MPQ2176

5.5V, 4A to 6A, 2.2MHz Synchronous Step-Down Converter, AEC-Q100 Qualified

DESCRIPTION

The MPQ2176 family of converters are monolithic, step-down switch-mode converters with built-in internal power MOSFETs. The family provides 4A to 6A of continuous output current (I_{OUT}) from a 2.4V to 5.5V input voltage (V_{IN}) range with excellent load and line regulation. The output voltage (V_{OUT}) can be regulated to as low as 0.4V.

The constant-on-time (COT) control scheme provides fast transient response and facilitates loop stabilization. Fault protections include cycle-by-cycle current limiting, input over-voltage protection (OVP), output OVP, and thermal shutdown. These protections provide reliable, fault-tolerant operation.

The MPQ2176 is ideal for a wide range of applications, such as automotive infotainment, clusters, telematics, and advanced driver-assistance systems (ADAS).

The MPQ2176 requires a minimal number of readily available, standard external components and is available in a small QFN-7 (1.5mmx2.5mm) package.

FEATURES

- Designed for Automotive Applications
  - Wide 2.4V to 5.5V Operating Input Voltage (V_{IN}) Range
  - 4A to 6A Continuous Output Current (I_{OUT}) Version in Pin-Compatible Family
  - Available in AEC-Q100 Grade 1
- Increases Battery Life
  - Advanced Asynchronous Modulation (AAM) Mode
- Designed for High Performance
  - Constant-On-Time (COT) Control Provides an Excellent Transient Response
  - Constant Switching Frequency (f_{SW}) in Steady State
  - 15mΩ and 9mΩ Internal Power MOSFET Switches
- Optimized for EMC/EMI
  - 2.2MHz f_{SW} in Continuous Conduction Mode (CCM)
  - Frequency Spread Spectrum (FSS) Modulation
  - MeshConnect™ Flip-Chip Package
- Additional Features
  - Enable (EN) Function
  - Power Good (PG)
  - ±1% 0.4V Feedback (FB) Accuracy
  - Short-Circuit Protection (SCP) with Hiccup Mode
  - Output Discharge
  - Available in a QFN-7 (1.5mmx2.5mm) Package
  - Available in a Wettable-Flank Package
- Functional Safety System Design Capable
  - MPSafe™ Compatible – Functional Safety Supporting Document Available

MPSafe™ FuSa Compatible

APPLICATIONS

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

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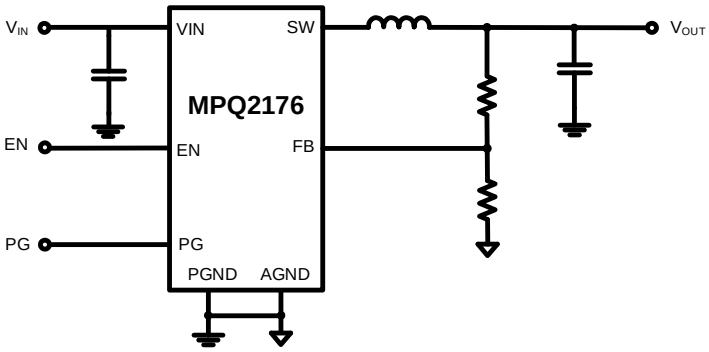
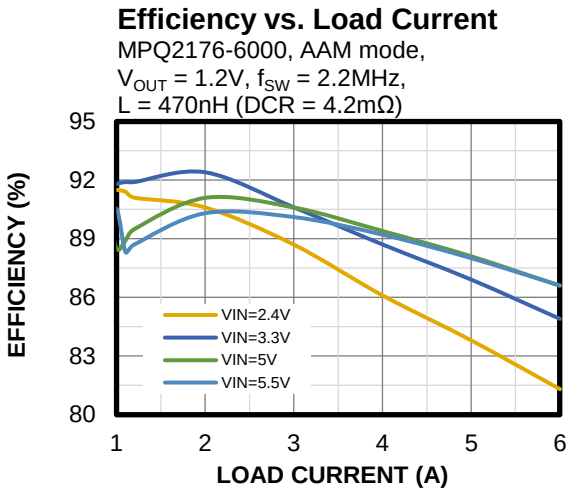
TYPICAL APPLICATION





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ORDERING INFORMATION

Part Number (1) (2) *	Package	Top Marking	MSL Rating**
MPQ2176GRAE-xxxx-AEC1***	QFN-7 (1.5mmx2.5mm)	*See Below*	1

* For Tape & Reel, add suffix -Z (e.g. MPQ2176GRAE-xxxx-AEC1-Z).

** Moisture Sensitivity Level Rating

*** Wettable Flank

Notes:

1) Part numbers may follow the naming rules in Table 1 but may not be included in the Ordering Information section. Contact MPS for details.
2) Part numbers can be marked as MPQ2176-WXYZ. Table 1 shows the naming rule for the 4-digit code.

Table 1: Part Number Digital Code Naming Rules

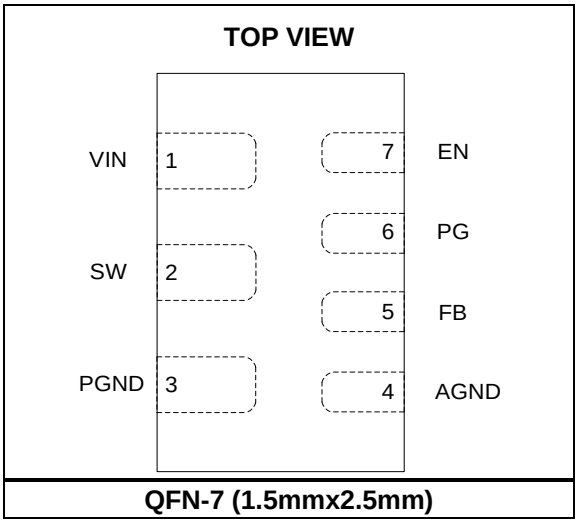
Digital Code	Naming Rule
W: Defines the supported load current	4: 4A
	5: 5A
	6: 6A
XY: Defines the output voltage	00: Adjustable output
Z: Defines the control mode	0: Advanced asynchronous modulation (AAM) mode without frequency spread spectrum (FSS)
	1: Forced continuous conduction mode (FCCM) without FSS
	2: AAM mode with FSS
	3: FCCM with FSS

TOP MARKING

$\overline{\text{PB}}$
YW
LL

PB: Product code of MPQ2176GRAE
Y: Year code
W: Week code
LL: Lot number

PACKAGE REFERENCE



QFN-7 (1.5mmx2.5mm)

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PIN FUNCTIONS

Pin #	Name	Description
1	VIN	**Supply voltage.** The MPQ2176 operates from a 2.4V to 5.5V unregulated input. A decoupling capacitor is required to prevent large voltage spikes from appearing at the input.
2	SW	**Output switching node.** SW is connected to the high-side, P-channel MOSFET's drain and the low-side, N-channel MOSFET's drain. Connect the power inductor to the SW pin with a wide trace and limit its area to avoid EMI radiation.
3	PGND	**Power ground.** Connect the PGND pin to a large GND plane to ensure excellent heat dissipation.
4	AGND	**Analog ground.** Connect the AGND pin to the DC/DC converter's GND.
5	FB	**Feedback pin.** The feedback reference's (V_{FB}) typical value is 0.4V. An external resistor divider from the output to AGND, and tapped to the FB pin, sets the output voltage (V_{OUT}). Place the resistor divider as close to the FB pin as possible. Avoid placing many vias on the FB traces.
6	PG	**Power good indicator.** The output of this pin is an open drain. If the PG pin is used, it must be connected to a power source through a pull-up resistor. PG goes high if V_{OUT} is within 96% to 105% of the nominal voltage; PG goes low if V_{OUT} is above 112% or below 90% of the nominal voltage. Float the PG pin if it is not used.
7	EN	**Enable.** Pull the EN pin below the specified threshold (0.72V) to shut the chip down. Pull EN above the specified threshold (0.82V) to enable the chip. EN can be directly connected to VIN. There is an internal 1.75MΩ resistor connected from the EN pin to ground. Float the EN pin if it is not used.

ABSOLUTE MAXIMUM RATINGS (3)

All pins .....-0.3V to +6.5V
Junction temperature (T_J) .....150°C
Lead temperature .....260°C
Continuous power dissipation (T_A = 25°C) (4) (8)
……. 2.58W
Storage temperature ..... -65°C to +150°C

ESD Ratings

Human body model (HBM) .....Class 2 (5)
Charged-device model (CDM) .....Class 2b (6)

Recommended Operating Conditions

Input voltage (V_{IN}) .....2.4V to 5.5V
Output voltage (V_{OUT}).....0.4V to 4V
Operating junction temp (T_J).... -40°C to +150°C

Thermal Resistance θ_{JA} θ_{JC}

JESD51-7……....87.7...7.8..°C/W (7)
EVQ2176-RA-00A……...48.3.....°C/W (8)

Ψ_{JT}

JESD51-7 ….....……..…….…....3.4..°C/W (7)
EVQ2176-RA-00A …….....4.9..°C/W (8)

Notes:

3) Exceeding these ratings may damage the device.
4) 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 regulator may go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.
5) Per AEC-Q100-002.
6) Per AEC-Q100-011.
7) Measured on a JESD51-7, 4-layer PCB. The value of θ_{JA} given in this table is 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 junction-to-case bottom, and the value of Ψ_{JT} shows the characterization parameter from junction-to-case top.
8) Measured on the MPS standard EVB, 8.3cmx8.3cm, 2oz copper thickness, 4-layer PCB. The value of Ψ_{JT} shows the characterization parameter from the junction-to-case top.

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ELECTRICAL CHARACTERISTICS

V_{IN} = 5V, T_J = -40°C to +150°C , typical value is tested at T_J = 25°C. The over-temperature limit is guaranteed by characterization, unless otherwise noted.

Parameter	Symbol	Conditions	Min	Typ	Max	Units
Input Supply						
Input voltage (V_{IN}) range	V_{IN}		2.4		5.5	V
Under-voltage lockout (UVLO) threshold rising	V_{UV_RISING}		2.12	2.25	2.38	V
UVLO threshold hysteresis	V_{UV_HYS}			220		mV
Supply current (shutdown)	I_{SHDN}	V_{EN} = 0V, T_J = 25°C		0.15	0.8	µA
		V_{EN} = 0V, T_J = -40°C to +150°C			400	µA
Supply current (quiescent)	I_Q	V_{FB} = 0.41V, non-switching, AAM mode, T_J = 25°C		15	22	µA
		V_{FB} = 0.41V, non-switching, AAM mode, T_J = -40°C to +150°C			142	µA
Supply current (active)	I_{Q_ACTIVE}	V_{FB} = 0.41V, non-switching, FCCM		500	680	µA
Feedback voltage	V_{FB}		396	400	404	mV
Feedback current	I_{FB}	V_{FB} = 0.41V		10	60	nA
Output discharge resistor	R_{DIS}	V_{EN} = 0V, V_{OUT} = 1.2V		56	65	Ω
Output over-voltage (OV) rising threshold	V_{OUT_OVP}		112%	115%	120%	V_{REF}
Output OV hysteresis	$V_{OUT_OVP_HYS}$			5%		V_{REF}
V_{IN} over-voltage protection (OVP)	V_{IN_OVP}	After V_{OUT} OVP enabled	6	6.3	6.5	V
VIN OVP hysteresis	$V_{IN_OVP_HYS}$			140		mV
Switches and Frequency						
Minimum on time (9)	t_{MIN-ON}	V_{OUT} = 0.4V	35	40	52	ns
Minimum off time (9)	$t_{MIN-OFF}$		37	50	60	ns
P-channel MOSFET switch on resistance	$R_{DS(ON)_P}$	V_{IN} = 5V		15	24	mΩ
N-channel MOSFET switch on resistance	$R_{DS(ON)_N}$	V_{IN} = 5V		9	15	mΩ
P-channel MOSFET switch leakage	$I_{SW_LKG_P}$	V_{EN} = 0V, V_{SW} = 0V, T_J = 25°C		0.15	0.8	µA
		V_{EN} = 0V, V_{SW} = 0V, T_J = -40°C to +150°C			400	µA
N-channel MOSFET switch leakage	$I_{SW_LKG_N}$	V_{EN} = 0V, V_{SW} = 5V, T_J = 25°C		1.7	5	µA
		V_{EN} = 0V, V_{SW} = 5V, T_J = -40°C to +150°C			125	µA
Switching frequency	f_{SW}	V_{IN} = 5V, V_{OUT} = 1.2V, operating in CCM	1900	2200	2700	kHz
Frequency spread spectrum (FSS) modulation spread (9)	f_{SS_SPREAD}			+1		%
				-1		%
FSS modulation rate (9)	f_{SS_RATE}			6.5		kHz

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ELECTRICAL CHARACTERISTICS *(continued)*

V_{IN} = 5V, T_J = -40°C to +150°C , typical value is tested at T_J = 25°C. The over-temperature limit is guaranteed by characterization, unless otherwise noted.

Parameter	Symbol	Conditions	Min	Typ	Max	Units
Enable (EN) Function						
EN turn-on delay	t_{ENON_D}	EN on to SW active	405	450	505	µs
EN turn-off delay	t_{ENOFF_D}	EN off to stop switching	2.7	3.5	4.8	µs
EN falling threshold	$V_{EN_FALLING}$		0.4	0.72		V
EN rising threshold	V_{EN_RISING}			0.82	1.2	V
EN pull-down resistor	R_{EN_LOW}		1.2	1.75	2.3	MΩ
EN input current	I_{EN}	V_{EN} = 2V		5	60	nA
		V_{EN} = 0V		0	50	nA
Power Good (PG) Function						
PG rising threshold	$V_{PG_VTH_RISING}$	V_{OUT} rising	93%	96%	99%	V_{REF}
		V_{OUT} falling	101%	105%	109%	V_{REF}
PG falling threshold	$V_{PG_VTH_FALLING}$	V_{OUT} rising	108%	112%	116%	V_{REF}
		V_{OUT} falling	86%	90%	93%	V_{REF}
PG rising deglitch time	t_{PG_R}	PG rising edge	40	60	90	µs
PG falling deglitch time	t_{PG_F}	PG falling edge	20	30	45	µs
PG sink current capability	V_{PG-L}	Sink 1mA		5	100	mV
PG self-bias	V_{PG_BIAS}	V_{EN} = 0V, V_{PG} = 5V		0.8	1.05	V
Soft Start						
Soft-start time	t_{SS}	Time from 5% to 95% of nominal V_{OUT}	0.7	1	1.3	ms
Protections						
P-channel MOSFET peak current limit	I_{LIMIT_PK}	MPQ2176-6xxx	9.5	10.5	11.5	A
		MPQ2176-5xxx	7.5	9	10.5	A
		MPQ2176-4xxx	6	7	8	A
N-channel MOSFET valley current limit	I_{LIMIT_VL}	MPQ2176-6xxx	6	7.5	9	A
		MPQ2176-5xxx	4.8	6	8	A
		MPQ2176-4xxx	3.8	5.5	7	A
Zero-current detection (ZCD) current	$I_{_ZCD}$	AAM mode		200		mA
Low-side (LS) reverse current limit	$I_{LIMIT_REVERSE}$	Current flowing from SW to GND	-5.7	-3.9	-2.2	A
Thermal shutdown (9)	T_{SD}			163		°C
Thermal hysteresis (9)	T_{SD_HYS}			17		°C

Note:

9) Guaranteed by design and bench characterization. Not tested in production.

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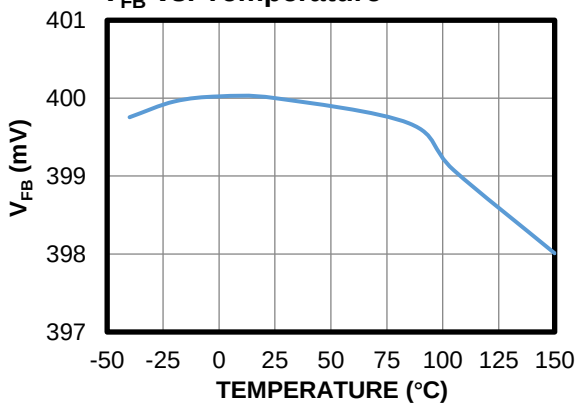
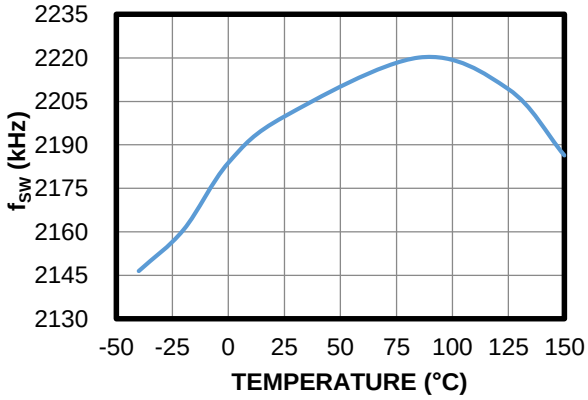
TYPICAL CHARACTERISTICS

V_{IN} = 5V, T_J = -40°C to +150°C, unless otherwise noted.

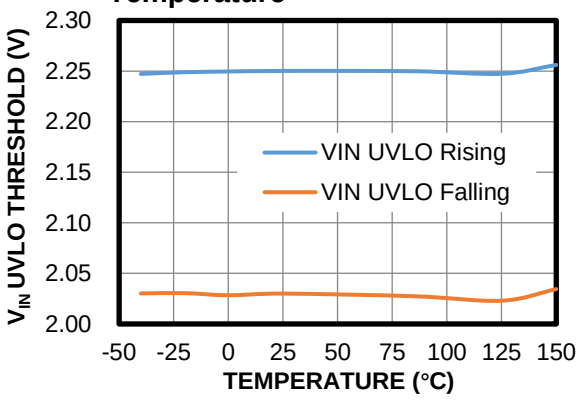
V_{FB} vs. Temperature



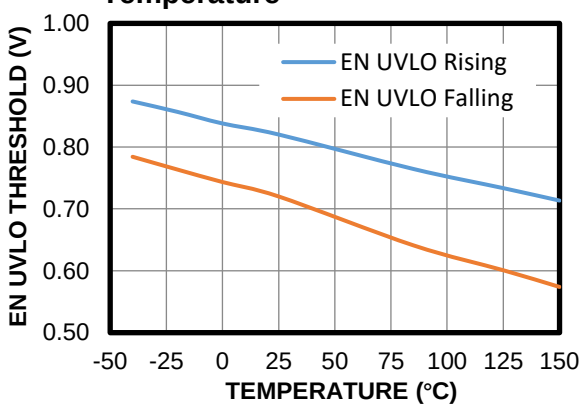
f_{SW} vs. Temperature



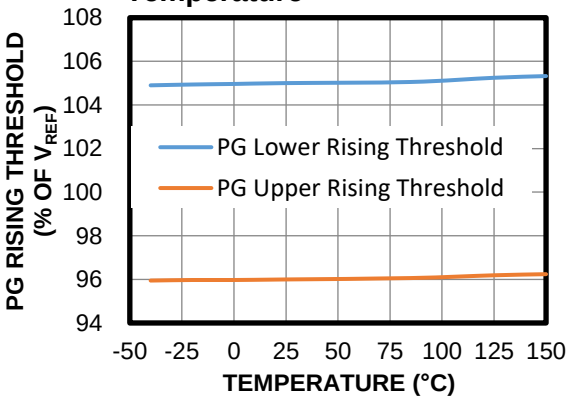
V_{IN} UVLO Threshold vs. Temperature



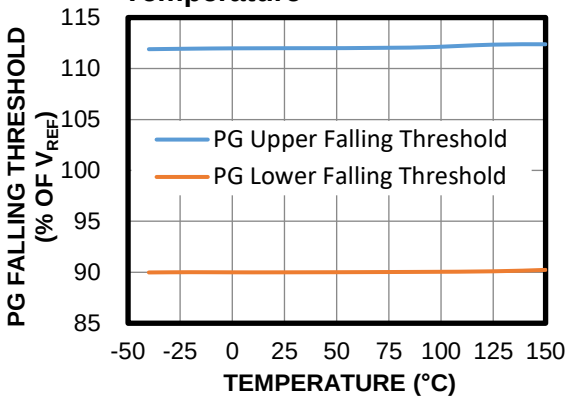
EN UVLO Threshold vs. Temperature



PG Rising Threshold vs. Temperature



PG Faling Threshold vs. Temperature



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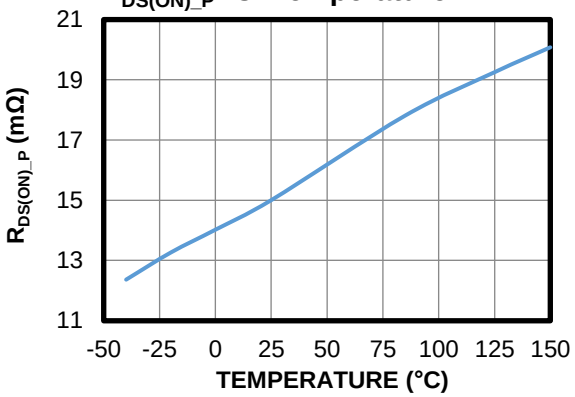
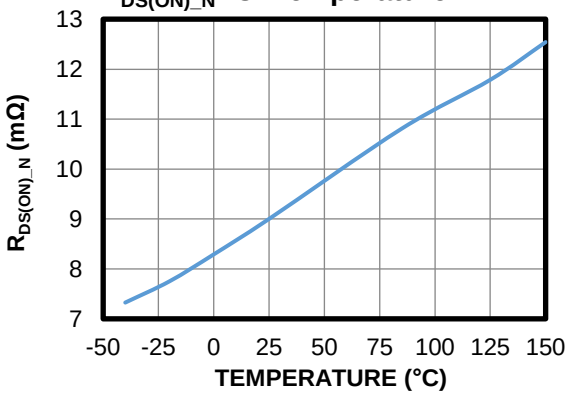
TYPICAL CHARACTERISTICS *(continued)*

V_{IN} = 5V, T_J = -40°C to +150°C, unless otherwise noted.

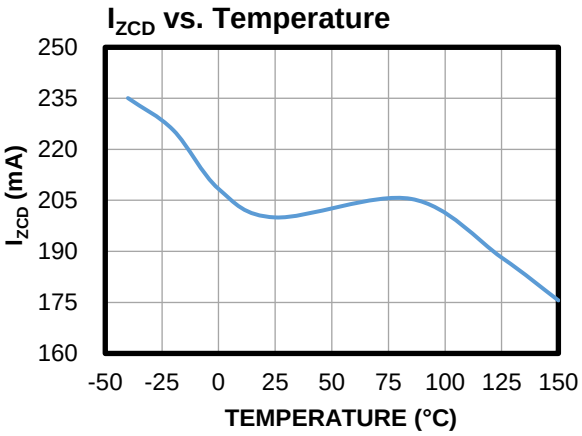
$R_{DS(ON)_P}$ vs. Temperature



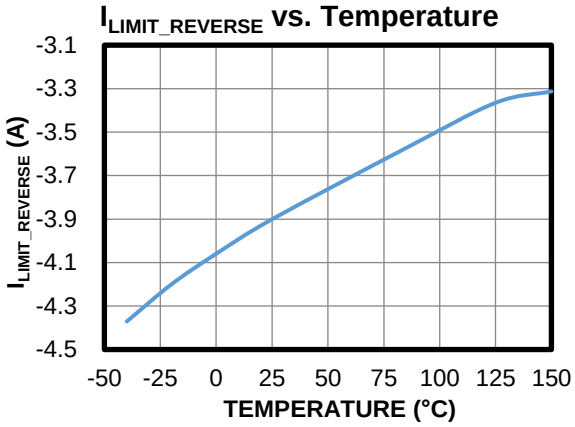
$R_{DS(ON)_N}$ vs. Temperature



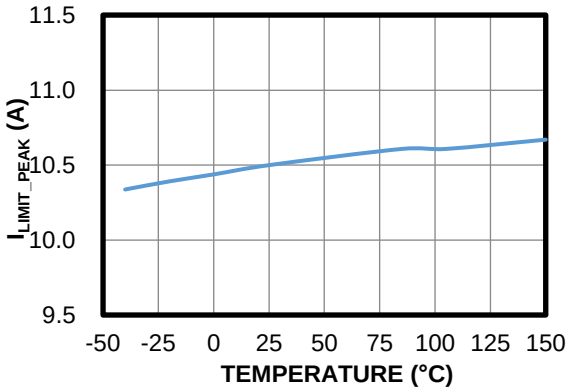
I_{ZCD} vs. Temperature



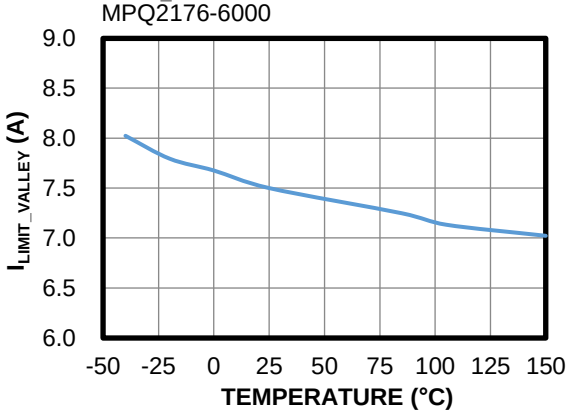
$I_{LIMIT_REVERSE}$ vs. Temperature



I_{LIMIT_PEAK} vs. Temperature
MPQ2176-6000



I_{LIMIT_VALLEY} vs. Temperature
MPQ2176-6000



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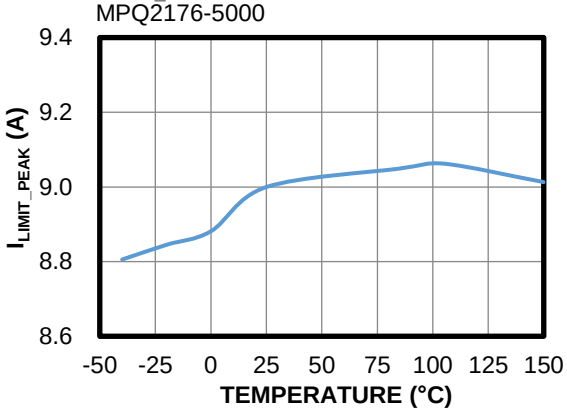
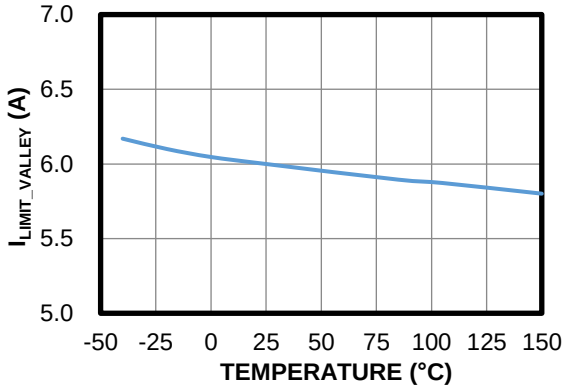
TYPICAL CHARACTERISTICS *(continued)*

V_{IN} = 5V, T_J = -40°C to +150°C, unless otherwise noted.

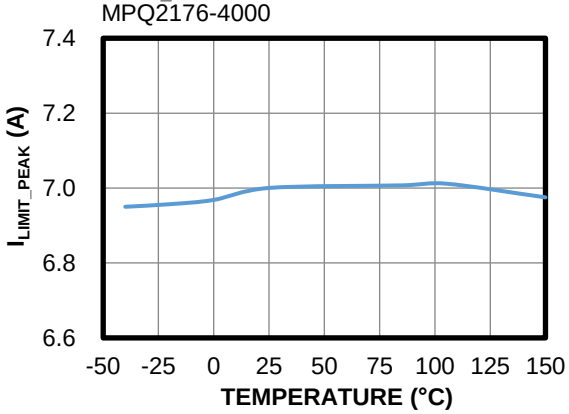
I_{LIMIT_PEAK} vs. Temperature
MPQ2176-5000



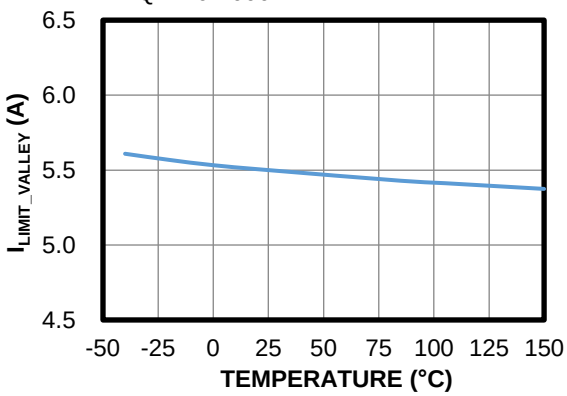
I_{LIMIT_VALLEY} vs. Temperature
MPQ2176-5000



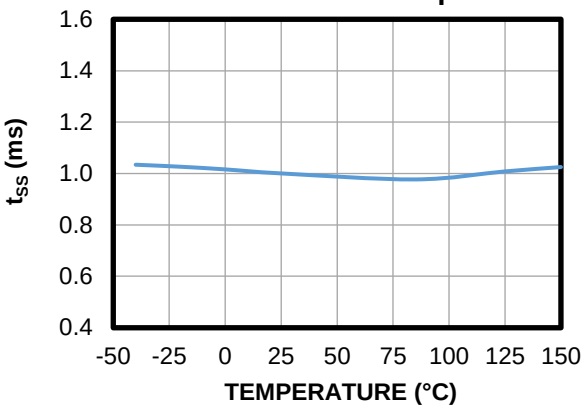
I_{LIMIT_PEAK} vs. Temperature
MPQ2176-4000



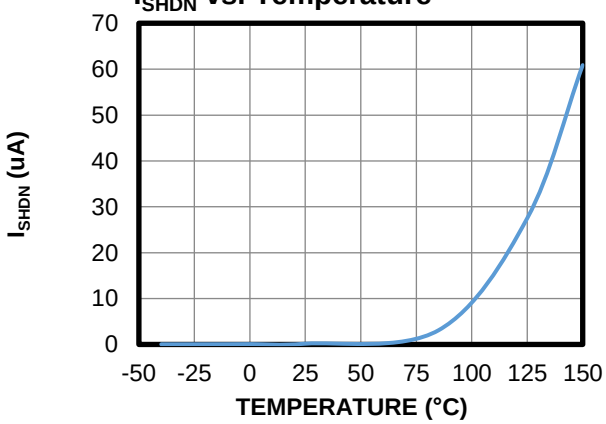
I_{LIMIT_VALLEY} vs. Temperature
MPQ2176-4000



Soft-Start Time vs. Temperature



I_{SHDN} vs. Temperature



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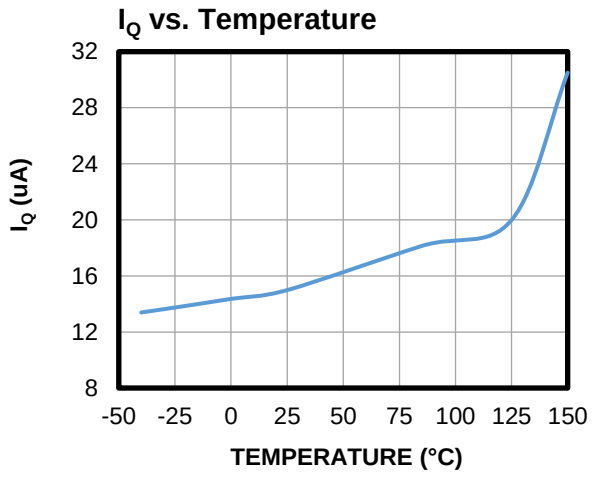
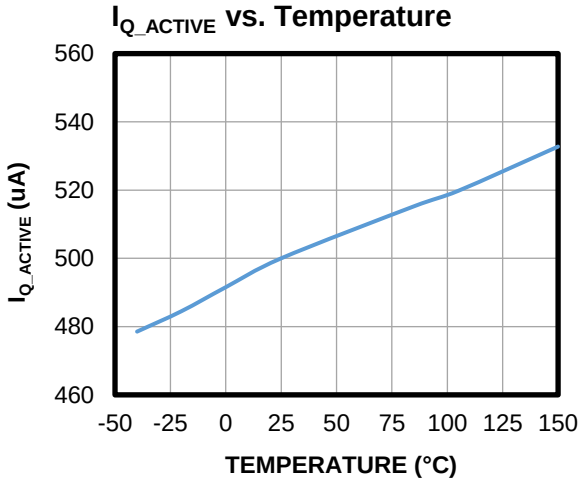
TYPICAL CHARACTERISTICS *(continued)*

V_{IN} = 5V, T_J = -40°C to +150°C, unless otherwise noted.





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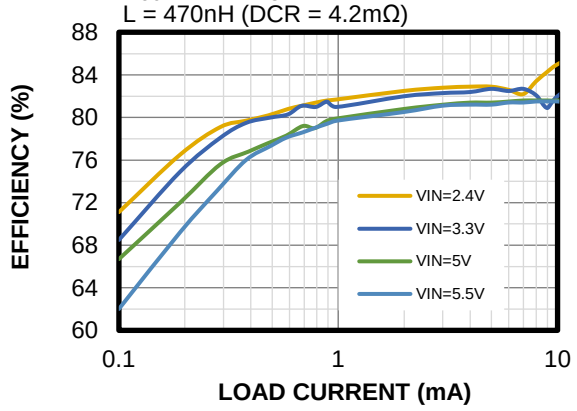
TYPICAL PERFORMANCE CHARACTERISTICS

V_{IN} = 5V, V_{OUT} = 1.2V, L = 470nH, C_{OUT} = 22µF x 3, T_A = 25°C, unless otherwise noted.

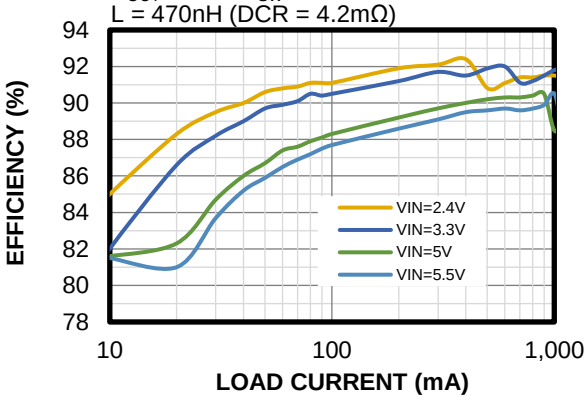
Efficiency vs. Load Current

MPQ2176-6000, AAM mode,
V_{OUT} = 1.2V, f_{SW} = 2.2MHz,
L = 470nH (DCR = 4.2mΩ)



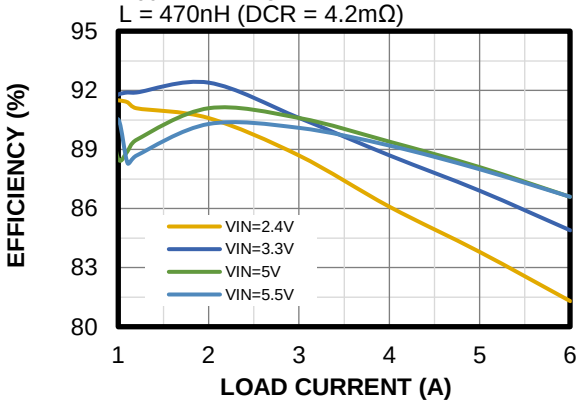
Efficiency vs. Load Current

MPQ2176-6000, AAM mode,
V_{OUT} = 1.2V, f_{SW} = 2.2MHz,
L = 470nH (DCR = 4.2mΩ)



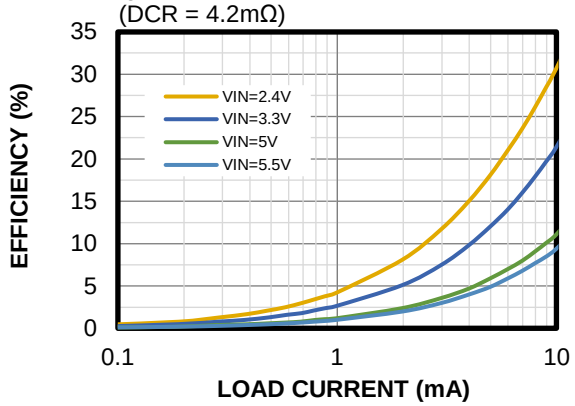
Efficiency vs. Load Current

MPQ2176-6000, AAM mode,
V_{OUT} = 1.2V, f_{SW} = 2.2MHz,
L = 470nH (DCR = 4.2mΩ)



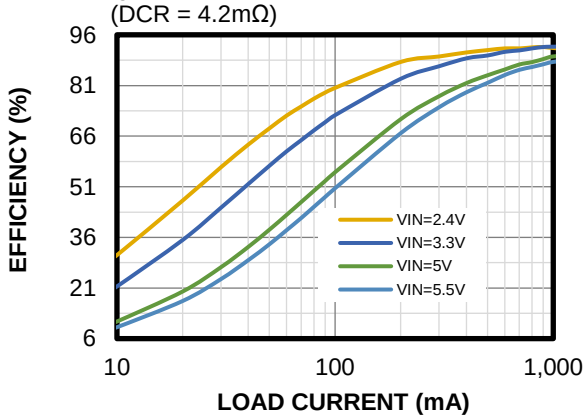
Efficiency vs. Load Current

MPQ2176-6001, FCCM, V_{OUT} = 1.2V,
f_{SW} = 2.2MHz, L = 470nH
(DCR = 4.2mΩ)



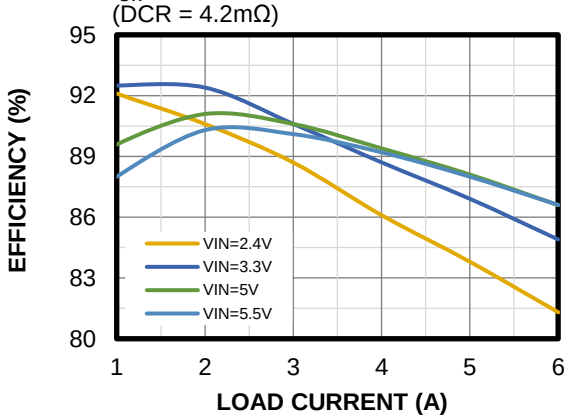
Efficiency vs. Load Current

MPQ2176-6001, FCCM, V_{OUT} = 1.2V,
f_{SW} = 2.2MHz, L = 470nH
(DCR = 4.2mΩ)



Efficiency vs. Load Current

MPQ2176-6001, FCCM, V_{OUT} = 1.2V,
f_{SW} = 2.2MHz, L = 470nH
(DCR = 4.2mΩ)



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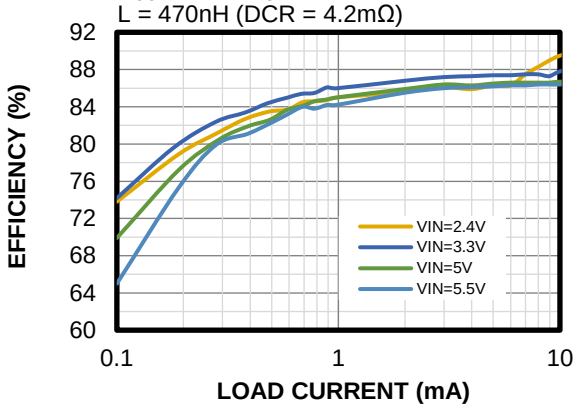
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 5V, V_{OUT} = 1.2V, L = 470nH, C_{OUT} = 22µF x 3, T_A = 25°C, unless otherwise noted.

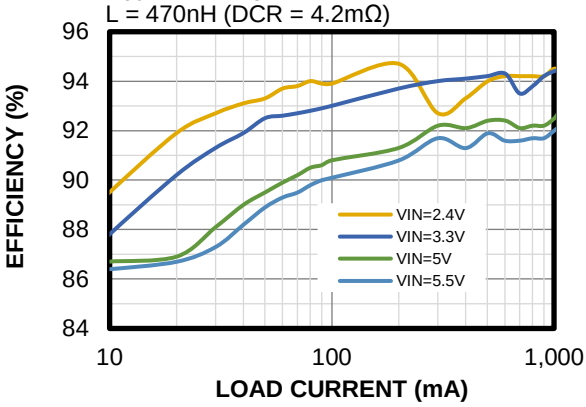
Efficiency vs. Load Current

MPQ2176-6000, AAM mode,
V_{OUT} = 1.8V, f_{SW} = 2.2MHz,
L = 470nH (DCR = 4.2mΩ)



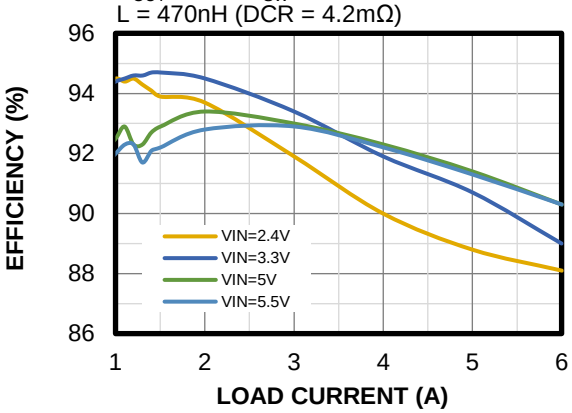
Efficiency vs. Load Current

MPQ2176-6000, AAM mode,
V_{OUT} = 1.8V, f_{SW} = 2.2MHz,
L = 470nH (DCR = 4.2mΩ)



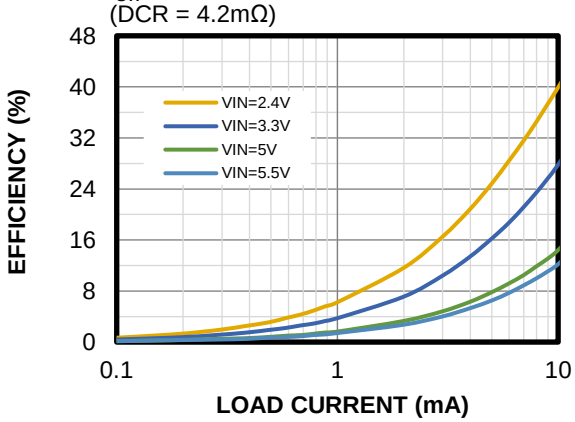
Efficiency vs. Load Current

MPQ2176-6000, AAM mode,
V_{OUT} = 1.8V, f_{SW} = 2.2MHz,
L = 470nH (DCR = 4.2mΩ)



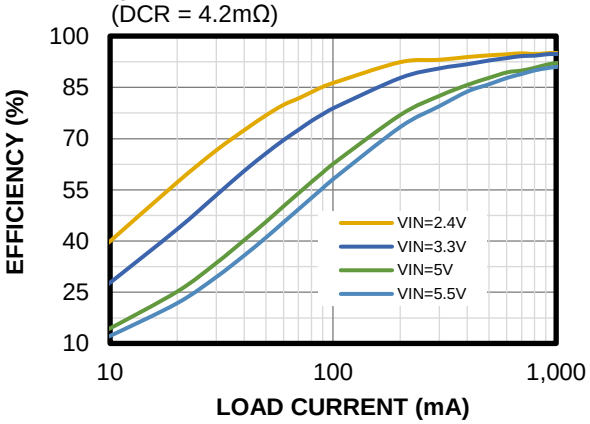
Efficiency vs. Load Current

MPQ2176-6001, FCCM, V_{OUT} = 1.8V,
f_{SW} = 2.2MHz, L = 470nH
(DCR = 4.2mΩ)



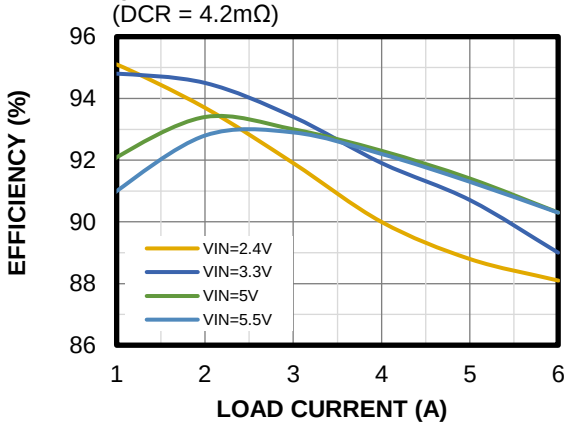
Efficiency vs. Load Current

MPQ2176-6001, FCCM, V_{OUT} = 1.8V,
f_{SW} = 2.2MHz, L = 470nH
(DCR = 4.2mΩ)



Efficiency vs. Load Current

MPQ2176-6001, FCCM, V_{OUT} = 1.8V,
f_{SW} = 2.2MHz, L = 470nH
(DCR = 4.2mΩ)



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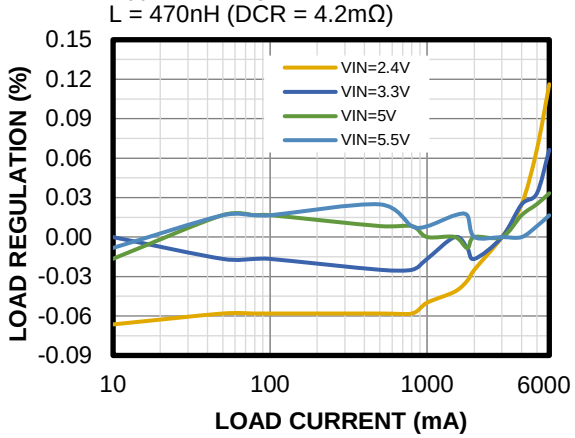
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 5V, V_{OUT} = 1.2V, L = 470nH, C_{OUT} = 22µF x 3, T_A = 25°C, unless otherwise noted.

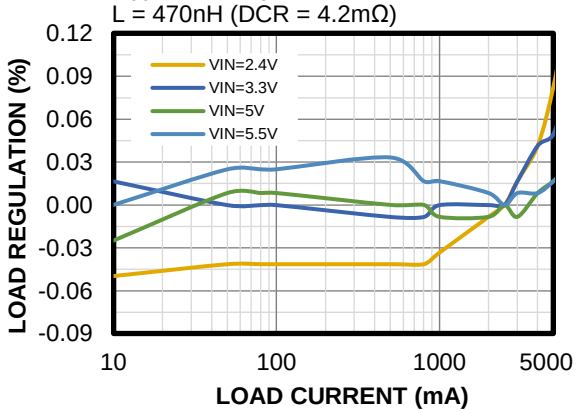
Load Regulation

MPQ2176-6002, AAM mode,
V_{OUT} = 1.2V, f_{SW} = 2.2MHz,
L = 470nH (DCR = 4.2mΩ)



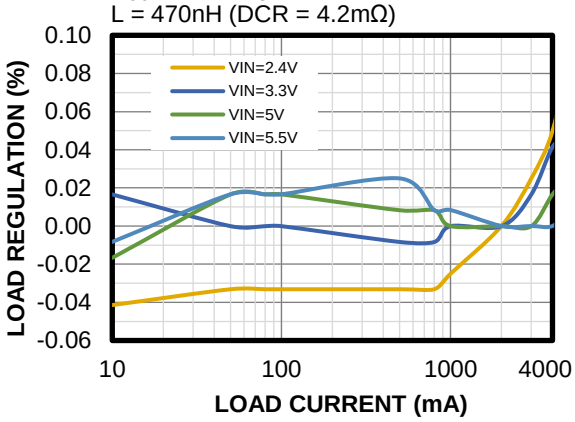
Load Regulation

MPQ2176-5002, AAM mode,
V_{OUT} = 1.2V, f_{SW} = 2.2MHz,
L = 470nH (DCR = 4.2mΩ)



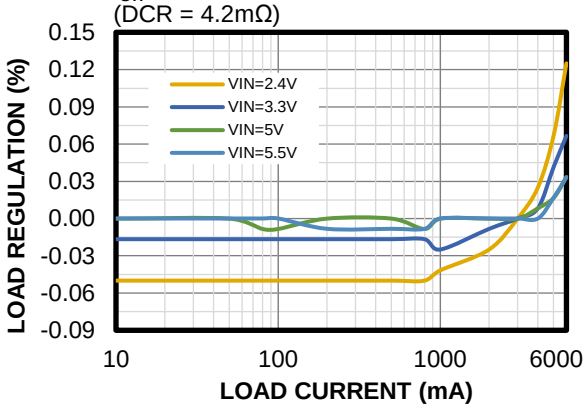
Load Regulation

MPQ2176-4002, AAM mode,
V_{OUT} = 1.2V, f_{SW} = 2.2MHz,
L = 470nH (DCR = 4.2mΩ)



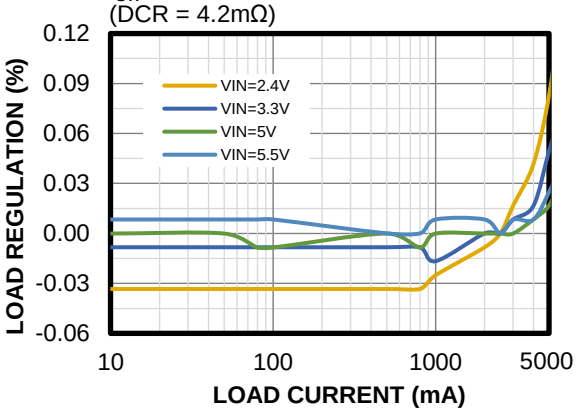
Load Regulation

MPQ2176-6003, FCCM, V_{OUT} = 1.2V,
f_{SW} = 2.2MHz, L = 470nH
(DCR = 4.2mΩ)



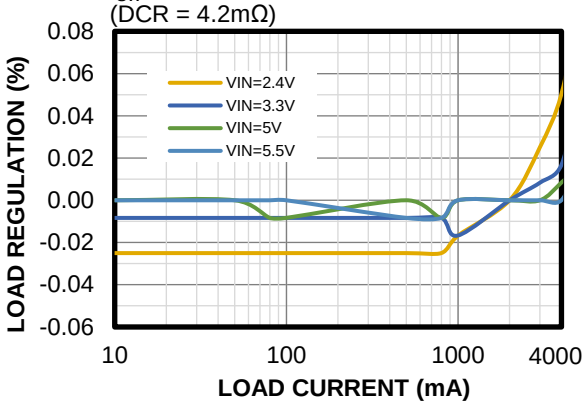
Load Regulation

MPQ2176-5003, FCCM, V_{OUT} = 1.2V,
f_{SW} = 2.2MHz, L = 470nH
(DCR = 4.2mΩ)



Load Regulation

MPQ2176-4003, FCCM, V_{OUT} = 1.2V,
f_{SW} = 2.2MHz, L = 470nH
(DCR = 4.2mΩ)



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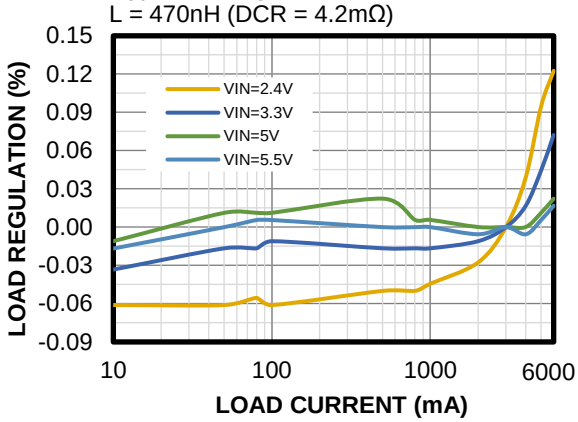
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 5V, V_{OUT} = 1.2V, L = 470nH, C_{OUT} = 22µF x 3, T_A = 25°C, unless otherwise noted.

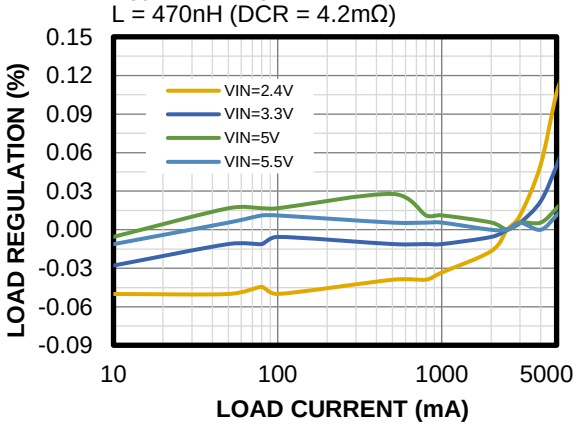
Load Regulation

MPQ2176-6002, AAM mode,
V_{OUT} = 1.8V, f_{SW} = 2.2MHz,
L = 470nH (DCR = 4.2mΩ)



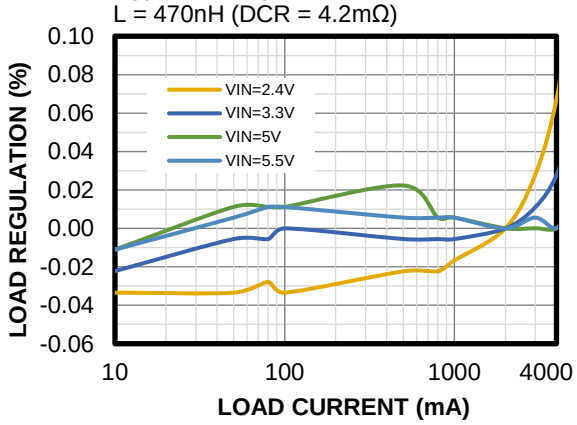
Load Regulation

MPQ2176-5002, AAM mode,
V_{OUT} = 1.8V, f_{SW} = 2.2MHz,
L = 470nH (DCR = 4.2mΩ)



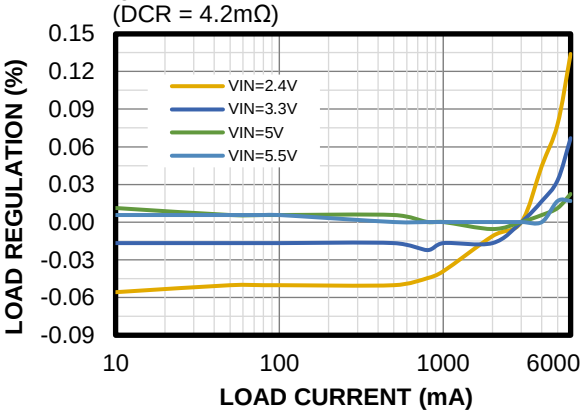
Load Regulation

MPQ2176-4002, AAM mode,
V_{OUT} = 1.8V, f_{SW} = 2.2MHz,
L = 470nH (DCR = 4.2mΩ)



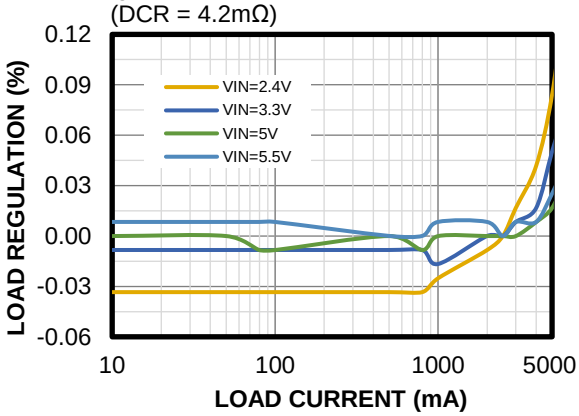
Load Regulation

MPQ2176-6003, FCCM, V_{OUT} = 1.8V,
f_{SW} = 2.2MHz, L = 470nH
(DCR = 4.2mΩ)



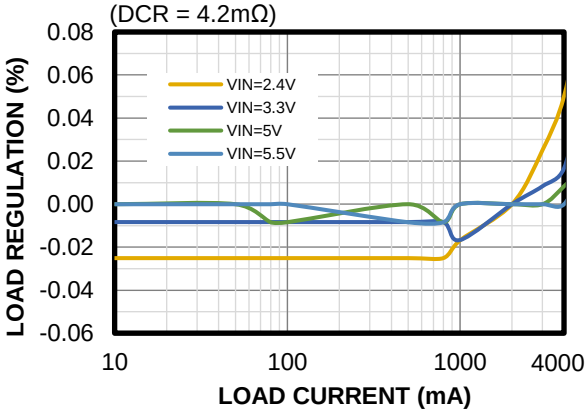
Load Regulation

MPQ2176-5003, FCCM, V_{OUT} = 1.2V,
f_{SW} = 2.2MHz, L = 470nH
(DCR = 4.2mΩ)



Load Regulation

MPQ2176-4003, FCCM, V_{OUT} = 1.2V,
f_{SW} = 2.2MHz, L = 470nH
(DCR = 4.2mΩ)



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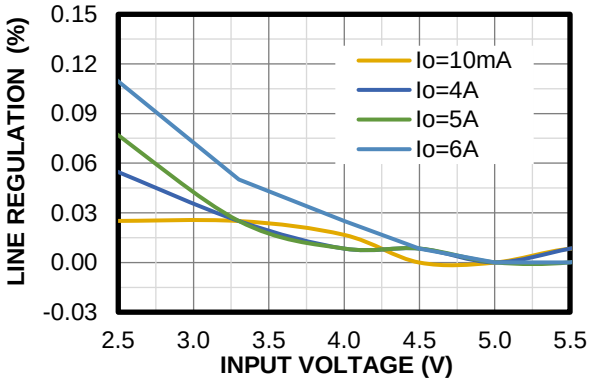
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 5V, V_{OUT} = 1.2V, L = 470nH, C_{OUT} = 22µF x 3, T_A = 25°C, unless otherwise noted.

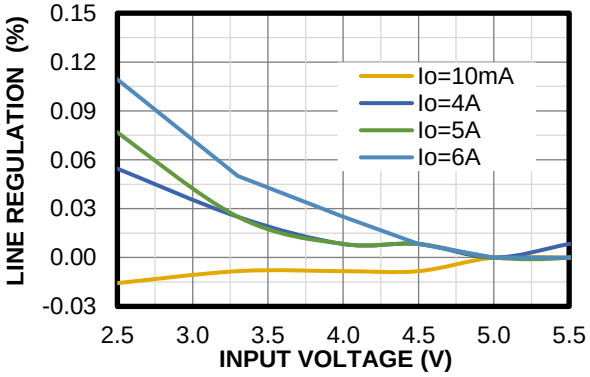
Line Regulation

AAM mode, V_{OUT} = 1.2V,f_{SW} = 2.2MHz,
L = 470nH, (DCR = 4.2mΩ)



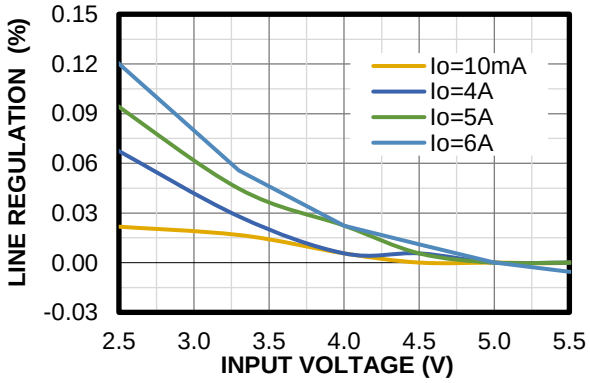
Line Regulation

FCCM, V_{OUT} = 1.2V, f_{SW} = 2.2MHz,
L = 470nH (DCR = 4.2mΩ)



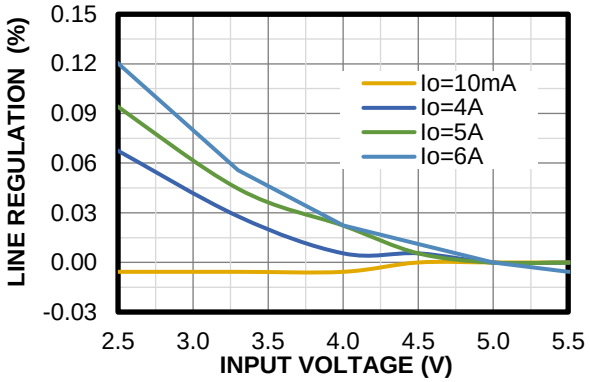
Line Regulation

AAM mode, V_{OUT} = 1.8V, f_{SW} = 2.2MHz,
L = 470nH (DCR = 4.2mΩ)



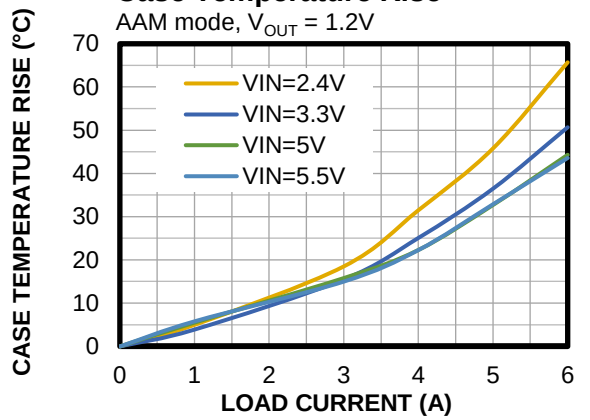
Line Regulation

FCCM, V_{OUT} = 1.8V, f_{SW} = 2.2MHz,
L = 470nH (DCR = 4.2mΩ)



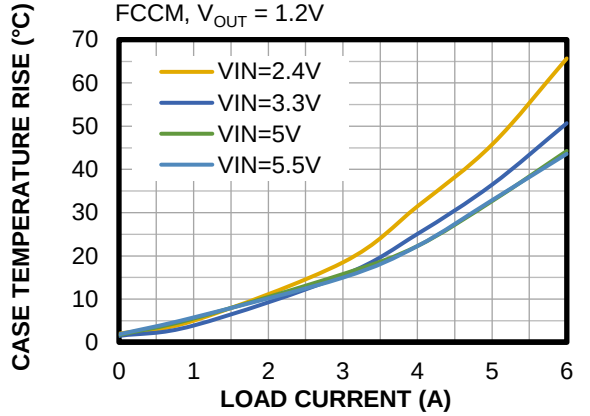
Case Temperature Rise

AAM mode, V_{OUT} = 1.2V



Case Temperature Rise

FCCM, V_{OUT} = 1.2V



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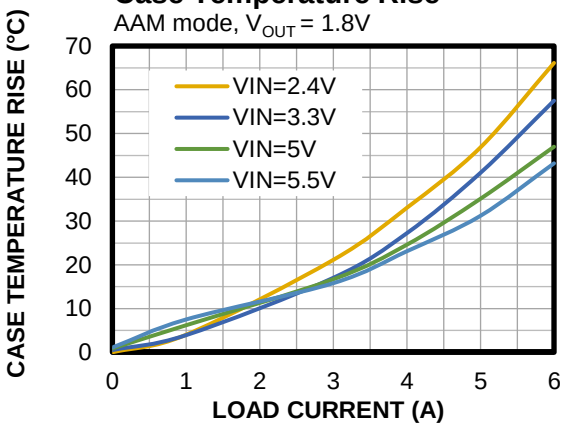
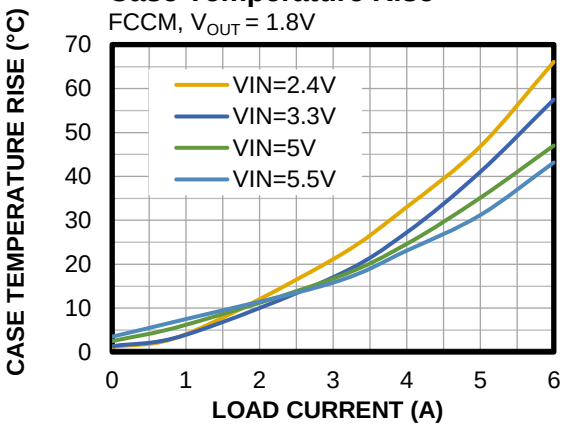
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 5V, V_{OUT} = 1.2V, L = 470nH, C_{OUT} = 22µF x 3, T_A = 25°C, unless otherwise noted.

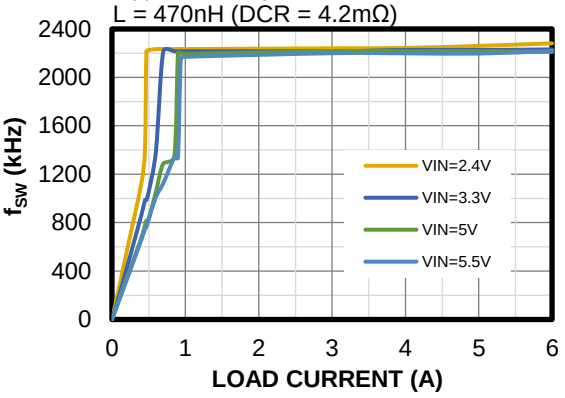
Case Temperature Rise
AAM mode, V_{OUT} = 1.8V



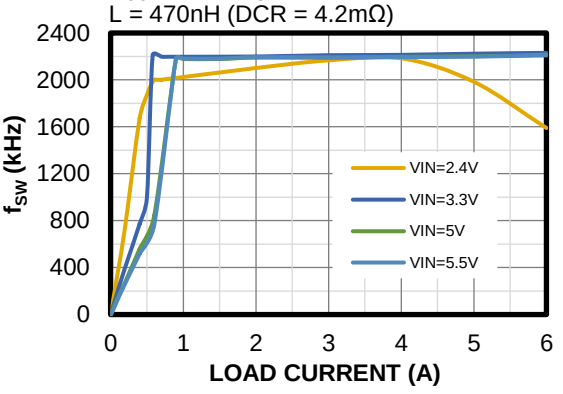
Case Temperature Rise
FCCM, V_{OUT} = 1.8V



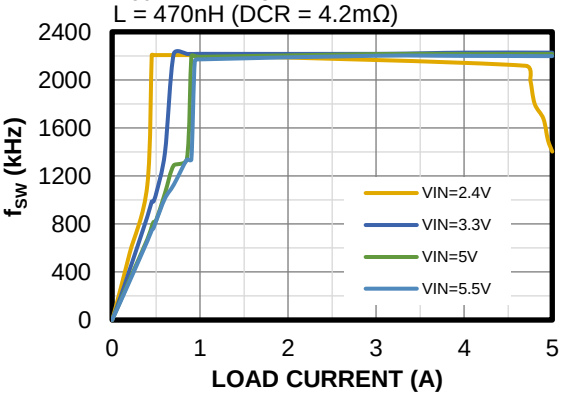
f_{SW} vs. Load Current
MPQ2176-6000, AAM mode,
V_{OUT} = 1.2V, f_{SW} = 2.2MHz,
L = 470nH (DCR = 4.2mΩ)



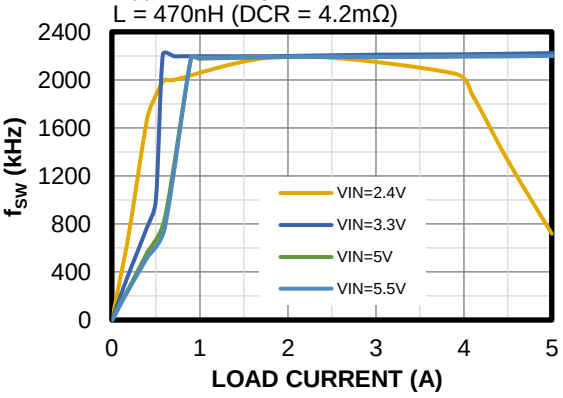
f_{SW} vs. Load Current
MPQ2176-6000, AAM mode,
V_{OUT} = 1.8V, f_{SW} = 2.2MHz,
L = 470nH (DCR = 4.2mΩ)



f_{SW} vs. Load Current
MPQ2176-5000, AAM mode,
V_{OUT} = 1.2V, f_{SW} = 2.2MHz,
L = 470nH (DCR = 4.2mΩ)



f_{SW} vs. Load Current
MPQ2176-5000, AAM mode,
V_{OUT} = 1.8V, f_{SW} = 2.2MHz,
L = 470nH (DCR = 4.2mΩ)



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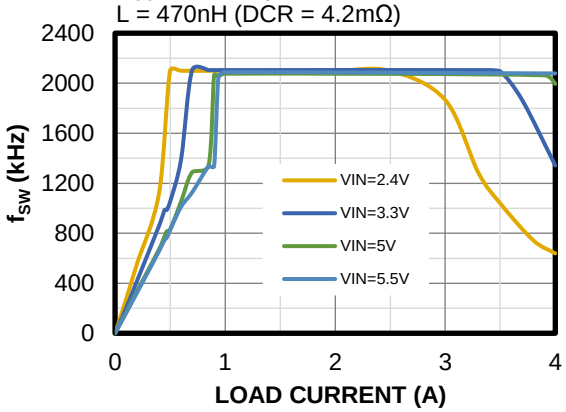
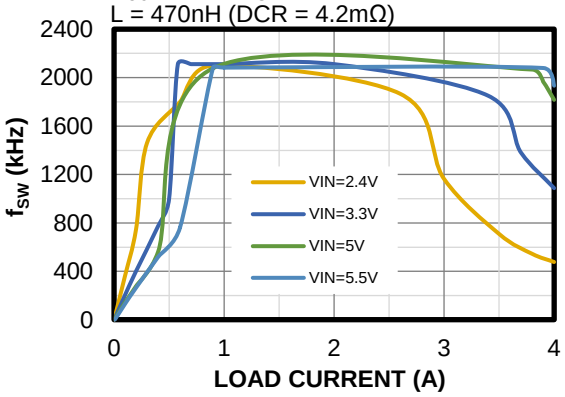
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 5V, V_{OUT} = 1.2V, L = 470nH, C_{OUT} = 22µF x 3, T_A = 25°C, unless otherwise noted.

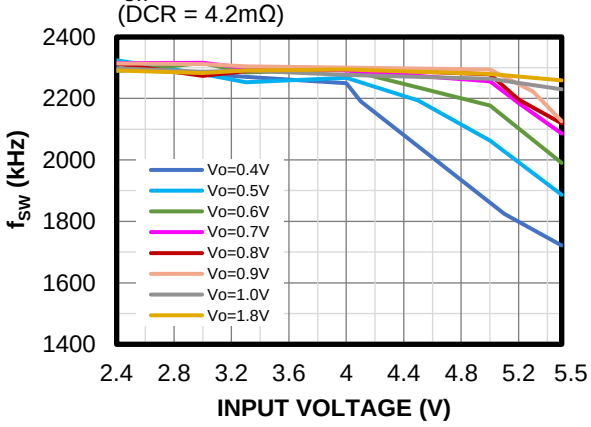
f_{SW} vs. Load Current
MPQ2176-4000, AAM mode,
V_{OUT} = 1.2V, f_{SW} = 2.2MHz,
L = 470nH (DCR = 4.2mΩ)



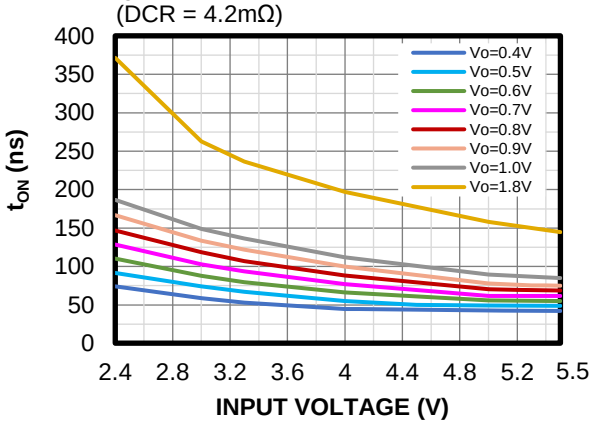
f_{SW} vs. Load Current
MPQ2176-4000, AAM mode,
V_{OUT} = 1.8V, f_{SW} = 2.2MHz,
L = 470nH (DCR = 4.2mΩ)



f_{SW} vs. V_{IN}
MPQ2176-6001, I_{OUT} = 0A,
f_{SW} = 2.2MHz, L = 470nH
(DCR = 4.2mΩ)



t_{ON} vs. V_{IN}
MPQ2176-6001, I_{OUT} = 0A,
f_{SW} = 2.2MHz, L = 470nH
(DCR = 4.2mΩ)



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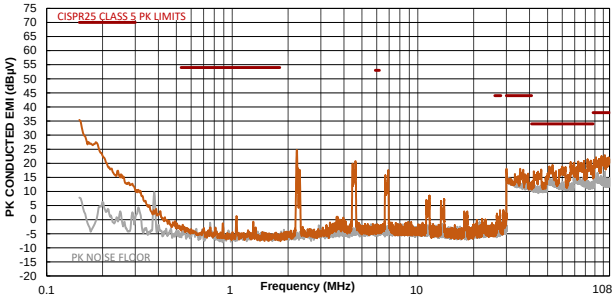
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 5.5V, V_{OUT} = 1.2V, L = 470nH (10), C_{OUT} = 22µF x 3, f_{SW} = 2.2MHz, I_{OUT} = 6A, T_A = 25°C, unless otherwise noted. (11)

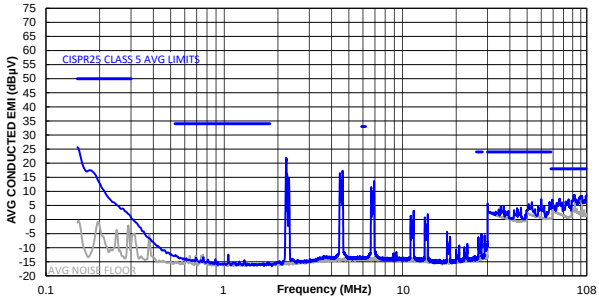
CISPR 25 Class 5 Peak Conducted Emissions

150kHz to 108MHz



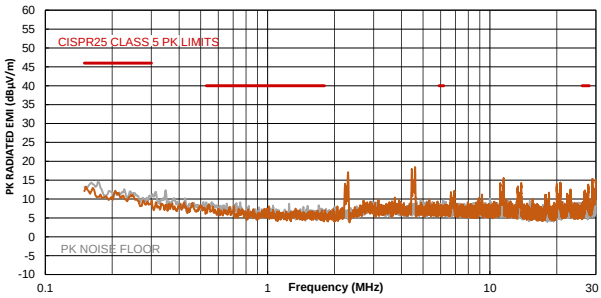
CISPR 25 Class 5 Average Conducted Emissions

150kHz to 108MHz



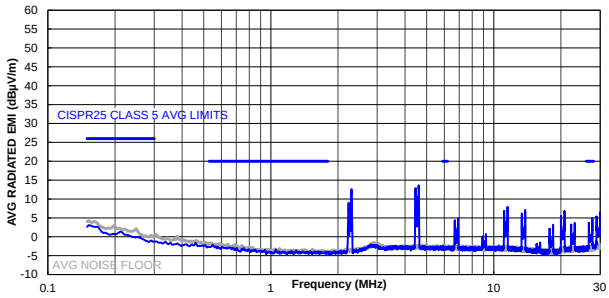
CISPR 25 Class 5 Peak Radiated Emissions

150kHz to 30MHz



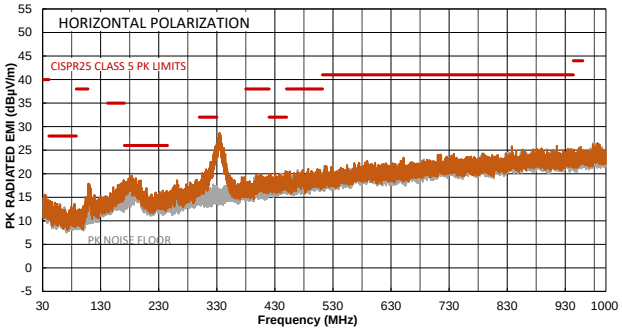
CISPR 25 Class 5 Average Radiated Emissions

150kHz to 30MHz



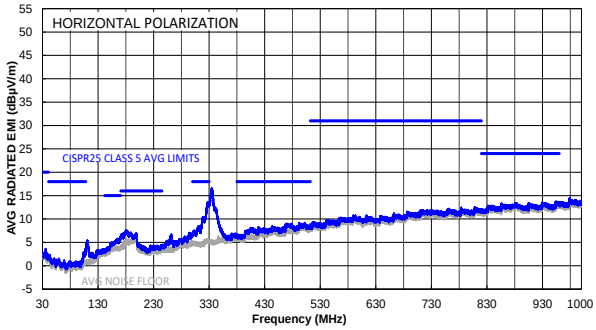
CISPR 25 Class 5 Peak Radiated Emissions

Horizontal, 30MHz to 1GHz



CISPR 25 Class 5 Average Radiated Emissions

Horizontal, 30MHz to 1GHz



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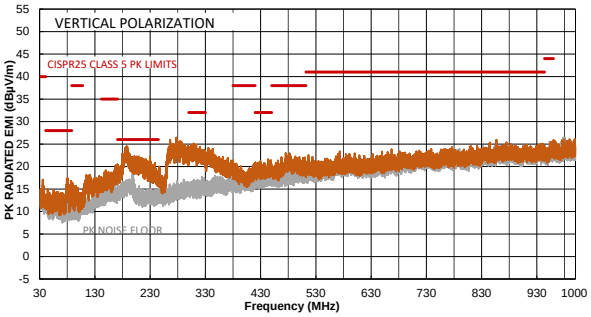
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 5.5V, V_{OUT} = 1.2V, L = 470nH (10), C_{OUT} = 22µF x 3, f_{SW} = 2.2MHz, I_{OUT} = 6A, T_A = 25°C, unless otherwise noted. (11)

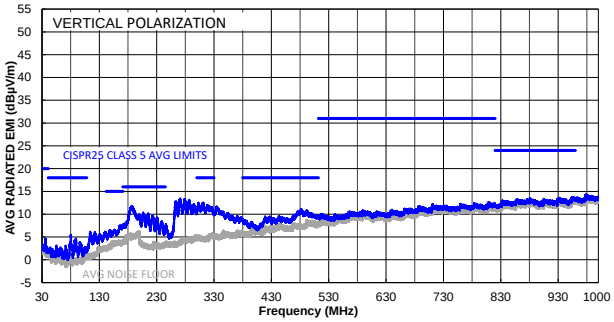
CISPR25 Class 5 Peak Radiated Emissions

Vertical, 30MHz to 1GHz



CISPR25 Class 5 Average Radiated Emissions

Vertical, 30MHz to 1GHz



Notes:

10) The inductor part number: XGL4020-471MEB; DCR = 4.2mΩ.
11) The EMC test results are based on the typical application circuit with EMI filters (see Figure 12 on page 41).

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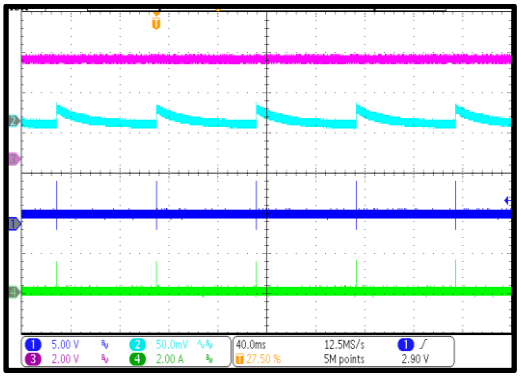
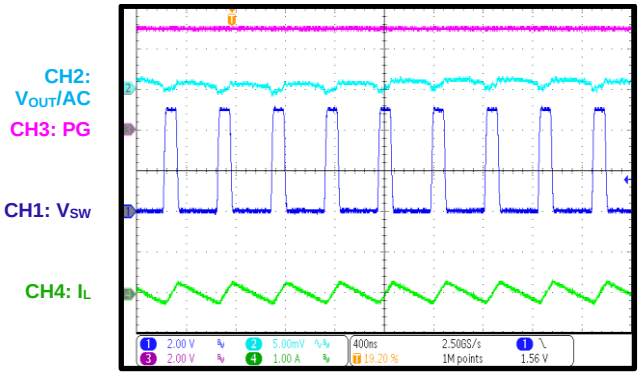
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 5V, V_{OUT} = 1.2V, L = 470nH, C_{OUT} = 22µF x 3, T_A = 25°C, unless otherwise noted.

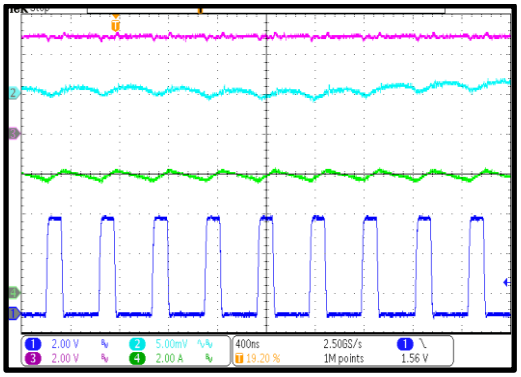
Steady State
AAM mode, I_{OUT} = 0A



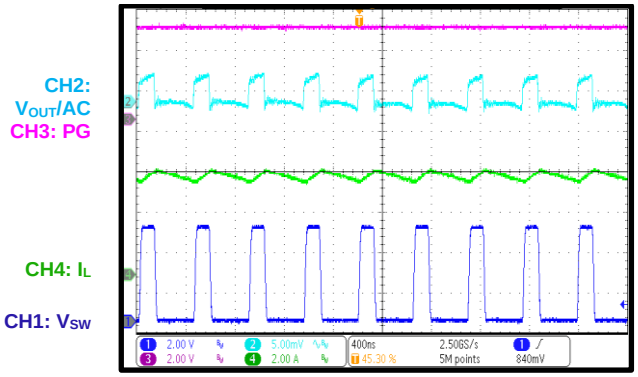
Steady State
FCCM, I_{OUT} = 0A



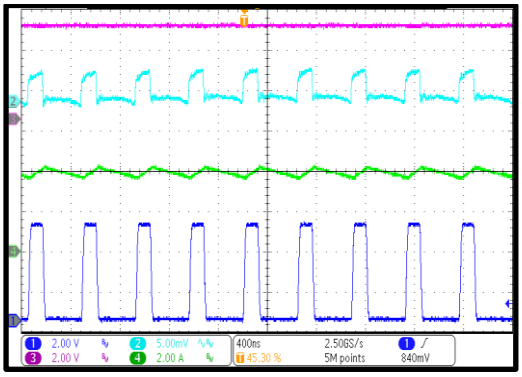
Steady State
I_{OUT} = 6A



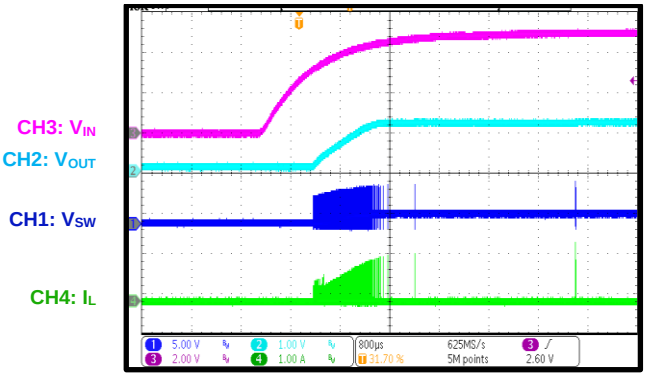
Steady State
I_{OUT} = 5A



Steady State
I_{OUT} = 4A



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



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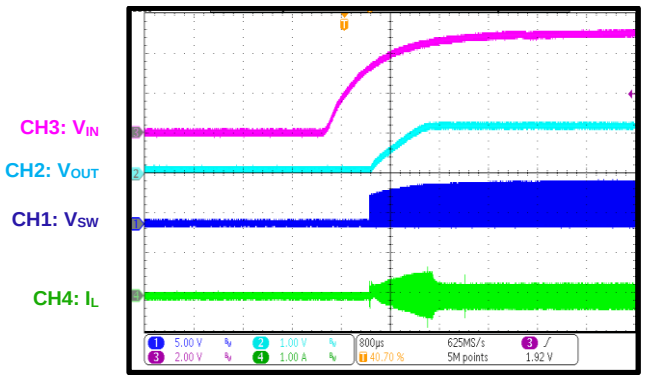
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 5V, V_{OUT} = 1.2V, L = 470nH, C_{OUT} = 22µF x 3, T_A = 25°C, unless otherwise noted.

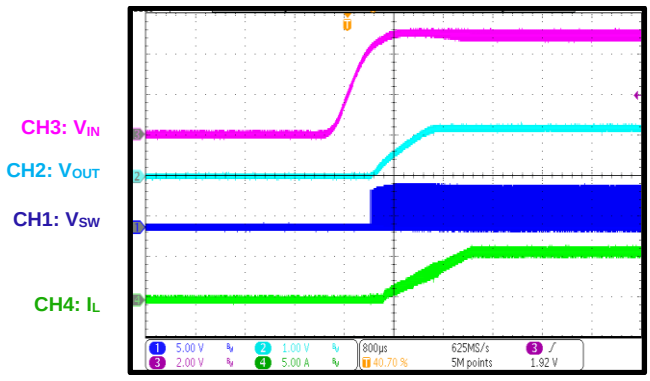
Start-Up through VIN

FCCM, I_{OUT} = 0A



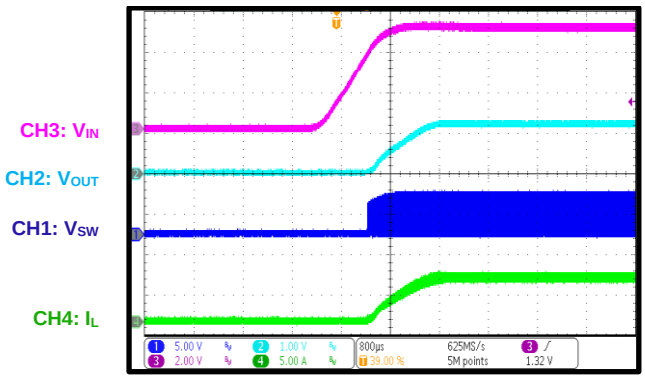
Start-Up through VIN

I_{OUT} = 6A



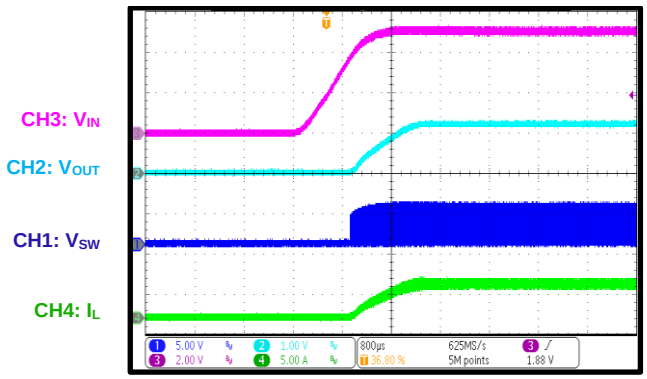
Start-Up through VIN

I_{OUT} = 5A



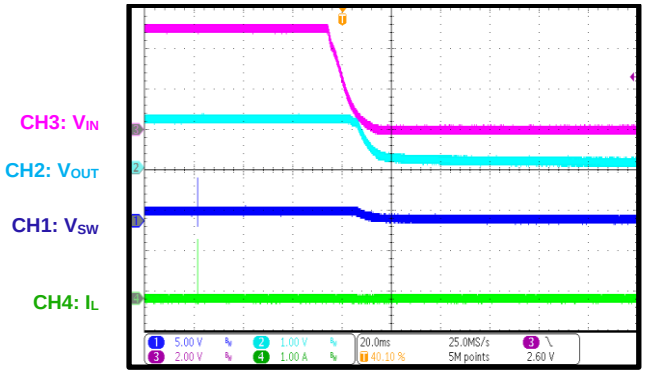
Start-Up through VIN

I_{OUT} = 4A



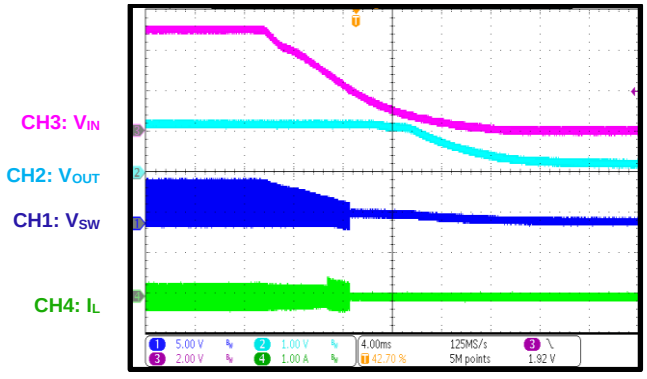
Shutdown through VIN

AAM mode, I_{OUT} = 0A



Shutdown through VIN

FCCM, I_{OUT} = 0A



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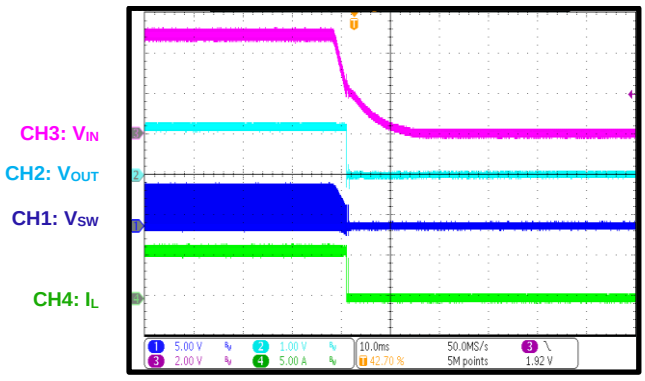
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 5V, V_{OUT} = 1.2V, L = 470nH, C_{OUT} = 22µF x 3, T_A = 25°C, unless otherwise noted.

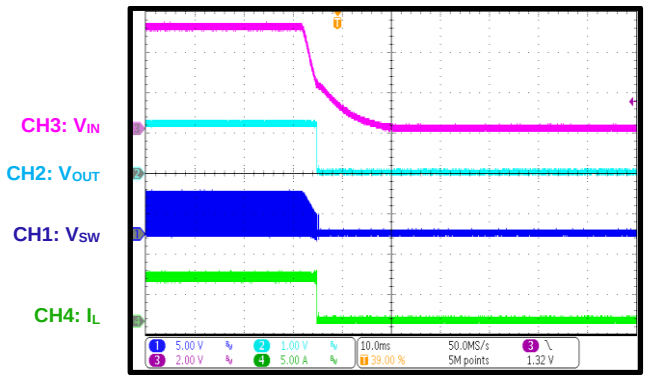
Shutdown through VIN

I_{OUT} = 6A



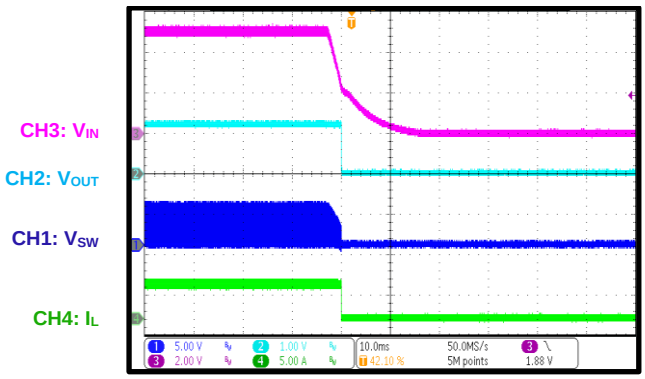
Shutdown through VIN

I_{OUT} = 5A



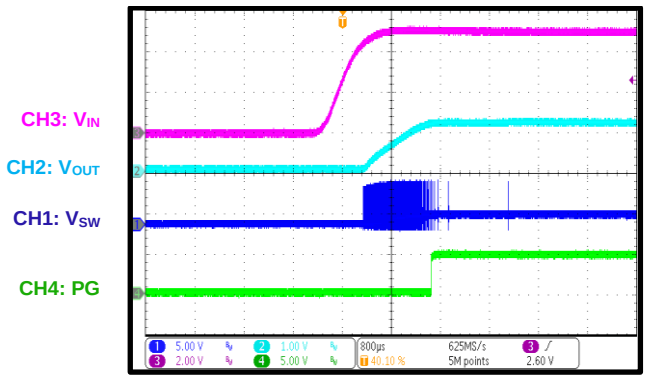
Shutdown through VIN

I_{OUT} = 4A



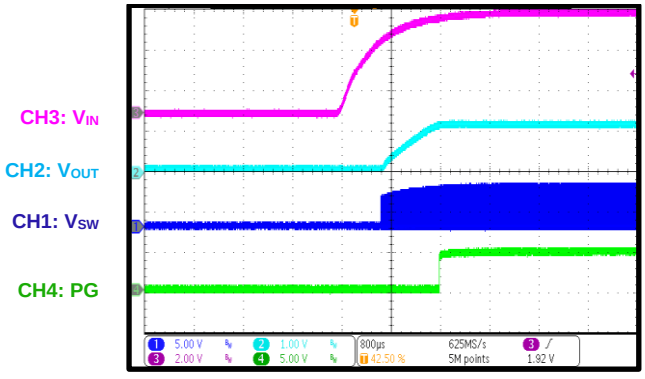
PG in Start-Up through VIN

AAM mode, I_{OUT} = 0A



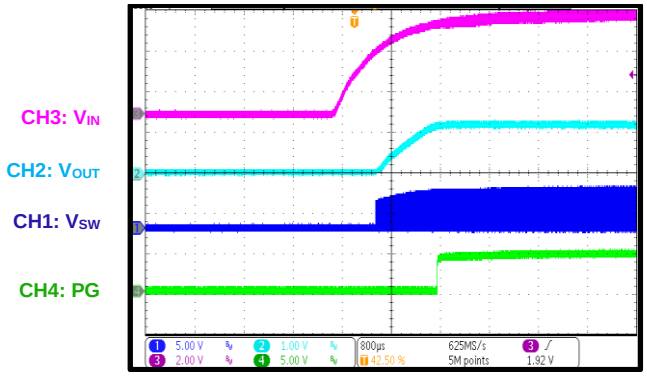
PG in Start-Up through VIN

FCCM, I_{OUT} = 0A



PG in Start-Up through VIN

I_{OUT} = 6A



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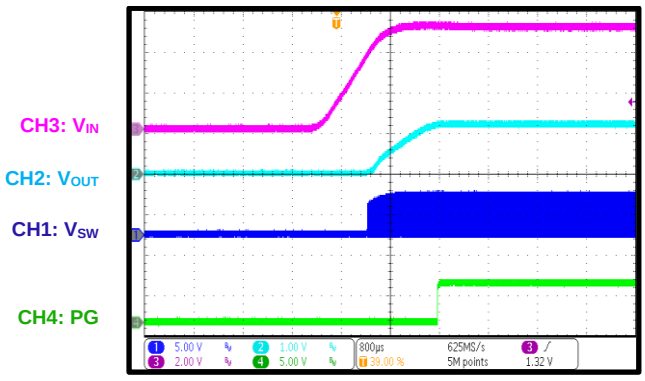
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 5V, V_{OUT} = 1.2V, L = 470nH, C_{OUT} = 22µF x 3, T_A = 25°C, unless otherwise noted.

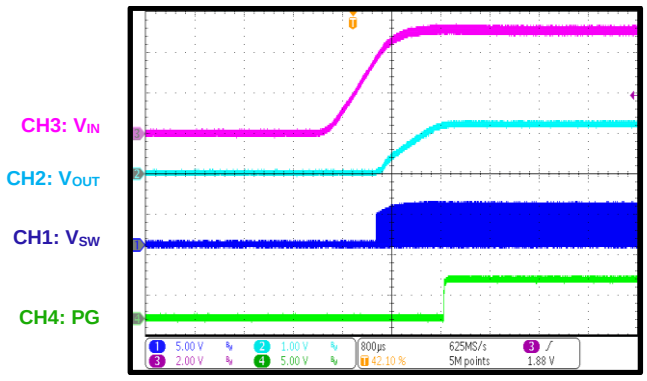
PG in Start-Up through VIN

I_{OUT} = 5A



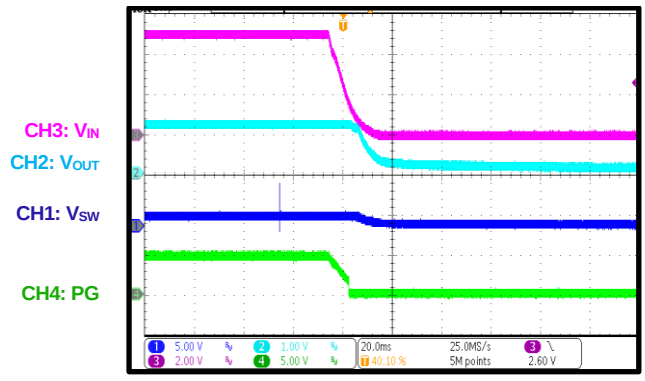
PG in Start-Up through VIN

I_{OUT} = 4A



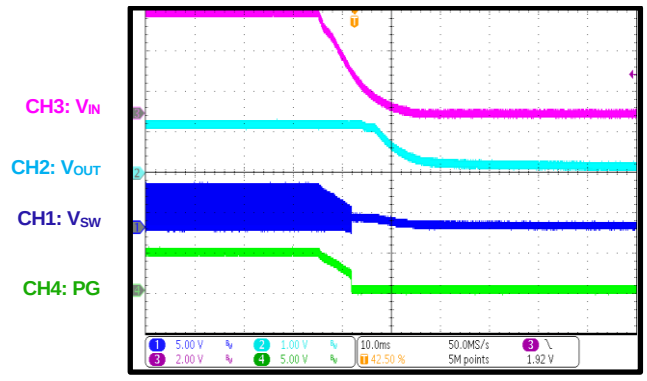
PG in Shutdown through VIN

AAM mode, I_{OUT} = 0A



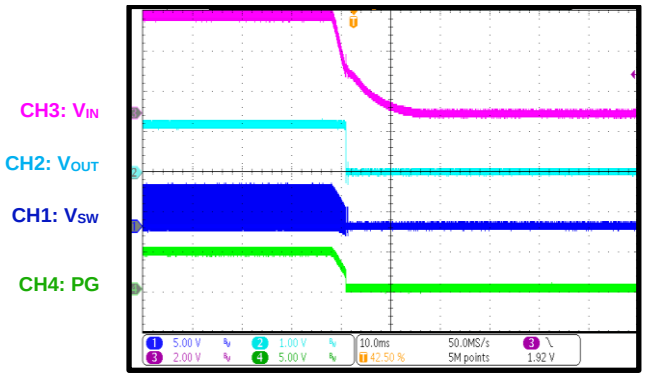
PG in Shutdown through VIN

FCCM, I_{OUT} = 0A



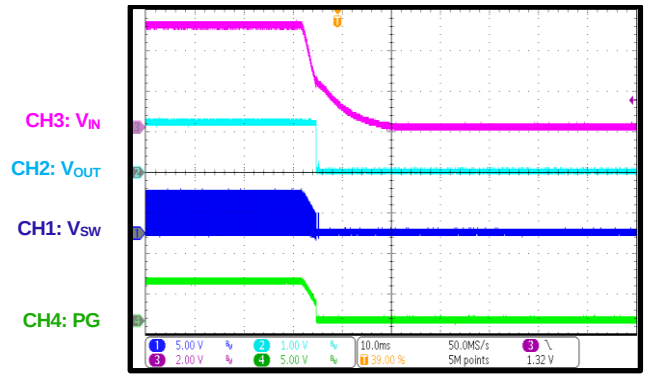
PG in Shutdown through VIN

I_{OUT} = 6A



PG in Shutdown through VIN

I_{OUT} = 5A



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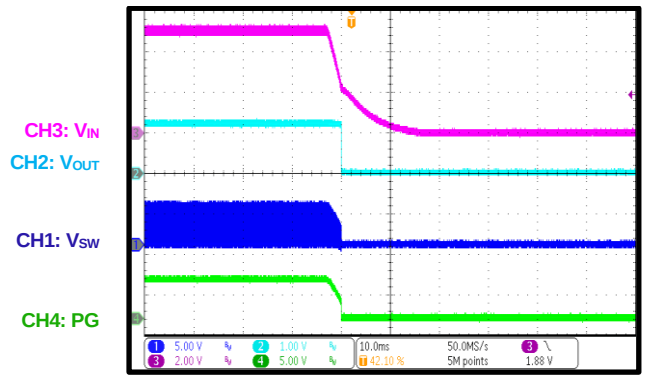
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 5V, V_{OUT} = 1.2V, L = 470nH, C_{OUT} = 22µF x 3, T_A = 25°C, unless otherwise noted.

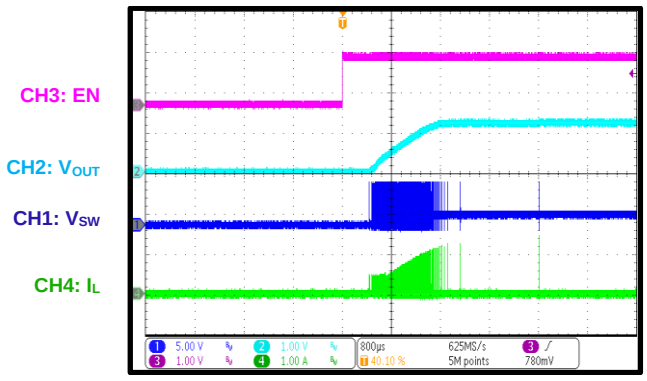
PG in Shutdown through VIN

I_{OUT} = 4A



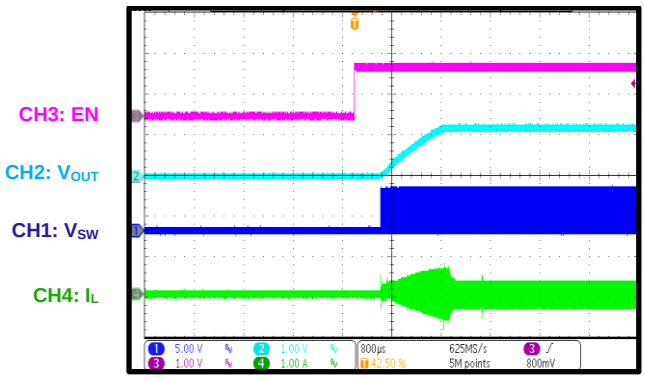
Start-Up through EN

AAM mode, I_{OUT} = 0A



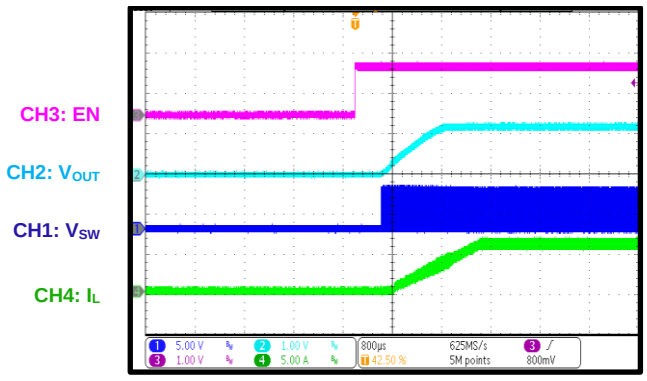
Start-Up through EN

FCCM, I_{OUT} = 0A



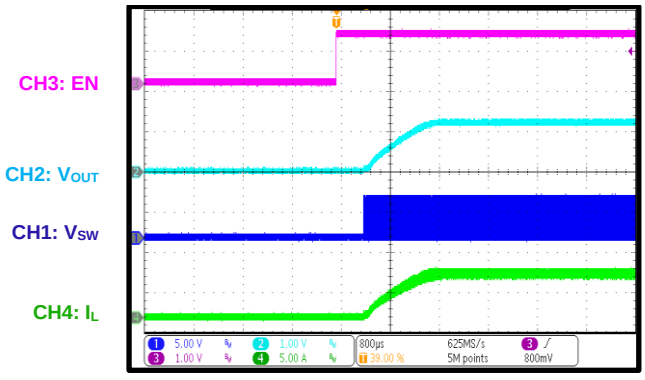
Start-Up through EN

I_{OUT} = 6A



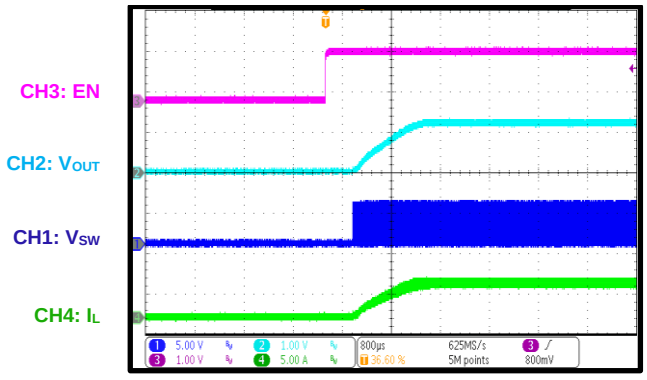
Start-Up through EN

I_{OUT} = 5A



Start-Up through EN

I_{OUT} = 4A



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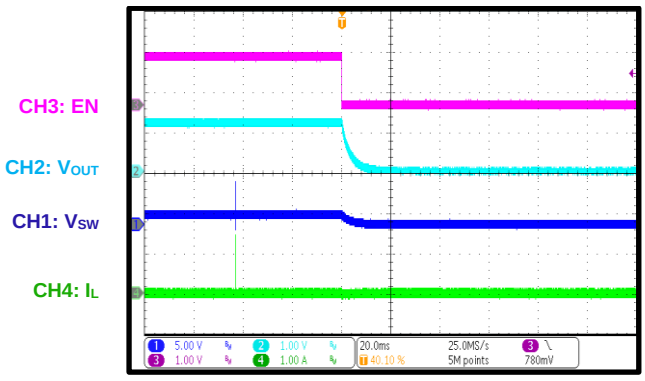
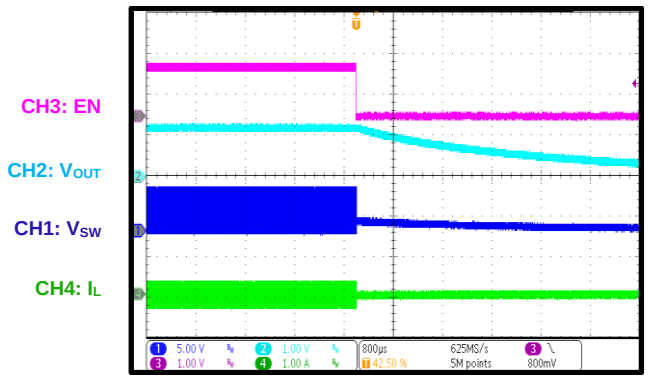
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 5V, V_{OUT} = 1.2V, L = 470nH, C_{OUT} = 22µF x 3, T_A = 25°C, unless otherwise noted.

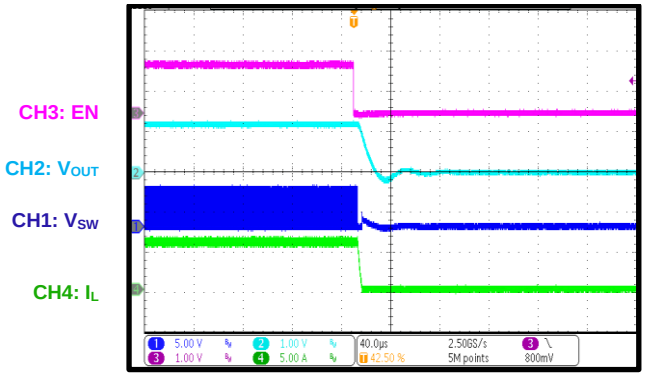
Shutdown through EN
AAM mode, I_{OUT} = 0A



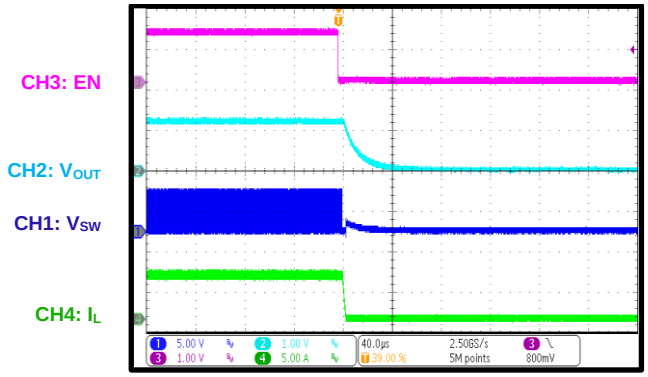
Shutdown through EN
FCCM, I_{OUT} = 0A



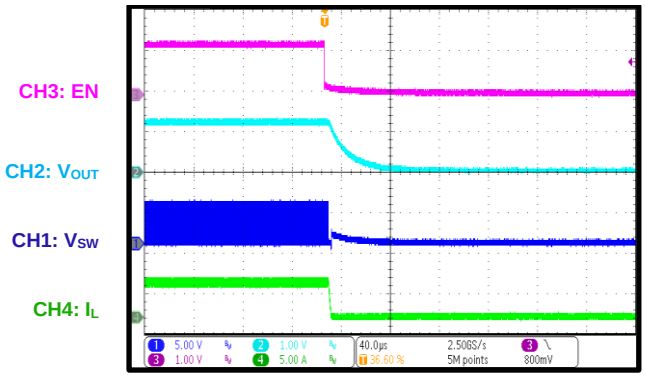
Shutdown through EN
I_{OUT} = 6A



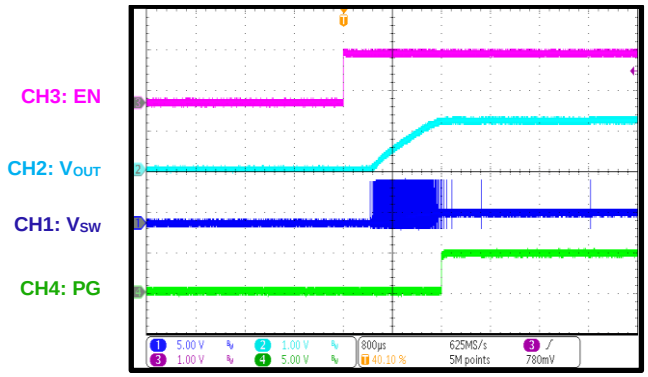
Shutdown through EN
I_{OUT} = 5A



Shutdown through EN
I_{OUT} = 4A



PG in Start-Up through EN
AAM mode, I_{OUT} = 0A



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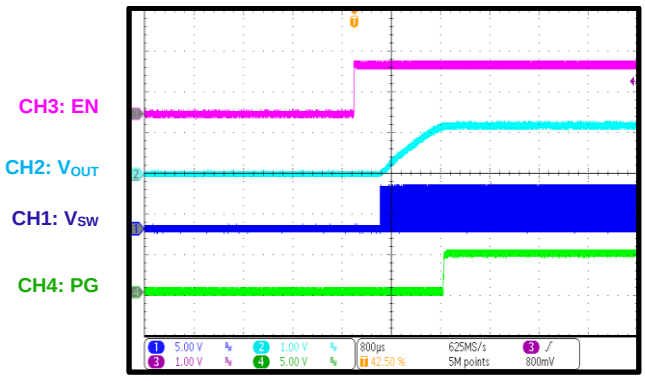
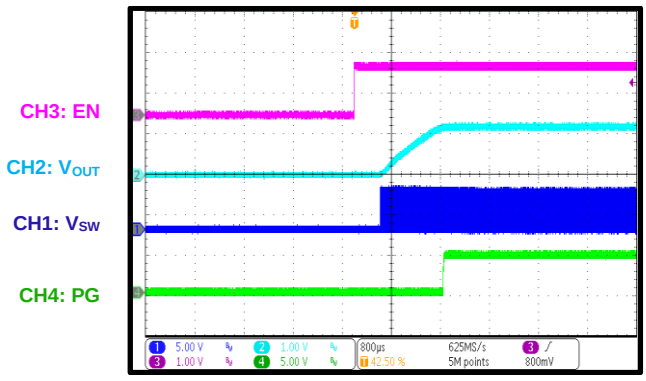
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 5V, V_{OUT} = 1.2V, L = 470nH, C_{OUT} = 22µF x 3, T_A = 25°C, unless otherwise noted.

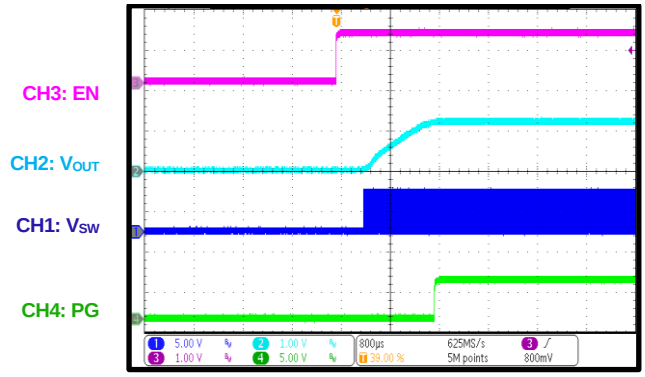
PG in Start-Up through EN
FCCM, I_{OUT} = 0A



PG in Start-Up through EN
I_{OUT} = 6A



PG in Start-Up through EN
I_{OUT} = 5A



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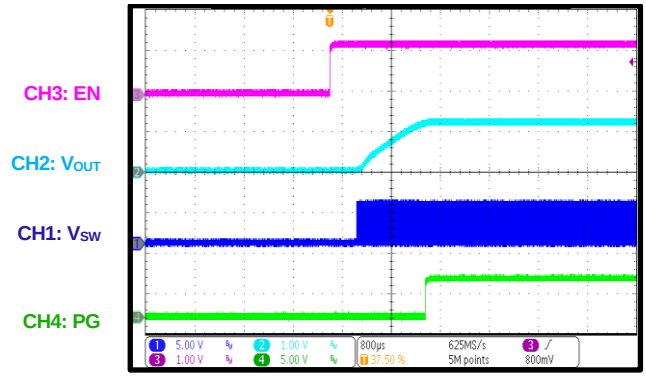
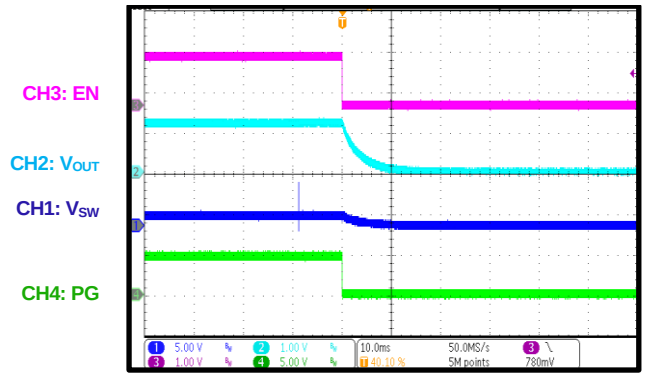
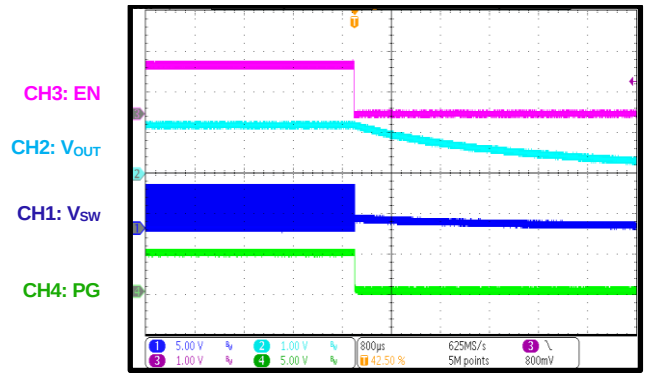
I_{OUT} = 4A



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



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



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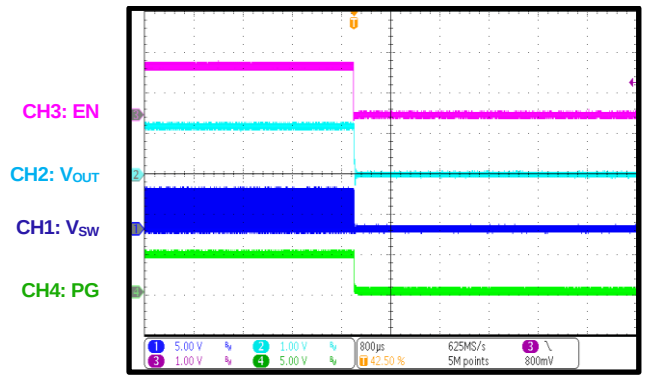
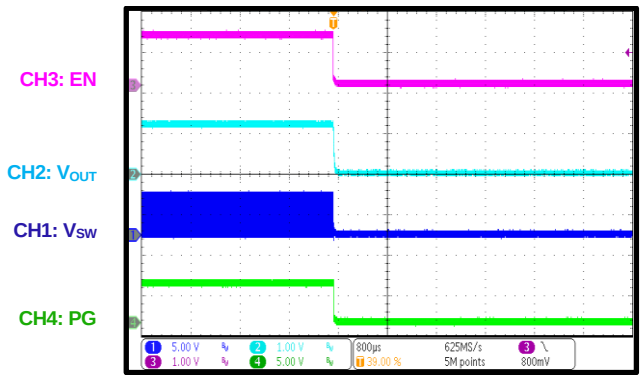
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 5V, V_{OUT} = 1.2V, L = 470nH, C_{OUT} = 22µF x 3, T_A = 25°C, unless otherwise noted.

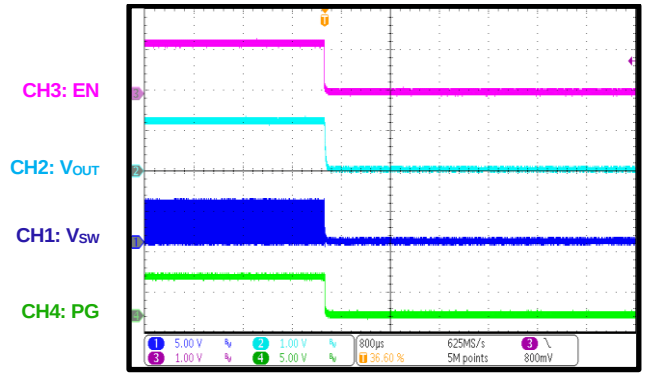
PG in Shutdown through EN
I_{OUT} = 6A



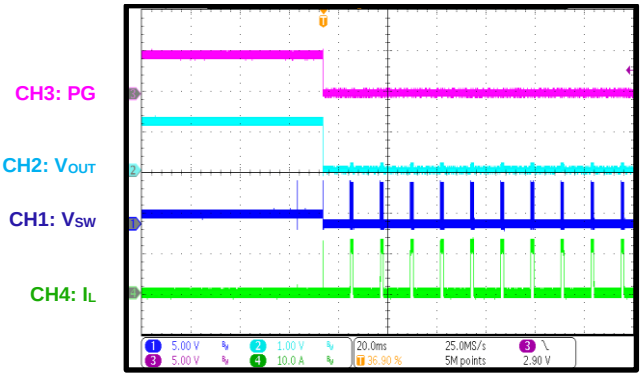
PG in Shutdown through EN
I_{OUT} = 5A



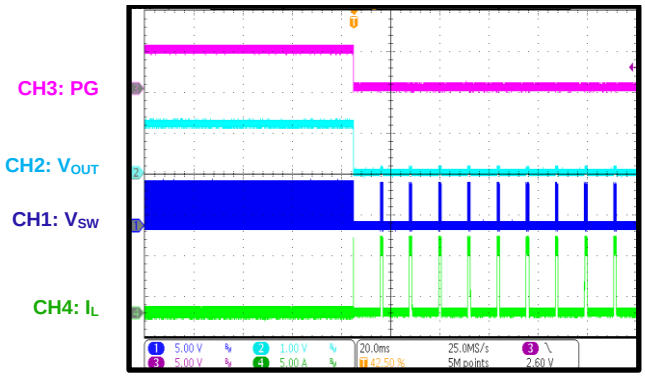
PG in Shutdown through EN
I_{OUT} = 4A



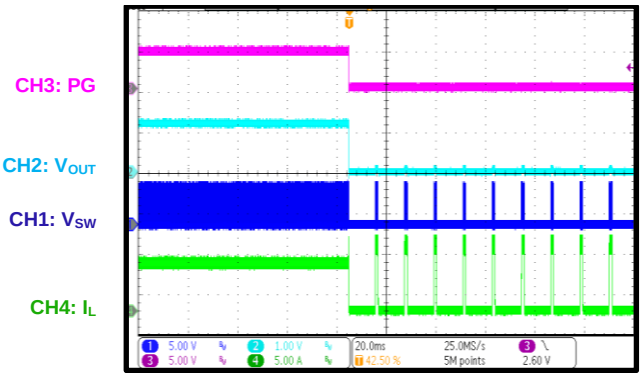
SCP Entry
MPQ2176-6000, AAM mode, I_{OUT} = 0A



SCP Entry
MPQ2176-6001, FCCM, I_{OUT} = 0A



SCP Entry
MPQ2176-600x, I_{OUT} = 6A



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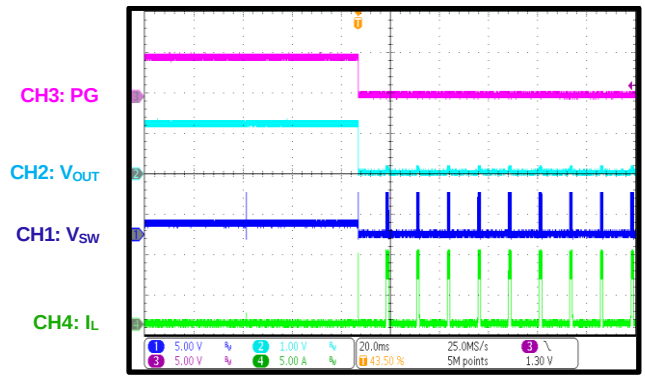
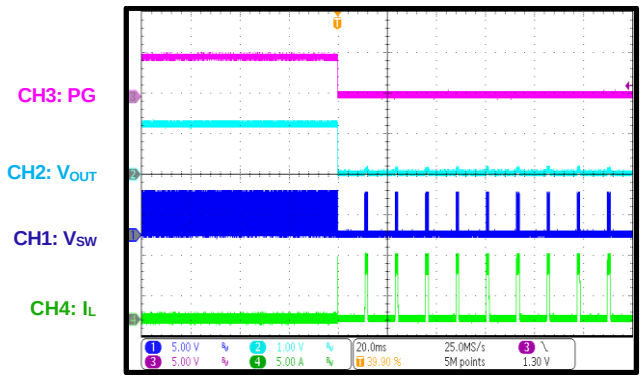
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 5V, V_{OUT} = 1.2V, L = 470nH, C_{OUT} = 22µF x 3, T_A = 25°C, unless otherwise noted.

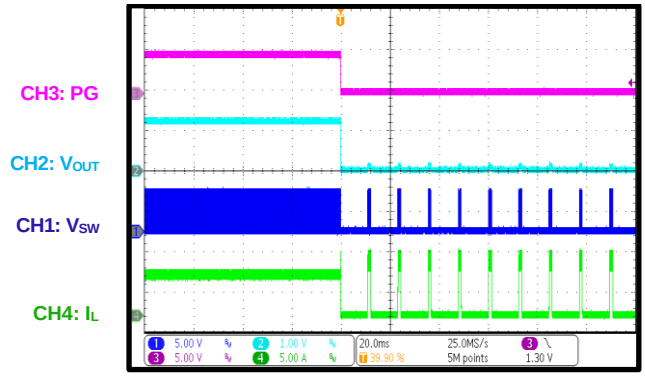
SCP Entry
MPQ2176-5000, AAM mode, I_{OUT} = 0A



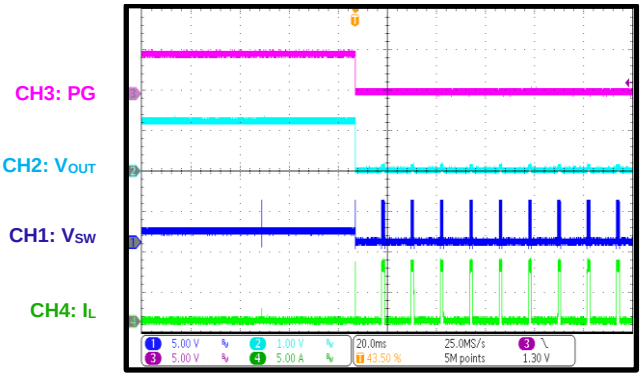
SCP Entry
MPQ2176-5001, FCCM, I_{OUT} = 0A



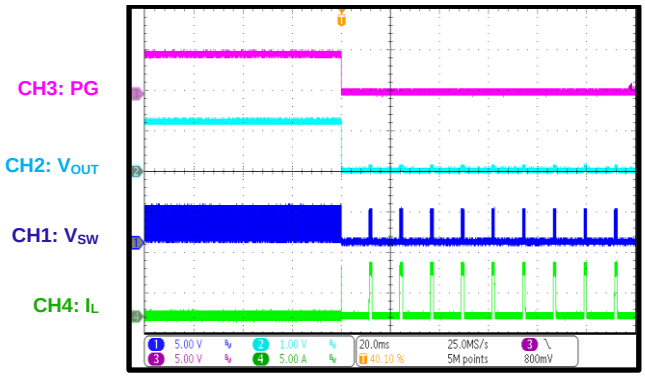
SCP Entry
MPQ2176-500x, I_{OUT} = 5A



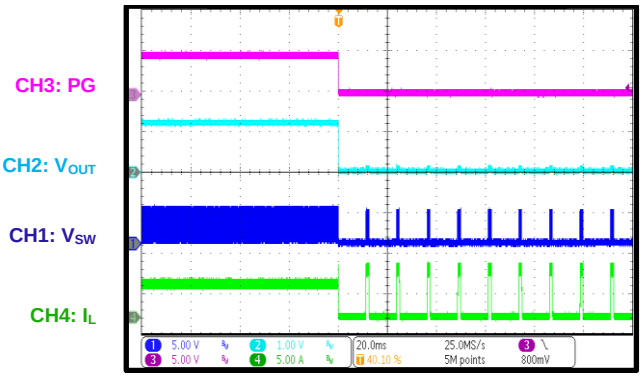
SCP Entry
MPQ2176-4000, AAM mode, I_{OUT} = 0A



SCP Entry
MPQ2176-4001, FCCM, I_{OUT} = 0A



SCP Entry
MPQ2176-400x, I_{OUT} = 4A



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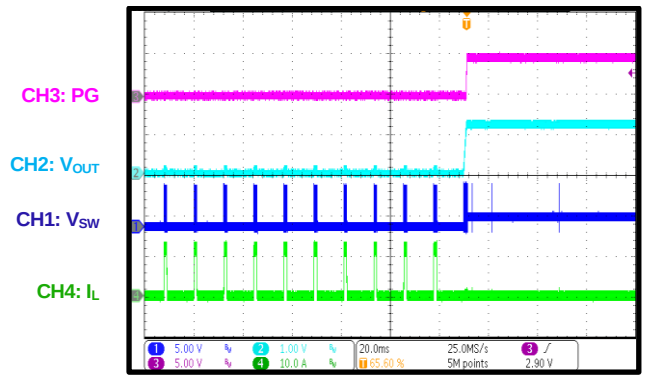
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 5V, V_{OUT} = 1.2V, L = 470nH, C_{OUT} = 22µF x 3, T_A = 25°C, unless otherwise noted.

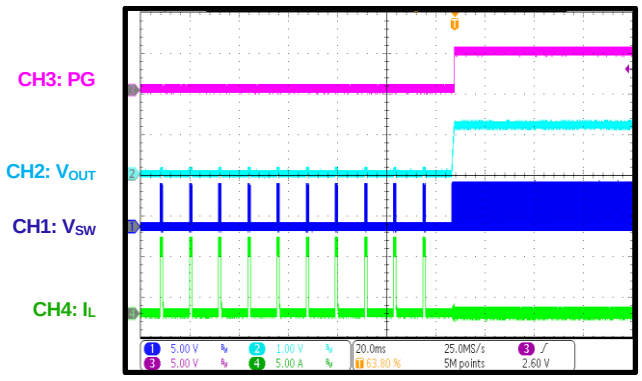
SCP Recovery

MPQ2176-6000, AAM mode, I_{OUT} = 0A



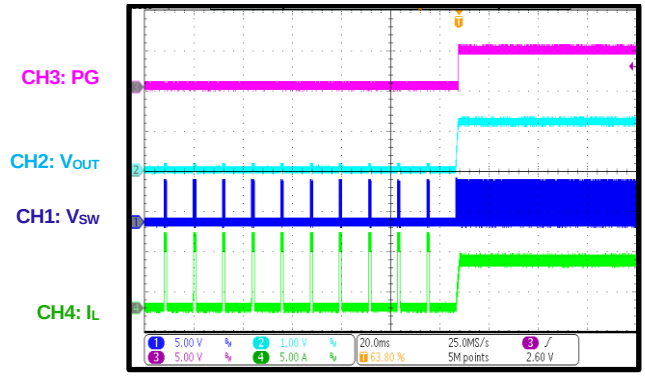
SCP Recovery

MPQ2176-6001, FCCM, I_{OUT} = 0A



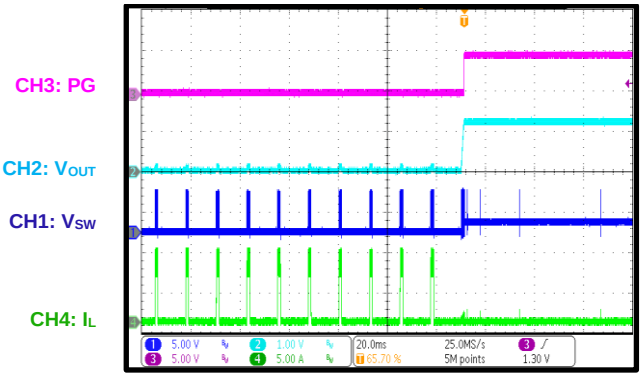
SCP Recovery

MPQ2176-600x, I_{OUT} = 6A



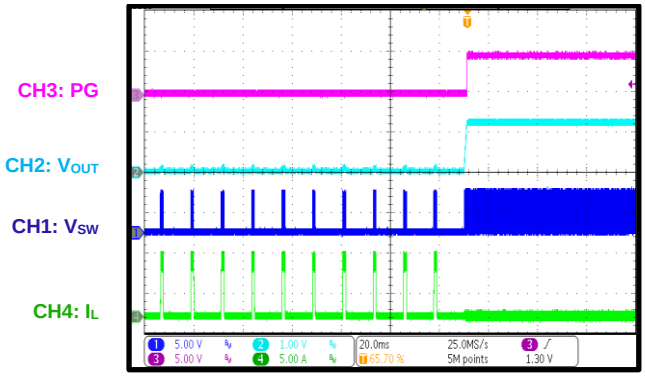
SCP Recovery

MPQ2176-5000, AAM mode, I_{OUT} = 0A



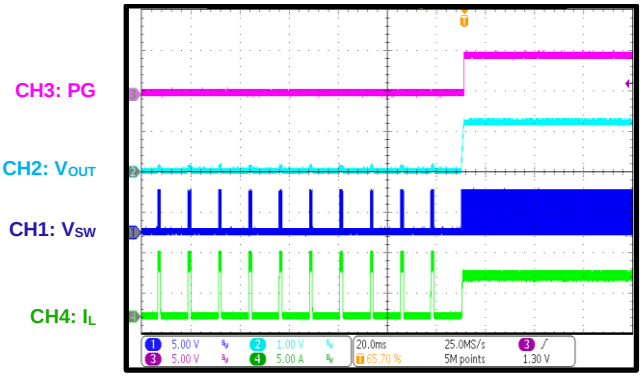
SCP Recovery

MPQ2176-5001, FCCM, I_{OUT} = 0A



SCP Recovery

MPQ2176-500x, I_{OUT} = 5A



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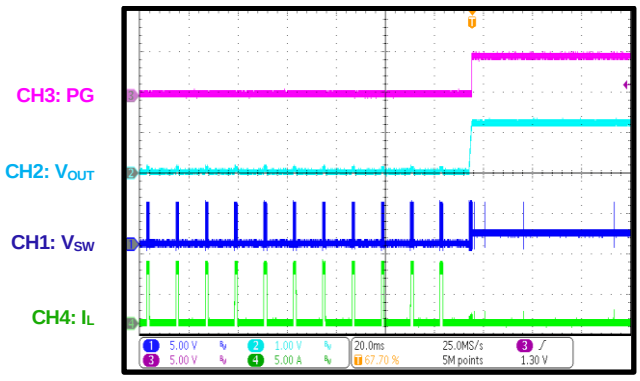
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 5V, V_{OUT} = 1.2V, L = 470nH, C_{OUT} = 22µF x 3, T_A = 25°C, unless otherwise noted.

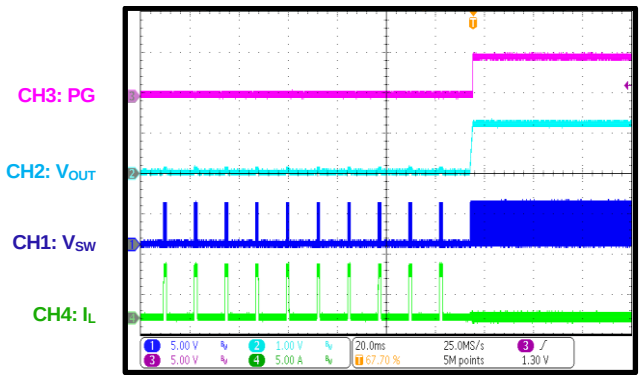
SCP Recovery

MPQ2176-4000, AAM mode, I_{OUT} = 0A



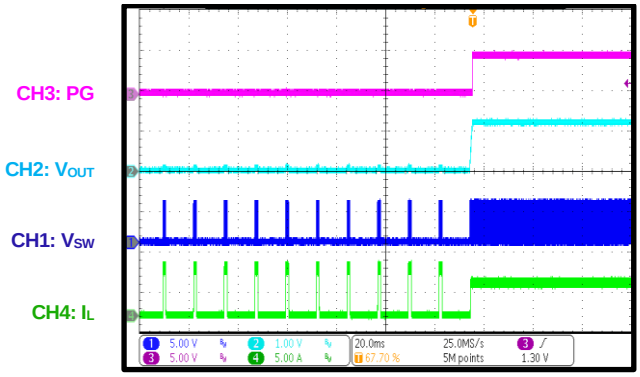
SCP Recovery

MPQ2176-4001, FCCM, I_{OUT} = 0A



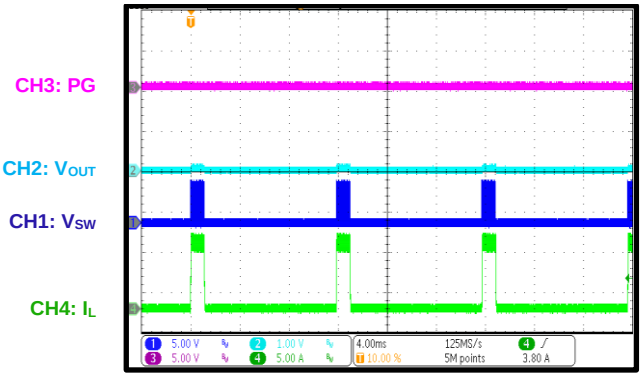
SCP Recovery

MPQ2176-400x, I_{OUT} = 4A



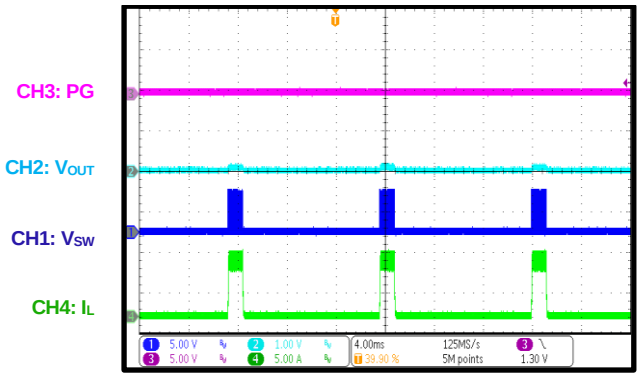
SCP Steady State

MPQ2176-600x



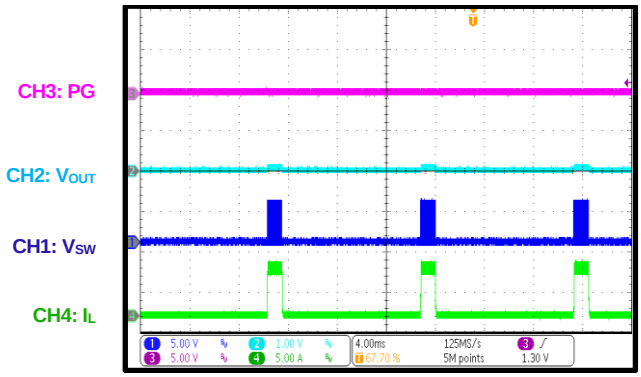
SCP Steady State

MPQ2176-500x



SCP Steady State

MPQ2176-400x



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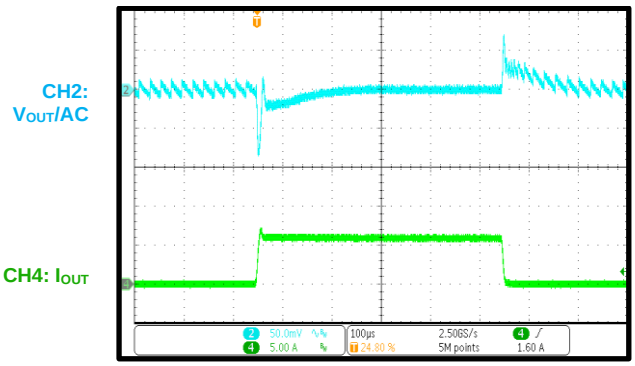
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 5V, V_{OUT} = 1.2V, L = 470nH, C_{OUT} = 22µF x 3, T_A = 25°C, unless otherwise noted.

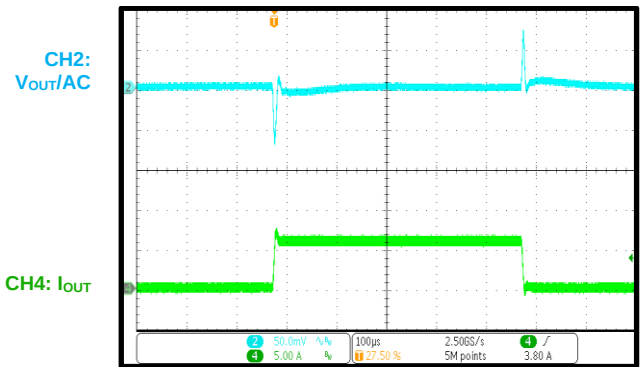
Load Transient Response

AAM mode, I_{OUT} = 0A to 6A, 1.6A/µs



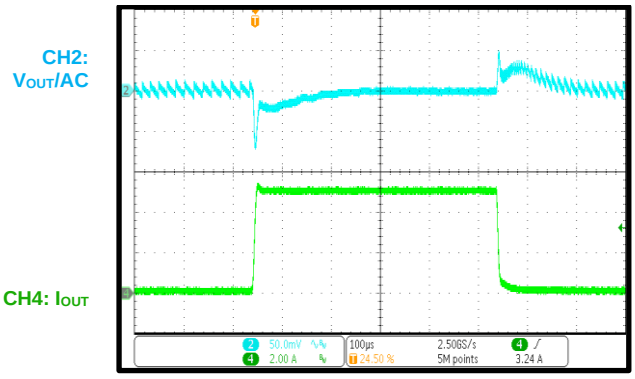
Load Transient Response

FCCM, I_{OUT} = 0A to 6A, 1.6A/µs



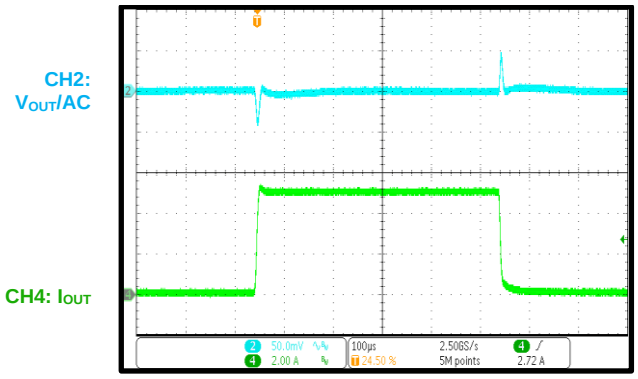
Load Transient Response

AAM mode, I_{OUT} = 0A to 5A, 1.6A/µs



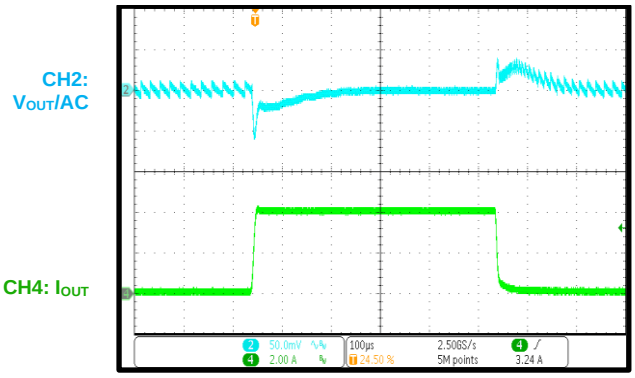
Load Transient Response

FCCM, I_{OUT} = 0A to 5A, 1.6A/µs



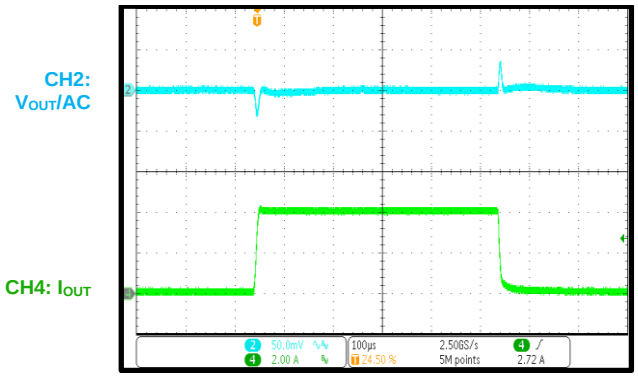
Load Transient Response

AAM mode, I_{OUT} = 0A to 4A, 1.6A/µs



Load Transient Response

FCCM, I_{OUT} = 0A to 4A, 1.6A/µs



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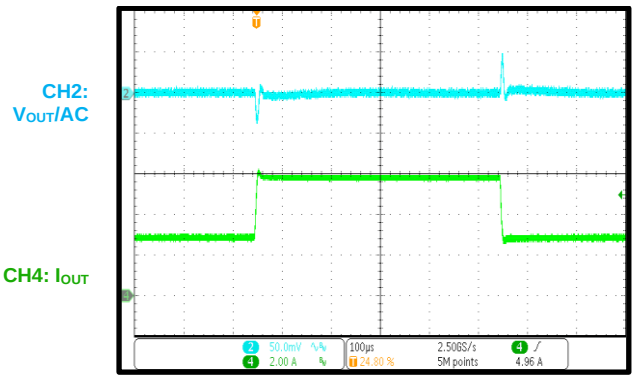
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 5V, V_{OUT} = 1.2V, L = 470nH, C_{OUT} = 22µF x 3, T_A = 25°C, unless otherwise noted.

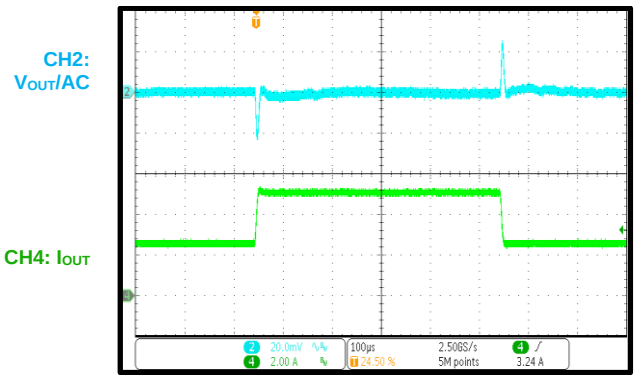
Load Transient Response

I_{OUT} = 3A to 6A, 1.6A/µs



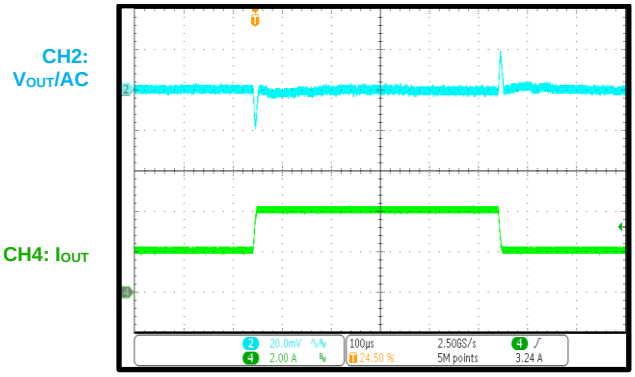
Load Transient Response

I_{OUT} = 2.5A to 5A, 1.6A/µs



Load Transient Response

I_{OUT} = 2A to 4A, 1.6A/µs



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FUNCTIONAL BLOCK DIAGRAM

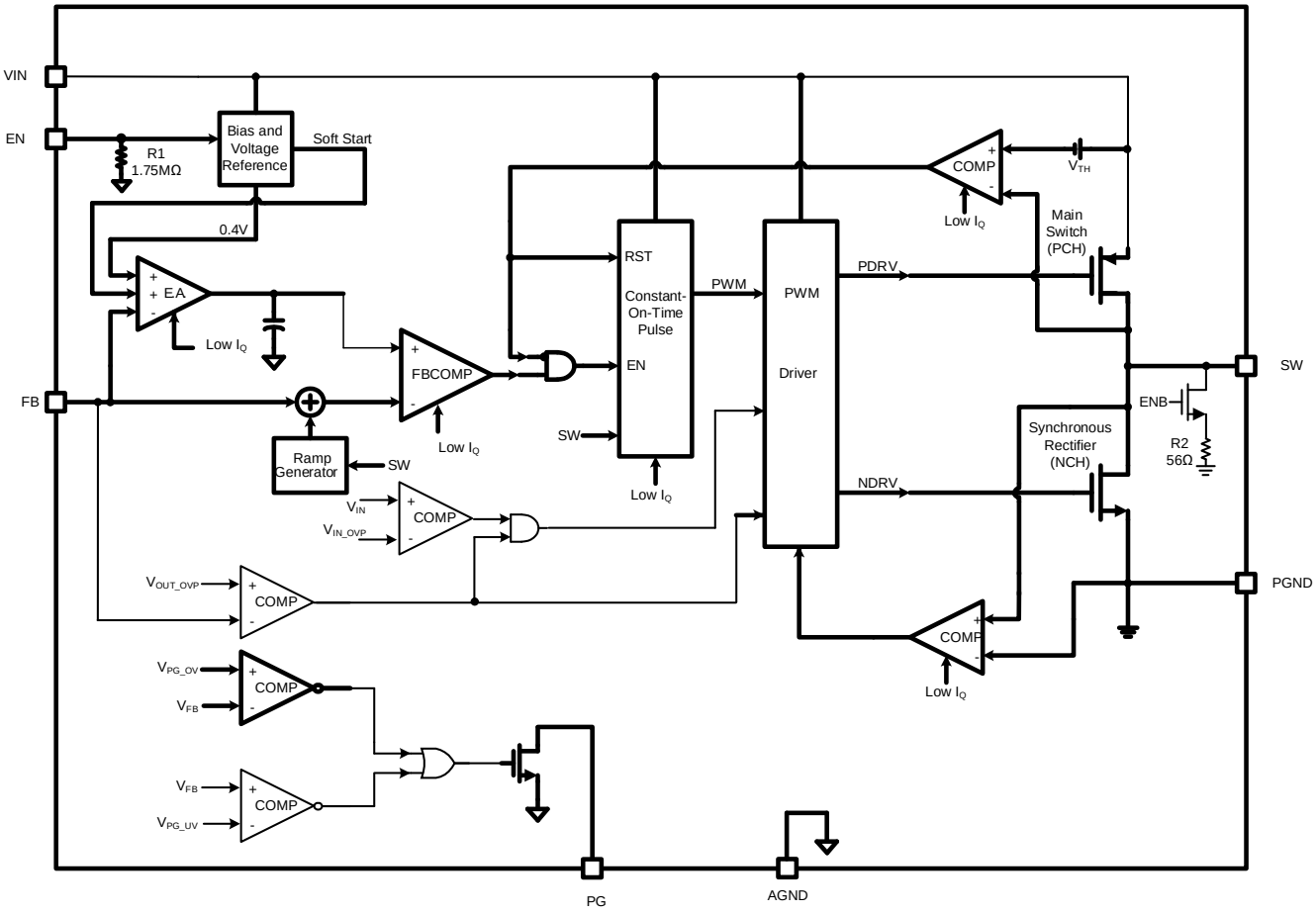

Figure 1: Functional Block Diagram

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OPERATION

The MPQ2176 family uses constant-on-time (COT) control with input voltage (V_{IN}) feed-forward to stabilize the switching frequency (f_{SW}) across the full input range. This family provides 4A to 6A of continuous output current (I_{OUT}) from a 2.4V to 5.5V V_{IN} with excellent load and line regulation. The output voltage (V_{OUT}) can be regulated to as low as 0.4V.

Constant-On-Time (COT) Control

Compared to fixed-frequency pulse-width modulation (PWM) control, COT control offers a simpler control loop and a faster transient response. To prevent inductor current (I_L) runaway during load transients, the MPQ2176 has a fixed minimum off time. When the low-side MOSFET (LS-FET) turns on, it remains on for at least as long as the minimum off time ($t_{MIN-OFF}$). Then the high-side MOSFET (HS-FET) turns on when the feedback voltage (V_{FB}) drops below the reference voltage (V_{REF}). This indicates an insufficient V_{OUT}. By using V_{IN} feed forward, the MPQ2176 maintains a nearly constant f_{SW} across the V_{IN} and V_{OUT} ranges.

The switching pulse on time (t_{ON}) can be calculated with Equation (1):

$$t_{ON} = \frac{V_{OUT}}{V_{IN}} \times 0.45\mu s \quad (1)$$

Light-Load Operation

The control mode under light-load conditions mainly depends on the “Z” in the 4-digit code “WXYZ” (see Table 1 on Page 3). The mode can be set to advanced asynchronous modulation (AAM) mode or forced continuous conduction mode (FCCM).

AAM power-saving mode can be implemented to guarantee high light-load efficiency for applications with a large duty cycle. Figure 2 shows the AAM mode control theory.

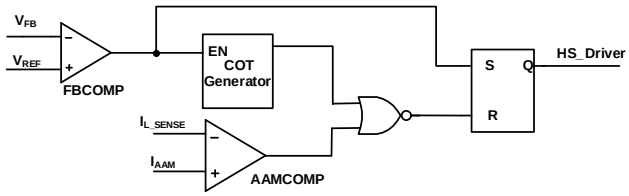

Figure 2: AAM Control Logic

The AAM mode current (I_{AAM}) is the internal AAM mode current threshold. The switching on time is determined by on-timer generator and the AAM mode comparator; the longer value between these options is used for the switching on time.

Figure 3 shows the operation if the AAM mode comparator pulse is longer than on-time generator. I_L must ramp up until it reaches the AAM threshold, then the LS-FET allows to turn on to ramp down I_L.

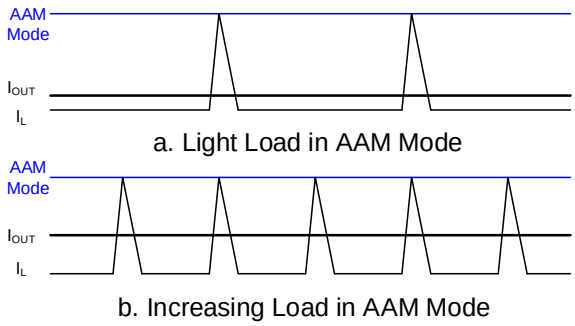

Figure 3: AAM Mode Comparator

Figure 4 shows the operation if the AAM mode comparator pulse is shorter than the on-timer generator. I_L is determined by the normal on time if the peak current already exceeds the AAM mode threshold. The AAM mode threshold does not determine the on time under this condition.

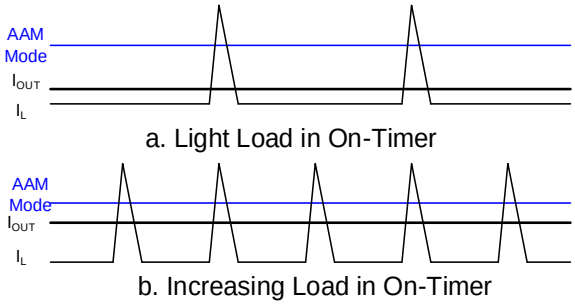

Figure 4: On-Timer Controls t_{ON}

The MPQ2176 has zero-current detection (ZCD) circuit to judge whether I_L starts to reverse. When I_L reaches the ZCD threshold, the LS-FET turns off.

AAM mode works with the ZCD circuit to force the MPQ2176 to always work in discontinuous conduction mode (DCM) mode under light loads, even if V_{OUT} is close to V_{IN}.

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When the MPQ2176 is set to be an FCCM part, the device works with a fixed frequency across the no-load to full-load range. The advantages of FCCM are its controllable frequency and lower output voltage ripple under light loads.

Sleep Mode Operation

When the MPQ2176 is set to be an AAM mode part, it features sleep mode to obtain higher efficiency at extremely light loads. In sleep mode, most of the circuit blocks' input currents decrease, especially for the error amplifier and PWM comparator.

When the load gets lighter, the MPQ2176 slows down the frequency. If the off time is longer than 3.5µs, the MPQ2176 enters sleep mode.

If a high-side pulse occurs, the MPQ2176 exits sleep mode.

Frequency Spread Spectrum (FSS)

The MPQ2176 uses an analog ramp signal to spread the internal oscillator frequency across a 2% (±1%) window at a 6.5kHz modulation frequency (see Figure 5).

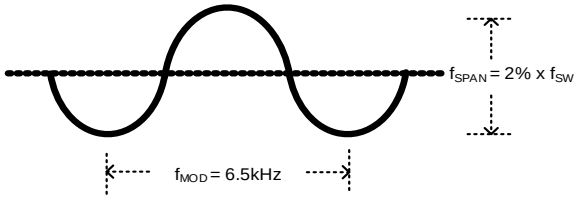

Figure 5: Frequency Spread Spectrum

Side bands are created by modulating f_{SW} with the analog ramp signal. The fundamental switching frequency's emission power and its harmonics are distributed into smaller segments. This significantly reduces EMI noise.

Internal Soft Start (SS)

The MPQ2176 has an internal soft start (SS) that ramps up V_{OUT} at a controlled slew rate to avoid overshoot at start-up. The soft start time (t_{SS}) is 1ms, typically.

Minimum On Time (t_{ON_MIN})

The allowable minimum on time (t_{ON_MIN}) depends on V_{OUT} to improve the device's dropout performance. During low duty cycle operation, this can result in frequency foldback below the nominal 2.2MHz switching frequency when the minimum on time value is exceeded.

Estimate the minimum on time for a given V_{OUT} with Equation (2): (12)

$$t_{ON_MIN} = 80.5\frac{ns}{V} \times V_{OUT} + 11ns \quad (2)$$

Note:

12) Guaranteed by design and bench characterization. Not tested in production.

Figure 6 shows how the allowable t_{ON_MIN} varies with different V_{OUT}.

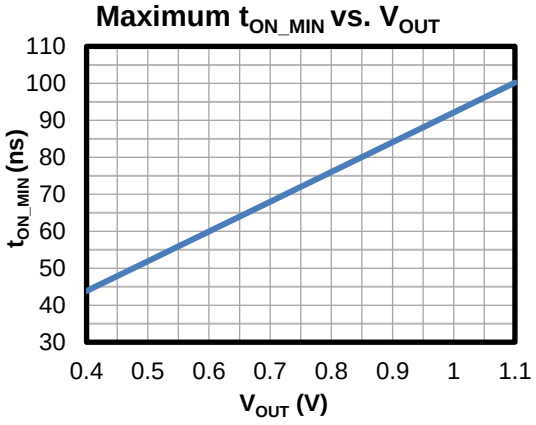

Figure 6: t_{ON_MIN} Increases as V_{OUT} Increases

Low-Dropout (LDO) Mode

When V_{OUT} is close to V_{IN}, the device triggers the minimum off time (a maximum value of 60ns), and the MPQ2176 is in low-dropout (LDO) mode. To achieve a larger duty cycle, f_{SW} decreases, and the device works with maximum duty cycle (97%).

Peak and Valley Current limit

The HS-FET and LS-FET have current-limit protection. When I_L reaches the HS-FET's peak current limit (typically 10.5A for the MPQ2176-6xxx) during the HS-FET on period, the HS-FET is forced off immediately to prevent the current from rising further. Then the LS-FET turns on and stays on until I_L drops below the LS-FET valley current limit (typically 7.5A for the MPQ2176-6xxx). The HS-FET turns on again once I_L has dropped to a sufficiently low threshold. This current-limit scheme prevents current runaway during overload or short-circuit events.

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Short-Circuit Protection (SCP) and Recovery

The MPQ2176 enters short-circuit protection (SCP) mode when it reaches the peak current limit and V_{OUT} drops below 40% of its normal output, initiating a protection and recovery response.

After the conditions are met for SCP, the device enters a hiccup mode. During hiccup mode, switching shuts down and soft start is held low for the duration of a 11ms timer. At the end of the 11ms timer period, the device automatically tries to soft start, ramping up the soft-start capacitor. Meanwhile, I_L switches between the peak and valley current limit levels. This switching continues until the short-circuit load releases and V_{OUT} recovers to 50% of its regulation value; if the soft-start period is reached with no change, then the part re-enters hiccup mode. The part repeats this cycle until the load and V_{OUT} return to normal operation conditions.

Thermal Shutdown

Thermal shutdown is implemented to prevent the chip from thermal runaway. If the silicon die temperature exceeds its upper threshold (163°C), the power MOSFETs shut down. Once the temperature drops below its lower threshold (146°C), the thermal shutdown condition is removed and the chip is enabled again.

Over-Voltage Protection (OVP)

The MPQ2176 monitors a resistor-divided feedback voltage (V_{FB}) to detect output over-voltage (OV) conditions. If V_{FB} exceeds 115% of V_{REF}, the controller enters the dynamic regulation period. During this period, the LS-FET turns on and remains on until the LS-FET current reaches the reverse current limit (typically -3.9A). Then the LS-FET turns off and the FETs remain in tri-state for 800ns typically, and the negative current flows through the HS-FET body diode until the zero-current level is reached. If V_{IN} is low enough, or if the inductance is too high, the zero current is not reached by the end of this 800ns timer. In this scenario, the LS-FET turns on for a short pulse, the ZCD threshold triggers a negative I_L, and the 800ns timer restarts.

The cycle continues until V_{FB} falls below 110% of V_{REF}, then the MPQ2176 exits this regulation period. If the dynamic regulation period cannot prevent V_{OUT} from increasing and a 6.3V V_{IN} is detected, then input over-voltage protection (OVP) occurs. The MPQ2176 stops switching, and does not resume normal operation until V_{IN} falls below 6.16V.

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APPLICATION INFORMATION

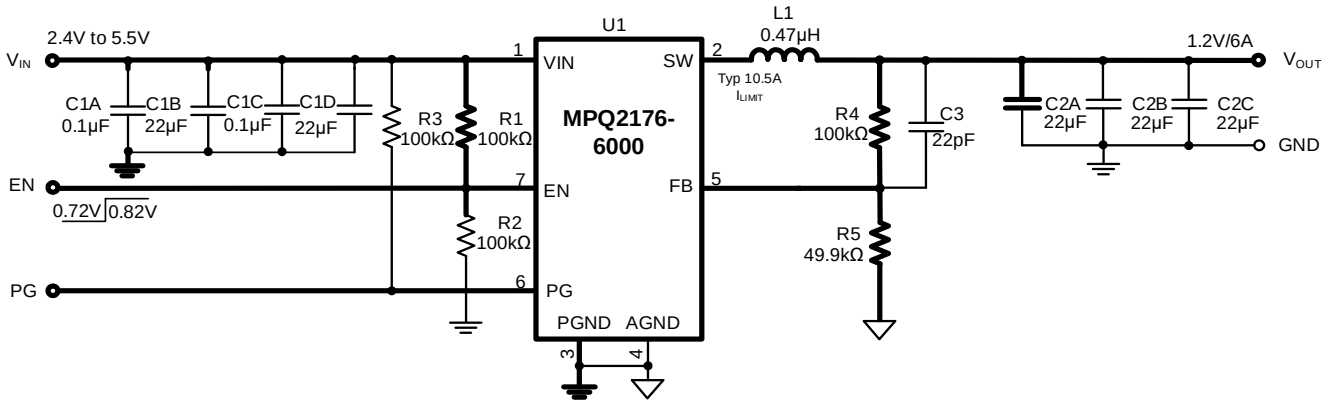

Figure 7: Typical Application Circuit for the MPQ2176-6000 (V_{OUT} = 1.2V, f_{SW} = 2.2MHz)

Table 2: Design Guide Index and Recommended Values

Pin #	Pin Name	Component	Design Guide Index	Value
1	VIN	C1A, C1B, C1C, C1D	Selecting the Input Capacitors (VIN, Pin 1)	0.1µF, 22µF 0.1µF, 22µF
2	SW	L1, C2A, C2B, C2C	Selecting the Inductor and Output Capacitor (SW, Pin 2)	470nH, 22µF, 22µF, 22µF,
3	PGND	-	GND Connection (PGND, Pin 3; AGND, Pin 4)	-
4	AGND	-	GND Connection (PGND, Pin 3; AGND, Pin 4)	-
5	FB	R4, R5, C3	Feedback (FB, Pin 5)	100kΩ, 49.9kΩ, 22pF
6	PG	R3	Power Good indicator (PG, Pin 6)	100kΩ
7	EN	R1 ,R2	Enable (EN, Pin 7)	100kΩ, 100kΩ

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Selecting the Input Capacitors (VIN, Pin 1)

The step-down converter has a discontinuous input current, and requires a capacitor to supply the AC current to the converter while maintaining the DC input voltage. Use low-ESR capacitors for the best performance. Ceramic capacitors with X5R or X7R dielectrics are highly recommended because of their low ESR and small temperature coefficients. For most applications, a 10µF capacitor is sufficient. Higher output voltages may require a 22µF capacitor to increase system stability.

The input capacitor requires an adequate ripple current rating because it absorbs the input switching current. Calculate the RMS current in the input capacitor with Equation (3):

$$I_{C1} = I_{LOAD} \times \sqrt{\frac{V_{OUT}}{V_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)} \quad (3)$$

The worst-case scenario occurs at $V_{IN} = 2 \times V_{OUT}$, calculated with Equation (4):

$$I_{C1} = \frac{I_{LOAD}}{2} \quad (4)$$

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 0.1µF capacitor as close to the IC as possible. When using ceramic capacitors, ensure that they have enough capacitance to provide sufficient charge to prevent excessive voltage ripple at the input. The input voltage ripple caused by the capacitance can be calculated with Equation (5):

$$\Delta V_{IN} = \frac{I_{LOAD}}{f_{SW} \times C1} \times \frac{V_{OUT}}{V_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \quad (5)$$

Selecting the Inductor and Output Capacitor (SW, Pin 2)

Selecting the Output Capacitor

The output capacitor (C2) stabilizes the DC output voltage. Ceramic capacitors are recommended. Low-ESR capacitors are recommended to limit the output voltage ripple. Estimate the output voltage ripple with Equation (6):

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_{SW} \times L_1} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \times \left(R_{ESR} + \frac{1}{8 \times f_{SW} \times C2}\right) \quad (6)$$

Where L_1 is the inductor value and R_{ESR} is the equivalent series resistance (ESR) value of the output capacitor.

When using ceramic capacitors, the capacitance dominates the impedance at the switching frequency, and causes most of the output voltage ripple. For simplification, the output voltage ripple can be calculated with Equation (7):

$$\Delta V_{OUT} = \frac{V_{OUT}}{8 \times f_{SW}^2 \times L_1 \times C2} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \quad (7)$$

For tantalum or electrolytic capacitors, the ESR dominates the impedance at the switching frequency. For simplification, the output ripple can be estimated with Equation (8):

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_{SW} \times L_1} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \times R_{ESR} \quad (8)$$

The characteristics of the output capacitor also affect the regulation system's stability.

Selecting the Inductor

Most applications work best with a 0.47µH to 1.5µH inductor. Select an inductor with a DC resistance below 25mΩ to optimize efficiency.

A high-frequency, switch-mode power supply with a magnetic device has strong electromagnetic inference in a system. Any un-shielded power inductor should be avoided, as it provides poor magnetic shielding. Shielded inductors, such as metal alloy or multiplayer chip powers, are the best candidates for applications, as they decrease the interference effectively.

For most designs, estimate the inductance with Equation (9):

$$L_1 = \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{V_{IN} \times \Delta I_L \times f_{SW}} \quad (9)$$

Where ΔI_L is the inductor ripple current.

Choose an inductor current to be approximately 30% of the maximum load current. The maximum inductor peak current can be calculated with Equation (10) on page 39:

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$$I_{L(MAX)} = I_{LOAD} + \frac{\Delta I_L}{2} \quad (10)$$

GND Connection (PGND, Pin 3; AGND, Pin 4)

See the PCB Layout Guidelines section on page 40 for more details.

Feedback (FB, Pin 5)

For the adjustable output, V_{FB} is typically 0.4V. The external resistor divider sets the output voltage (see Figure 8). Select the feedback resistor (R4) that reduces the V_{OUT} leakage current (typically not exceeding 100kΩ). There is no strict requirement on the feedback resistor. Select R4 to exceed 10kΩ. R5 can then be calculated with Equation (11):

$$R5 = \frac{R4}{\frac{V_{OUT}}{0.4} - 1} \quad (11)$$

Figure 8 shows the feedback circuit.

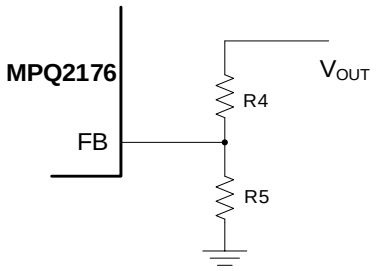

Figure 8: Feedback Network

Table 3 lists the recommended parameters for common V_{OUT} values.

Table 3: Parameter Selection for Common Output Voltages

V_{OUT} (V)	R4 (kΩ)	R5 (kΩ)	L (μH)
1	100	64.8	0.47
1.2	100	49.9	0.47
1.8	100	28.7	0.47
2.5	100	19.1	0.47
3.3	100	13.7	0.47

Power Good indicator (PG, Pin 6)

The MPQ2176 has one power good (PG) output to indicate normal operation after soft start. PG is the open drain of an internal MOSFET, which has a maximum on resistance ($R_{DS(ON)}$) of 400Ω. PG can be connected to VIN or an external voltage source through an external resistor (e.g. 100kΩ). After V_{IN} is applied, the MOSFET turns on and PG is pulled to GND before SS is ready. If V_{FB} is within 96% to 105% of V_{REF}, PG is pulled high by the external voltage source. If V_{FB} exceeds 112% or drops below 90% of V_{REF}, the PG voltage (V_{PG}) is pulled to GND to indicate an output failure. Float PG if it is not used.

If V_{IN} and EN are not available and PG is pulled up by an external power supply, then PG will self-bias and assert. If a 100kΩ pull-up resistor is used, the voltage on the PG pin is below 1.05V.

Enable (EN, Pin 7)

When V_{IN} exceeds the under-voltage lockout threshold (UVLO) (typically 2.25V), the MPQ2176 can be enabled by pulling the EN pin to exceed the rising threshold (0.82V). Leave the EN pin floating or pull EN below 0.72V to disable the MPQ2176. There is an internal 1.75MΩ resistor connected from the EN pin to ground.

When the device is disabled, the part goes into output discharge mode automatically, and its internal discharge MOSFET provides a resistive discharge path from SW to PGND through a 56Ω resistance for the output capacitor. If V_{IN} is below the UVLO threshold, output discharge mode is disabled.

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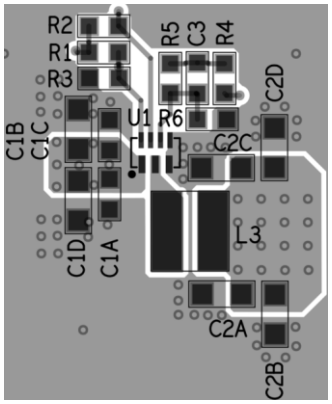
PCB Layout Guidelines [13]

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 9 and follow the guidelines below:

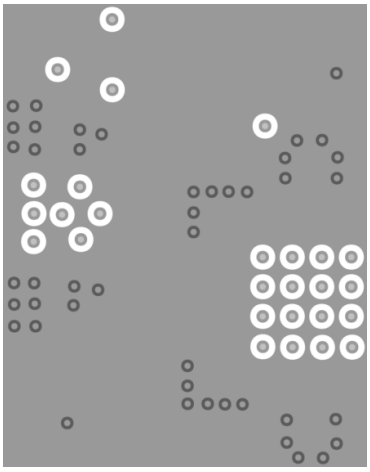
1. Place symmetric input capacitors as close to VIN and PGND as possible.
2. Connect a large ground plane directly to PGND.
3. If the bottom layer is a ground plane, add vias near PGND.
4. Ensure that the high-current paths at ground and VIN have short, direct, and wide traces.
5. Place the ceramic input 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. Reduce the SW node routing size to improve EMI.
8. Place the feedback resistors close to the chip to ensure that the trace connected to FB is as short as possible.
9. Use multiple vias to connect the power planes to the internal layers.

Note:

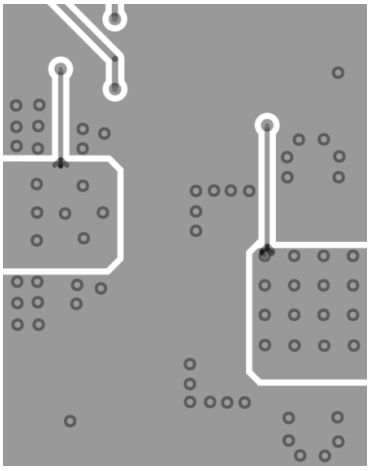
13) The recommended PCB layout is based on Figure 10 on page 41.



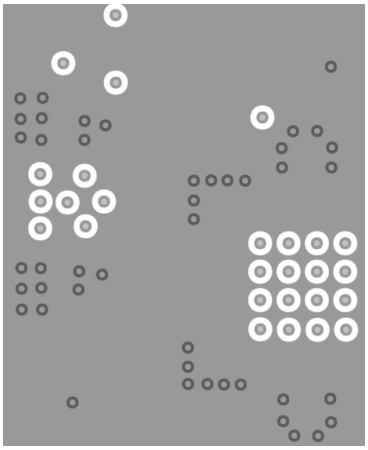
Top Layer



Mid-Layer 1



Mid-Layer 2



Bottom Layer

Figure 9: Recommended PCB Layout

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TYPICAL APPLICATION CIRCUITS

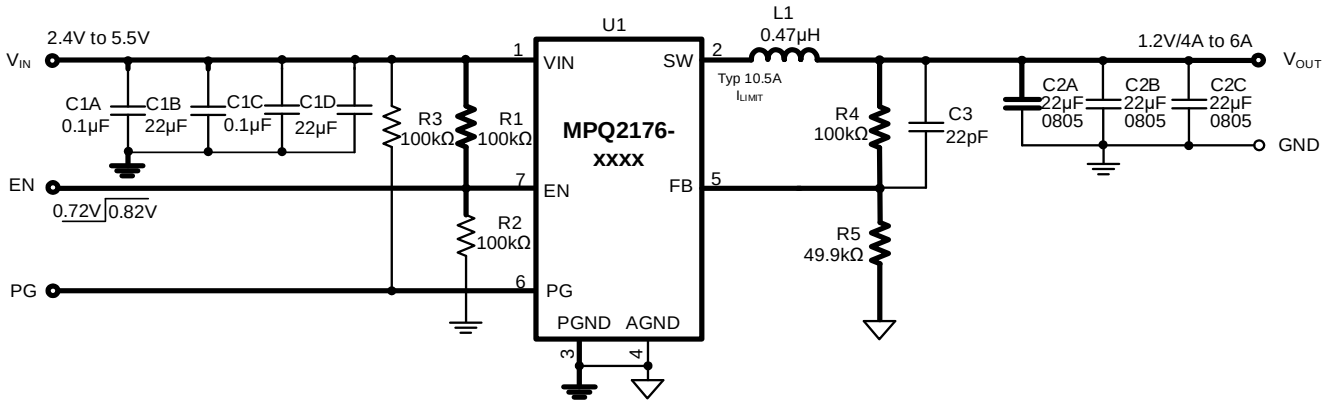

Figure 10: Typical Application Circuit for the MPQ2176-xxxx (V_{OUT} = 1.2V, f_{SW} = 2.2MHz)

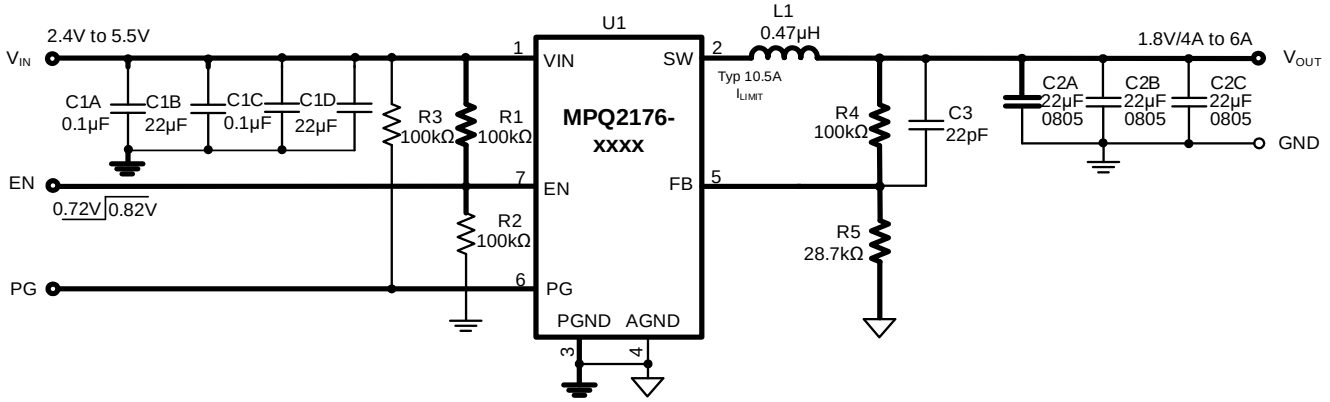

Figure 11: Typical Application Circuit for the MPQ2176-xxxx (V_{OUT} = 1.8V, f_{SW} = 2.2MHz)

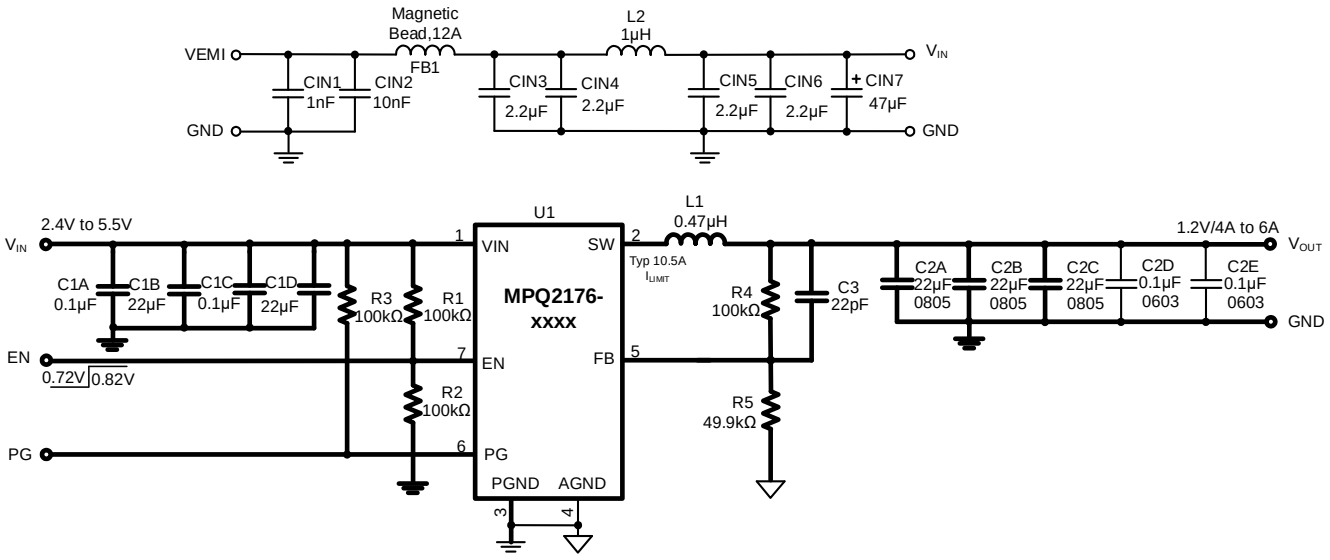

Figure 12: Typical Application Circuit for the MPQ2176-xxxx (V_{OUT} = 1.2V, f_{SW} = 2.2MHz with EMI Filter)

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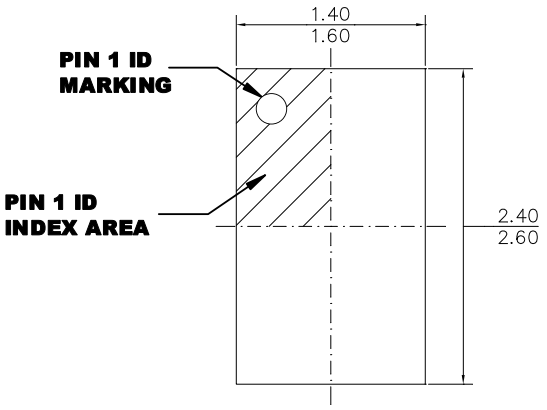
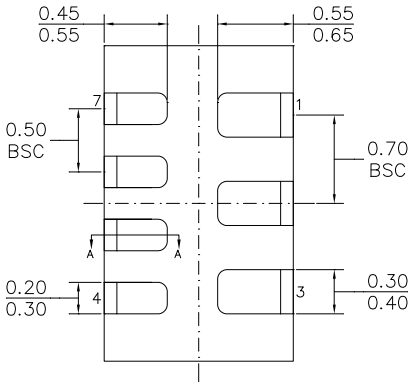
PACKAGE INFORMATION

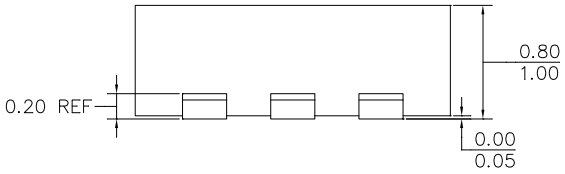
QFN-7 (1.5mmx2.5mm)
Wettable Flank



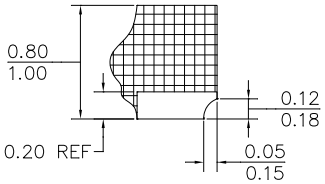
TOP VIEW



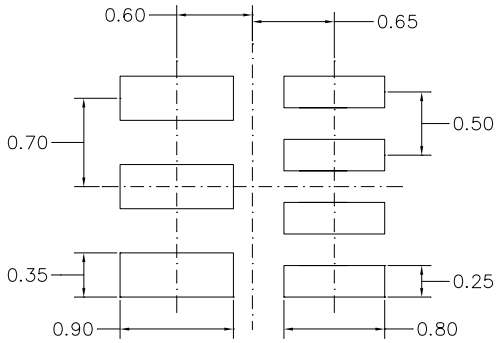
BOTTOM VIEW



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.

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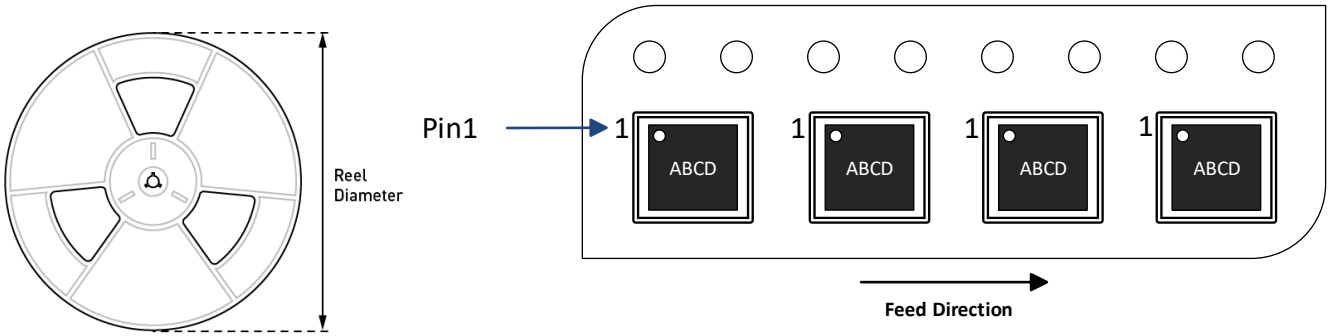
CARRIER INFORMATION



Part Number	Package Description	Quantity/ Reel	Quantity/ Tube	Quantity/ Tray	Reel Diameter	Carrier Tape Width	Carrier Tape Pitch
MPQ2176GRAE-xxxx-AEC1-Z	QFN-7 (1.5mmx2.5mm)	5000	N/A	N/A	13in	8mm	4mm

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REVISION HISTORY

Revision #	Revision Date	Description	Pages Updated
1.0	7/23/2025	Initial Release	-

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