# MPQ4371

## 36V, 6A to 11A, Low-EMI, Synchronous Step-Down Converter with ZDP™, AEC-Q100 Qualified

## DESCRIPTION

The MPQ4371 family of buck converters are configurable-frequency (200kHz to 2.5MHz), synchronous, step-down switching regulators with integrated low on-resistance HS-FETs and LS-FETs. The family covers a 6A to 11A output current ($I_{OUT}$) range and employs zero-delay PWM (ZDP™) control, an MPS-exclusive technology that delivers fast transient response while reducing external capacitor count.

The wide 3.3V to 36V input voltage ($V_{IN}$) range accommodates a variety of step-down applications in automotive input environment. A 1.8µA shutdown mode quiescent current allows use in battery-powered applications. High power conversion efficiency across the wide load range is achieved by scaling down the switching frequency ($f_{SW}$) under light loads to reduce the switching and gate driving losses.

An open-drain power good signal indicates when the output is within 94% to 106% of its nominal voltage. Frequency foldback prevents inductor current runaway during start-up. Thermal shutdown provides reliable, fault-tolerant operation. A high duty cycle and low-dropout mode support automotive cold-crank conditions.

The MPQ4371 is available in QFN-23 (4mmx5mm) or TQFN-23 (4mmx5mm) packages with wettable flanks. It is available in AEC-Q100 Grade 1.

## FEATURES

- Designed for Automotive Transients
  - 3.3V to 36V Input Voltage ($V_{IN}$) Range
  - Load Dump Up to 42V
  - Low-Dropout (LDO) Mode
  - Available in AEC-Q100 Grade 1
- Highly Scalable Family
  - 6A to 11A Output Current ($I_{OUT}$) Versions in Pin-Compatible Family
  - Multi-Phase Capabilities Up to 8 Phases
- Designed for High-Performance and Reduced Component Overhead
  - ZDP™ Control for Fast Transient Response and Fewer Capacitors

## FEATURES *(continued)*

  - ±1% Output Accuracy
  - Fixed or Adjustable $V_{OUT}$ Options
  - Fixed Output [1]: 1V, 1.2V, 1.8V, 2.5V, 3.3V, 3.8V, or 5V
  - Adjustable $V_{OUT}$ Up to 12V
  - Internal Soft Start
  - Output Discharge from SW
  - 30ns Minimum On Time
- High Efficiency for Increased Battery Life and Improved Thermals
  - 1.8µA Shutdown Current, 3.5µA Standby Current
  - AAM Mode Increases Efficiency under Light Loads
  - Integrated Low Resistance High-Side and Low-Side MOSFETs (22mΩ/11mΩ)
- Optimized for Low EMC/EMI
  - 200kHz to 2.5MHz Configurable $f_{SW}$
  - Symmetric VIN Pinout Placement
  - Low Noise at High Frequency Band by Quiet-FET™ Switching Technology
  - FSS Modulation
  - Synchronization to an External Clock
  - CISPR25 Class 5 Compliant
  - Mesh-Connect™ Package
  - Available in QFN-23 (4mmx5mm) or TQFN-23 (4mmx5mm) Packages with Wettable Flanks
- Functional Safety System Design Capability
  - MPSafe™-Compatible: Functional Safety Supporting Document Available

MPSafe™ FuSa Compatible

## APPLICATIONS

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

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**Note:**

1) See the Ordering Information section on page 3 for the exact availability of each fixed output version. Additional output voltages may be available. Contact MPS for details.


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## TYPICAL APPLICATION

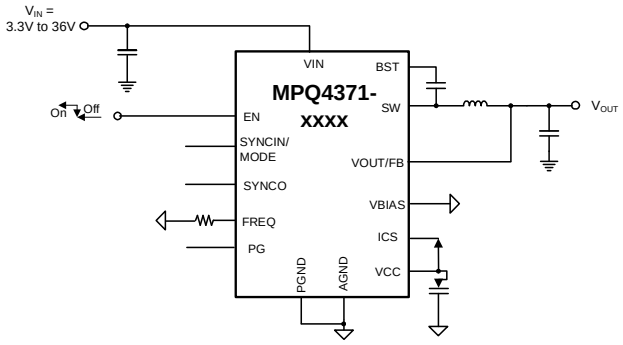



**Figure 1: Fixed Output Version**

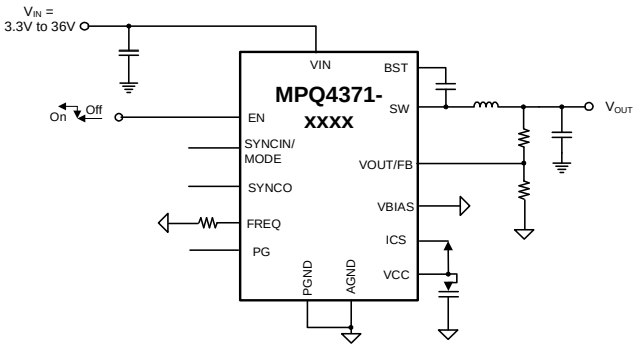
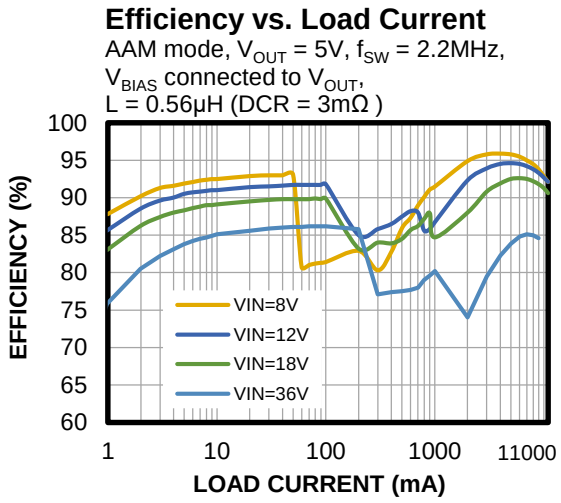
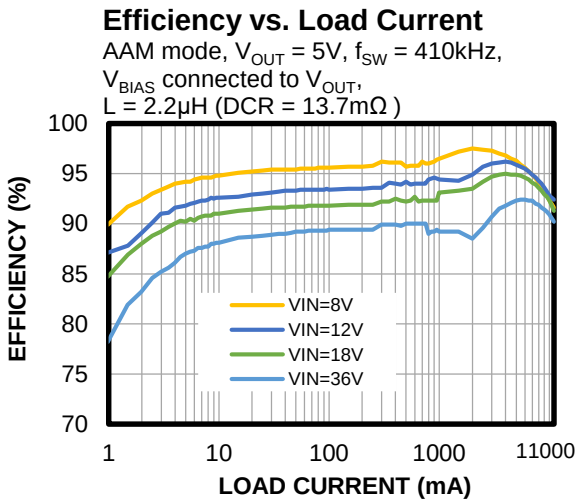



**Figure 2: Adjustable Output Version**





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# ORDERING INFORMATION

| Part Number [2][3]* | Package | Top Marking | MSL Rating** |
|---|---|---|---|
| MPQ4371GVE-xxxx-AEC1*** | QFN-23 (4mmx5mm) | *See Below* | 1 |
| MPQ4371GVTE-xxxx-AEC1*** | TQFN-23 (4mmx5mm) | *See Below* | 1 |

* For Tape & Reel, add suffix -Z (e.g. MPQ4371GVE-xxxx-AEC1-Z).

** Moisture Sensitivity Level Rating

*** Wettable Flank

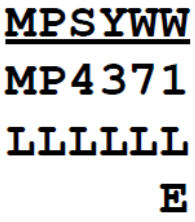
**Notes:**

2) Contact MPS for details regarding fixed-output versions.
3) The detailed information of part number can be marked as MPQ4371-WXYZ. Table 1 shows the meaning of 4-digit code.

**Table 1: Part Number Digit Code Naming Rules**

| Digit Code | Naming Rule |
|---|---|
| W: Defines the nominal load current | 1: 11A |
| | 0: 10A |
| | 8: 8A |
| | 6: 6A |
| X: Defines the output voltage | 0: Adjustable output |
| | 1: Fixed 1V output |
| | A: Fixed 1.2V output |
| | B: Fixed 1.8V output |
| | 2: Fixed 2.5V output |
| | 3: Fixed 3.3V output |
| | 4: Fixed 3.8V output |
| | 5: Fixed 5V output |
| Y: Defines the frequency spread spectrum (FSS) configuration | 0: With FSS |
| | A: Without FSS |
| Z: Defines the multi-phase capability | 0: Single-phase |
| | 1: Multi-phase |

# TOP MARKING




MPS: MPS prefix
Y: Year code
WW: Week code
MP4371: Part number
LLLLLL: Lot number
E: Wettable flank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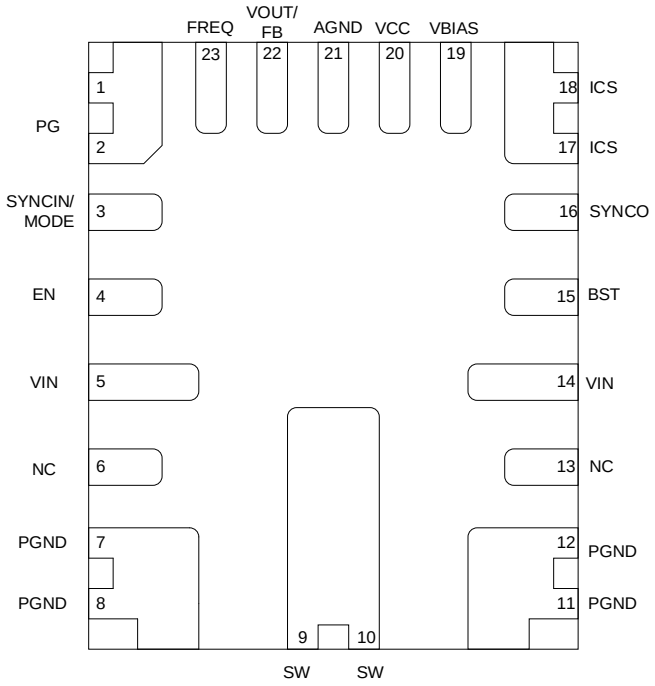
# PACKAGE REFERENCE

**TOP VIEW**




**QFN-23 (4mmx5mm)**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## PIN FUNCTIONS

| Pin # | Name | Description |
|---|---|---|
| 1, 2 | PG | **Power good (PG) output and secondary phase selection.** The output of the PG pin is an open drain.<br>For single-phase applications, PG must be connected to a power source by a pull-up resistor if the PG function is used. PG goes high if the output voltage ($V_{OUT}$) is within 94% to 106% of the nominal voltage; PG goes low if $V_{OUT}$ exceeds 107% or falls below 93% of the nominal voltage. In single-phase applications, float PG when it is not used.<br>For multi-phase applications, if the device is in primary mode, the PG pin's function is the same as it would be for a single-phase application. If the device is in secondary mode, connect a resistor to ground to set the phase shift. Then power good indication is disabled and does not pull high. The PG pin cannot be left floating for secondary devices. See the Power Good (PG) Indication or Phase Shift Setting section on page 70 for more information. |
| 3 | SYNCIN/ MODE | **External sync input and primary mode selection.** Apply a clock signal to this pin to synchronize the internal oscillator frequency to the external clock. If the device is set as a primary device, use an external clock or pull this pin high to enter forced continuous conduction mode (FCCM). Pull this pin low to enable discontinuous conduction mode (DCM) and pulse-skipping at light loads. The pin has a weak internal pull-down resistor, so this pin can be floating to set advanced asynchronous modulation (AAM) mode. When the part is set as a secondary device, connect this pin to the primary device's SYNCO pin. |
| 4 | EN | **Enable.** Pulling this pin below the specified threshold (0.85V) shuts the chip down. Pulling EN above the specified threshold (1V) enables the chip. EN can be directly connected to VIN. Do not float this pin. |
| 5, 14 | VIN | **Input supply.** VIN supplies power to all the internal control circuitry and the power switch connected to SW. A proper decoupling capacitance must be connected between VIN and PGND at each side of the IC to minimize switching spikes. |
| 6, 13 | NC | **No connection.** The NC pin does not have an internal connection to the die. It can be left floating. |
| 7, 8, 11, 12 | PGND | **Power ground.** Connect the PGND pin to a large GND plane to ensure excellent heat dissipation. |
| 9, 10 | SW | **Switch node.** The SW pin is connected to the high-side MOSFET's source and the low-side MOSFET's drain. Connect the power inductor to this pin with a wide trace and limit its area to avoid EMI radiation. |
| 15 | BST | **Bootstrap.** The BST pin is the positive power supply for the high-side MOSFET driver connected to SW. Connect a bypass capacitor between BST and SW. |
| 16 | SYNCO | **Sync output and mode select for secondary.** When SYNCO is at high impedance, the device operates in primary operation mode, this pin outputs a clock signal in phase with the internal oscillator signal or external clock at the SYNCIN/MODE pin. In single-phase operation, this pin must be floating.<br>In multi-phase applications, if this pin is tied to a low-impedance ground, voltage source, or clock, the device operates as a secondary device. When working as a secondary device, this pin selects the light-load operating mode (high for FCCM; low for AAM mode). In multi-phase applications, connect the SYNCO pin of all secondary devices together with the primary device's SYNC/MODE pin. |
| 17, 18 | ICS | **Current-sharing pin.** In a single-phase applications, connect ICS to the VCC pin. In a multi-phase application, connect the ICS pins from all the parts together in order to improve the current sharing between the different phases. |


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## PIN FUNCTIONS *(continued)*

| Pin # | Name | Description |
|---|---|---|
| 19 | VBIAS | **Internal LDO supply.** VBIAS is the power supply for the VCC regulator.<br>The VCC regulator uses VBIAS as a power supply if the BIAS pin's voltage ($V_{BIAS}$) is between 4.5V and 5.5V. This pin can be connected directly to the output voltage when $V_{OUT}$ is between 4.6V to 5.5V to improve the converter's efficiency, especially at high frequencies. Alternatively, connect this pin to another 5V rail if it is available in the system, and the current draw is <30mA. Add one decoupling capacitor between the VBIAS pin and GND if this function is used.<br>When there is no suitable power source for VBIAS, or the function is not used, connect this pin to the output voltage or GND.<br>If $V_{OUT}$ > 5.5V, avoid connecting the VBIAS pin to the output. Avoid providing an external VBIAS voltage before VIN. Do not float this pin. |
| 20 | VCC | **Internal LDO output.** VCC supplies 5V of power to the internal control circuit and gate drivers. A decoupling capacitor must be connected from VCC to AGND, and placed close to this pin. |
| 21 | AGND | **Analog ground.** Connect the AGND pin to the DC/DC GND and close to the VCC capacitor. |
| 22 | VOUT/FB | **$V_{OUT}$ regulation input / feedback divider.** For the fixed-output version, connect this pin to the output voltage directly to regulate $V_{OUT}$.<br>For the adjustable-output version, set $V_{OUT}$ by connecting FB to the center point between the external resistor divider from the output and AGND. The feedback voltage is 0.6V. Place the resistor divider as close to FB as possible. Avoid placing many vias on the FB traces. |
| 23 | FREQ | **Switching frequency configurations.** Connect a resistor from the FREQ pin to ground to set the switching frequency ($f_{SW}$). |


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## ABSOLUTE MAXIMUM RATINGS (4)

VIN, EN .....-0.3V to +42V
SW ..... -0.3V to $V_{IN(MAX)}$ + 0.3V
BST ..... $V_{SW}$ + 5.5V
VBIAS.....-0.3V to +6V
All other pins .....-0.3V to +6V
Continuous power dissipation ($T_A$ = 25°C) (5) (9)
QFN-23 (4mmx5mm) ..... 5.48 W
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 (6)
Charged-device model (CDM) ..... Class C2b (7)

### *Recommended Operating Conditions*

Input voltage ($V_{IN}$) .....3.3V to 36V
$V_{BIAS}$.....4.5V to 5.5V
Output voltage ($V_{OUT}$).....0.6V to 12V
Operating junction temp ($T_J$).... -40°C to +150°C

### *Thermal Resistance* $\theta_{JA}$ $\theta_{JC}$

QFN-23 (4mmx5mm)
JESD51-7.....41.2.....3.9....°C/W (8)
EVQ4371-V-00A.....22.8.....°C/W (9)

$\Psi_{JT}$

JESD51-7..... 0.5.....°C/W (8)
EVQ4371-V-00A.....1.14....°C/W (9)
TQFN-23 (4mmx5mm)
JESD51-7.....41.2.....3.9....°C/W (8)

$\Psi_{JT}$

JESD51-7..... 0.4.....°C/W (8)

**Notes:**

4) Exceeding these ratings may damage the device.
5) The maximum allowable power dissipation is a function of the maximum junction temperature, $T_J$ (MAX), the junction-to-ambient thermal resistance, $\theta_{JA}$, 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) - $T_A$) / $\theta_{JA}$. 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.
6) Per AECQ100-002.
7) Per AECQ100-011.
8) Measured 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 $\theta_{Jc}$ shows the thermal resistance from junction-to-case bottom. The value of $\Psi_{JT}$ shows the characterization parameter from junction-to-case top.
9) Measured on an MPS standard EVB: 8.3cmx8.3cm, 2oz. copper thickness, 4-layer PCB. The value of $\Psi_{JT}$ shows the characterization parameter from junction-to-case top.


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## 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 | $VIN_{UV_RISING}$ | | 3.6 | 3.8 | 4.1 | V |
| $V_{IN}$ UVLO falling threshold | $VIN_{UV_FALLING}$ | | 2.7 | 2.9 | 3.1 | V |
| $V_{IN}$ UVLO hysteresis | $VIN_{UV_HYS}$ | | | 0.9 | | V |
| VIN quiescent current (10) | $I_Q$ | FB = 0.63V, no load, SYNCIN/MODE = GND (AAM mode), non-switching, $T_J$ = -40 to +85°C | | 3.5 | 8.6 | µA |
| | | FB = 0.63V, no load, SYNCIN/MODE = GND (AAM mode), non-switching, $T_J$ = -40 to +125°C | | | 15 | µA |
| VIN quiescent current (switching) (10) | $I_{Q_SLEEP}$ | SYNCIN/MODE = GND (AAM mode), switching, $V_{BIAS}$ = 5V, no load, $T_J$ = -40 to +85°C | | 4.5 | 9 | µA |
| | | SYNCIN/MODE = GND (AAM mode), switching, $V_{BIAS}$ = 5V, no load, $T_J$ = -40 to +125°C | | | 16.5 | µA |
| VIN active current (non-switching) | $I_{Q_ACTIVE}$ | FB = 0.63V, no load, SYNCIN/MODE = VCC (CCM), non-switching | | 1300 | 2300 | µA |
| VIN shutdown current | $I_{SHDN}$ | EN = 0V, $T_J$ = -40°C to +85°C | | 1.8 | 4 | µA |
| | | EN = 0V | | | 22.5 | µA |
| $V_{IN}$ over-voltage protection (OVP) threshold | $V_{INOVP_RISING}$ | | 36 | 38 | 40 | V |
| $V_{IN}$ OVP hysteresis | $V_{INOVP_HYS}$ | | | 1 | | V |
| **VCC and VBIAS** | | | | | | |
| VCC voltage | $V_{CC}$ | $I_{VCC}$ = 0mA, VCC from VIN | 4.8 | 5.0 | 5.2 | V |
| | | $I_{VCC}$ = 30mA, $V_{BIAS}$ = 5V | | 4.95 | | V |
| VCC regulation | | $I_{VCC}$ = 30mA | | 1 | | % |
| VCC current limit | $I_{LIMIT_VCC}$ | $V_{CC}$ = 4V | 89 | 120 | 167 | mA |
| | | $V_{CC}$ = 0V | 40 | 70 | 120 | mA |
| VBIAS take-over rising threshold | $V_{BIAS-RISING}$ | | | 4.5 | | V |
| VBIAS take-over hysteresis | | | | 200 | | mV |
| **Soft Start** | | | | | | |
| Soft-start time | $t_{SS}$ | EN high to PG high | 4 | 5 | 6 | ms |


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## 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 |
|---|---|---|---|---|---|---|
| **EN Function** | | | | | | |
| EN rising threshold | $V_{EN_RISING}$ | | 0.8 | 1 | 1.2 | V |
| EN falling threshold | $V_{EN_FALLING}$ | | 0.65 | 0.85 | 1.05 | V |
| EN hysteresis voltage | $V_{EN_HYS}$ | | | 150 | | mV |
| **Output and Regulation** | | | | | | |
| FB voltage (adjustable output version) | $V_{FB}$ | | 594 | 600 | 606 | mV |
| $V_{OUT}$ regulation voltage (fixed output version) | $V_{OUT_REG}$ | $V_{IN}$ = 3.3V to 36V | -1 | | +1 | % |
| FB leakage in fixed output version | $I_{VOUT}$ | $V_{OUT}$ = $V_{VOUT_REG}$ | | 2.3 | | µA |
| FB leakage in adjustable output version | | FB = 0.63V | | 1 | 100 | nA |
| $V_{OUT}$ Discharge from SW | $I_{DISCHARGE}$ | EN = 0V, $V_{OUT}$ = 0.3V, $V_{IN}$ = 3.3 to 36V | 2 | | | mA |
| **Switches and Frequency** | | | | | | |
| Minimum on time(10) | $t_{ON_MIN}$ | | 12 | 30 | 35 | ns |
| Minimum off time(10) | $t_{OFF_MIN}$ | | | 100 | 125 | ns |
| Minimum off time in low-dropout mode (10) | $t_{OFF_MIN_DROPOUT}$ | | | 50 | 60 | ns |
| Switch leakage current | $I_{SW_LKG}$ | | | 0.01 | 9 | µA |
| High-side MOSFET (HS-FET) on resistance | $R_{ON_HS}$ | $V_{BST}$-$V_{SW}$ = 5V | | 22 | 42 | mΩ |
| Low-side MOSFET (LS-FET) on resistance | $R_{ON_LS}$ | $V_{CC}$ = 5V | | 11 | 22 | mΩ |
| Switching frequency | $f_{SW}$ | $R_{FREQ}$ = 88.7kΩ | 370 | 410 | 450 | kHz |
| | | $R_{FREQ}$ = 33kΩ | 900 | 1000 | 1100 | kHz |
| | | $R_{FREQ}$ = 15kΩ | 1980 | 2200 | 2420 | kHz |
| **SYNCIN and SYNCO** | | | | | | |
| SYNCIN voltage rising threshold | $V_{SYNC_RISING}$ | | | | 1.4 | V |
| SYNCIN voltage falling threshold | $V_{SYNC_FALLING}$ | | 0.4 | | | V |
| SYNCIN timeout | $t_{MODE}$ | SYNCIN/MODE low to DCM | 30 | | 65 | µs |
| SYNCIN clock range | $f_{SYNC}$ | % of free-running frequency ($f_{SW}$) | 90 | | 110 | % |
| SYNCO high voltage | $V_{SYNCO_HIGH}$ | $I_{SYNCO}$ = -1mA | 3.3 | 4.5 | | V |
| SYNCO low voltage | $V_{SYNCO_LOW}$ | $I_{SYNCO}$ = 1mA | | | 0.4 | V |
| **BST** | | | | | | |
| BST-SW refresh rising threshold | $V_{UVBST-SW-RISING}$ | | | 2.5 | | V |
| BST-SW refresh falling threshold | $V_{UVBST-SW-FALLING}$ | | | 2.3 | | V |
| BST-SW refresh hysteresis | $V_{UVBST-SW_HYS}$ | | 0.19 | | | V |


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## 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 |
|---|---|---|---|---|---|---|
| **ICS** | | | | | | |
| Current-sharing gain | $G_{CS}$ | | | 30 | | mV/A |
| **PG Function** | | | | | | |
| PG rising threshold | $V_{PGVTH_RISING}$ | $V_{OUT}$ rising | 91% | 94% | 97% | $V_{OUT}$ |
| | | $V_{OUT}$ falling | 103% | 106% | 109% | |
| PG falling threshold | $V_{PGVTH_FALLING}$ | $V_{OUT}$ falling | 90% | 93% | 96% | |
| | | $V_{OUT}$ rising | 104% | 107% | 110% | |
| PG trip threshold hysteresis | $V_{PGVTH_HYS}$ | | | 1 | | |
| PG output voltage low | $V_{PG_LOW}$ | $I_{SINK}$ = 1mA | | 10 | 100 | mV |
| PG rising deglitch | $t_{PG_R_DELAY}$ | | | 120 | | µs |
| PG falling deglitch | $t_{PG_F_DELAY}$ | | | 100 | | µs |
| **Protections** | | | | | | |
| HS current limit (11) | $I_{LIMIT_HS}$ | Duty cycle = 30%, for MPQ4371-1XYZ | 16.6 | 19 | 22 | A |
| | | Duty cycle = 30%, for MPQ4371-0XYZ | 15.2 | 17.2 | 19 | |
| | | Duty cycle = 30%, for MPQ4371-8XYZ | 12.6 | 13.8 | 15 | |
| | | Duty cycle = 30%, for MPQ4371-6XYZ | 8.6 | 10.3 | 12 | |
| LS valley current limit (11) | $I_{LIMIT_LS}$ | Duty cycle = 30%, for MPQ4371-1XYZ | 11.2 | 13.2 | | A |
| | | Duty cycle = 30%, for MPQ4371-0XYZ | 10.2 | 13 | 15.2 | |
| | | Duty cycle = 30%, for MPQ4371-8XYZ | 8.2 | 9.6 | | |
| | | Duty cycle = 30%, for MPQ4371-6XYZ | 6.2 | 7.2 | | |
| Zero-current detection (ZCD) current | $I_{ZCD}$ | AAM mode | 0 | 100 | 300 | mA |
| LS reverse current limit | $I_{LIMIT_REVERSE}$ | FCCM | -5.2 | -4 | -2.8 | A |
| Thermal shutdown (10) | $T_{SD}$ | | 150 | 180 | | °C |
| Thermal shutdown hysteresis (10) | $T_{SD_HYS}$ | | | 30 | | °C |

**Notes:**

10) Derived from bench characterization, not tested in production.
11) Cannot test in production for the MPQ4371-1XYZ/8XYZ/6XYZ. Guaranteed by design and bench test characterization.


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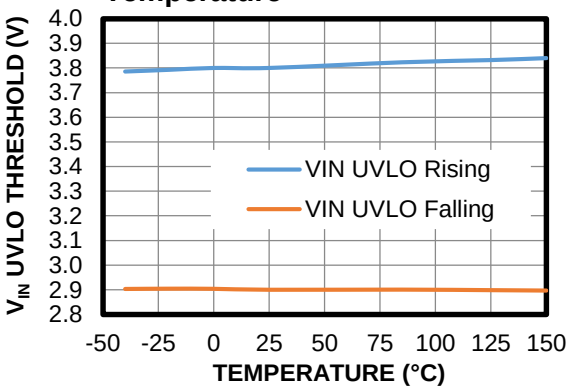
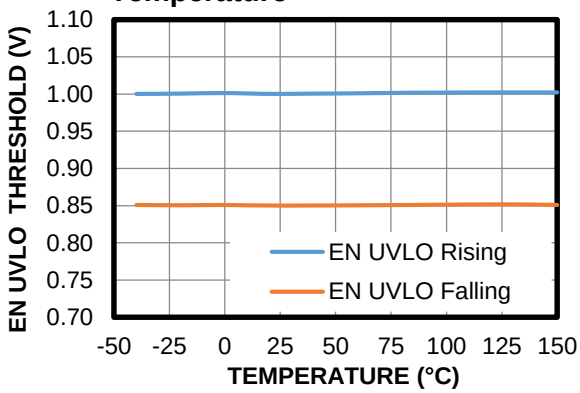
# TYPICAL CHARACTERISTICS

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, $T_J$ = -40°C to +150°C, unless otherwise noted.**

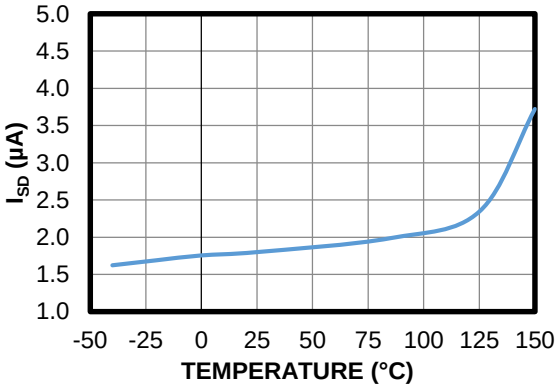
### $V_{IN}$ UVLO Threshold vs. Temperature



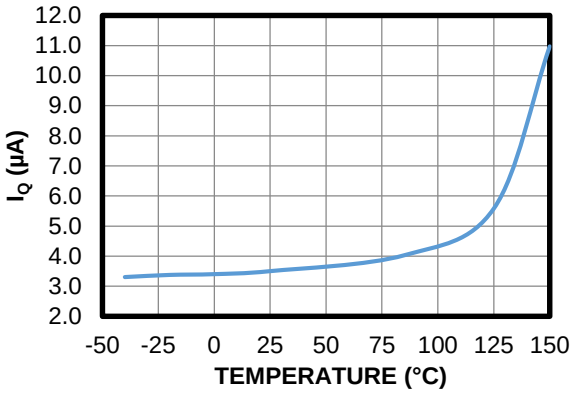

### EN UVLO Threshold vs. Temperature



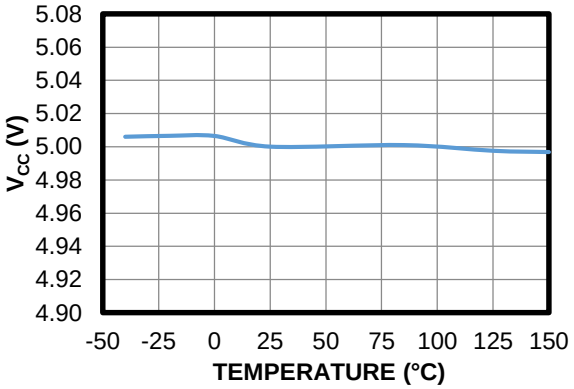

### VIN Shutdown Current vs. Temperature



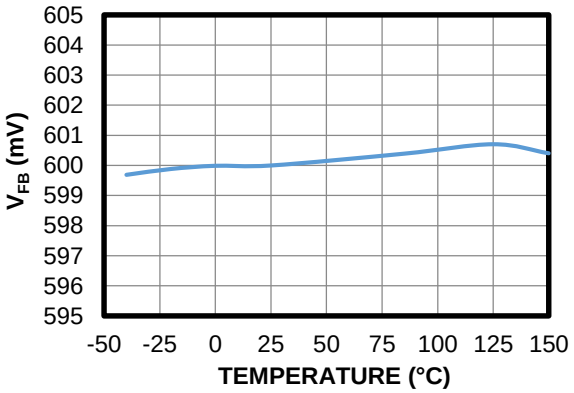

### Quiescent Current vs. Temperature




### $V_{CC}$ vs. Temperature




### $V_{FB}$ vs. Temperature





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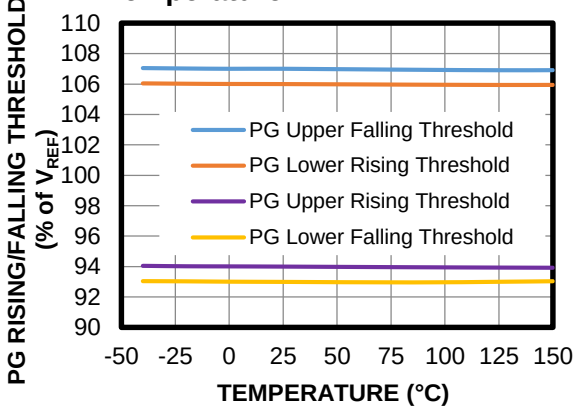
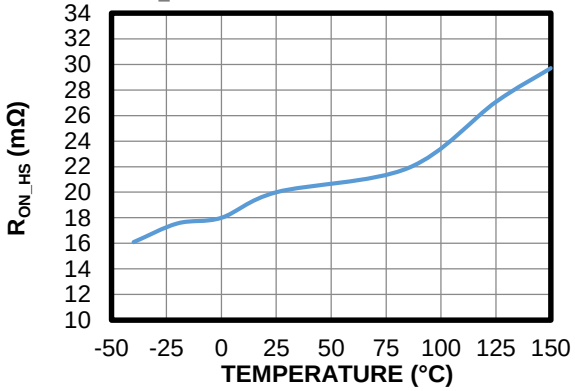
## TYPICAL CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, $T_J$ = -40°C to +150°C, unless otherwise noted.**

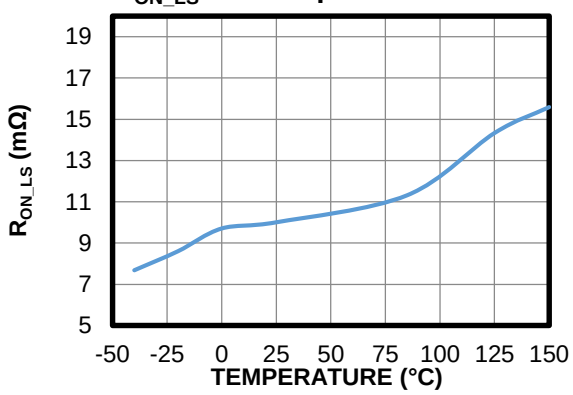
PG Rising/Falling Threshold vs. Temperature



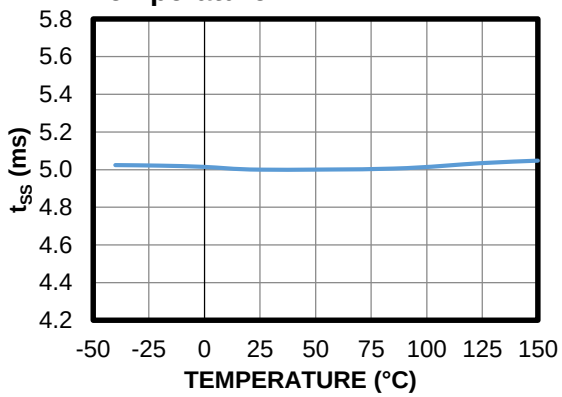

$R_{ON_HS}$ vs. Temperature



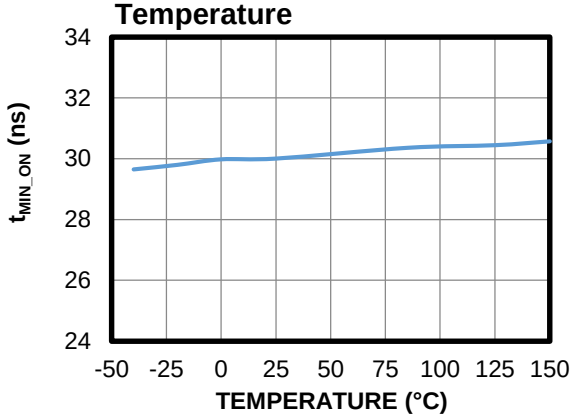

$R_{ON_LS}$ vs. Temperature



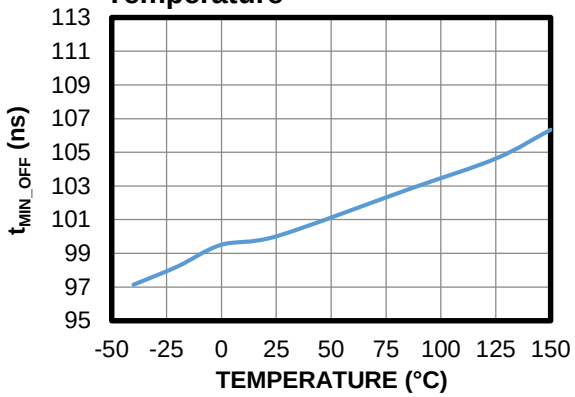

Soft-Start Time vs. Temperature




HS Minimum Time vs. Temperature




HS Minimum Off Time vs. Temperature





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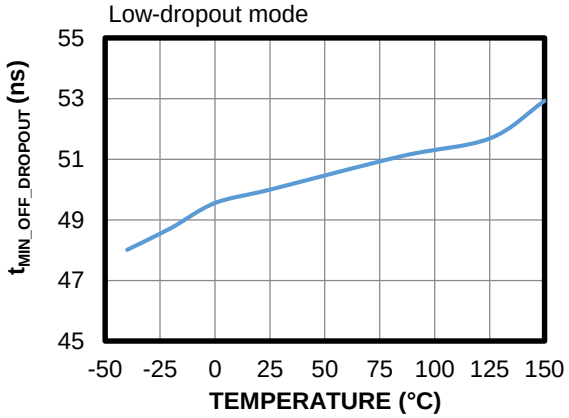
## TYPICAL CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, $T_J$ = -40°C to +150°C, unless otherwise noted.**

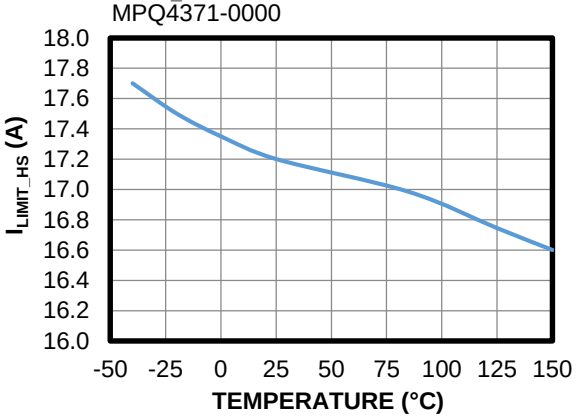
**HS Minimum Off Time vs. Temperature**

Low-dropout mode



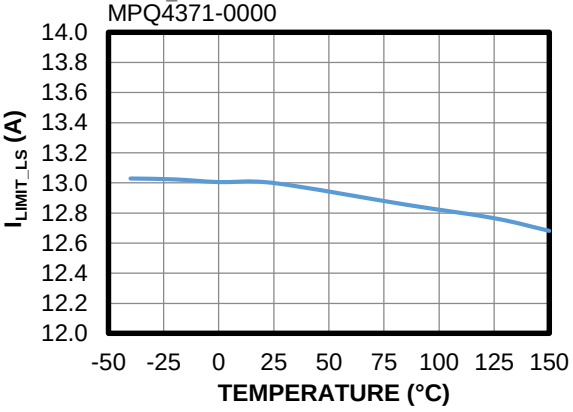

**$I_{LIMIT_HS}$ vs. Temperature**

MPQ4371-0000

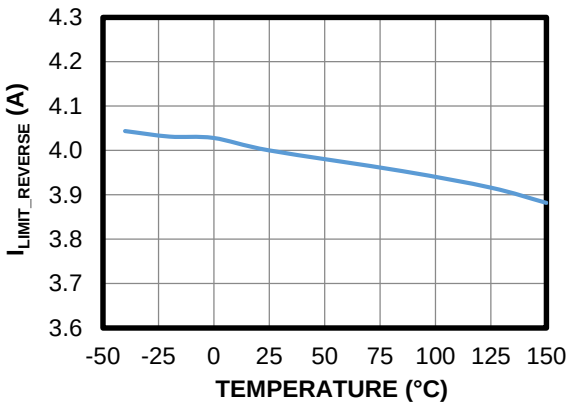



**$I_{LIMIT_LS}$ vs. Temperature**

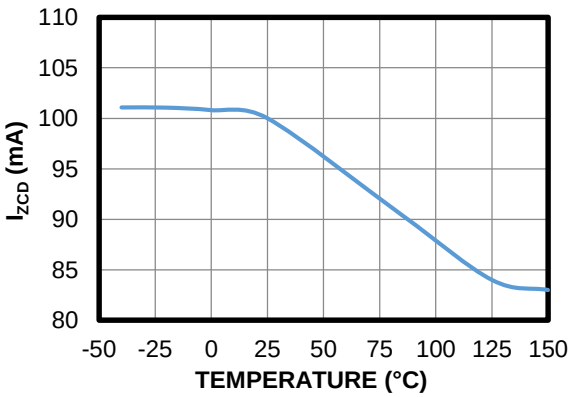
MPQ4371-0000




**$I_{LIMIT_REVERSE}$ vs. Temperature**

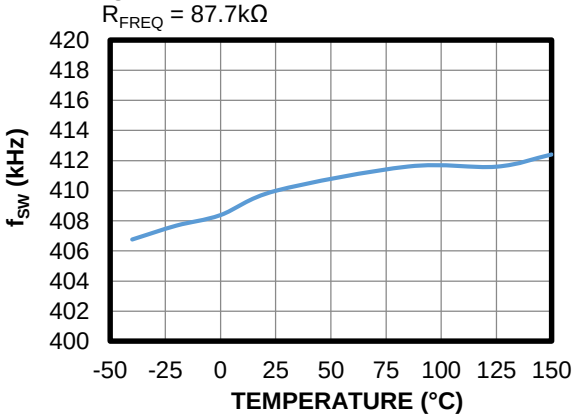



**$I_{ZCD}$ vs. Temperature**




**$f_{SW}$ vs. Temperature**

$R_{FREQ}$ = 87.7kΩ





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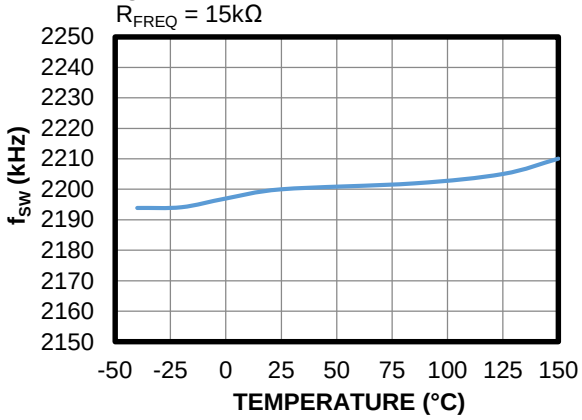
## TYPICAL CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, $T_J$ = -40°C to +150°C, unless otherwise noted.**

**$f_{SW}$ vs. Temperature**

$R_{FREQ}$ = 15kΩ





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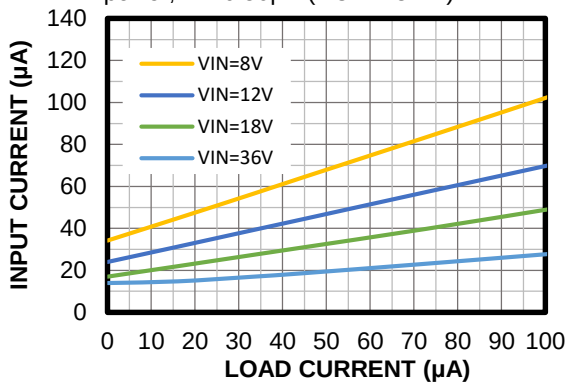
## TYPICAL PERFORMANCE CHARACTERISTICS

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, $f_{SW}$ = 2.2MHz, L = 0.56µH (DCR = 3mΩ), $T_A$ = 25°C, unless otherwise noted.**

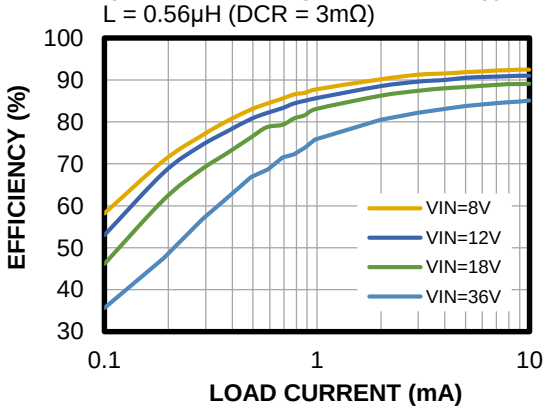
### Input Current vs. Load Current

AAM mode, $V_{OUT}$ = 5V,
$f_{SW}$ = 2.2MHz, $V_{BIAS}$ connected to 5V
power, L = 0.56µH (DCR = 3mΩ)



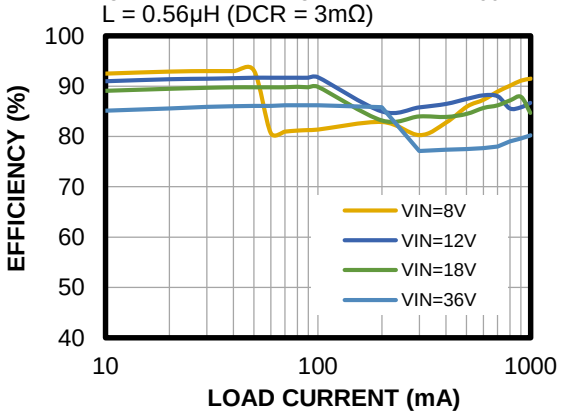

### Efficiency vs. Load Current

AAM mode, $V_{OUT}$ = 5V,
$f_{SW}$ = 2.2MHz, $V_{BIAS}$ connected to $V_{OUT}$,
L = 0.56µH (DCR = 3mΩ)



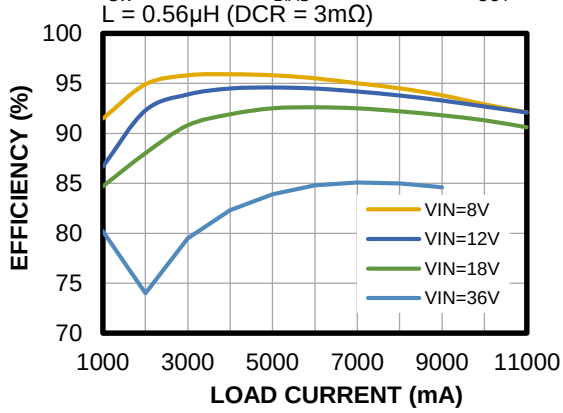

### Efficiency vs. Load Current

AAM mode, $V_{OUT}$ = 5V,
$f_{SW}$ = 2.2MHz, $V_{BIAS}$ connected to $V_{OUT}$,
L = 0.56µH (DCR = 3mΩ)



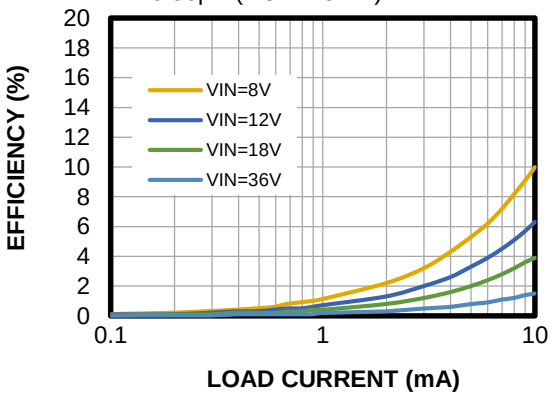

### Efficiency vs. Load Current

AAM mode, $V_{OUT}$ = 5V,
$f_{SW}$ = 2.2MHz, $V_{BIAS}$ connected to $V_{OUT}$,
L = 0.56µH (DCR = 3mΩ)



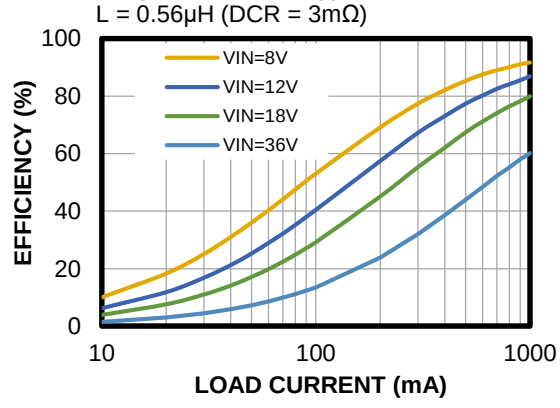

### Efficiency vs. Load Current

FCCM, $V_{OUT}$ = 5V, $f_{SW}$ = 2.2MHz,
$V_{BIAS}$ connected to $V_{OUT}$,
L = 0.56µH (DCR = 3mΩ)




### Efficiency vs. Load Current

FCCM, $V_{OUT}$ = 5V, $f_{SW}$ = 2.2MHz,
$V_{BIAS}$ connected to $V_{OUT}$,
L = 0.56µH (DCR = 3mΩ)





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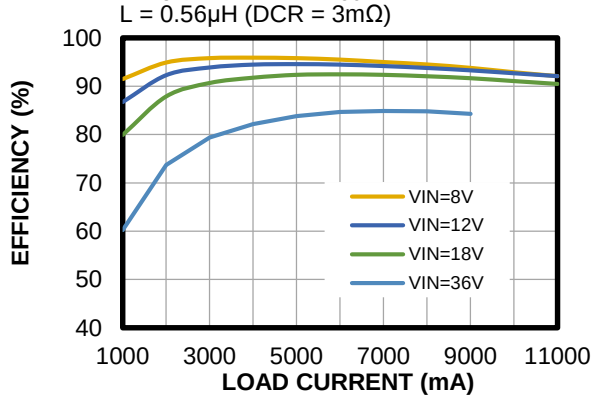
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, $f_{SW}$ = 2.2MHz, L = 0.56µH (DCR = 3mΩ), $T_A$ = 25°C, unless otherwise noted.**

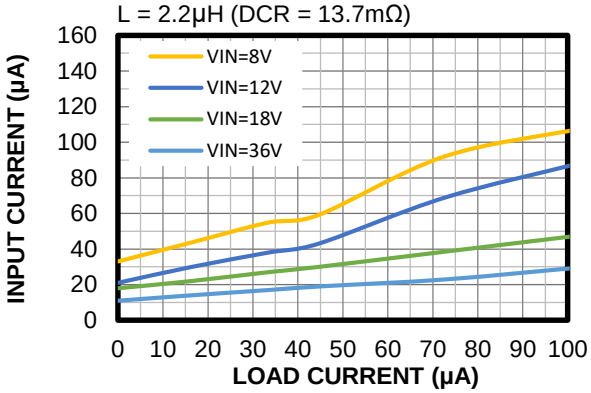
### Efficiency vs. Load Current

FCCM, $V_{OUT}$ = 5V, $f_{SW}$ = 2.2MHz,
$V_{BIAS}$ connected to $V_{OUT}$,
L = 0.56µH (DCR = 3mΩ)



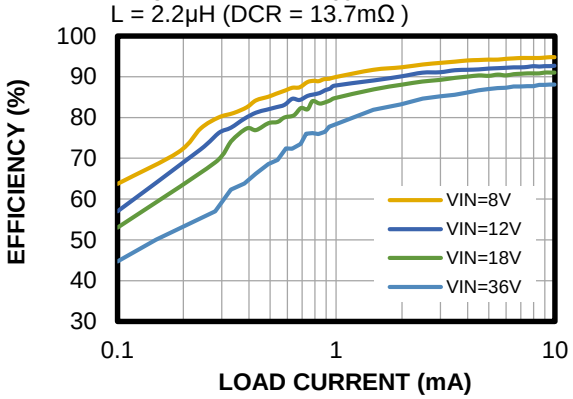

### Input Current vs. Load Current

AAM mode, $V_{OUT}$ = 5V, $f_{SW}$ = 410kHz,
$V_{BIAS}$ connected to $V_{OUT}$,
L = 2.2µH (DCR = 13.7mΩ)



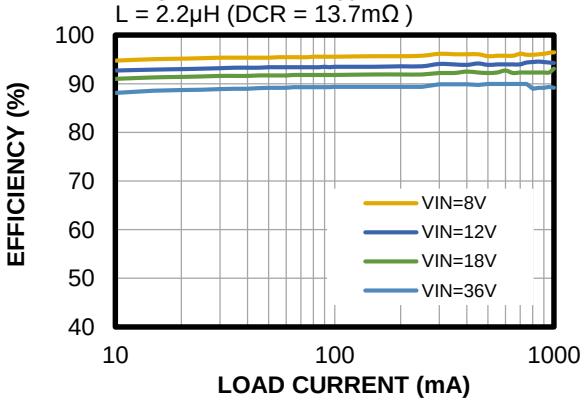

### Efficiency vs. Load Current

AAM mode, $V_{OUT}$ = 5V, $f_{SW}$ = 410kHz,
$V_{BIAS}$ connected to $V_{OUT}$,
L = 2.2µH (DCR = 13.7mΩ )



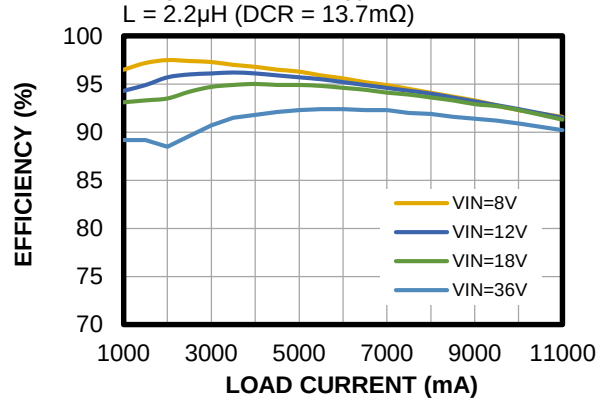

### Efficiency vs. Load Current

AAM mode, $V_{OUT}$ = 5V, $f_{SW}$ = 410kHz,
$V_{BIAS}$ connected to $V_{OUT}$,
L = 2.2µH (DCR = 13.7mΩ )



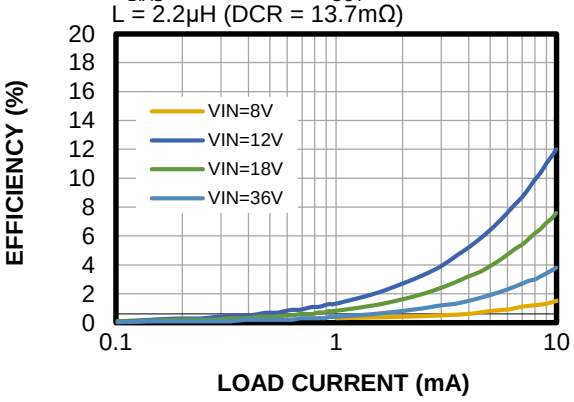

### Efficiency vs. Load Current

AAM mode, $V_{OUT}$ = 5V, $f_{SW}$ = 410kHz,
$V_{BIAS}$ connected to $V_{OUT}$,
L = 2.2µH (DCR = 13.7mΩ)




### Efficiency vs. Load Current

FCCM, $V_{OUT}$ = 5V, $f_{SW}$ = 410kHz,
$V_{BIAS}$ connected to $V_{OUT}$,
L = 2.2µH (DCR = 13.7mΩ)





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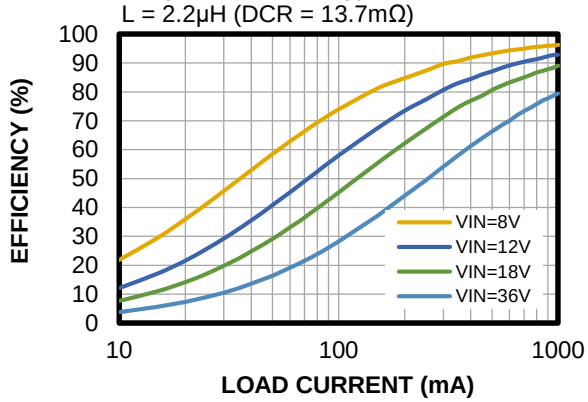
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, $f_{SW}$ = 2.2MHz, L = 0.56µH (DCR = 3mΩ), $T_A$ = 25°C, unless otherwise noted.**

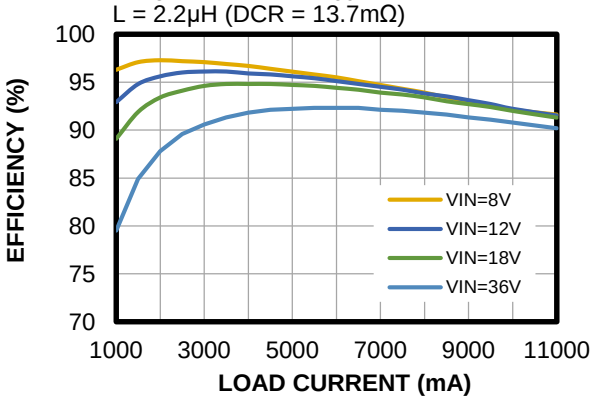
### Efficiency vs. Load Current

FCCM, $V_{OUT}$ = 5V, $f_{SW}$ = 410kHz, $V_{BIAS}$ connected to $V_{OUT}$, L = 2.2µH (DCR = 13.7mΩ)



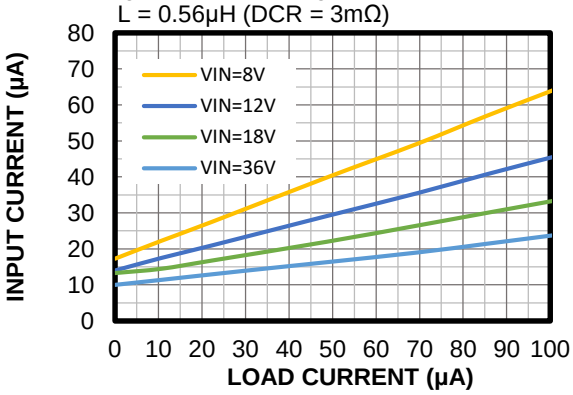

### Efficiency vs. Load Current

FCCM, $V_{OUT}$ = 5V, $f_{SW}$ = 410kHz, $V_{BIAS}$ connected to $V_{OUT}$, L = 2.2µH (DCR = 13.7mΩ)



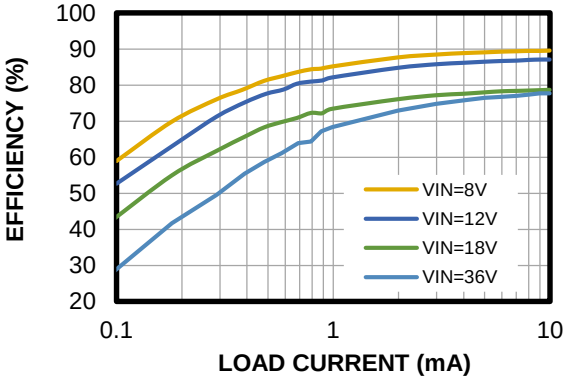

### Input Current vs. Load Current

AAM mode, $V_{OUT}$ = 3.3V, $f_{SW}$ = 2.2MHz, $V_{BIAS}$ connected to GND, L = 0.56µH (DCR = 3mΩ)



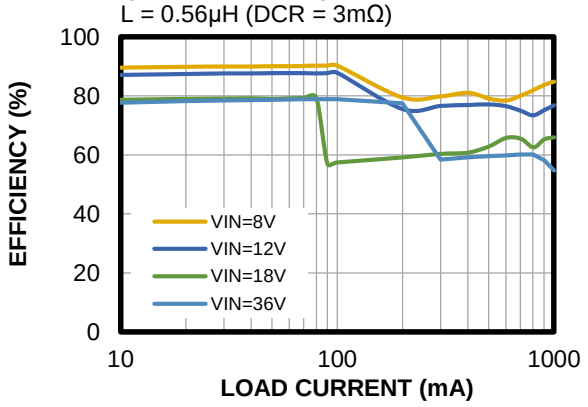

### Efficiency vs. Load Current

AAM mode, $V_{OUT}$ = 3.3V, $f_{SW}$ = 2.2MHz, $V_{BIAS}$ connected to GND, L = 0.56µH (DCR = 3mΩ)



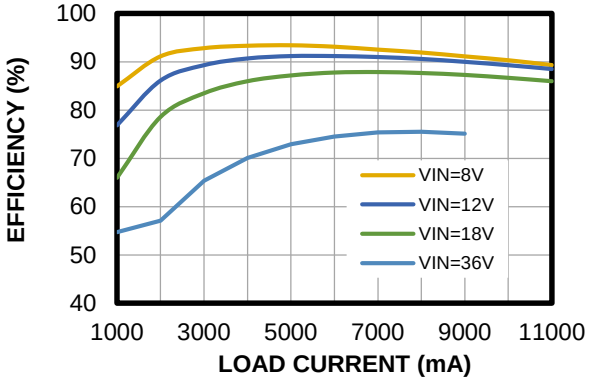

### Efficiency vs. Load Current

AAM mode, $V_{OUT}$ = 3.3V, $f_{SW}$ = 2.2MHz, $V_{BIAS}$ connected to GND, L = 0.56µH (DCR = 3mΩ)




### Efficiency vs. Load Current

AAM mode, $V_{OUT}$ = 3.3V, $f_{SW}$ = 2.2MHz, $V_{BIAS}$ connected to GND, L = 0.56µH (DCR = 3mΩ )





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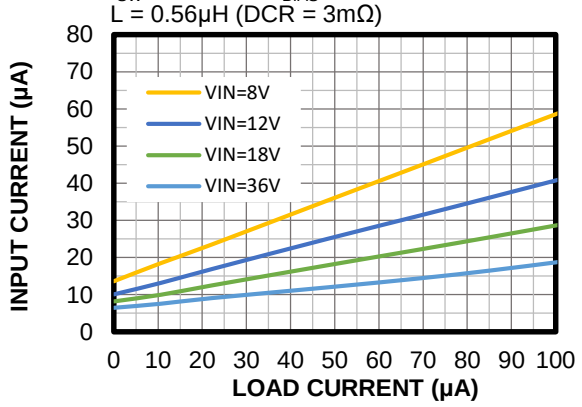
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, $f_{SW}$ = 2.2MHz, L = 0.56µH (DCR = 3mΩ), $T_A$ = 25°C, unless otherwise noted.**

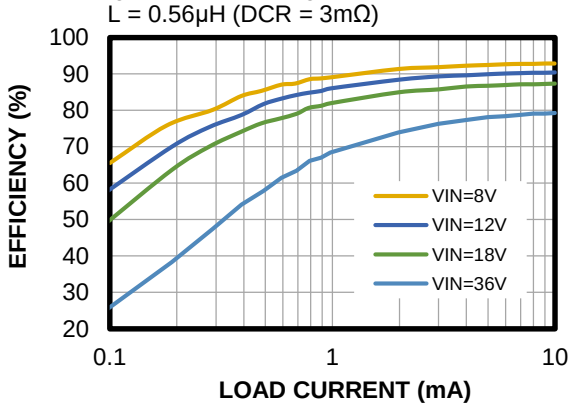
### Input Current vs. Load Current

AAM mode, $V_{OUT}$ = 3.3V,
$f_{SW}$ = 2.2MHz, $V_{BIAS}$ connected to 5V power,
L = 0.56µH (DCR = 3mΩ)



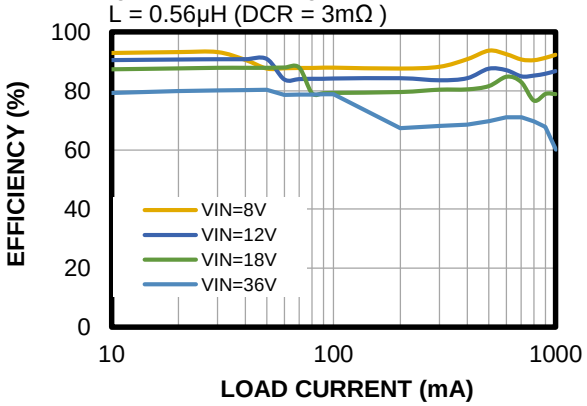

### Efficiency vs. Load Current

AAM mode, $V_{OUT}$ = 3.3V,
$f_{SW}$ = 2.2MHz, $V_{BIAS}$ connected to 5V power,
L = 0.56µH (DCR = 3mΩ)



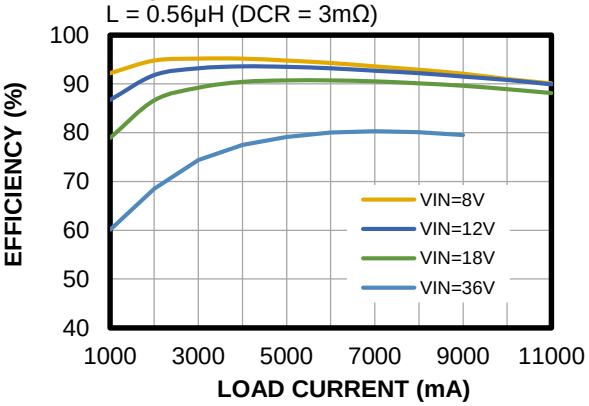

### Efficiency vs. Load Current

AAM mode, $V_{OUT}$ = 3.3V,
$f_{SW}$ = 2.2MHz, $V_{BIAS}$ connected to 5V power,
L = 0.56µH (DCR = 3mΩ )



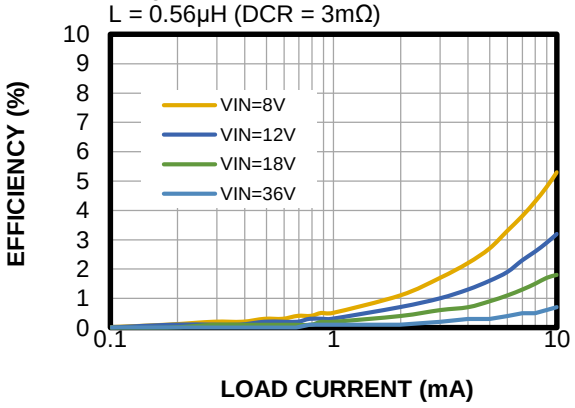

### Efficiency vs. Load Current

AAM mode, $V_{OUT}$ = 3.3V, $f_{SW}$ = 2.2MHz,
$V_{BIAS}$ connected to 5V power,
L = 0.56µH (DCR = 3mΩ)



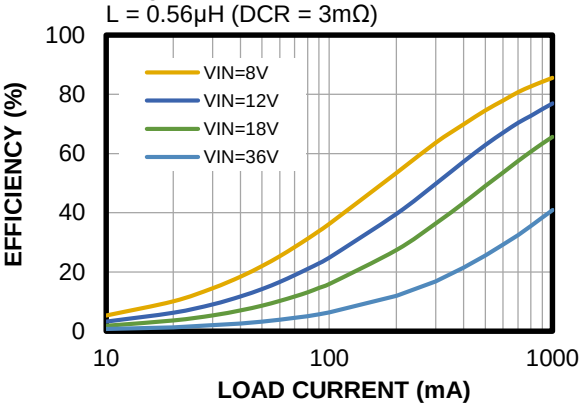

### Efficiency vs. Load Current

FCCM, $V_{OUT}$ = 3.3V, $f_{SW}$ = 2.2MHz,
$V_{BIAS}$ connected to GND,
L = 0.56µH (DCR = 3mΩ)




### Efficiency vs. Load Current

FCCM, $V_{OUT}$ = 3.3V, $f_{SW}$ = 2.2MHz,
$V_{BIAS}$ connected to GND,
L = 0.56µH (DCR = 3mΩ)





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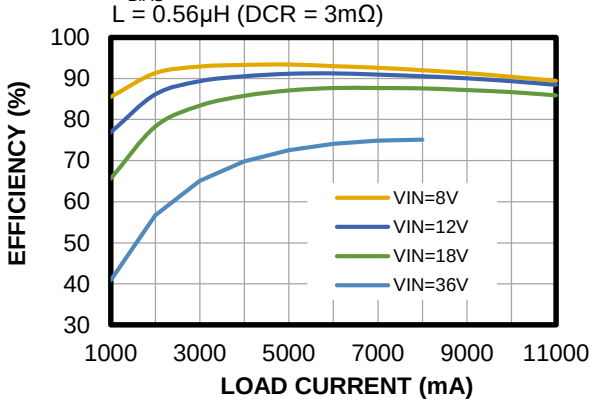
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, $f_{SW}$ = 2.2MHz, L = 0.56µH (DCR = 3mΩ), $T_A$ = 25°C, unless otherwise noted.**

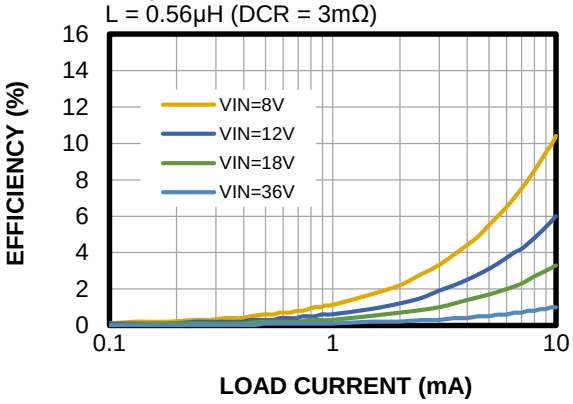
**Efficiency vs. Load Current**

FCCM, $V_{OUT}$ = 3.3V, $f_{SW}$ = 2.2MHz,
$V_{BIAS}$ connected to GND,
L = 0.56µH (DCR = 3mΩ)



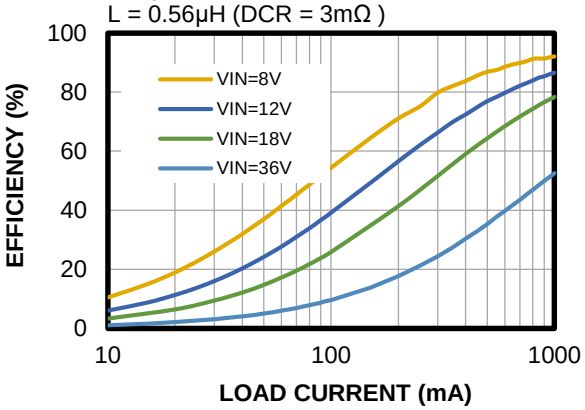

**Efficiency vs. Load Current**

FCCM, $V_{OUT}$ = 3.3V, $f_{SW}$ = 2.2MHz,
$V_{BIAS}$ connected to 5V power,
L = 0.56µH (DCR = 3mΩ)



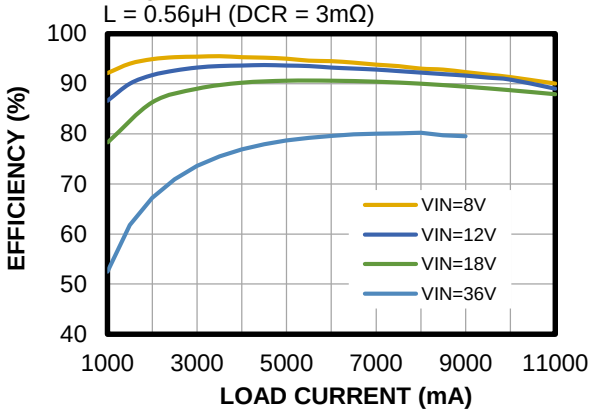

**Efficiency vs. Load Current**

FCCM, $V_{OUT}$ = 3.3V, $f_{SW}$ = 2.2MHz,
$V_{BIAS}$ connected to 5V power,
L = 0.56µH (DCR = 3mΩ )



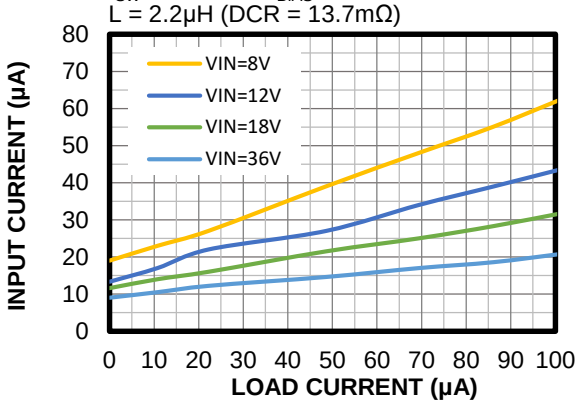

**Efficiency vs. Load Current**

FCCM, $V_{OUT}$ = 3.3V, $f_{SW}$ = 2.2MHz,
$V_{BIAS}$ connected to 5V power,
L = 0.56µH (DCR = 3mΩ)



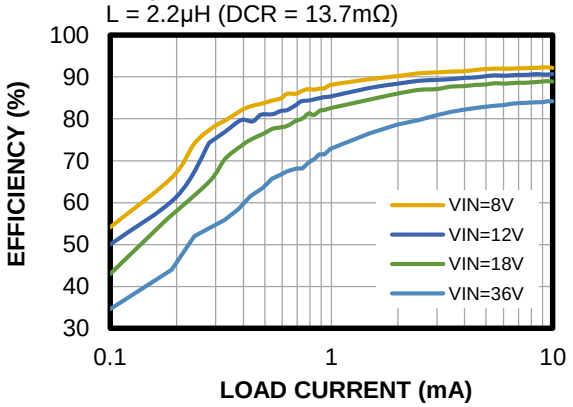

**Input Current vs. Load Current**

AAM mode, $V_{OUT}$ = 3.3V,
$f_{SW}$ = 410kHz, $V_{BIAS}$ connected to GND,
L = 2.2µH (DCR = 13.7mΩ)




**Efficiency vs. Load Current**

AAM mode, $V_{OUT}$ = 3.3V, $f_{SW}$ = 410kHz,
$V_{BIAS}$ connected to GND,
L = 2.2µH (DCR = 13.7mΩ)





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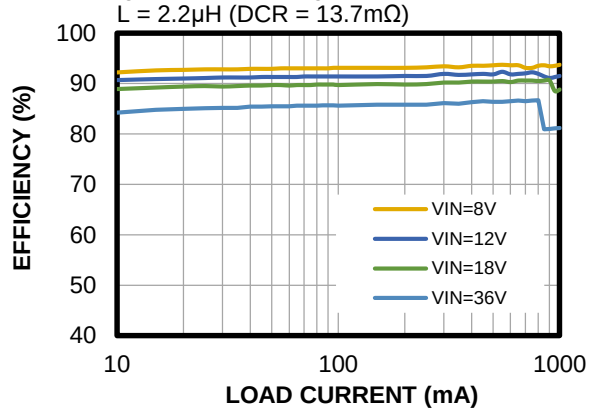
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, $f_{SW}$ = 2.2MHz, L = 0.56µH (DCR = 3mΩ), $T_A$ = 25°C, unless otherwise noted.**

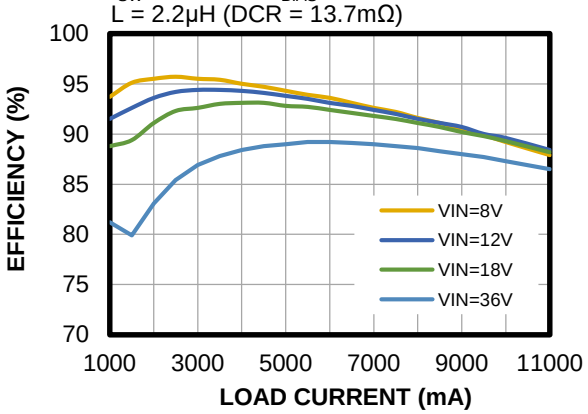
### Efficiency vs. Load Current

AAM mode, $V_{OUT}$ = 3.3V,
$f_{SW}$ = 410kHz, $V_{BIAS}$ connected to GND,
L = 2.2µH (DCR = 13.7mΩ)



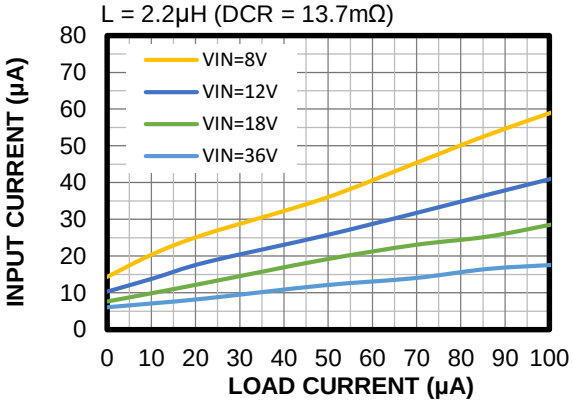

### Efficiency vs. Load Current

AAM mode, $V_{OUT}$ = 3.3V,
$f_{SW}$ = 410kHz, $V_{BIAS}$ connected to GND,
L = 2.2µH (DCR = 13.7mΩ)



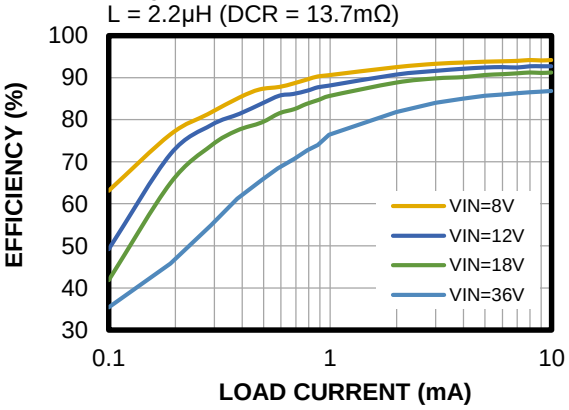

### Input Current vs. Load Current

AAM mode, $V_{OUT}$ = 3.3V, $f_{SW}$ = 410kHz,
$V_{BIAS}$ connected to 5V power,
L = 2.2µH (DCR = 13.7mΩ)



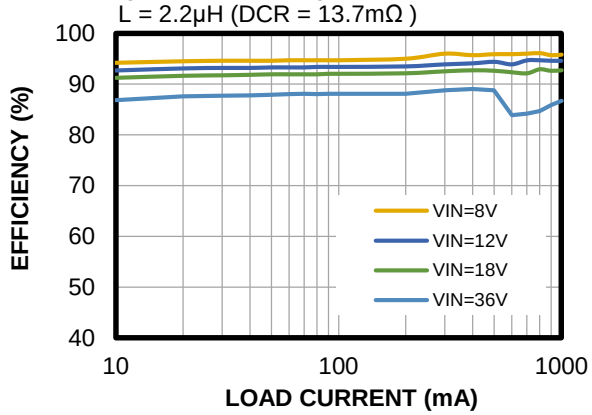

### Efficiency vs. Load Current

AAM mode, $V_{OUT}$ = 3.3V, $f_{SW}$ = 410kHz,
$V_{BIAS}$ connected to 5V power,
L = 2.2µH (DCR = 13.7mΩ)



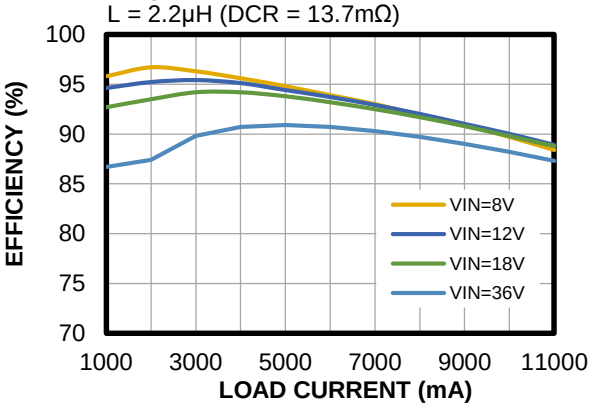

### Efficiency vs. Load Current

AAM mode, $V_{OUT}$ = 3.3V,
$f_{SW}$ = 410kHz, $V_{BIAS}$ connected to 5V power,
L = 2.2µH (DCR = 13.7mΩ )




### Efficiency vs. Load Current

AAM mode, $V_{OUT}$ = 3.3V, $f_{SW}$ = 410kHz,
$V_{BIAS}$ connected to 5V power,
L = 2.2µH (DCR = 13.7mΩ)





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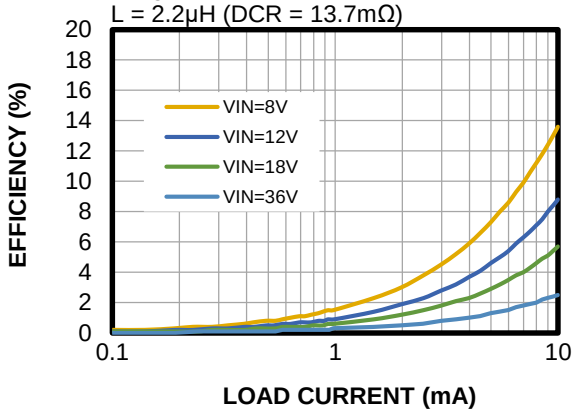
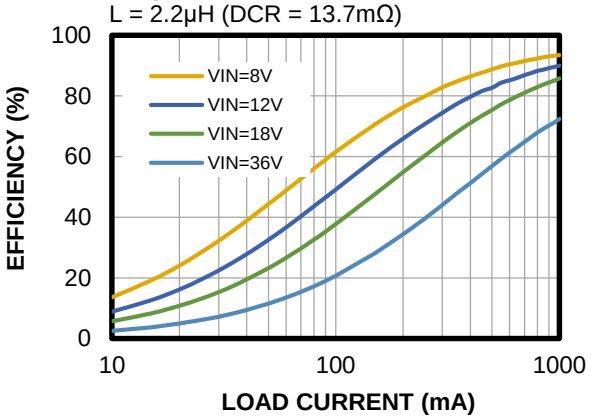
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, $f_{SW}$ = 2.2MHz, L = 0.56µH (DCR = 3mΩ), $T_A$ = 25°C, unless otherwise noted.**

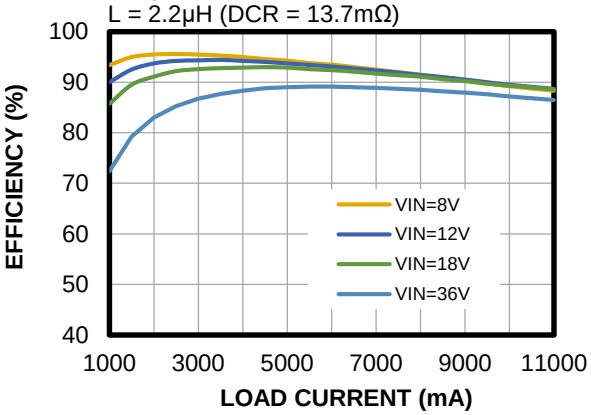
**Efficiency vs. Load Current**
FCCM, $V_{OUT}$ = 3.3V, $f_{SW}$ = 410kHz,
$V_{BIAS}$ connected to GND,
L = 2.2µH (DCR = 13.7mΩ)



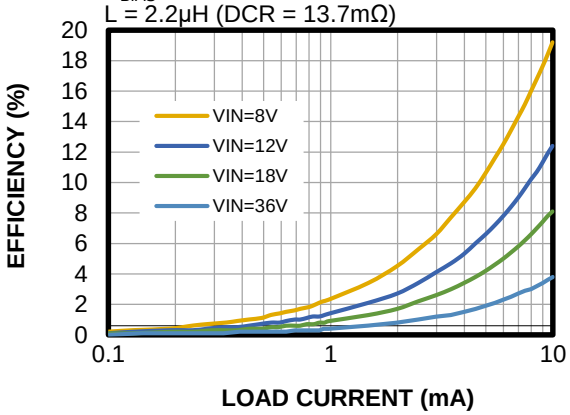

**Efficiency vs. Load Current**
FCCM, $V_{OUT}$ = 3.3V, $f_{SW}$ = 410kHz,
$V_{BIAS}$ connected to GND,
L = 2.2µH (DCR = 13.7mΩ)



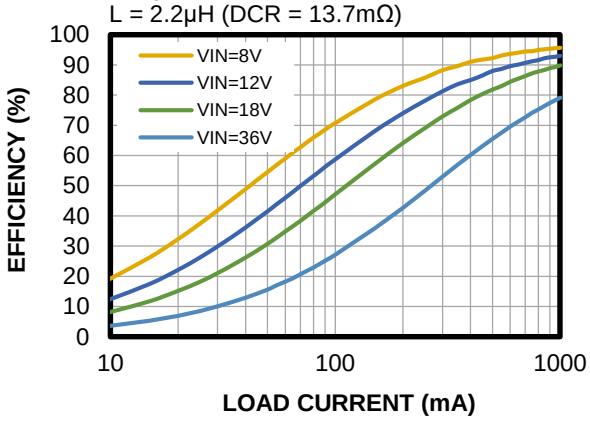

**Efficiency vs. Load Current**
FCCM, $V_{OUT}$ = 3.3V, $f_{SW}$ = 410kHz,
$V_{BIAS}$ connected to GND,
L = 2.2µH (DCR = 13.7mΩ)



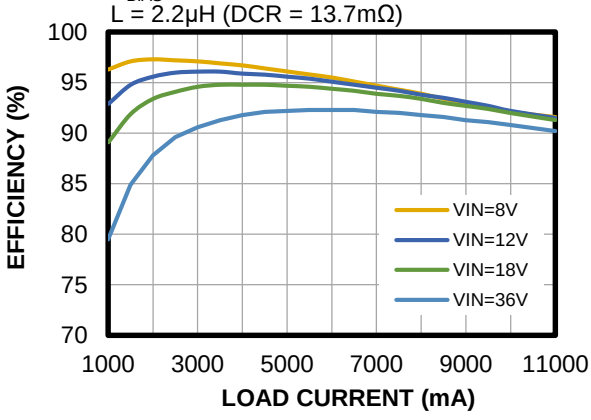

**Efficiency vs. Load Current**
FCCM, $V_{OUT}$ = 3.3V, $f_{SW}$ = 410kHz,
$V_{BIAS}$ connected to 5V power,
L = 2.2µH (DCR = 13.7mΩ)




**Efficiency vs. Load Current**
AAM mode, $V_{OUT}$ = 3.3V, $f_{SW}$ = 410kHz,
$V_{BIAS}$ connected to 5V power,
L = 2.2µH (DCR = 13.7mΩ)




**Efficiency vs. Load Current**
AAM mode, $V_{OUT}$ = 3.3V, $f_{SW}$ = 410kHz,
$V_{BIAS}$ connected to 5V power,
L = 2.2µH (DCR = 13.7mΩ)





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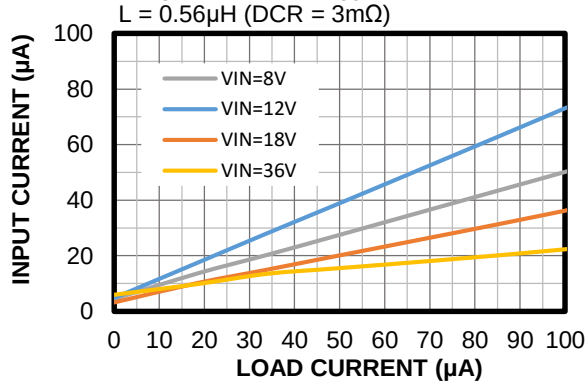
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, $f_{SW}$ = 2.2MHz, L = 0.56µH (DCR = 3mΩ), $T_A$ = 25°C, unless otherwise noted.**

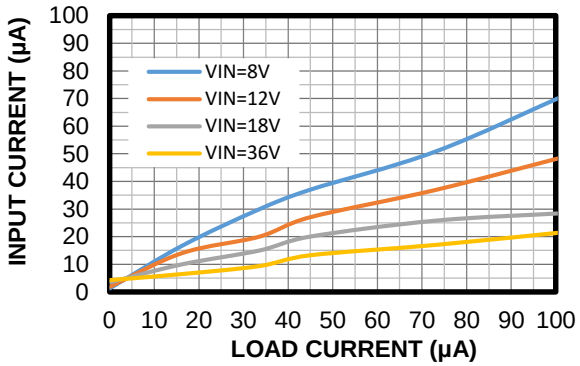
### Input Current vs. Load Current

MPQ4371-x5xx, AAM mode,
$V_{OUT}$ = 5V, $f_{SW}$ = 2.2MHz,
$V_{BIAS}$ connected to $V_{OUT}$,
L = 0.56µH (DCR = 3mΩ)



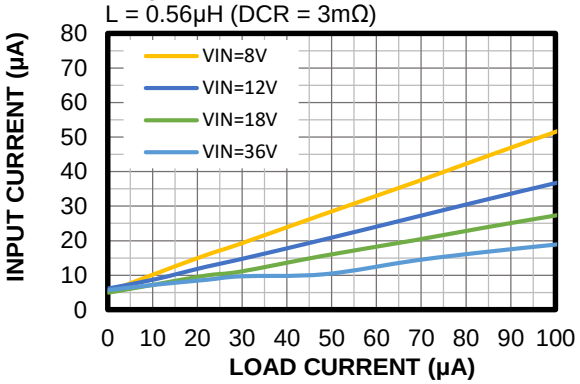

### Input Current vs. Load Current for

MPQ4371-x5xx, AAM mode, $V_{OUT}$ = 5V,
$f_{SW}$ = 410kHz, $V_{BIAS}$ connected to $V_{OUT}$,
L = 2.2µH (DCR = 13.7mΩ)



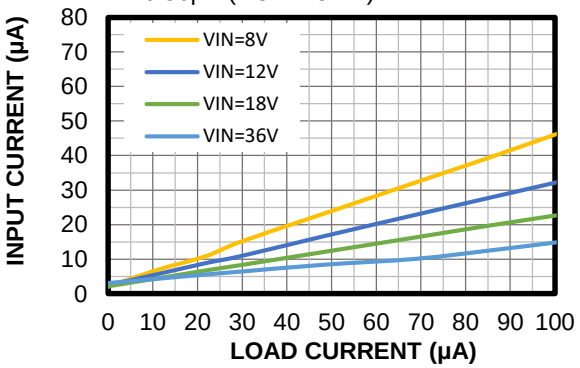

### Input Current vs. Load Current

MPQ4371-x3xx, AAM mode,
$V_{OUT}$ = 3.3V, $f_{SW}$ = 2.2MHz,
$V_{BIAS}$ connected to GND,
L = 0.56µH (DCR = 3mΩ)



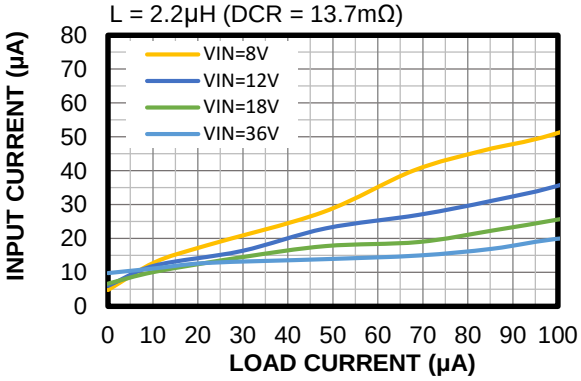

### Input Current vs. Load Current

MPQ4371-x3xx, AAM mode,
$V_{OUT}$ = 3.3V, $f_{SW}$ = 2.2MHz
$V_{BIAS}$ connected to 5V power,
L = 0.56µH (DCR = 3mΩ)



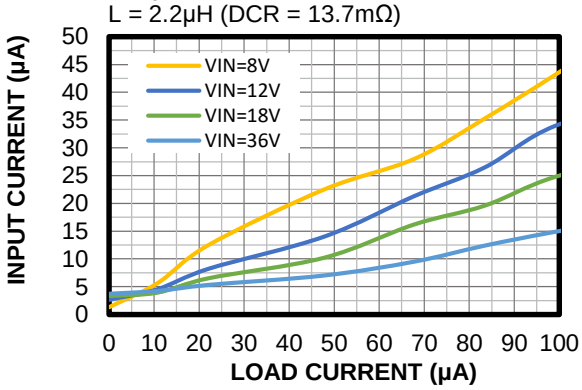

### Input Current vs. Load Current

MPQ4371-x3xx, AAM mode,
$V_{OUT}$ = 3.3V, $f_{SW}$ = 410kHz,
$V_{BIAS}$ connected to GND,
L = 2.2µH (DCR = 13.7mΩ)




### Input Current vs. Load Current

MPQ4371-x3xx, AAM mode,
$V_{OUT}$ = 3.3V, $f_{SW}$ = 410kHz,
$V_{BIAS}$ connected to 5V power,
L = 2.2µH (DCR = 13.7mΩ)





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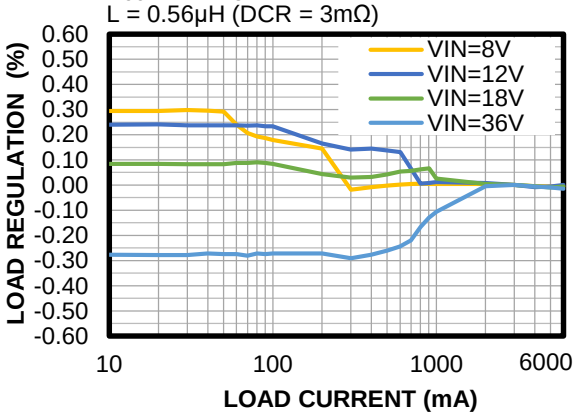
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, $f_{SW}$ = 2.2MHz, L = 0.56µH (DCR = 3mΩ), $T_A$ = 25°C, unless otherwise noted.**

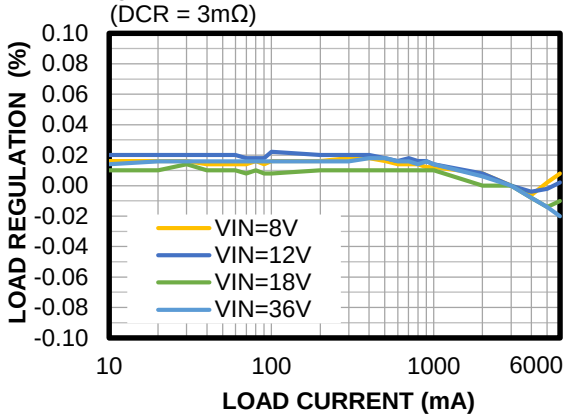
### Load Regulation

MPQ4371-6000, AAM mode,
$V_{OUT}$ = 5V, $f_{SW}$ = 2.2MHz,
L = 0.56µH (DCR = 3mΩ)



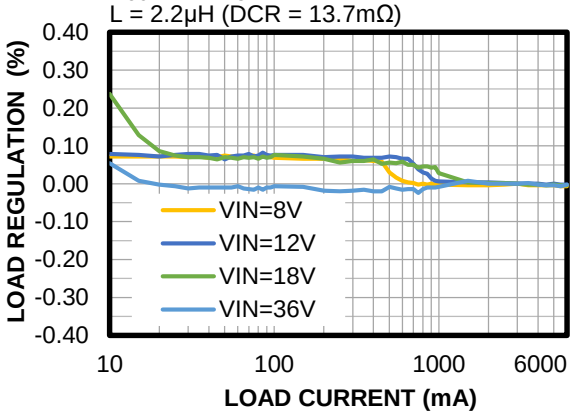

### Load Regulation

MPQ4371-6000, FCCM, $V_{OUT}$ = 5V,
$f_{SW}$ = 2.2MHz, L = 0.56µH
(DCR = 3mΩ)



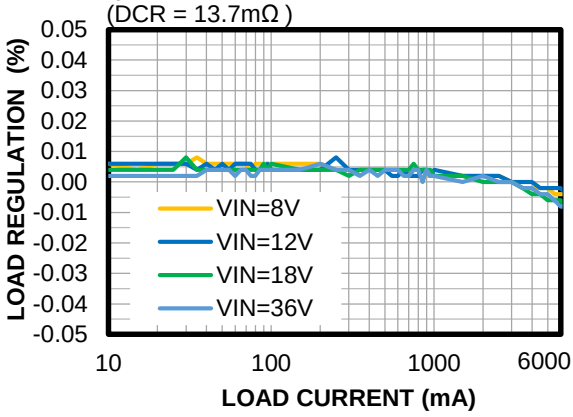

### Load Regulation

MPQ4371-6000, AAM mode,
$V_{OUT}$ = 5V, $f_{SW}$ = 410kHz,
L = 2.2µH (DCR = 13.7mΩ)



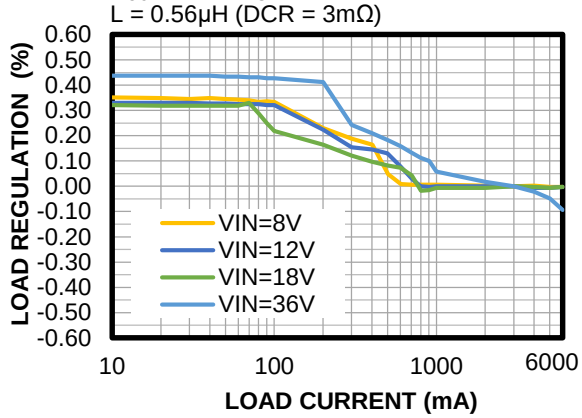

### Load Regulation

MPQ4371-6000, FCCM, $V_{OUT}$ = 5V,
$f_{SW}$ = 410kHz, L = 2.2µH
(DCR = 13.7mΩ )



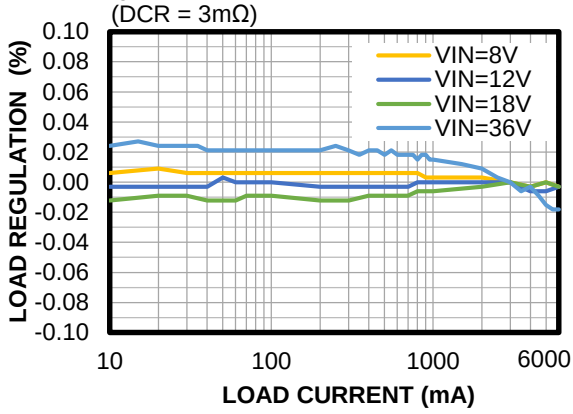

### Load Regulation

MPQ4371-6000, AAM mode,
$V_{OUT}$ = 3.3V, $f_{SW}$ = 2.2MHz,
L = 0.56µH (DCR = 3mΩ)




### Load Regulation

MPQ4371-6000, FCCM, $V_{OUT}$ = 3.3V,
$f_{SW}$ = 2.2MHz, L = 0.56µH
(DCR = 3mΩ)





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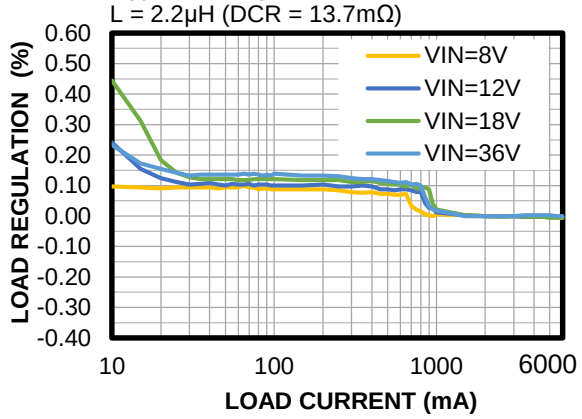
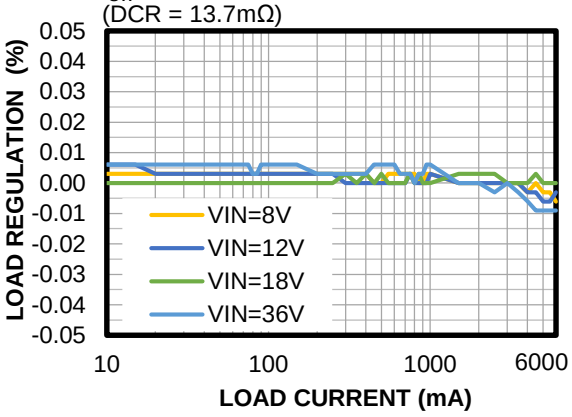
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, $f_{SW}$ = 2.2MHz, L = 0.56µH (DCR = 3mΩ), $T_A$ = 25°C, unless otherwise noted.**

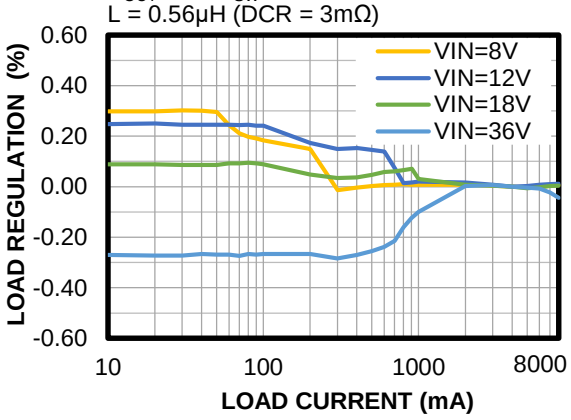
**Load Regulation**
MPQ4371-6000, AAM mode,
$V_{OUT}$ = 3.3V, $f_{SW}$ = 410kHz,
L = 2.2µH (DCR = 13.7mΩ)



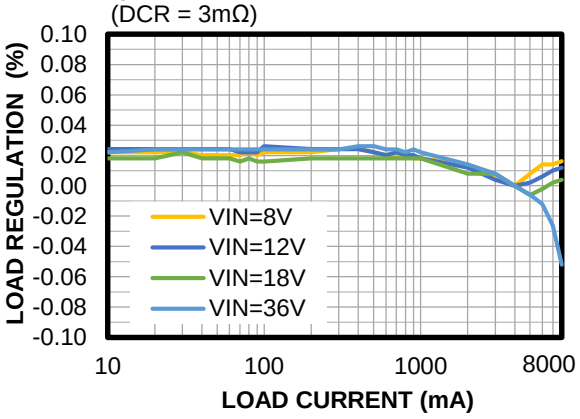

**Load Regulation**
MPQ4371-6000, FCCM, $V_{OUT}$ = 3.3V,
$f_{SW}$ = 410kHz, L = 2.2µH
(DCR = 13.7mΩ)



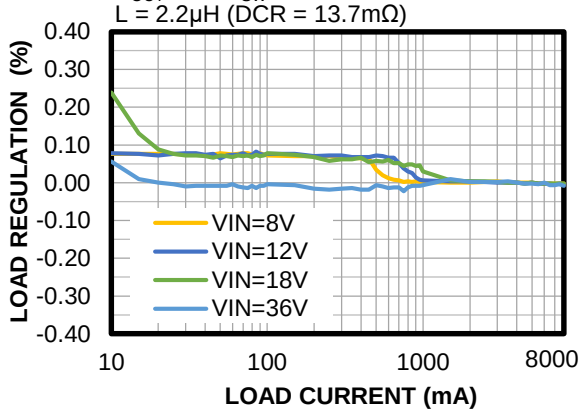

**Load Regulation**
MPQ4371-8000, AAM mode,
$V_{OUT}$ = 5V, $f_{SW}$ = 2.2MHz,
L = 0.56µH (DCR = 3mΩ)



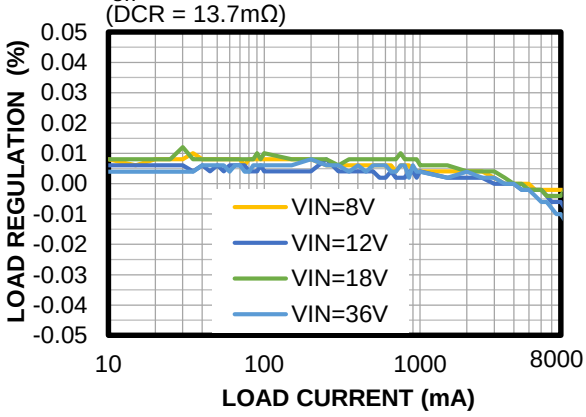

**Load Regulation**
MPQ4371-8000, FCCM, $V_{OUT}$ = 5V,
$f_{SW}$ = 2.2MHz, L = 0.56µH
(DCR = 3mΩ)




**Load Regulation**
MPQ4371-8000, AAM mode,
$V_{OUT}$ = 5V, $f_{SW}$ = 410kHz,
L = 2.2µH (DCR = 13.7mΩ)




**Load Regulation**
MPQ4371-8000, FCCM, $V_{OUT}$ = 5V,
$f_{SW}$ = 410kHz, L = 2.2µH
(DCR = 13.7mΩ)





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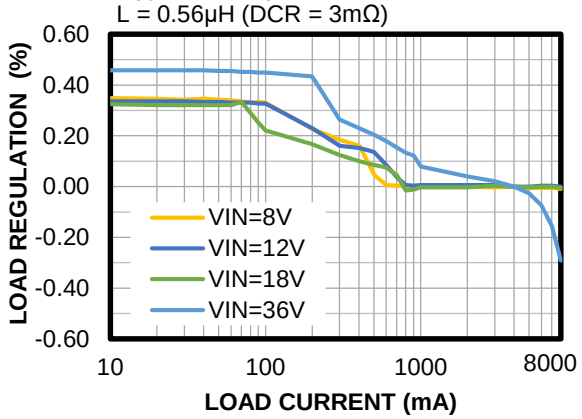
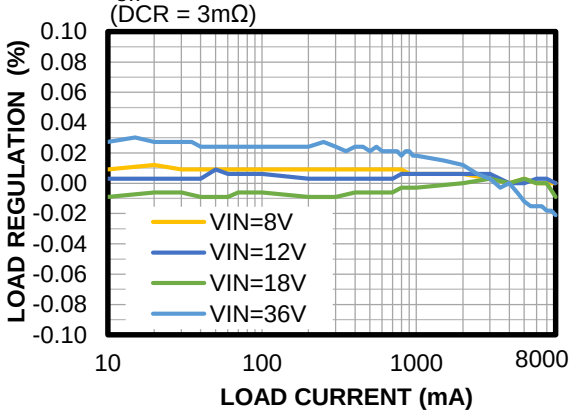
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, $f_{SW}$ = 2.2MHz, L = 0.56µH (DCR = 3mΩ), $T_A$ = 25°C, unless otherwise noted.**

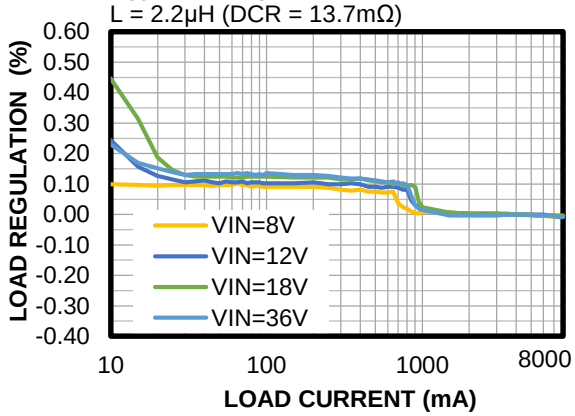
**Load Regulation**
MPQ4371-8000, AAM mode,
$V_{OUT}$ = 3.3V, $f_{SW}$ = 2.2MHz,
L = 0.56µH (DCR = 3mΩ)



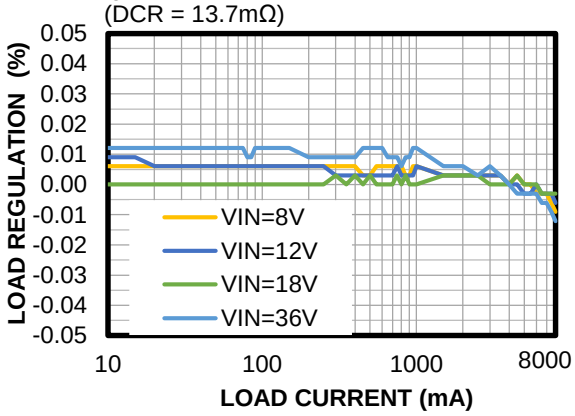

**Load Regulation**
MPQ4371-8000, FCCM, $V_{OUT}$ = 3.3V,
$f_{SW}$ = 2.2MHz, L = 0.56µH
(DCR = 3mΩ)



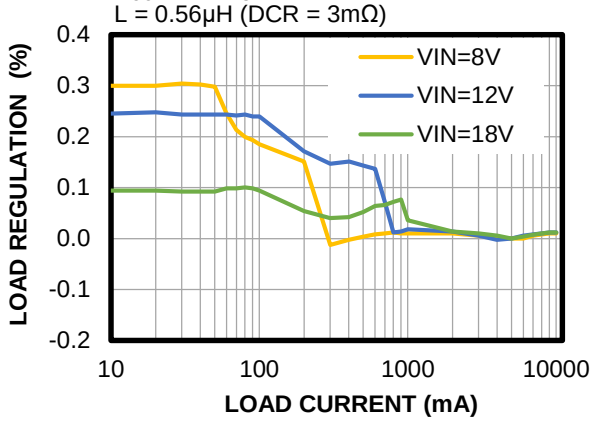

**Load Regulation**
MPQ4371-8000, AAM mode,
$V_{OUT}$ = 3.3V, $f_{SW}$ = 410kHz
L = 2.2µH (DCR = 13.7mΩ)



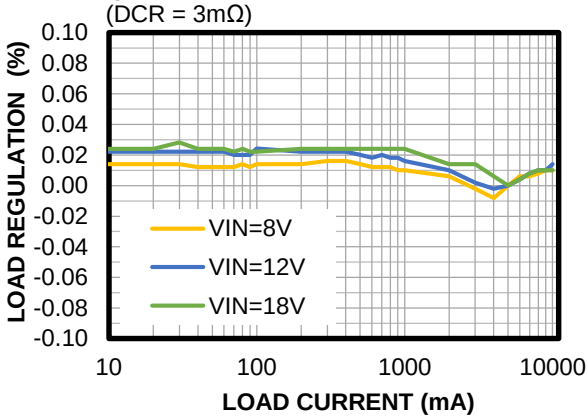

**Load Regulation**
MPQ4371-8000, FCCM, $V_{OUT}$ = 3.3V,
$f_{SW}$ = 410kHz, L = 2.2µH
(DCR = 13.7mΩ)




**Load Regulation**
MPQ4371-0000, AAM mode,
$V_{OUT}$ = 5V, $f_{SW}$ = 2.2MHz,
L = 0.56µH (DCR = 3mΩ)




**Load Regulation**
MPQ4371-0000, FCCM, $V_{OUT}$ = 5V,
$f_{SW}$ = 2.2MHz, L = 0.56µH
(DCR = 3mΩ)





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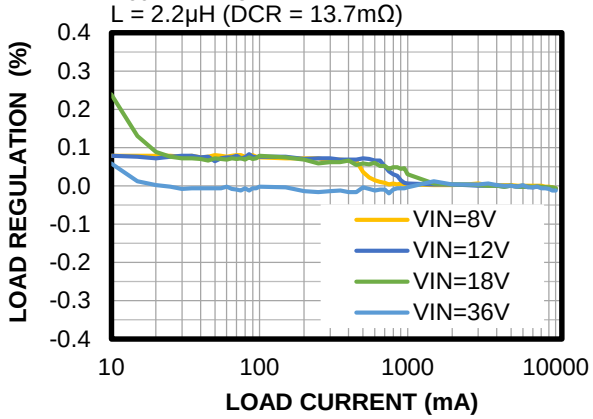
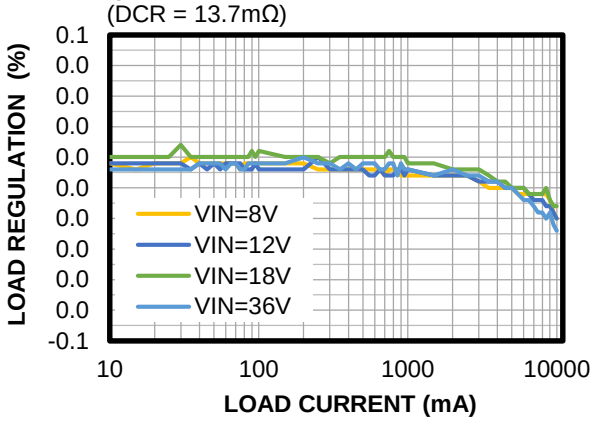
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, $f_{SW}$ = 2.2MHz, L = 0.56µH (DCR = 3mΩ), $T_A$ = 25°C, unless otherwise noted.**

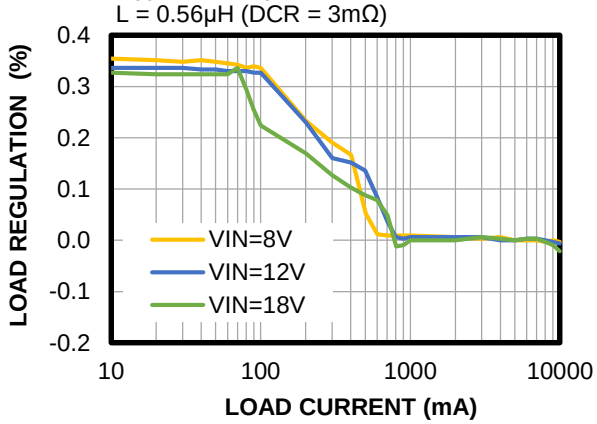
**Load Regulation**
MPQ4371-0000, AAM mode,
$V_{OUT}$ = 5V, $f_{SW}$ = 410kHz,
L = 2.2µH (DCR = 13.7mΩ)



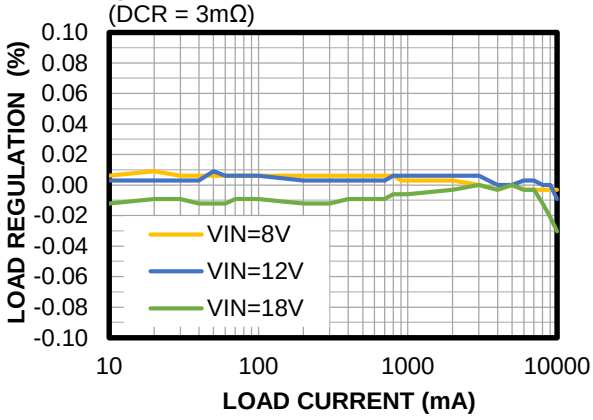

**Load Regulation**
MPQ4371-0000, FCCM, $V_{OUT}$ = 5V,
$f_{SW}$ = 410kHz, L = 2.2µH
(DCR = 13.7mΩ)



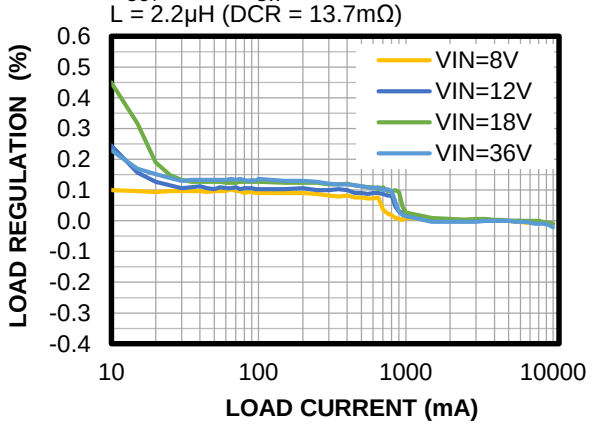

**Load Regulation**
MPQ4371-0000, AAM mode,
$V_{OUT}$ = 3.3V, $f_{SW}$ = 2.2MHz,
L = 0.56µH (DCR = 3mΩ)



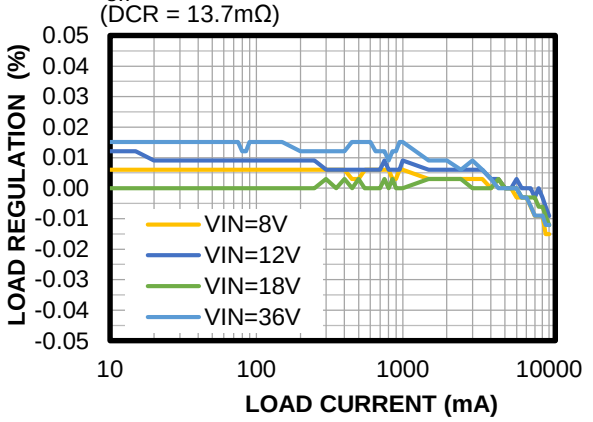

**Load Regulation**
MPQ4371-0000, FCCM, $V_{OUT}$ = 3.3V,
$f_{SW}$ = 2.2MHz, L = 0.56µH
(DCR = 3mΩ)




**Load Regulation**
MPQ4371-0000, AAM mode,
$V_{OUT}$ = 3.3V, $f_{SW}$ = 410kHz,
L = 2.2µH (DCR = 13.7mΩ)




**Load Regulation**
MPQ4371-0000, FCCM, $V_{OUT}$ = 3.3V,
$f_{SW}$ = 410kHz, L = 2.2µH
(DCR = 13.7mΩ)





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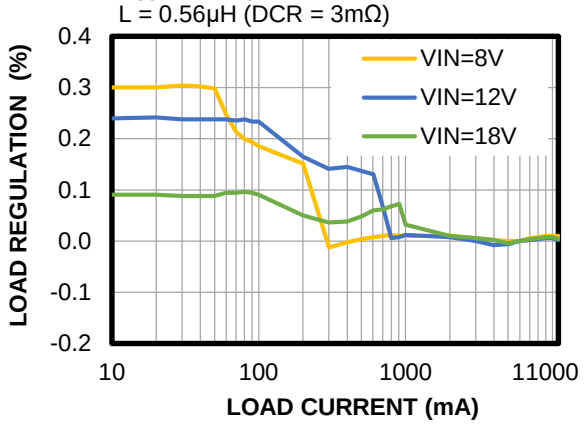
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, $f_{SW}$ = 2.2MHz, L = 0.56µH (DCR = 3mΩ), $T_A$ = 25°C, unless otherwise noted.**

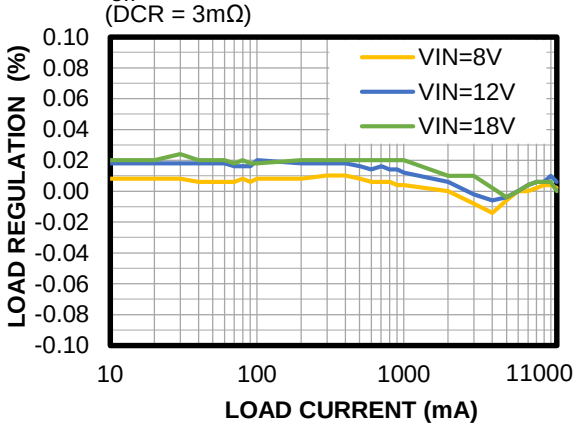
### Load Regulation

MPQ4371-1000, AAM mode,
$V_{OUT}$ = 5V, $f_{SW}$ = 2.2MHz,
L = 0.56µH (DCR = 3mΩ)



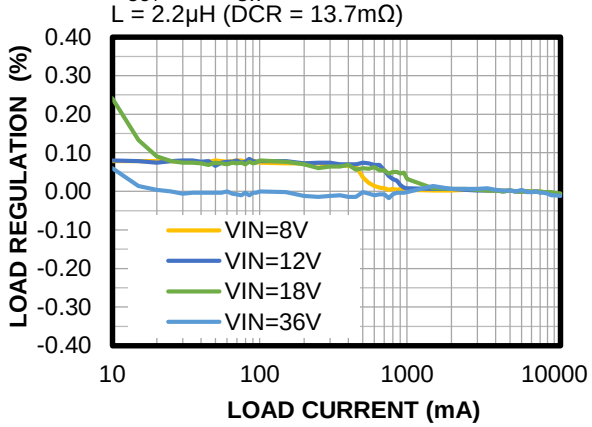

### Load Regulation

MPQ4371-1000, FCCM, $V_{OUT}$ = 5V,
$f_{SW}$ = 2.2MHz, L = 0.56µH
(DCR = 3mΩ)



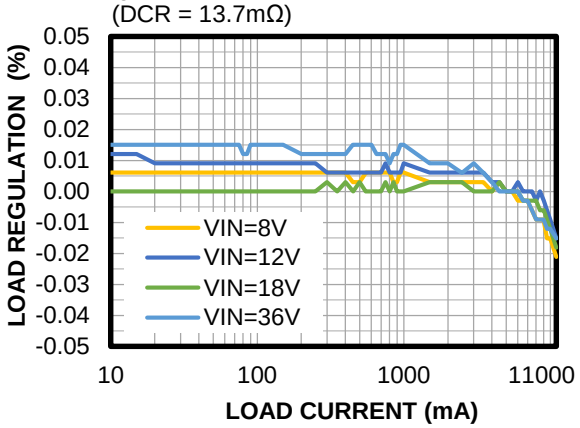

### Load Regulation

MPQ4371-1000, AAM mode,
$V_{OUT}$ = 5V, $f_{SW}$ = 410kHz,
L = 2.2µH (DCR = 13.7mΩ)



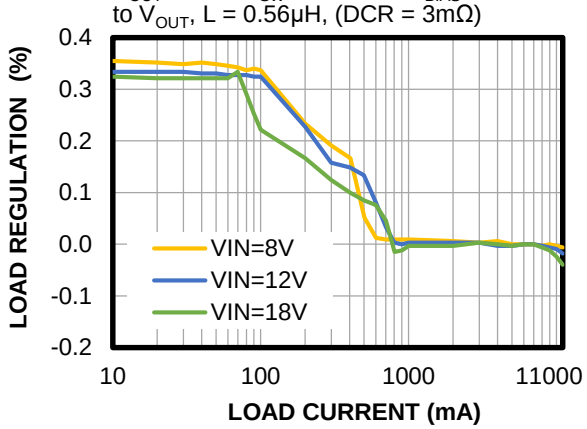

### Load Regulation

MPQ4371-1000, FCCM, $V_{OUT}$ = 5V,
$f_{SW}$ = 410kHz, L = 2.2µH
(DCR = 13.7mΩ)



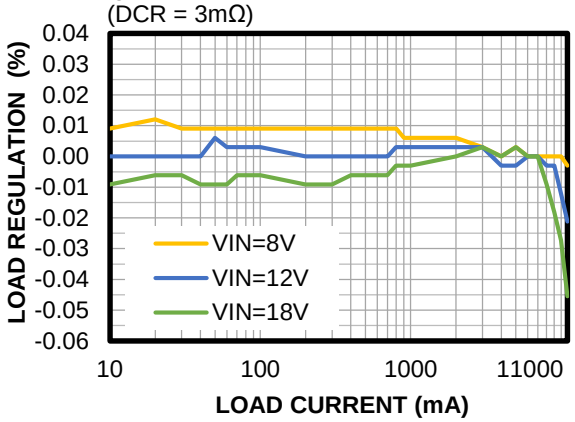

### Load Regulation

MPQ4371-1000, AAM mode,
$V_{OUT}$ = 3.3V, $f_{SW}$ = 2.2MHz, $V_{BIAS}$ connected
to $V_{OUT}$, L = 0.56µH, (DCR = 3mΩ)




### Load Regulation

MPQ4371-1000, FCCM, $V_{OUT}$ = 3.3V,
$f_{SW}$ = 2.2MHz, L = 0.56µH
(DCR = 3mΩ)





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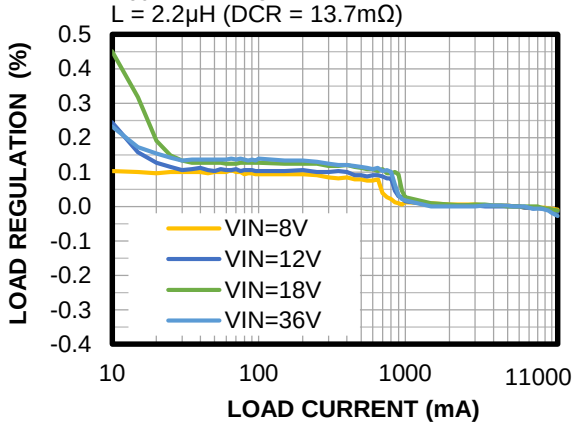
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, $f_{SW}$ = 2.2MHz, L = 0.56µH (DCR = 3mΩ), $T_A$ = 25°C, unless otherwise noted.**

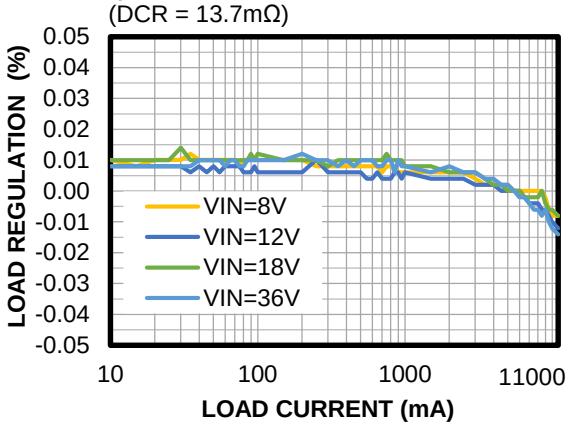
**Load Regulation**

MPQ4371-1000, AAM mode,
$V_{OUT}$ = 3.3V, $f_{SW}$ = 410kHz,
L = 2.2µH (DCR = 13.7mΩ)



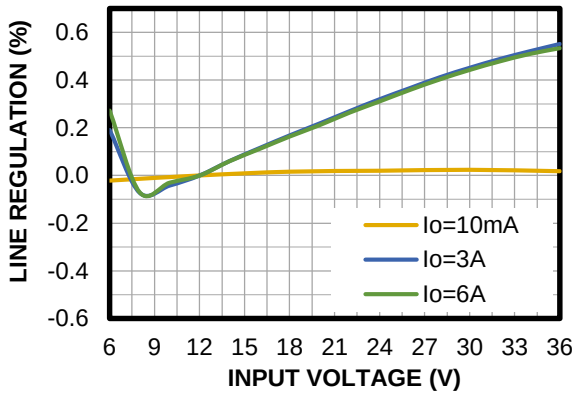

**Load Regulation**

MPQ4371-1000, FCCM, $V_{OUT}$ = 3.3V,
$f_{SW}$ = 410kHz, L = 2.2µH
(DCR = 13.7mΩ)



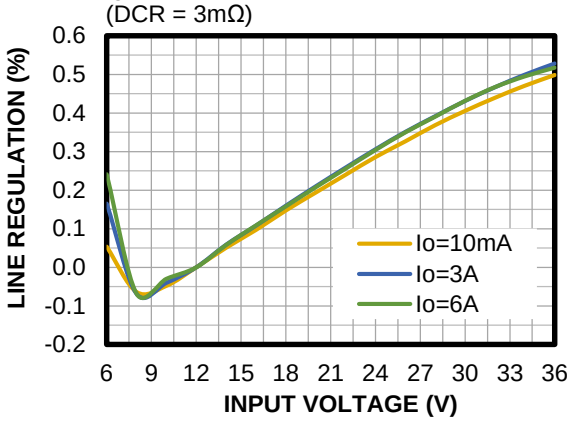

**Line Regulation**

MPQ4371-6000, AAM mode,
$V_{OUT}$ = 5V, $f_{SW}$ = 2.2MHz,
L = 0.56µH (DCR = 3mΩ)



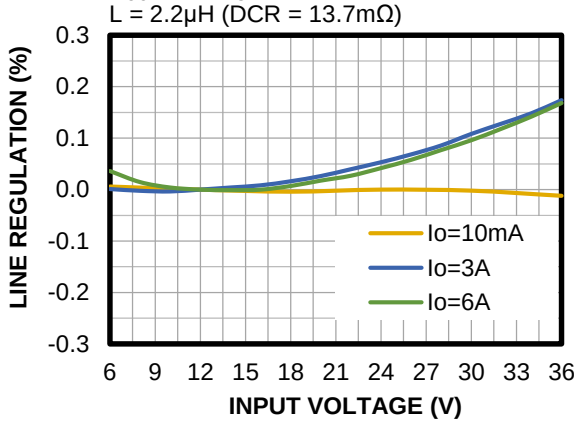

**Line Regulation**

MPQ4371-6000, FCCM, $V_{OUT}$ = 5V,
$f_{SW}$ = 2.2MHz, L = 0.56µH
(DCR = 3mΩ)



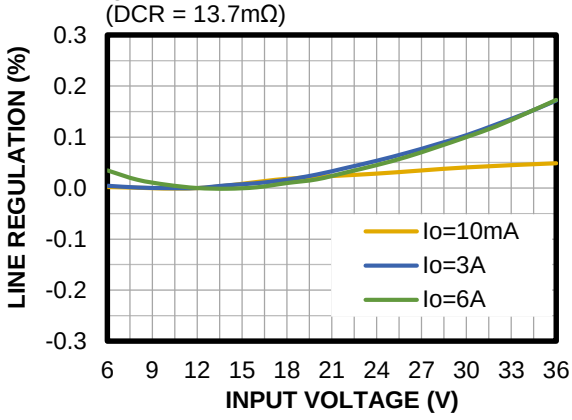

**Line Regulation**

MPQ4371-6000, AAM mode,
$V_{OUT}$ = 5V, $f_{SW}$ = 410kHz,
L = 2.2µH (DCR = 13.7mΩ)




**Line Regulation**

MPQ4371-6000, FCCM, $V_{OUT}$ = 5V,
$f_{SW}$ = 410kHz, L = 2.2µH
(DCR = 13.7mΩ)





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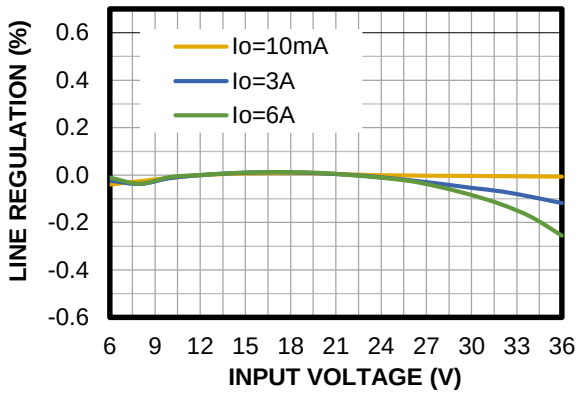
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, $f_{SW}$ = 2.2MHz, L = 0.56µH (DCR = 3mΩ), $T_A$ = 25°C, unless otherwise noted.**

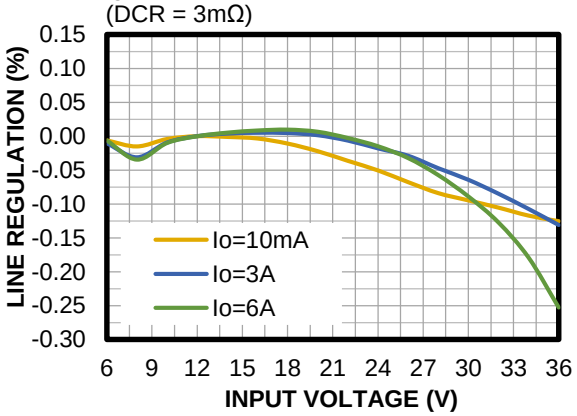
### Line Regulation

MPQ4371-6000, AAM mode,
$V_{OUT}$ = 3.3V, $f_{SW}$ = 2.2MHz,
L = 0.56µH (DCR = 3mΩ)



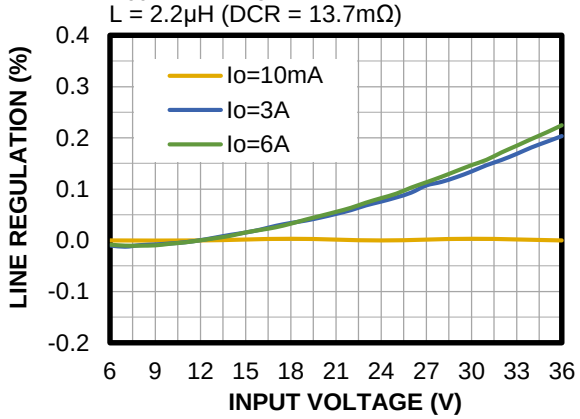

### Line Regulation

MPQ4371-6000, FCCM, $V_{OUT}$ = 3.3V,
$f_{SW}$ = 2.2MHz, L = 0.56µH
(DCR = 3mΩ)



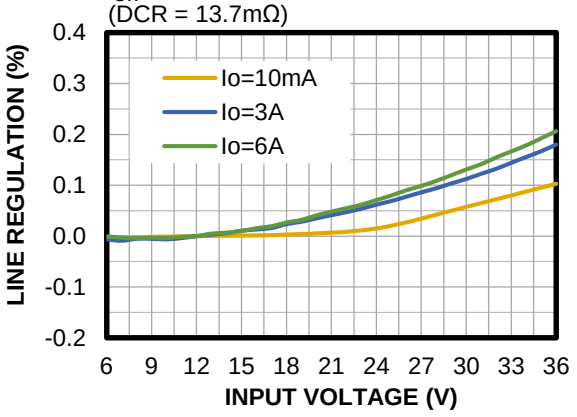

### Line Regulation

MPQ4371-6000, AAM mode,
$V_{OUT}$ = 3.3V, $f_{SW}$ = 410kHz,
L = 2.2µH (DCR = 13.7mΩ)



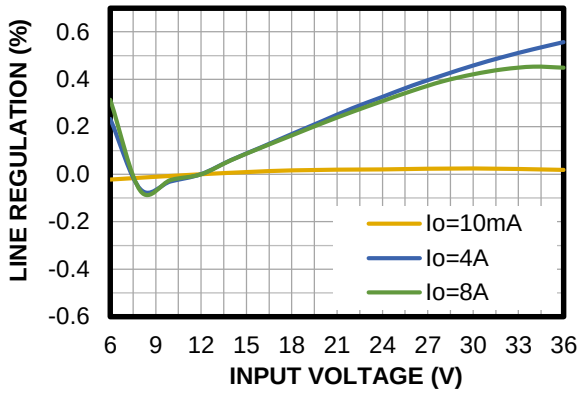

### Line Regulation

MPQ4371-6000, FCCM, $V_{OUT}$ = 3.3V,
$f_{SW}$ = 410kHz, L = 2.2µH
(DCR = 13.7mΩ)



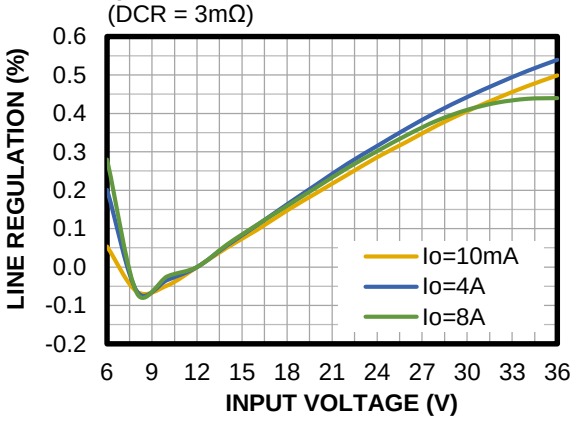

### Line Regulation

MPQ4371-8000, AAM mode,
$V_{OUT}$ = 5V, $f_{SW}$ = 2.2MHz,
L = 0.56µH (DCR = 3mΩ)




### Line Regulation

MPQ4371-8000, FCCM, $V_{OUT}$ = 5V,
$f_{SW}$ = 2.2MHz, L = 0.56µH
(DCR = 3mΩ)





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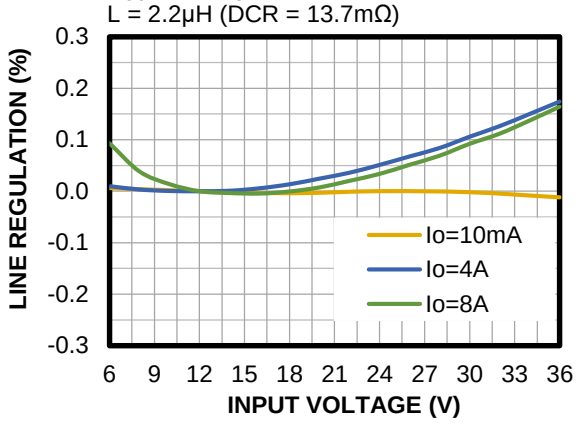
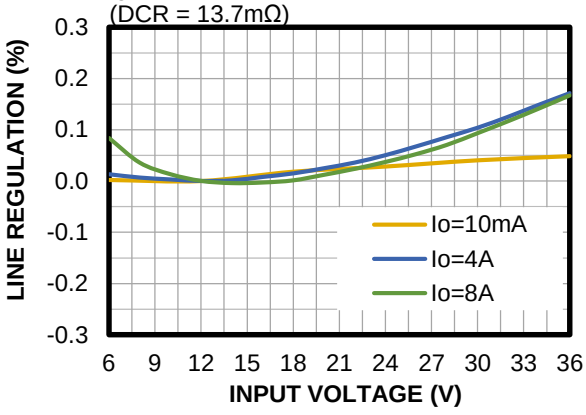
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, $f_{SW}$ = 2.2MHz, L = 0.56µH (DCR = 3mΩ), $T_A$ = 25°C, unless otherwise noted.**

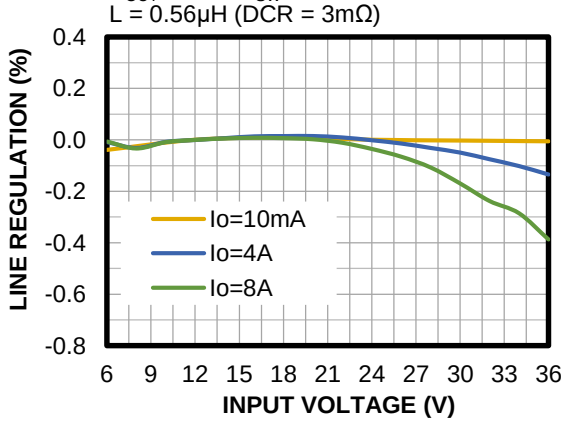
**Line Regulation**
MPQ4371-8000**,** AAM mode,
$V_{OUT}$ = 5V, $f_{SW}$ = 410kHz,
L = 2.2µH (DCR = 13.7mΩ)



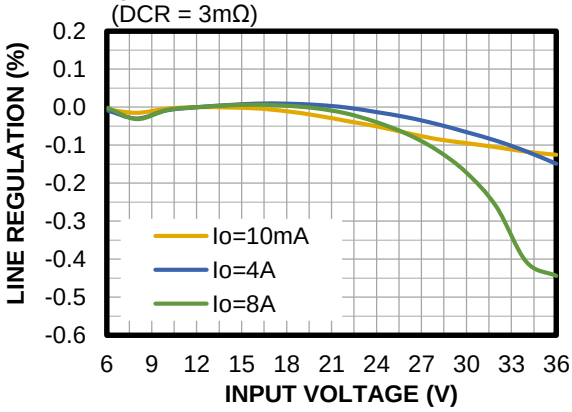

**Line Regulation**
MPQ4371-8000, FCCM, $V_{OUT}$ = 5V,
$f_{SW}$ = 410kHz, L = 2.2µH
(DCR = 13.7mΩ)



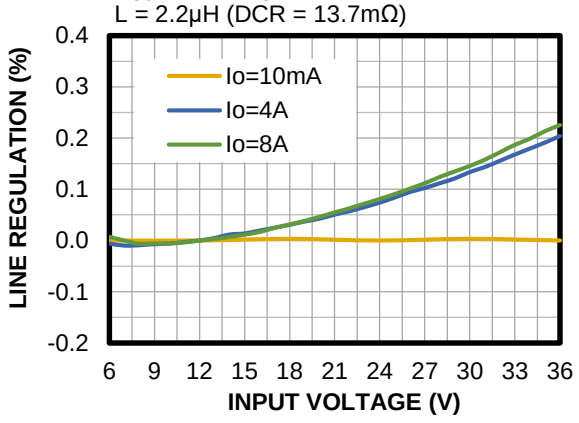

**Line Regulation**
MPQ4371-8000, AAM mode,
$V_{OUT}$ = 3.3V, $f_{SW}$ = 2.2MHz,
L = 0.56µH (DCR = 3mΩ)



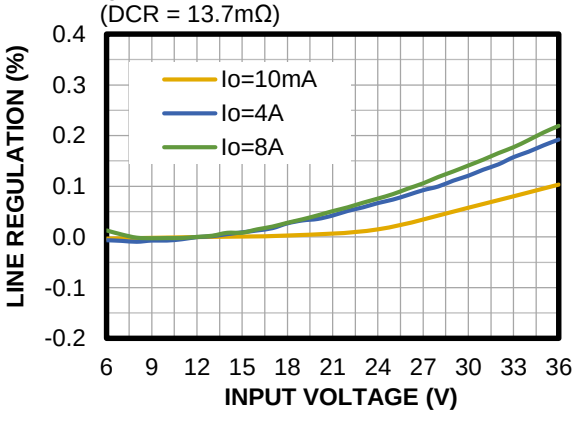

**Line Regulation**
MPQ4371-8000, FCCM, $V_{OUT}$ = 3.3V,
$f_{SW}$ = 2.2MHz, L = 0.56µH
(DCR = 3mΩ)




**Line Regulation**
MPQ4371-8000, AAM mode,
$V_{OUT}$ = 3.3V, $f_{SW}$ = 410kHz,
L = 2.2µH (DCR = 13.7mΩ)




**Line Regulation**
MPQ4371-8000, FCCM, $V_{OUT}$ = 3.3V,
$f_{SW}$ = 410kHz, L = 2.2µH
(DCR = 13.7mΩ)





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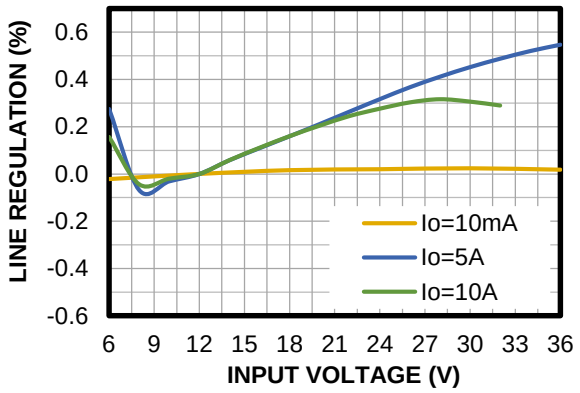
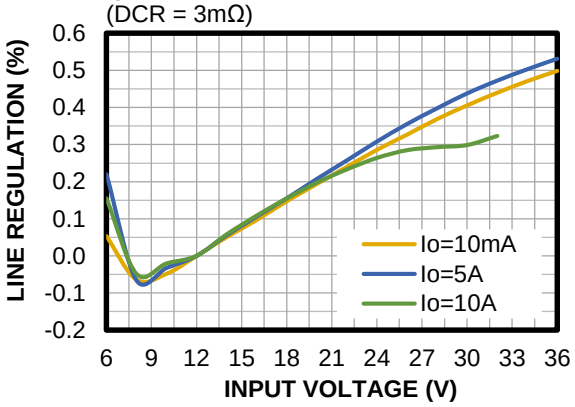
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, $f_{SW}$ = 2.2MHz, L = 0.56µH (DCR = 3mΩ), $T_A$ = 25°C, unless otherwise noted.**

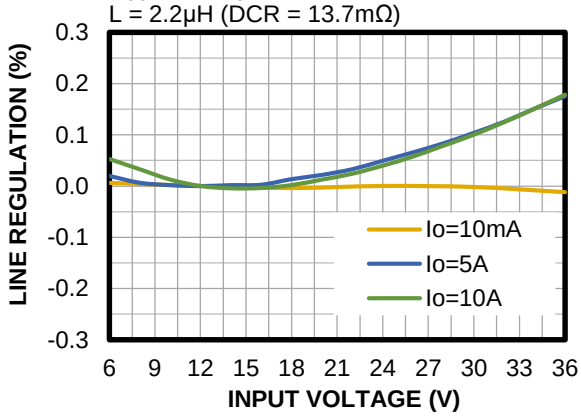
**Line Regulation**
MPQ4371-0000, AAM mode,
$V_{OUT}$ = 5V, $f_{SW}$ = 2.2MHz,
L = 0.56µH (DCR = 3mΩ)



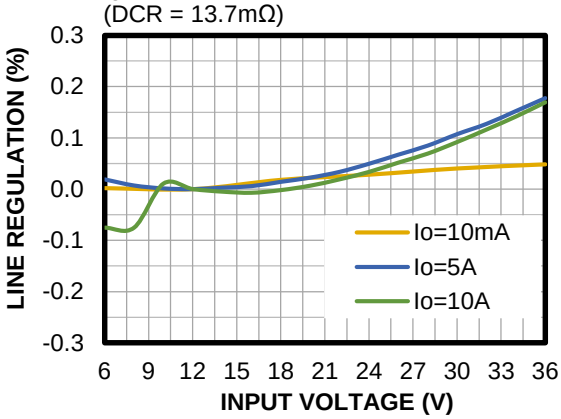

**Line Regulation**
MPQ4371-0000, FCCM, $V_{OUT}$ = 5V,
$f_{SW}$ = 2.2MHz, L = 0.56µH
(DCR = 3mΩ)



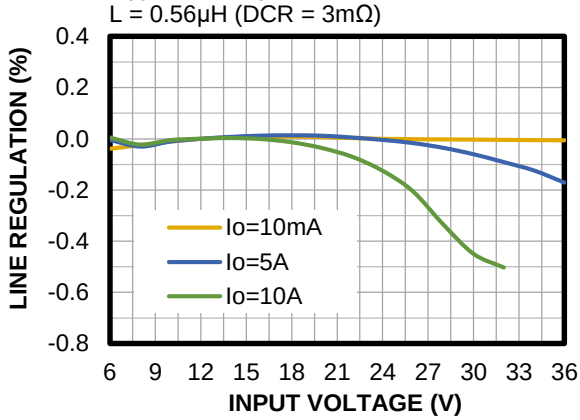

**Line Regulation**
MPQ4371-0000, AAM mode,
$V_{OUT}$ = 5V, $f_{SW}$ = 410kHz,
L = 2.2µH (DCR = 13.7mΩ)



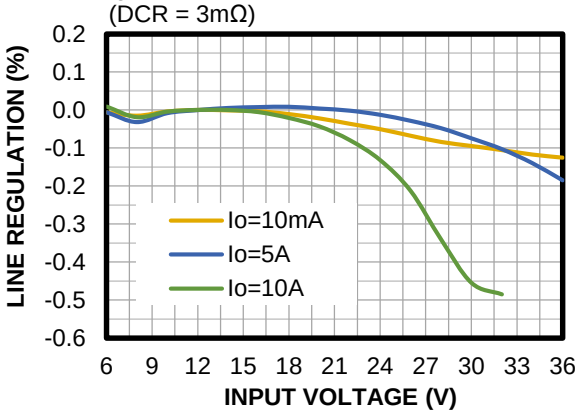

**Line Regulation**
MPQ4371-0000, FCCM, $V_{OUT}$ = 5V,
$f_{SW}$ = 410kHz, L = 2.2µH
(DCR = 13.7mΩ)




**Line Regulation**
MPQ4371-0000, AAM mode,
$V_{OUT}$ = 3.3V, $f_{SW}$ = 2.2MHz
L = 0.56µH (DCR = 3mΩ)




**Line Regulation**
MPQ4371-0000, FCCM, $V_{OUT}$ = 3.3V,
$f_{SW}$ = 2.2MHz, L = 0.56µH
(DCR = 3mΩ)





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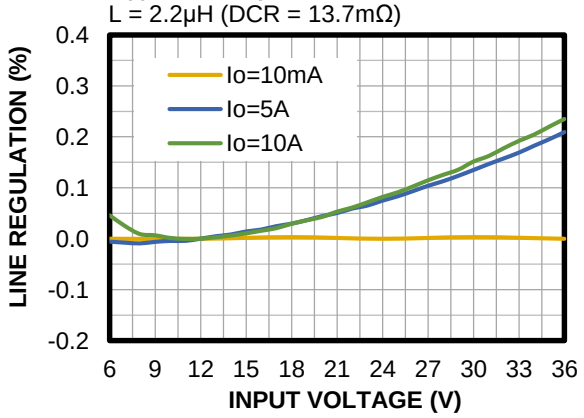
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, $f_{SW}$ = 2.2MHz, L = 0.56µH (DCR = 3mΩ), $T_A$ = 25°C, unless otherwise noted.**

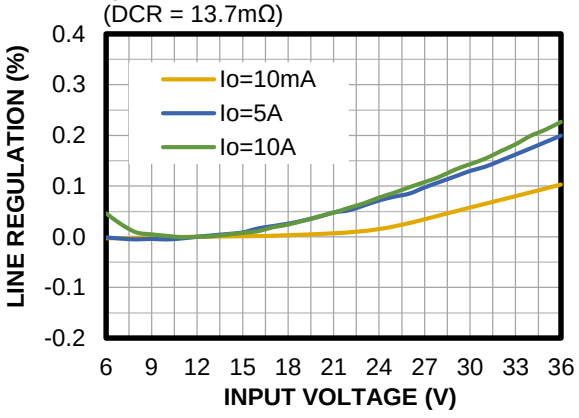
### Line Regulation

MPQ4371-0000, AAM mode,
$V_{OUT}$ = 3.3V, $f_{SW}$ = 410kHz,
L = 2.2µH (DCR = 13.7mΩ)



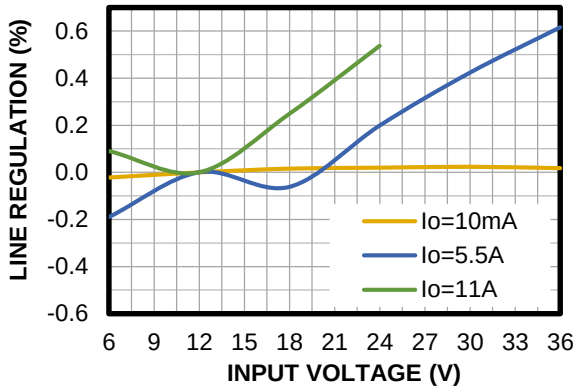

### Line Regulation

MPQ4371-0000, FCCM, $V_{OUT}$ = 3.3V,
$f_{SW}$ = 410kHz, L = 2.2µH
(DCR = 13.7mΩ)



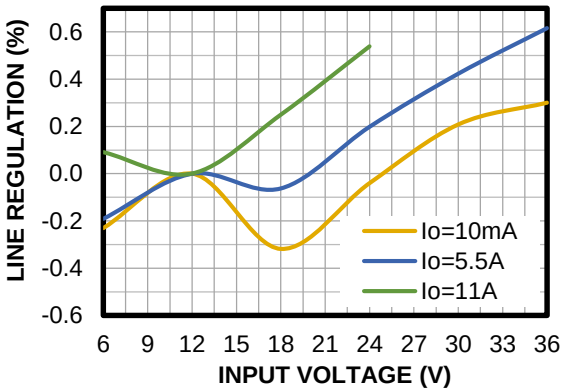

### Line Regulation

MPQ4371-1000, AAM mode,
$V_{OUT}$ = 5V, $f_{SW}$ = 2.2MHz,
L = 0.56µH (DCR = 3mΩ)



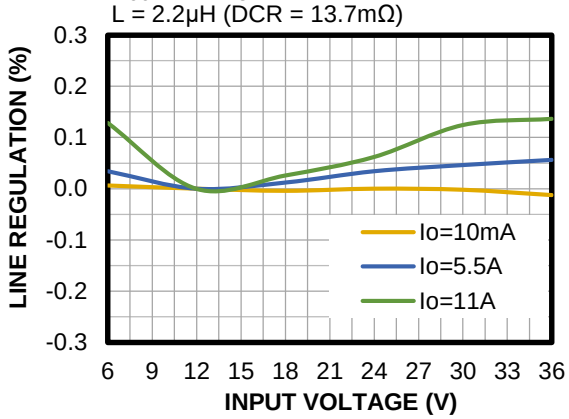

### Line Regulation

MPQ4371-1000, FCCM, $V_{OUT}$ = 5V,
$f_{SW}$ = 2.2MHz, L = 0.56µH
(DCR = 3mΩ)



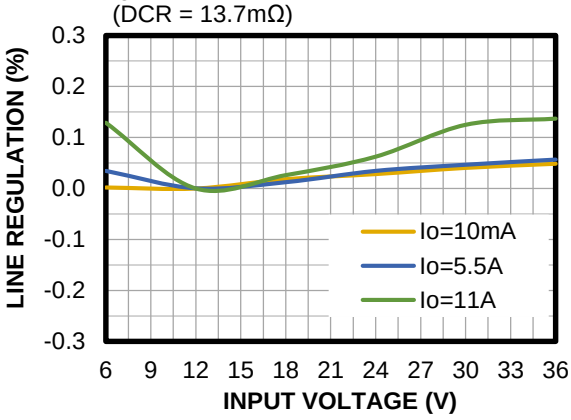

### Line Regulation

MPQ4371-1000, AAM mode,
$V_{OUT}$ = 5V, $f_{SW}$ = 410kHz,
L = 2.2µH (DCR = 13.7mΩ)




### Line Regulation

MPQ4371-1000, FCCM, $V_{OUT}$ = 5V,
$f_{SW}$ = 410kHz, L = 2.2µH
(DCR = 13.7mΩ)





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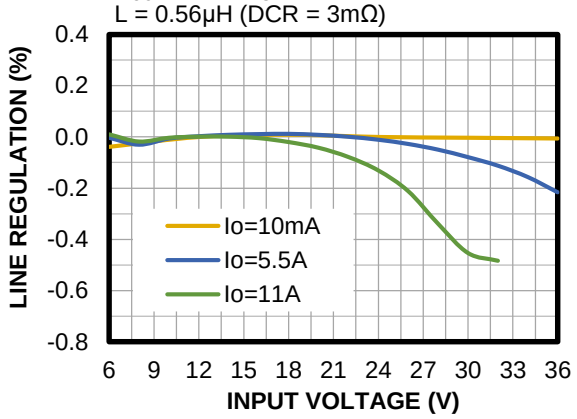
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, $f_{SW}$ = 2.2MHz, L = 0.56µH (DCR = 3mΩ), $T_A$ = 25°C, unless otherwise noted.**

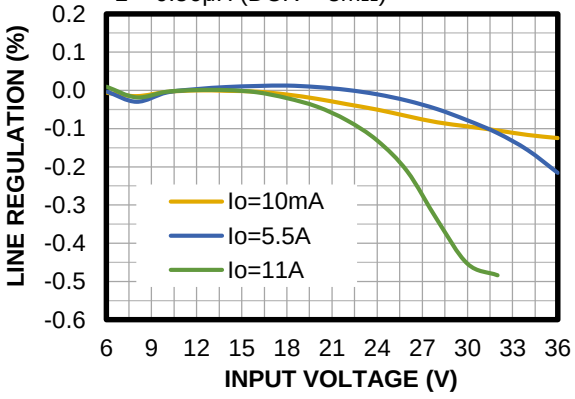
### Line Regulation

MPQ4371-1000, AAM mode,
$V_{OUT}$ = 3.3V, $f_{SW}$ = 2.2MHz,
L = 0.56µH (DCR = 3mΩ)



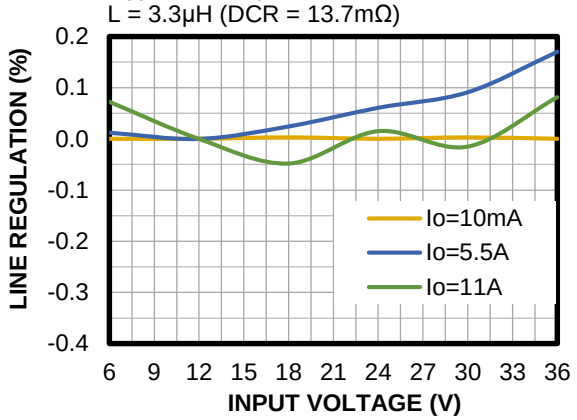

### Line Regulation

MPQ4371-1000, FCCM,
$V_{OUT}$ = 3.3V, $f_{SW}$ = 2.2MHz,
L = 0.56µH (DCR = 3mΩ)



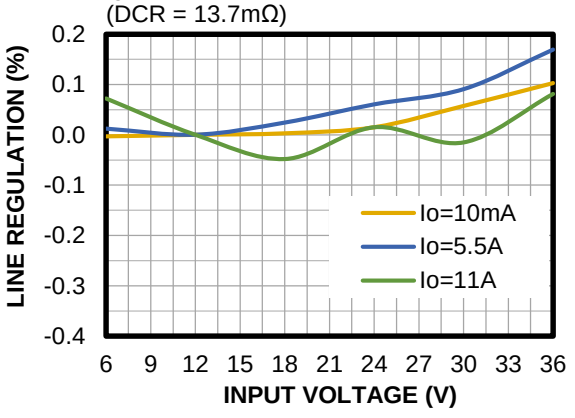

### Line Regulation

MPQ4371-1000, AAM mode,
$V_{OUT}$ = 3.3V, $f_{SW}$ = 410kHz,
L = 3.3µH (DCR = 13.7mΩ)



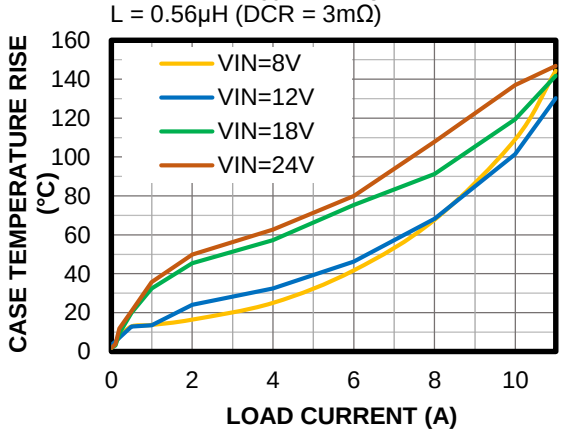

### Line Regulation

MPQ4371-1000, FCCM, $V_{OUT}$ = 3.3V,
$f_{SW}$ = 410kHz, L = 2.2µH
(DCR = 13.7mΩ)



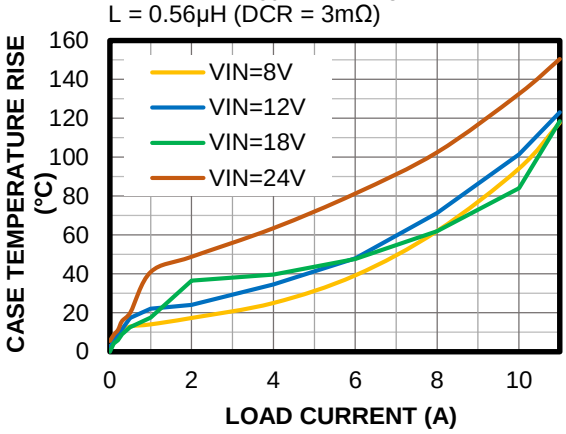

### Case Temperature Rise

AAM mode, $V_{OUT}$ = 5V, $f_{SW}$ = 2.2MHz,
L = 0.56µH (DCR = 3mΩ)




### Case Temperature Rise

AAM mode, $V_{OUT}$ = 3.3V, $f_{SW}$ = 2.2MHz,
L = 0.56µH (DCR = 3mΩ)





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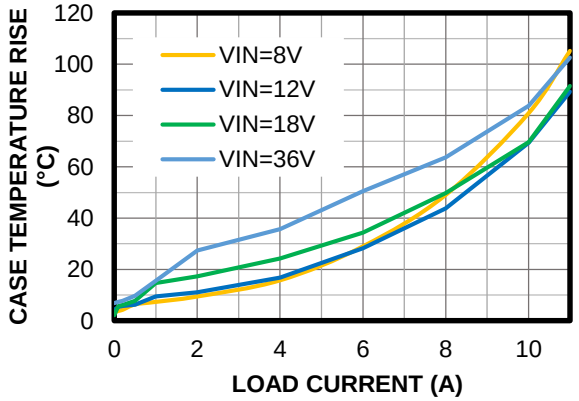
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, $f_{SW}$ = 2.2MHz, L = 0.56µH (DCR = 3mΩ), $T_A$ = 25°C, unless otherwise noted.**

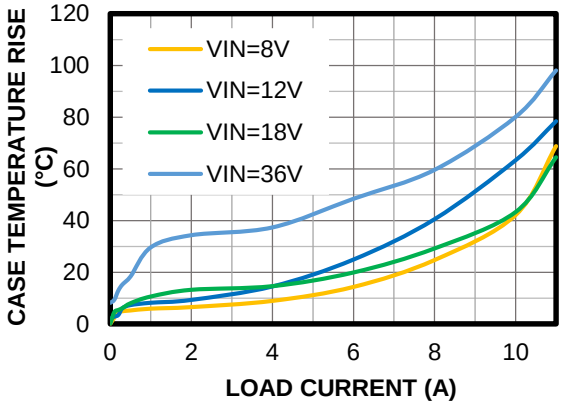
### Case Temperature Rise

AAM mode, $V_{OUT}$ = 5V, $f_{SW}$ = 410kHz, L = 2.2µH (DCR = 13.7mΩ)



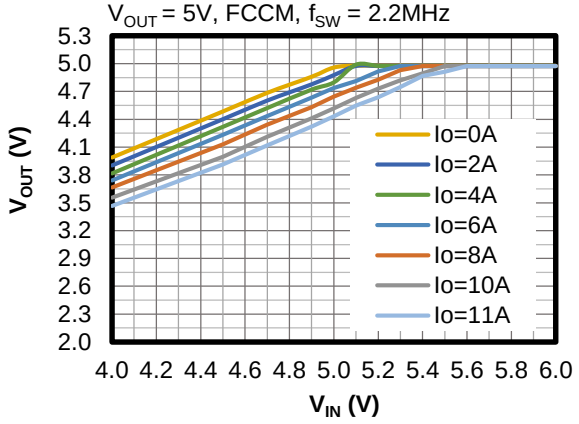

### Case Temperature Rise

AAM mode, $V_{OUT}$ = 3.3V, $f_{SW}$ = 410kHz, L = 2.2µH (DCR = 13.7mΩ)



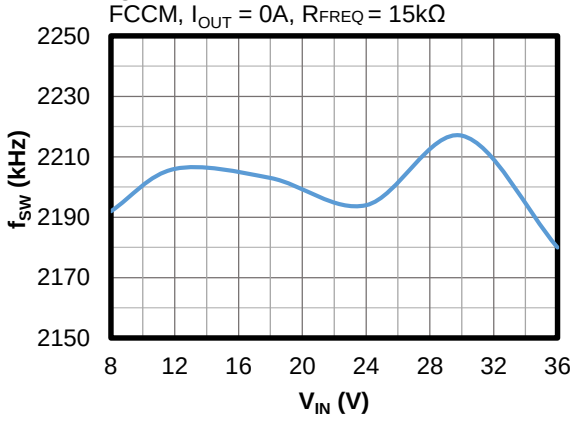

### Low Dropout

$V_{OUT}$ = 5V, FCCM, $f_{SW}$ = 2.2MHz



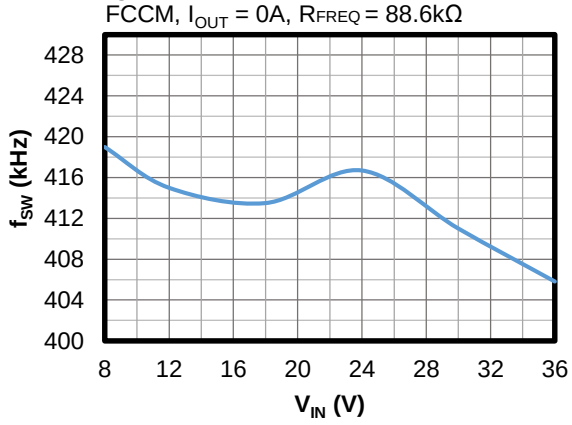

### $f_{SW}$ vs. $V_{IN}$

FCCM, $I_{OUT}$ = 0A, $R_{FREQ}$ = 15kΩ



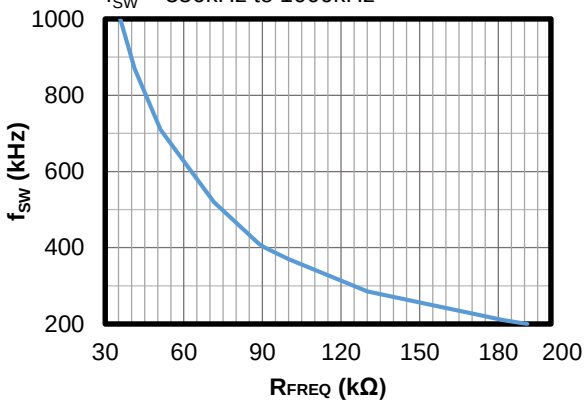

### $f_{SW}$ vs. $V_{IN}$

FCCM, $I_{OUT}$ = 0A, $R_{FREQ}$ = 88.6kΩ




### $f_{SW}$ vs. $R_{FREQ}$

$f_{SW}$ = 350kHz to 1000kHz





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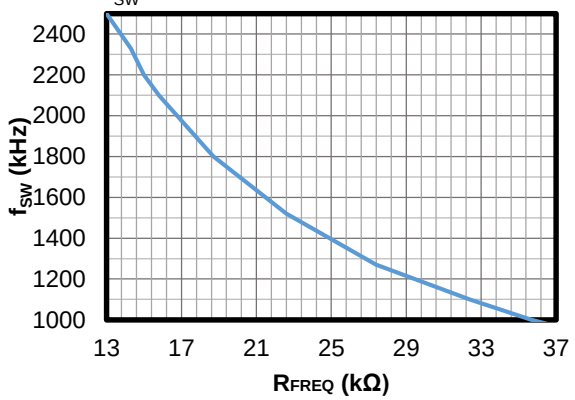
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, $f_{SW}$ = 2.2MHz, L = 0.56µH (DCR = 3mΩ), $T_A$ = 25°C, unless otherwise noted.**

**$f_{SW}$ vs. $R_{FREQ}$**

$f_{SW}$ = 1000kHz to 2500kHz





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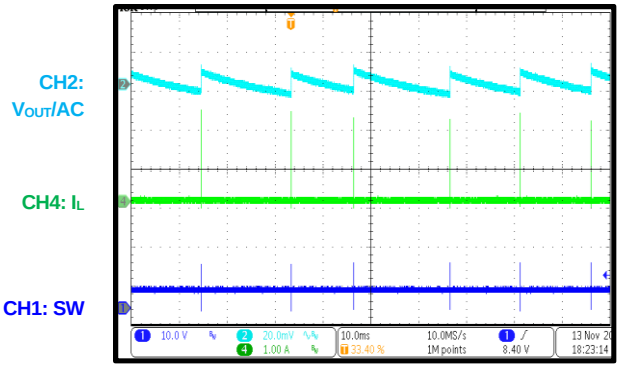
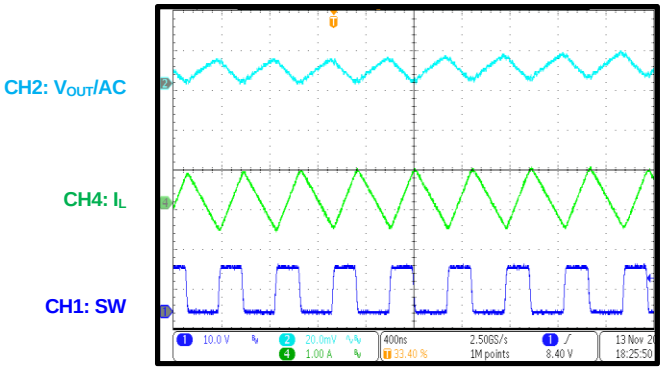
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, single-phase, L = 0.56µH, $f_{SW}$ = 2.2MHz, AAM mode, $T_A$ = 25°C, unless otherwise noted.**

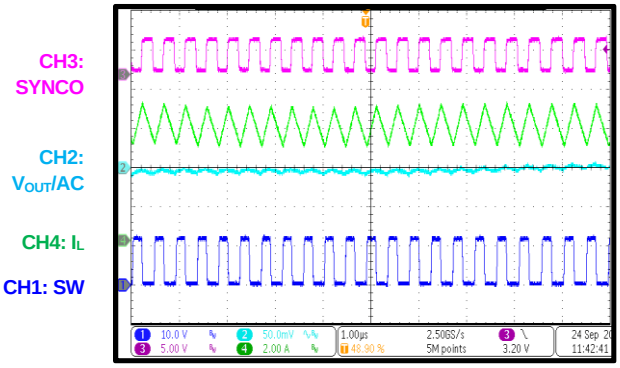
**Steady State**
$I_{OUT}$ = 0A, AAM mode



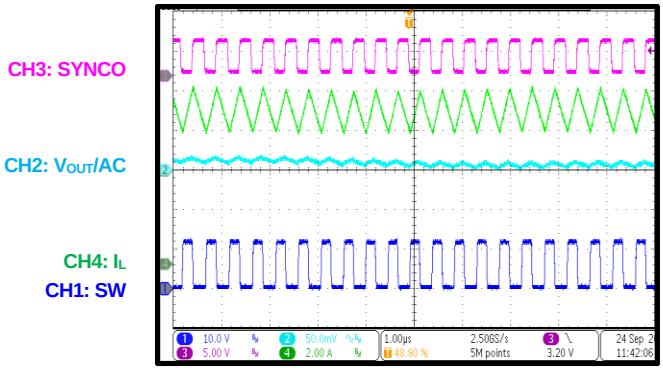

**Steady State**
$I_{OUT}$ = 0A, FCCM



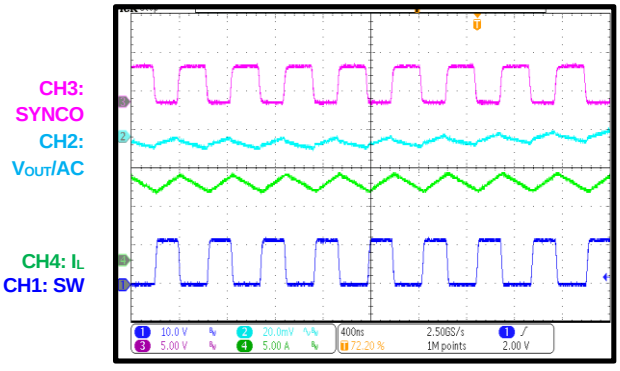

**Steady State**
$I_{OUT}$ = 6A



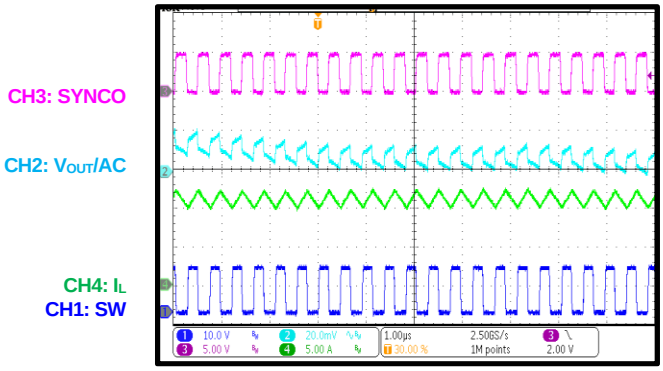

**Steady State**
$I_{OUT}$ = 8A




**Steady State**
$I_{OUT}$ = 10A




**Steady State**
$I_{OUT}$ = 11A





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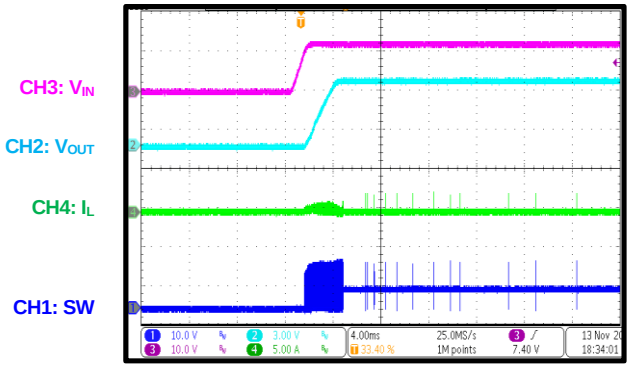
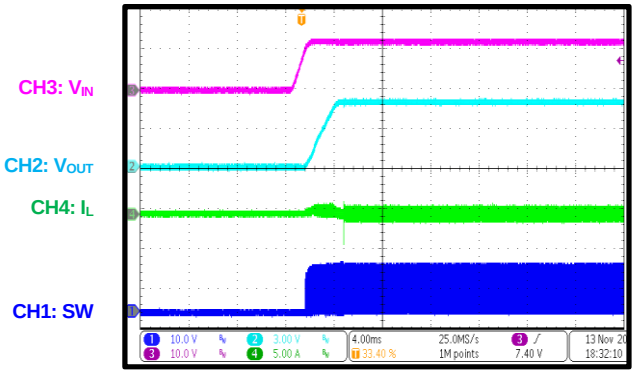
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, single-phase, L = 0.56µH, $f_{SW}$ = 2.2MHz, AAM mode, $T_A$ = 25°C, unless otherwise noted.**

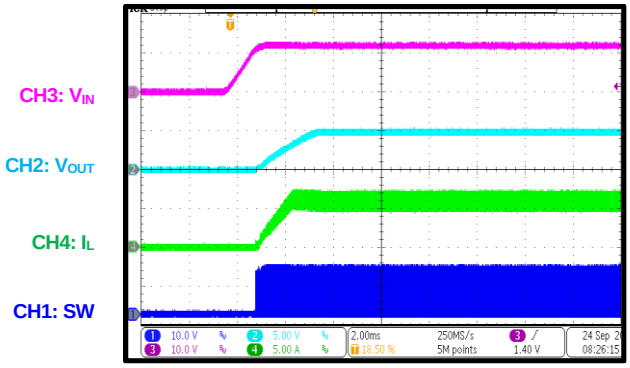
### Start-Up through VIN
$I_{OUT}$ = 0A, AAM mode



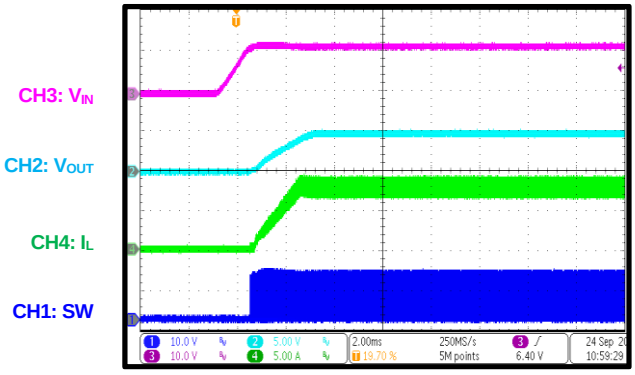

### Start-Up through VIN
$I_{OUT}$ = 0A, FCCM



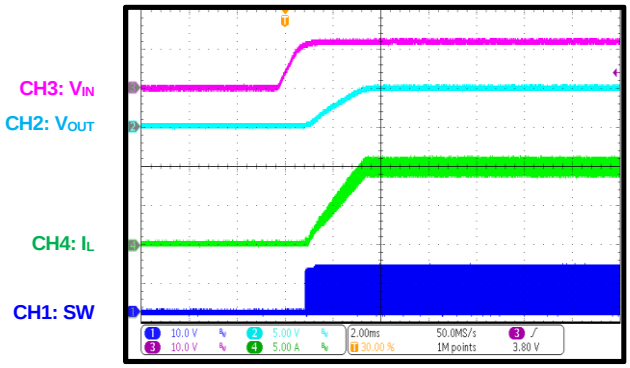

### Start-Up through VIN
$I_{OUT}$ = 6A



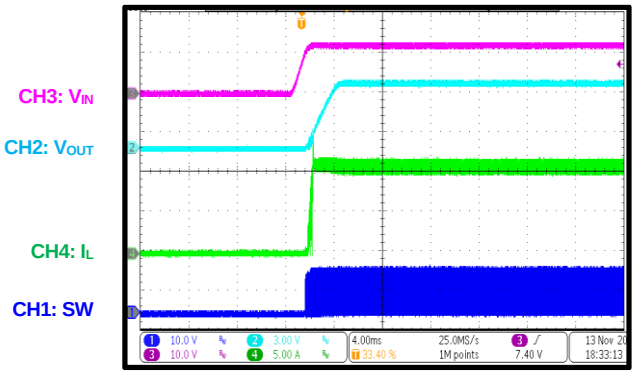

### Start-Up through VIN
$I_{OUT}$ = 8A




### Start-Up through VIN
$I_{OUT}$ = 10A




### Start-Up through VIN
$I_{OUT}$ = 11A





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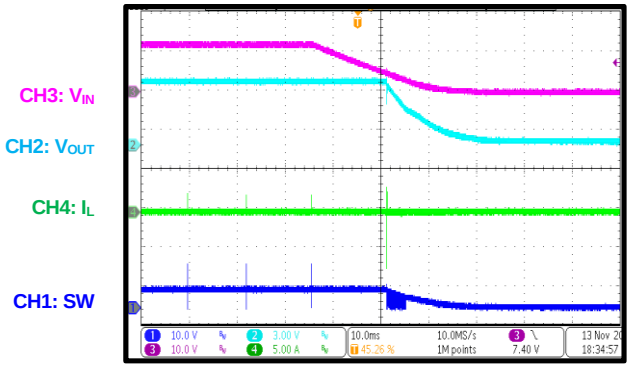
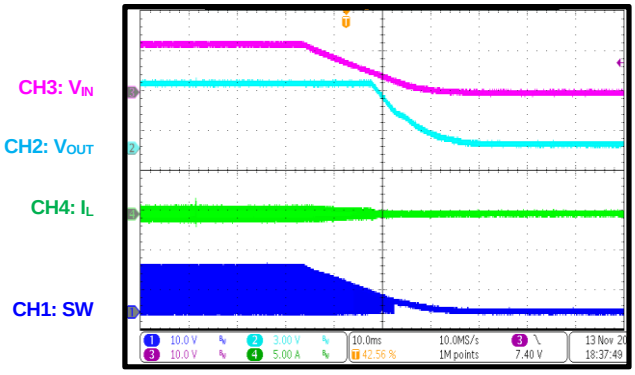
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, single-phase, L = 0.56µH, $f_{SW}$ = 2.2MHz, AAM mode, $T_A$ = 25°C, unless otherwise noted.**

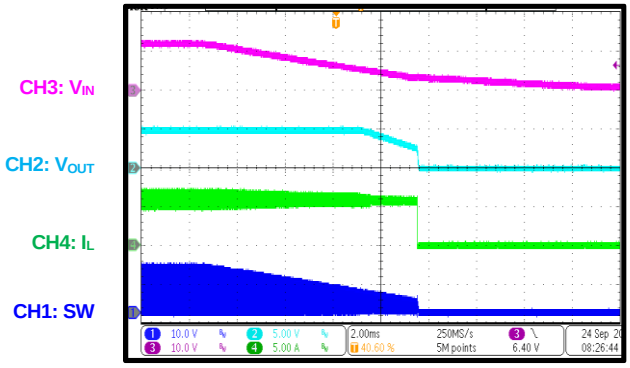
### Shutdown through VIN
$I_{OUT}$ = 0A, AAM mode



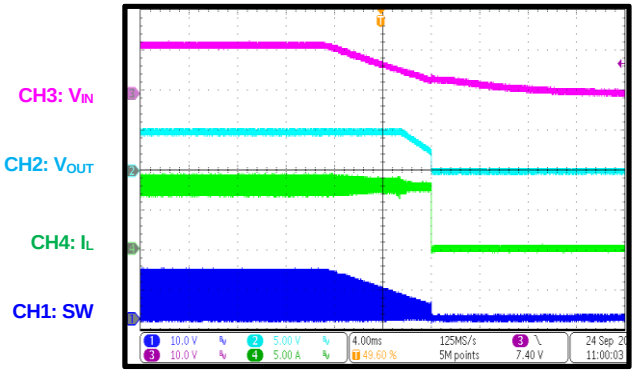

### Shutdown through VIN
$I_{OUT}$ = 0A, FCCM



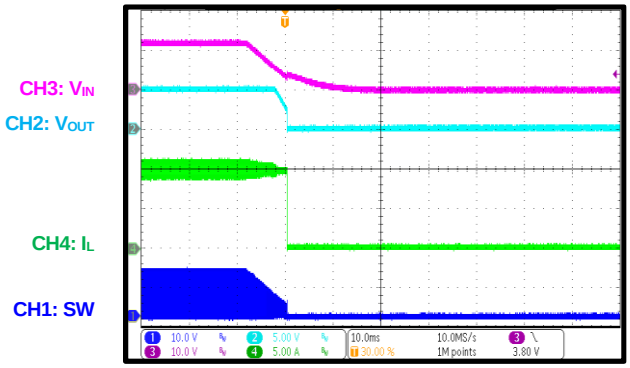

### Shutdown through VIN
$I_{OUT}$ = 6A



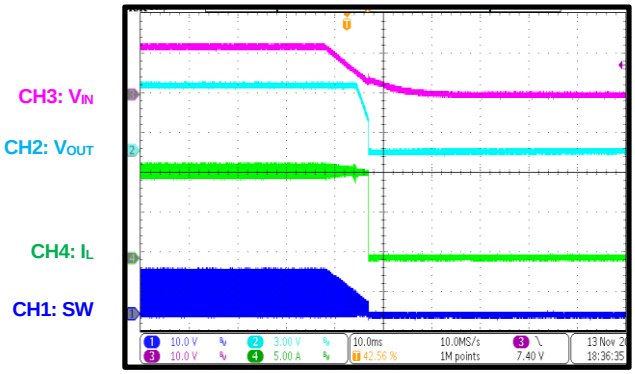

### Shutdown through VIN
$I_{OUT}$ = 8A




### Shutdown through VIN
$I_{OUT}$ = 10A




### Shutdown through VIN
$I_{OUT}$ = 11A





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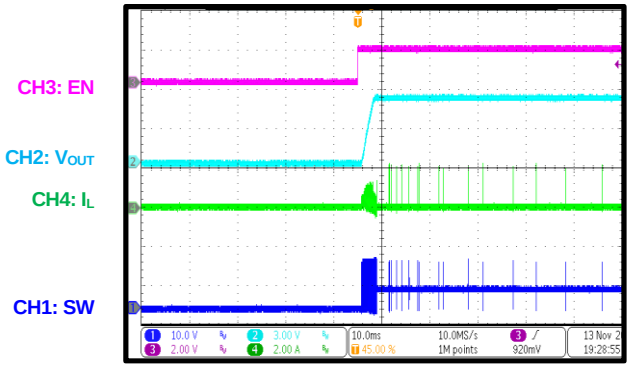
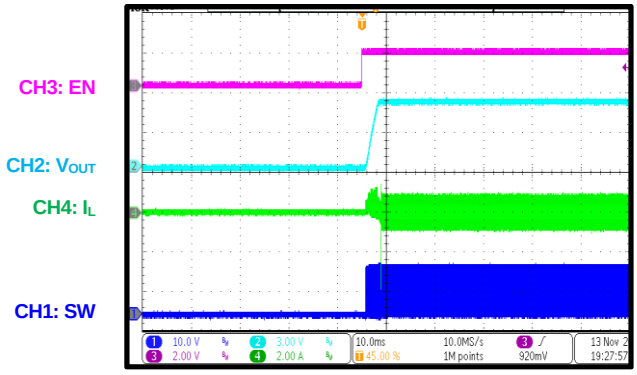
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, single-phase, L = 0.56µH, $f_{SW}$ = 2.2MHz, AAM mode, $T_A$ = 25°C, unless otherwise noted.**

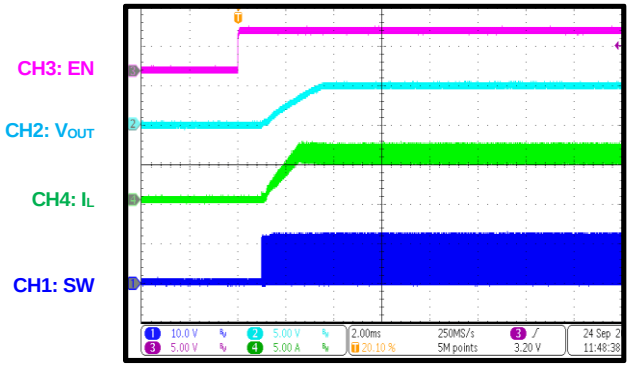
### Start-Up through EN
$I_{OUT}$ = 0A, AAM mode



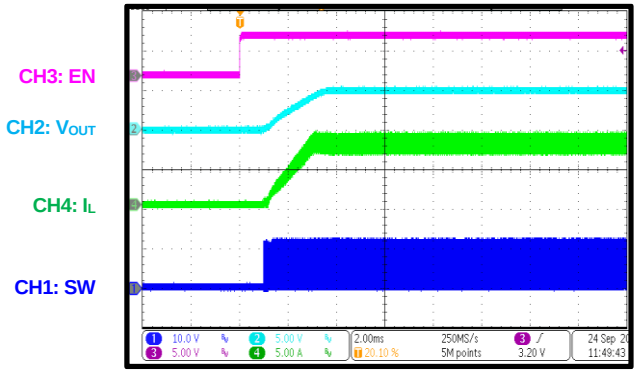

### Start-Up through EN
$I_{OUT}$ = 0A, FCCM



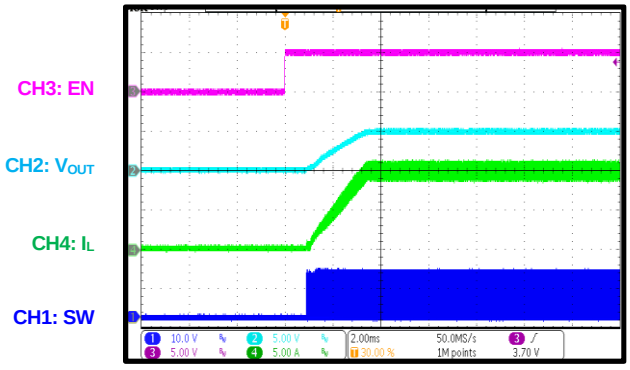

### Start-Up through EN
$I_{OUT}$ = 6A



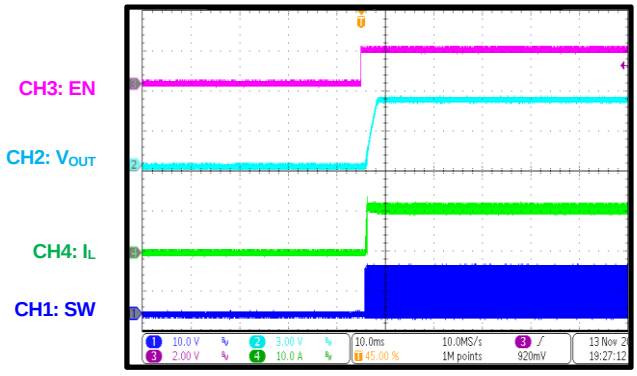

### Start-Up through EN
$I_{OUT}$ = 8A




### Start-Up through EN
$I_{OUT}$ = 10A




### Start-Up through EN
$I_{OUT}$ = 11A





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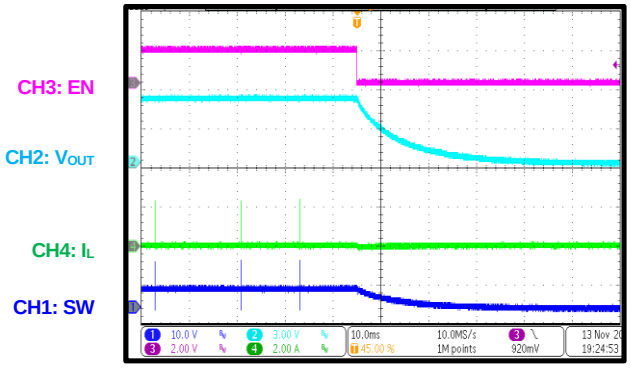
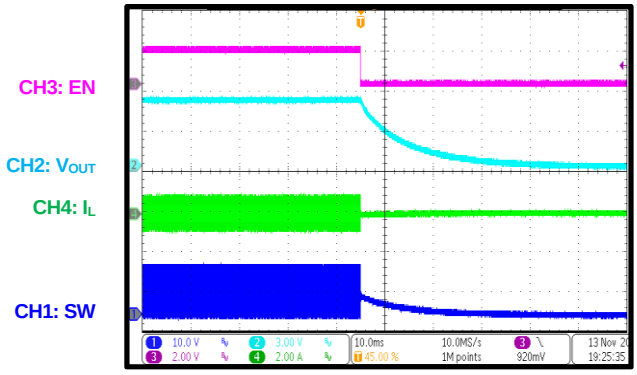
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, single-phase, L = 0.56µH, $f_{SW}$ = 2.2MHz, AAM mode, $T_A$ = 25°C, unless otherwise noted.**

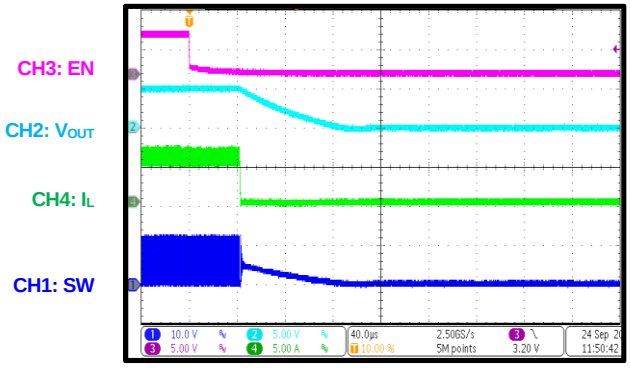
### Shutdown through EN
$I_{OUT}$ = 0A, AAM mode



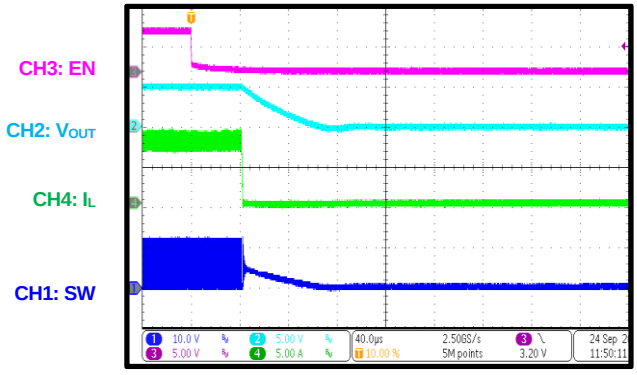

### Shutdown through EN
$I_{OUT}$ = 0A, FCCM



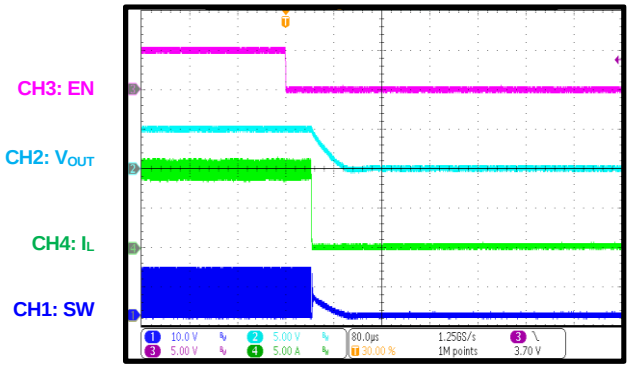

### Shutdown through EN
$I_{OUT}$ = 6A



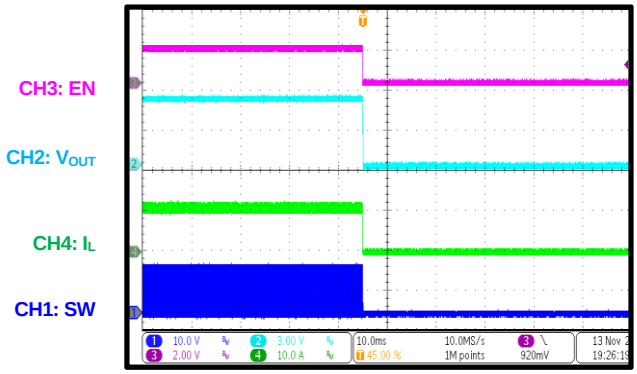

### Shutdown through EN
$I_{OUT}$ = 8A




### Shutdown through EN
$I_{OUT}$ = 10A




### Shutdown through EN
$I_{OUT}$ = 11A





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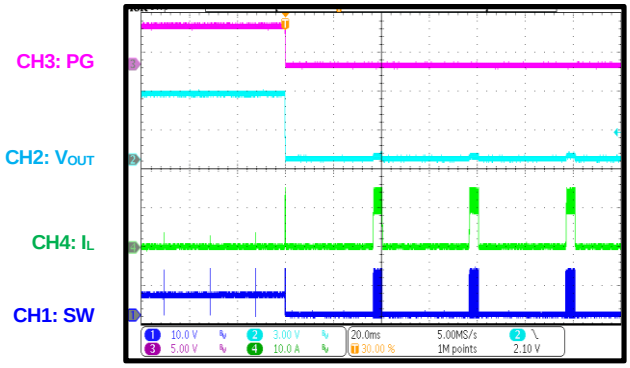
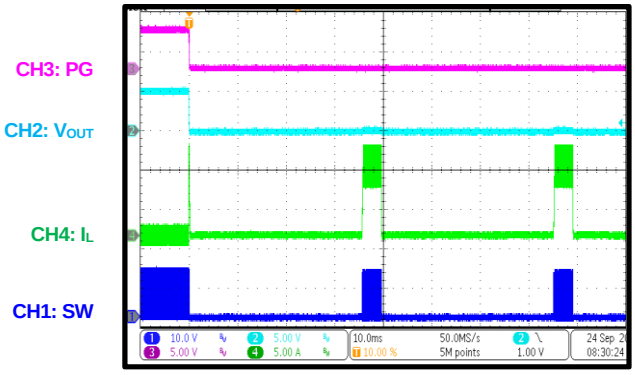
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, single-phase, L = 0.56µH, $f_{SW}$ = 2.2MHz, AAM mode, $T_A$ = 25°C, unless otherwise noted.**

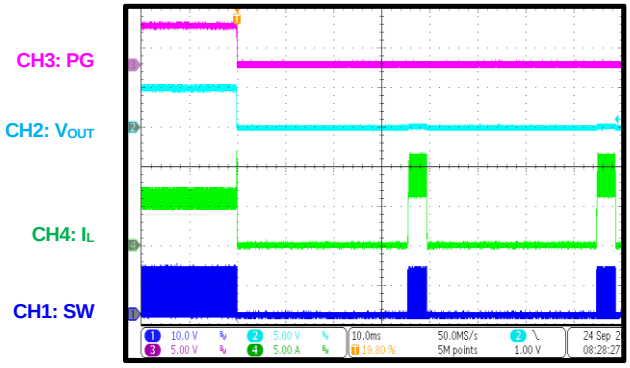
### SCP Entry
MPQ4371-6xxx, $I_{OUT}$ = 0A, AAM mode



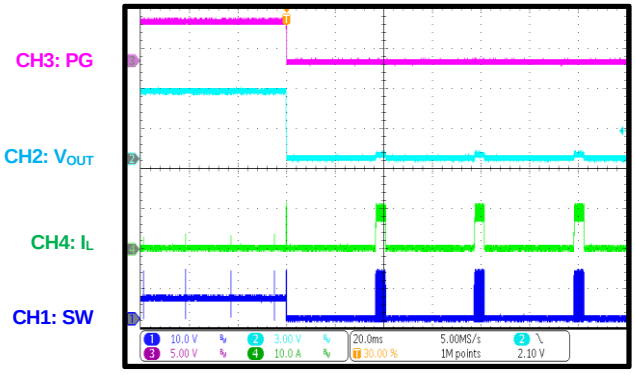

### SCP Entry
MPQ4371-6xxx, $I_{OUT}$ = 0A, FCCM



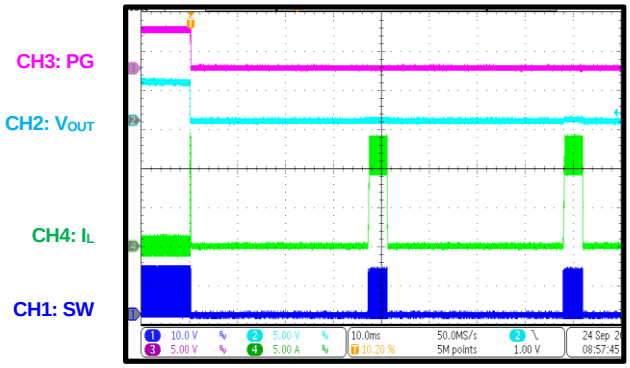

### SCP Entry
MPQ4371-6xxx, $I_{OUT}$ = 6A



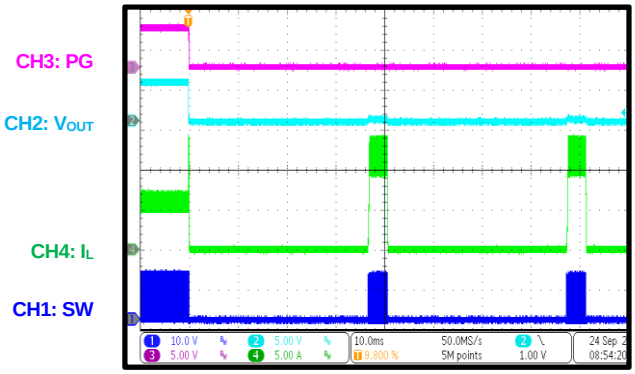

### SCP Entry
MPQ4371-8xxx, $I_{OUT}$ = 0A, AAM mode




### SCP Entry
MPQ4371-8xxx, $I_{OUT}$ = 0A, FCCM




### SCP Entry
MPQ4371-8xxx, $I_{OUT}$ = 8A





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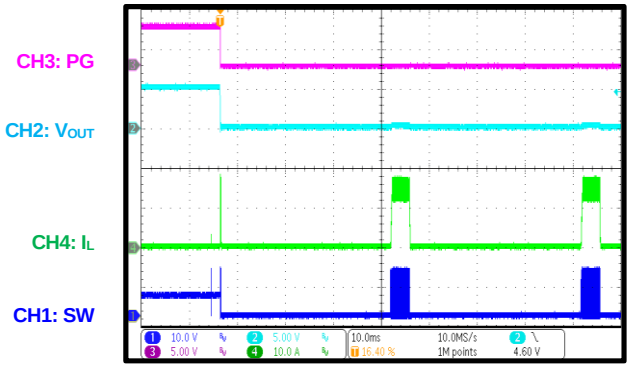
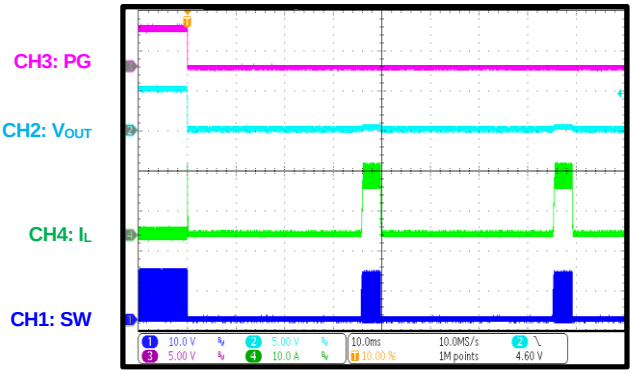
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, single-phase, L = 0.56µH, $f_{SW}$ = 2.2MHz, AAM mode, $T_A$ = 25°C, unless otherwise noted.**

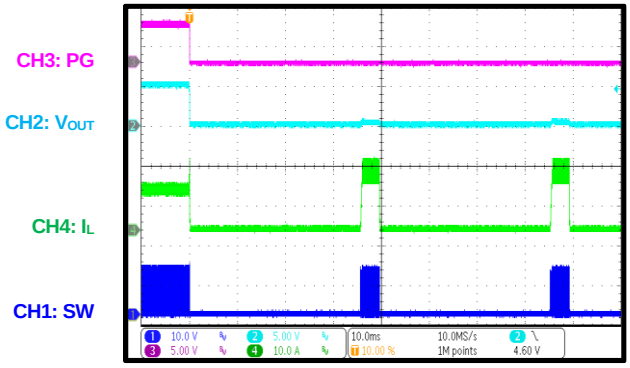
### SCP Entry
MPQ4371-0xxx, $I_{OUT}$ = 0A, AAM mode



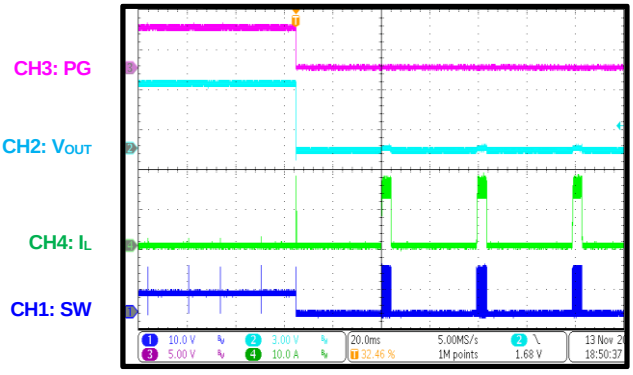

### SCP Entry
MPQ4371-0xxx, $I_{OUT}$ = 0A, FCCM



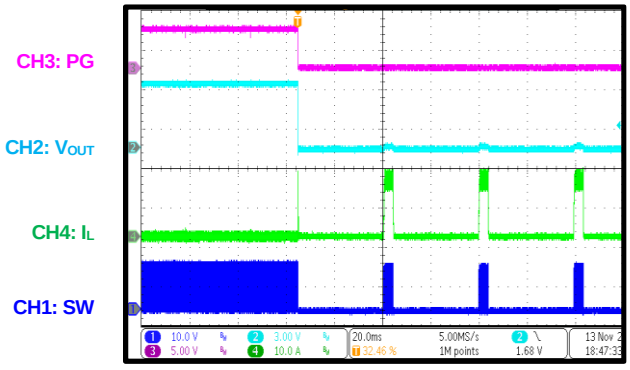

### SCP Entry
MPQ4371-0xxx, $I_{OUT}$ = 10A, FCCM



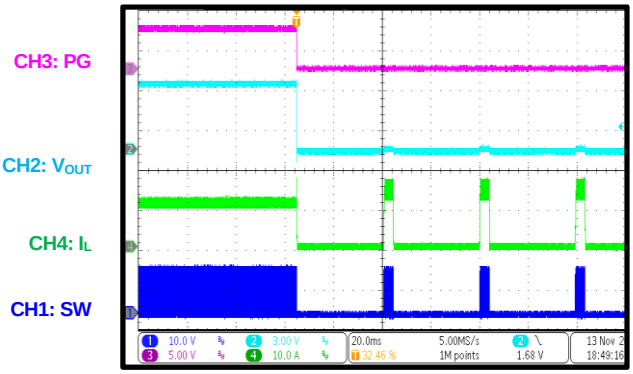

### SCP Entry
MPQ4371-1xxx, $I_{OUT}$ = 0A, AAM mode




### SCP Entry
MPQ4371-1xxx, $I_{OUT}$ = 0A, FCCM




### SCP Entry
MPQ4371-1xxx, $I_{OUT}$ = 11A





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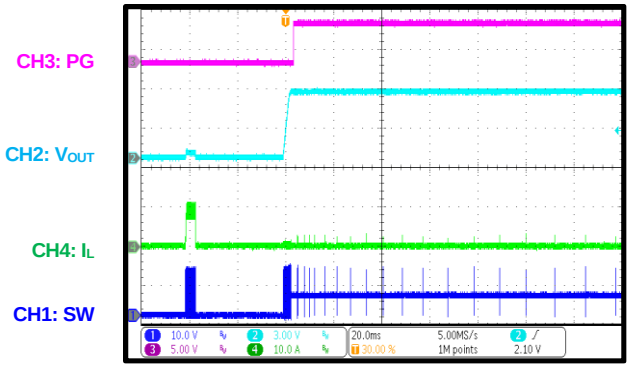
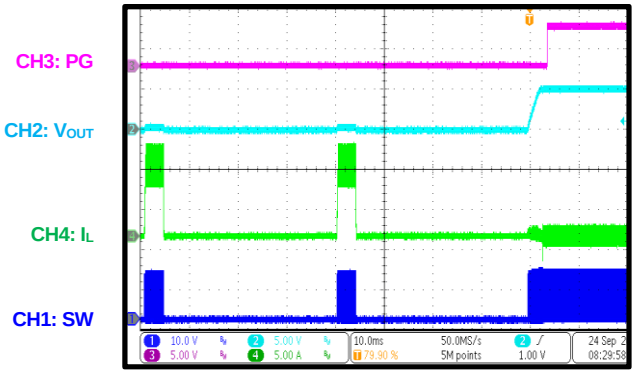
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, single-phase, L = 0.56µH, $f_{SW}$ = 2.2MHz, AAM mode, $T_A$ = 25°C, unless otherwise noted.**

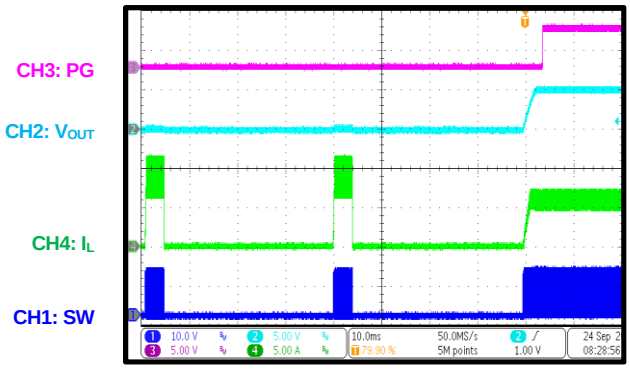
### SCP Recovery
MPQ4371-6xxx, $I_{OUT}$ = 0A, AAM mode



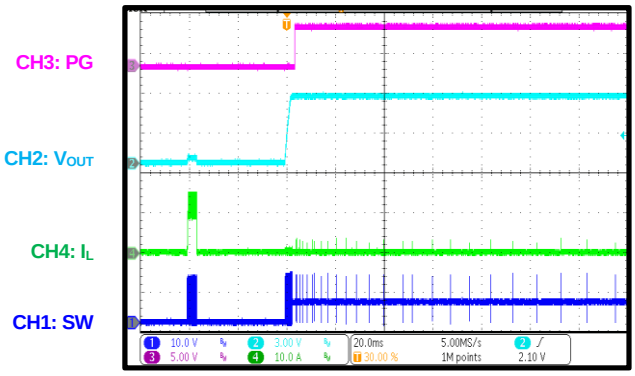

### SCP Recovery
MPQ4371-6xxx, $I_{OUT}$ = 0A, FCCM



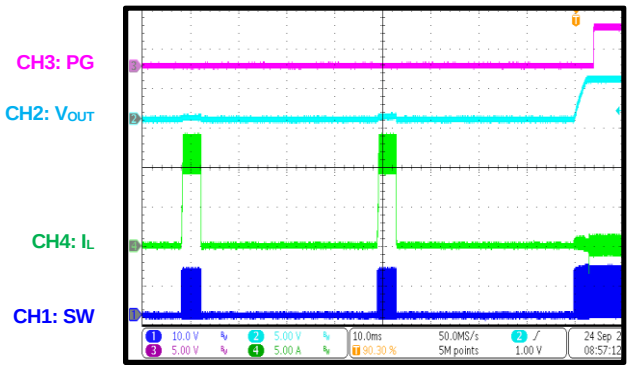

### SCP Recovery
MPQ4371-6xxx, $I_{OUT}$ = 6A



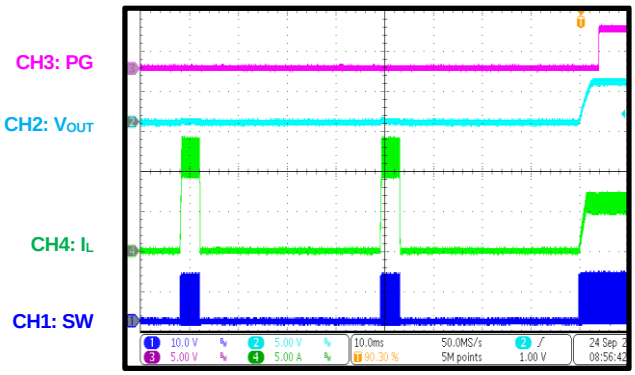

### SCP Recovery
MPQ4371-8xxx, $I_{OUT}$ = 0A, AAM mode




### SCP Recovery
MPQ4371-8xxx, $I_{OUT}$ = 8A, FCCM




### SCP Recovery
MPQ4371-8xxx, $I_{OUT}$ = 8A





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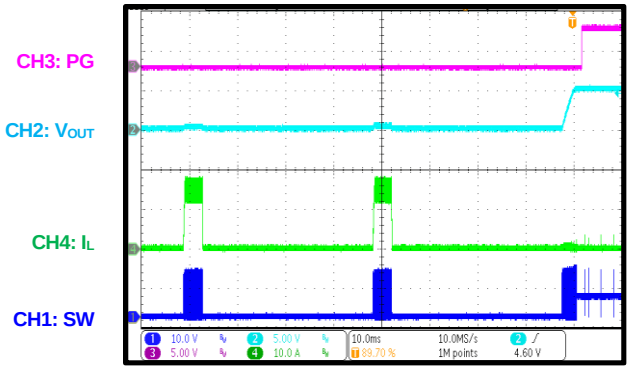
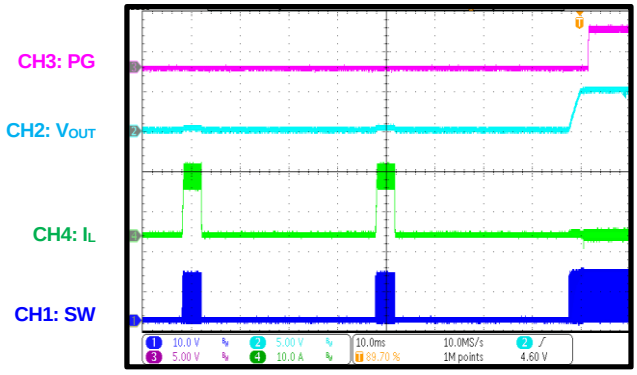
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, single-phase, L = 0.56µH, $f_{SW}$ = 2.2MHz, AAM mode, $T_A$ = 25°C, unless otherwise noted.**

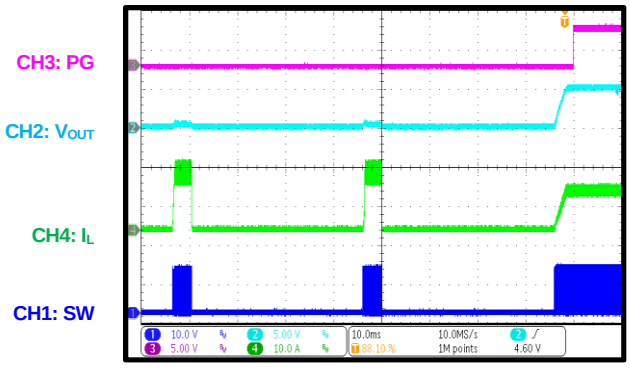
### SCP Recovery
MPQ4371-0xxx, $I_{OUT}$ = 0A, AAM mode



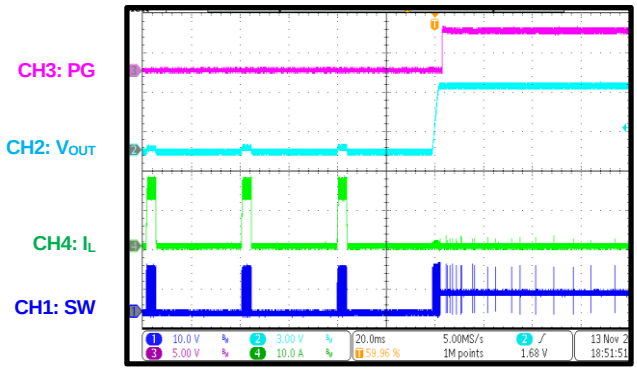

### SCP Recovery
MPQ4371-0xxx, $I_{OUT}$ = 0A, FCCM



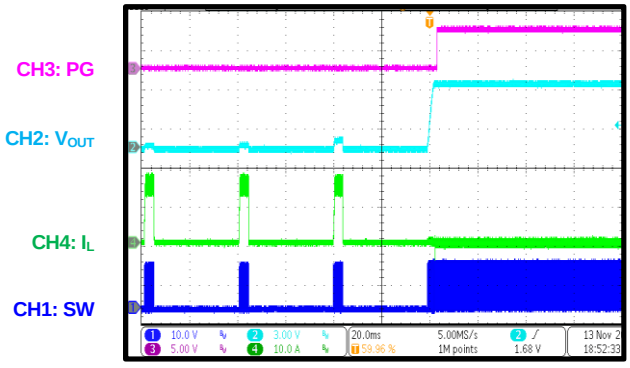

### SCP Recovery
MPQ4371-0xxx, $I_{OUT}$ = 10A



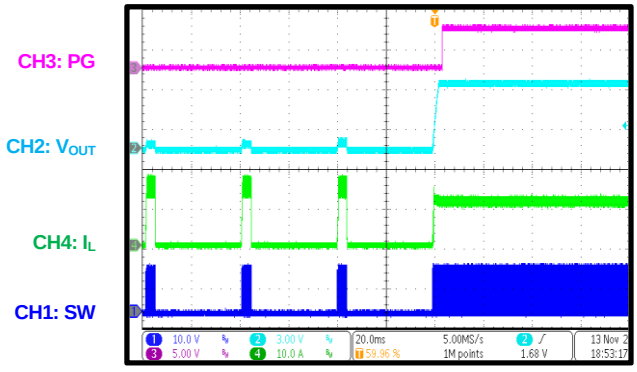

### SCP Recovery
MPQ4371-1xxx, $I_{OUT}$ = 0A, AAM mode




### SCP Recovery
MPQ4371-1xxx, $I_{OUT}$ = 0A, FCCM




### SCP Recovery
MPQ4371-1xxx, $I_{OUT}$ = 11A





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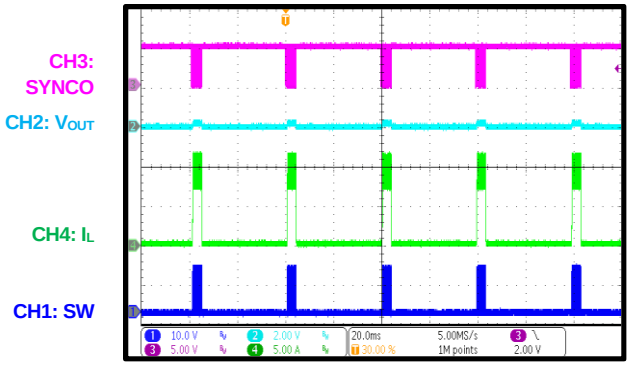
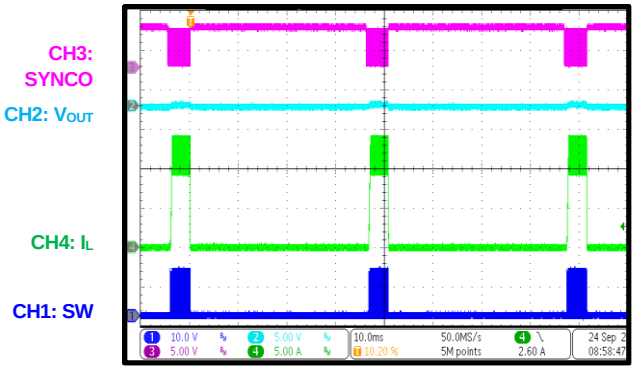
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, single-phase, L = 0.56µH, $f_{SW}$ = 2.2MHz, AAM mode, $T_A$ = 25°C, unless otherwise noted.**

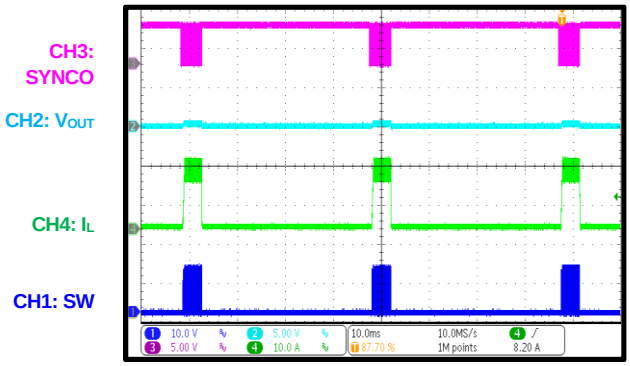
### SCP Steady State
MPQ4371-6xxx



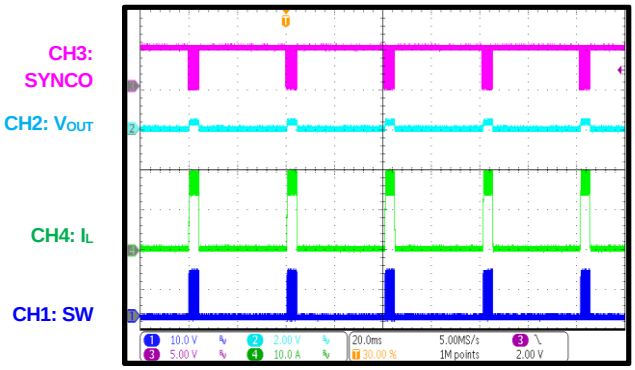

### SCP Steady State
MPQ4371-8xxx



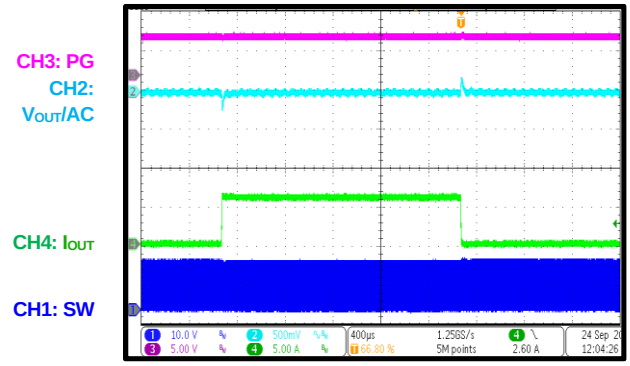

### SCP Steady State
MPQ4371-0xxx



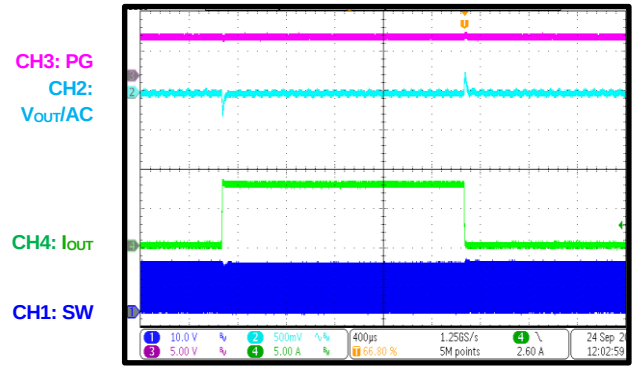

### SCP Steady State
MPQ4371-1xxx




### Load Transient Response
$I_{OUT}$ = 0A to 6A, 1.6A/µs, FCCM




### Load Transient Response
$I_{OUT}$ = 0A to 8A, 1.6A/µs, FCCM





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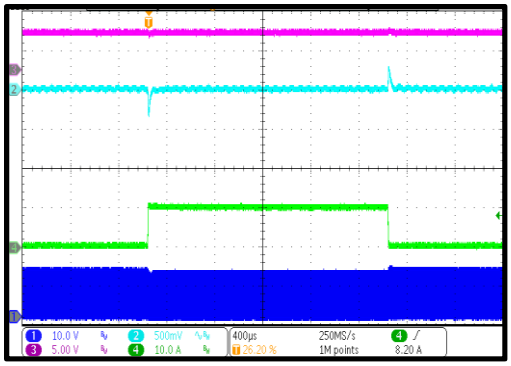
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, single-phase, L = 0.56µH, $f_{SW}$ = 2.2MHz, AAM mode, $T_A$ = 25°C, unless otherwise noted.**

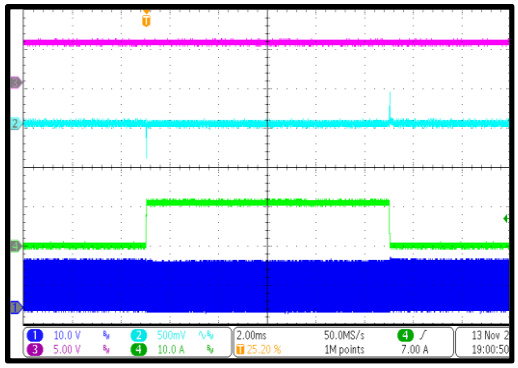
### Load Transient Response

$I_{OUT}$ = 0A to 10A, 1.6A/µs, FCCM



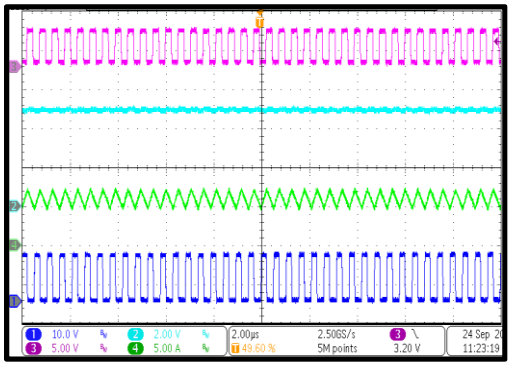

### Load Transient Response

$I_{OUT}$ = 0A to 11A, 1.6A/µs, FCCM



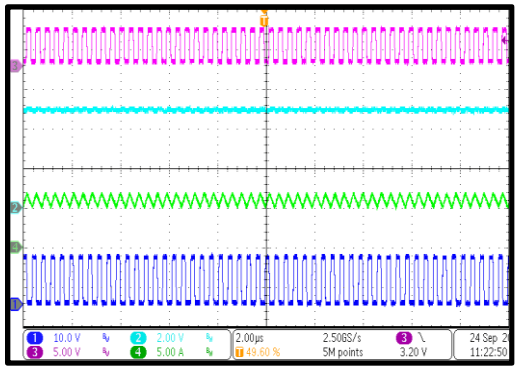

### SYNCIN Operation

$I_{OUT}$ = 6A, $f_{SW}$ = 2.2MHz,
SYNC frequency = 1.9MHz



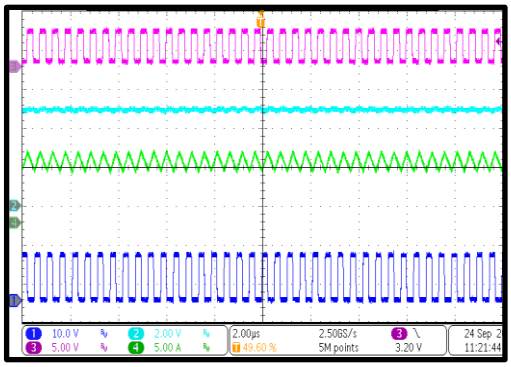

### SYNCIN Operation

$I_{OUT}$ = 6A, $f_{SW}$ = 2.2MHz,
SYNC frequency = 2.6MHz



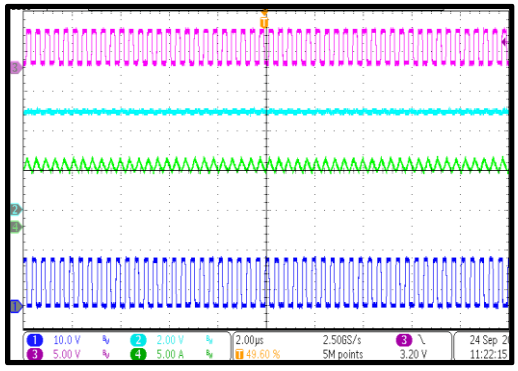

### SYNCIN Operation

$I_{OUT}$ = 8A, $f_{SW}$ = 2.2MHz,
SYNC frequency = 1.9MHz




### SYNCIN Operation

$I_{OUT}$ = 8A, $f_{SW}$ = 2.2MHz,
SYNC frequency = 2.6MHz





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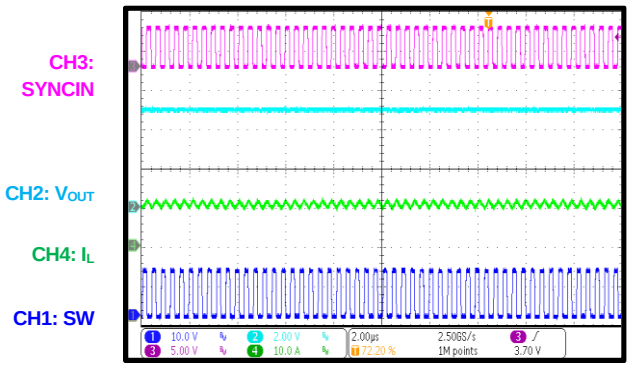
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, single-phase, L = 0.56µH, $f_{SW}$ = 2.2MHz, AAM mode, $T_A$ = 25°C, unless otherwise noted.**

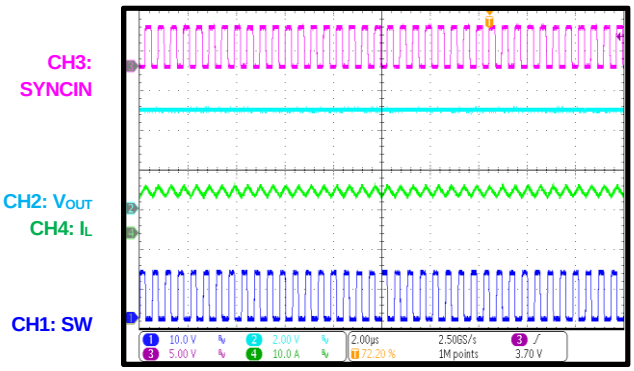
### SYNCIN Operation

$I_{OUT}$ = 10A, $f_{SW}$ = 2.2MHz,
SYNC frequency = 1.9MHz



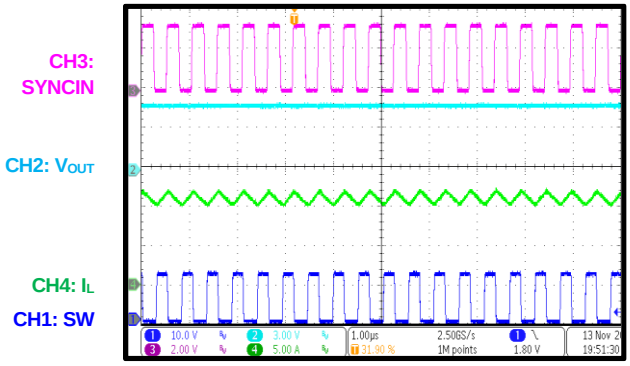

### SYNCIN Operation

$I_{OUT}$ = 10A, $f_{SW}$ = 2.2MHz,
SYNC frequency = 2.6MHz



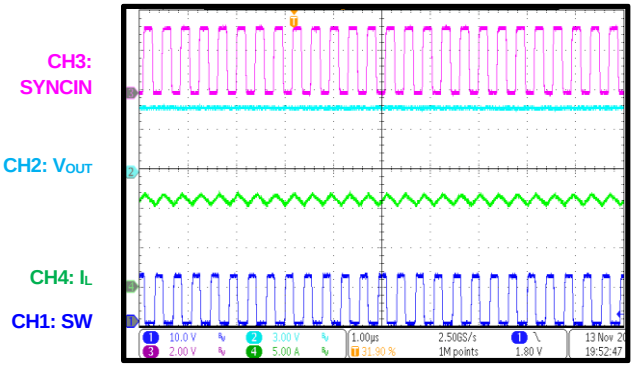

### SYNCIN Operation

$I_{OUT}$ = 11A, $f_{SW}$ = 2.2MHz,
SYNC frequency = 1.9MHz



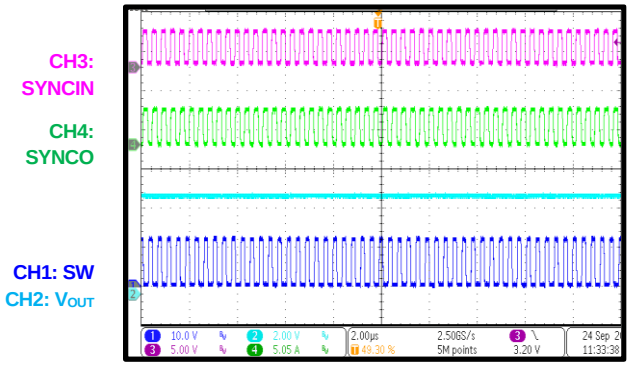

### SYNCIN Operation

$I_{OUT}$ = 11A, $f_{SW}$ = 2.2MHz,
SYNC frequency = 2.6MHz



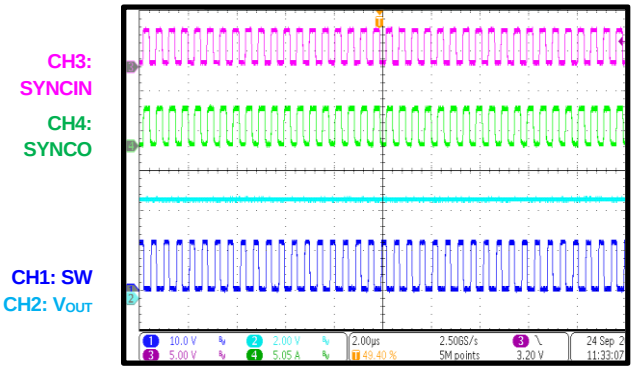

### SYNCO Operation

$I_{OUT}$ = 11A, $f_{SW}$ = 2.2MHz,
SYNC frequency = 1.9MHz




### SYNCO Operation

$I_{OUT}$ = 11A, $f_{SW}$ = 2.2MHz,
SYNC frequency = 2.6MHz





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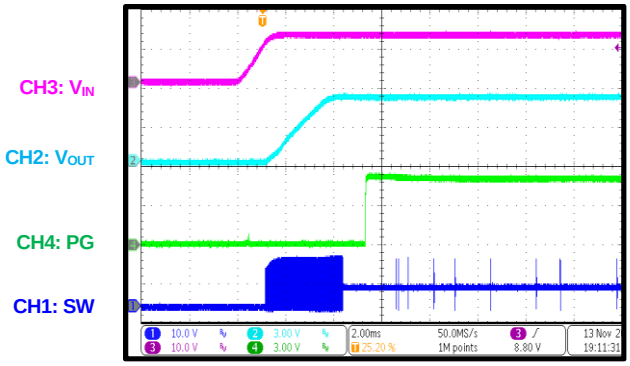
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, single-phase, L = 0.56µH, $f_{SW}$ = 2.2MHz, AAM mode, $T_A$ = 25°C, unless otherwise noted.**

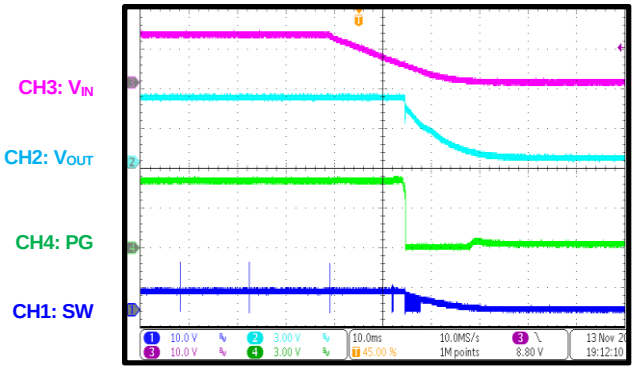
### PG in Start-Up through VIN

$I_{OUT}$ = 0A, AAM mode



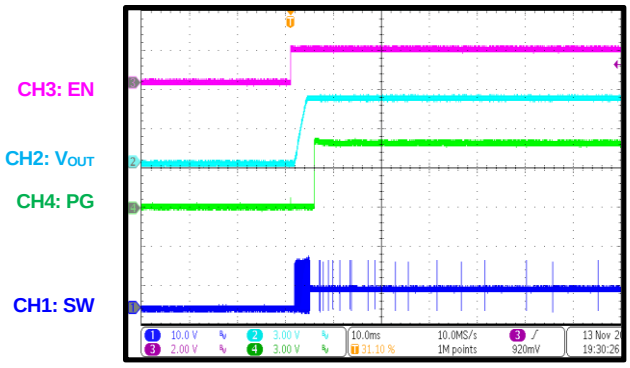

### PG in Shutdown through VIN

$I_{OUT}$ = 0A, AAM mode



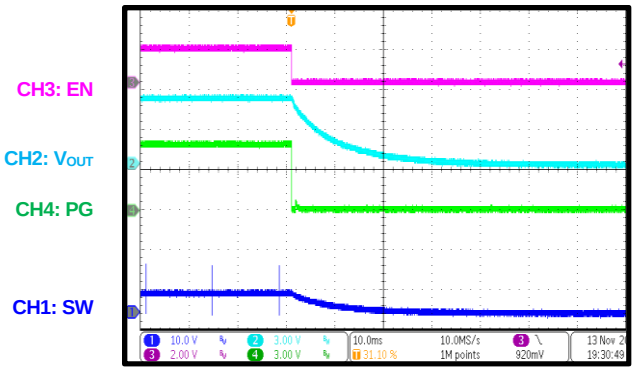

### PG in Start-Up through EN

$I_{OUT}$ = 0A, AAM mode



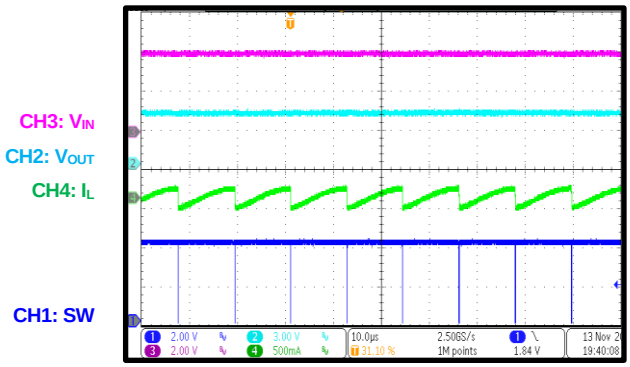

### PG in Shutdown through EN

$I_{OUT}$ = 0A, AAM mode



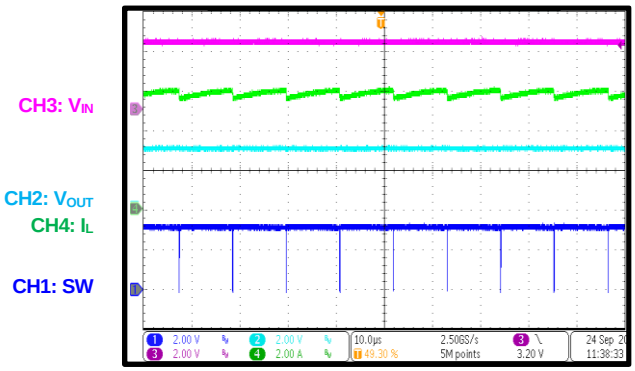

### Dropout Operation

$V_{IN}$ = 4V, $V_{OUT}$ set to 5V, $I_{OUT}$ = 0A




### Dropout Operation

$V_{IN}$ = 4V, $V_{OUT}$ set to 5V, $I_{OUT}$ = 6A





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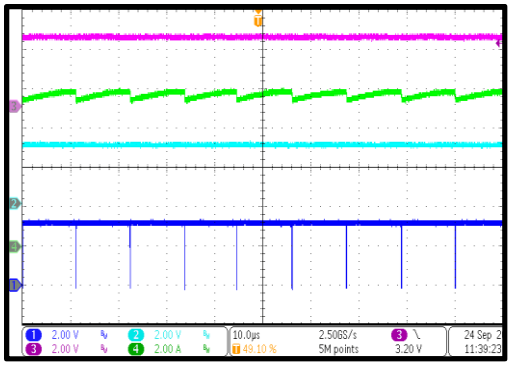
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, single-phase, L = 0.56µH, $f_{SW}$ = 2.2MHz, AAM mode, $T_A$ = 25°C, unless otherwise noted.**

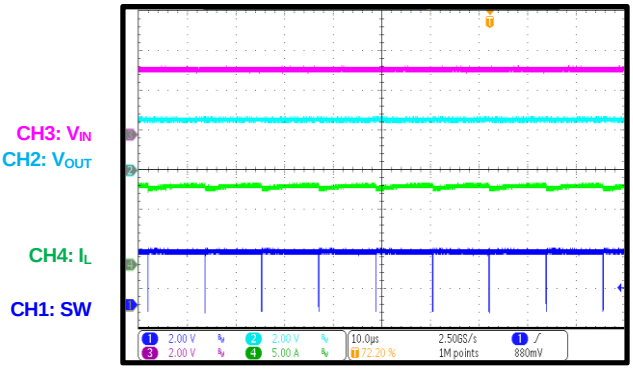
### Dropout Operation

$V_{IN}$ = 4V, $V_{OUT}$ set to 5V, $I_{OUT}$ = 8A



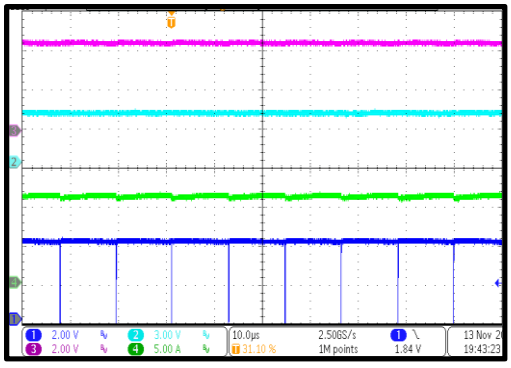

### Dropout Operation

$V_{IN}$ = 4V, $V_{OUT}$ set to 5V, $I_{OUT}$ = 10A



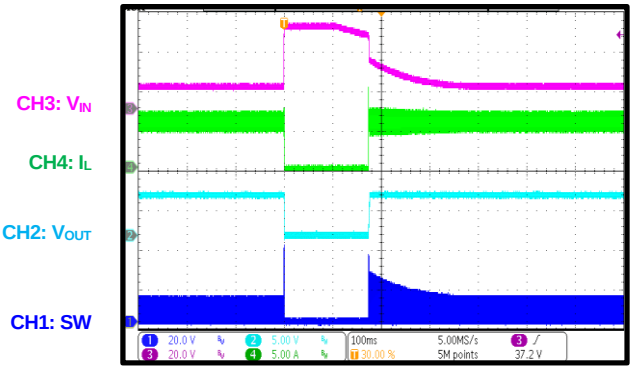

### Dropout Operation

$V_{IN}$ = 3.3V, $V_{OUT}$ set to 5V, $I_{OUT}$ = 11A



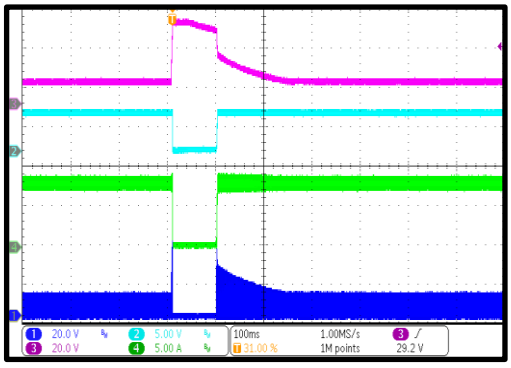

### Load Dump

$V_{IN}$ = 12V to 42V, $I_{OUT}$ = 6A



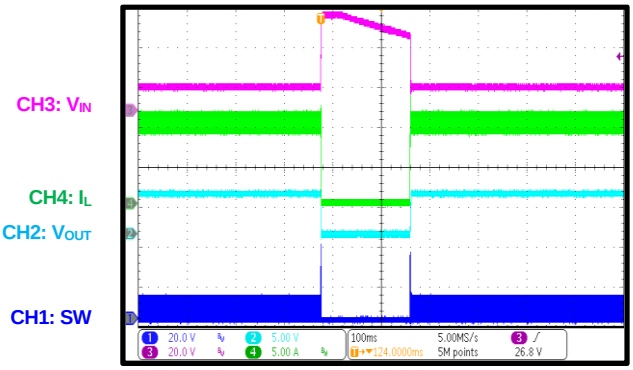

### Load Dump

$V_{IN}$ = 12V to 42V, $I_{OUT}$ = 8A




### Load Dump

$V_{IN}$ = 12V to 42V, $I_{OUT}$ = 10A





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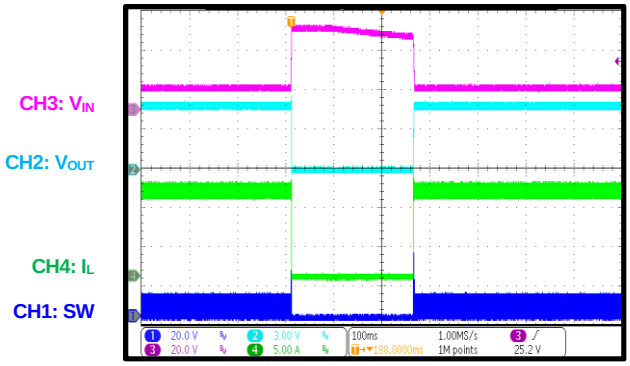
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, single-phase, L = 0.56µH, $f_{SW}$ = 2.2MHz, AAM mode, $T_A$ = 25°C, unless otherwise noted.**

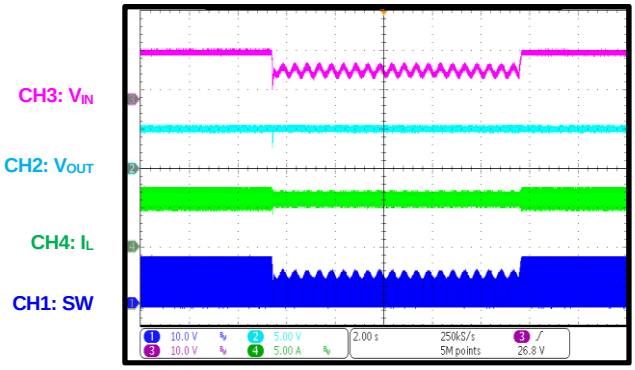
### Load Dump

$V_{IN}$ = 12V to 42V, $I_{OUT}$ = 11A



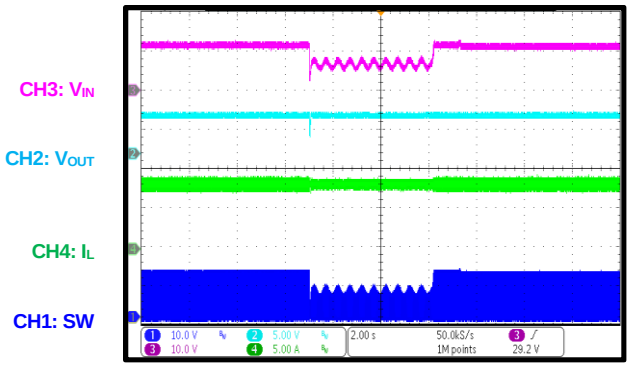

### Cold Crank

$I_{OUT}$ = 6A



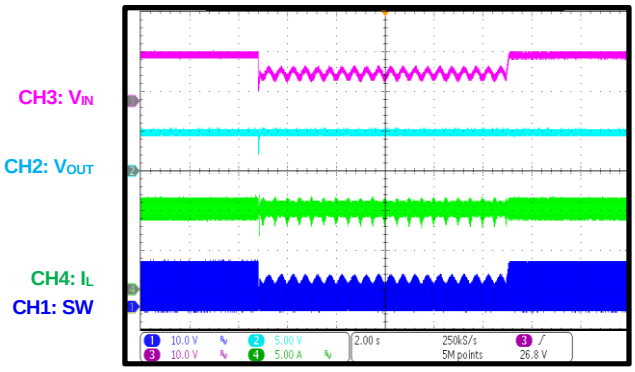

### Cold Crank

$I_{OUT}$ = 8A



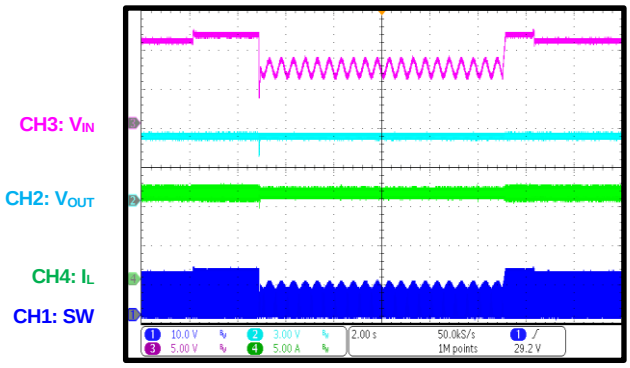

### Cold Crank

$I_{OUT}$ = 10A



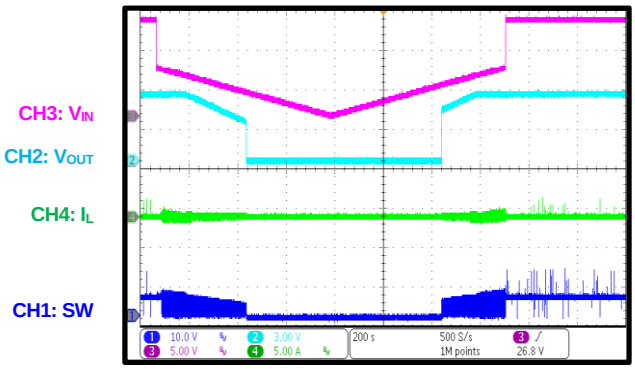

### Cold Crank

$I_{OUT}$ = 11A




### $V_{IN}$ Ramping Down and Up

$I_{OUT}$ = 0A, AAM mode





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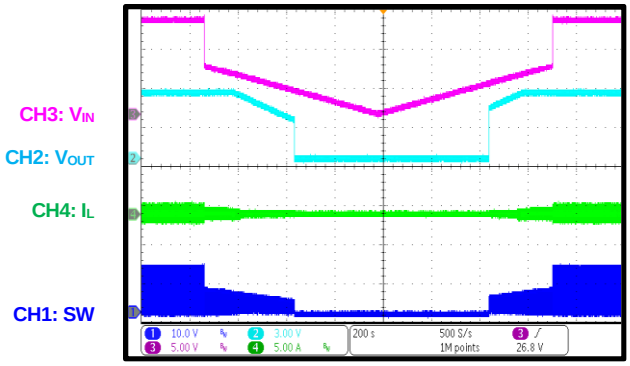
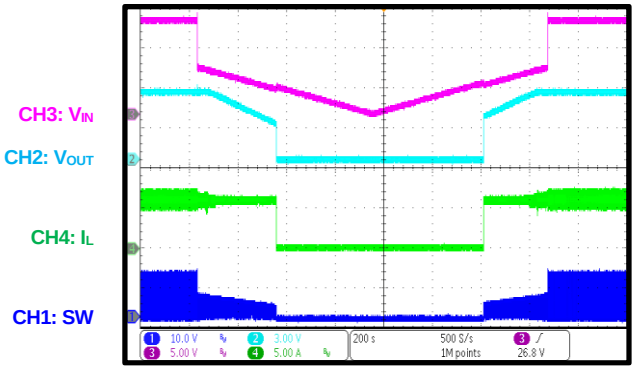
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, single-phase, L = 0.56µH, $f_{SW}$ = 2.2MHz, AAM mode, $T_A$ = 25°C, unless otherwise noted.**

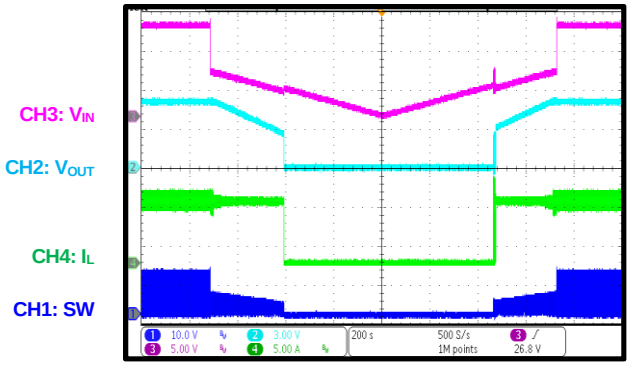
### $V_{IN}$ Ramping Down and Up
$I_{OUT}$ = 0A, FCCM



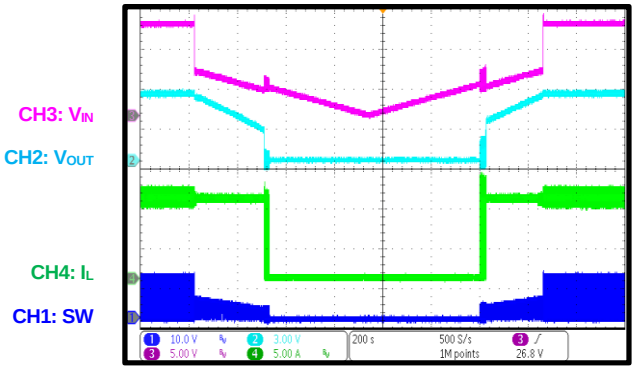

### $V_{IN}$ Ramping Down and Up
$I_{OUT}$ = 6A



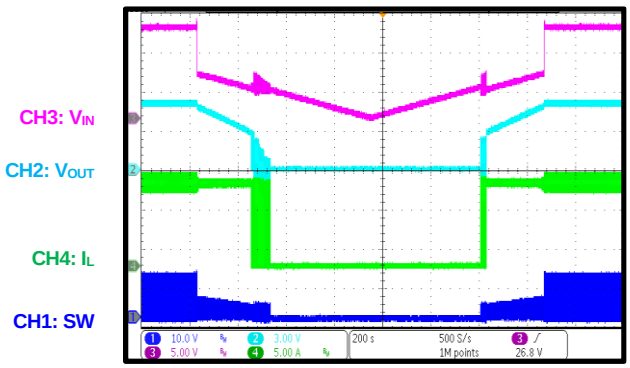

### $V_{IN}$ Ramping Down and Up
$I_{OUT}$ = 8A




### $V_{IN}$ Ramping Down and Up
$I_{OUT}$ = 10A




### $V_{IN}$ Ramping Down and Up
$I_{OUT}$ = 11A





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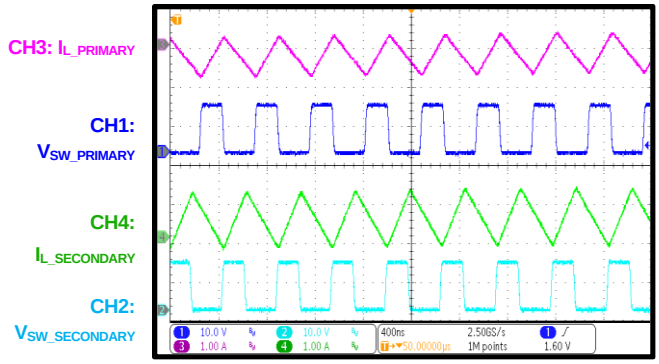
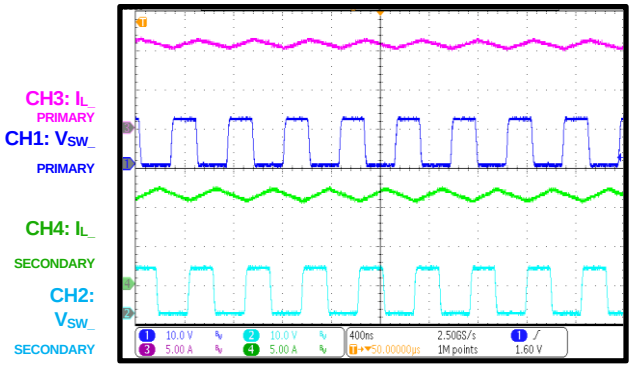
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, dual-phase, L = 0.56µH, $f_{SW}$ = 2.2MHz, AAM mode, $T_A$ = 25°C, unless otherwise noted.**

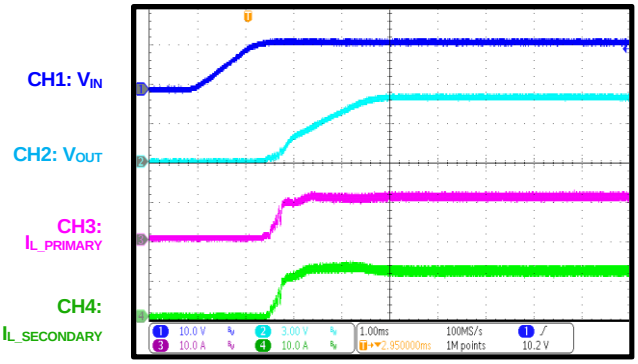
### Steady State
$I_{OUT}$ = 0A



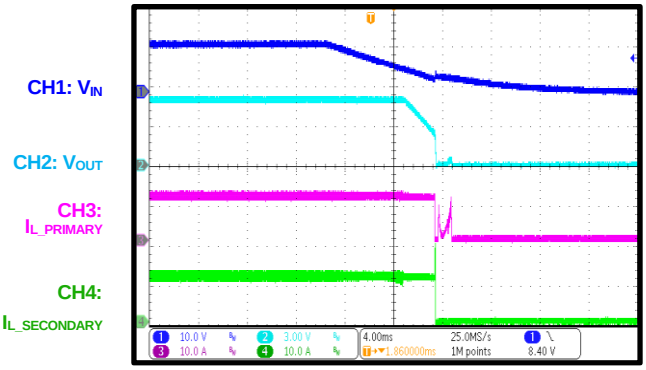

### Steady State
$I_{OUT}$ = 22A



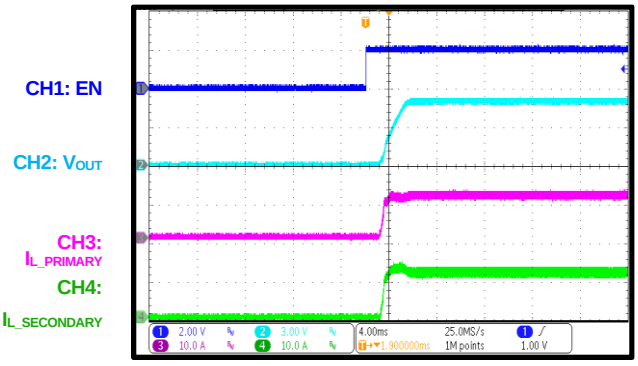

### Start-Up through VIN
$I_{OUT}$ = 22A



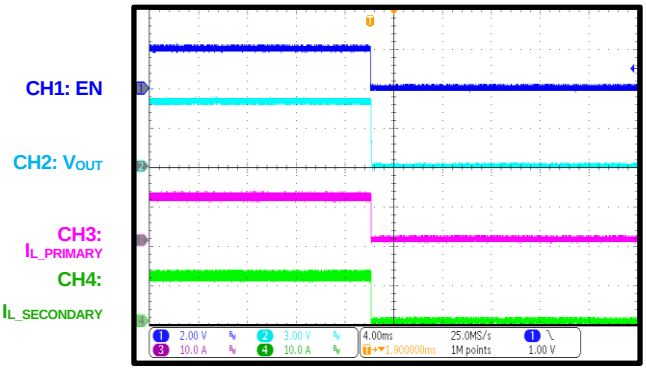

### Shutdown through VIN
$I_{OUT}$ = 22A




### Start-Up through EN
$I_{OUT}$ = 22A




### Shutdown through EN
$I_{OUT}$ = 22A





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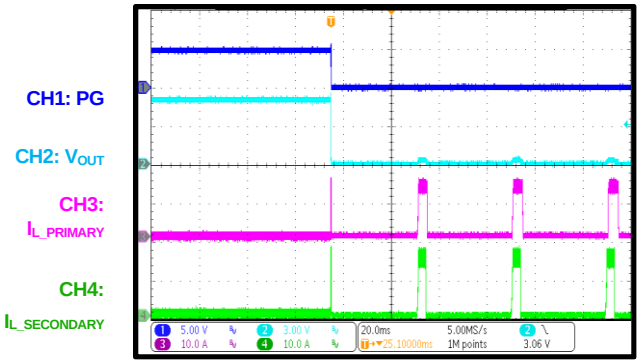
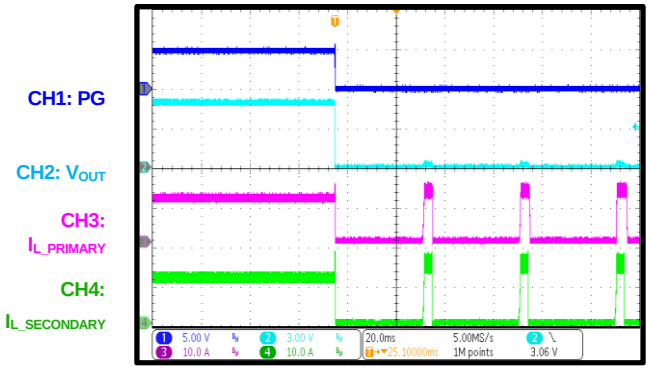
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, dual-phase, L = 0.56µH, $f_{SW}$ = 2.2MHz, AAM mode, $T_A$ = 25°C, unless otherwise noted.**

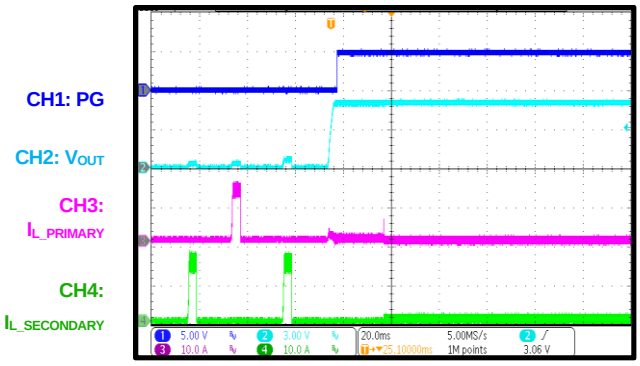
### SCP Entry
$I_{OUT}$ = 0A



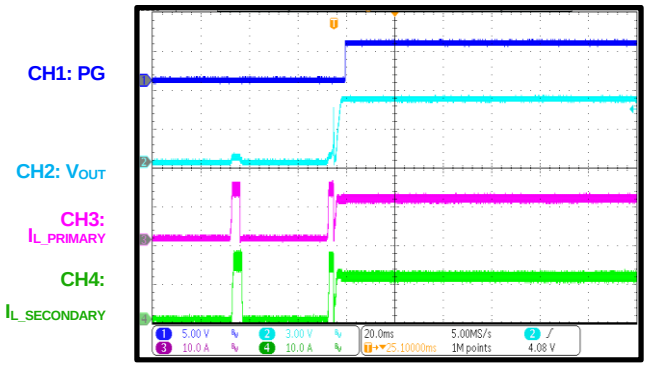

### SCP Entry
$I_{OUT}$ = 22A



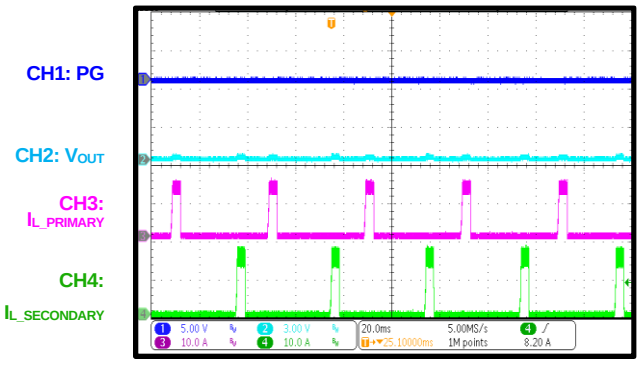

### SCP Recovery
$I_{OUT}$ = 0A



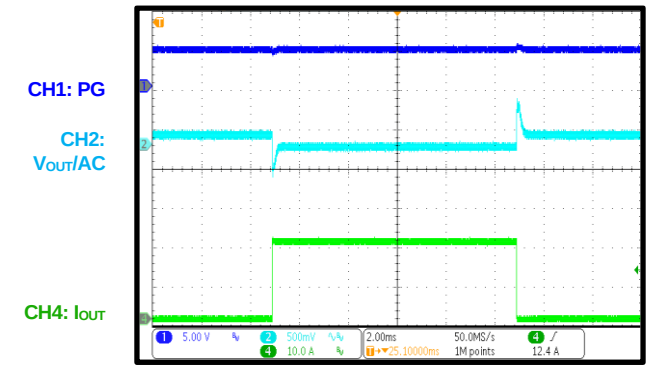

### SCP Recovery
$I_{OUT}$ = 22A




### SCP Steady State




### Load Transient Response
$I_{OUT}$ = 0A to 22A, 1.6A/µs





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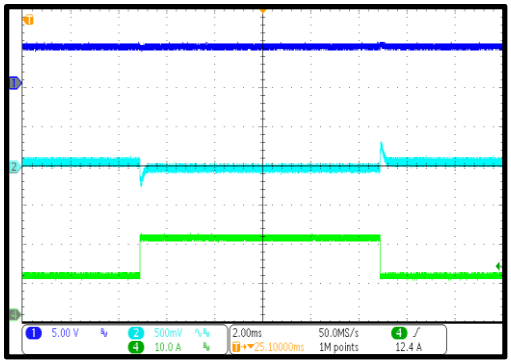
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, dual-phase, L = 0.56µH, $f_{SW}$ = 2.2MHz, AAM mode, $T_A$ = 25°C, unless otherwise noted.**

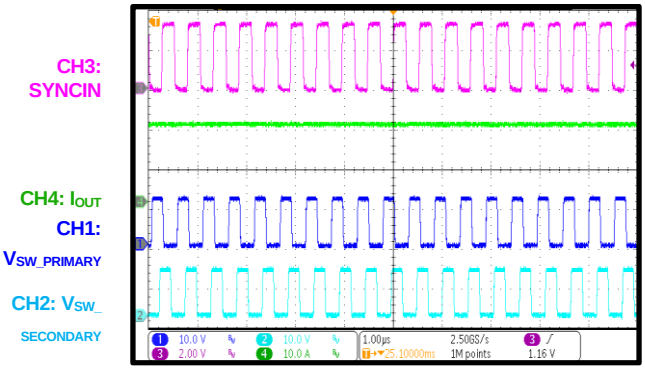
### Load Transient Response

$I_{OUT}$ = 10A to 22A, 1.6A/µs



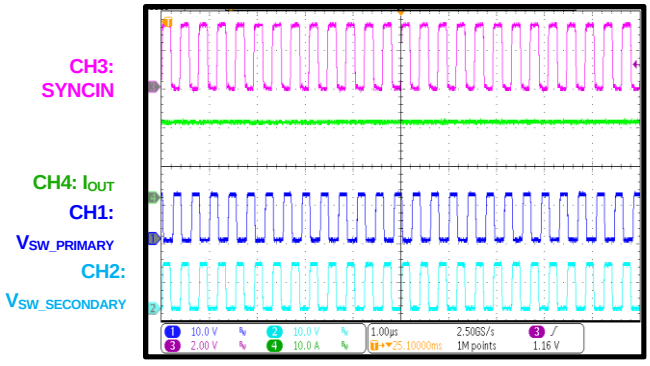

### SYNCIN Operation

$I_{OUT}$ = 22A, SYNC frequency = 1.9MHz



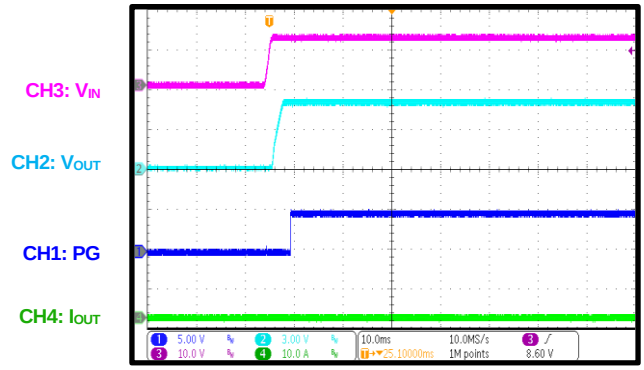

### SYNCIN Operation

$I_{OUT}$ = 22A, SYNC frequency = 2.6MHz



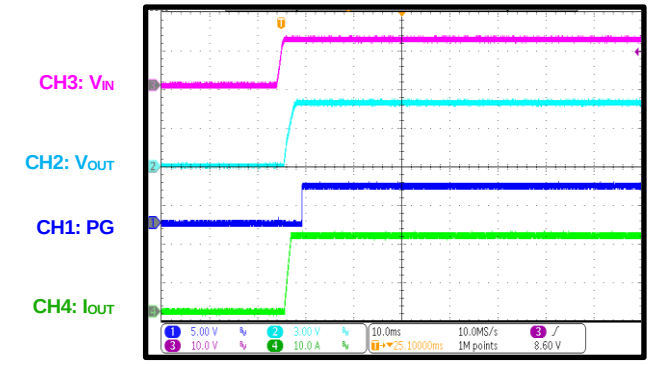

### PG in Start-Up through VIN

$I_{OUT}$ = 0A



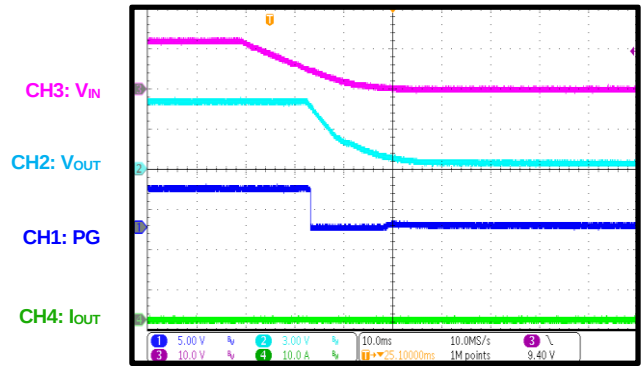

### PG in Start-Up through VIN

$I_{OUT}$ = 22A




### PG in Shutdown through VIN

$I_{OUT}$ = 0A





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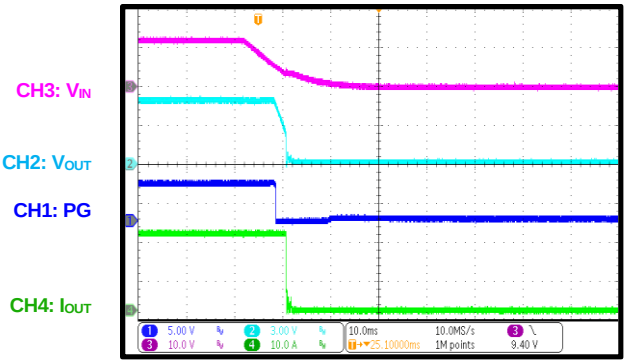
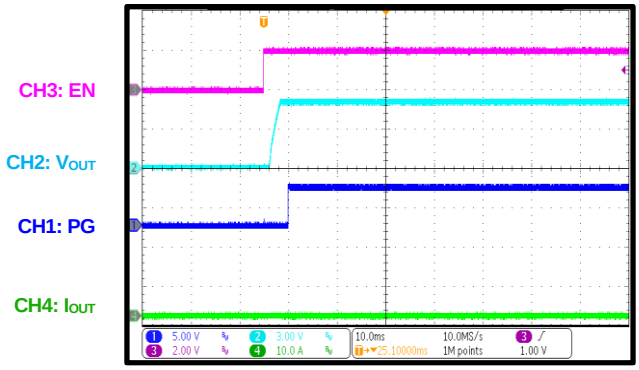
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, dual-phase, L = 0.56µH, $f_{SW}$ = 2.2MHz, AAM mode, $T_A$ = 25°C, unless otherwise noted.**

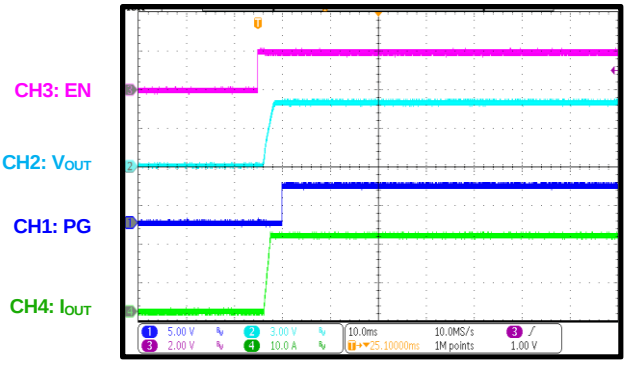
### PG in Shutdown through VIN
$I_{OUT}$ = 22A



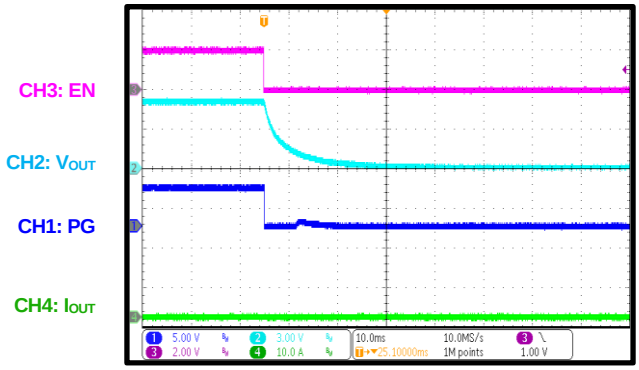

### PG in Start-Up through EN
$I_{OUT}$ = 0A



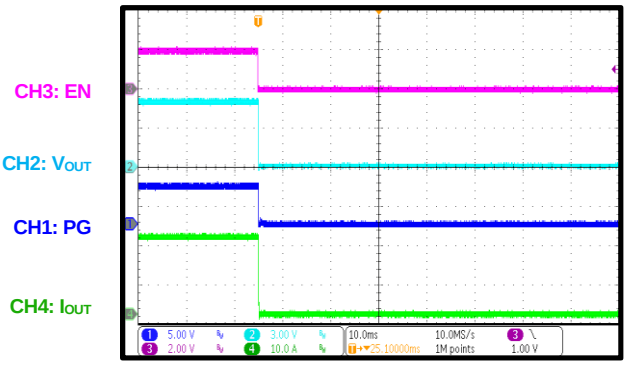

### PG in Start-Up through EN
$I_{OUT}$ = 22A



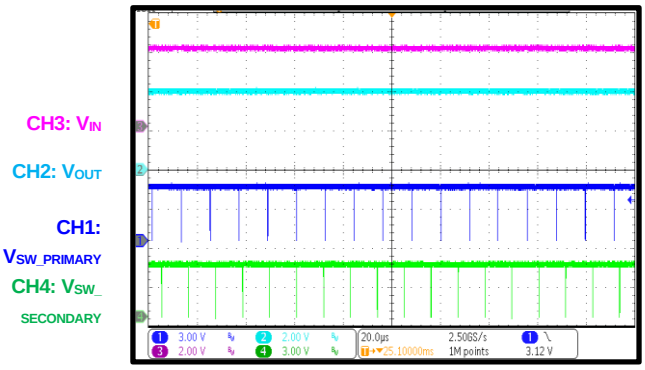

### PG in Shutdown through EN
$I_{OUT}$ = 0A




### PG in Shutdown through EN
$I_{OUT}$ = 22A




### Dropout Operation
$V_{IN}$ = 4V, $V_{OUT}$ set to 5V, $I_{OUT}$ = 0A





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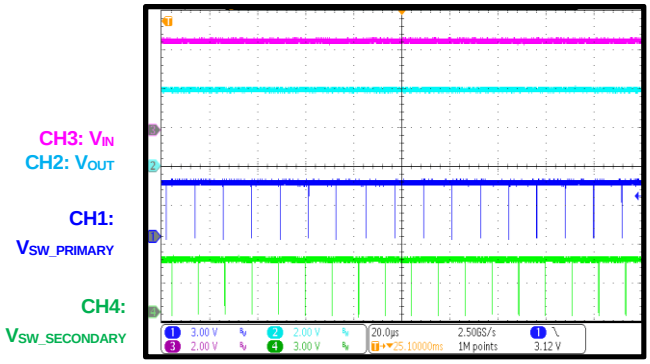
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

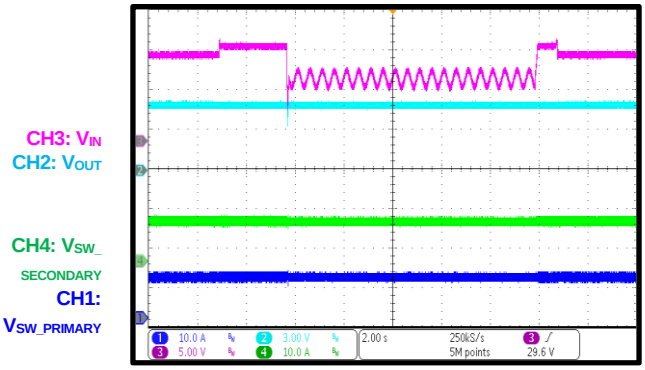
**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, dual-phase, L = 0.56µH, $f_{SW}$ = 2.2MHz, AAM mode, $T_A$ = 25°C, unless otherwise noted.**

### Dropout Operation

$V_{IN}$ = 4V, $V_{OUT}$ set to 5V, $I_{OUT}$ = 22A

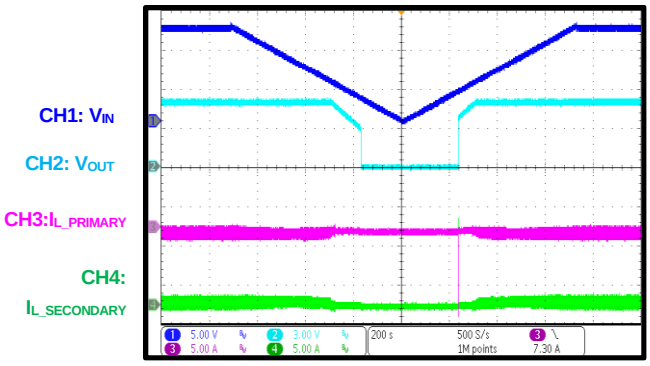



### Cold Crank



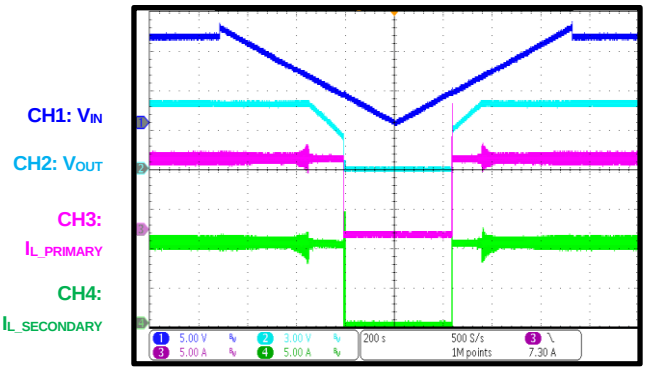

### $V_{IN}$ Ramping Down and Up

$I_{OUT}$ = 0A




### $V_{IN}$ Ramping Down and Up

$I_{OUT}$ = 22A





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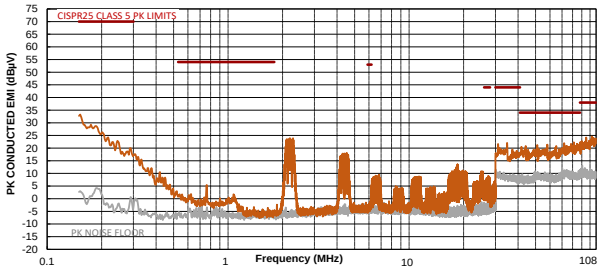
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, single-phase, L = 0.56µH (12), $f_{SW}$ = 2.2MHz, AAM mode, $T_A$ = 25°C, unless otherwise noted.** (13)

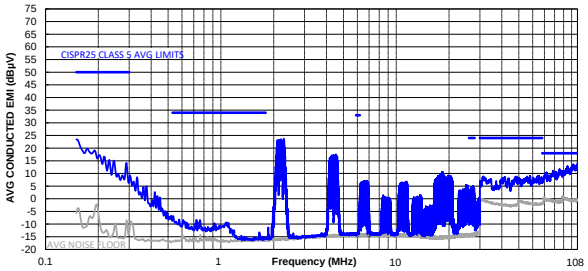
### CISPR 25 Class 5 Peak Conducted Emissions

150kHz to 108MHz



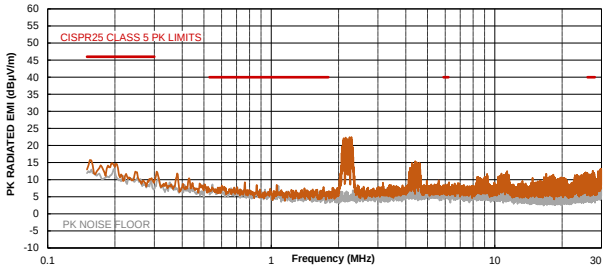

### CISPR 25 Class 5 Average Conducted Emissions

150kHz to 108MHz



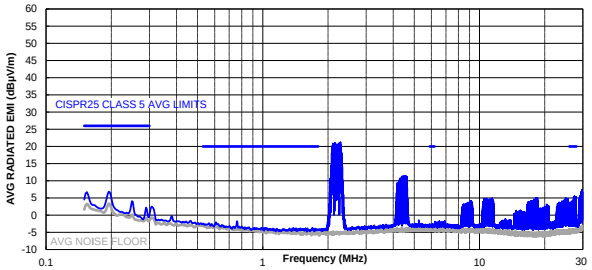

### CISPR 25 Class 5 Peak Radiated Emissions

150kHz to 30MHz



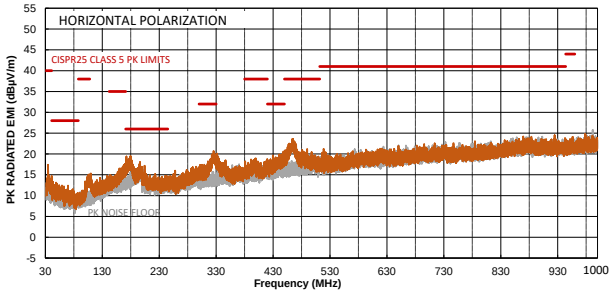

### CISPR25 Class 5 Average Radiated Emissions

150kHz to 30MHz



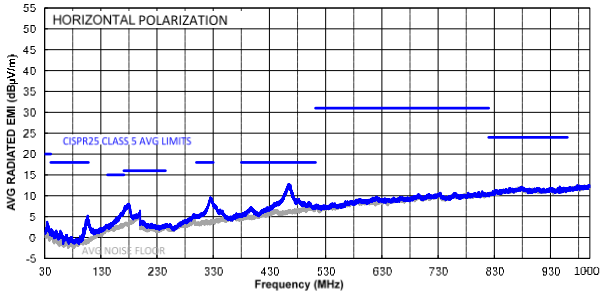

### CISPR 25 Class 5 Peak Radiated Emissions

Horizontal, 30MHz to 1GHz




### CISPR 25 Class 5 Average Radiated Emissions

Horizontal, 30MHz to 1GHz





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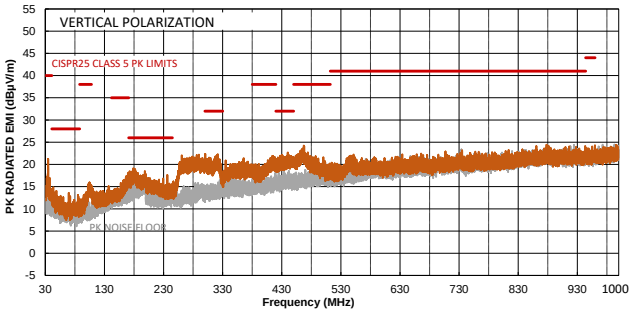
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, single-phase, L = 0.56µH** (12)**, $f_{SW}$ = 2.2MHz, AAM mode, $T_A$ = 25°C, unless otherwise noted.** (13)

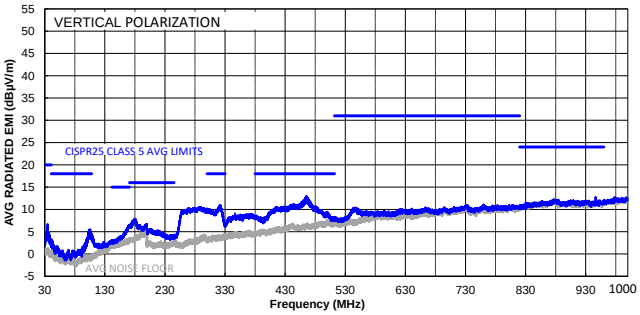
### CISPR 25 Class 5 Peak Radiated Emissions

Vertical, 30MHz to 1GHz




### CISPR 25 Class 5 Average Radiated Emissions

Vertical, 30MHz to 1GHz





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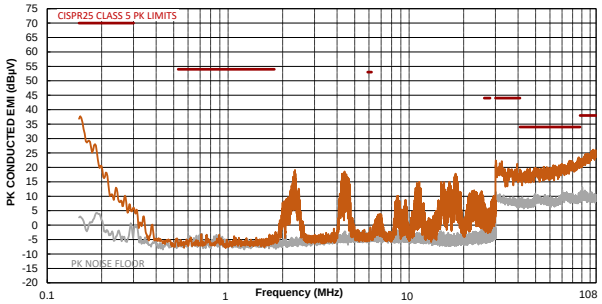
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, dual-phase, L = 0.56µH (12), $f_{SW}$ = 2.2MHz, AAM mode, $T_A$ = 25°C, unless otherwise noted.** (14)

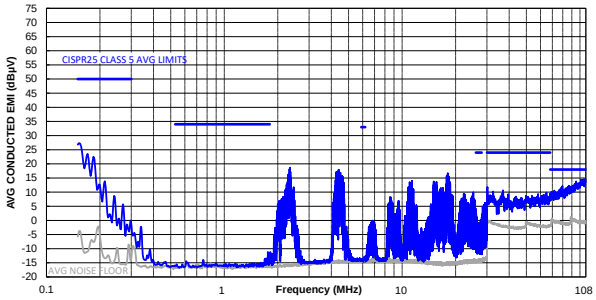
### CISPR 25 Class 5 Peak Conducted Emissions

150kHz to 108MHz



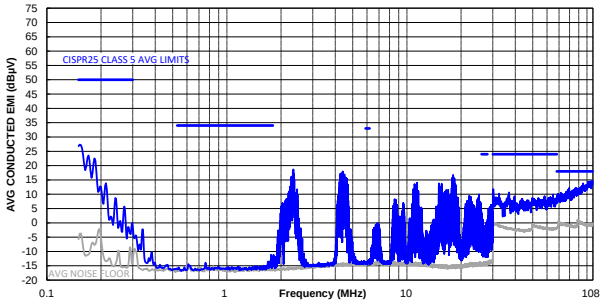

### CISPR 25 Class 5 Average Conducted Emissions

150kHz to 108MHz



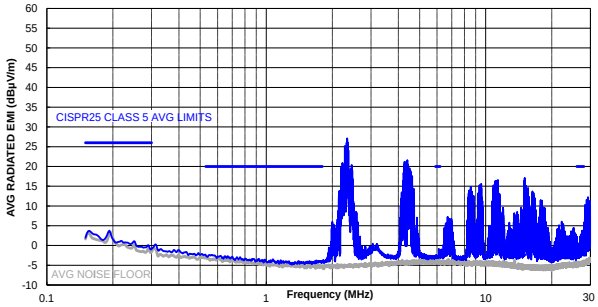

### CISPR 25 Class 5 Peak Radiated Emissions

150kHz to 30MHz



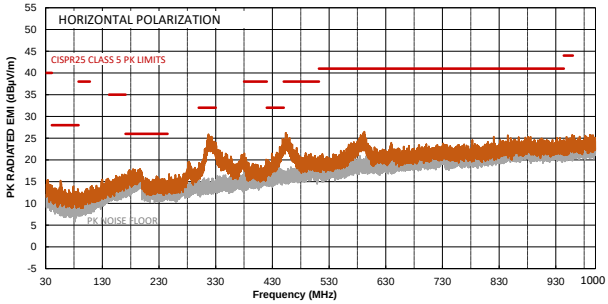

### CISPR 25 Class 5 Average Radiated Emissions

150kHz to 30MHz



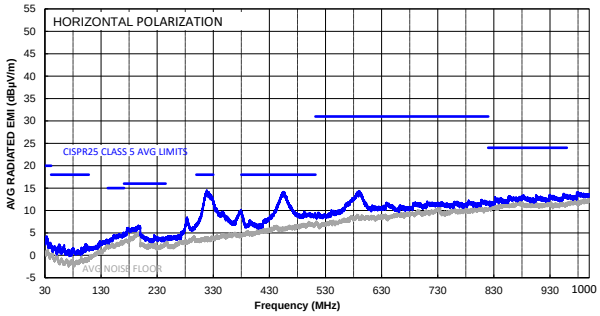

### CISPR 25 Class 5 Peak Radiated Emissions

Horizontal, 30MHz to 1GHz




### CISPR 25 Class 5 Average Radiated Emissions

Horizontal, 30MHz to 1GHz





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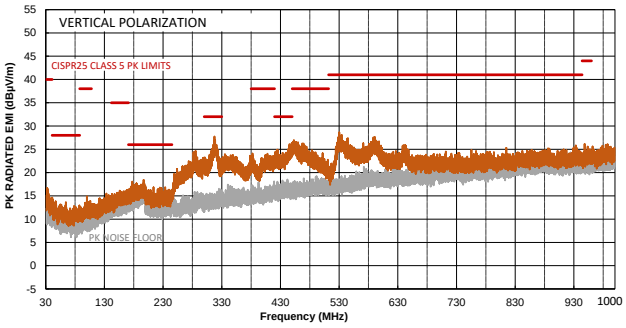
## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

**$V_{IN}$ = 12V, $V_{OUT}$ = 5V, dual-phase, L = 0.56µH** (12)**, $f_{SW}$ = 2.2MHz, AAM mode, $T_A$ = 25°C, unless otherwise noted.** (14)

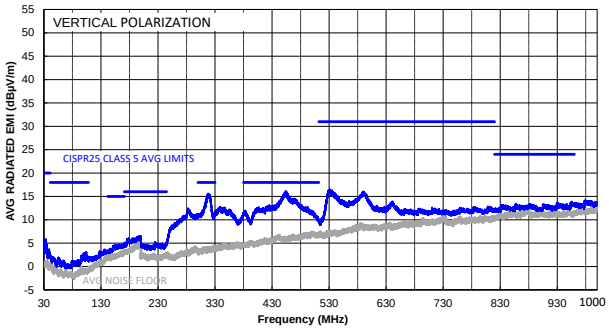
### CISPR 25 Class 5 Peak Radiated Emissions

Vertical, 30MHz to 1GHz




### CISPR 25 Class 5 Average Radiated Emissions

Vertical, 30MHz to 1GHz




**Notes**:

12) Inductor part number: XEL6030-561MEB/C. DCR = 3mΩ.
13) The EMC test results are based on the application circuit with EMI filters (see Figure 19 on page 77).
14) The EMC test results are based on the application circuit with EMI filters (see Figure 23 on page 79).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# FUNCTIONAL BLOCK DIAGRAMS

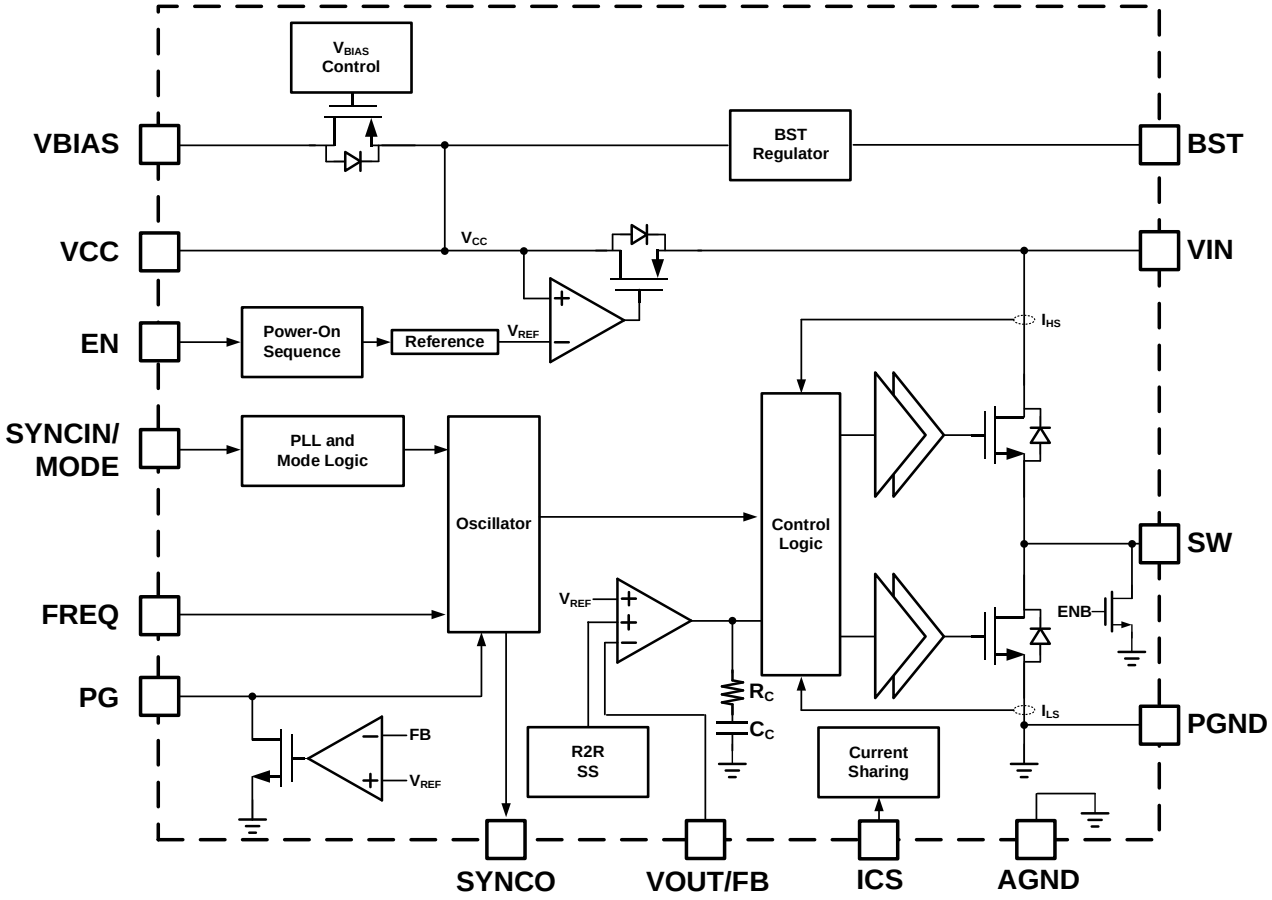


**Figure 3: Functional Block Diagram for Adjustable-Output Version**


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## FUNCTIONAL BLOCK DIAGRAMS *(continued)*

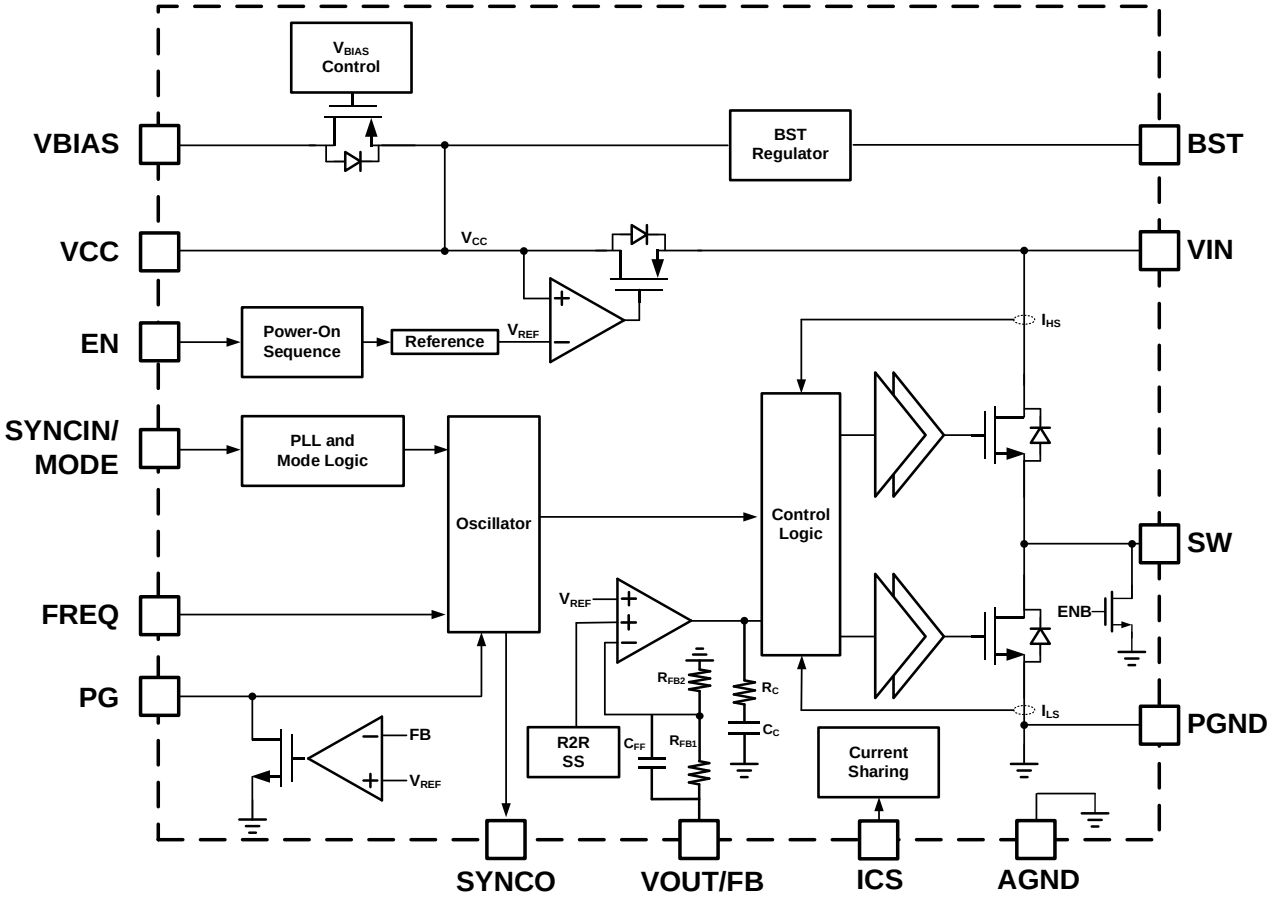


**Figure 4: Functional Block Diagram for Fixed-Output Version**


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## TIMING SEQUENCE DIAGRAM

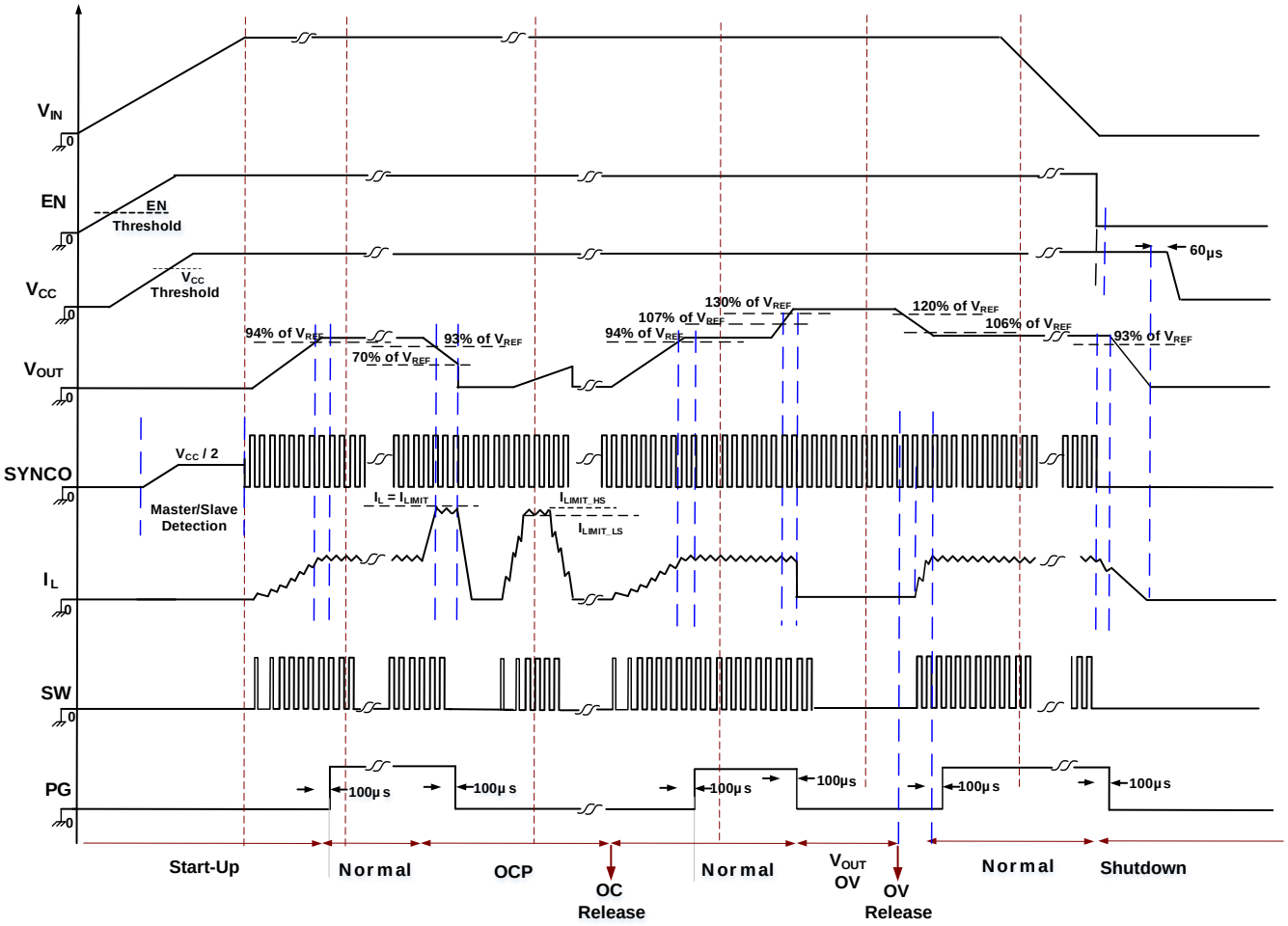


**Figure 5: Timing Sequence Diagram**


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# OPERATION

The MPQ4371 family of buck converters are configurable-frequency (200kHz to 2.5MHz), synchronous, step-down switching regulators with integrated low on resistance HS-FETs and LS-FETs. The family covers a 6A to 11A output current ($I_{OUT}$) range and employs zero-delay pulse-width modulation (PWM) (ZDP™) control, an MPS-exclusive technology that delivers fast transient response while reducing external capacitor count. In addition, it maintains the fixed $f_{SW}$, and its low operational quiescent current makes this device well-suited for battery-powered applications.

### Zero-Delay PWM (ZDP™) Control

Automotive applications generally require fixed-frequency operation to reduce EMI concerns, but traditional topologies with fixed-frequency control have major limitations. For example, voltage mode is difficult to compensate in automotive environments, while peak current mode control struggles to keep up with stringent modern system-on-chip (SoC) transient requirements without excessive output capacitance. With these requirements in mind, the MPQ4371 features fixed-frequency ZDP™ control.

ZDP™ control combines current information with the hysteretic-style output voltage control in a clocked system. This provides an optimal transient response while maintaining a high phase margin across a wide variety of operating conditions and external component values. This control maintains superior EMI performance. The improved transient response reduces output capacitor requirements and lowers system cost. Trailing edge modulation facilitates a narrow minimum on time for high conversion ratio applications.

At the beginning of the PWM cycle, the high-side MOSFET (HS-FET) turns off, and the low-side MOSFET (LS-FET) turns on immediately until the control signal reaches the COMP voltage ($V_{COMP}$). The HS-FET remains off for at least 80ns at the beginning of the cycle.

### Light-Load Operation

Under light-load conditions, the MPQ4371 can operate in two different operation modes by setting the state of the SYNCIN/MODE pin.

The MPQ4371 works in forced continuous conduction mode (FCCM) when the SYNCIN/MODE pin is pulled above 1.4V or an external clock is used. In FCCM, the MPQ4371 works with a fixed frequency from the no-load to full-load range. The MPQ4371 has a reverse current limit to prevent the negative current from dropping too low and damaging the components. Once the negative inductor current reaches the reverse current limit, the HS-FET immediately turns on, and the LS-FET turns off. The advantages of FCCM are its constant frequency and lower output voltage ripple at light loads. FCCM also has a better response to sudden load changes.

The MPQ4371 works in advanced asynchronous modulation (AAM) mode when the SYNCIN/MODE pin is pulled below 0.4V. AAM mode cannot be entered until soft start has finished. AAM mode optimizes efficiency under light-load and no-load conditions.

In AAM mode, the LS-FET emulates a diode and the HS-FET has a fixed one-shot on-time to charge the inductor and regulate the output. As the load decreases, the interval between each one-shot increases. When this interval is longer than 8µs, the MPQ4371 enters sleep mode, which turns off some internal circuits and extends the on time to achieve an ultra-low quiescent current. When the load increases, and the interval becomes shorter than 6µs, the device exits sleep mode and re-enters AAM mode. The part can exit AAM mode immediately if the SYNCIN/MODE pin goes high. If there is a fault (e.g. over-current, over-temperature), then the MPQ4371 does not disable the internal circuits in sleep mode.

### Start-Up and Shutdown

If both the input voltage ($V_{IN}$) and EN exceed their appropriate thresholds, the chip starts. 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.

While the internal supply rail is up, an internal timer holds the HS-FET and LS-FET off for about 100µs to blank the start-up glitches. When the


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soft-start block is enabled, it first holds its soft-start output low to ensure that the remaining circuits are ready, and then slowly ramps up.

Four events shut down the chip: EN going low, $V_{IN}$ going low, thermal shutdown and $V_{IN}$ over-voltage (OV) shutdown. In the shutdown procedure, the signaling path is blocked first to avoid any fault triggering, then $V_{COMP}$ and the internal supply rail are pulled down. The floating driver is not subject to this shutdown command, but its charging path is disabled.

### Error Amplifier (EA)

The error amplifier (EA) compares the FB pin's voltage ($V_{FB}$) with the internal reference (0.6V). The output of the EA is then compared to $V_{FB}$ again. The output of this comparator is compared to the current information to control the power MOSFET's duty cycle.

### Low-Dropout (LDO) Mode

When $V_{IN}$ drops close to the output voltage ($V_{OUT}$) and the device detects the minimum off time (100ns) that the HS-FET is using, the MPQ4371 is in low-dropout mode. The MPQ4371 reduces $f_{SW}$ to achieve a high duty cycle. When $f_{SW}$ drops to about 100kHz, the minimum off time is about 50ns to achieve a higher duty cycle. During soft start, the MPQ4371 only enters low-dropout mode after 60% of the SS time has elapsed.

The effective duty cycle during the regulator's dropout period is mainly influenced by the voltage drop across the power MOSFET, the inductor's resistance, and the PCB resistance.

### Frequency Spread Spectrum (FSS)

The MPQ4371 uses dual spread spectrum modulation. First, the MPQ4371 has a 15kHz modulating frequency ($f_{MOD1}$) with ≤128 steps and a triangular profile to spread the internal oscillator frequency across a ±6.2% window. The number of steps varies with the configured oscillator frequency so that the exact same $f_{SW}$ steps cycle by cycle.

A second modulating frequency ($f_{MOD2}$) of 120kHz varies the oscillator frequency across a ±2.5% window with a maximum of 16 steps. This higher modulating frequency improves the effect of FSS across the high-frequency EMI measurements, where the resolution bandwidth (RBW) is 120kHz (see Figure 6).

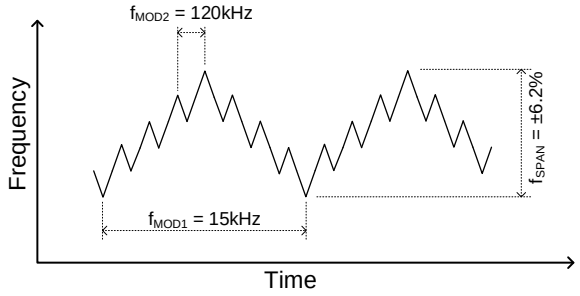


**Figure 6: FSS**

The emission power of the fundamental $f_{SW}$ and its harmonics is distributed into smaller pieces by creating side-bands when modulating $f_{SW}$ with the triangle modulation waveform. This significantly reduces the amplitude of individual EMI spikes (also called spurs).

### Soft Start

The MPQ4371 has an internal soft start implemented to prevent the converter's output voltage from overshooting during start-up. The default soft-start duration is 4ms.

### Pre-Biased Start-Up

When the MPQ4371 starts up and $V_{FB}$ is < 100% of its target, the MPQ4371 initiates soft start.

If $V_{FB}$ is between 100% and 130% of its target at start-up while in FCCM, this means that the output has a pre-biased voltage. Neither the HS-FET nor LS-FET turn on until the internal soft start process is 80% complete. Then the MPQ4371 starts switching and regulates the output before soft start finishes.

If $V_{FB}$ exceeds 130% of its target at start-up, the MPQ4371 start to slowly discharge the output through the discharging FET on SW. Once $V_{FB}$ reaches 120% of its target, the MPQ4371 starts the internal soft start and operates following the pre-biased start-up process, as explained in the previous paragraph.

### SYNCIN and SYNCO

$f_{SW}$ can be synchronized to the rising edge of a clock signal applied at the SYNCIN/MODE pin. The recommended SYNCIN frequency range is between 200kHz and 2.5MHz. The SYNCIN frequency should be set to match the internal $f_{SW}$ with a ±10% tolerance.

The SYNCO pin provides a clock signal that is in phase with the internal oscillator when there is no SYNCIN signal, or a clock signal in phase


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with SYNCIN. Figure 7 shows when an external clock signal is applied at SYNCIN. This makes it simple to enable a dual-phase interleaving configuration.

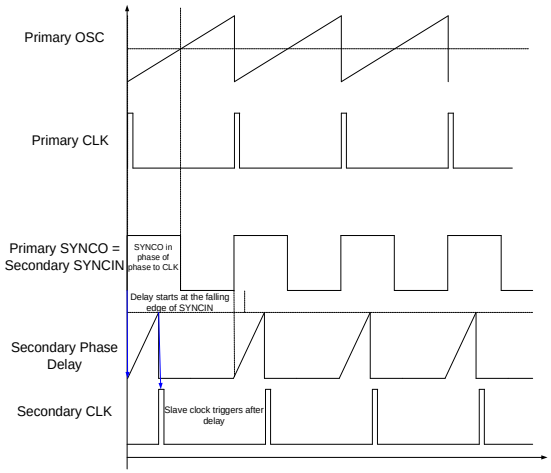


**Figure 7: SYNCIN and SYNCO Scheme**

## Primary/Secondary Selection and Multi-Phase Function

"Primary" and "secondary" are terms are used to describe the role of the different ICs in a multi-phase power converter. The primary device generates a clock signal to which the secondary device is synchronized, and it also asserts PG based on the output regulation.

The device detects the SYNCO pin's status during start-up to configure the primary and secondary selection. If the chip detects a high impendence on the SYNCO pin, the device is configured to be a primary device. If the SYNCO pin is pulled high (connected to VCC or an external voltage) or low (connected to GND), the device is configured to be a secondary device.

To work in a multi-phase topology, The VOUT/FB pins of the devices must be connected together directly or through feedback resistors.

The ICS pins must be connected together, and a local, lower-value capacitor much be placed between each ICS pin and GND.

The primary device's SYNCO pin is connected to the SYNCIN/MODE pins of the secondary devices, which are interleaved. If the primary device's SYNCIN/MODE pin is used for mode selection, the secondary devices' SYNCO pins can be tied to the primary device's SYNCIN/MODE pin; pull SYNCIN/MODE low to select AAM mode, or pull it high for FCCM. If the primary device's SYNCIN/MODE pin is applied with the external clock signal to synchronize the internal oscillator frequency, the SYNCO pins of the secondary devices can only be pulled high or low, and they cannot be connected to the primary device's SYNCN/MODE pin. With multi-phase applications, avoid floating the primary device's SYNCIN/MODE pin, or connect it to GND/VCC through a larger resistor (>20kΩ).

Pull the PG pin to a power source through a resistor or leave it floating if it is not used for the primary device. For secondary devices, connect a resistor to ground on the PG pin to set the phase delay and allow for simple multi-phase operation; Connect PG directly to GND to select no delay on the SYNCIN signal for secondary phase.

Figure 8 shows a dual-phase configuration.

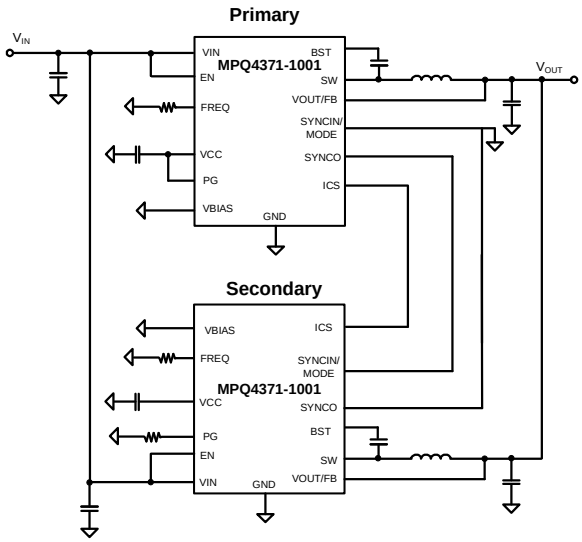


**Figure 8: Dual-Phase Configuration**

Figure 9 on page 67 shows a 4-phase configuration.


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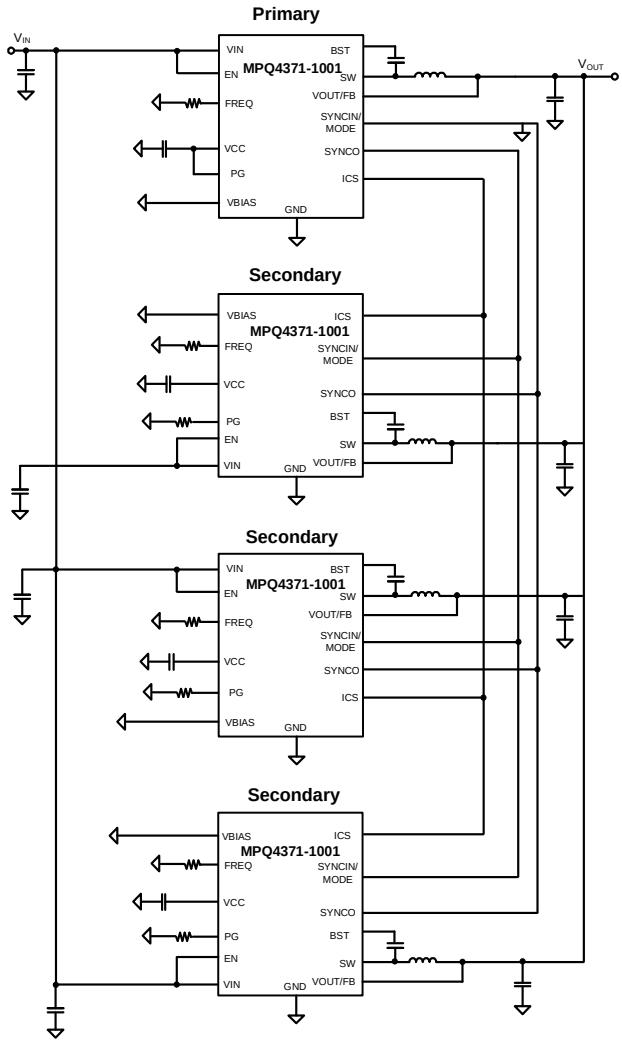


**Figure 9: 4-Phase Configuration**

For multi-phase applications, start with AAM mode then change to FCCM after the PG signal of the primary phase pulls high.

### Thermal Shutdown

Thermal shutdown is implemented to prevent the chip from thermal runaway. When the silicon die temperature exceeds its upper threshold (180°C), the MPQ4371 shuts down the power MOSFETs. When the temperature falls below the lower threshold (150°C), thermal shutdown is removed, so the chip is enabled again.

### $V_{IN}$ Over-Voltage Protection (OVP)

The MPQ4371 stops switching when $V_{IN}$ exceeds its OV rising threshold (typically 38V). The device resumes normal regulation and switching when $V_{IN}$ drops to its OV falling threshold (typically 37V).

If the MPQ4371 is operating in sleep mode, this OVP function is turned off between the no-switching periods. The $V_{IN}$ OVP function only works during the one-shot HS on time and detects if $V_{IN}$ reaches the OVP threshold.

### 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 (typically 17.2A for the MPQ4371-0xxx) while the HS-FET is on, the HS-FET is forced off immediately to prevent the current from rising further. If there is an internal clock signal before the peak current limit is reached, the HS-FET also turns off.

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 (typically 12A for the MPQ4371-0xxx). 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.

### Short-Circuit Protection (SCP)

If $V_{OUT}$ drops below 93% of its nominal output and the EA's output is clamped, the MPQ4371 counts the valley current limit counter (LSOC) about 128 times and enters hiccup mode.

If $V_{OUT}$ drops below 70% of its nominal output, the MPQ4371 counts the LSOC about 8 times then enters hiccup mode. The device restarts with a full soft start after about 32ms. This hiccup process repeats until the fault is removed.

During the hiccup period, when $V_{FB}$ reaches 80% of internal reference, the part considers the SCP recovery action. In this scenario, the device re-initiates a soft start, which can prevents large output voltage spikes if the MPQ4371 recovers during the SCP period.

### Output Over-Voltage Protection (OVP) and Discharge

If $V_{OUT}$ exceeds 130% of its nominal regulation value in non-sleep mode (e.g. FCCM), the MPQ4371 stops switching. Then an internal discharge path from SW to GND is activated to discharge $V_{OUT}$. The discharge is disabled when $V_{OUT}$ drops back to 120% of its nominal value, and the device resumes switching when $V_{OUT}$ drops below the nominal output voltage.


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If the device is operating in a sleep mode, the output OVP function is turned off, and the PG rising and falling thresholds are used to detect OVP. The discharge circuit is activated if $V_{OUT}$ is exceeds 107% of its normal regulation value, and discharging is disabled when $V_{OUT}$ drops back to 106% of its nominal value. The MPQ4371 resumes switching when $V_{OUT}$ drops below its nominal value.

If $V_{OUT}$ exceeds 130% of its nominal regulation value in a non-sleep mode (e.g. AAM mode or DCM) within 160µs, the MPQ4371 follows the non-sleep mode (e.g. CCM) function.

If the period is longer than 160µs, the MPQ4371 enters sleep mode, and the OVP threshold becomes 107% or 106% of the nominal value, which same as sleep mode OVP function.

Not only does output OVP trigger the discharge function; the output discharge function is also activated during EN shutdown.


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# APPLICATION INFORMATION

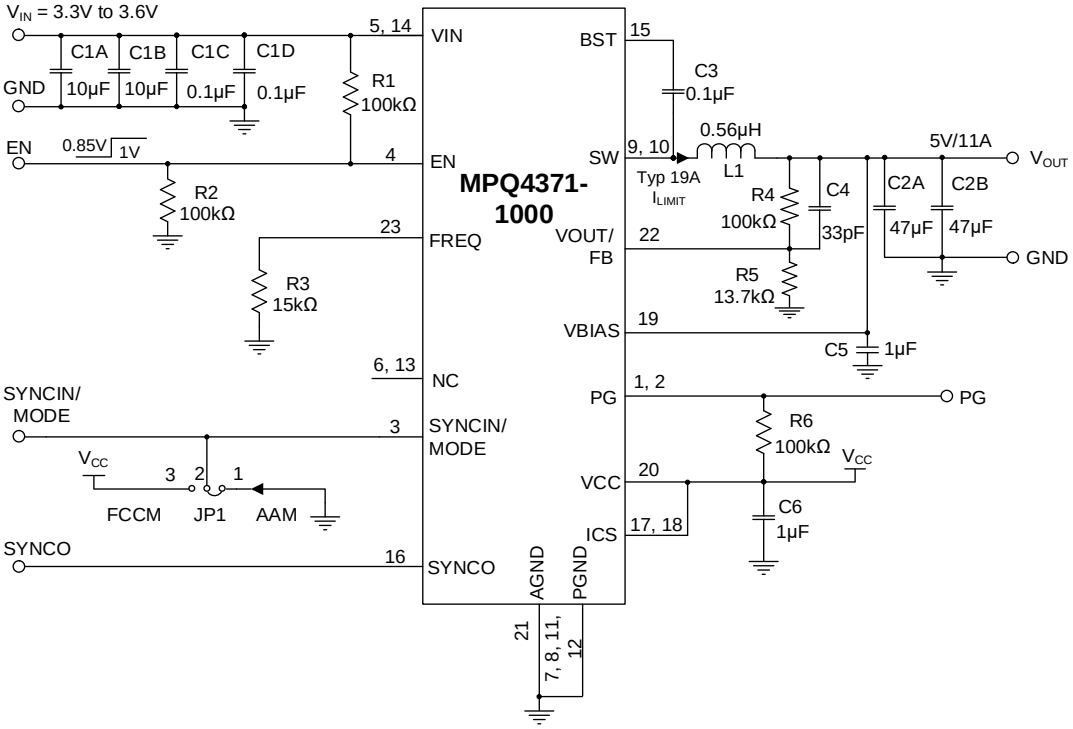


**Figure 10: Typical Application Circuit for the MPQ4371-1000 ($V_{OUT}$ = 5V, $f_{SW}$ = 2.2MHz)**

**Table 1: Design Guide Index and Recommended Values**

| Pin # | Pin name | Component | Design Guide Index | Value |
|---|---|---|---|---|
| 1, 2 | PG | R6 | Power Good (PG) Indication or Phase Shift Setting (PG, Pins 1–2) | 100kΩ |
| 3 | SYNCIN/MODE | - | Sync Input and MODE Selection (SYNCIN/MODE, Pin 3) | - |
| 4 | EN | R1, R2 | Enable and VIN Under-Voltage Lockout (UVLO) (EN, Pin 4) | 100kΩ,100kΩ |
| 5, 14 | VIN | C1A, C1B, C1C, C1D | Selecting the Input Capacitors (VIN, Pins 5 and 14) | 10µF, 10µF,0.1µF, 0.1µF |
| 6, 13 | NC | N/A | N/A | - |
| 7, 8, 11, 12 | PGND | - | GND Connection (PGND, Pins 7–8 and Pins 11–12; AGND, Pin 21) | - |
| 9, 10 | SW | L1, C2A, C2B | Selecting the Inductor and Output Capacitors (SW, Pins 9–10) | 0.56µH,47µF, 47µF |
| 15 | BST | C3 | Floating Driver and Bootstrap Charging (BST, Pin 15) | 0.1µF |
| 16 | SYNCO | - | Sync Output (SYNCO, Pin 16) | - |
| 17, 18 | ICS | - | Current Sharing (ICS, Pins 17–18) | - |
| 19 | VBIAS | C5 | Internal LDO Supply (VBIAS, Pin 19) | 1µF |
| 20 | VCC | C6 | Internal LDO Supply (VCC, Pin 20) | 1µF |
| 21 | AGND | - | GND Connection (PGND, Pins 7–8 and Pins 11–12; AGND, Pin 21) | - |
| 22 | VOUT/FB | R4, R5, C4 | Setting the Feedback (VOUT/FB, Pin 22) | 100kΩ, 13.7kΩ, 33pF |
| 23 | FREQ | R3 | Setting the Switching Frequency ($f_{SW}$) (FREQ, Pin 23) | 15kΩ |


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### Power Good (PG) Indication or Phase Shift Setting (PG, Pins 1–2)

For single-phase applications and for the primary device in multi-phase applications, the PG resistance ($R_{PG}$, also R6) is recommended to be about 100kΩ. The MPQ4371 has an open-drain PG output that indicates whether the regulator output is within its specific nominal output window. 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 $V_{OUT}$ is within 94% to 106% of the nominal voltage; PG goes low if $V_{OUT}$ exceeds 107% or falls below 93% of the nominal voltage. Float PG if it is not used.

For secondary devices in multi-phase applications, this pin can set the phase shift by connecting a resistor ($R_{PHASE}$) to ground. Table 2 shows the relationship between the phase shift and $R_{PHASE}$ under high- and low-frequency conditions.

**Table 2 : Phase Shift vs. $R_{PHASE}$**

| Phase Shift | $R_{PHASE}$ at $f_{SW_PRIMARY}$ = 410kHz | $R_{PHASE}$ at $f_{SW_PRIMARY}$ = 2.2MHz |
|---|---|---|
| 90º | 33kΩ | 4.87kΩ |
| 120º | 46.4kΩ | 7.32kΩ |
| 180º | 73.2kΩ | 12.1kΩ |
| 240º | 97.6kΩ | 16.9kΩ |
| 270º | 115kΩ | 19.1kΩ |
| 359º | 150kΩ | 26.1kΩ |

### Sync Input and MODE Selection (SYNCIN/MODE, Pin 3)

For single-phase applications and primary devices in multi-phase applications, when this pin is used as the sync input pin, $f_{SW}$ can be synchronized to the rising edge of a clock signal applied at the SYNCIN/MODE pin. The recommended SYNCIN frequency range is between 90% and 110% of the set $f_{SW}$. When this pin is used for mode selection, pull this pin high so that the MPQ4371 operates in FCCM; pull this pin low or float this pin for AAM mode. Table 3 shows the detailed mode selection.

**Table 3: Mode Selection**

| SYNCIN/MODE Input | Operation |
|---|---|
| Floating | AAM mode |
| <0.4V | AAM mode |
| >1.4V | FCCM |
| External clock in | FCCM |

For secondary devices in multi-phase applications, it is recommended to connect the SYNCIN/MODE pin of the secondary devices to the primary device's SYNCO pin. In this scenario, keep the primary device's SYNCO pin at a high impedance.

### Enable and $V_{IN}$ Under-Voltage Lockout (EN, Pin 4)

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

#### *Enabled by External Logic High/Low (H/L) Signal*

When the EN voltage reaches about 0.7V, the VCC supply turns on. When $V_{IN}$ exceeds about 2.7V, then $V_{IN}$ provides an accurate reference voltage for the EN threshold. Forcing EN to exceed its rising threshold voltage of 1V turns on the device. The device is turned off by driving EN below 0.85V.

#### *Configurable $V_{IN}$ UVLO*

When $V_{IN}$ is sufficiently high, the chip can be enabled and disabled by the EN pin. The EN pin can generate a configurable $V_{IN}$ UVLO threshold and hysteresis.

The MPQ4371 has an internal, fixed UVLO threshold. The rising threshold is 3.8V, while the falling threshold is about 2.9V. For applications that need a higher UVLO point, an external resistor divider can be placed between VIN and EN to achieve a higher equivalent UVLO threshold (see Figure 11).

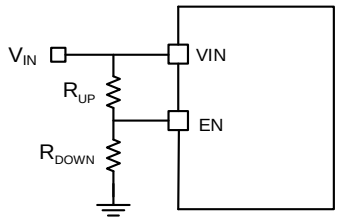


**Figure 11: Adjustable UVLO Using EN Divider**

The UVLO rising and falling thresholds can be calculated with Equation (1) and Equation (2), respectively:

$$VIN_{UV_RISING} = (1+\frac{R_{UP}}{R_{DOWN}})\times V_{EN_RISING} \quad (1)$$

$$VIN_{UV_FALLING} = (1+\frac{R_{UP}}{R_{DOWN}})\times V_{EN_FALLING} \quad (2)$$


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Where $V_{EN_RISING}$ is 1V, and $V_{EN_FALLING}$ is 0.85V.

### Selecting the Input Capacitors (VIN, Pins 5 and 14)

The step-down converters have a discontinuous input current, and require a capacitor to supply AC current to the converters 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 another, lower-value capacitor (e.g. 0.1µF) with a small package size (0603) to absorb high-frequency switching noise. Place this capacitor as close to VIN and GND as possible.

Since $C_{IN}$ absorbs the input switching current, it requires an adequate ripple current rating. The RMS current in the input capacitor can be estimated with Equation (3):

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

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

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

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 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 (5):

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

### Selecting the Inductor and Output Capacitors (SW, Pins 9–10)

#### *Selecting the Inductor*

A 0.1µH 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 voltage ripple, but also has a larger physical size, higher series resistance, and lower saturation current. A good rule to determine the inductance is to allow the inductor ripple current to be approximately 30% of the maximum load current. The inductance can be calculated with Equation (6):

$$L = \frac{V_{OUT}}{f_{sw} x \Delta I_L} x (1 - \frac{V_{OUT}}{V_{IN}}) \quad (6)$$

Where $\Delta I_L$ is the peak-to-peak inductor ripple current.

Choose the inductor ripple current to be approximately 30% of the maximum load current. The maximum inductor peak current can be calculated with Equation (7):

$$I_{LP} = I_{LOAD} + \frac{V_{OUT}}{2 x f_{sw} x L} x (1 - \frac{V_{OUT}}{V_{IN}}) \quad (7)$$

#### *Selecting the Output Capacitor*

The output capacitor 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. The output voltage ripple can be estimated with Equation (8):

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

Where L is the inductance, and $R_{ESR}$ is the output capacitor's equivalent series resistance (ESR).

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 (9):

$$\Delta V_{OUT} = \frac{V_{OUT}}{8 \times f_{SW}^2 \times L \times C_{OUT}} \times (1 - \frac{V_{OUT}}{V_{IN}}) \quad (9)$$


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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 (10):

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_{SW} \times L} \times (1 - \frac{V_{OUT}}{V_{IN}}) \times R_{ESR} \quad (10)$$

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

**Floating Driver and Bootstrap Charging (BST, Pin 15)**

The BST capacitor ($C_{BST}$, also called C3) is recommended to be between 0.1µF to 0.47µF.

It is not recommended to place a resistor ($R_{BST}$) in series with the BST capacitor, as this results in minimal EMI improvement and increases power dissipation. The MPQ4371 employs a sophisticated FET turn-on technique that greatly reduces the high-frequency EMI and eliminates the need for this resistor. If $R_{BST}$ is necessary, it should be below 20Ω.

The voltage between BST and SW ($V_{BST-SW}$) is regulated to about 5V by the dedicated internal bootstrap regulator. When $V_{BOOT-SW}$ is below its regulation value, an N-channel MOSFET (NMOS) pass transistor connected from VCC to BST is turned on to charge $C_{BST}$. When the HS-FET is on, the BST voltage exceeds $V_{CC}$, which means that 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. 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 $f_{SW}$.

The BST refresh function can only be triggered during the start-up period, sleep mode, or if the feedback over-voltage (OV) condition is triggered.

**Sync Output (SYNCO, Pin 16)**

For single-phase applications and for the primary device in multi-phase applications, the SYNCO pin outputs a clock signal in phase with the internal oscillator signal or external SYNCIN clock.

For secondary devices in multi-phase applications, this pin can be connected to the SYNCIN/MODE pin of the primary device, or it can be pulled low or high to select AAM mode or FCCM, respectively. The mode setting threshold is same as the selections for the SYNCIN/MODE pin (see Table 3 on page 70).

**Current Sharing (ICS, Pins 17–18)**

The ICS pin's function is disabled if the voltage of this pin exceeds 2.4V. Connect ICS to VCC to disable this function in single-phase applications.

In multi-phase applications, connect the ICS pins together for each MPQ4371 phase. Connect a small capacitor between the ICS pin and GND to filter the noise disturbance. For high-frequency conditions (e.g. 2.2MHz), it is recommended for the capacitance to be between 22pF and 180pF. For low-frequency conditions (e.g. 410kHz), it is recommended for the capacitance to be between 100pF and 1.2nF.

**Internal LDO Supply (VBIAS, Pin 19)**

The VBIAS capacitor (C5) is recommended to be 1µF.

The VBIAS pin is the internal LDO's supply pin. When the VBIAS pin is connected to a 5V voltage, VBIAS is the power supply for the VCC regulator. The input supply current can be lower to obtain a higher efficiency. When $V_{BIAS}$ exceeds 4.5V, this pin takes over VCC; when $V_{BIAS}$ is below 4.3V, this function is disabled.

VBIAS can be connected directly to the output voltage when $V_{OUT}$ is between 4.6V to 5.5V to improve the converter's efficiency, especially at high frequencies. Alternatively, connect VBIAS to another 5V rail if one is available in the system, and the current draw is <30mA. Add one decoupling capacitor between the VBIAS pin and GND if this function is used.

When there is no suitable power source for VBIAS, or its function is not used, connect this pin to VOUT or GND. For applications where $V_{OUT}$ > 5.5V, avoid connecting the VBIAS pin to the output. Do not provide an external VBIAS voltage before VIN. Do not float this pin.


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### Internal LDO Supply (VCC, Pin 20)

The VCC capacitor (C6) is recommended to be 1µF.

The VCC capacitor should be 10 times larger than BST capacitor. A VCC capacitor larger than 68µF is not recommended.

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, $V_{CC}$ is in full regulation and maintains a 5V voltage. When $V_{IN}$ is lower, the VCC output degrades.

When VCC is powered by VBIAS, $V_{CC}$ follows $V_{BIAS}$.

### Setting the Feedback (VOUT/FB, Pin 22)

For the adjustable output version, $V_{FB}$ is typically 0.6V. The external resistor divider connected to FB sets the output voltage (see Figure 12).

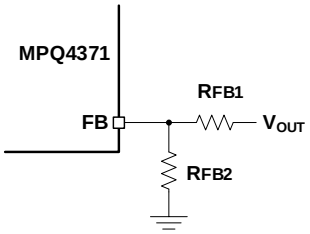


**Figure 12: Feedback Divider Network of Adjustable-Output Version**

Calculate $R_{FB2}$ with Equation (11):

$$R_{FB2} = \frac{R_{FB1}}{\frac{V_{OUT}}{0.6V} - 1} \quad (11)$$

Table 4 lists the recommended feedback resistor values for common output voltages.

**Table 4: Feedback Resistor Selection for Adjustable Output Version**

| $V_{OUT}$ (V) | $R_{FB1}$ (kΩ) | $R_{FB2}$ (kΩ) |
|---|---|---|
| 1.0 | 66.5 (1%) | 100 (1%) |
| 3.3 | 100 (1%) | 22.1 (1%) |
| 5.0 | 100 (1%) | 13.7 (1%) |

For the fixed output version, the FB resistor divider is integrated internally, so connect FB to $V_{OUT}$ directly to set the output voltage (see Figure 13). The following fixed outputs are available: 1V, 1.2V, 1.8V, 2.5V, 3.3V, 3.8V, and 5V.

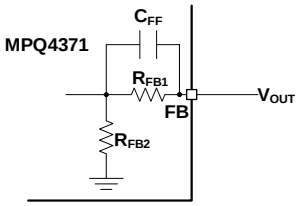


**Figure 13: Feedback Divider Network of Fixed-Output Version**

Table 5 shows the relationship between the internal $R_{FB}$ and $V_{OUT}$.

**Table 5: $R_{FB}$ vs. $V_{OUT}$ for Fixed Output Version**

| $V_{OUT}$ (V) | $R_{FB2}$ (MΩ) | $R_{FB1}$ (MΩ) | $C_{FF}$ (pF) |
|---|---|---|---|
| 1.0 | 2.0 | 1.333 | 3.0 |
| 1.2 | 2.0 | 2.0 | 3.0 |
| 1.8 | 2.0 | 4.0 | 3.0 |
| 2.5 | 2.0 | 6.333 | 3.0 |
| 3.3 | 2.0 | 9.0 | 3.0 |
| 3.8 | 2.0 | 10.667 | 3.0 |
| 5.0 | 2.0 | 14.667 | 3.0 |

### Setting the Switching Frequency Setting ($f_{SW}$) (FREQ, Pin 23)

A resistor (R3, also called $R_{FREQ}$) can be used to $f_{SW}$. Table 6 shows the $R_{FREQ}$ values to set the adjustable $f_{SW}$.

**Table 6: $R_{FREQ}$ vs. $f_{SW}$**

| $R_{FREQ}$ (kΩ) | $f_{SW}$ (kHz) |
|---|---|
| 13 | 2500 |
| 14.3 | 2330 |
| 15 | 2200 |
| 15.8 | 2100 |
| 18.7 | 1800 |
| 22.6 | 1520 |
| 27.4 | 1270 |
| 32.4 | 1100 |
| 41.2 | 870 |
| 51.1 | 710 |
| 71.5 | 520 |
| 88.7 | 410 |
| 100 | 370 |
| 130 | 285 |
| 191 | 200 |

### GND Connection (PGND, Pins 7–8 and Pins 11–12; AGND, Pin 21)

See the PCB Layout Guidelines section on page 74 for more details.


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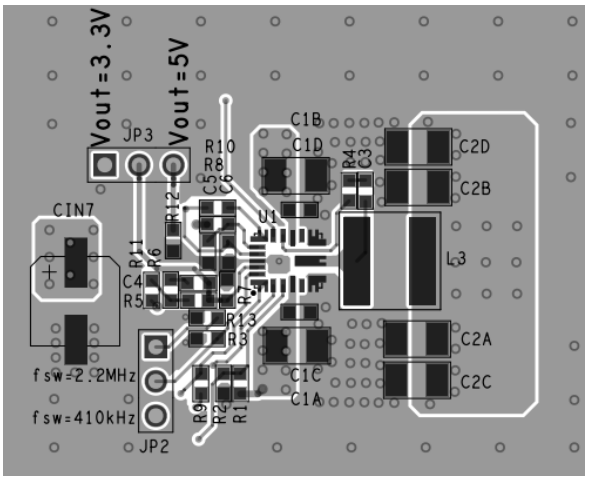
## PCB Layout Guidelines (14)

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 14 and follow the guidelines below:

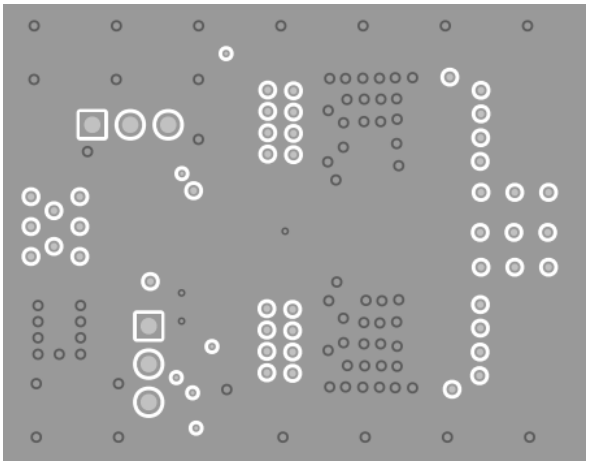
1. Place symmetrical input capacitors as close to VIN and GND as possible.
2. Use a large ground plane to connect directly to PGND.
3. Add vias near PGND if the bottom layer is a ground plane.
4. Ensure that the high-current paths at GND and VIN have short, direct, and wide traces.
5. Place the ceramic 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 GND as possible.
8. Route SW and BST away from sensitive analog areas, such as FB.
9. Use multiple vias to connect the power planes to the internal layers.

**Note:**

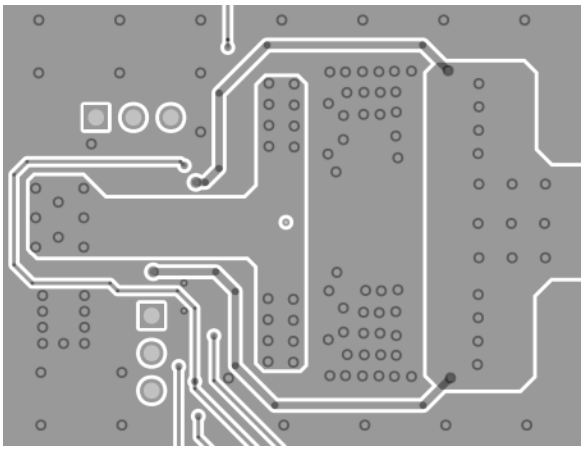
15) The recommended PCB layout is based on Figure 15 on page 75.



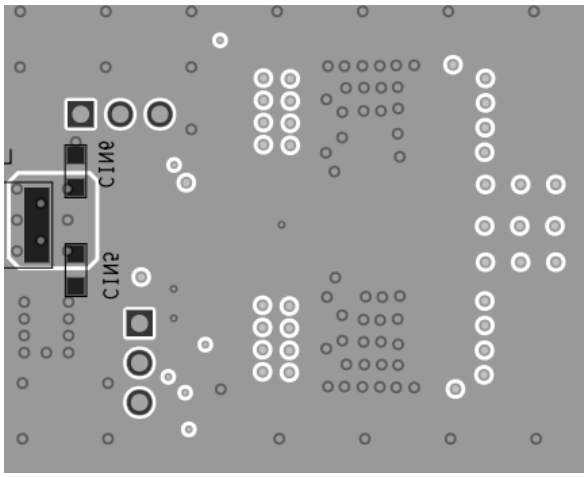

**Top Layer**



**Mid-Layer 1**



**Mid-Layer 2**




**Bottom Layer**

**Figure 14: Recommended PCB Layout**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# TYPICAL APPLICATION CIRCUITS

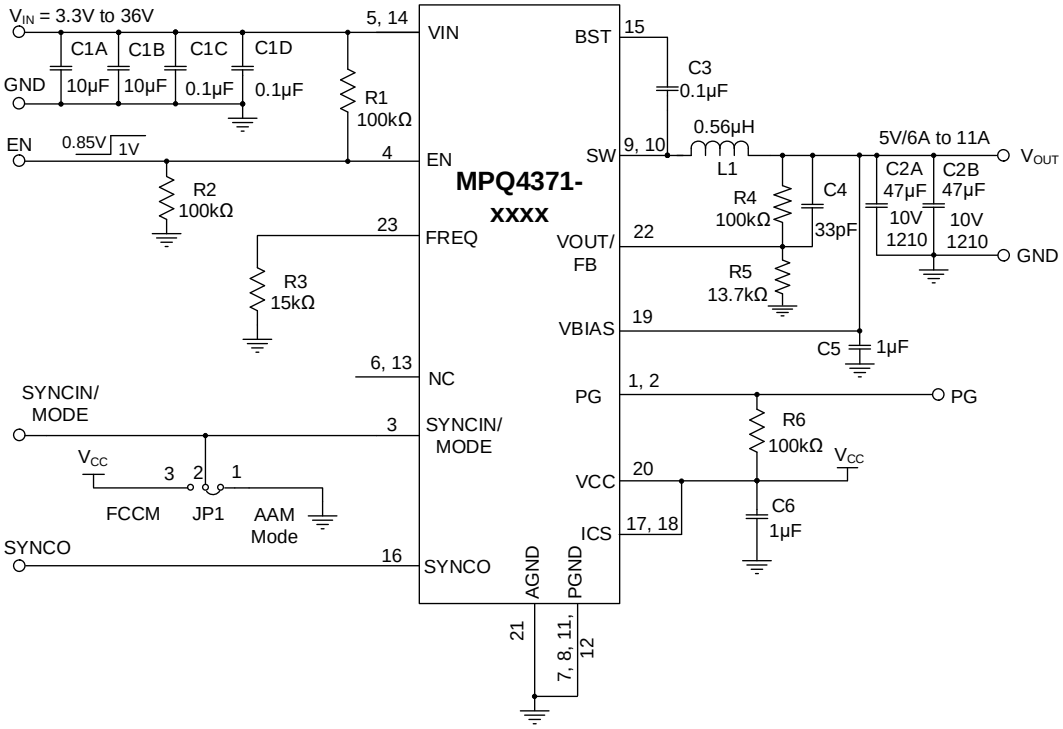


**Figure 15: Typical Application Circuit (Single-Phase, $V_{OUT}$ Adjustable for the MPQ4371-xxxx, $V_{OUT}$ = 5V, $f_{SW}$ = 2.2MHz)**

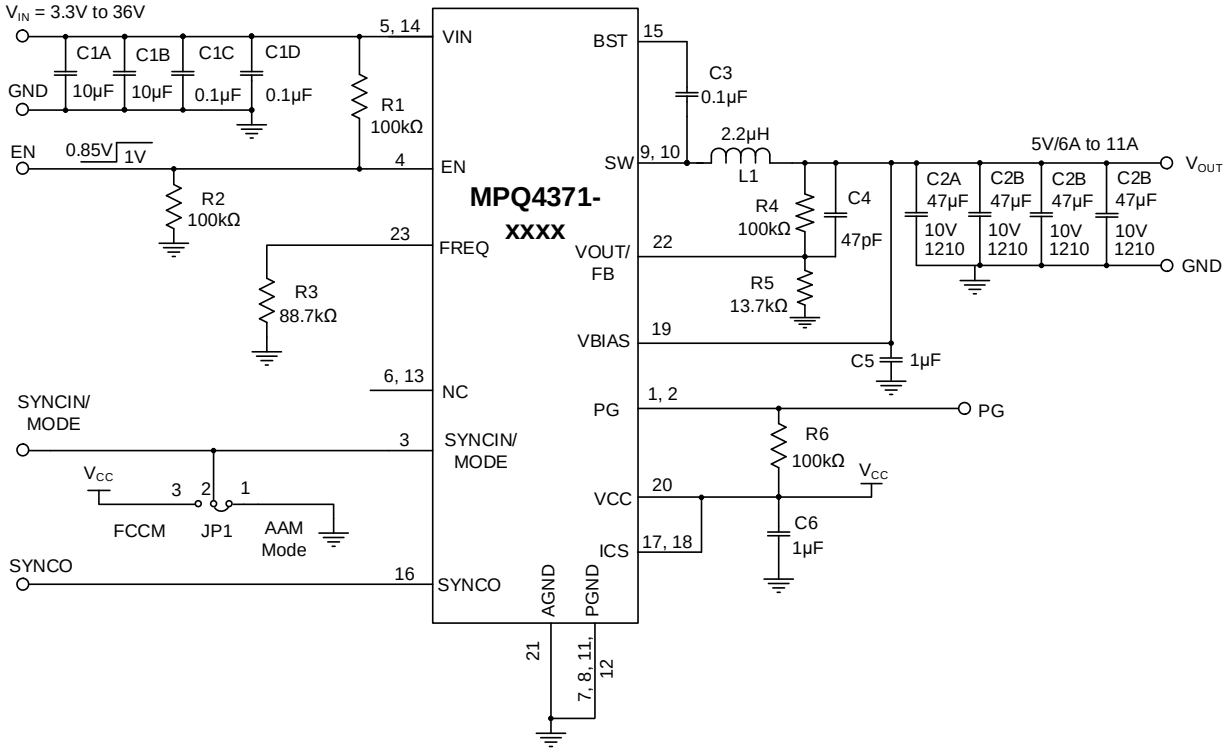


**Figure 16: Typical Application Circuit (Single-Phase, $V_{OUT}$ Adjustable for the MPQ4371-xxxx, $V_{OUT}$ = 5V, $f_{SW}$ = 410kHz)**


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## TYPICAL APPLICATION CIRCUITS *(continued)*

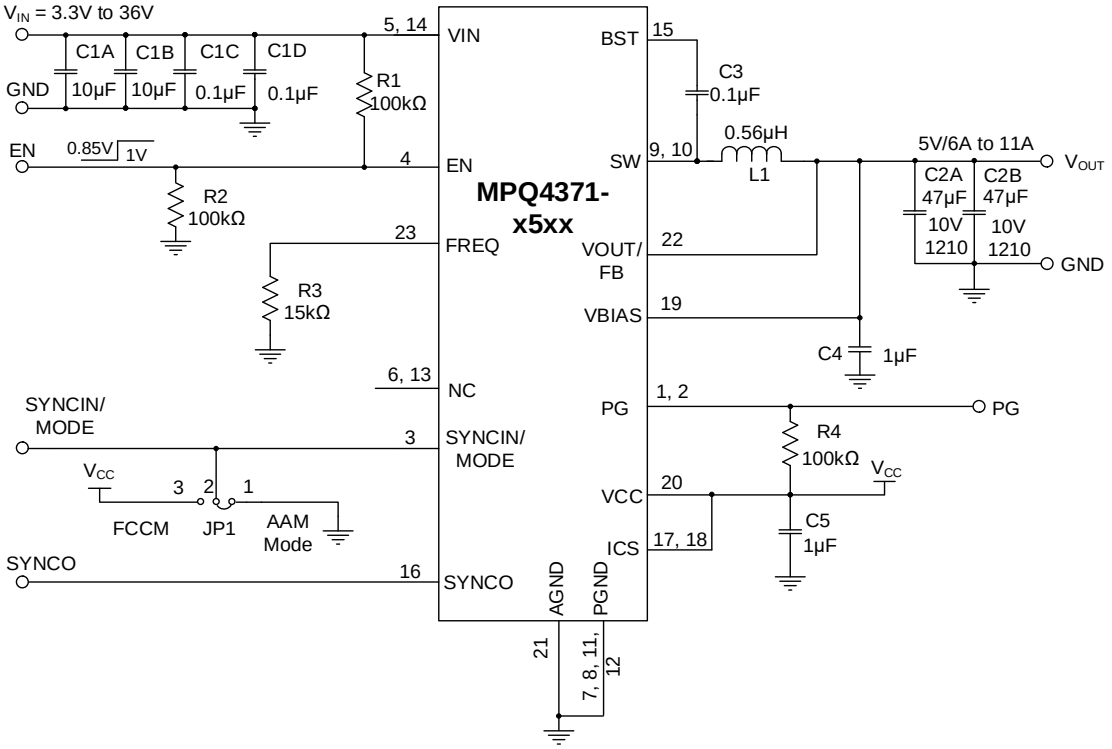


**Figure 17: Typical Application Circuit (Single-Phase, 5V Fixed $V_{OUT}$ for the MPQ4371-xxxx, $f_{SW}$ = 2.2MHz)**

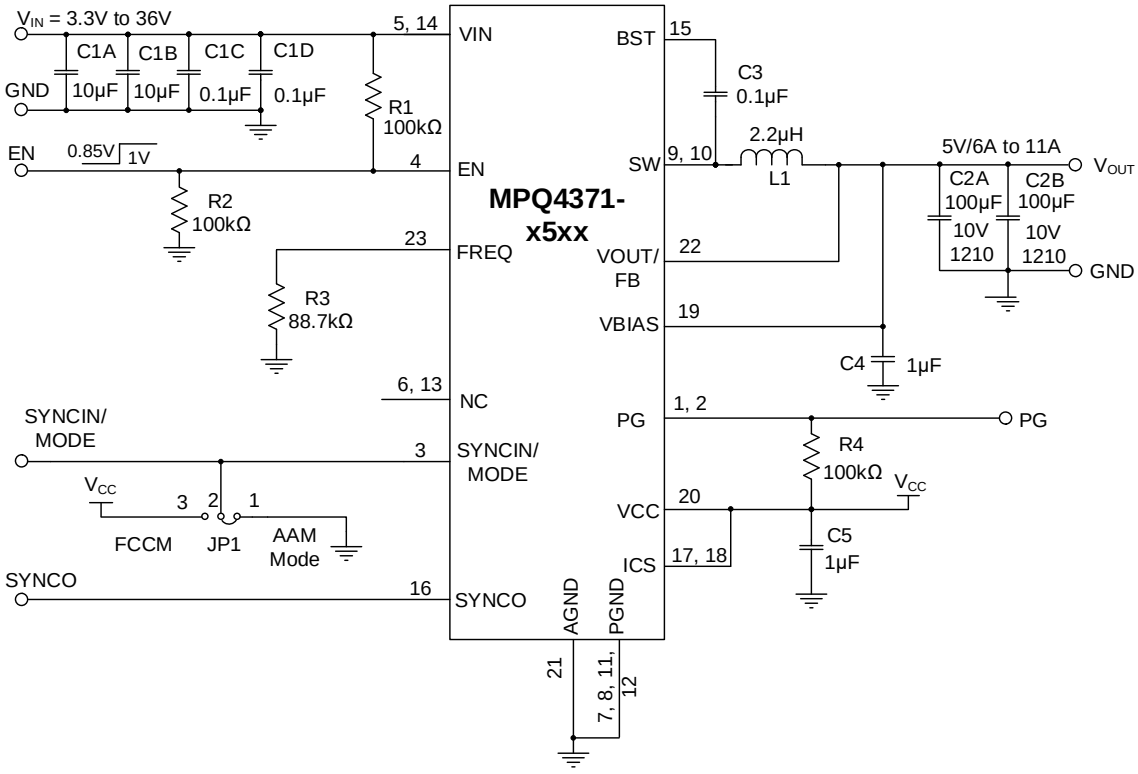


**Figure 18: Typical Application Circuit (Single-Phase, 5V Fixed $V_{OUT}$ for the MPQ4371-xxxx, $f_{SW}$ = 410kHz)**


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## TYPICAL APPLICATION CIRCUITS *(continued)*

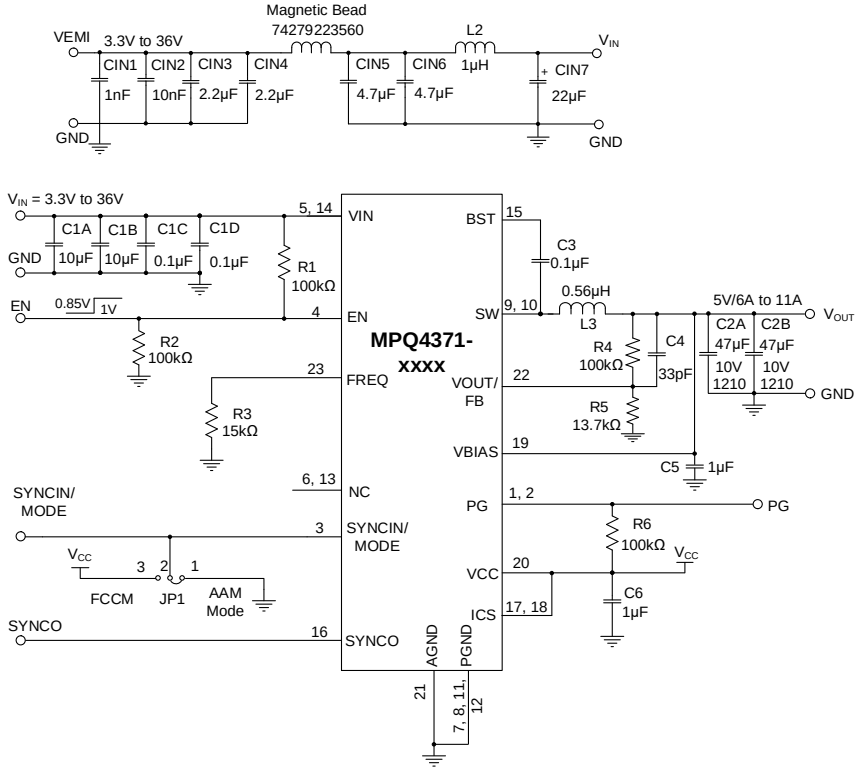


**Figure 19: Typical Application Circuit (Single-Phase, $V_{OUT}$ Adjustable for the MPQ4371-xxxx, $V_{OUT}$ = 5V, $f_{SW}$ = 2.2MHz with EMI Filter)**

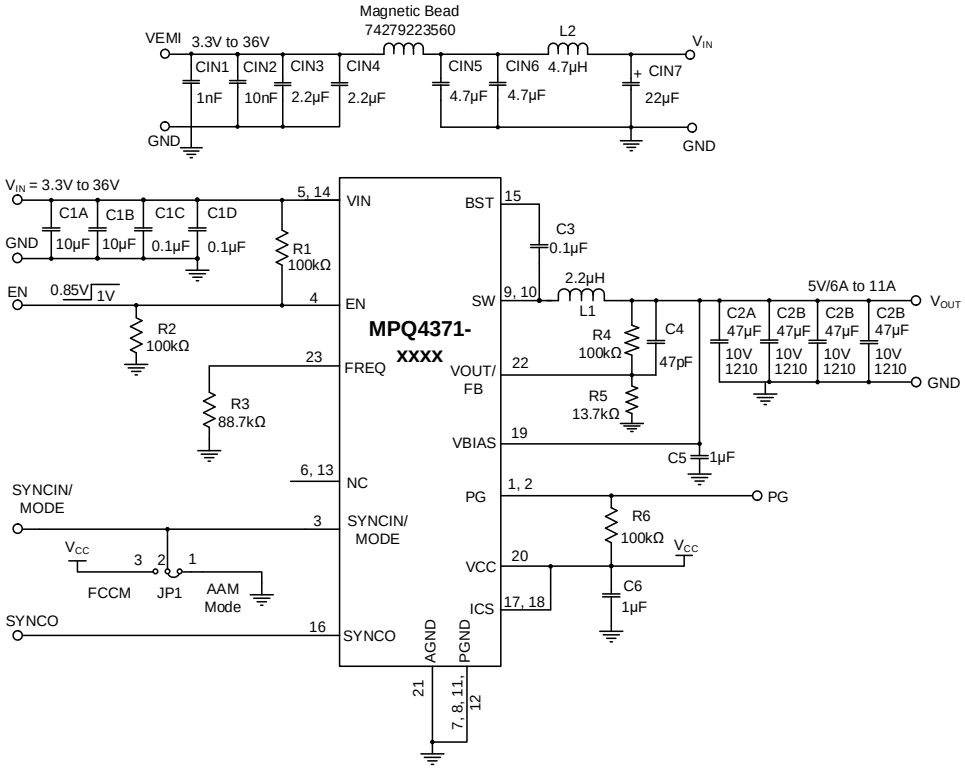


**Figure 20: Typical Application Circuit (Single-Phase, $V_{OUT}$ Adjustable for the MPQ4371-xxxx, $V_{OUT}$ = 5V, $f_{SW}$ = 410kHz with EMI Filter)**


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# TYPICAL APPLICATION CIRCUITS *(continued)*

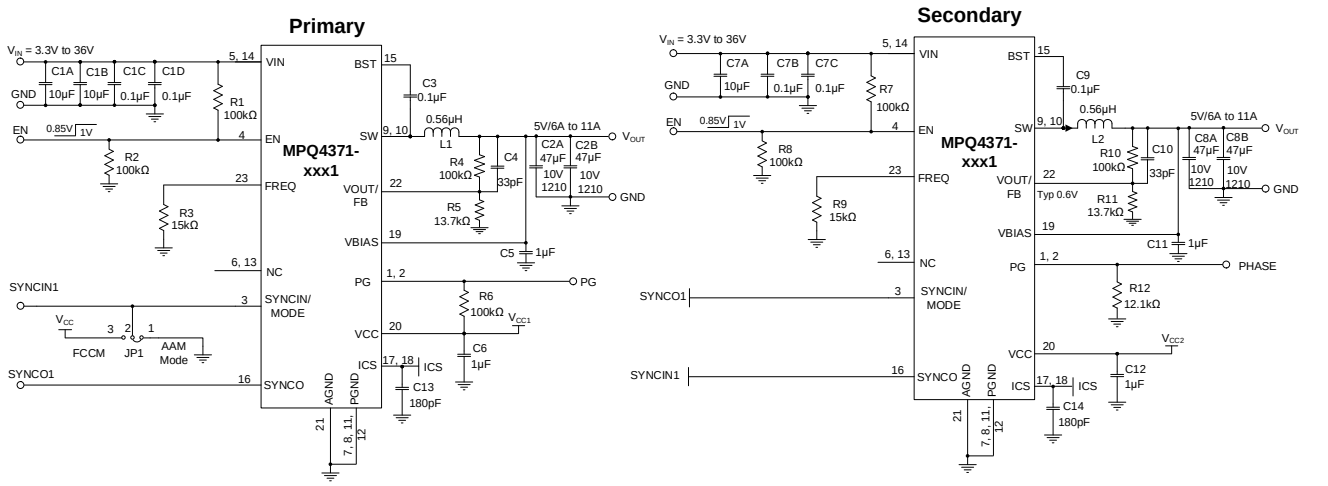


**Figure 21: Typical Application Circuit (Dual-Phase, $V_{OUT}$ Adjustable for the MPQ4371-xxx1, $V_{OUT}$ = 5V, $f_{SW}$ = 2.2MHz)**

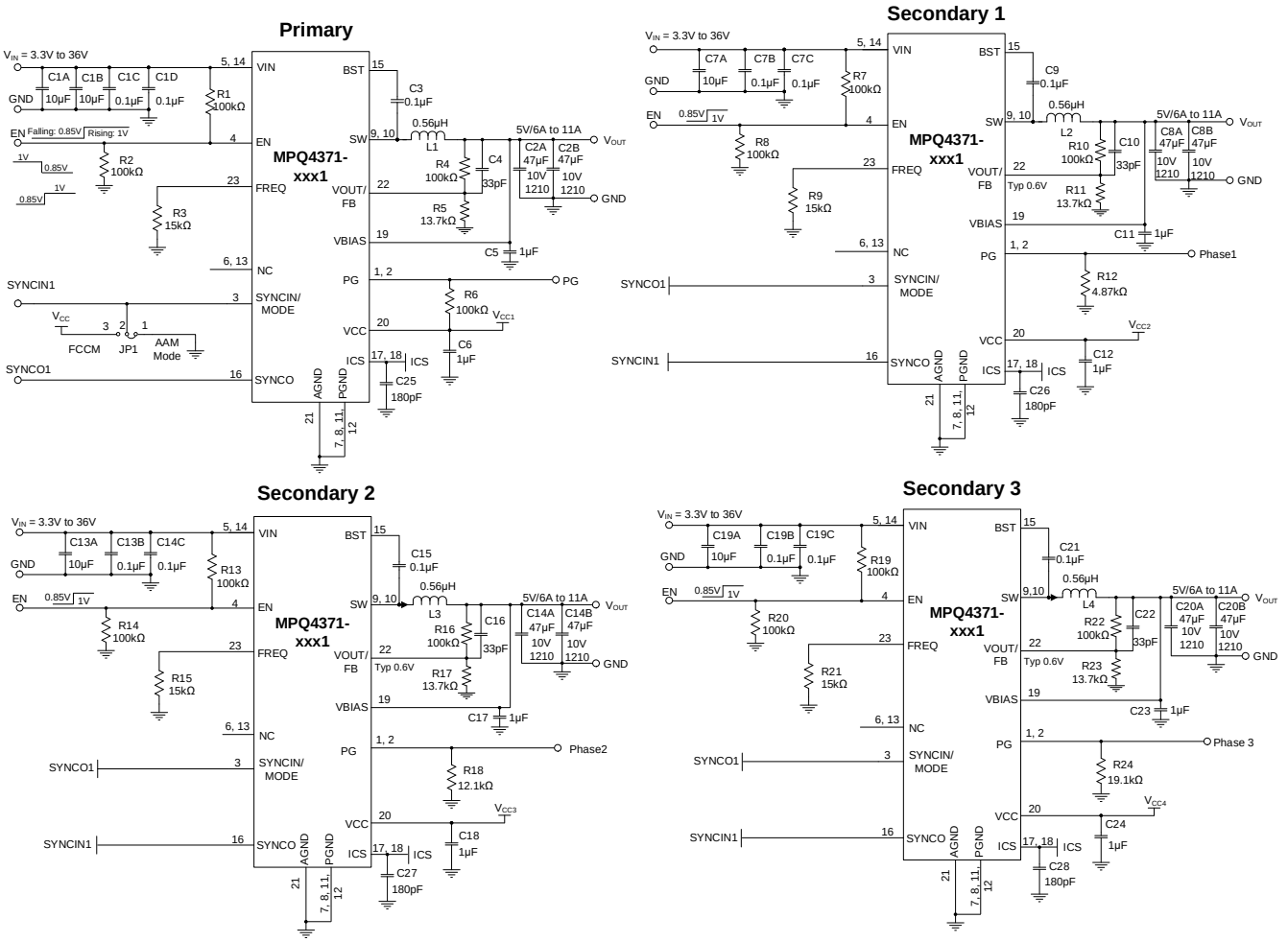


**Figure 22: Typical Application Circuit (Four-Phase, $V_{OUT}$ = 5V for the MPQ4371-xxx1, $f_{SW}$ = 2.2MHz)**


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# TYPICAL APPLICATION CIRCUITS *(continued)*

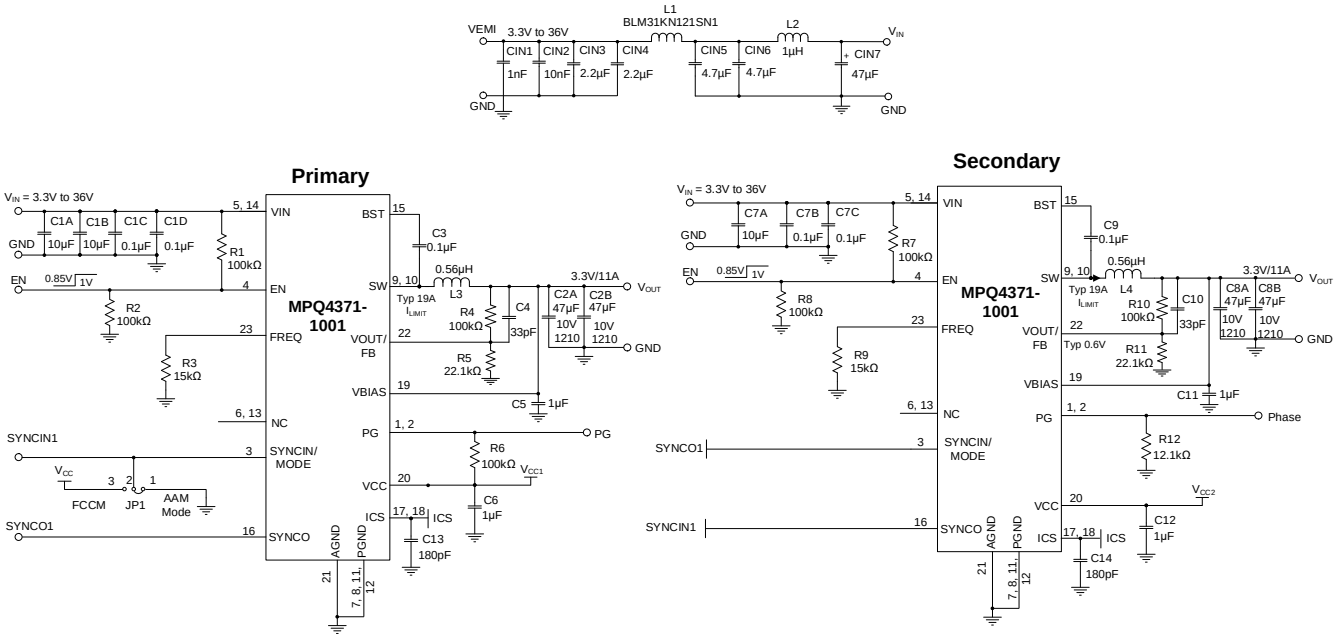


**Figure 23: Typical Application Circuit (Dual-Phase, $V_{OUT}$ Adjustable for the MPQ4371-1001, $V_{OUT}$ = 3.3V, $f_{SW}$ = 2.2MHz, $I_{OUT}$ = 22A with EMI Filter)**


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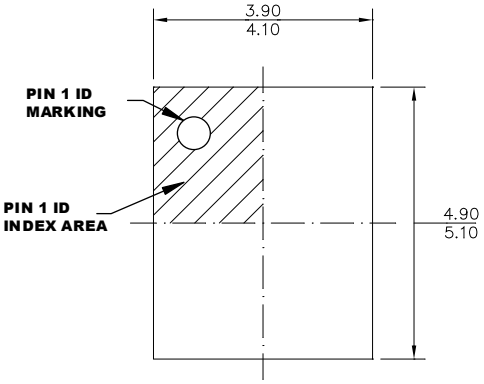
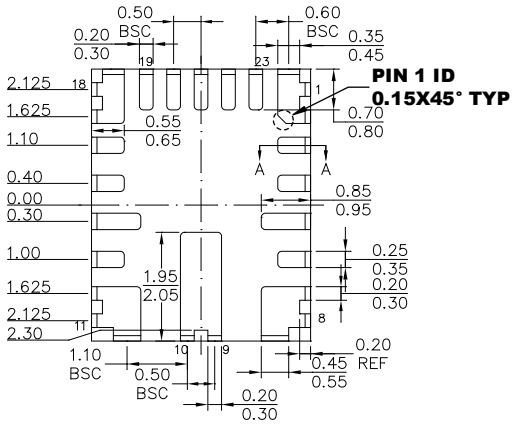
# PACKAGE INFORMATION

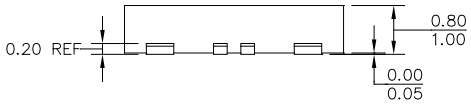
## QFN-23 (4mmx5mm)



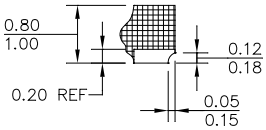

**TOP VIEW**



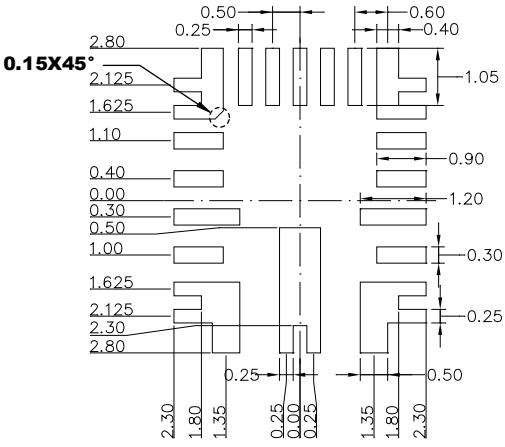

**BOTTOM VIEW**




**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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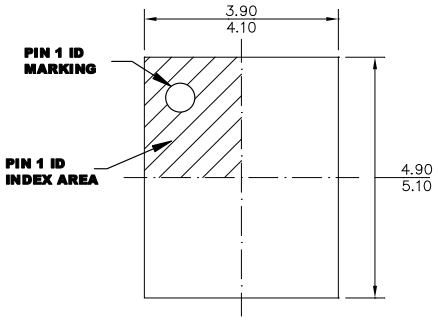
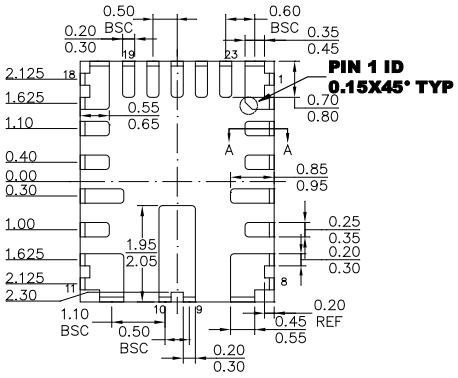
## PACKAGE INFORMATION *(continued)*

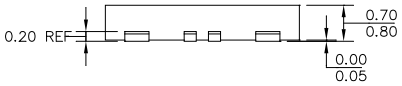
### TQFN-23 (4mmx5mm)



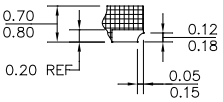

**TOP VIEW**



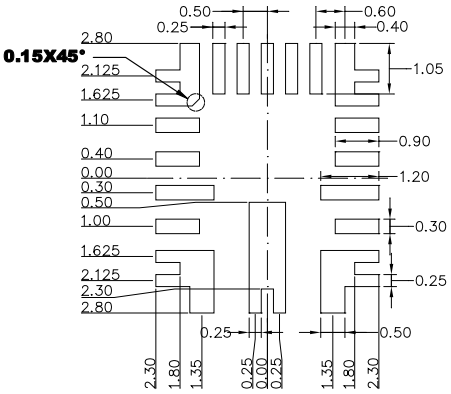

**BOTTOM VIEW**




**SIDE VIEW**




**SECTION A-A**

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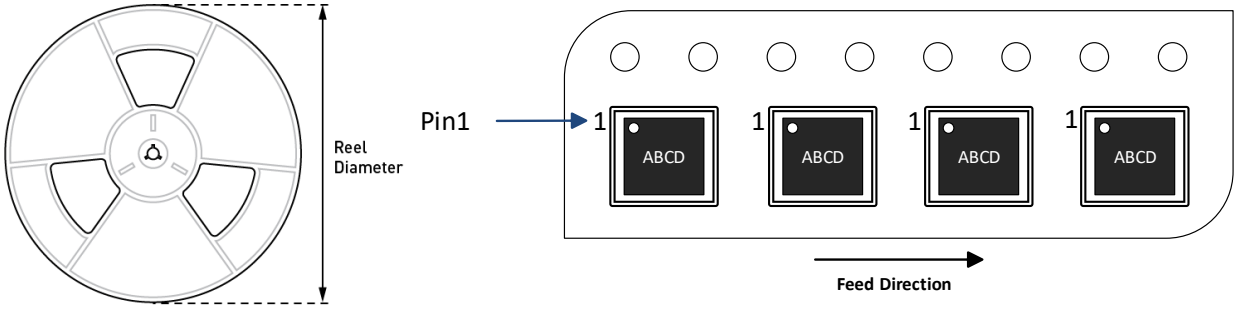
## CARRIER INFORMATION




| Part Number | Package Description | Quantity/ Reel | Quantity/ Tube (16) | Reel Diameter | Carrier Tape Width | Carrier Tape Pitch |
|---|---|---|---|---|---|---|
| MPQ4371GVE-xxxx-AEC1-Z | QFN-23 (4mmx5mm) | 5000 | N/A | 13in | 12mm | 8mm |
| MPQ4371GVTE-xxxx-AEC1-Z | TQFN-23 (4mmx5mm) | 5000 | 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 ordering code for a 500-piece partial reel is “-P”; the tape & reel dimensions are the same as the full reel.)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## REVISION HISTORY

| Revision # | Revision Date | Description | Pages Updated |
|---|---|---|---|
| 1.0 | 3/21/2024 | Initial Release | - |

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