The Future of Analog IC Technology

MP9162A

2A, 6V, 1.5MHz, 17µA I_Q, COT, Synchronous, Step-Down Converter

DESCRIPTION

The MP9162A is a monolithic, step-down, switch-mode converter with built-in, internal power MOSFETs. It can achieve 2A of continuous output current from a 2.5V-to-6V input voltage with excellent load and line regulation. The output voltage can be regulated as low as 0.6V.

The constant-on-time (COT) control scheme provides a fast transient response and eases loop stabilization. Fault condition protections include cycle-by-cycle current limiting and thermal shutdown.

The MP9162A is available in a small QFN-8 (2.0mmx1.5mm) package and requires only a minimal number of readily available, standard, external components.

The MP9162A is ideal for a wide range of applications, including high-performance DSPs, FPGAs, PDAs, and portable instruments.

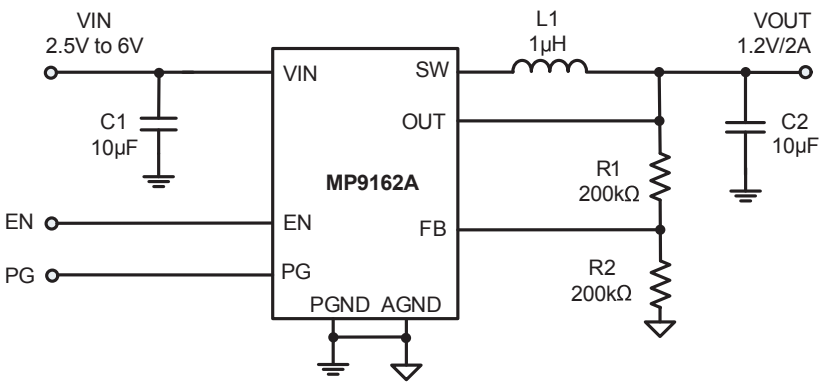
FEATURES

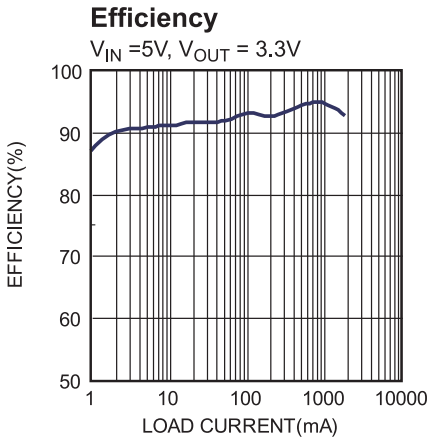
- Very Low I_Q: 17µA
- Default 1.5MHz Switching Frequency
- 1.5% V_{FB} Accuracy
- EN and Power Good for Power Sequencing
- Wide 2.5V to 6V Operating Input Range
- Output Adjustable from 0.6V
- Up to 2A of Output Current
- 100% Duty Cycle in Dropout
- 110mΩ and 60mΩ Internal Power MOSFET Switches
- Cycle-by-Cycle Over-Current Protection (OCP)
- Short-Circuit Protection (SCP) with Hiccup Mode
- Stable with Low ESR Output Ceramic Capacitors
- Available in a QFN-8 (1.5mmx2.0mm) Package

APPLICATIONS

- Wireless/Networking Cards
- Portable Instruments
- Battery-Powered Devices
- Low-Voltage I/O System Power

TYPICAL APPLICATION





ORDERING INFORMATION

Part Number	Package	Top Marking
MP9162AGQH*	QFN-8 (1.5mmx2.0mm)	*See Below*

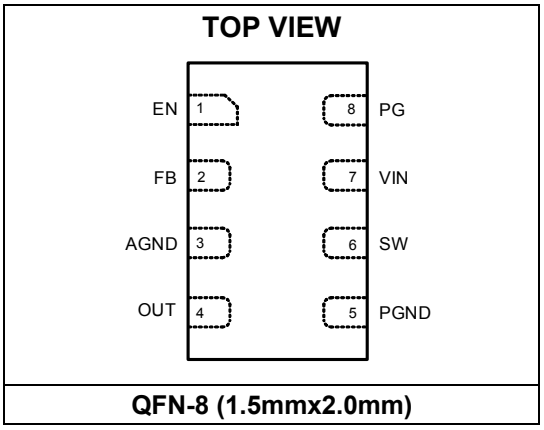
* For Tape & Reel, add suffix –Z (e.g. MP9162AGQH-Z)

TOP MARKING

EB
LL

EB: product code of MP9162AGQH;
LL: Lot number

PACKAGE REFERENCE



QFN-8 (1.5mmx2.0mm)

ABSOLUTE MAXIMUM RATINGS (1)

Supply voltage (V_{IN}) 6.5V
V_{SW}.....-0.3V (-1.5V for <20ns and -4V for <8ns) to 6.5V (10V for <10ns)
All other pins ..... -0.3V to 6.5V
Junction temperature ..... 150°C
Lead temperature..... 260°C
Continuous power dissipation (T_A = +25°C) **(2)**
……..... 1.14W
Storage temperature .....-65°C to +150°C

Recommended Operating Conditions (3)

Supply voltage (V_{IN}) ..... 2.5V to 6V
Operating junction temp. (T_J)....-40°C to +125°C

Thermal Resistance (4)	θ_{JA}	θ_{JC}
QFN-8 (1.5mmx2.0mm)	110	55	°C/W

NOTES:

1) Exceeding these ratings may damage the device.
2) The maximum allowable power dissipation is a function of the maximum junction temperature T_J (MAX), the junction-to-ambient thermal resistance θ_{JA}, and the ambient temperature T_A. The maximum allowable continuous power dissipation at any ambient temperature is calculated by P_D (MAX) = (T_J (MAX)-T_A)/θ_{JA}. Exceeding the maximum allowable power dissipation produces an excessive die temperature, causing the regulator to go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.
3) The device is not guaranteed to function outside of its operating conditions.
4) Measured on JESD51-7, 4-layer PCB.

ELECTRICAL CHARACTERISTICS

V_{IN} = 5V, T_A = +25°C, unless otherwise noted.

Parameter	Symbol	Condition	Min	Typ	Max	Units
Feedback voltage	V_{FB}	2.5V ≤ V_{IN} ≤ 6V, T_A = 25°C	-1.5	0.600	+1.5	V/%
		T_A = -40°C to +85°C(6)	-2.5		+2.5	
Feedback current	I_{FB}	V_{FB} = 0.6V		10	50	nA
P-FET switch on resistance	R_{DSON_P}			110		mΩ
N-FET switch on resistance	R_{DSON_N}			60		mΩ
Switch leakage		V_{EN} = 0V, V_{IN} = 6V, V_{SW} = 0V and 6V		0	1	µA
P-FET current limit			2.6	3.2	4.0	A
On time	T_{ON}	V_{IN} = 5V, V_{OUT} = 1.2V		166		ns
		V_{IN} = 3.6V, V_{OUT} = 1.2V		220		
Switching frequency	F_s	V_{OUT} = 1.2V, T_A = 25°C	-20	1500	+20	kHz/%
		T_A = -40°C to +85°C(6)	-25	1500	+25	kHz/%
Minimum off time(6)	$T_{MIN-OFF}$			60		ns
Soft-start time	T_{SS-ON}	V_{OUT} from 10% to 90%	0.6	1.15	1.7	ms
Power good upper trip threshold	PG_H	FB voltage with respect to the regulation		+10		%
Power good lower trip threshold	PG_L			-10		%
Power good delay	PG_D			50		µs
Power good sink current capability	V_{PG-L}	Sink 1mA			0.4	V
Power good logic high voltage	V_{PG-H}	V_{IN} = 5V, V_{FB} = 0.6V	4.9			V
Power good internal pull-up resistor	R_{PG}			550		kΩ
Under-voltage lockout threshold rising			2.15	2.3	2.45	V
Under-voltage lockout threshold hysteresis				260		mV
EN input logic low voltage					0.4	V
EN input logic high voltage			1.2			V
EN input current		V_{EN} = 2V		1.5		µA
		V_{EN} = 0V		0		µA
Supply current (shutdown)		V_{EN} = 0V, V_{IN} = 3V		20	100	nA
Supply current (quiescent)		V_{EN} = 2V, V_{FB} = 0.63V, V_{IN} = 5V		17	20	µA
Thermal shutdown(5)				150		°C
Thermal hysteresis(5)				30		°C

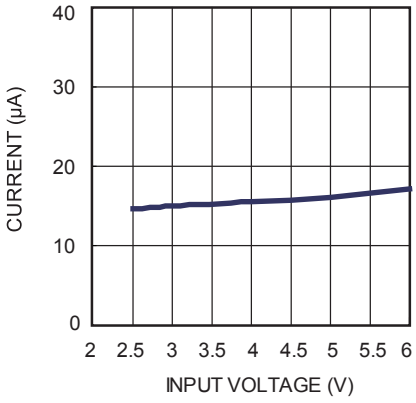
NOTES:

5) Guaranteed by design.
6) Guaranteed by characterization test.

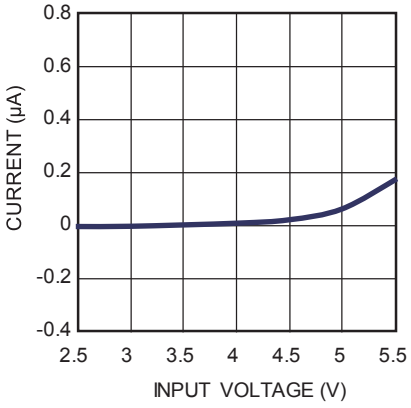
TYPICAL PERFORMANCE CHARACTERISTICS

V_{IN} = 5V, V_{OUT} = 1.2V, L = 1.0µH, T_A = +25°C, unless otherwise noted.

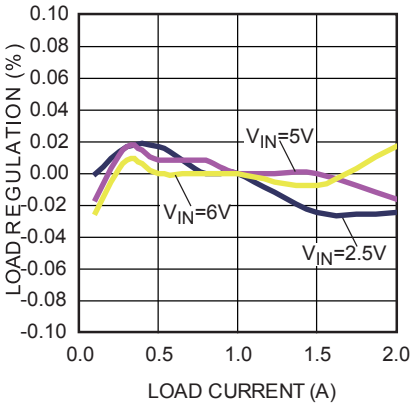
Quiescent Current vs. Input Voltage



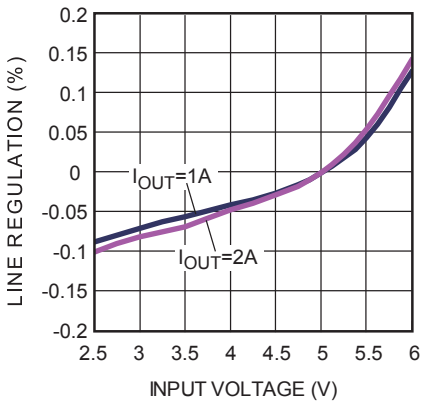
Shutdown Current vs. Input Voltage



Load Regulation

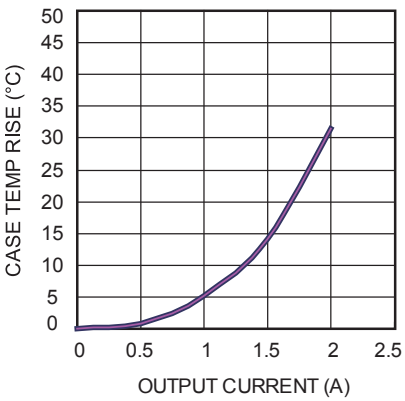


Line Regulation



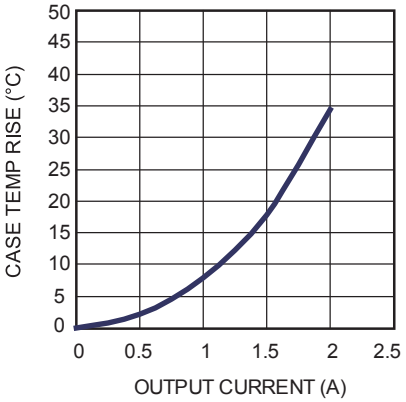
Case Temperature Rise

V_{IN}=3V, V_{OUT}=1.2V

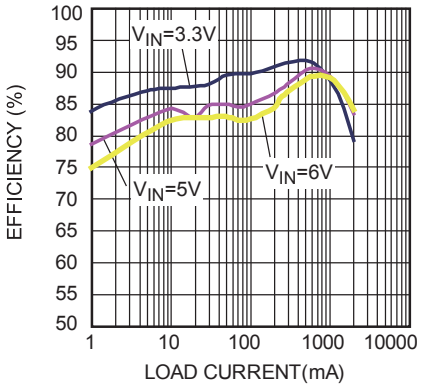


Case Temperature Rise

V_{IN}=5V, V_{OUT}=3.3V

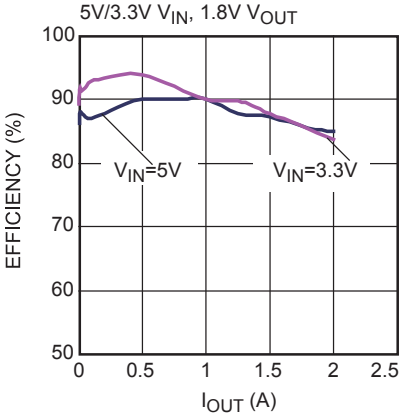


Efficiency



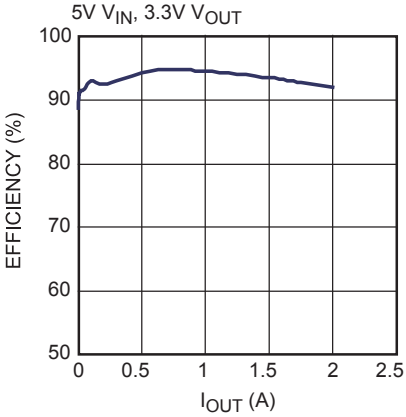
Efficiency

5V/3.3V V_{IN}, 1.8V V_{OUT}



Efficiency

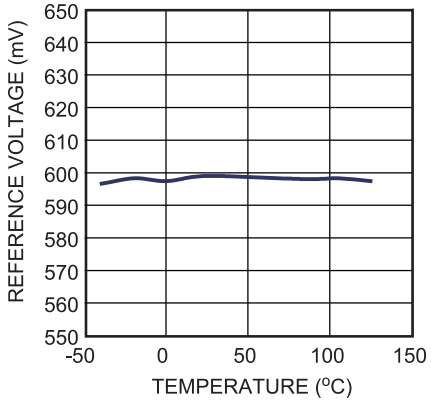
5V V_{IN}, 3.3V V_{OUT}



TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 5V, V_{OUT} = 1.2V, L = 1.0µH, T_A = +25°C, unless otherwise noted.

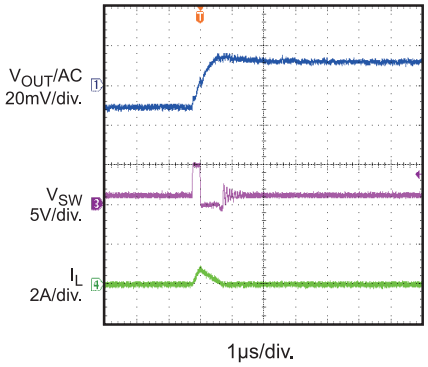
Reference Voltage vs. Temperature



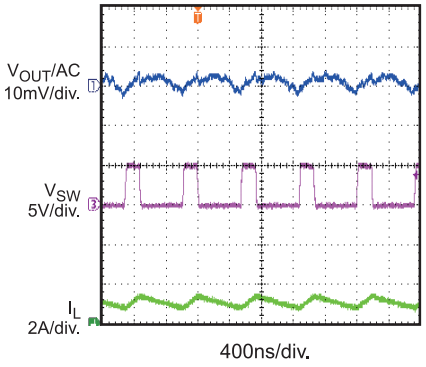
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 5V, V_{OUT} = 1.2V, L = 1.0µH, T_A = +25°C, unless otherwise noted.

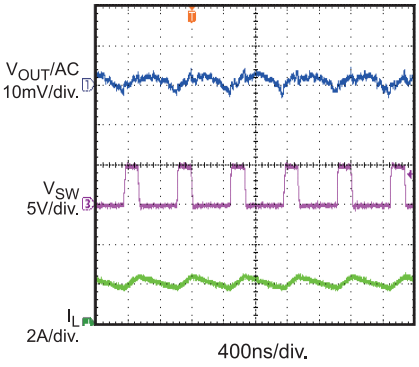
Output Ripple
I_{OUT}=0A



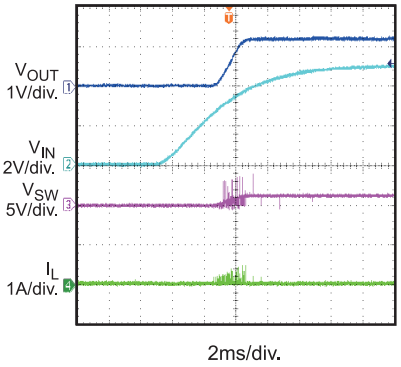
Output Ripple
I_{OUT}=1A



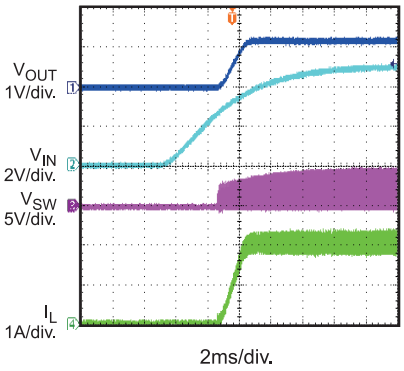
Output Ripple
I_{OUT}=2A



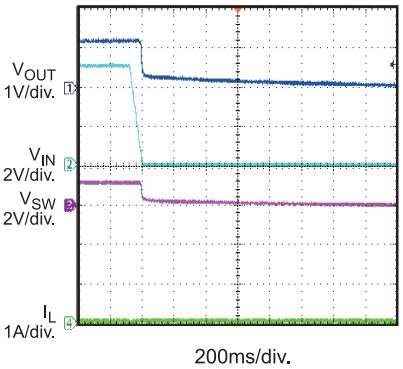
VIN Power-Up without Load



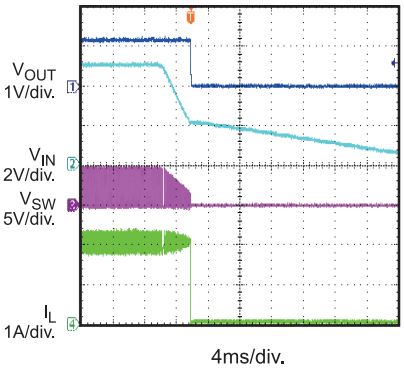
VIN Power-Up with 2A Load



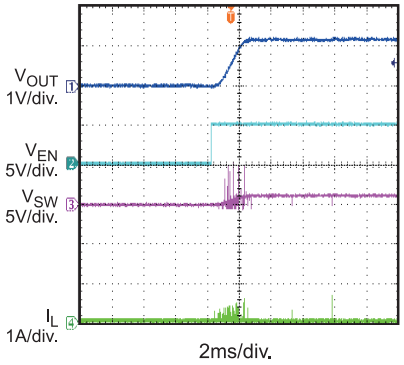
VIN Shutdown without Load



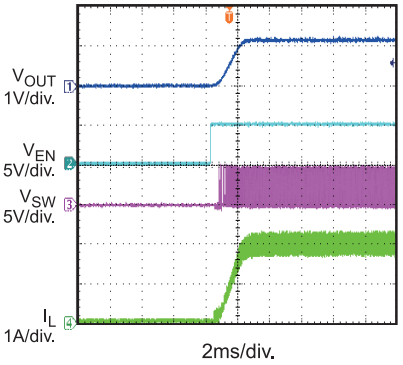
VIN Shutdown with 2A Load



EN Start-Up without Load



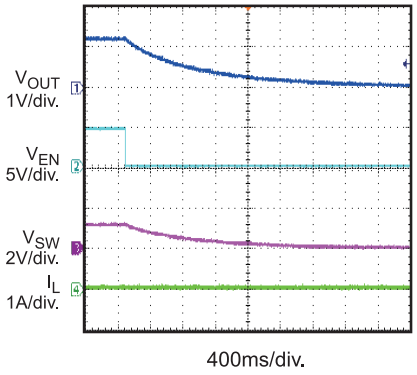
EN Start-Up with 2A Load



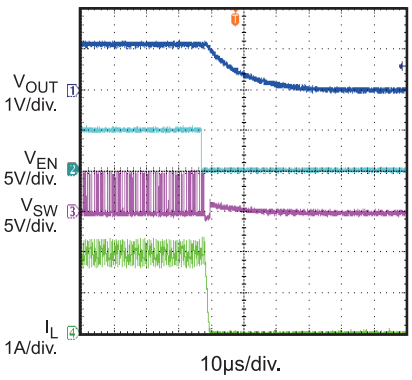
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

V_{IN} = 5V, V_{OUT} = 1.2V, L = 1.0µH, T_A = +25°C, unless otherwise noted.

EN Shutdown without Load



EN Shutdown with 2A Load



PIN FUNCTIONS

Pin # (QFN-8)	Name	Description
1	EN	**On/off control.**
2	FB	**Feedback.** An external resistor divider from the output to AGND tapped to FB sets the output voltage.
3	AGND	**Analog ground for the internal control circuit.**
4	OUT	**Input sense for the output voltage.**
5	PGND	**Power ground.**
6	SW	**Switch output.**
7	VIN	**Supply voltage.** The MP9162A operates from a +2.5V to +6V unregulated input. C1 is needed to prevent large voltage spikes from appearing at the input.
8	PG	**Power good indicator.** The output of PG is an open drain with an internal pull-up resistor to VIN. PG is pulled up to VIN when the FB voltage is within ±10% of the regulation level. If the FB voltage is out of that regulation range, then it is low.

BLOCK DIAGRAM

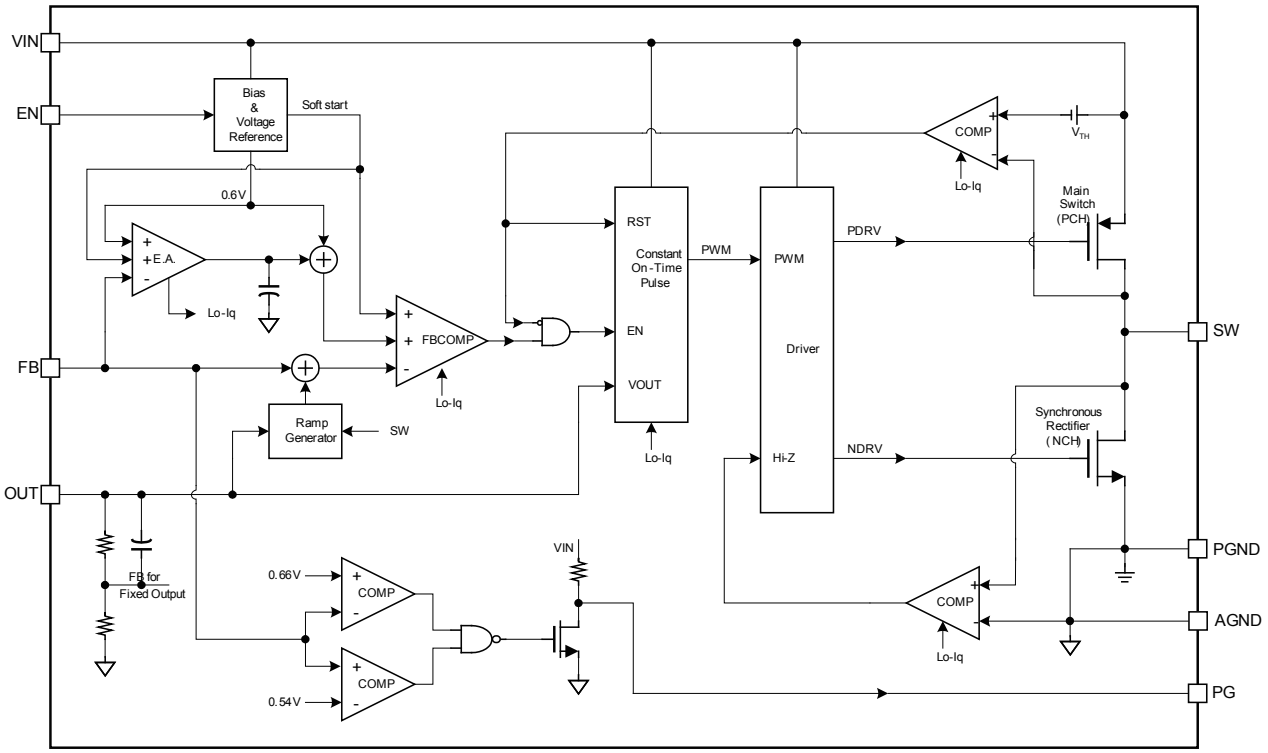


Figure 1: Functional Block Diagram

OPERATION

The MP9162A uses a constant-on-time control with an input voltage feed-forward to stabilize the switching frequency over a full input voltage range. During light loads, the MP9162A employs proprietary control of the low-side switches and inductor currents to eliminate ringing on the switching node and improve efficiency.

Constant-on-Time Control (COT)

Compared to fixed frequency PWM control, constant-on-time (COT) control offers a simpler control loop and a faster transient response. By using an input voltage feed-forward, the MP9162A maintains a nearly constant switching frequency across the input and output voltage ranges. The on time of the switching pulse can be estimated with Equation (1):

$$T_{ON} = \frac{V_{OUT}}{V_{IN}} \cdot 0.667\mu s \quad (1)$$

To prevent inductor current runaway during the load transient, the MP9162A uses a fixed minimum off time of 60ns. This minimum off time limit does not affect the operation of the MP9162A in its steady state in any way.

Light-Load Operation

In light-load conditions, the MP9162A uses a proprietary control scheme to save power and improve efficiency. The MP9162A uses a zero-current cross circuit (ZCD) to detect if the inductor current is starting to reverse. The low-side switch turns off when the inductor current starts to reverse and begins working in discontinuous conduction mode (DCM).

The delay for the internal circuit propagation time is typically 50ns. This means that the inductor current continues falling after ZCD is triggered in this delay. If the inductor current falling slew rate is fast (V_{OUT} is high or close to V_{IN}), then the low-side MOSFET turns off, the inductor current may be negative, and the MP9162A cannot enter DCM operation. If DCM is required, the off time of the low-side MOSFET in CCM should be longer than 100ns (2x the propagation delay).

For example, if V_{IN} is 3.6V and V_{OUT} is 3.3V, the off time in CCM is 55ns. It is difficult to enter DCM at light load. Using a smaller inductor can help the MP9162A enter DCM more easily.

Enable (EN)

When the input voltage is greater than the under-voltage lockout (UVLO) threshold (typically 2.3V), the MP9162A is enabled by pulling EN higher than 1.2V. Leaving EN floating or grounded disables the MP9162A. There is an internal 1MΩ resistor from EN to ground.

Soft Start

The MP9162A has a built-in soft start that ramps up the output voltage at a controlled slew rate to avoid overshooting at start-up. The soft-start time is typically about 1.15ms.

Power Good Indicator

The MP9162A uses an open drain with a 550kΩ pull-up resistor as a power good indicator (PG). When the FB voltage is within ±10% of the regulation voltage (i.e.: 0.6V), PG is pulled up to V_{IN} by an internal resistor. If the FB voltage is out of the ±10% window, PG is pulled down to ground by an internal MOSFET. The MOSFET has a maximum $R_{DS(ON)}$ of less than 400Ω.

Current Limit

The MP9162A has a typical 3.2A current limit on the high-side switch. When the high-side switch reaches its current limit, the MP9162A enters hiccup mode until the current drops. This prevents the inductor current from rising and possibly damaging the components.

Short Circuit and Recovery

The MP9162A enters short-circuit protection mode when the current limit is reached and attempts to recover from the short circuit by entering hiccup mode. In short-circuit protection, the MP9162A disables the output power stage, discharges a soft-start capacitor, and tries to soft start automatically. If the short-circuit condition still remains after the soft start ends, the MP9162A repeats this operation until the short circuit disappears, and the output rises back to regulation levels.

APPLICATION INFORMATION

Setting the Output Voltage

The external resistor divider sets the output voltage (see the Typical Application on page 1). The feedback resistor (R1) cannot be too large or too small, considering the trade-off between a dynamic circuit and stability in the circuit. Set R1 to be around 120kΩ to 200kΩ. R2 can then be calculated with Equation (2):

$$R2 = \frac{R1}{\frac{V_{out}}{0.6} - 1} \quad (2)$$

The feedback circuit is shown in Figure 2.

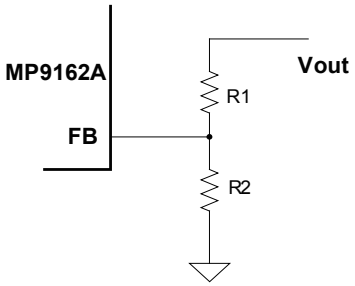


Figure 2: Feedback Network

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

Table 1: Resistor Selection for Common Output Voltages

V_{OUT} (V)	R1 (kΩ)	R2 (kΩ)
1.0	200 (1%)	300 (1%)
1.2	200 (1%)	200 (1%)
1.8	200 (1%)	100 (1%)
2.5	200 (1%)	63.2 (1%)
3.3	200 (1%)	44.2 (1%)

Selecting the Inductor

A 0.68μH-to-2.2μH inductor is recommended for most applications. For the highest efficiency, choose an inductor with a DC resistance of less than 15mΩ. For most designs, the inductance value can be derived from Equation (3):

$$L_1 = \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{V_{IN} \times \Delta I_L \times f_{OSC}} \quad (3)$$

Where ΔI_L is the inductor ripple current.

Set the inductor current to be approximately 30% of the maximum load current. The maximum inductor peak current is calculated in Equation (4):

$$I_{L(MAX)} = I_{LOAD} + \frac{\Delta I_L}{2} \quad (4)$$

Selecting the Input Capacitor

The input current to the step-down converter is discontinuous and requires a capacitor to supply the AC current to the step-down converter while maintaining the DC input voltage. For best performance, use low ESR capacitors. Ceramic capacitors with X5R or X7R dielectrics are highly recommended because of their low ESR values and small temperature coefficients. For most applications, a 10μF capacitor is sufficient. For a higher output voltage, a 47μF capacitor may be needed to improve system stability.

Since the input capacitor absorbs the input switching current, it requires an adequate ripple current rating. The RMS current in the input capacitor can be estimated with Equation (5):

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

The worse case condition occurs at $V_{IN} = 2V_{OUT}$, shown in Equation (6):

$$I_{C1} = \frac{I_{LOAD}}{2} \quad (6)$$

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, use a small, high-quality ceramic capacitor (i.e.: 0.1μF) placed 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 capacitance can be estimated with Equation (7):

$$\Delta V_{IN} = \frac{I_{LOAD}}{f_S \times C1} \times \frac{V_{OUT}}{V_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \quad (7)$$

Selecting the Output Capacitor

The output capacitor (C2) is required to maintain the DC output voltage. Low ESR ceramic capacitors are recommended to keep the output voltage ripple low. The output voltage ripple can be estimated by Equation (8):

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

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

When using ceramic capacitors, the impedance at the switching frequency is dominated by the capacitance, which mainly causes output voltage ripples. For simplification, the output voltage ripple can be estimated with Equation (9):

$$\Delta V_{OUT} = \frac{V_{OUT}}{8 \times f_S^2 \times L_1 \times C2} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \quad (9)$$

When using tantalum or electrolytic capacitors, the ESR dominates the impedance at the switching frequency. For simplification, the output ripple can be approximated with Equation (10):

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_S \times L_1} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \times R_{ESR} \quad (10)$$

The characteristics of the output capacitor affect the stability of the regulation system.

PCB Layout Guidelines

Efficient PCB layout is critical for stable operation. A poor layout design can result in poor line or load regulation and stability issues. For best results, refer to Figure 3 and follow the guidelines below.

1. Place the high-current paths (GND, VIN, and SW) as close to the device as possible with short, direct, and wide traces.
2. Place the input capacitor as close to VIN and GND as possible.
3. Place the external feedback resistors next to FB.
4. Keep the switching node (SW) short and away from the feedback network.

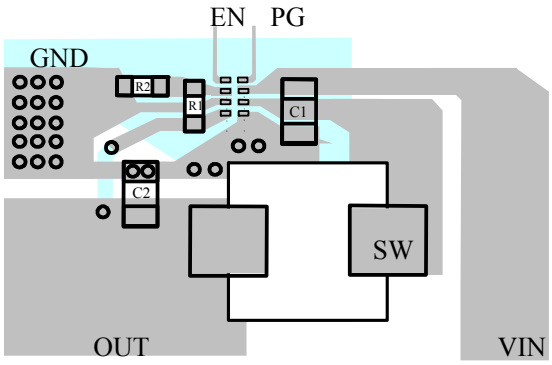


Figure 3: PCB Layout Recommendation

Design Example

Table 2 is a design example following the application guidelines for the specifications below:

Table 2: Design Example

V_{IN}	5V
V_{OUT}	1.2V
f_{SW}	1500kHz

The detailed application schematic is shown in Figure 4. The typical performance and circuit waveforms are shown in the Typical Performance Characteristics section on page 4. For more device applications, please refer to the related evaluation board datasheets.

TYPICAL APPLICATION CIRCUITS

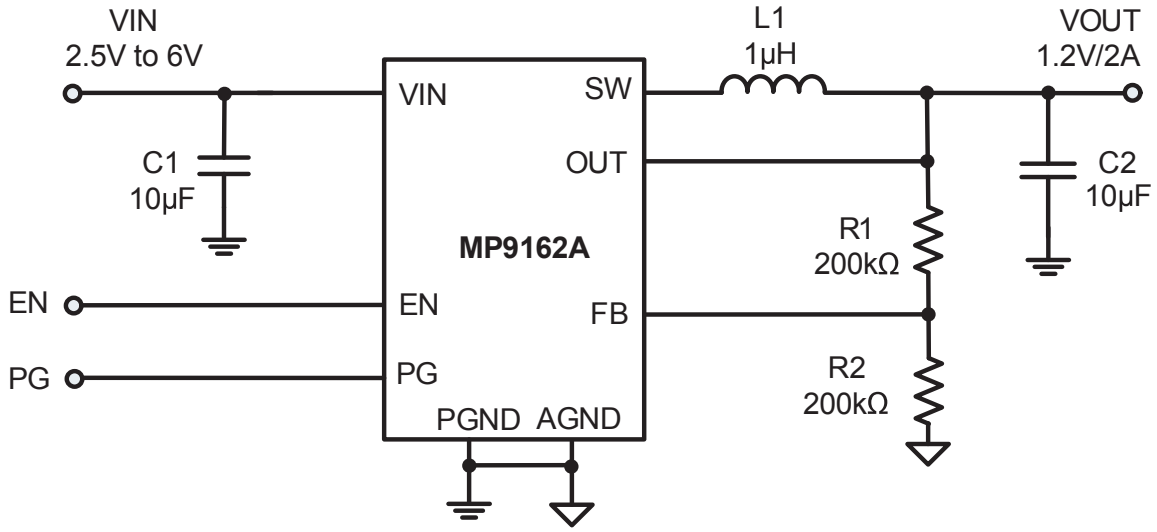
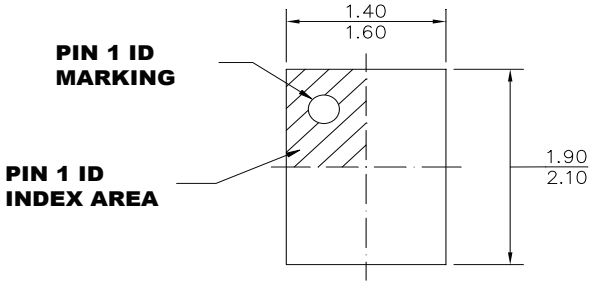


Figure 4: Typical Application Circuit

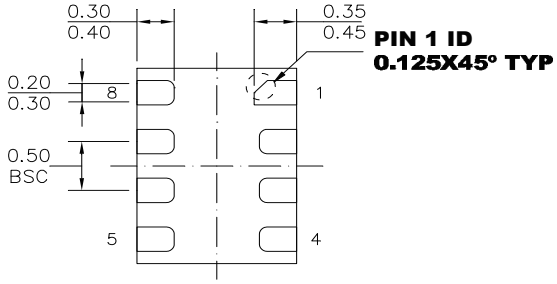
PACKAGE INFORMATION

QFN-8 (1.5mmx2.0mm)

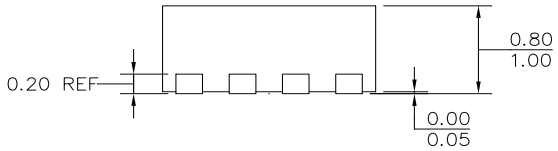
PACKAGE OUTLINE DRAWING FOR 8L FCQFN (1.5X2.0MM)
MF-PO-D-0141 revision 0.0



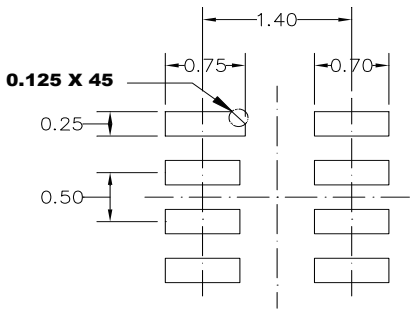
TOP VIEW



BOTTOM VIEW



SIDE VIEW



RECOMMENDED LAND PATTERN

NOTE:

1) ALL DIMENSIONS ARE IN MILLIMETERS.
2) EXPOSED PADDLE SIZE DOES NOT INCLUDE MOLD FLASH.
3) LEAD COPLANARITY SHALL BE 0.10 MILLIMETERS MAX.
4) JEDEC REFERENCE IS MO-220.
5) DRAWING IS NOT TO SCALE.