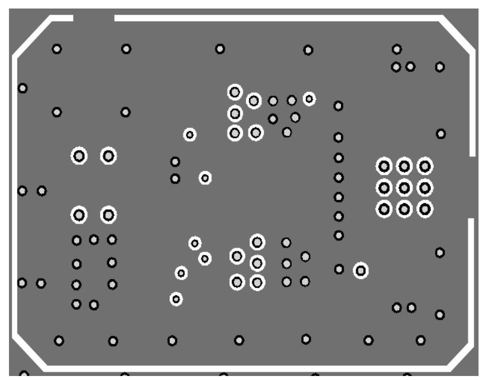
1. Place symmetric input capacitors as close to VIN and GND as possible.
2. Use a large ground plane to connect directly to PGND.
3. Add vias near PGND if the bottom layer is a ground plane.
4. Ensure that the high-current paths at GND and VIN have short, direct, and wide traces.
5. Place the ceramic input capacitor, especially the small package size (0603) input bypass capacitor, as close to VIN and PGND as possible to minimize high-frequency noise.
6. Keep the connection between the input capacitor and VIN as short and wide as possible.
7. Place the VCC capacitor as close to VCC and AGND as possible.
8. Route SW and BOOT away from sensitive analog areas, such as FB.
9. Place the feedback resistors close to the chip to ensure that the trace that connects to FB is as short as possible.
10. Use multiple vias to connect the power planes to the internal layers.

Notes:

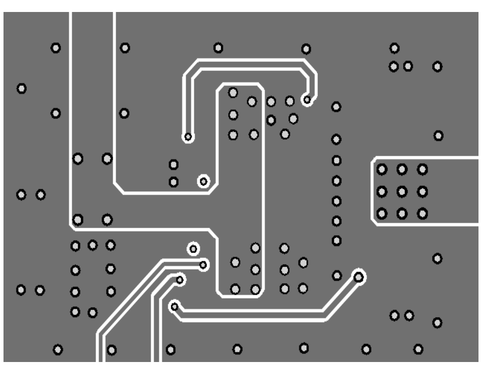
15) The recommended PCB layout is based on Figure 7 on page 67.



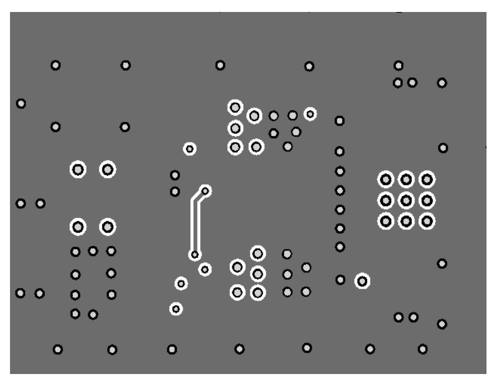
Top Layer and Top Silk



Mid-Layer 1



Mid-Layer 2



Bottom Layer and Bottom Silk

Figure 11: Recommended PCB Layout

TYPICAL APPLICATION CIRCUITS

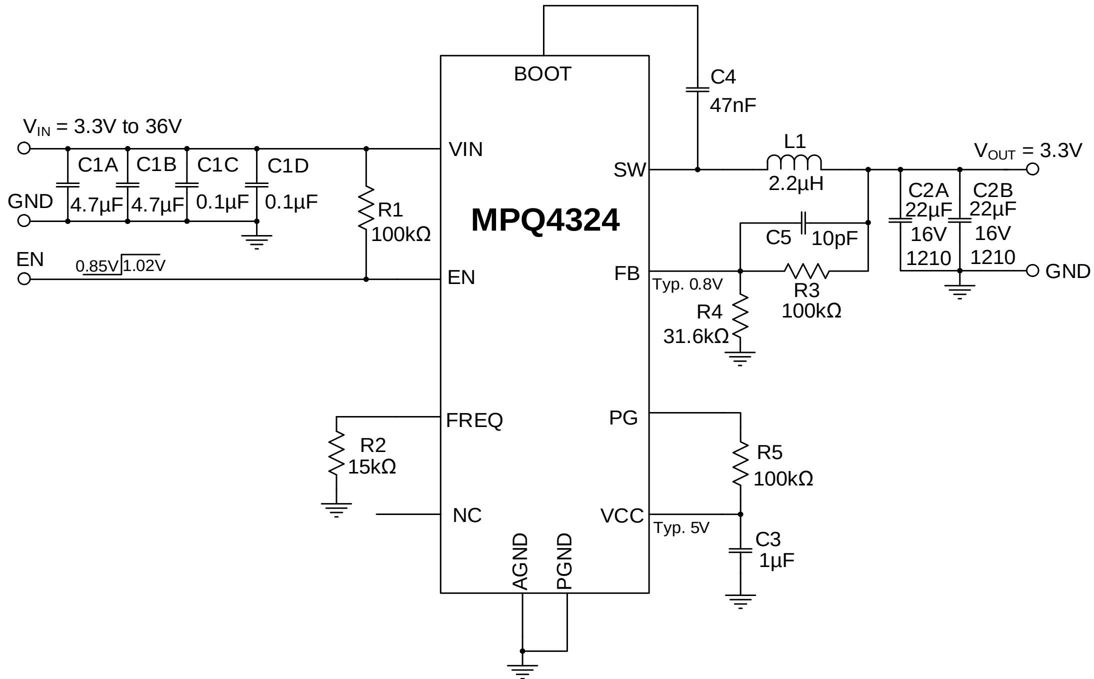


Figure 12: Typical Application Circuit (V_{OUT} = 3.3V, f_{SW} = 2.2MHz, 1.5A/2A/3A/4A Version)

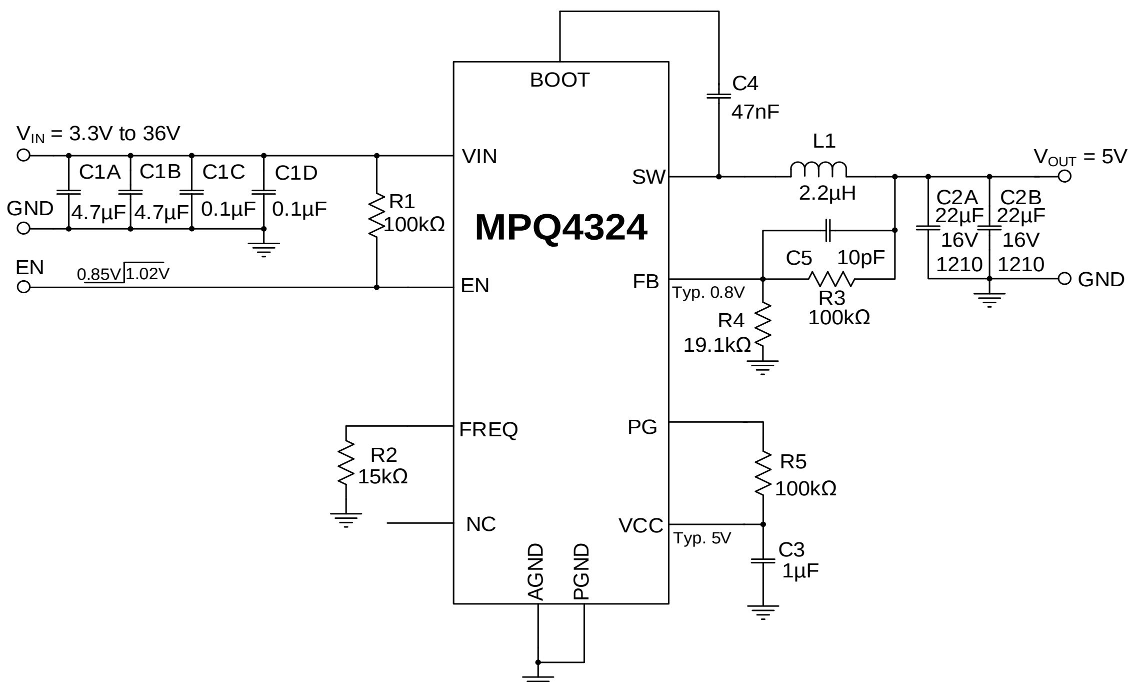


Figure 13: Typical Application Circuit (V_{OUT} = 5V, f_{SW} = 2.2MHz, 1.5A/2A/3A/4A Version)

TYPICAL APPLICATION CIRCUITS *(continued)*

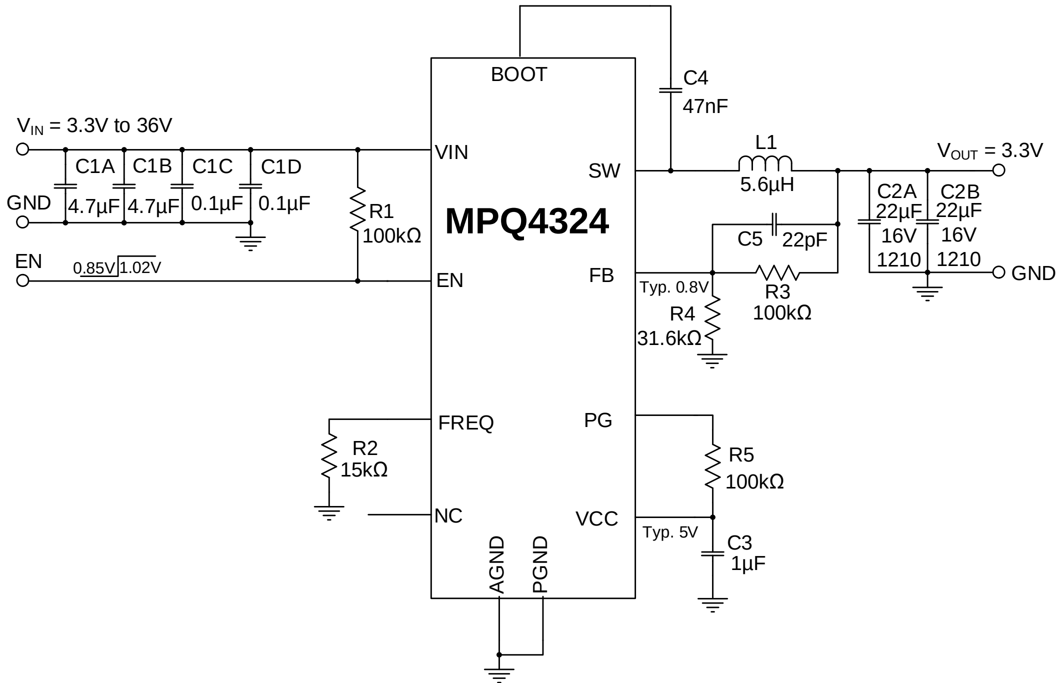


Figure 14: Typical Application Circuit (V_{OUT} = 3.3V, f_{SW} = 2.2MHz, 1A Version)

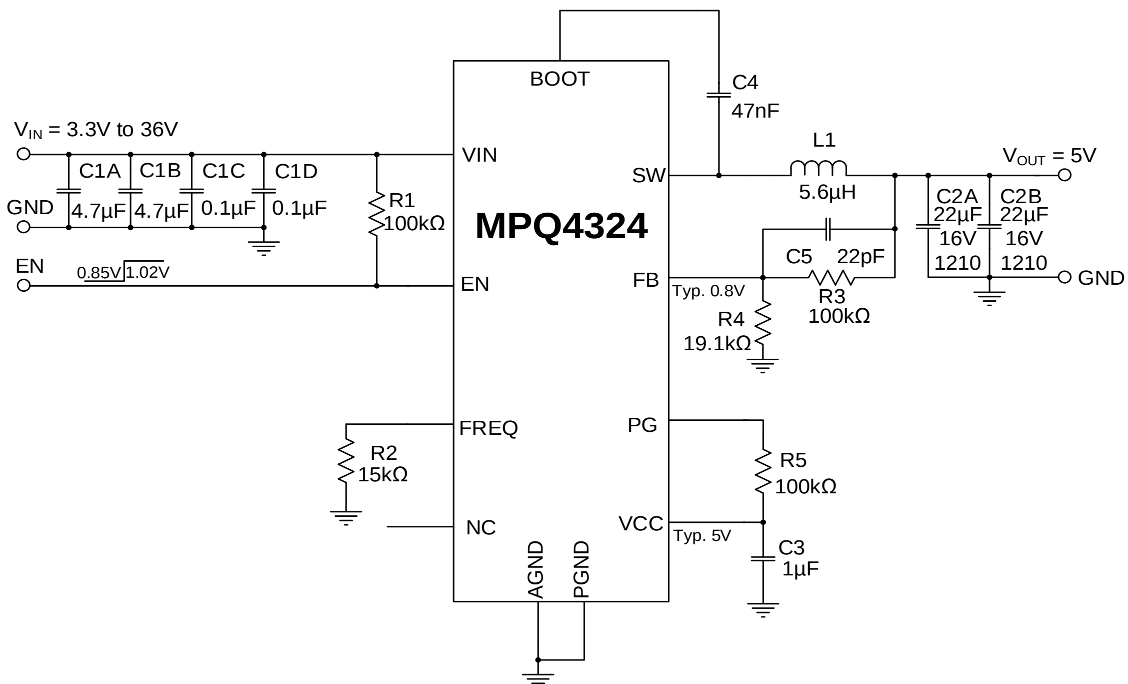


Figure 15: Typical Application Circuit (V_{OUT} = 5V, f_{SW} = 2.2MHz, 1A Version)

TYPICAL APPLICATION CIRCUITS *(continued)*

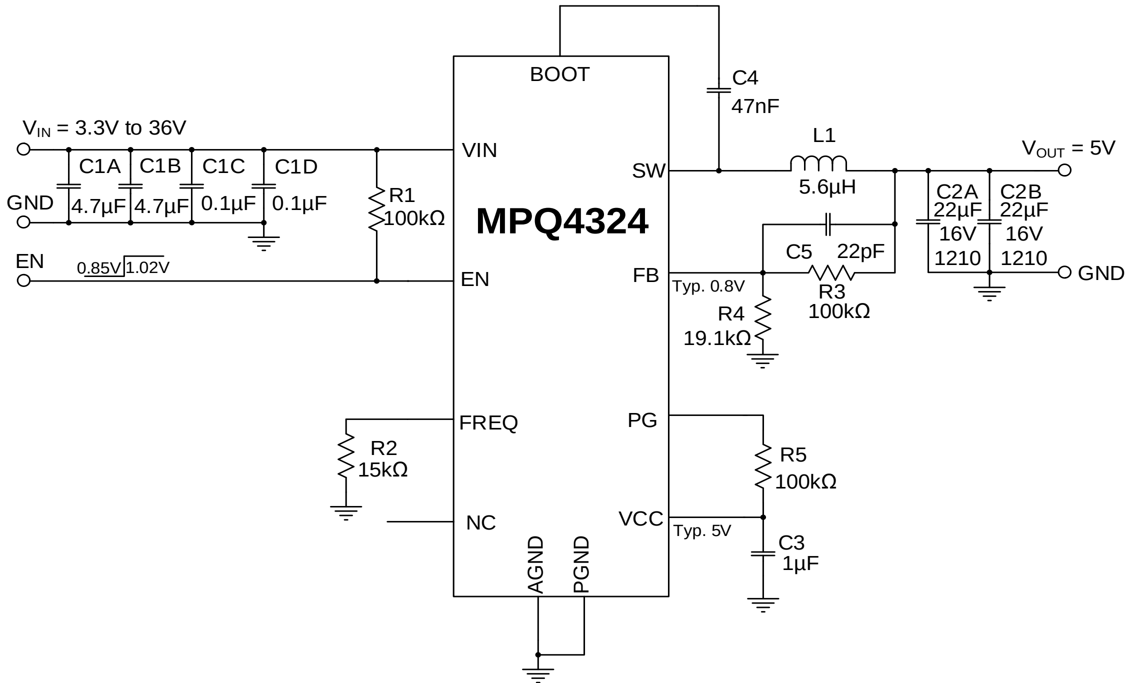


Figure 16: Typical Application Circuit (V_{OUT} = 5V, f_{SW} = 2.2MHz, FCCM, 0.5A Version)

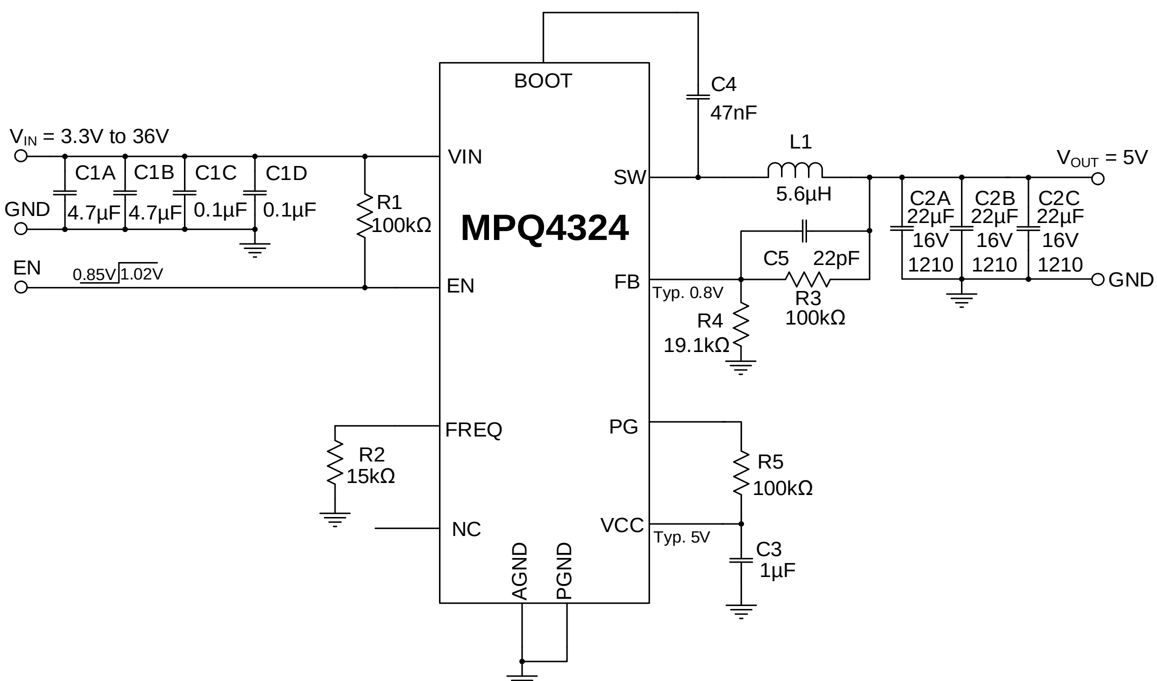


Figure 17: Typical Application Circuit (V_{OUT} = 5V, R_{FREQ} = 15kΩ, AAM Mode, 0.5A Version)

TYPICAL APPLICATION CIRCUITS *(continued)*

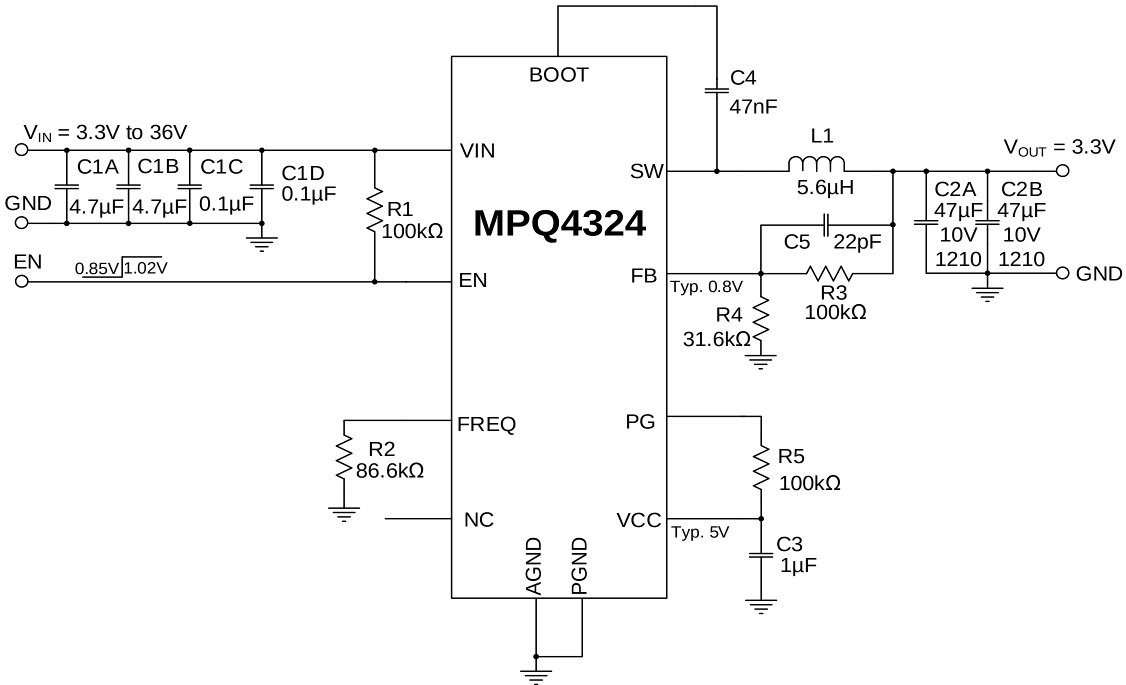


Figure 18: Typical Application Circuit (V_{OUT} = 3.3V, f_{SW} = 415kHz, I_{OUT} = 3A/4A)

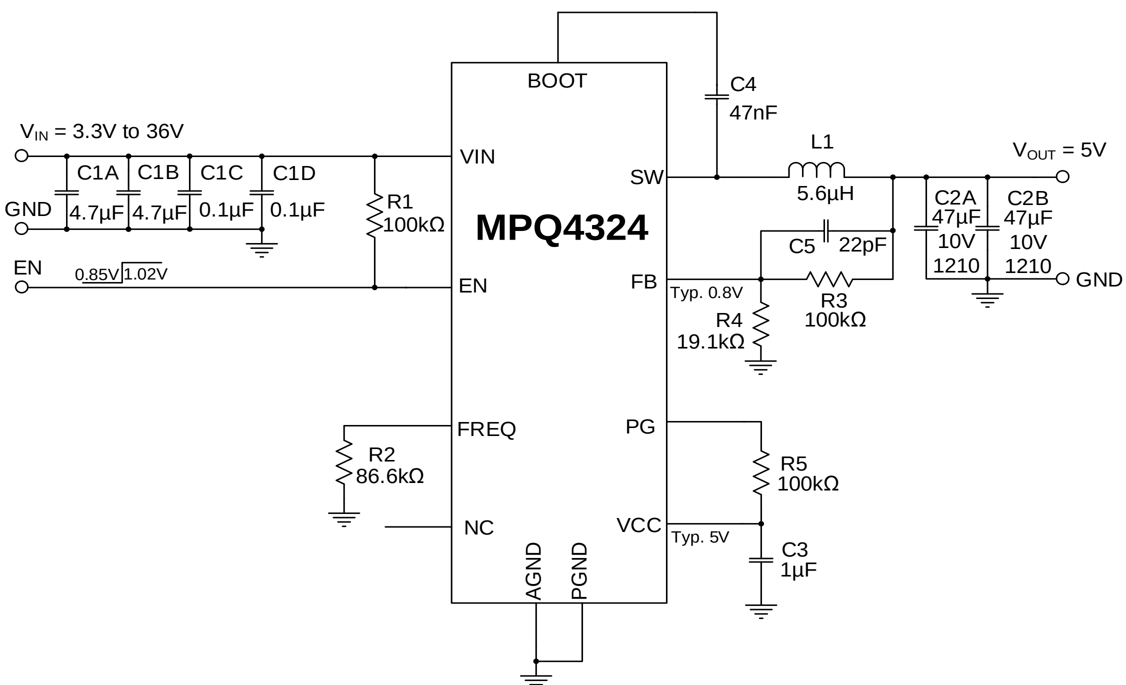


Figure 19: Typical Application Circuit (V_{OUT} = 5V, f_{SW} = 415kHz, I_{OUT} = 3A/4A)

TYPICAL APPLICATION CIRCUITS *(continued)*

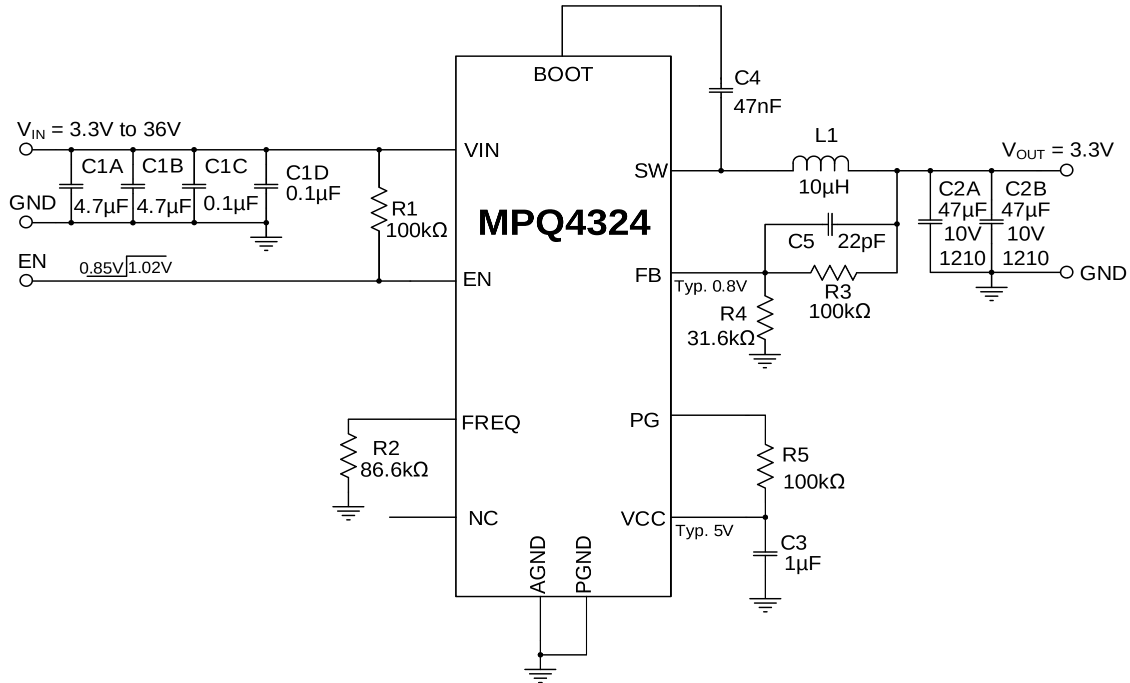


Figure 20: Typical Application Circuit (V_{OUT} = 3.3V, f_{SW} = 415kHz, I_{OUT} = 2A/1.5A)

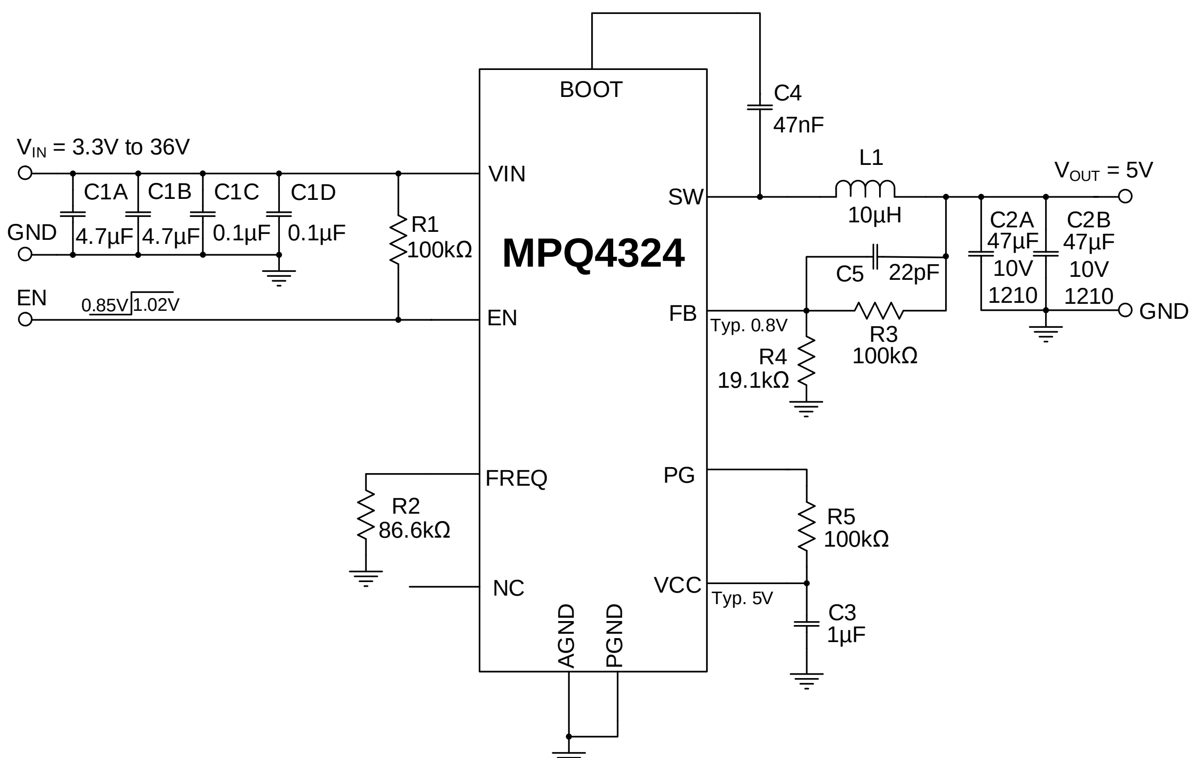


Figure 21: Typical Application Circuit (V_{OUT} = 5V, f_{SW} = 415kHz, I_{OUT} = 2A/1.5A)

TYPICAL APPLICATION CIRCUITS *(continued)*

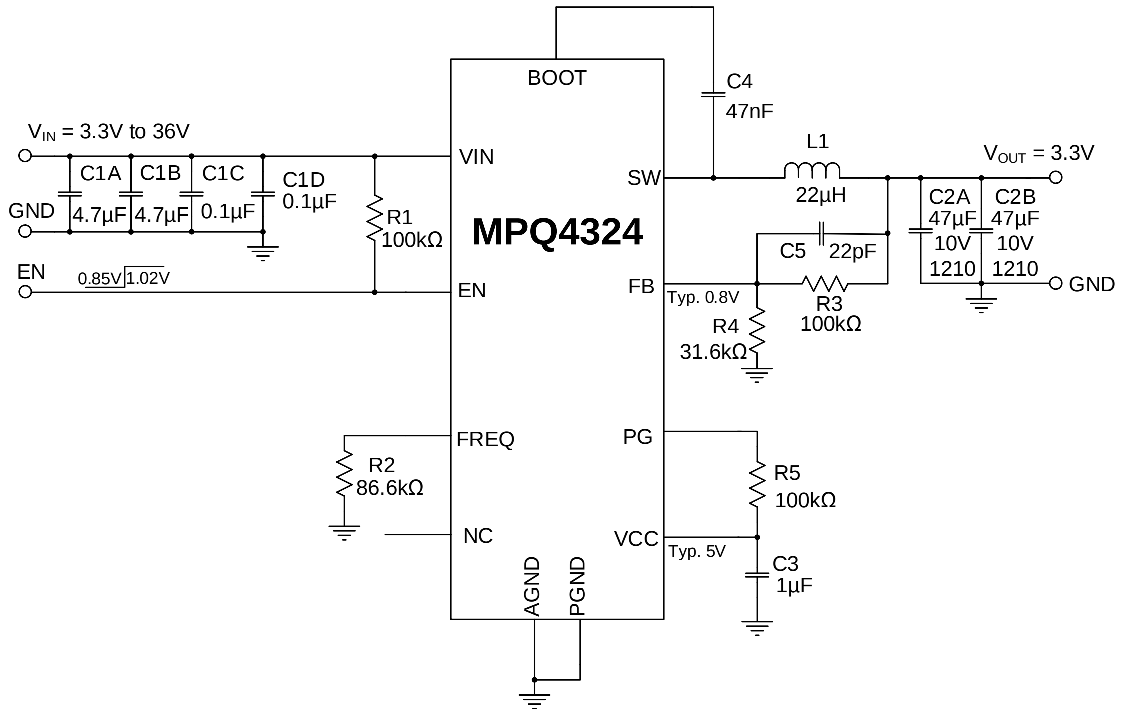


Figure 22: Typical Application Circuit (V_{OUT} = 3.3V, f_{SW} = 415kHz, 0.5A/1A Version)

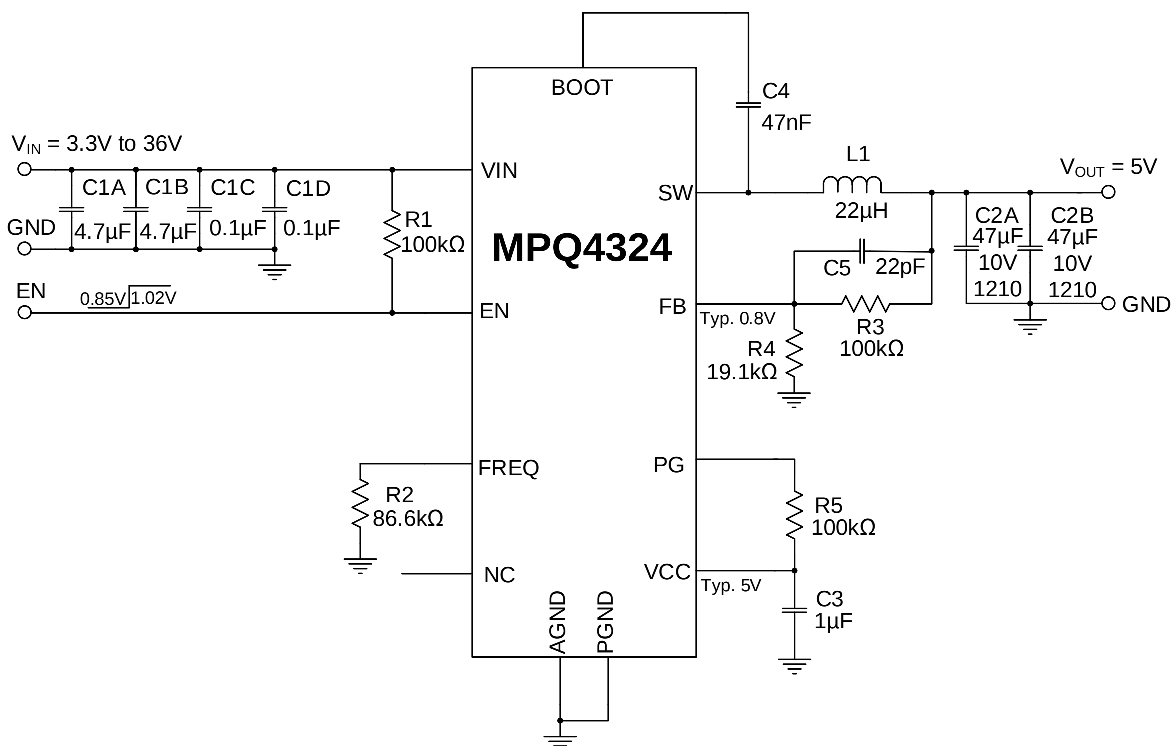


Figure 23: Typical Application Circuit (V_{OUT} = 5V, f_{SW} = 415kHz, 0.5A/1A Version)

TYPICAL APPLICATION CIRCUITS *(continued)*

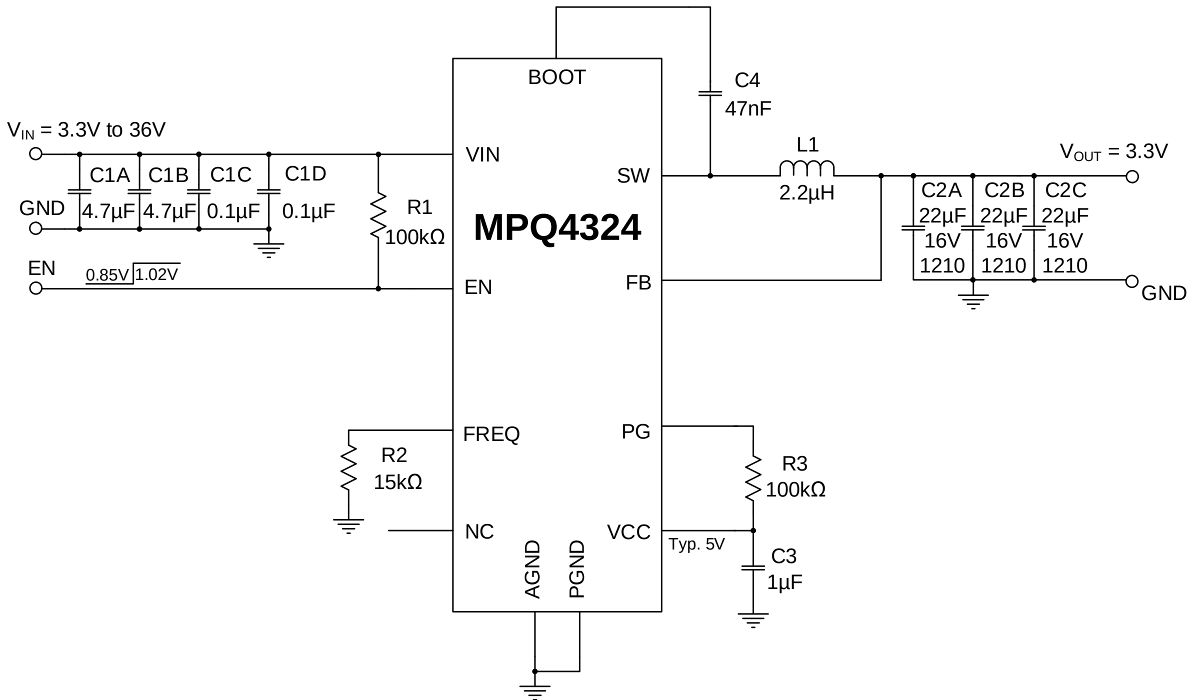


Figure 24: Typical Application Circuit (3.3V Fixed Output, f_{SW} = 2.2MHz, 1.5A/2A/3A/4A Version)

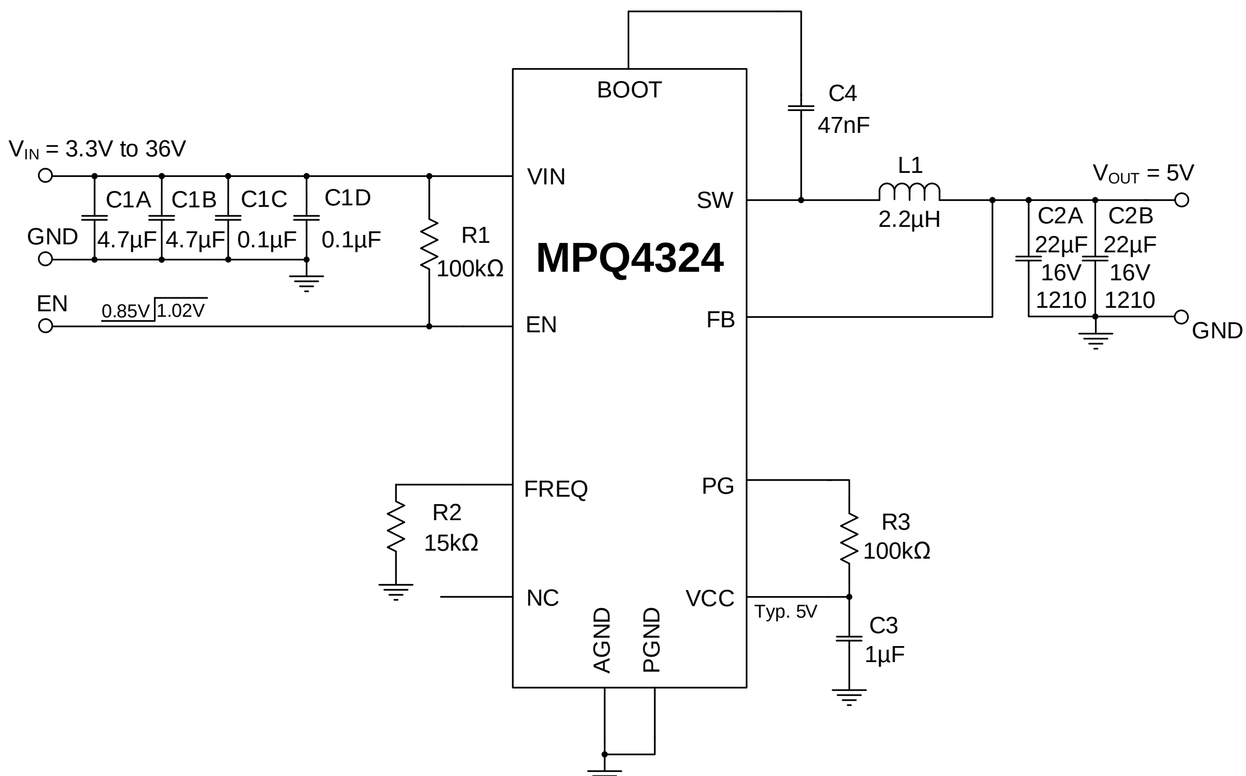


Figure 25: Typical Application Circuit (5V Fixed Output, f_{SW} = 2.2MHz, I_{OUT} = 1.5A/2A/3A/4A Version)

TYPICAL APPLICATION CIRCUITS *(continued)*

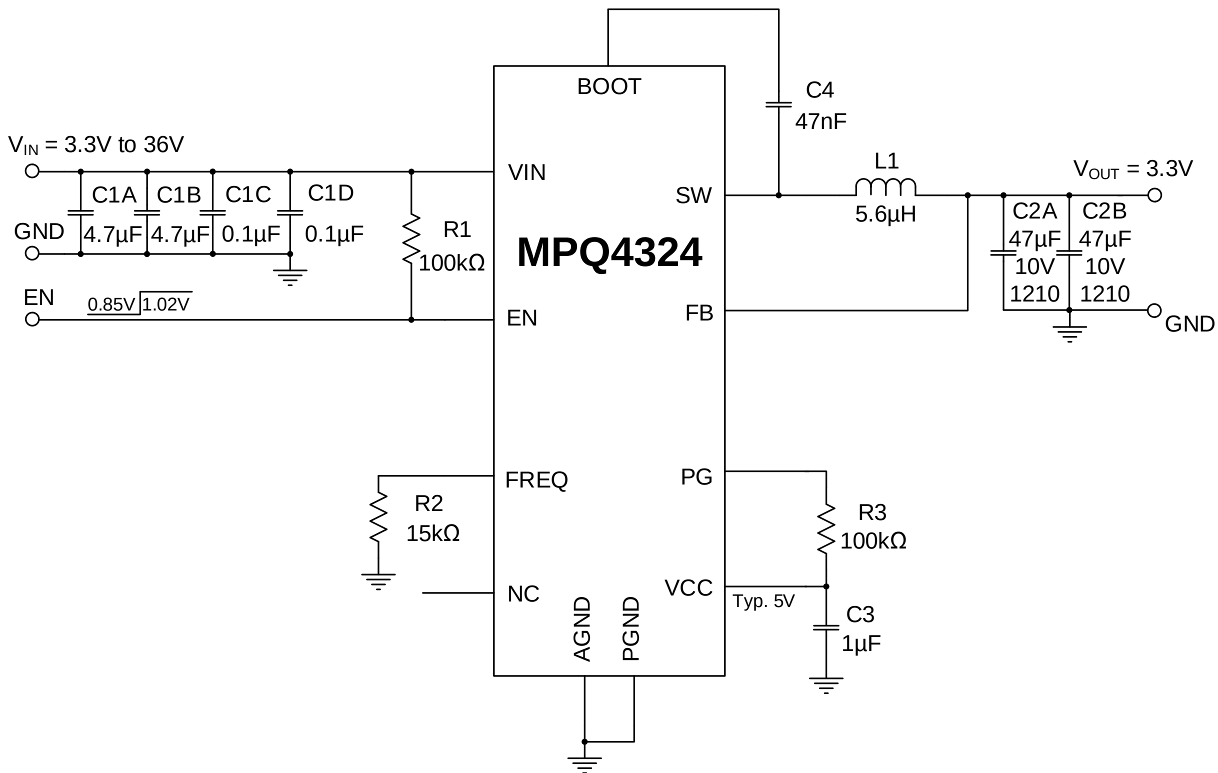


Figure 26: Typical Application Circuit (3.3V Fixed Output, f_{SW} = 2.2MHz, 0.5A/1A Version)

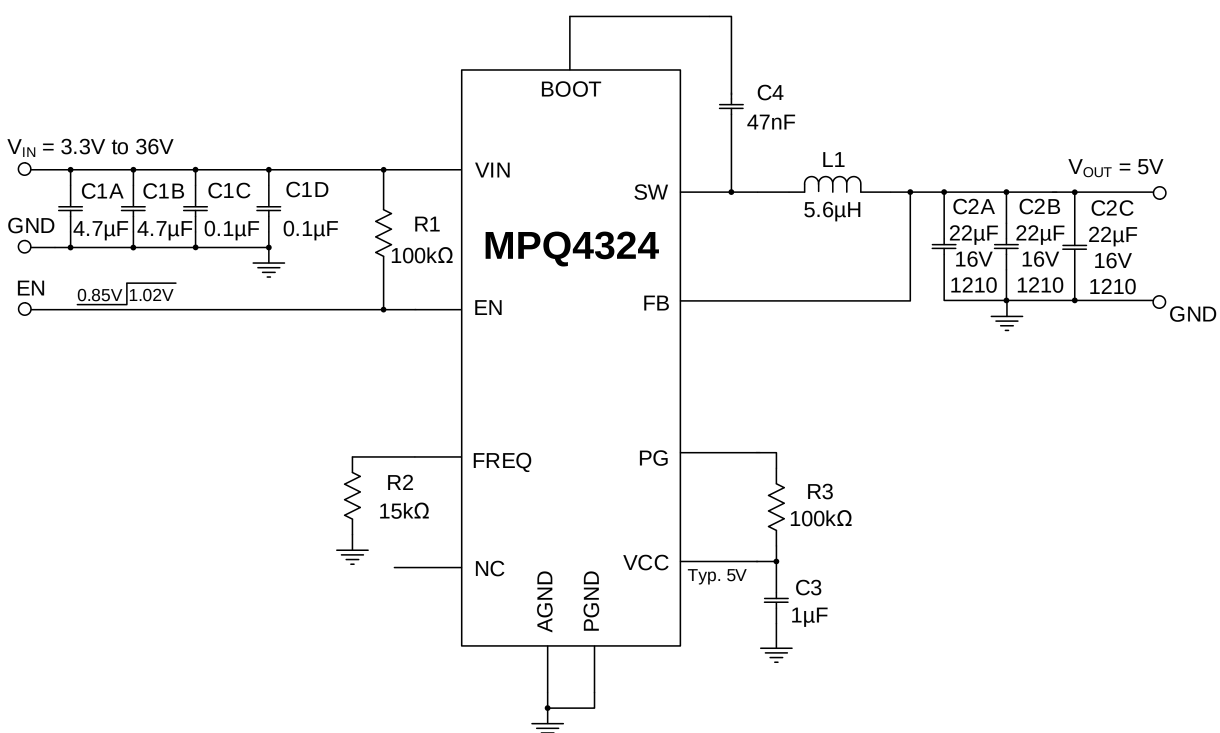


Figure 27: Typical Application Circuit (5V Fixed Output, f_{SW} = 2.2MHz, 0.5A/1A Version)

TYPICAL APPLICATION CIRCUITS *(continued)*

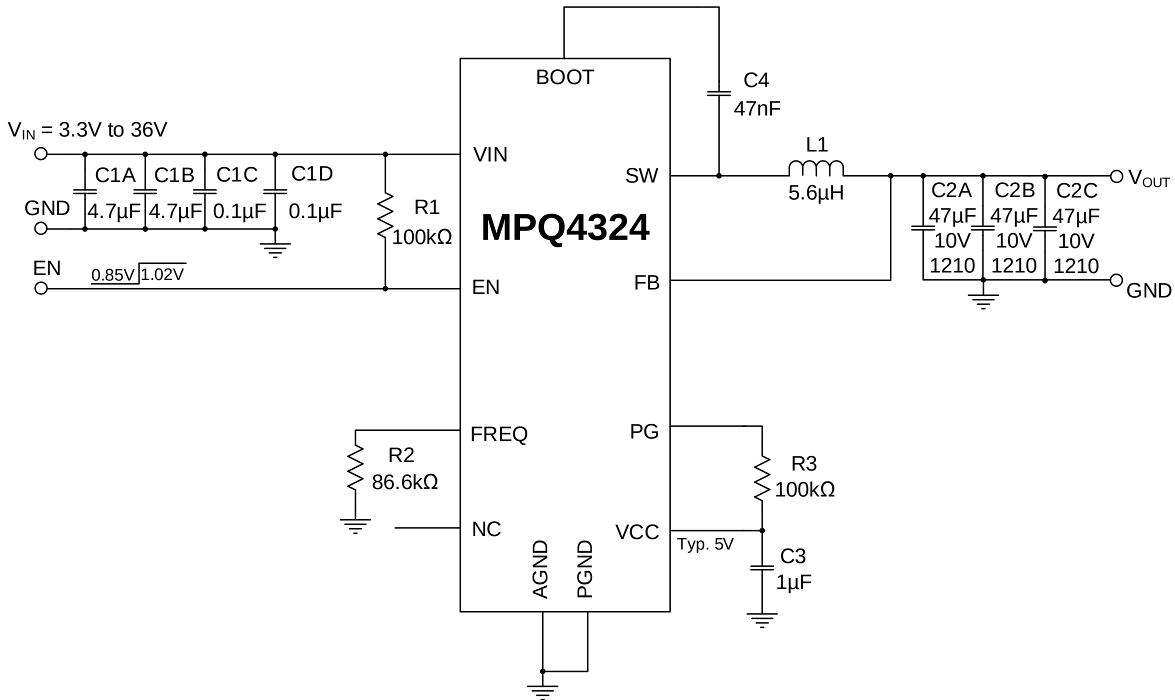


Figure 28: Typical Application Circuit (3.3V Fixed Output, f_{SW} = 415kHz, 3A/4A Version)

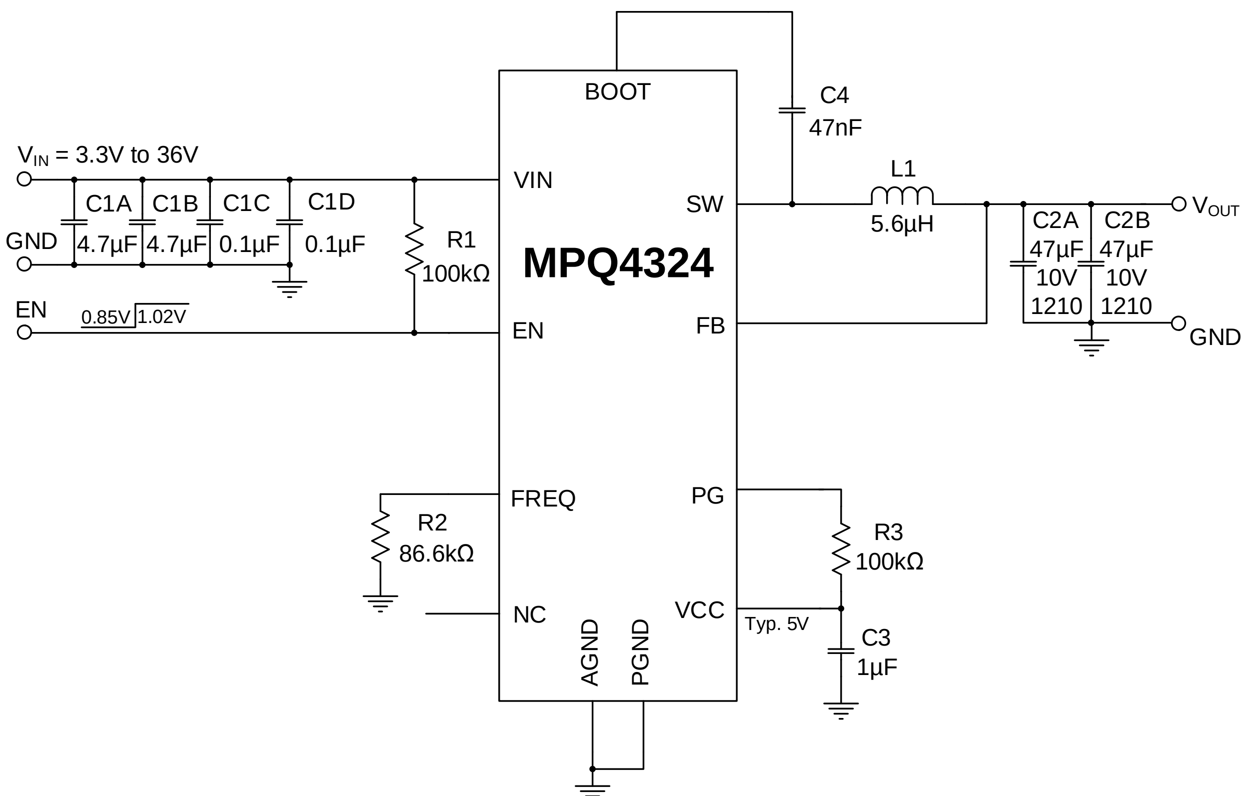


Figure 29: Typical Application Circuit (5V Fixed Output, f_{SW} = 415kHz, 3A/4A Version)

TYPICAL APPLICATION CIRCUITS *(continued)*

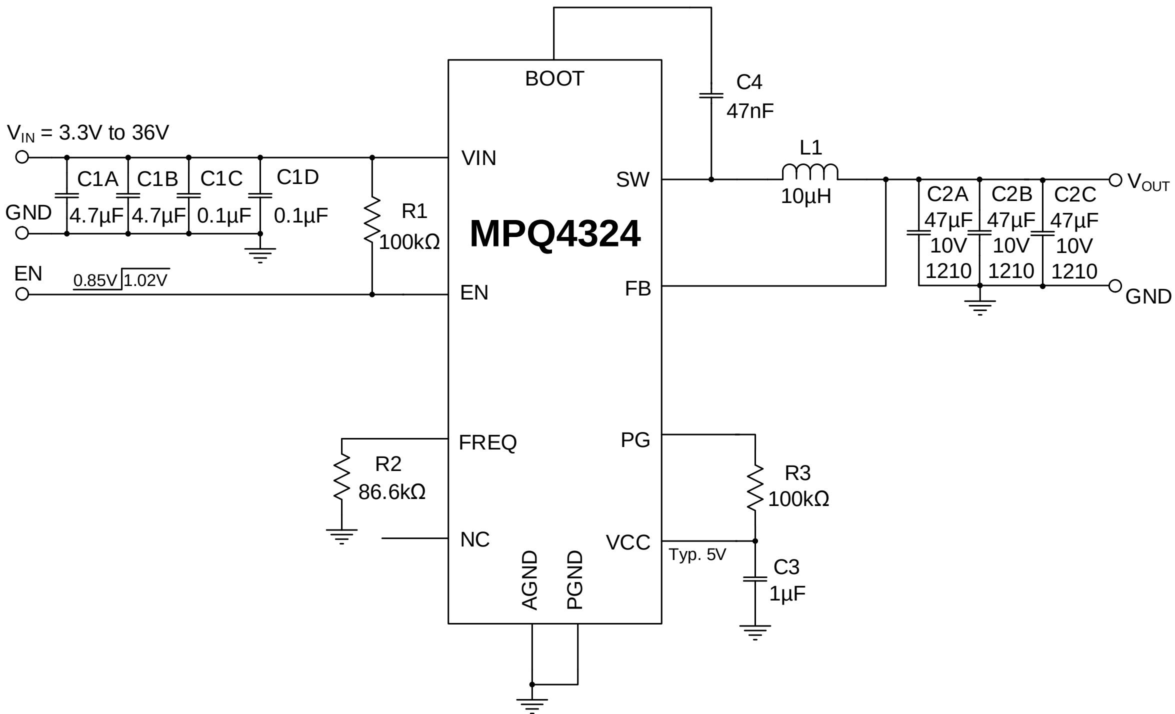


Figure 30: Typical Application Circuit (3.3V Fixed Output, f_{SW} = 415kHz, 2A/1.5A Version)

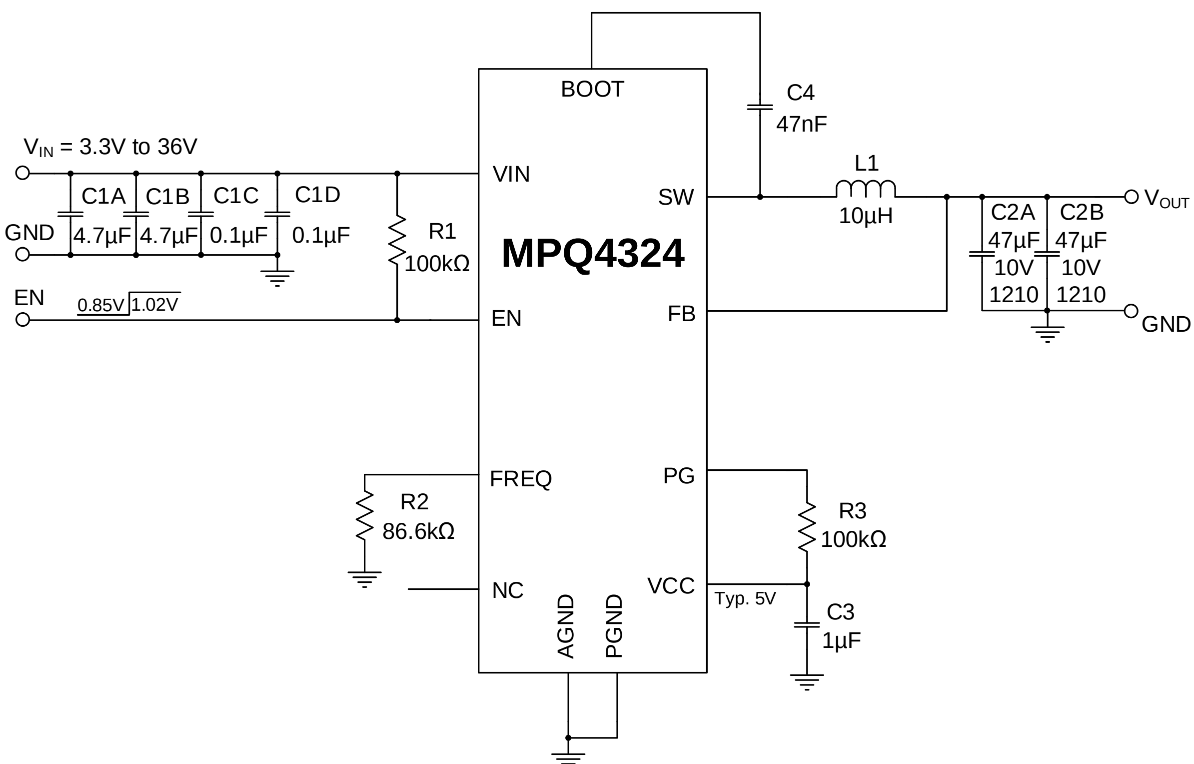


Figure 31: Typical Application Circuit (5V Fixed Output, f_{SW} = 415kHz, 2A/1.5A Version)

TYPICAL APPLICATION CIRCUITS *(continued)*

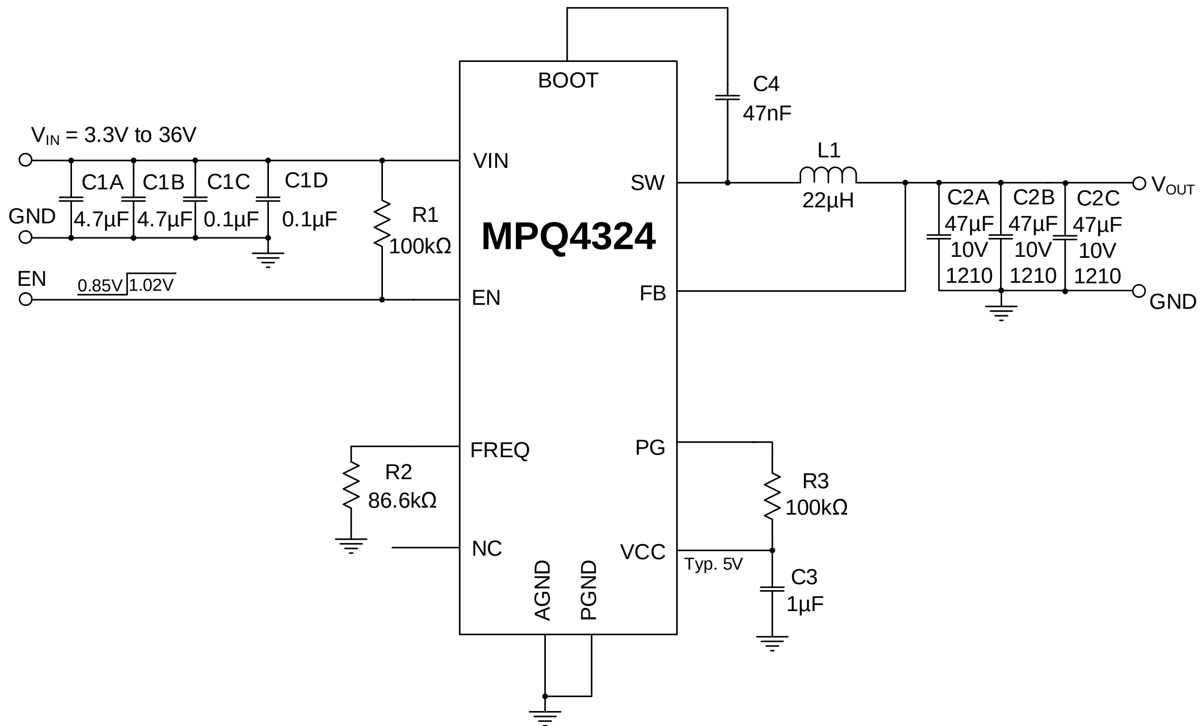


Figure 32: Typical Application Circuit (3.3V Fixed Output, f_{SW} = 415kHz, 0.5A/1A Version)

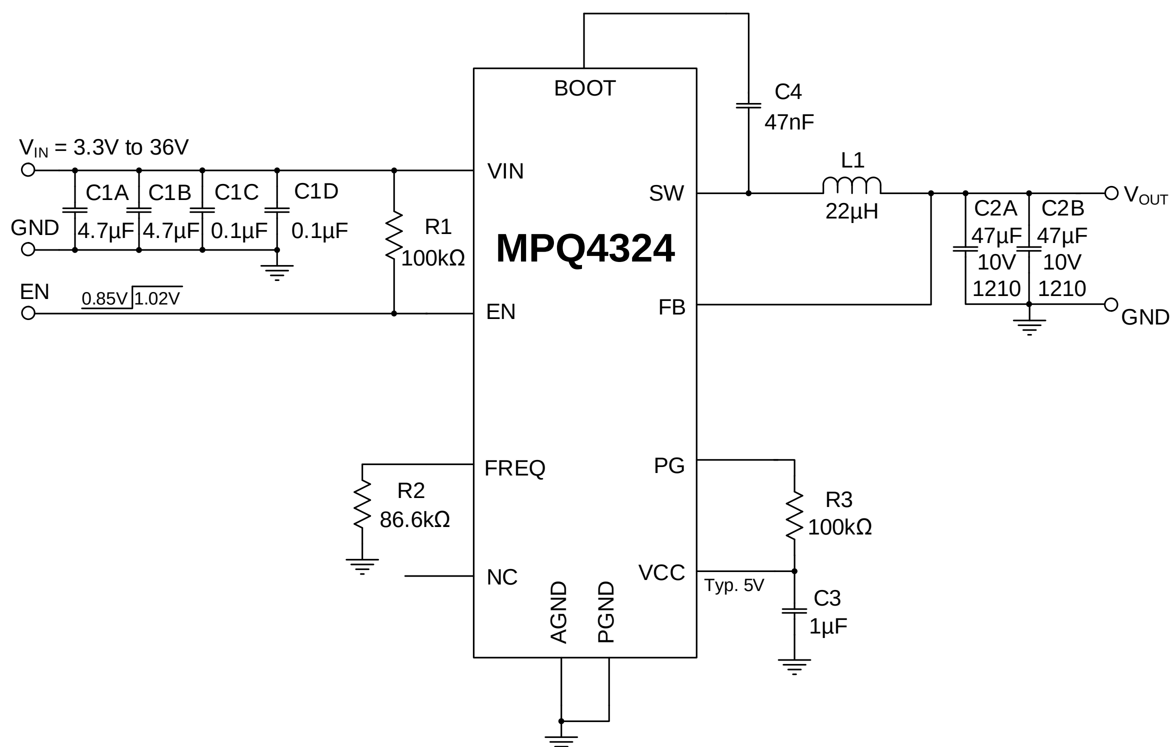


Figure 33: Typical Application Circuit (5V Fixed Output, f_{SW} = 415kHz,0.5A/1A Version)

TYPICAL APPLICATION CIRCUITS *(continued)*

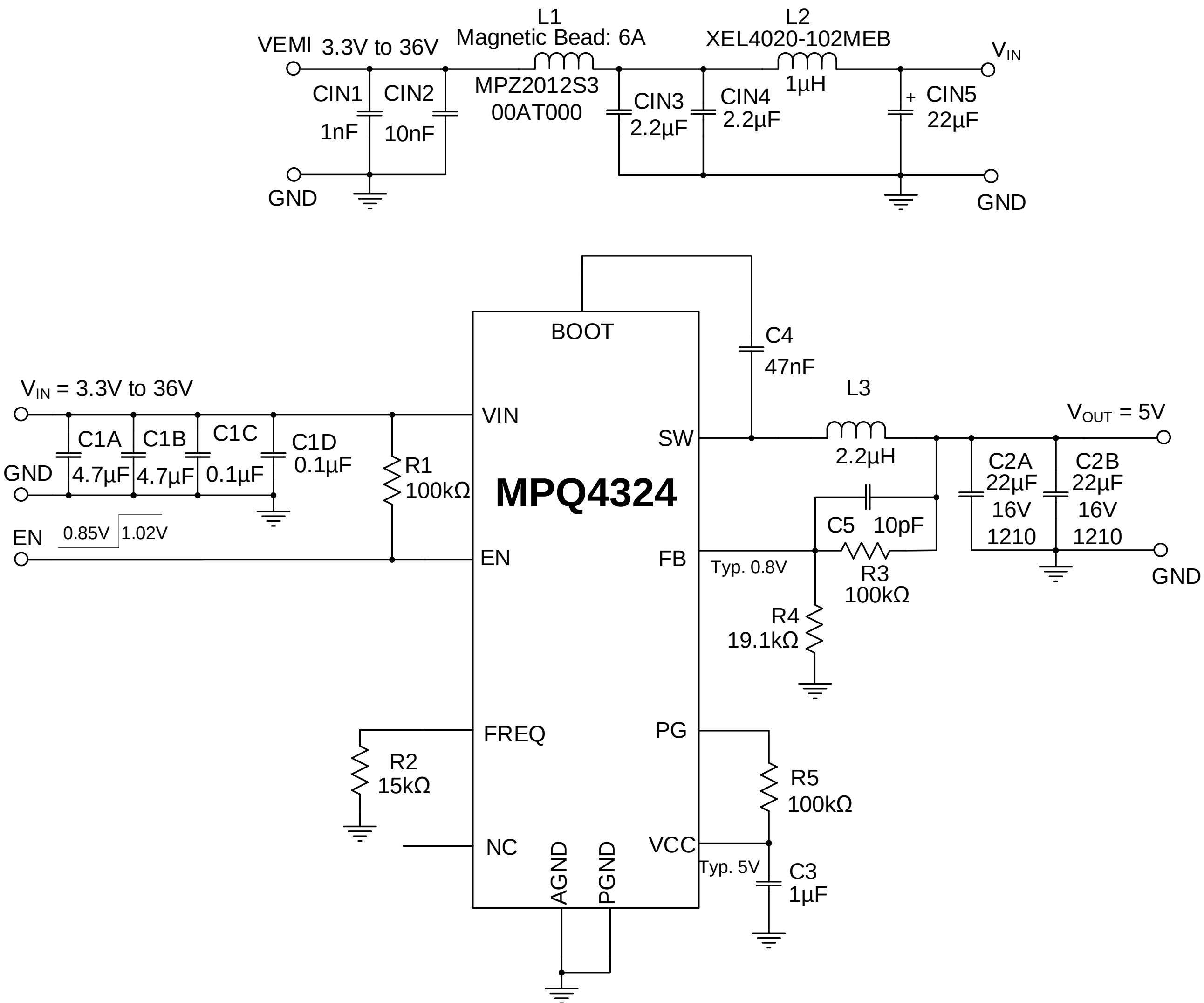


Figure 34: Typical Application Circuit (V_{OUT} = 5V, f_{SW} = 2.2MHz with EMI Filters, 4A Version)

TYPICAL APPLICATION CIRCUITS *(continued)*

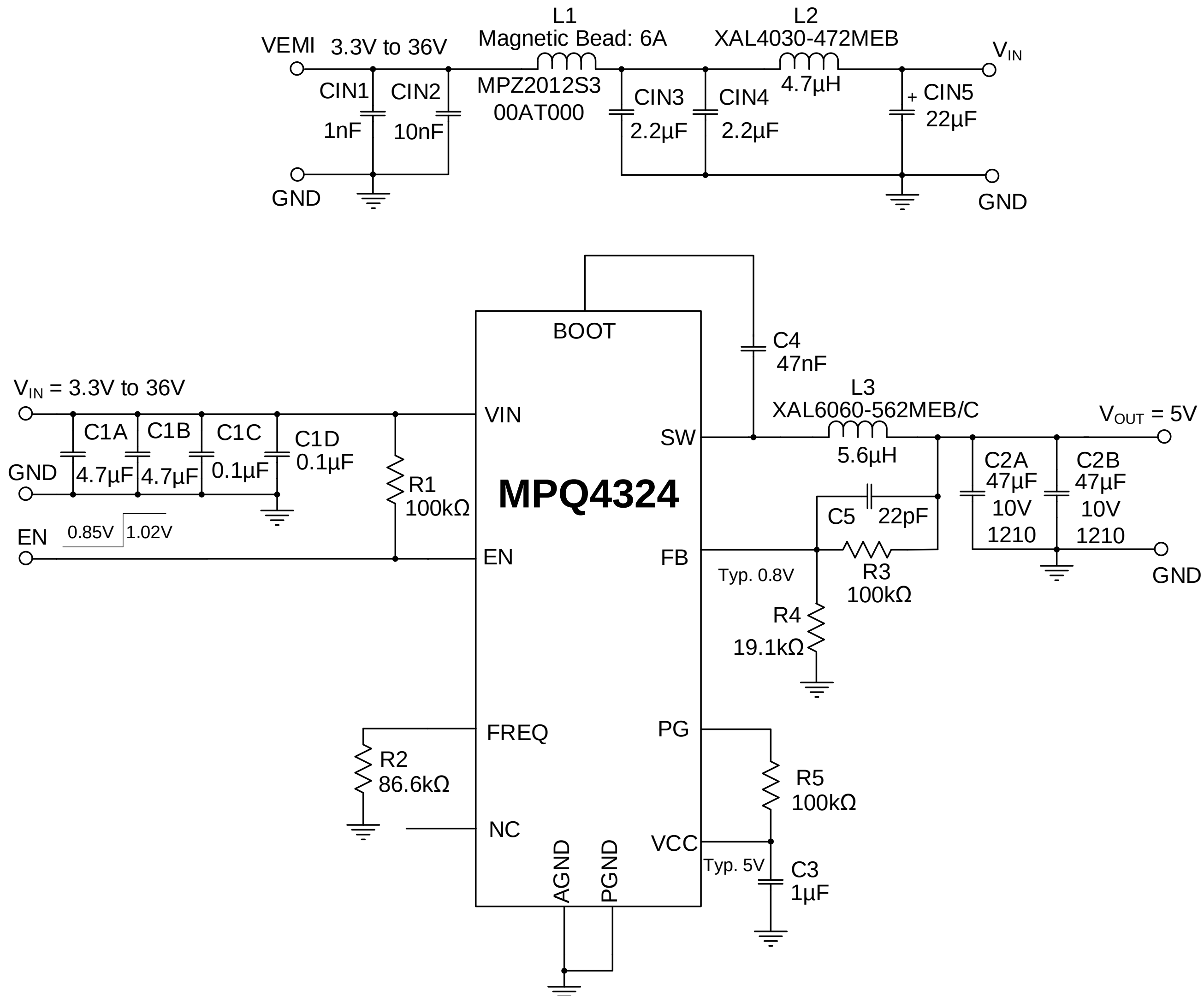
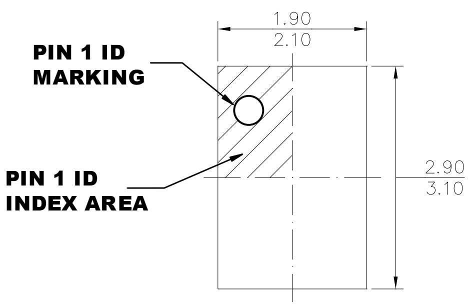


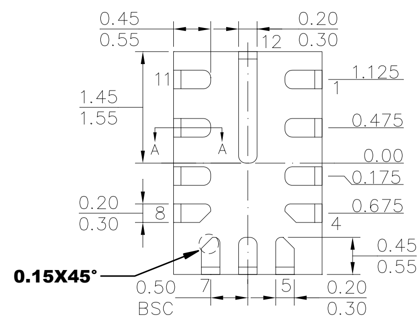
Figure 35: Typical Application Circuit (V_{OUT} = 5V, f_{SW} = 415kHz with EMI Filters, 4A Version)

PACKAGE INFORMATION

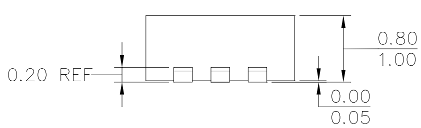
QFN-12 (2mmx3mm)
Wettable Flank



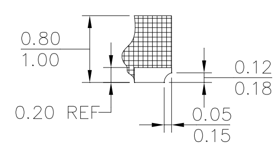
TOP VIEW



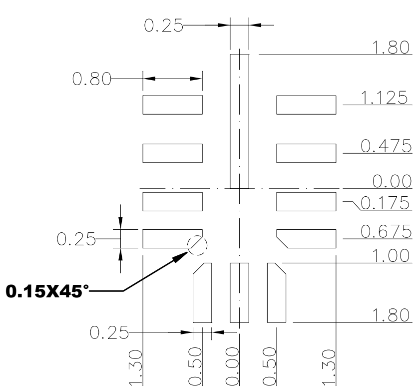
BOTTOM VIEW



SIDE VIEW



SECTION A-A



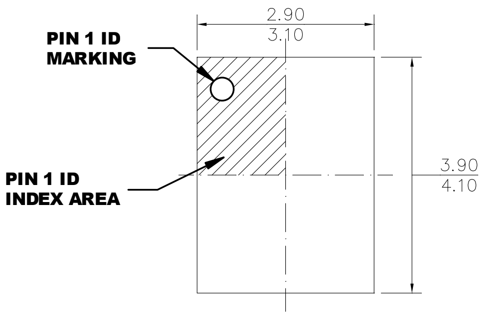
RECOMMENDED LAND PATTERN

NOTE:

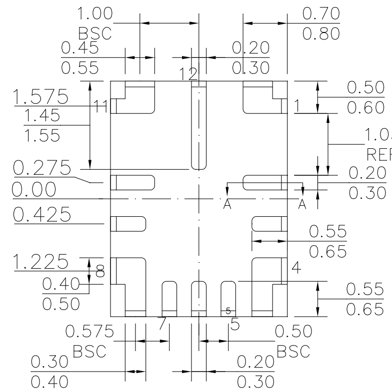
1) THE LEAD SIDE IS WETTABLE.
2) ALL DIMENSIONS ARE IN MILLIMETERS.
3) LEAD COPLANARITY SHALL BE 0.08 MILLIMETERS MAX.
4) JEDEC REFERENCE IS MO-220.
5) DRAWING IS NOT TO SCALE.

PACKAGE INFORMATION *(continued)*

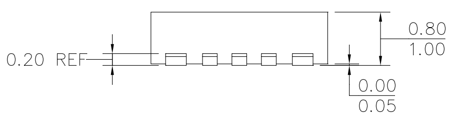
QFN-12 (3mmx4mm)
Wettable Flank



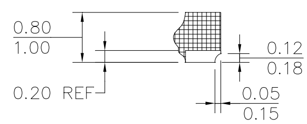
TOP VIEW



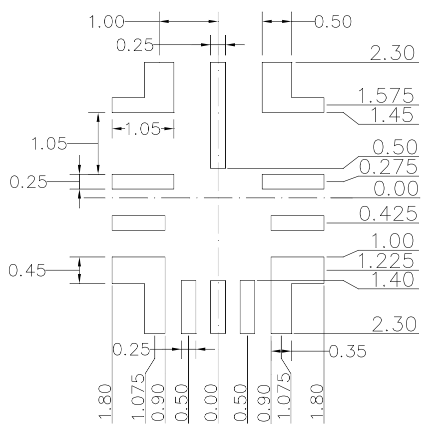
BOTTOM VIEW



SIDE VIEW



SECTION A-A



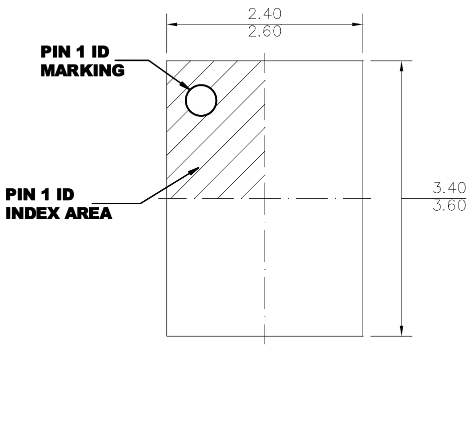
RECOMMENDED LAND PATTERN

NOTE:

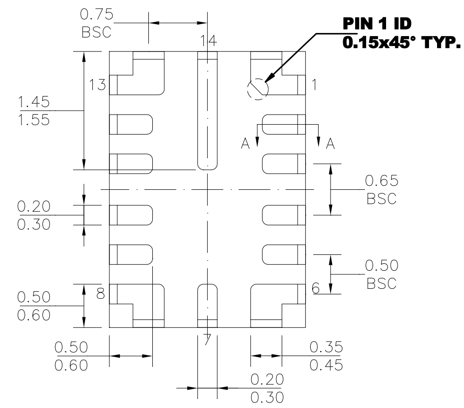
1) THE LEAD SIDE IS WETTABLE.
2) ALL DIMENSIONS ARE IN MILLIMETERS.
3) LEAD COPLANARITY SHALL BE 0.08 MILLIMETERS MAX.
4) JEDEC REFERENCE IS MO-220.
5) DRAWING IS NOT TO SCALE.

PACKAGE INFORMATION *(continued)*

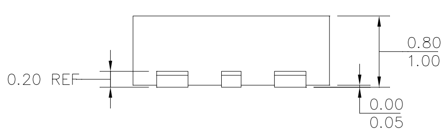
QFN-14 (2.5mmx3.5mm)
Wettable Flank



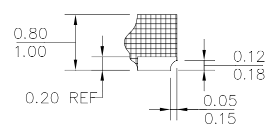
TOP VIEW



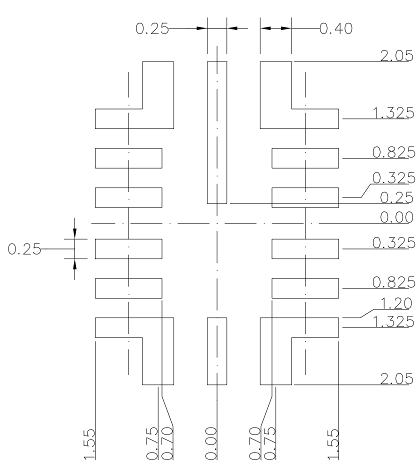
BOTTOM VIEW



SIDE VIEW



SECTION A-A

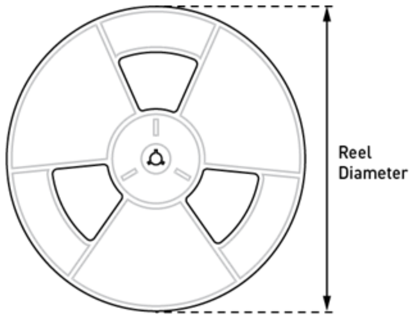


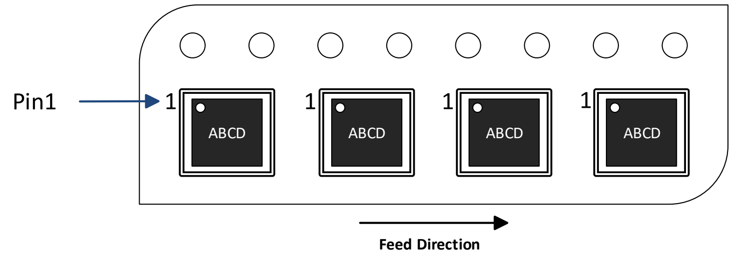
RECOMMENDED LAND PATTERN

NOTE:

1) THE LEAD SIDE IS WETTABLE.
2) ALL DIMENSIONS ARE IN MILLIMETERS.
3) LEAD COPLANARITY SHALL BE 0.08 MILLIMETERS MAX.
4) JEDEC REFERENCE IS MO-220.
5) DRAWING IS NOT TO SCALE.

CARRIER INFORMATION





Part Number	Package Description	Quantity/ Reel	Quantity/ Tube (16)	Quantity/ Tray	Reel Diameter	Carrier Tape Width	Carrier Tape Pitch
MPQ4324GDE-xxxx-AEC1-Z	QFN-12 (2mmx3mm)	5000	N/A	N/A	13in	12mm	8mm
MPQ4324GLE-xxxx-AEC1-Z	QFN-12 (3mmx4mm)	5000	N/A	N/A	13in	12mm	8mm
MPQ4324GRHE-xxxx-AEC1-Z	QFN-14 (2.5mmx3.5mm)	5000	N/A	N/A	13in	12mm	8mm

Note:

16) N/A indicates "not available" in tubes. For the 500-piece tape & reel prototype quantities, contact the factory. (The order code for the 500-piece partial reel is "-P"; tape & reel dimensions are the same as the full reel.)

REVISION HISTORY

Revision #	Revision Date	Description	Pages Updated
1.0	8/22/2024	Initial Release	-