

### DESCRIPTION

The MP8770C is a fully integrated, high-frequency, synchronous rectified step-down switch-mode converter with internal power MOSFETs. The MP8770C offers a very compact solution to achieve 8A of continuous output current with excellent load and line regulation over a wide input range. The MP8770C uses synchronous mode operation for higher efficiency over the output current load range.

Constant-on-time (COT) control operation provides very fast transient response and easy loop design, as well as very tight output regulation.

Full protection features include short-circuit protection (SCP), over-current protection (OCP), under-voltage protection (UVP), and thermal shutdown.

The MP8770C requires a minimal number of readily available, standard external components, and is available in a space-saving QFN-16 (3mmx3mm) package.

### FEATURES

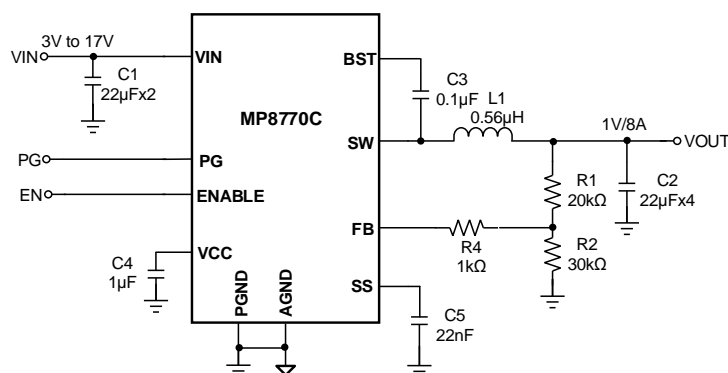
- Wide 3V to 17V Operating Input Range
- 8A Output Current
- 22mΩ/10mΩ Low  $R_{DS(ON)}$  Internal Power MOSFETs
- 100μA Quiescent Current
- Output Adjustable from 0.6V
- High-Efficiency Synchronous Mode Operation
- Pre-Biased Start-Up
- Fixed 700kHz Switching Frequency
- Forced PWM Operation
- External Programmable Soft-Start Time
- EN and Power Good for Power Sequencing
- Over-Current Protection (OCP) and Hiccup Mode
- Thermal Shutdown
- Available in a QFN-16 (3mmx3mm) Package

### APPLICATIONS

- Security Cameras
- Portable Devices, XDSL Devices
- Digital Set-Top Boxes
- Flat-Panel Televisions and Monitors
- General Purpose

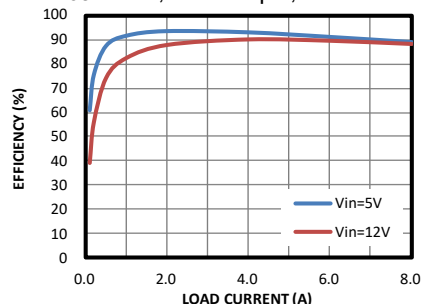
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### TYPICAL APPLICATION



### Efficiency vs. Load Current

$V_{OUT} = 1V$ ,  $L = 0.56\mu H$ ,  $DCR = 1.5m\Omega$



## ORDERING INFORMATION

Part Number*	Package	Top Marking
MP8770CGQ	QFN-16 (3mmx3mm)	See Below

\* For Tape & Reel, add suffix -Z (e.g. MP8770CGQ-Z).

## TOP MARKING

**BGCY**

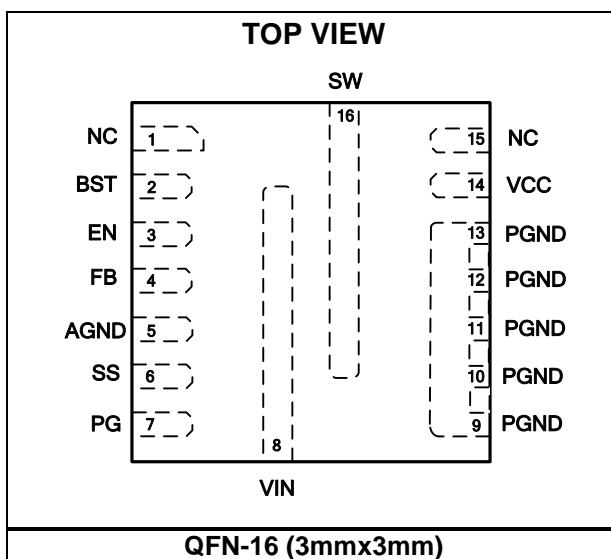
**LLL**

BGC: Product code of MP8770CGQ

Y: Year code

LLL: Lot number

## PACKAGE REFERENCE



## PIN FUNCTIONS

Pin #	Name	Description
1, 15	NC	<b>No connection.</b> Pin must be left floating.
2	BST	<b>Bootstrap.</b> A capacitor connected between the SW and BS pins is required to form a floating supply across the high-side switch driver. It is recommended for the BST resistor to be less than 4.7Ω.
3	EN	<b>Enable.</b> Pull EN high to enable the MP8770C. When floating, EN is pulled down to GND by an internal 1.2MΩ resistor so it is disabled.
4	FB	<b>Feedback.</b> Sets the output voltage when connected to the tap of an external resistor divider that is connected between output and GND.
5	AGND	<b>Signal ground.</b> AGND is not internally connected to the system ground. Ensure that AGND is connected to the system ground in PCB layout.
6	SS	<b>Soft start.</b> Connect a capacitor across SS and GND to set the soft-start time and avoid start-up inrush current.
7	PG	<b>Power good output.</b> The output of this pin is an open drain. It will change state if UVP, OCP, OTP, or OV occurs.
8	VIN	<b>Supply voltage.</b> The MP8770C operates from a 3V to 17V input rail. C1 is needed to decouple the input rail. Use a wide PCB trace to make the connection.
9, 10, 11, 12, 13	PGND	<b>System ground.</b> This pin is the reference ground of the regulated output voltage, so care must be taken during PCB layout. It is recommended to connect it to GND with copper pours and vias.
14	VCC	<b>Internal bias supply output.</b> Decouple with a 1μF capacitor. The VCC capacitor should be placed close to the VCC and GND pins.
16	SW	<b>Switch output.</b> Use a wide PCB trace to make the connection.

ABSOLUTE MAXIMUM RATINGS <sup>(1)</sup>

V <sub>IN</sub> .....	-0.3V to +20V
V <sub>SW</sub> - 0.3V (-5V < 10ns) to + V <sub>IN</sub> +0.7V (23V < 10ns)	
V <sub>BST</sub> .....	V <sub>SW</sub> + 4V
V <sub>EN</sub> .....	V <sub>IN</sub>
All other pins.....	-0.3V to +4V
Continuous power dissipation (T <sub>A</sub> = 25°C) <sup>(2)</sup> <sup>(4)</sup>	3.2W
Junction temperature .....	150°C
Lead temperature .....	260°C
Storage temperature .....	-65°C to +125°C

Recommended Operating Conditions <sup>(3)</sup>

Supply voltage (V <sub>IN</sub> ) .....	3V to 17V
Output voltage (V <sub>OUT</sub> ) .....	0.6V to V <sub>IN</sub> * D <sub>MAX</sub> or 12V max
Operating junction temp.....	-40°C to +125°C

Thermal Resistance      θ<sub>JA</sub>    θ<sub>JC</sub>

QFN-16 (3mmx3mm)		
EV8770C-Q-00A <sup>(4)</sup> .....	38.....	10....°C/W
JESD51-7 <sup>(5)</sup> .....	50.....	12...°C/W

## Notes:

- Exceeding these ratings may damage the device.
- The maximum allowable power dissipation is a function of the maximum junction temperature T<sub>J</sub> (MAX), the junction-to-ambient thermal resistance θ<sub>JA</sub>, and the ambient temperature T<sub>A</sub>. The maximum allowable continuous power dissipation at any ambient temperature is calculated by P<sub>D</sub> (MAX) = (T<sub>J</sub> (MAX) - T<sub>A</sub>) / θ<sub>JA</sub>. Exceeding the maximum allowable power dissipation will cause excessive die temperature, and the regulator will go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.
- The device is not guaranteed to function outside of its operating conditions.
- Measured on EV8770C-Q-00A, 4-layer PCB.
- The value of θ<sub>JA</sub> given in this table is only valid for comparison with other packages and cannot be used for design purposes. These values were calculated in accordance with JESD51-7, and simulated on a specified JEDEC board. They do not represent the performance obtained in an actual application.

## ELECTRICAL CHARACTERISTICS <sup>(6)</sup>

$V_{IN} = 12V$ ,  $T_J = -40^{\circ}C$  to  $+125^{\circ}C$ , typical value is tested at  $T_J = 25^{\circ}C$ , unless otherwise noted.

Parameter	Symbol	Condition	Min	Typ	Max	Units
Input voltage range	$V_{IN}$		3		17	V
<b>Supply Current</b>						
Supply current (shutdown)	$I_{IN}$	$V_{EN} = 0V$			5	$\mu A$
Supply current (quiescent)	$I_Q$	$V_{EN} = 2V$ , $V_{FB} = 0.65V$		100	150	$\mu A$
<b>MOSFET</b>						
HS switch on resistance	$HS_{RDS-ON}$	$V_{BST-SW} = 3.3V$		22		m $\Omega$
LS switch on resistance	$LS_{RDS-ON}$	$V_{CC} = 3.3V$		10		m $\Omega$
Switch leakage	$SW_{LKG}$	$V_{EN} = 0V$ , $V_{SW} = 17V$			1	$\mu A$
<b>Current Limit</b>						
Valley current limit	$I_{LIMIT\_VY}$		8	10		A
Short hiccup duty cycle <sup>(7)</sup>	$D_{HICCUP}$			10		%
<b>Switching Frequency and Minimum On/Off Timer</b>						
Switching frequency	$f_{SW}$		600	700	800	kHz
Minimum on time <sup>(7)</sup>	$t_{ON\_MIN}$			50		ns
Minimum off time <sup>(7)</sup>	$t_{OFF\_MIN}$			100		ns
<b>Reference and Soft Start</b>						
Feedback voltage	$V_{FB}$	$T_J = 25^{\circ}C$	594	600	606	mV
		$T_J = -40^{\circ}C$ to $+125^{\circ}C$	591	600	609	
Feedback current	$I_{FB}$	$V_{FB} = 700mV$		10	50	nA
Soft-start current	$I_{SS\_START}$		4	6	8	$\mu A$
<b>Enable and UVLO</b>						
EN rising threshold	$V_{EN\ RISING}$		1.1	1.25	1.4	V
EN falling threshold	$V_{EN\ FALLING}$		0.9	1	1.1	V
EN pin pull-down resistor	$R_{EN\_PD}$			1.2		M $\Omega$
<b>VCC</b>						
VCC under-voltage lockout rising threshold	$V_{CCVth}$		2.6	2.8	3	V
VCC under-voltage lockout threshold	$V_{CCHYS}$			350		mV
VCC regulator	$V_{CC}$			3.4		V
VCC load regulation	$Reg_{VCC}$	$I_{CC} = 5mA$		3		%

# ELECTRICAL CHARACTERISTICS (continued) <sup>(6)</sup>

$V_{IN} = 12V$ ,  $T_J = -40^{\circ}C$  to  $+125^{\circ}C$ , typical value is tested at  $T_J = 25^{\circ}C$ , unless otherwise noted.

Parameter	Symbol	Condition	Min	Typ	Max	Units
<b>Power Good</b>						
Power good UV rising threshold	$PGUV_{vth\_Hi}$		0.85	0.9	0.95	$V_{FB}$
Power good UV falling threshold	$PGUV_{vth\_Lo}$		0.75	0.80	0.85	$V_{FB}$
Power good OV rising threshold	$PGOV_{vth\_Hi}$		1.15	1.2	1.25	$V_{FB}$
Power good OV falling threshold	$PGOV_{vth\_Lo}$		1.05	1.1	1.15	$V_{FB}$
Power good delay	$PG_{Td}$	Both edge		50		$\mu s$
Power good sink current capability	$V_{PG}$	Sink 4mA			0.4	V
Power good leakage current	$I_{PG\_LEAK}$	$V_{PG} = 5V$			10	$\mu A$
<b>Thermal Protection</b>						
Thermal shutdown <sup>(7)</sup>	$T_{SD}$			150		$^{\circ}C$
Thermal hysteresis <sup>(7)</sup>	$T_{SD-HYS}$			20		$^{\circ}C$

## Notes:

6) Not tested in production. Guaranteed by over-temperature correlation.

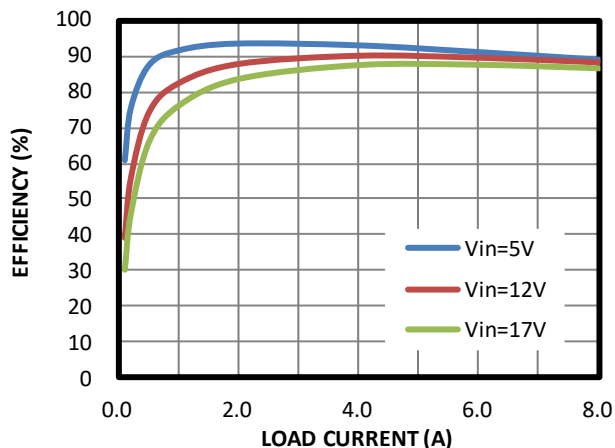
7) Guaranteed by design and characterization test.

# TYPICAL PERFORMANCE CHARACTERISTICS

$V_{IN} = 12V$ ,  $V_{OUT} = 1V$ ,  $L = 0.56\mu H$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

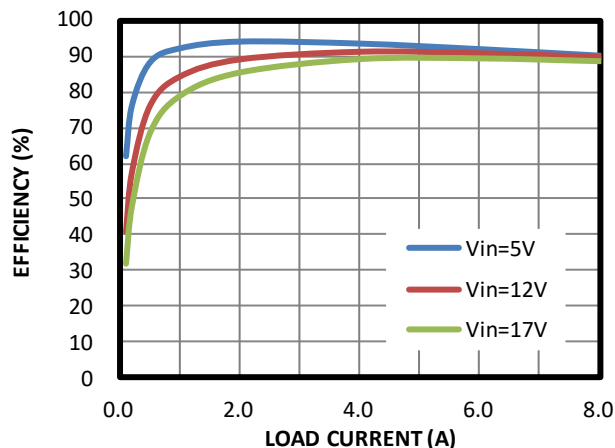
## Efficiency vs. Load Current

$V_{OUT} = 1V$ ,  $L = 0.56\mu H$ ,  $DCR = 1.5m\Omega$



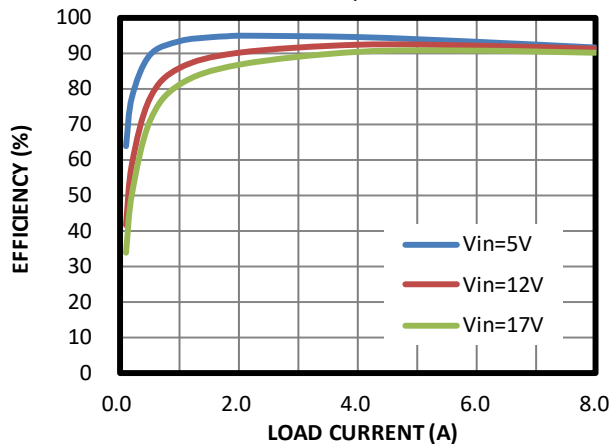
## Efficiency vs. Load Current

$V_{OUT} = 1.2V$ ,  $L = 0.56\mu H$ ,  $DCR = 1.5m\Omega$



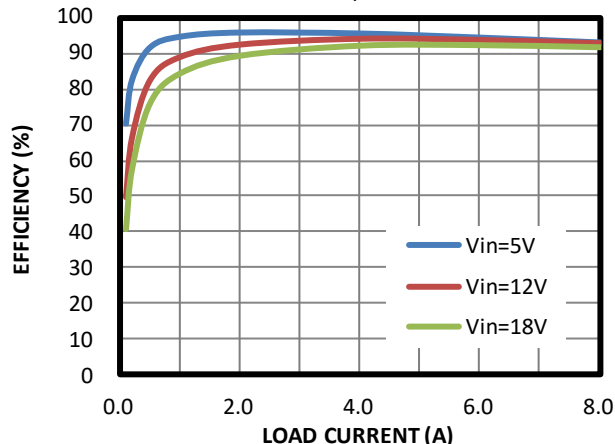
## Efficiency vs. Load Current

$V_{OUT} = 1.5V$ ,  $L = 0.56\mu H$ ,  $DCR = 1.5m\Omega$



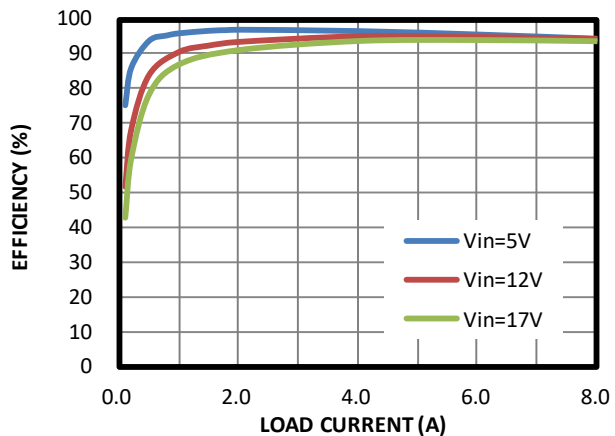
## Efficiency vs. Load Current

$V_{OUT} = 1.8V$ ,  $L = 0.82\mu H$ ,  $DCR = 0.9m\Omega$



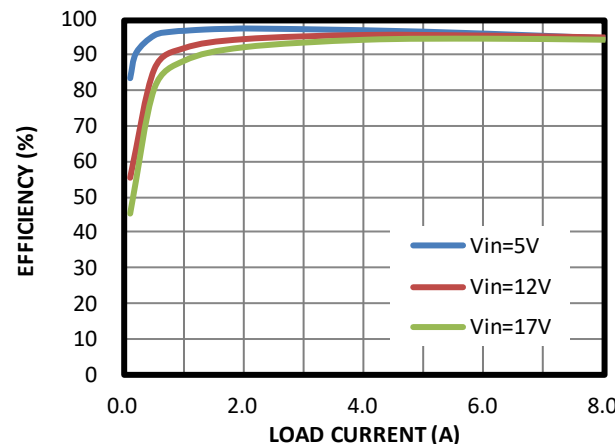
## Efficiency vs. Load Current

$V_{OUT} = 2.5V$ ,  $L = 0.82\mu H$ ,  $DCR = 0.9m\Omega$



## Efficiency vs. Load Current

$V_{OUT} = 3.3V$ ,  $L = 1\mu H$ ,  $DCR = 1.35m\Omega$

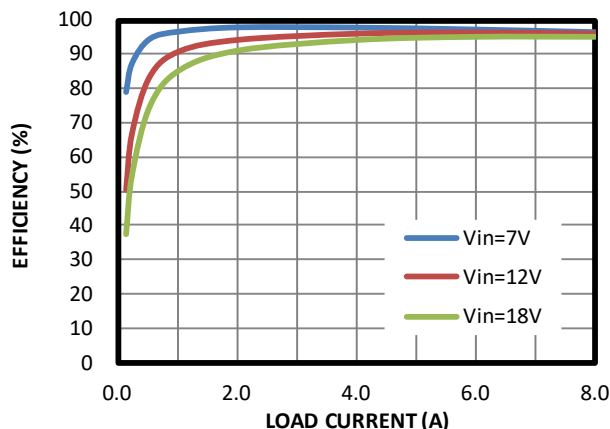


# TYPICAL PERFORMANCE CHARACTERISTICS (continued)

$V_{IN} = 12V$ ,  $V_{OUT} = 1V$ ,  $L = 0.56\mu H$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

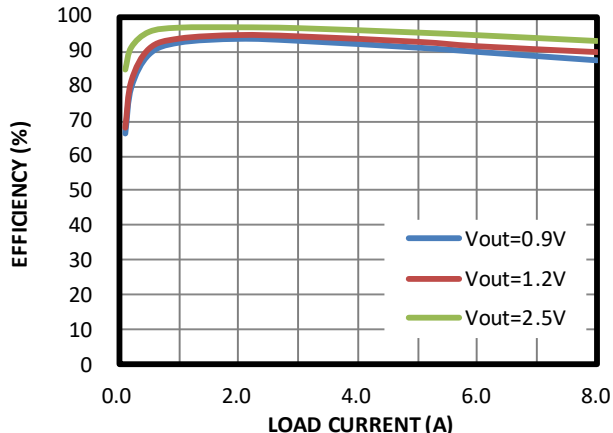
**Efficiency vs. Load Current**

$V_{OUT} = 5V$ ,  $L = 1.2\mu H$ ,  $DCR = 1.8m\Omega$



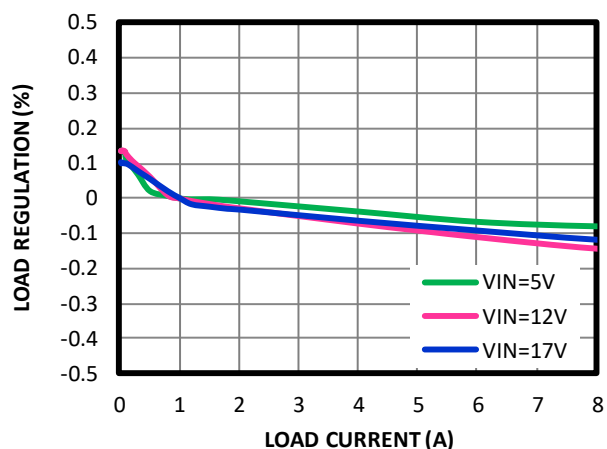
**Efficiency vs. Load Current**

$V_{IN} = 3.3V$ ,  $L = 0.68\mu H$ ,  $DCR = 1.58m\Omega$



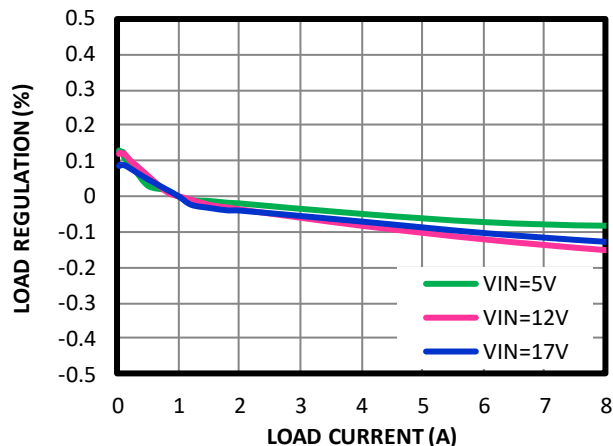
**Load Regulation vs. Load Current**

$V_{OUT} = 1V$



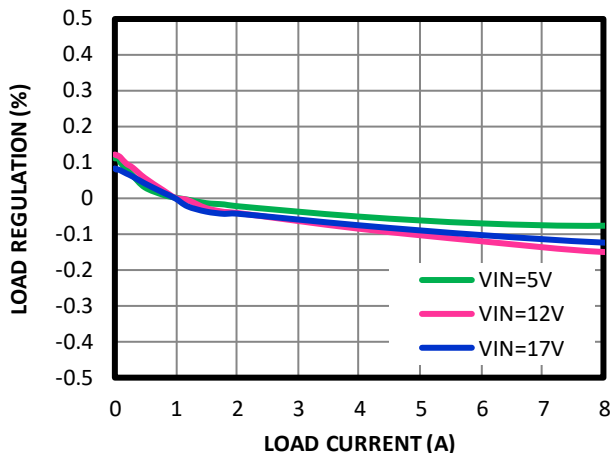
**Load Regulation vs. Load Current**

$V_{OUT} = 1.2V$



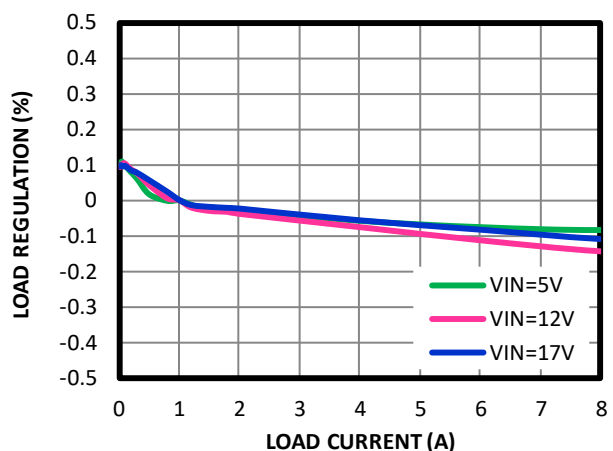
**Load Regulation vs. Load Current**

$V_{OUT} = 1.5V$



**Load Regulation vs. Load Current**

$V_{OUT} = 1.8V$

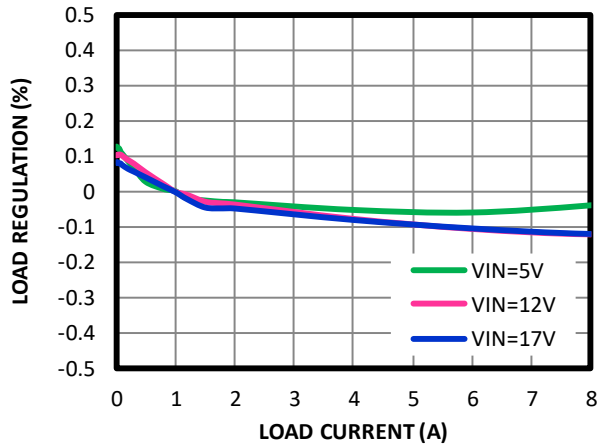


## TYPICAL PERFORMANCE CHARACTERISTICS (continued)

$V_{IN} = 12V$ ,  $V_{OUT} = 1V$ ,  $L = 0.56\mu H$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

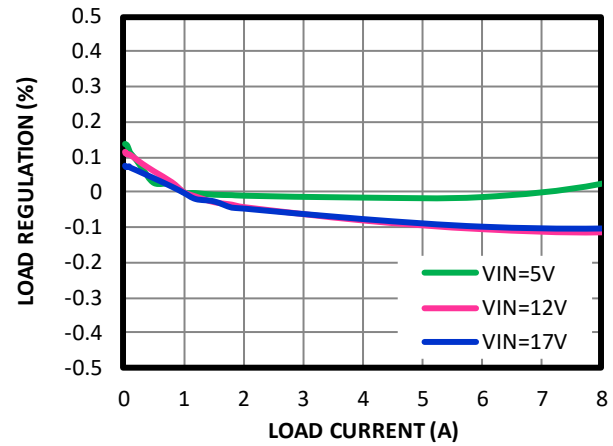
**Load Regulation vs. Load Current**

$V_{OUT} = 2.5V$



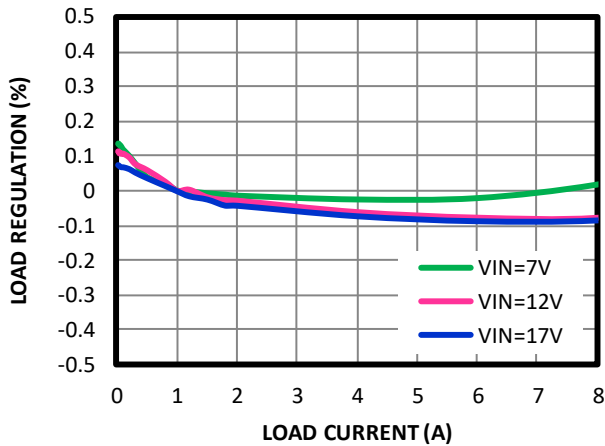
**Load Regulation vs. Load Current**

$V_{OUT} = 3.3V$

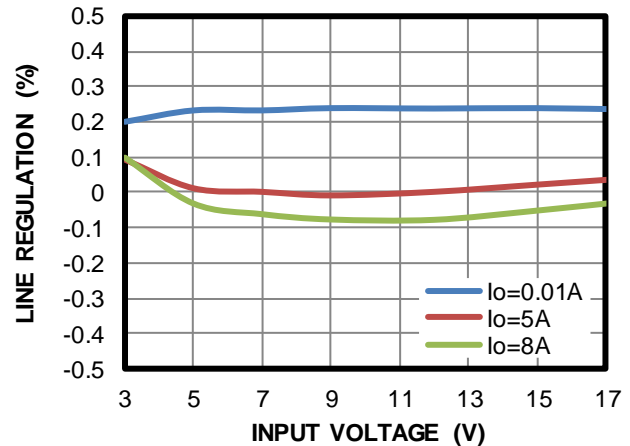


**Load Regulation vs. Load Current**

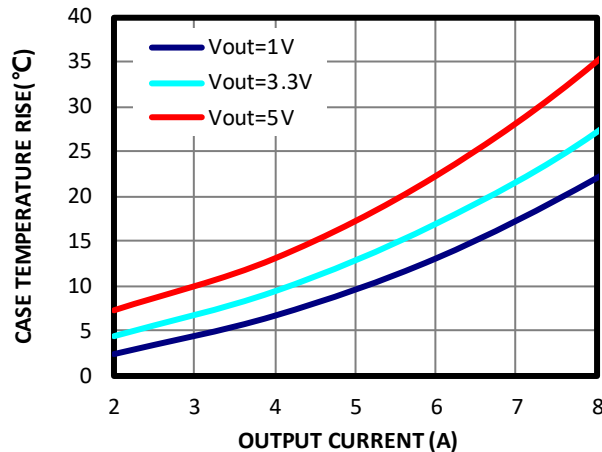
$V_{OUT} = 5V$



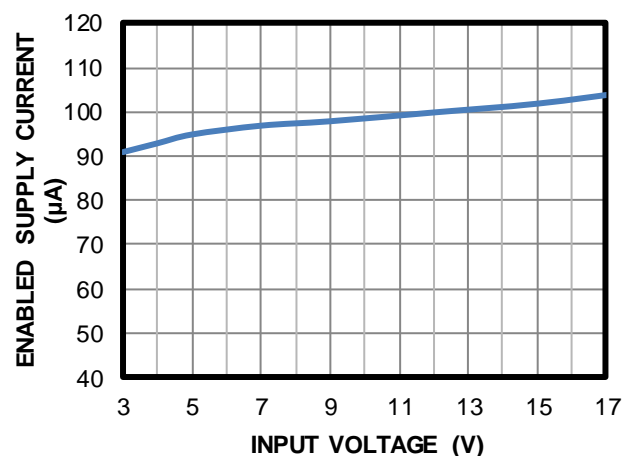
**Line Regulation vs. Input Voltage**



**Case Temperature Rise vs. Output Current**



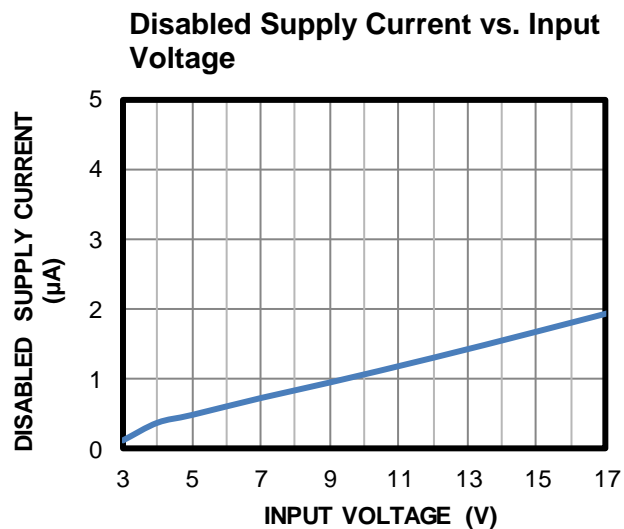
**Enabled Supply Current vs. Input Voltage**





## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

$V_{IN} = 12V$ ,  $V_{OUT} = 1V$ ,  $L = 0.56\mu H$ ,  $T_A = 25^\circ C$ , unless otherwise noted.



## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

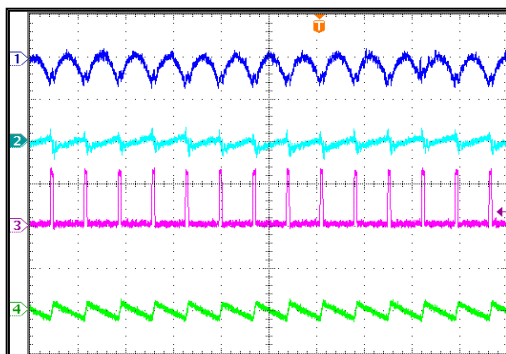
$V_{IN} = 12V$ ,  $V_{OUT} = 1V$ ,  $L = 0.56\mu H$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

### Input/Output Ripple

$I_{OUT} = 0A$

CH1:  
 $V_{OUT}/AC$   
10mV/div.  
CH2:  $V_{IN}/AC$   
20mV/div.

CH3:  $V_{SW}$   
10V/div.  
CH4:  $I_L$   
5A/div.



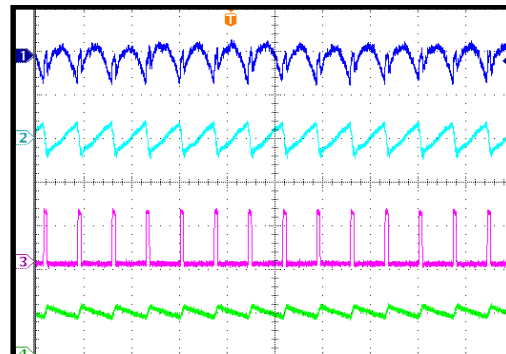
2µs/div.

### Input/Output Ripple

$I_{OUT} = 8A$

CH1:  
 $V_{OUT}/AC$   
10mV/div.  
CH2:  
 $V_{IN}/AC$   
500mV/div.

CH3:  $V_{SW}$   
10V/div.  
CH4:  $I_L$   
10A/div.



2µs/div.

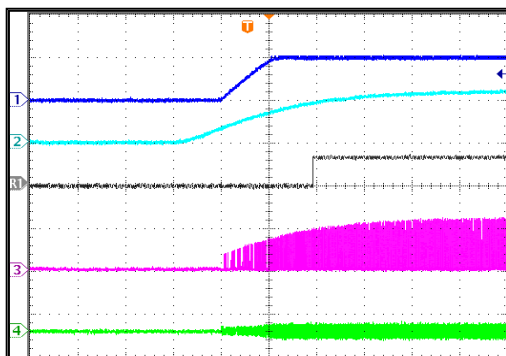
### Start-Up through Input Voltage

$I_{OUT} = 0A$

CH1:  $V_{OUT}$   
1V/div.  
CH2:  $V_{IN}$   
10V/div.

CH3:  $V_{PG}$   
5V/div.  
CH4:  $V_{SW}$   
10V/div.

CH5:  $I_L$   
5A/div.



2ms/div.

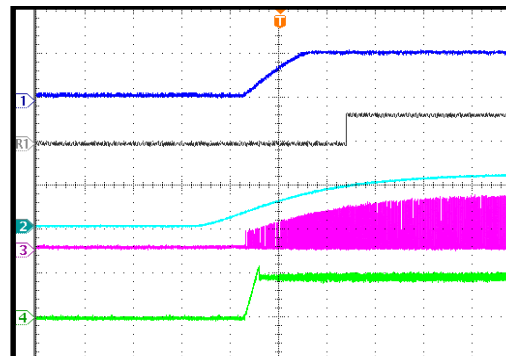
### Start-Up through Input Voltage

$I_{OUT} = 8A$

CH1:  $V_{OUT}$   
1V/div.  
CH2:  $V_{IN}$   
10V/div.

CH3:  $V_{PG}$   
5V/div.  
CH4:  $V_{SW}$   
10V/div.

CH5:  $I_L$   
10A/div.



2ms/div.

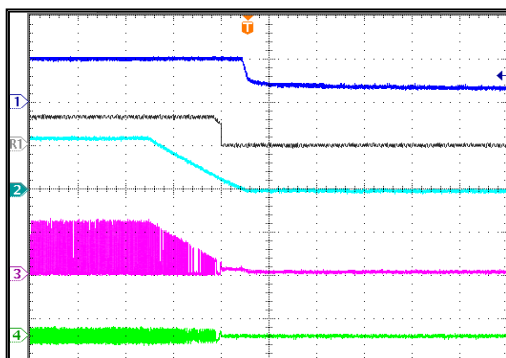
### Shutdown through Input Voltage

$I_{OUT} = 0A$

CH1:  $V_{OUT}$   
1V/div.  
CH2:  $V_{PG}$   
5V/div.

CH3:  $V_{IN}$   
10V/div.  
CH4:  $V_{SW}$   
10V/div.

CH5:  $I_L$   
5A/div.



40ms/div.

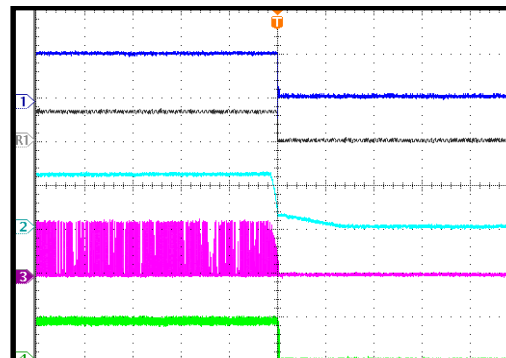
### Shutdown through Input Voltage

$I_{OUT} = 8A$

CH1:  $V_{OUT}$   
1V/div.  
CH2:  $V_{PG}$   
5V/div.

CH3:  $V_{IN}$   
10V/div.  
CH4:  $V_{SW}$   
10V/div.

CH5:  $I_L$   
10A/div.



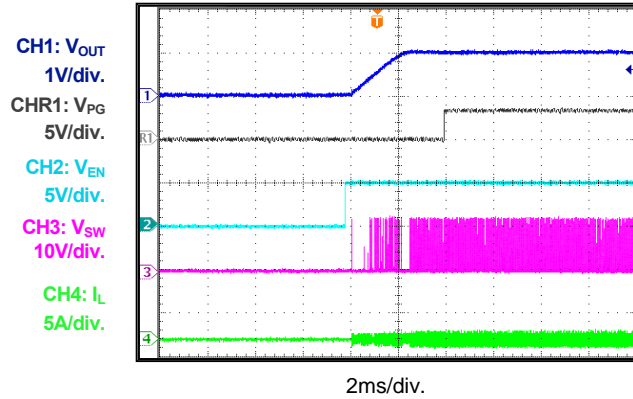
40ms/div.

## TYPICAL PERFORMANCE CHARACTERISTICS (continued)

$V_{IN} = 12V$ ,  $V_{OUT} = 1V$ ,  $L = 0.56\mu H$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

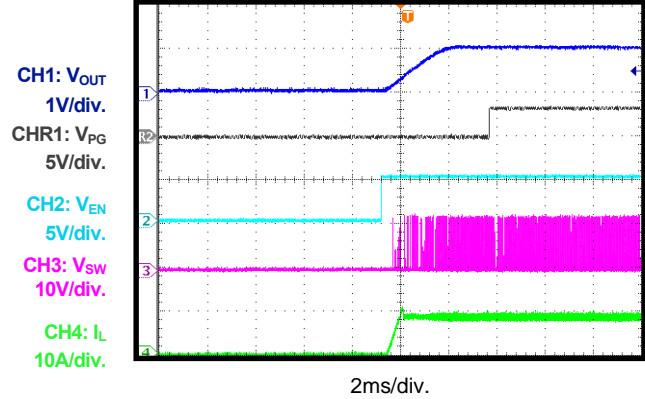
### Start-Up through EN

$I_{OUT} = 0A$



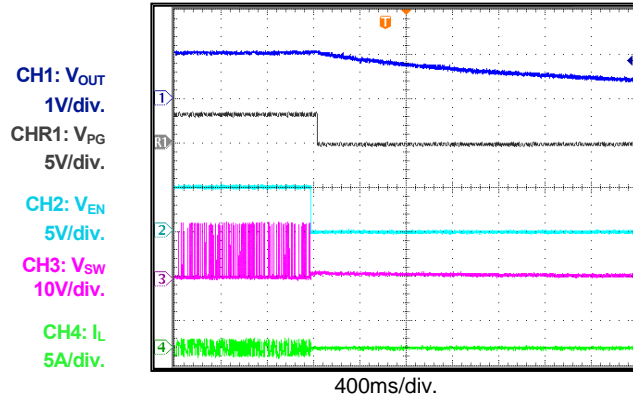
### Start-Up through EN

$I_{OUT} = 8A$



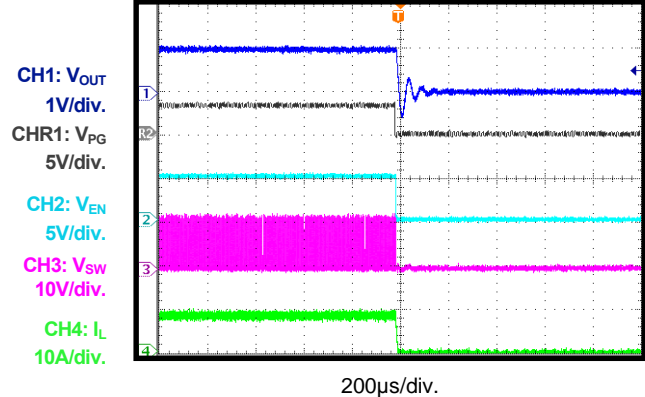
### Shutdown through EN

$I_{OUT} = 0A$



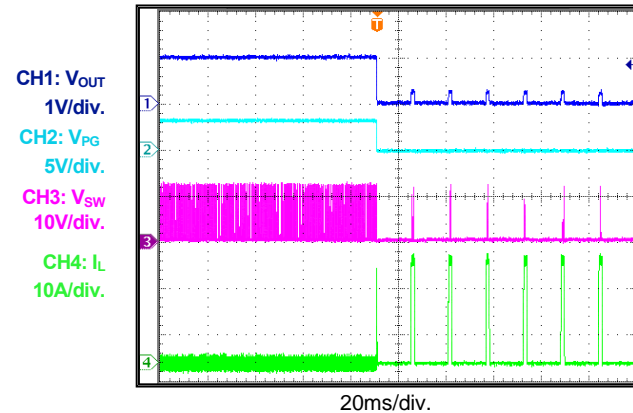
### Shutdown through EN

$I_{OUT} = 8A$



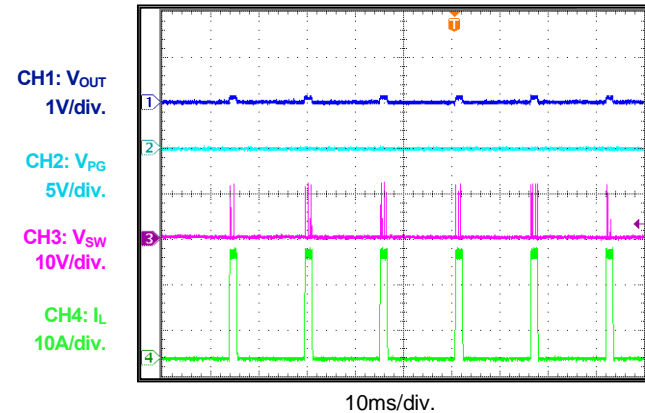
### Short-Circuit Protection Entry

$I_{OUT} = 0A$



### Short-Circuit Protection Steady State

Short output to GND

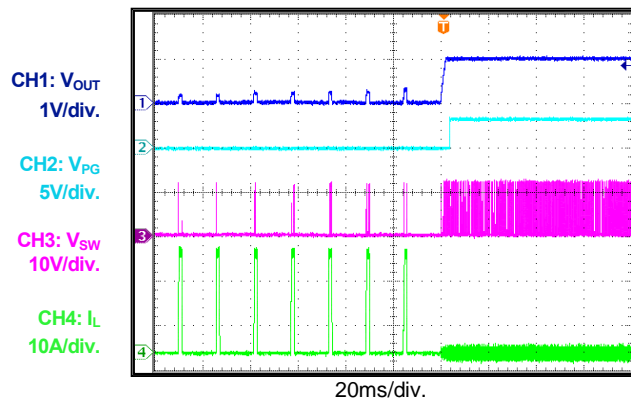


## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

$V_{IN} = 12V$ ,  $V_{OUT} = 1V$ ,  $L = 0.56\mu H$ ,  $T_A = 25^\circ C$ , unless otherwise noted.

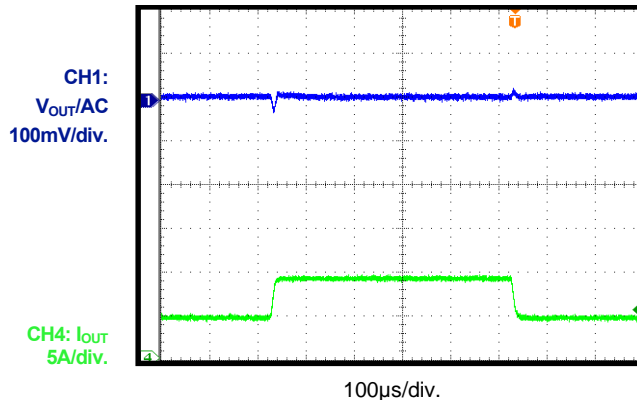
### Short-Circuit Protection Recovery

$I_{OUT} = 0A$

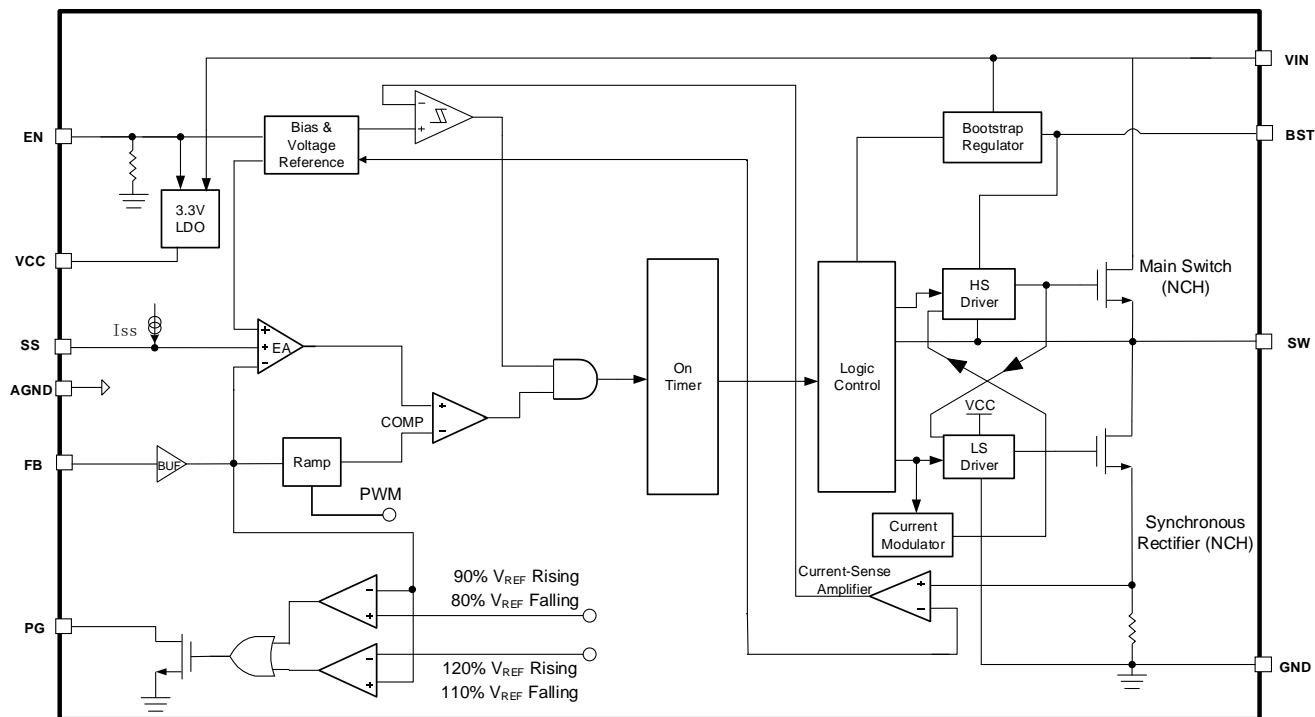


### Load Transient

$I_{OUT} = 4A$  to  $8A$



## FUNCTIONAL BLOCK DIAGRAM



**Figure 1: Functional Block Diagram**

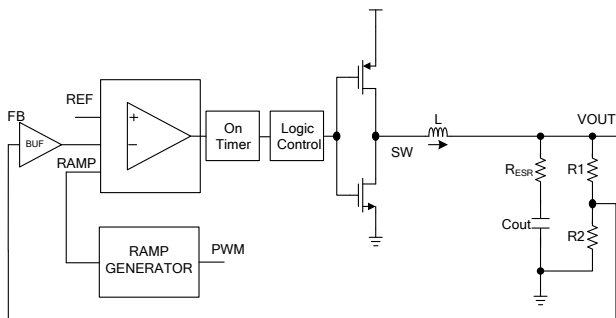
## OPERATION

The MP8770C is a fully integrated, synchronous rectified step-down switch mode converter. Constant-on-time (COT) control is employed to provide fast transient response and easy loop stabilization. Figure 2 shows the simplified ramp compensation block in the MP8770C. At the beginning of each cycle, the high-side MOSFET (HS-FET) is turned on when the feedback voltage ( $V_{FB}$ ) is below the reference voltage ( $V_{REF}$ ), which indicates insufficient output voltage. The on period is determined by both the output voltage and input voltage to make the switching frequency fairly constant across the entire input voltage range.

After the on period elapses, the HS-FET turns off. The HS-FET turns on again when  $V_{FB}$  drops below  $V_{REF}$ . By repeating this operation, the converter regulates the output voltage.

The MP8770C operates in continuous conduction mode (CCM). The integrated low-side MOSFET (LS-FET) turns on when the HS-FET is in its off state to minimize conduction loss. If both the HS-FET and LS-FET are turned on at the same time, a dead short occurs between input and GND. This is called shoot-through. In order to avoid shoot-through, a dead time (DT) is internally generated between the HS-FET off and LS-FET on periods, or vice versa.

An internal compensation is applied for COT control for more stable operation even when ceramic capacitors are used as output capacitors. This internal compensation improves jitter performance without affecting the line or load regulation.



**Figure 2: Simplified Ramp Compensation Block**

### VCC Regulator

The 3.4V internal regulator powers most of the internal circuitries. This regulator takes the  $V_{IN}$

input and operates in the full  $V_{IN}$  range. When  $V_{IN}$  exceeds 3.4V, the output of the regulator is in full regulation. When  $V_{IN}$  falls below 3.4V, the regulator output decreases following  $V_{IN}$ . A 1 $\mu$ F decoupling ceramic capacitor is needed at the pin.

### Enable

EN is a digital control pin that turns the regulator on and off. Drive EN above 1.25V to turn on the regulator, drive it below 1V to turn it off.

When floating, EN is pulled down to GND by an internal 1.2M $\Omega$  resistor.

EN can be connected directly to  $V_{IN}$ . It supports a 17V input range.

### Under-Voltage Lockout (UVLO)

Under-voltage lockout (UVLO) protects the chip from operating at an insufficient supply voltage. The MP8770C's UVLO comparator monitors the output voltage of the internal regulator's VCC.

The VCC UVLO rising threshold is about 2.8V, while its falling threshold is 2.45V.

When the input voltage exceeds the UVLO rising threshold voltage, the MP8770C powers up. It shuts off when the input voltage falls below the UVLO falling threshold voltage. This is a non-latch protection.

### Soft Start

The MP8770C employs a soft start (SS) mechanism to ensure smooth output ramping during power-up. When the EN pin goes high, an internal (6 $\mu$ A) current source charges up the SS capacitor. The SS capacitor voltage takes over  $V_{REF}$  to the PWM comparator. The output voltage smoothly ramps up with the SS voltage. Once SS voltage ( $V_{SS}$ ) rises above  $V_{REF}$ , it continues to ramp up and  $V_{REF}$  takes over. At this point, soft start finishes and the device enters steady state operation.

The SS capacitor value can be determined with Equation (1):

$$C_{SS} \text{ (nF)} = 0.83 \times \frac{t_{ss} \text{ (ms)} \times I_{ss} \text{ (uA)}}{V_{REF} \text{ (V)}} \quad (1)$$

If the output capacitance is a large value, it is not recommended to set the SS time too short. This

avoids accidentally reaching the current limit during SS. An SS capacitor less than 4.7nF should be avoided.

### Power Good Indicator (PG)

The PG pin is the open drain of a MOSFET that connects to VCC or some other voltage source through a resistor (e.g. 100kΩ). The MOSFET turns on with the application of an input voltage so that the PG pin is pulled to GND before SS is ready. After  $V_{FB}$  reaches 90% of  $V_{REF}$ , the PG pin is pulled high after a 50μs delay. When the  $V_{FB}$  drops to 80% of  $V_{REF}$ , the PG pin is pulled low.

When UVLO or OTP occurs, the PG pin is pulled low immediately. If OC (over-current) occurs, the PG pin is pulled low when  $V_{FB}$  drops below 80% of  $V_{REF}$  after a 0.05ms delay. When OV occurs, PG is pulled low when  $V_{FB}$  rises above 120% of  $V_{REF}$  after a 0.05ms delay. If  $V_{FB}$  falls back below 110% of  $V_{REF}$ , PG is pulled high after a 0.05ms delay.

If the input supply fails to power the MP8770C, PG is clamped low, even though PG is tied to an external DC source through a pull-up resistor. Figure 3 shows the relationship between the PG voltage and the pull-up current.

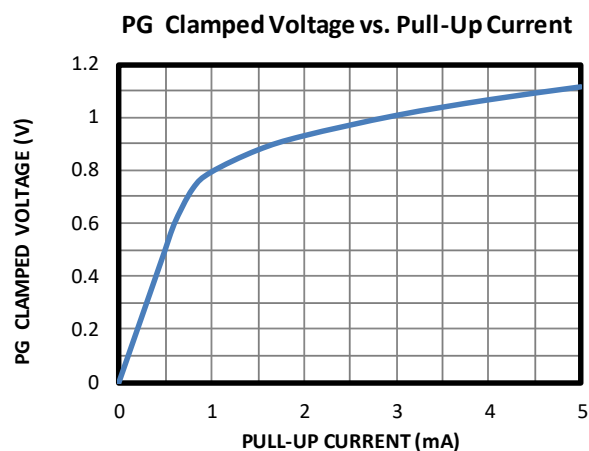


Figure 3: PG Clamped Voltage vs. Pull-Up Current

### Over-Current Protection (OCP) and Short-Circuit Protection (SCP)

The MP8770C has valley limit control. The LS-FET monitors the current flowing through it. The HS-FET waits until the valley current limit disappears to turn on again. Meanwhile, the output voltage drops until  $V_{FB}$  is below the under-voltage (UV) threshold, typically 50% below the

reference. Once UV is triggered, the MP8770C enters hiccup mode to periodically restart the part.

During OCP, the device tries to recover from an over-current fault with hiccup mode. This means the chip disables the output power stage, discharges the soft-start capacitor, then automatically tries to soft start again.

If the over-current condition still remains after soft start ends, the device repeats this operation cycle until the over-current conditions disappear and the output rises back to regulation level. OCP is a non-latch protection.

### Pre-Bias Start-Up

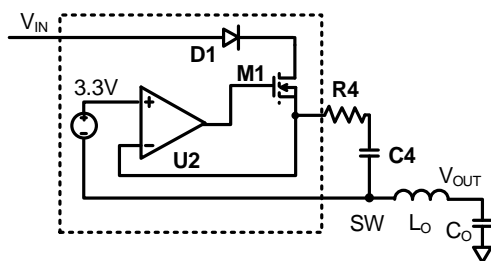
The MP8770C has been designed for monotonic start-up into pre-biased loads. If the output is pre-biased to a certain voltage during start-up, the BST voltage is refreshed and charged, and the voltage on the soft-start capacitor is also charged. If the BST voltage exceeds its rising threshold voltage and the soft-start capacitor voltage exceeds the sensed output voltage at the FB pin, the part starts to work normally.

### Thermal Shutdown

Thermal shutdown prevents the chip from operating at exceedingly high temperatures. When the silicon die temperature exceeds 150°C, it shuts down the whole chip. When the temperature falls below its lower threshold (typically 130°C), the chip is enabled again.

### Floating Driver and Bootstrap Charging

An external bootstrap capacitor powers the floating power MOSFET driver. This floating driver has its own UVLO protection, with a rising threshold of 1.7V and a hysteresis of 150mV.  $V_{IN}$  regulates the bootstrap capacitor voltage internally through D1, M1, R4, C4, L<sub>O</sub>, and C<sub>O</sub> (see Figure 4). If  $V_{IN} - V_{SW}$  exceeds 3.3V, U2 regulates M1 to maintain a 3.3V BST voltage across C4. It is recommended for the BST resistor (R4) to be less than 4.7Ω.



**Figure 4: Internal Bootstrap Charger**

### Start-Up and Shutdown

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

Three events can shut down the chip:  $EN$  low,  $V_{IN}$  low, and thermal shutdown. The shutdown procedure starts by initially blocking the signaling path to avoid any fault triggering, and then the internal supply rail is pulled down.



## APPLICATION INFORMATION

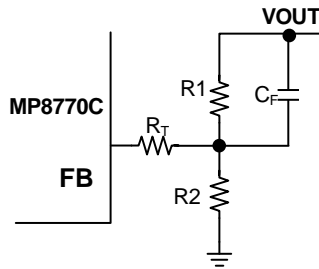
### COMPONENT SELECTION

#### Setting the Output Voltage

The external resistor divider is used to set the output voltage. First, choose a value for R2. R2 should be chosen reasonably, as a small R2 value leads to considerable quiescent current loss and too large a value makes the FB noise sensitive. It is recommended to choose a value between 2kΩ and 100kΩ for R2. Typically, a current less than 250μA through R2 offers a good balance between system stability and no load loss. R1 is then determined with Equation (2):

$$R1 = \frac{V_{OUT} - V_{REF}}{V_{REF}} \times R2 \quad (2)$$

Figure 5 shows the feedback circuit.



**Figure 5: Feedback Network**

Table 1 lists the recommended resistor values for common output voltages.

**Table 1: Resistor Selection for Common Output Voltages**

V <sub>OUT</sub> (V)	R1 (kΩ)	R2 (kΩ)	L (μH)	C <sub>F</sub> (pF)	R <sub>T</sub> (kΩ)
1.0	20	30	0.56	56	1
1.2	20	20	0.56	56	1
1.5	20	13	0.56	56	1
1.8	20	10	0.82	56	1
2.5	20	6.34	0.82	56	1
3.3	20	4.42	1	56	1
5	20	2.7	1.2	56	1

#### Selecting the Inductor

The inductor is necessary to supply constant current to the output load while being driven by the switched input voltage. A larger-value inductor will result in less ripple current and a lower output ripple voltage. However, it also has a larger physical footprint, higher series

resistance, and a lower saturation current. A good rule for determining the inductance value is to design the peak-to-peak ripple current in the inductor to be between 30% and 40% of the maximum output current. The peak inductor current should also be below the maximum switch current limit. The inductance value can be calculated with Equation (3):

$$L = \frac{V_{OUT}}{f_{SW} \times \Delta I_L} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \quad (3)$$

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

The inductor should not saturate under the maximum inductor peak current, where the peak inductor current can be calculated with Equation (4):

$$I_{LP} = I_{OUT} + \frac{V_{OUT}}{2f_{SW} \times L} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \quad (4)$$

#### Selecting the Input Capacitor

The step-down converter has a discontinuous input current, and requires a capacitor to supply the AC current to the converter while maintaining the DC input voltage. Ceramic capacitors are recommended for best performance, and should be placed as close to the VIN pin as possible. Capacitors with X5R and X7R ceramic dielectrics are recommended because they are fairly stable with temperature fluctuations.

The capacitors must also have a ripple current rating greater than the maximum input ripple current of the converter. The input ripple current can be estimated with Equation (5):

$$I_{CIN} = I_{OUT} \times \sqrt{\frac{V_{OUT}}{V_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)} \quad (5)$$

The worst-case condition occurs at  $V_{IN} = 2V_{OUT}$ , calculated with Equation (6):

$$I_{CIN} = \frac{I_{OUT}}{2} \quad (6)$$

For simplification, choose the input capacitor with an RMS current rating greater than half of the maximum load current.

The input capacitance value determines the input voltage ripple of the converter. If there is an input voltage ripple requirement in the system, choose the input capacitor that meets the specification.

The input voltage ripple can be estimated with Equation (7):

$$\Delta V_{IN} = \frac{I_{OUT}}{f_{SW} \times C_{IN}} \times \frac{V_{OUT}}{V_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \quad (7)$$

The worst-case condition occurs at  $V_{IN} = 2V_{OUT}$ , calculated with Equation (8):

$$\Delta V_{IN} = \frac{1}{4} \times \frac{I_{OUT}}{f_{SW} \times C_{IN}} \quad (8)$$

### Selecting the Output Capacitor

The output capacitor is required to maintain the DC output voltage. Ceramic or POSCAP capacitors are recommended. The output voltage ripple can be estimated with Equation (9):

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

For ceramic capacitors, the capacitance dominates the impedance at the switching frequency. The output voltage ripple is mainly caused by the capacitance. For simplification, the output voltage ripple can be estimated with Equation (10):

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

In the case of POSCAP capacitors, the ESR dominates the impedance at the switching frequency. For simplification, the output ripple can be estimated with Equation (11):

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

Besides considering the output ripple, a larger output capacitor also can get better load transient response. However, maximum output capacitor limitation should be also considered in design application. If the output capacitor value is too high, the output voltage cannot reach the design value during the soft-start time, and the device will fail to regulate. The maximum output capacitor value  $C_{O\_MAX}$  can be limited with Equation (12):

$$C_{O\_MAX} = (I_{LIM\_AVG} - I_{OUT}) \times t_{ss} / V_{OUT} \quad (12)$$

Where  $I_{LIM\_AVG}$  is the average start-up current during soft-start period, and  $t_{ss}$  is the soft-start time.

### Design Example

A design example is provided below when the ceramic capacitors are applied:

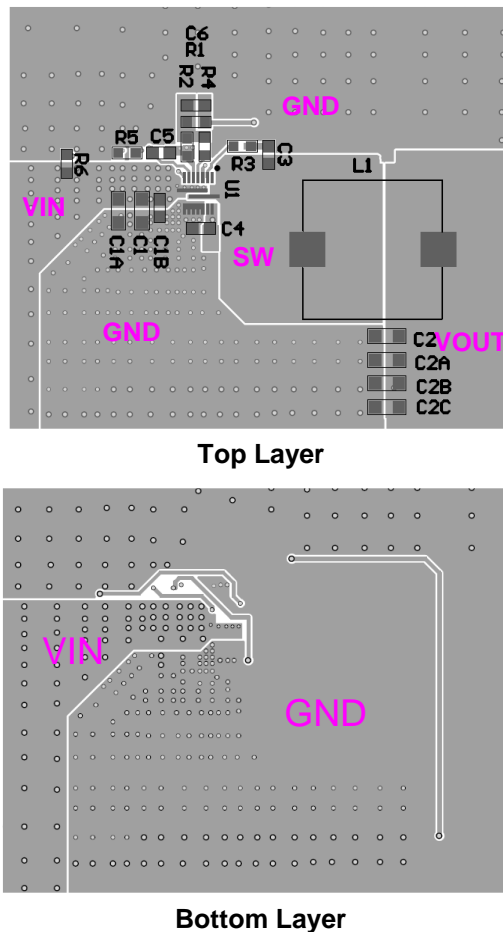
<b>V<sub>IN</sub></b>	12V
<b>V<sub>OUT</sub></b>	1V
<b>I<sub>OUT</sub></b>	8A

For detailed application schematics, see the Typical Application Circuits section on page 20. For the typical performance and waveforms, see the Typical Characteristics section on page 6. For more device applications, refer to the related evaluation board datasheet.

## PCB Layout Guidelines

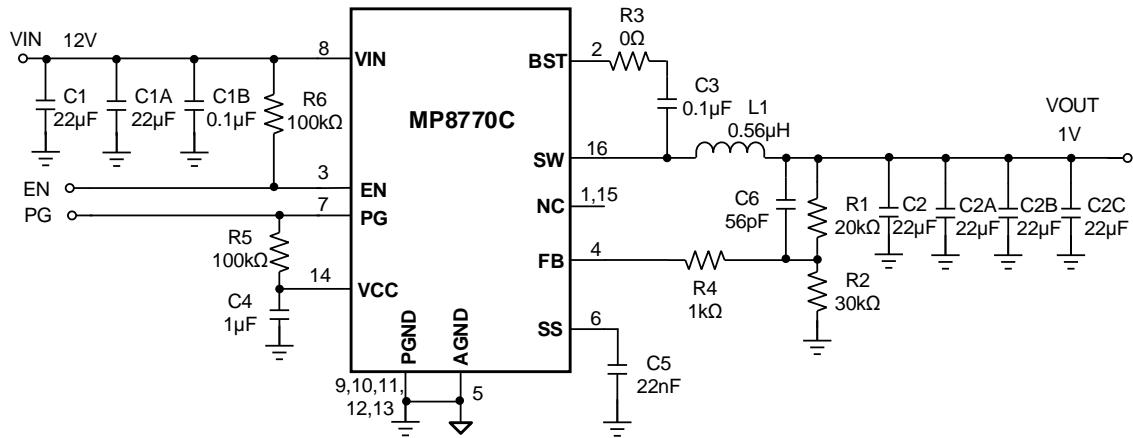
Efficient layout is very important for proper device function. Poor layout design can result in poor line or load regulation and stability issues. It is strongly recommended to use a 4-layer board layout, with the two middle layers being GND. For best performance, refer to Figure 6 and follow the guidelines below:

1. Place the high current paths (GND, IN, and SW) very close to the device with short, direct, and wide traces.
2. Place the input capacitor as close as possible to the IN and GND pins.
3. Place the VCC decoupling capacitor close to the device.
4. Connect AGND and PGND at the point of the VCC capacitor's ground connection.
5. Place the external feedback resistors next to the FB pin.
6. Keep the switching node (SW) short and away from the feedback network.

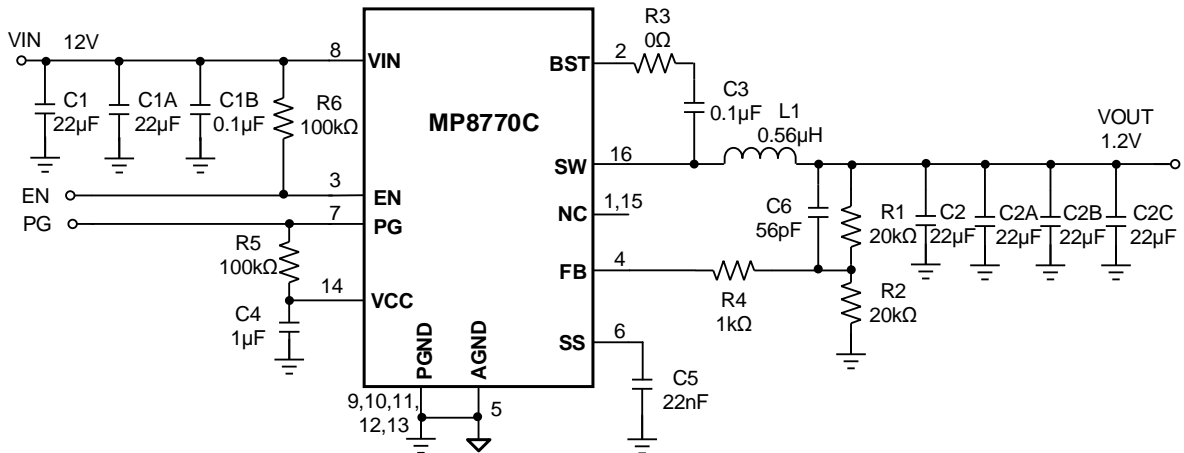


**Figure 6: Recommended PCB Layout**

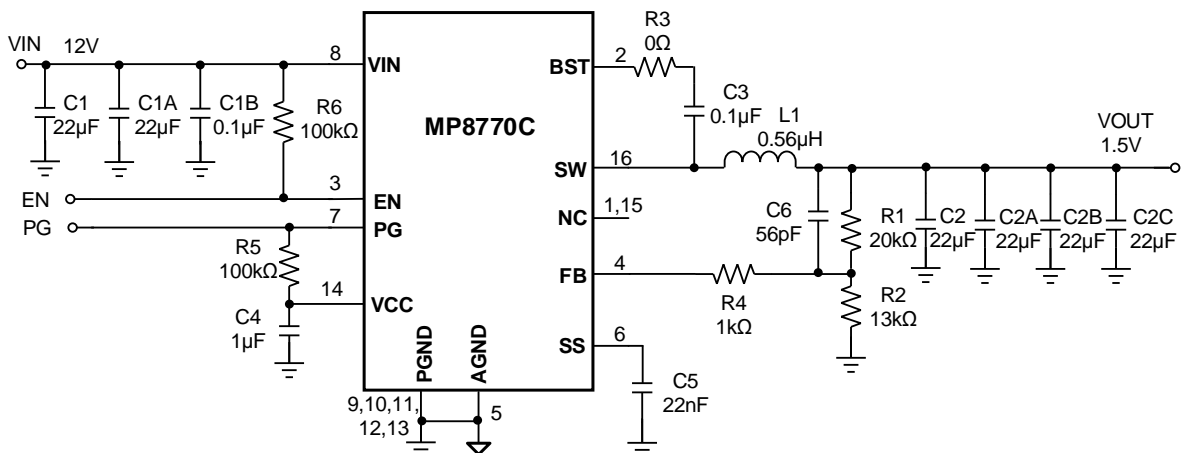
## TYPICAL APPLICATION CIRCUITS



**Figure 7:  $V_{IN} = 12V$ ,  $V_{OUT} = 1V$ ,  $I_{OUT} = 8A$  <sup>(8)</sup>**

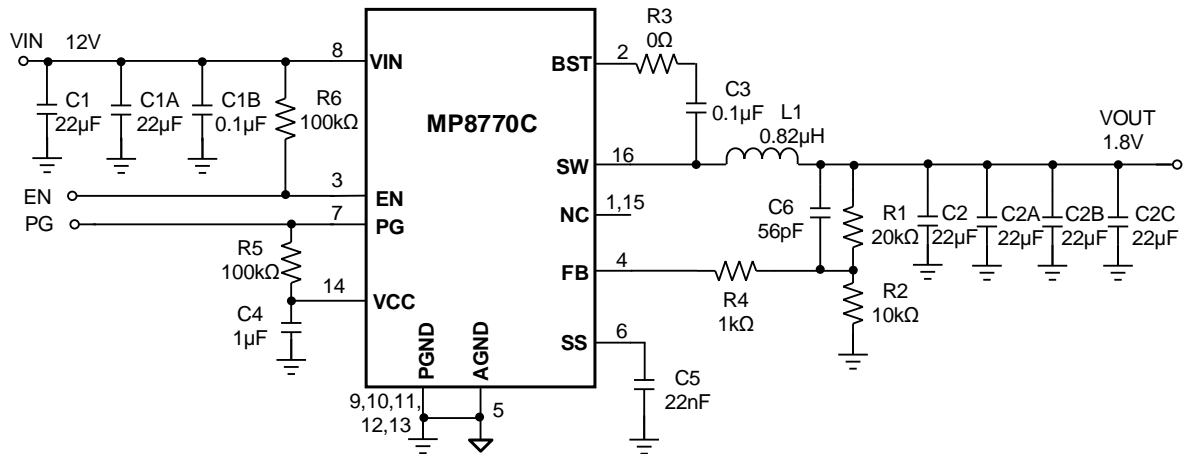


**Figure 8:  $V_{IN} = 12V$ ,  $V_{OUT} = 1.2V$ ,  $I_{OUT} = 8A$  <sup>(8)</sup>**

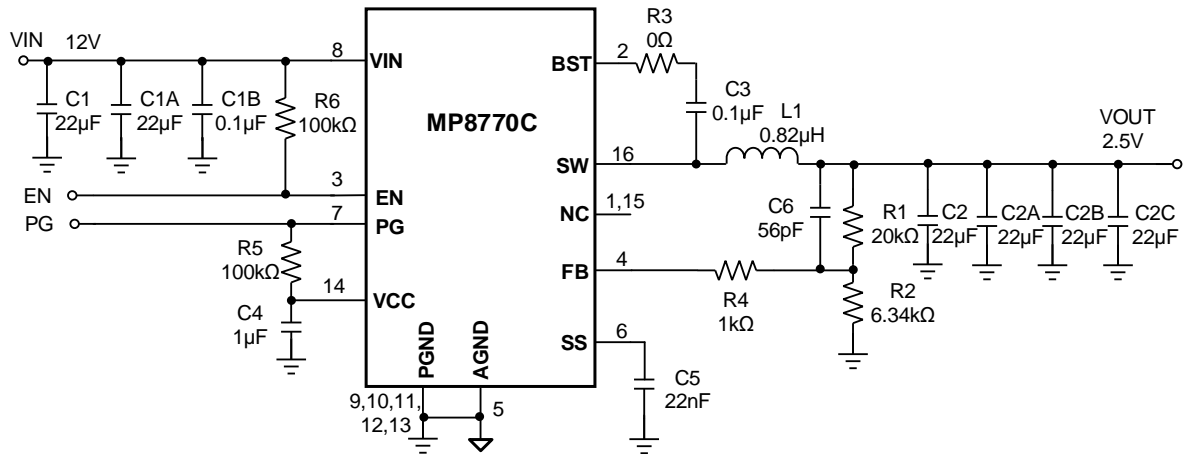


**Figure 9:  $V_{IN} = 12V$ ,  $V_{OUT} = 1.5V$ ,  $I_{OUT} = 8A$  <sup>(8)</sup>**

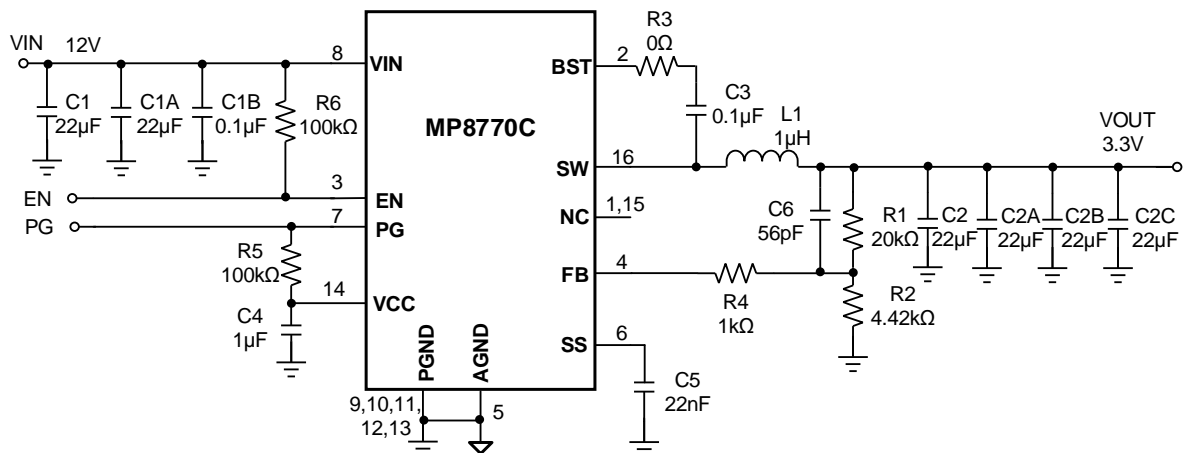
**TYPICAL APPLICATION CIRCUITS (continued)**



**Figure 10:  $V_{IN} = 12V$ ,  $V_{OUT} = 1.8V$ ,  $I_{OUT} = 8A$  <sup>(8)</sup>**

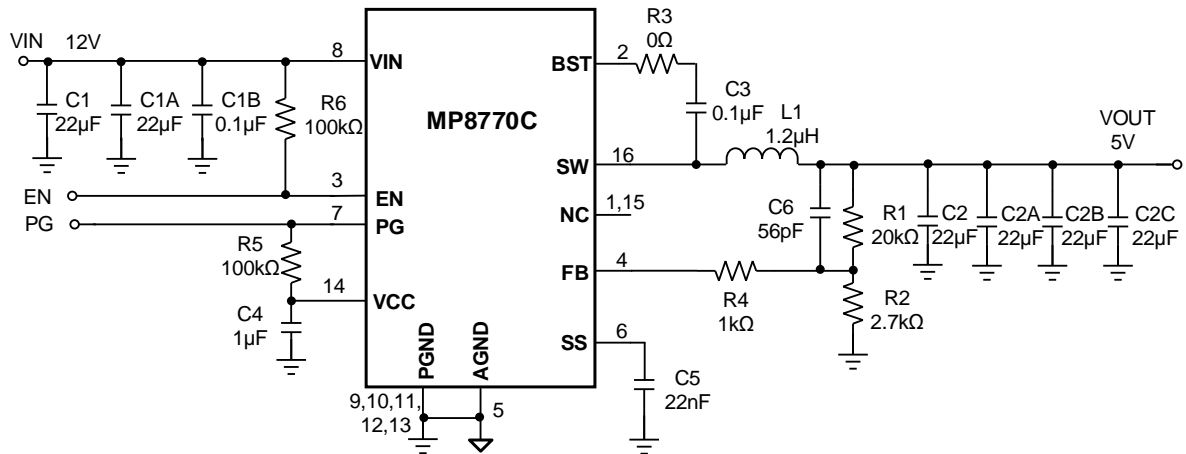


**Figure 11:  $V_{IN} = 12V$ ,  $V_{OUT} = 2.5V$ ,  $I_{OUT} = 8A$  <sup>(8)</sup>**



**Figure 12:  $V_{IN} = 12V$ ,  $V_{OUT} = 3.3V$ ,  $I_{OUT} = 8A$  <sup>(8)</sup>**

## TYPICAL APPLICATION CIRCUITS *(continued)*



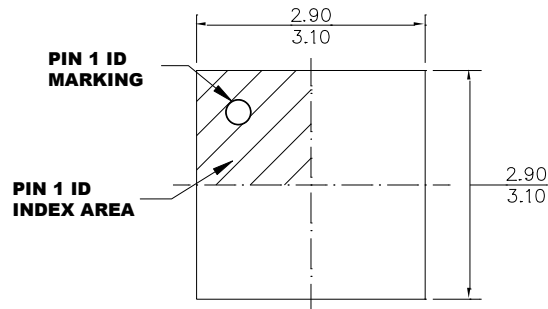
**Figure 13:  $V_{IN} = 12V$ ,  $V_{OUT} = 5V$ ,  $I_{OUT} = 8A$  <sup>(8)</sup>**

**Note:**

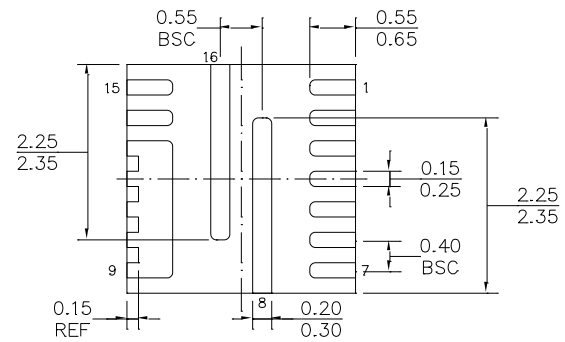
8) When  $V_{IN}$  is low, see the Selecting the Input Capacitor Section on page 17.

## PACKAGE INFORMATION

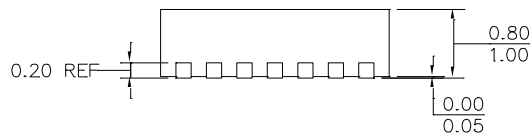
### QFN-16 (3mmx3mm)



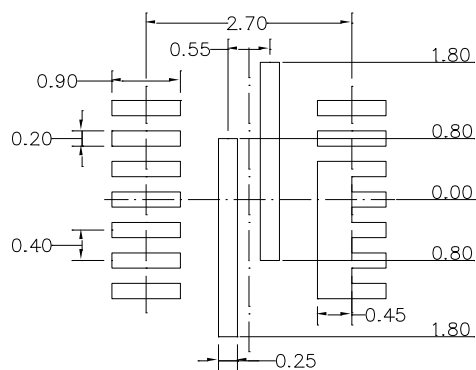
### TOP VIEW



### BOTTOM VIEW



### SIDE VIEW



## **RECOMMENDED LAND PATTERN**

**NOTE:**

- 1) ALL DIMENSIONS ARE IN MILLIMETERS.  
2) LEAD COPLANARITY SHALL BE 0.10 MILLIMETERS MAX.  
3) JEDEC REFERENCE IS MO-220.  
4) DRAWING IS NOT TO SCALE.

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