

## DESCRIPTION

The MPQ8904 is a low-current, low-dropout, linear regulator that operates on a single 2.5V-to-6.5V input supply. An external resistor controls the output voltage. The MPQ8904 can supply up to 500mA of load current. The enable pin (EN) allows the part to enter a low-current shutdown mode (EN=0). The MPQ8904 features thermal overload and current limit protection. It is available in an 8-pin QFN (2×3mm) package.

## FEATURES

- Power-Good Open Collector Output
- Guaranteed Industrial/Automotive Temp. Range Limits
- Operates from a 2.5V-to-6.5V Input
- Low 300mV Dropout at 500mA Output
- Stable with Very Small Ceramic Capacitors
- 2.5% Feedback Reference
- Adjustable Output Voltage from 0.5V to 5V
- Better than 0.001%/mA Load Regulation
- Stable with Low-ESR Output Capacitor
- Low 140μA Ground Current
- Internal Thermal Protection
- Current Limit Protection
- 7μA Typical Quiescent Current at Shutdown
- Available in AEC-Q100 Qualified Grade 1

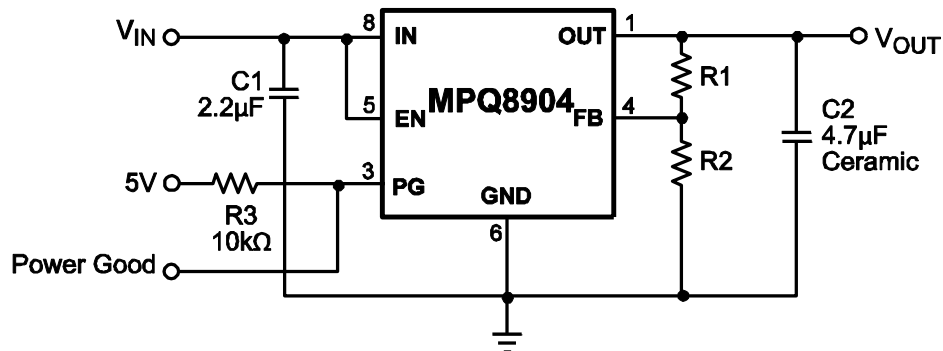
## APPLICATIONS

- Low-Current Regulators
- Battery-Powered Systems
- Mobile Devices, such as Cell Phones and GPS Navigators

All MPS parts are lead-free, halogen free, and adhere to the RoHS directive. For MPS green status, please visit MPS website under Quality Assurance.

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## TYPICAL APPLICATION



### ORDERING INFORMATION

Part Number	Package	Top Marking
MPQ8904DD-AEC1*	QFN-8 (2mm x 3mm)	See Below
MPQ8904DD**		

\* For Tape & Reel, add suffix -Z (e.g. MPQ8904DD-AEC1-Z);  
 For RoHS, compliant packaging, add suffix -LF (e.g. MPQ8904DD-AEC1-LF-Z).

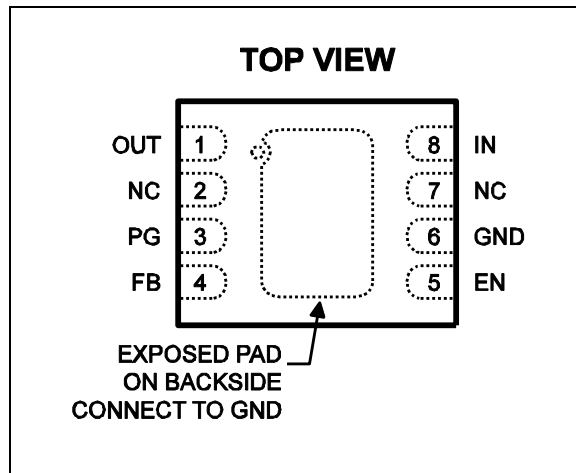
\*\* For Tape & Reel, add suffix -Z (e.g. MPQ8904DD-Z);  
 For RoHS, compliant packaging, add suffix -LF (e.g. MPQ8904DD-LF-Z).

### TOP MARKING

**T3YW**  
**LLL**

T3: product code of MPQ8904DD and MPQ8904DD-AEC1;  
 Y: year code;  
 W: week code;  
 LLL: lot number;

### PACKAGE REFERENCE



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

IN, FB to GND.....	-0.3V to +7V
EN to GND.....	-0.3V to $V_{IN} + 0.3V$
OUT.....	-0.3V to $V_{IN} + 0.3V$
Continuous Power Dissipation ( $T_A = +25^{\circ}C$ ) <sup>(2)</sup>	.....2.5W
Junction Temperature.....	150°C
Lead Temperature.....	260°C
Storage Temperature.....	-65°C to +150°C

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

Input Voltage $V_{IN}$ .....	2.5V to 6.5V
Output Voltage.....	0.5V to 5V
Load Current.....	500mA Maximum
Operating Junction Temp. ( $T_J$ ).....	-40°C to +125°C

<b>Thermal Resistance</b> <sup>(4)</sup>	$\theta_{JA}$	$\theta_{JC}$
QFN-8 (2mm x 3mm).....	55	12... °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  $\theta_{JA}$ , 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 will cause excessive die temperature, and the regulator will 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 approximately 1" square of 1 oz copper.

## ELECTRICAL CHARACTERISTICS

$V_{IN} = 3.3V$ ,  $V_{OUT} = 1.2V$ ,  $C_{OUT} = 4.7\mu F$ ,  $C_{IN} = 2.2\mu F$ ,  $T_J = -40^{\circ}C$  to  $+125^{\circ}C$ , Typical value are  $T_J = 25^{\circ}C$ , unless otherwise noted.

Parameter	Symbol	Condition	Min	Typ <sup>(4)</sup>	Max	Units
Operating Voltage		$I_{OUT} = 1mA$	2.5		6.5	V
Ground Pin Current <sup>(7)</sup>		$I_{OUT} = 1mA$		140	200	$\mu A$
		$I_{OUT} = 500mA$		7	12	mA
Shutdown Current		$V_{EN} = 0V$ , $V_{IN} = 5V$		7	15	$\mu A$
FB Regulation Voltage		$T_J = +25^{\circ}C$	0.484	0.496	0.508	V
		$-40^{\circ}C \leq T_J \leq +125^{\circ}C$	0.478	0.496	0.513	
Dropout Voltage <sup>(8)</sup>		$I_{OUT} = 500mA$	200	300	450	mV
Line Regulation <sup>(6)</sup>		$I_{OUT} = 1mA$ , $V_{IN} = (V_{OUT} + 0.5V)$ to $6.5V$ <sup>(7)</sup>	-0.1	0.015	0.1	%/V
Load Regulation <sup>(6)</sup>		$I_{OUT} = 1mA$ to $500mA$ , $V_{IN} = V_{OUT} + 0.5V$	-0.1	0.005	0.1	%/mA
Power-Good Output Voltage, Low <sup>9</sup>	$V_{OL}$	$I_{sink} = 0.5mA$	0	0.5	1	V
EN Input, High			1.2			V
EN Input, Low					0.4	V
EN Input Bias Current		$V_{EN} = 1.5V$		0.05	1	$\mu A$
Thermal Protection <sup>(5)</sup>				155		$^{\circ}C$
Current Limit			650	850		mA

**Notes:**

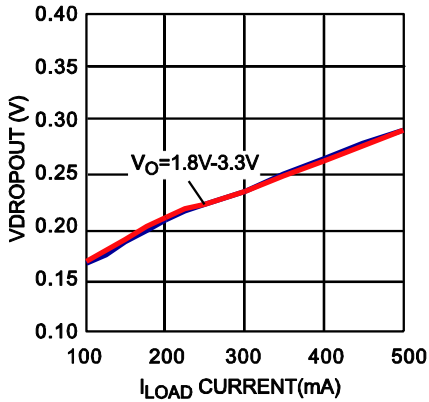
- 5) Parameter is guaranteed by design, not production tested.
- 6) Resistors for  $V_{OUT}$  measurement are 10k $\Omega$ , 14k $\Omega$ , 1%
- 7) The ground current does not include current through feedback current
- 8) Dropout Voltage is defined as the input to output differential when the output voltage drops 1% below its nominal value
- 9)  $V_{FEEDBACK}$  is 90% of the regulated value with 10k $\Omega$  pull-up to 5V

## TYPICAL PERFORMANCE CHARACTERISTICS

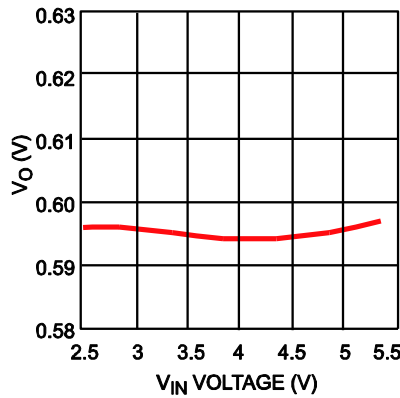
Based on the Figure Typical Application Circuit

C1=2.2μF, C2 =4.7μF, C3=1nF, T<sub>A</sub> = +25°C, unless otherwise noted.

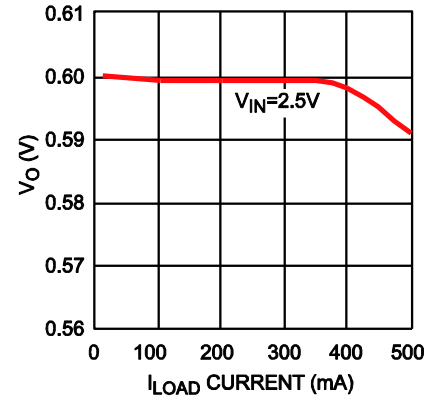
**Voltage Dropout vs Current**



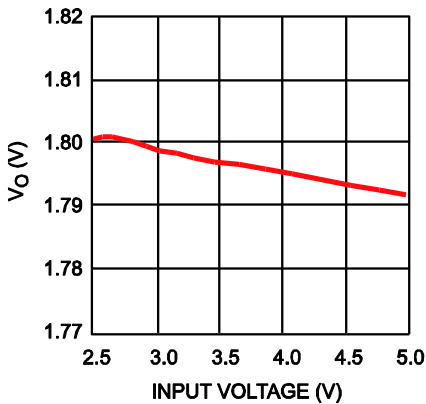
**Line Regulation**



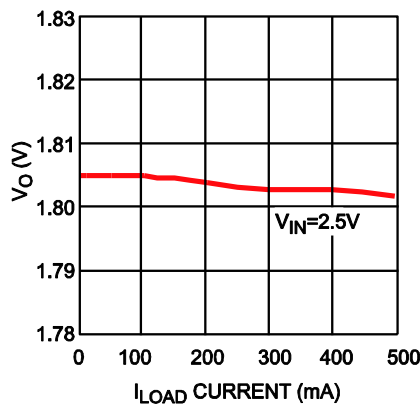
**Load Regulation**



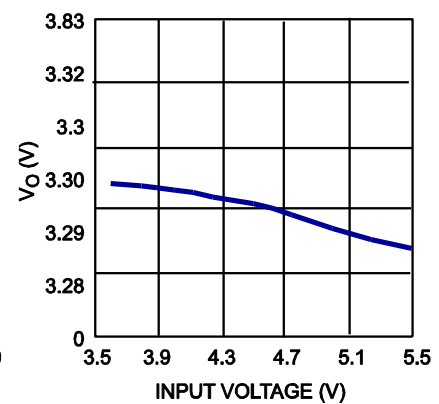
**Line Regulation**



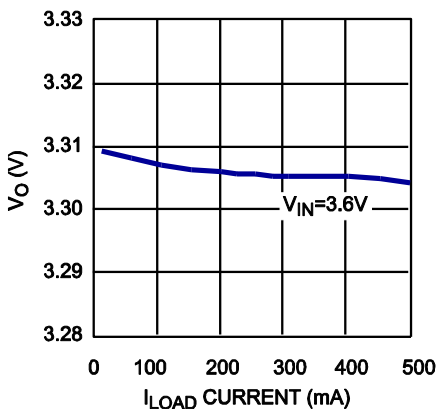
**Load Regulation**



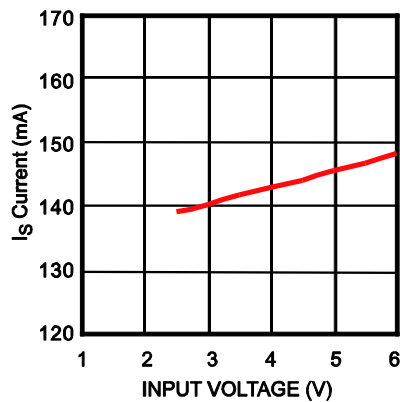
**Line Regulation**



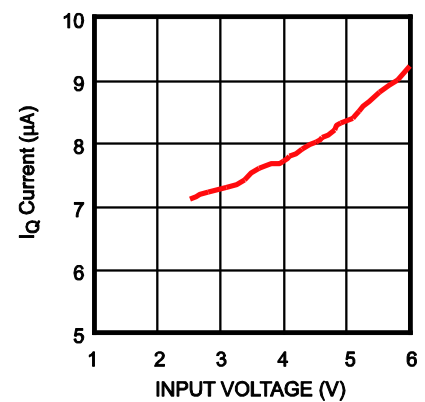
**Load Regulation**



**Supply Current vs. Input Voltage**

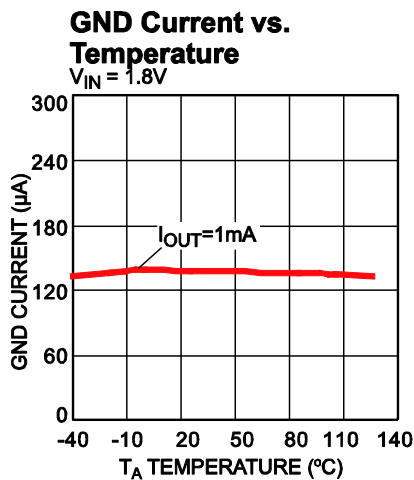
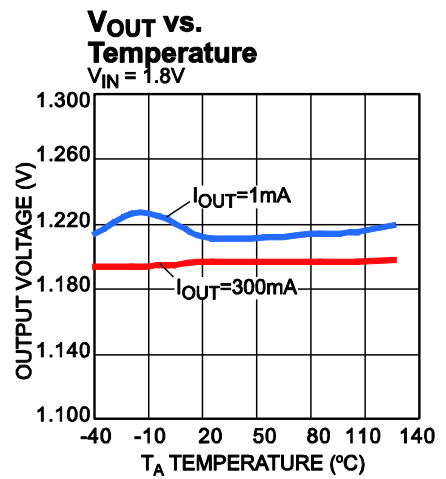
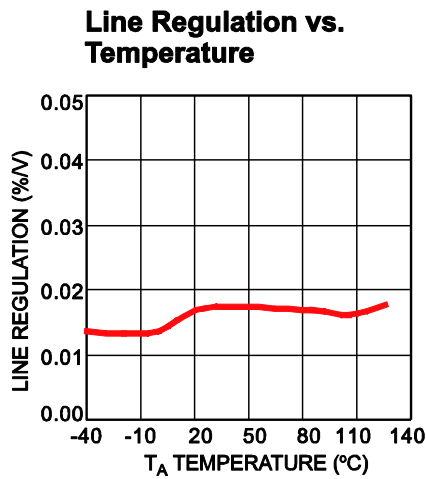
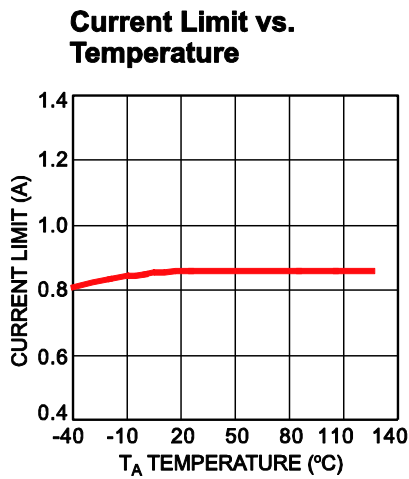
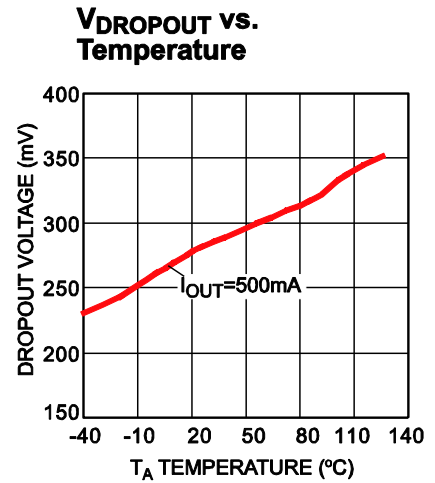
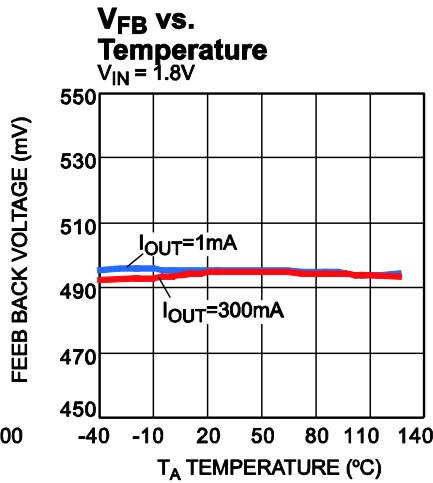
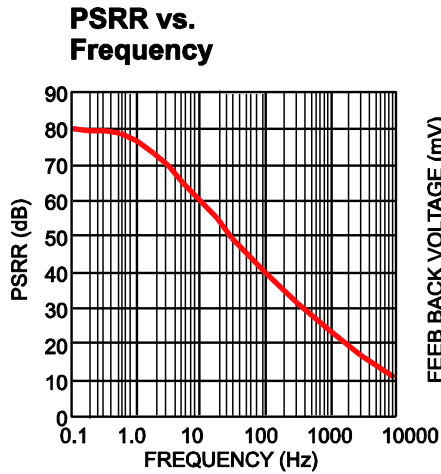


**Shut Down Current vs. Input Voltage**



**TYPICAL PERFORMANCE CHARACTERISTICS (continued)**

C1=2.2μF, C2 =4.7μF, C3=1nF, T<sub>A</sub> = +25°C, unless otherwise noted.

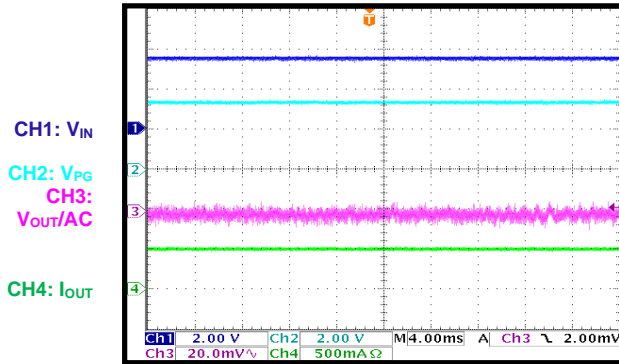


## TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

C1=2.2μF, C2=4.7μF, C3=1nF, T<sub>A</sub> = +25°C, unless otherwise noted.

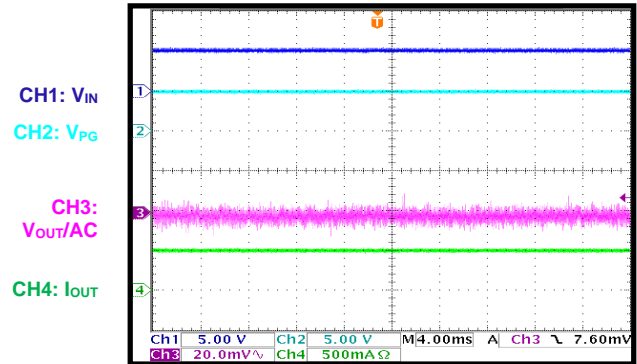
### Steady State

V<sub>IN</sub> = 3.3V, V<sub>OUT</sub> = 2.5V, I<sub>OUT</sub> = 0.5A



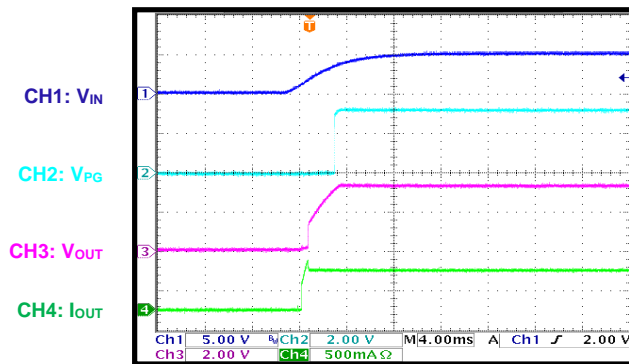
### Steady State

V<sub>IN</sub> = 5V, V<sub>OUT</sub> = 1.8V, I<sub>OUT</sub> = 0.5A



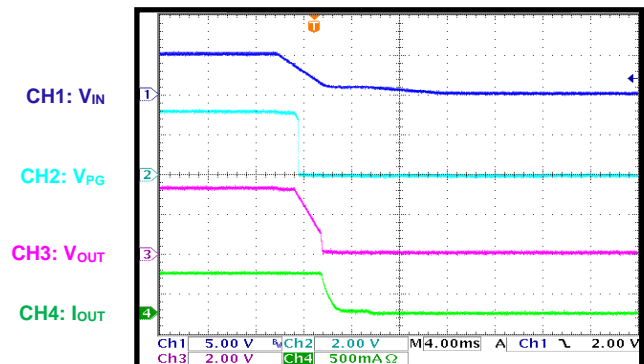
### Start-Up through VIN

V<sub>IN</sub> = 5V, V<sub>OUT</sub> = 3.3V, I<sub>OUT</sub> = 0.5A



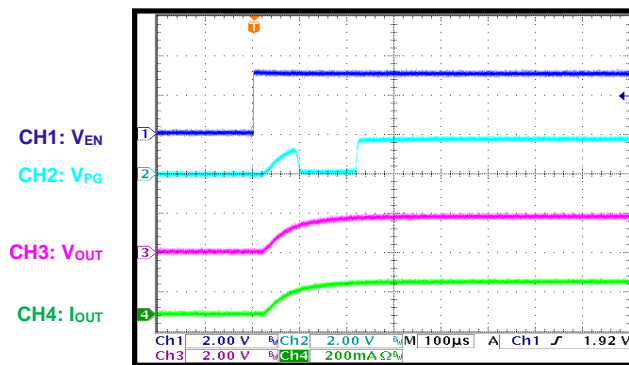
### Shutdown through VIN

V<sub>IN</sub> = 5V, V<sub>OUT</sub> = 3.3V, I<sub>OUT</sub> = 0.5A



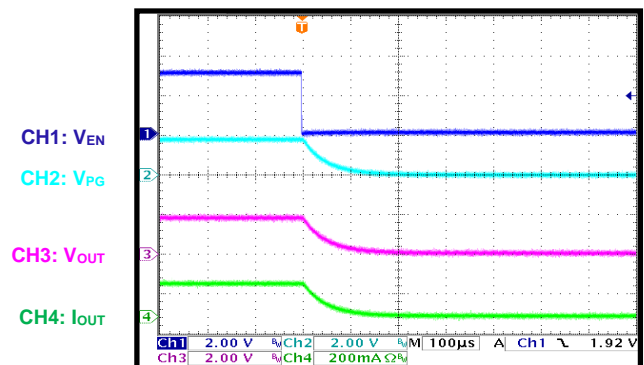
### Start-Up through EN

V<sub>IN</sub> = 5V, V<sub>OUT</sub> = 1.8V, I<sub>OUT</sub> = 0.15A



### Shutdown through EN

V<sub>IN</sub> = 5V, V<sub>OUT</sub> = 1.8V, I<sub>OUT</sub> = 0.15A

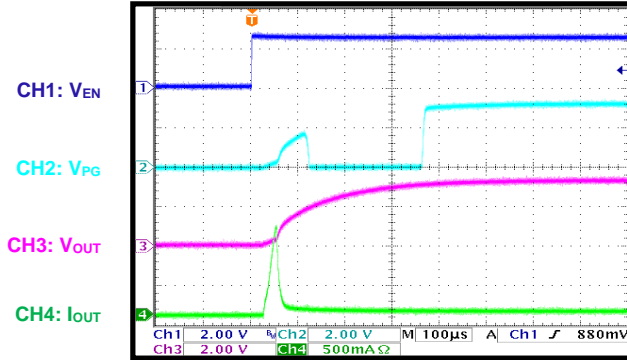


**TYPICAL PERFORMANCE CHARACTERISTICS (continued)**

C1=2.2µF, C2=4.7µF, C3=1nF, T<sub>A</sub> = +25°C, unless otherwise noted.

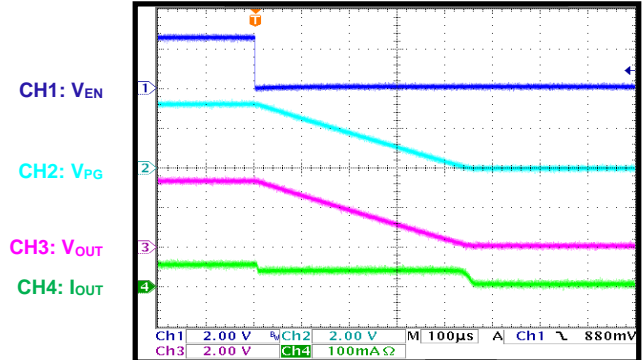
**Start-Up through EN**

V<sub>IN</sub> = 5V, V<sub>OUT</sub> = 3.3V, I<sub>OUT</sub> = 50mA



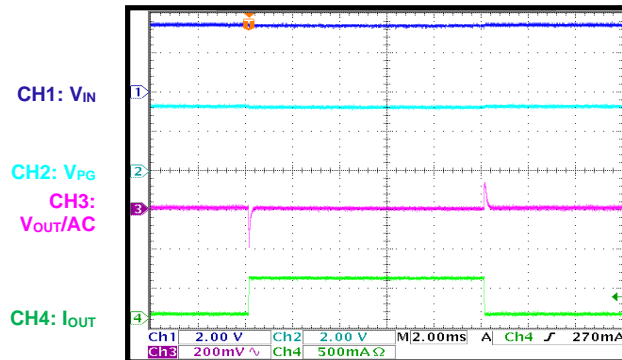
**Shutdown through EN**

V<sub>IN</sub> = 5V, V<sub>OUT</sub> = 3.3V, I<sub>OUT</sub> = 50mA



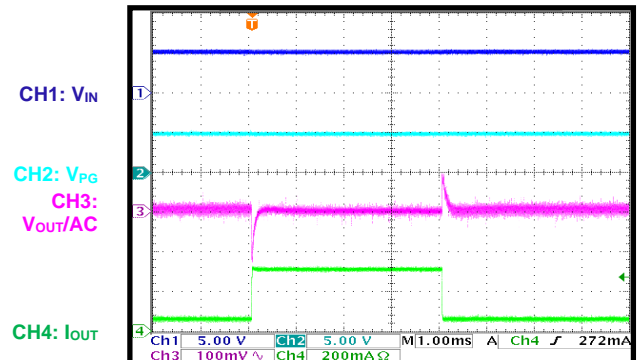
**Load Transient**

V<sub>IN</sub> = 3.3V, V<sub>OUT</sub> = 1.8V, I<sub>OUT</sub> = 0.05A to 0.5A



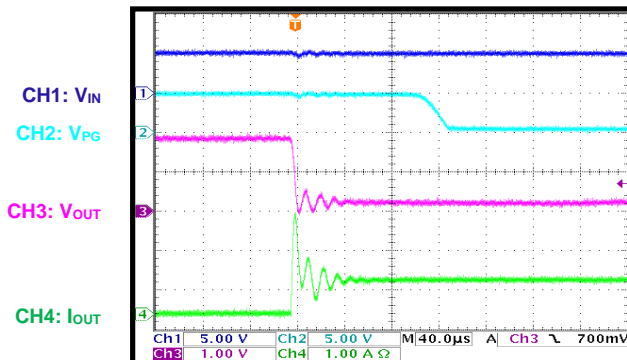
**Load Transient**

V<sub>IN</sub> = 5V, V<sub>OUT</sub> = 1.8V, I<sub>OUT</sub> = 0.05A to 0.3A



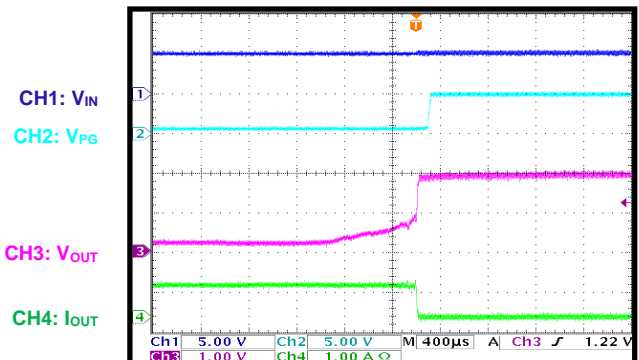
**Short-Circuit Protection**

V<sub>IN</sub> = 5V, V<sub>OUT</sub> = 1.8V



**SCP Recovery**

V<sub>IN</sub> = 5V, V<sub>OUT</sub> = 1.8V





## PIN FUNCTIONS

Pin #	Name	Description
1	OUT	Regulator Output. Bypass OUT to GND with a $\geq 4.7\mu\text{F}$ capacitor.
2	NC	No connect.
3	PG	Power-Good Open Collector Output. Monitors the regulator output. If the regulator output falls below 10% of its regulation point, the power-good pin goes low.
4	FB	Feedback. Connect a resistive voltage divider from OUT to FB to set the output voltage. OUT feedback threshold is 0.5V.
5	EN	Enable Input. Drive EN above 1.2V to turn on the MPQ8904. Drive EN below 0.4V to turn it off.
6	GND	Ground.
7	NC	No connect.
8	IN	Power Source Input. IN supplies the internal power to the MPQ8904 and is the source for the pass transistor. Bypass IN to GND with a $\geq 2.2\mu\text{F}$ capacitor.
Exposed Pad		Connect to GND.

## OPERATION

The MPQ8904 is a low-current, low-voltage, low-dropout, linear regulator. It is intended for devices that require very low voltage and low quiescent current power, such as wireless modems and cellular phones.

The MPQ8904 uses a PNP pass element and features internal thermal shutdown and internal current limit circuit.

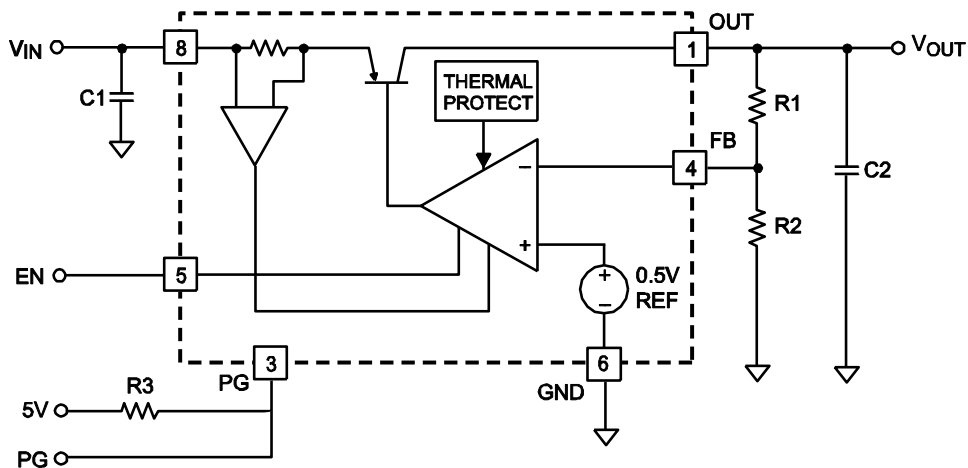


Figure 1: Functional Block Diagram

## APPLICATION INFORMATION

### Setting the Output Voltage

The MPQ8904 has an adjustable output voltage set via an external resistor divider (R1 and R2 in Figure).

$$R1 = R2 \times \left( \frac{V_{OUT} - V_{FB}}{V_{FB}} \right)$$

where  $V_{FB} = 0.5V$  is the OUT feedback threshold voltage.

Example: For a 2.5V output and  $R2=10k\Omega$

$$R1 = 10k \times \left( \frac{2.5 - 0.5}{0.5} \right) = 40k$$

Use a standard 40kΩ (±1%) resistor for R1.

Table 1 lists selected R1 values for typical output voltages ( $R2 = 10k\Omega$ ).

### Power-Good

The power-good (PG) pin monitors the output voltage; if the output voltage goes below 10% of its regulation point, the PG pin goes low. The PG pin is an open collector output that connects to a pull-up resistor (typically 10kΩ). Tie the pull-up resistor to 0V-to-5.5V supply, such as regulated input voltage.

**Table 1: Adjustable Output Voltage Values vs. R1 (R2 =10kΩ)**

V <sub>OUT</sub> (V)	R1 (Ω)
1.25	15k
1.5	20k
1.8	26k

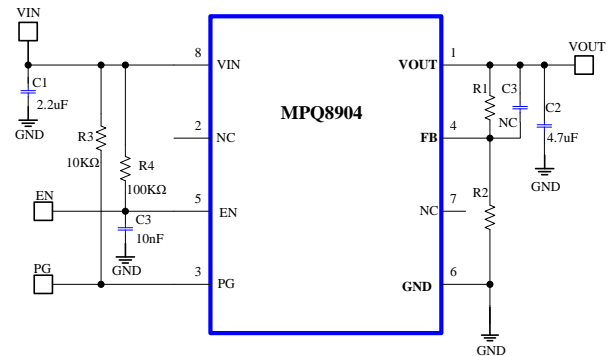
2	30k
2.5	40k
2.8	46k
3	50k
3.3	56k
4	70k
5	90k

### Bypass Capacitors

Bypass the reference voltage can be bypassed with an external capacitor to reduce noise. Use a low-ESR ceramic capacitor for the best performance.

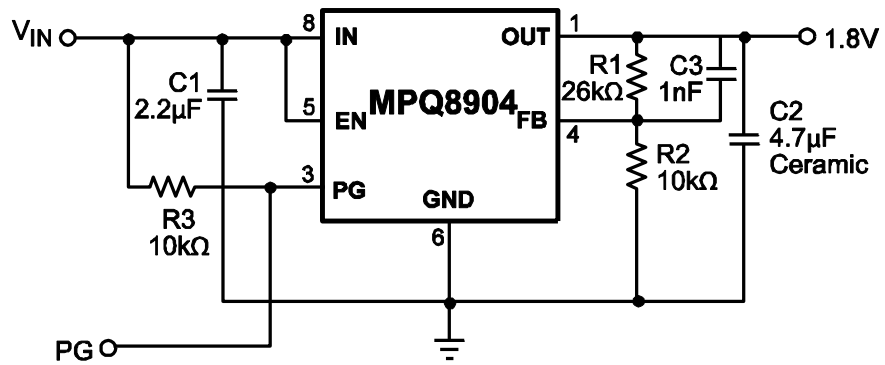
### Fast Power On

The MPQ8904 may need an RC circuit to slow down the fast power on if the power on time is less than 100μs (see Figure 2). The typical resistor (R4) value is 100kΩ and the typical capacitor (C3) value is 10nF.



**Figure 2: Fast Power-On Start-Up Circuit**

**TYPICAL APPLICATION CIRCUIT**



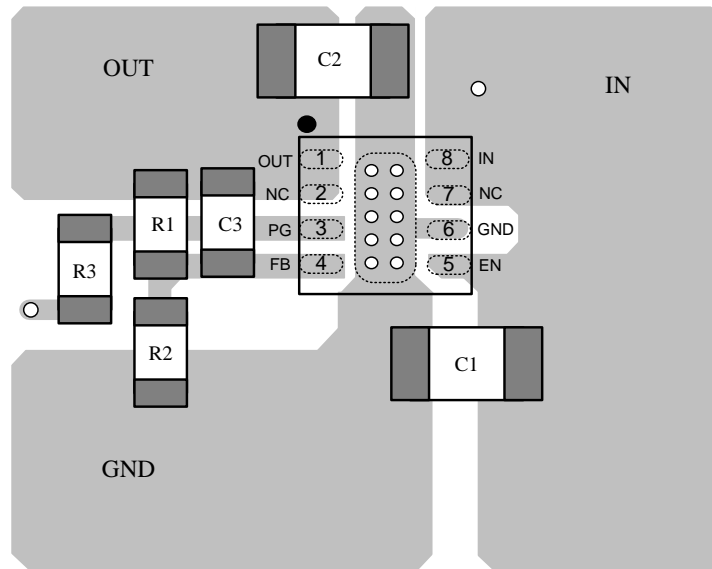
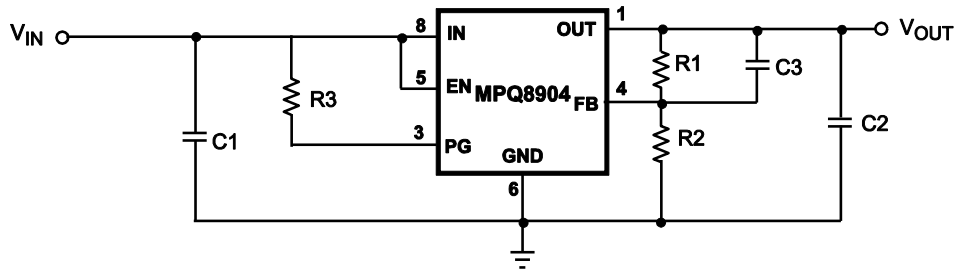
**Figure 3: Typical Application Circuit**

## PCB layout guide

PCB layout is very important to achieve good regulation, ripple rejection, transient response and thermal performance. For optimal performance, duplicate the EVB layout from Figure 4.

For any changes, follow the guidelines below:

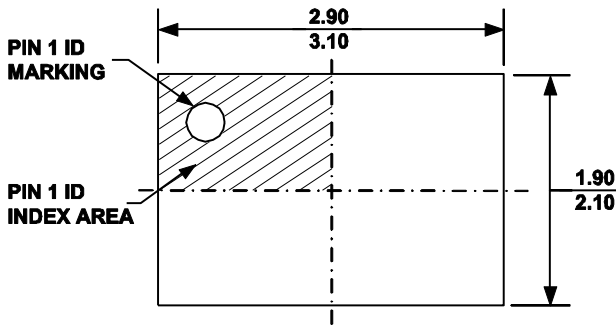
- 1) Place the input and output ceramic bypass capacitors close to their respective IN and OUT pins.
- 2) Use short and direct feedback connections. Place the feedback resistors and compensation components as close to the chip as possible.
- 3) Connect IN, OUT and GND to large copper surfaces to help cool the chip to improve thermal performance and long-term reliability.



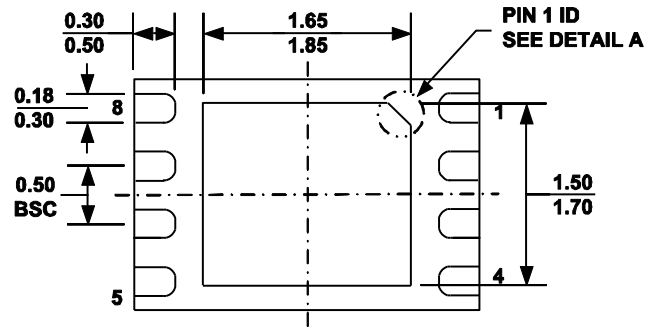
**Figure 4: PCB Layout, Top Layer**

**PACKAGE INFORMATION**

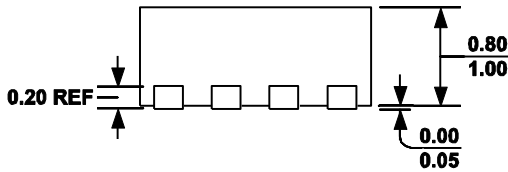
**QFN-8 (2mm x 3mm)**



**TOP VIEW**



**BOTTOM VIEW**

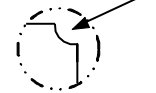


**SIDE VIEW**

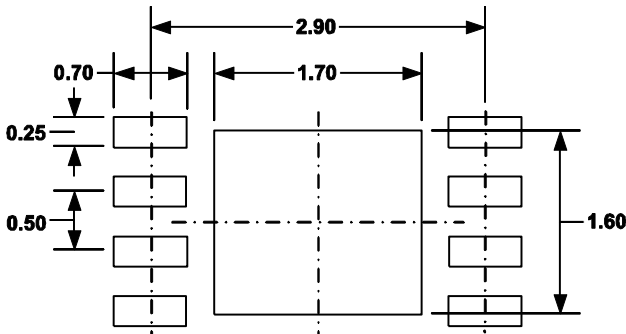
**PIN 1 ID OPTION A**  
0.30x45° TYP.



**PIN 1 ID OPTION B**  
R0.20 TYP.



**DETAIL A**



**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 MILLIMETER MAX.
- 4) DRAWING CONFORMS TO JEDEC MO-229, VARIATION VCED-2.
- 5) DRAWING IS NOT TO SCALE.

**REVISION HISTORY**

Revision #	Revision Date	Description	Pages Updated
1.0	5/21/2013	Initial Release	-
1.01	2/28/2015	Added the MPQ8904DD orderable SKU to the Ordering Information section.	2
1.02	3/11/2016	Added the Fast Power On section and Figure 2.	9
		Updated the numbering of Figure 2 to Figure 3.	10
1.03	6/3/2019	Updated the following waveforms: <ul style="list-style-type: none"> <li>• Enable Turn On: Updated the <math>V_{EN}</math>, <math>V_{PG}</math>, and <math>I_{LOAD}</math> values (previously 1V/div., 0.2A/div., and 0.1A/div., respectively) to 2V/div., 1V/div., and 0.2A/div., respectively</li> <li>• Enable Turn Off: Updated the <math>V_O</math> and <math>V_{PG}</math> values (previously 0.5V/div. and 0.2A/div.) both to 1V/div.</li> <li>• Thermal Protection: Added the unit for <math>I_{LOAD}</math></li> </ul>	7
		Updated the schematic in Figure 4.	11
1.04	6/30/2020	Updated $V_{EN} = 1.45V$ to $V_{EN} = 0V$ for the shutdown current test condition in the Electrical Characteristics section.	4
		Updated the Y-axis unit from mA to $\mu S$ in the Shut Down Current vs. Input Voltage curve.	5
1.1	3/8/2024	Updated the Y-axis unit from $\mu S$ to $\mu A$ in the Shut Down Current vs. Input Voltage curve.	5
		Corrected the typo (“Temperature”) in all relevant curve titles and X-axis labels.	6
		Replaced all seven waveforms (Line Transient, Load Transient, Enable Turn On, Enable Turn Off, Thermal Protection, Short Circuit Protection, and Short Circuit Recovery) with six new waveforms (Steady State for $V_{IN} = 3.3V$ , Steady State for $V_{IN} = 5V$ , Start-Up through $V_{IN}$ , Shutdown through $V_{IN}$ , and Start-Up through EN and Shutdown through EN for $V_{OUT} = 1.8V$ ) to correct the CH1, CH2, CH3, and CH4 labels.	7
		Added six new waveforms (Start-Up through EN and Shutdown through EN for $V_{OUT} = 3.3V$ , through EN, Load Transient for $V_{IN} = 3.3V$ , Load Transient for $V_{IN} = 5V$ , Short-Circuit Protection, and SCP Recovery).	8
		Added the missing "4" for “Figure 4” in the PCB layout guide section.	12

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