

## Regulated 3.3V, Low-Ripple Charge Pump with Low-Operating Current SLEEP Mode or BYPASS Mode

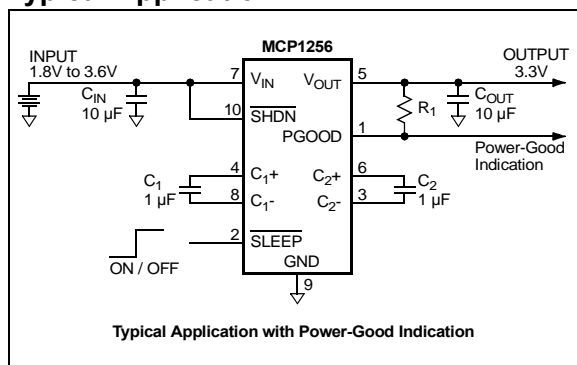
### Features

- Inductorless 1.5x, 2x Boost DC/DC Converter
- Output Voltage: 3.3V
- High Output Voltage Accuracy:
  - $\pm 3.0\%$  ( $V_{OUT}$  Fixed)
- Output Current Up To 100 mA
- 20 mV<sub>PP</sub> Output Voltage Ripple
- Thermal Shutdown and Short Circuit Protection
- Uses Small Ceramic Capacitors
- Switching Frequency: 650 kHz
- Low-Power SLEEP Mode: MCP1256/7
- BYPASS Mode: MCP1258/9
- Low-Power Shutdown Mode: 0.1  $\mu$ A (Typical)
- Shutdown Input Compatible with 1.8V Logic
- $V_{IN}$  Range: 1.8V to 3.6V
- Soft-Start Circuitry to Minimize Inrush Current
- Temperature Range: -40°C to +125°C
- Packaging:
  - 10-Pin, 3 mm x 3 mm DFN
  - 10-Pin, MSOP

### Applications

- Pagers
- Portable Measurement Instruments
- Home Automation Products
- PIC<sup>®</sup> MCU Bias

### Typical Application



### Description

The MCP1256, MCP1257, MCP1258 and MCP1259 are inductorless, positive regulated charge pump DC/DC converters. The devices generate a regulated 3.3V output voltage from a 1.8V to 3.6V input. The devices are specifically designed for applications operating from 2-cell alkaline, Ni-Cd, or Ni-MH batteries or by one primary lithium MnO<sub>2</sub> (or similar) coin cell battery.

The MCP1256, MCP1257, MCP1258 and MCP1259 provide high efficiency by automatically switching between 1.5x and 2x boost operation. In addition, at light output loads, the MCP1256 and MCP1257 can be placed in a SLEEP mode, lowering the quiescent current while maintaining the regulated output voltage. Alternatively, the MCP1258 and MCP1259 provide a BYPASS feature connecting the input voltage to the output. This allows for real-time clocks, microcontrollers or other system devices to remain biased with virtually no current being consumed by the MCP1258 or MCP1259.

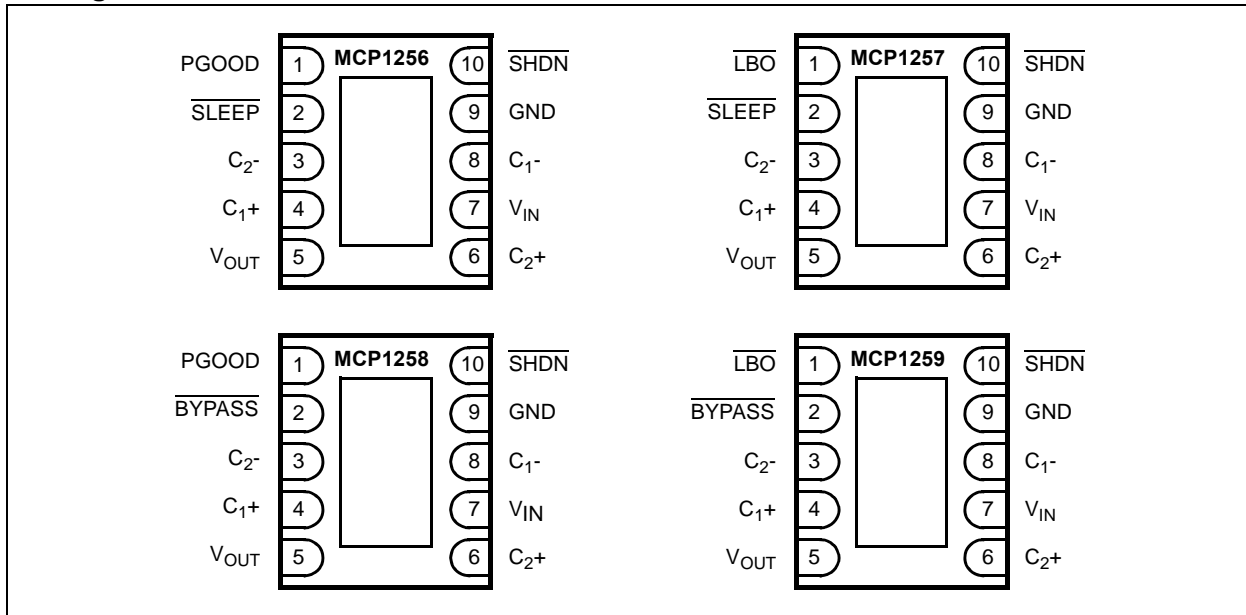
In normal operation, the output voltage ripple is below 20 mV<sub>PP</sub> at load currents up to 100 mA. Normal operation occurs at a fixed switching frequency of 650 kHz, avoiding interference with sensitive IF bands.

The MCP1256 and MCP1258 feature a power-good output that can be used to detect out-of-regulation conditions. The MCP1257 and MCP1259 feature a low-battery indication that issues a warning if the input voltage drops below a preset voltage threshold. Extremely low supply current and few external parts (4 capacitors) make these devices ideal for small, battery-powered applications. A Shutdown mode is also provided for further power reduction.

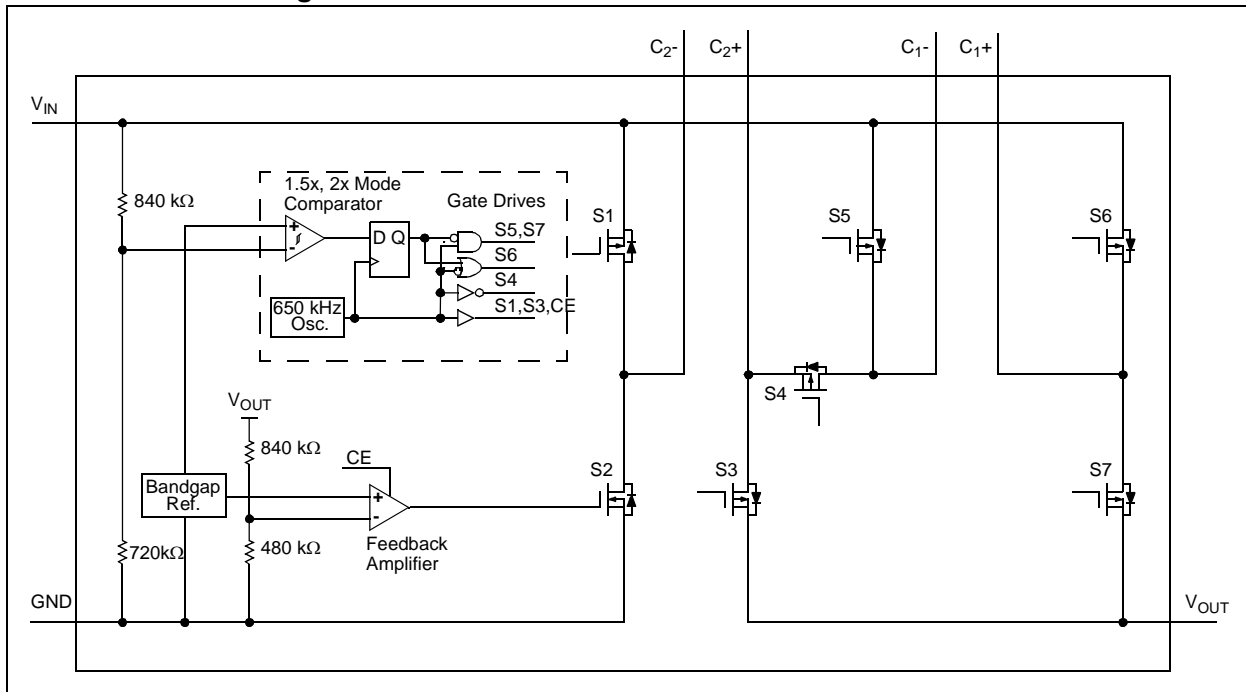
The devices incorporate thermal and short-circuit protection. Two package offerings are provided: 10-pin MSOP and 10-lead 3 mm x 3 mm DFN. The devices are completely characterized over the junction temperature range of -40°C to +125°C.

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## Package Pinouts



## Functional Block Diagram



**TABLE 1: SWITCH LOGIC**

Mode	Phase	Oscillator	Q	S1	S2(CE)	S3	S4	S5	S6	S7
1.5x	Charging	H	L	H	H	H	L	H	L	H
1.5x	Transfer	L	L	L	L	L	H	L	H	L
2x	Charging	H	H	H	H	H	L	L	H	L
2x	Transfer	L	H	L	L	L	H	L	H	L
BYPASS	—	—	—	H	L	H	H	H	L	L

**Legend:** L is Logic Low, H is Logic High

## 1.0 ELECTRICAL CHARACTERISTICS

### Absolute Maximum Ratings†

Power Supply Voltage,  $V_{IN}$ .....3.8V  
 Voltage on Any Pin w.r.t. GND ..... -0.3V to ( $V_{IN}+0.3V$ )  
 Output Short Circuit Duration .....continuous  
 Storage Temperature Range ..... -65°C to +150°C  
 Ambient Temperature with Power Applied .... -55°C to +125°C  
 Maximum Junction Temperature ..... +150°C  
 ESD protection on all pins  
 Human Body Model (1.5 kΩ in Series with 100 pF)..... ≥ 2 kV  
 Machine Model (200 pF, No Series Resistance) .....200V

† **Notice:** Stresses above those listed under “Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operational listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

### DC CHARACTERISTICS

**Electrical Specifications:** Unless otherwise indicated, all limits apply for  $V_{IN} = 1.8V$  to  $3.6V$ ,  $\overline{SHDN} = V_{IN}$ ,  $C_{IN} = C_{OUT} = 10 \mu F$ ,  $C_1 = C_2 = 1 \mu F$ ,  $I_{OUT} = 10 \text{ mA}$ ,  $T_J = -40^\circ C$  to  $+125^\circ C$ . Typical values are at  $T_J = +25^\circ C$ .

Parameters	Sym	Min	Typ	Max	Units	Conditions
<b>ALL DEVICES</b>						
Supply Voltage	$V_{IN}$	1.8	—	3.6	V	
Output Voltage	$V_{OUT}$	—	3.3	—	V	
Output Voltage Accuracy	$V_{OUT}$	-3.0	±0.5	+3.0	%	$I_{OUT} = 10 \text{ mA}$ to $I_{OUT(MAX)}$
Output Current	$I_{OUT(MAX)}$	30	—	—	mA	$1.8V \leq V_{IN} < 2.0V$
		70	—	—	mA	$2.0V \leq V_{IN} < 2.2V$
		100	—	—	mA	$2.2V \leq V_{IN} \leq 3.6V$
Short Circuit Current	$I_{SC}$	—	150	—	mA	$V_{OUT} = 0V$ , $V_{IN} = 1.8V$ to $3.6V$
Power Efficiency	$\eta$	—	84.5	—	%	$V_{IN} = 1.8V$ , $I_{OUT} = 10 \text{ mA}$
		—	84.5	—	%	$V_{IN} = 1.8V$ , $I_{OUT} = 50 \text{ mA}$
		—	76.4	—	%	$V_{IN} = 2.0V$ , $I_{OUT} = 10 \text{ mA}$
		—	80.1	—	%	$V_{IN} = 2.0V$ , $I_{OUT} = 50 \text{ mA}$
		—	64.0	—	%	$V_{IN} = 2.4V$ , $I_{OUT} = 10 \text{ mA}$
		—	67.1	—	%	$V_{IN} = 2.4V$ , $I_{OUT} = 50 \text{ mA}$
		—	67.5	—	%	$V_{IN} = 2.4V$ , $I_{OUT} = 100 \text{ mA}$
		—	69.7	—	%	$V_{IN} = 2.8V$ , $I_{OUT} = 10 \text{ mA}$
		—	76.0	—	%	$V_{IN} = 2.8V$ , $I_{OUT} = 50 \text{ mA}$
		—	76.7	—	%	$V_{IN} = 2.8V$ , $I_{OUT} = 100 \text{ mA}$
		—	65.0	—	%	$V_{IN} = 3.0V$ , $I_{OUT} = 10 \text{ mA}$
—	71.0	—	%	$V_{IN} = 3.0V$ , $I_{OUT} = 50 \text{ mA}$		
—	71.6	—	%	$V_{IN} = 3.0V$ , $I_{OUT} = 100 \text{ mA}$		
<b>Shutdown Input - SHDN</b>						
SHDN Input Voltage Low	$V_{IL(\overline{SHDN})}$	—	—	0.4	V	
SHDN Input Voltage High	$V_{IH(\overline{SHDN})}$	1.4	—	—	V	
SHDN Input Leakage Current	$I_{LK(\overline{SHDN})}$	—	0.001	0.1	μA	
SHDN Quiescent Current	$I_Q$	—	0.25	2	μA	$V_{\overline{SHDN}} = 0V$ , $T_J = +25^\circ C$
<b>Thermal Shutdown</b>						
Thermal Shutdown Threshold	$T_J$	—	160	—	°C	
Thermal Shutdown Hysteresis	$T_{J(HYS)}$	—	15	—	°C	

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## DC CHARACTERISTICS (CONTINUED)

<b>Electrical Specifications:</b> Unless otherwise indicated, all limits apply for $V_{IN} = 1.8V$ to $3.6V$ , $\overline{SHDN} = V_{IN}$ , $C_{IN} = C_{OUT} = 10 \mu F$ , $C_1 = C_2 = 1 \mu F$ , $I_{OUT} = 10 mA$ , $T_J = -40^\circ C$ to $+125^\circ C$ . Typical values are at $T_J = +25^\circ C$ .						
Parameters	Sym	Min	Typ	Max	Units	Conditions
<b>MCP1256 and MCP1257 Devices</b>						
<b>SLEEP Mode Input - SLEEP</b>						
SLEEP Input Voltage Low	$V_{IL(\overline{SLEEP})}$	—	—	0.4	V	
SLEEP Input Voltage High	$V_{IH(\overline{SLEEP})}$	1.4	—	—	V	
SLEEP Input Leakage Current	$I_{LK(\overline{SLEEP})}$	—	0.001	0.1	$\mu A$	
SLEEP Quiescent Current	$I_Q$	—	10	20	$\mu A$	$V_{\overline{SLEEP}} = 0V$ , $I_{OUT} = 0 mA$
<b>MCP1256 and MCP1258 Devices</b>						
<b>Power-Good Output - PGOOD</b>						
PGOOD Threshold	$V_{TH}$	—	93	—	%	Percent of $V_{OUT}$ Falling
PGOOD Hysteresis	$V_{HYS}$	—	110	—	mV	$V_{OUT}$ Rising
PGOOD Output Low Voltage	$V_{OL}$	—	25	100	mV	$I_{SINK} = 0.5 mA$ , $V_{IN} = 1.8V$
PGOOD Input Leakage Current	$I_{LK(\overline{PGOOD})}$	—	0.02	1	$\mu A$	$V_{\overline{PGOOD}} = V_{IN}$
<b>MCP1257 and MCP1259</b>						
<b>Low-Battery Output - LBO</b>						
LBO Threshold	$V_{TH}$	—	1.95	—	V	$V_{IN}$ Falling
LBO Hysteresis	$V_{HYS}$	—	240	—	mV	$V_{IN}$ Rising
LBO Output Low Voltage	$V_{OL}$	—	25	100	mV	$I_{SINK} = 0.5 mA$ , $V_{IN} = 1.8V$
LBO Input Leakage Current	$I_{LK(\overline{LBO})}$	—	0.02	1	$\mu A$	$V_{\overline{LBO}} = V_{IN}$
<b>MCP1258 and MCP1259</b>						
<b>BYPASS Mode Input - BYPASS</b>						
BYPASS Input Voltage Low	$V_{IL(\overline{BYPASS})}$	—	—	0.4	V	
BYPASS Input Voltage High	$V_{IH(\overline{BYPASS})}$	1.4	—	—	V	
BYPASS Input Leakage Current	$I_{LK(\overline{BYPASS})}$	—	0.001	0.1	$\mu A$	
BYPASS Quiescent Current	$I_Q$	—	0.25	2	$\mu A$	$V_{\overline{BYPASS}} = 0V$ , $I_{OUT} = 0 mA$ , $T_J = +25^\circ C$
BYPASS Input-to-Output Impedance	$R_{\overline{BYPASS}}$	—	1.5	—	$\Omega$	$V_{IN} = 2.4V$

## AC CHARACTERISTICS

**Electrical Specifications:** Unless otherwise indicated, all limits apply for  $V_{IN} = 1.8V$  to  $3.6V$ ,  $\overline{SHDN} = V_{IN}$ ,  $C_{IN} = C_{OUT} = 10 \mu F$ ,  $C_1 = C_2 = 1 \mu F$ ,  $I_{OUT} = 10 mA$ ,  $T_J = -40^\circ C$  to  $+125^\circ C$ . Typical values are at  $T_J = +25^\circ C$ .

Parameters	Sym	Min	Typ	Max	Units	Conditions
<b>ALL DEVICES</b>						
Internal Oscillator Frequency	$F_{OSC}$	—	650	—	kHz	
Output Voltage Ripple, Normal Operation	$V_{RIP}$	—	5	—	mVp-p	$C_{OUT} = 10 \mu F$ , $I_{OUT} = 10 mA$
		—	20	—	mVp-p	$C_{OUT} = 10 \mu F$ , $I_{OUT} = 100 mA$
		—	12	—	mVp-p	$C_{OUT} = 2.2 \mu F$ , $I_{OUT} = 10 mA$
		—	55	—	mVp-p	$C_{OUT} = 2.2 \mu F$ , $I_{OUT} = 100 mA$
$V_{OUT}$ Wake-up Time From Shutdown	$T_{WKUP}$	—	175	—	$\mu s$	$V_{IN} = 3.0V$ , $I_{OUT} = 10 mA$ , $\overline{SHDN} = V_{IH(MIN)}$ , $V_{OUT}$ from 0 to 90% Nominal Regulated Output Voltage
<b>MCP1256 and MCP1257</b>						
Output Voltage Ripple, SLEEP Mode	$V_{RIP}$	—	40	—	mVp-p	$C_{OUT} = 10 \mu F$ , $I_{OUT} = 0.1 mA$
		—	60	—	mVp-p	$C_{OUT} = 10 \mu F$ , $I_{OUT} = 4 mA$
		—	40	—	mVp-p	$C_{OUT} = 2.2 \mu F$ , $I_{OUT} = 0.1 mA$
		—	60	—	mVp-p	$C_{OUT} = 2.2 \mu F$ , $I_{OUT} = 4 mA$
<b>MCP1258 and MCP1259</b>						
$V_{OUT}$ Wake-up Time From BYPASS	$T_{WKUP}$	—	150	—	$\mu s$	$V_{IN} = 3.0V$ , $I_{OUT} = 10 mA$ , $\overline{SHDN} = V_{IH(MIN)}$ , $V_{OUT}$ from 0 to 90% Nominal Regulated Output Voltage

## TEMPERATURE SPECIFICATIONS

**Electrical Specifications:** Unless otherwise indicated, all limits apply for  $V_{IN} = 1.8V$  to  $3.6V$ ,  $\overline{SHDN} = V_{IN}$ ,  $C_{IN} = C_{OUT} = 10 \mu F$ ,  $C_1 = C_2 = 1 \mu F$ ,  $I_{OUT} = 10 mA$ ,  $T_J = -40^\circ C$  to  $+125^\circ C$ . Typical values are at  $T_J = +25^\circ C$ .

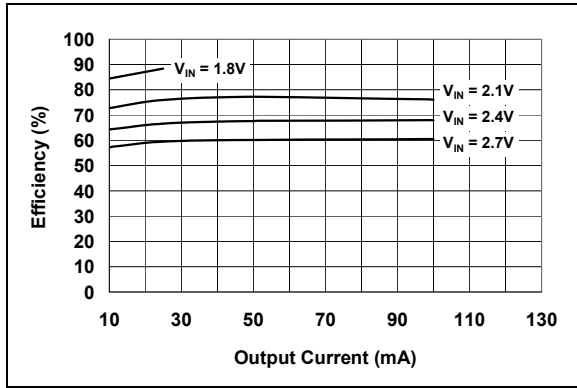
Parameters	Sym	Min	Typ	Max	Units	Conditions
<b>Temperature Ranges</b>						
Specified Temperature Range	$T_J$	-40	—	+125	$^\circ C$	
Operating Temperature Range	$T_J$	-40	—	+125	$^\circ C$	
Storage Temperature Range	$T_A$	-65	—	+150	$^\circ C$	
<b>Thermal Package Resistances</b>						
Thermal Resistance, 10-Lead, MSOP	$\theta_{JA}$	—	200	—	$^\circ C/W$	4-Layer JC51-7 Standard Board, Natural Convection
Thermal Resistance, 10-Lead, DFN 3 mm x 3 mm	$\theta_{JA}$	—	57	—	$^\circ C/W$	4-Layer JC51-7 Standard Board, Natural Convection

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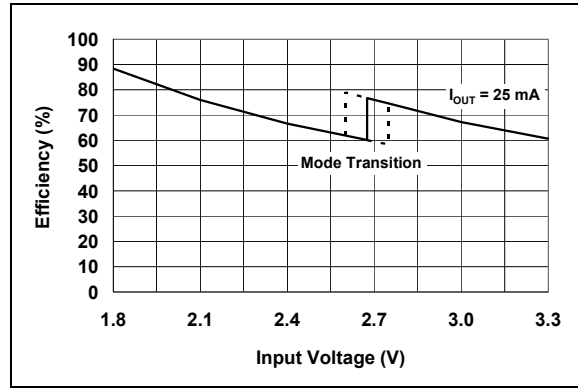
## 2.0 TYPICAL PERFORMANCE CURVES

**Note:** The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside the specified operating range (e.g., outside specified power supply range) and therefore outside the warranted range.

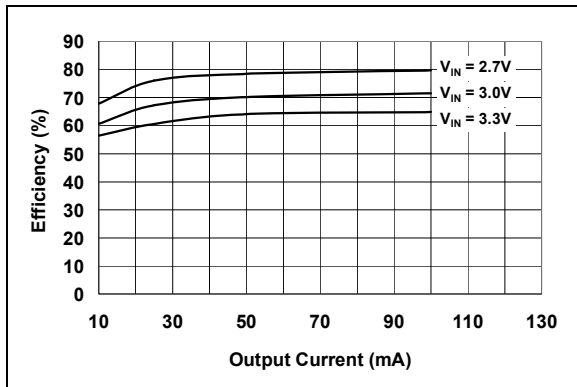
**NOTE:** Unless otherwise indicated,  $C_{IN} = C_{OUT} = 10 \mu F$ ,  $C_1 = C_2 = 1 \mu F$ ,  $I_{OUT} = 10 \text{ mA}$ , and  $T_A = +25^\circ\text{C}$ .



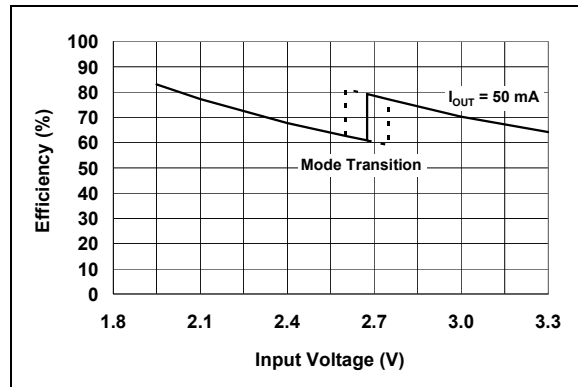
**FIGURE 2-1:** Efficiency ( $\eta$ ) vs. Output Current ( $I_{OUT}$ ).



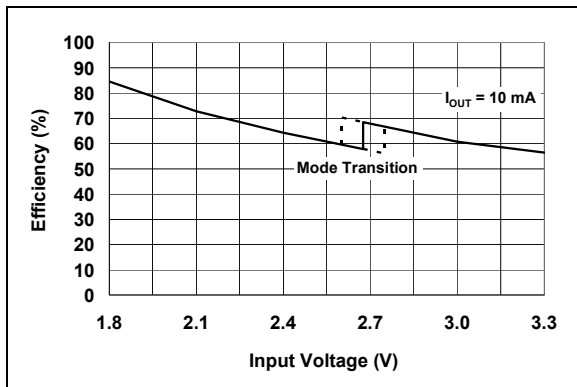
**FIGURE 2-4:** Efficiency ( $\eta$ ) vs. Supply Voltage ( $V_{IN}$ ).



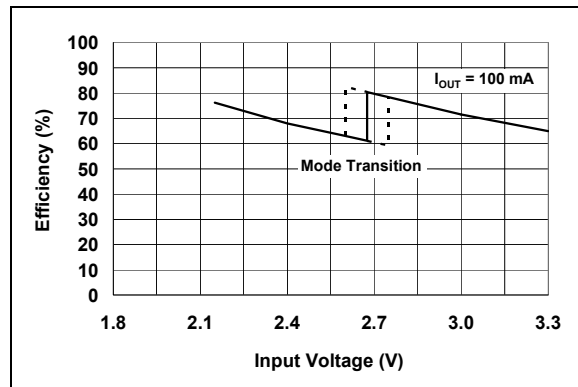
**FIGURE 2-2:** Efficiency ( $\eta$ ) vs. Output Current ( $I_{OUT}$ ).



**FIGURE 2-5:** Efficiency ( $\eta$ ) vs. Supply Voltage ( $V_{IN}$ ).



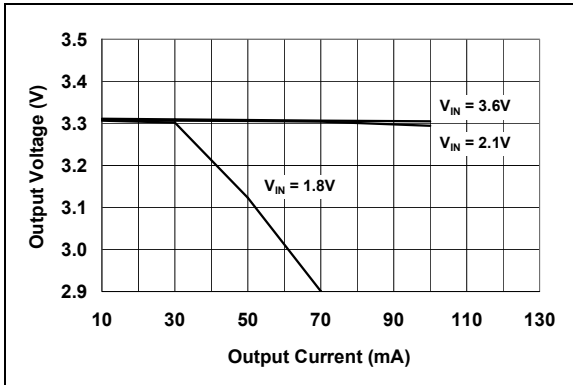
**FIGURE 2-3:** Efficiency ( $\eta$ ) vs. Supply Voltage ( $V_{IN}$ ).



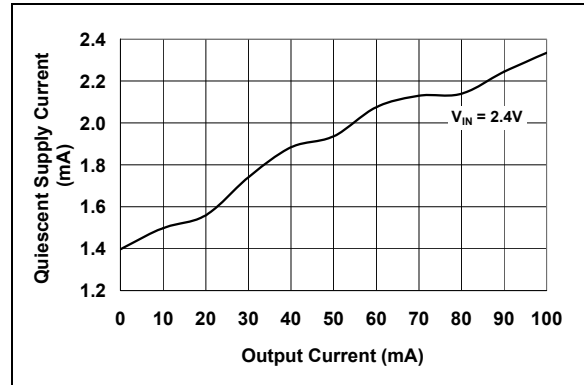
**FIGURE 2-6:** Efficiency ( $\eta$ ) vs. Supply Voltage ( $V_{IN}$ ).

## TYPICAL PERFORMANCE CURVES (CONTINUED)

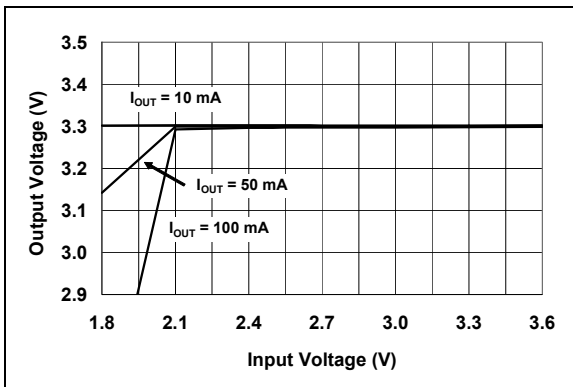
**NOTE:** Unless otherwise indicated,  $C_{IN} = C_{OUT} = 10 \mu\text{F}$ ,  $C_1 = C_2 = 1 \mu\text{F}$ ,  $I_{OUT} = 10 \text{ mA}$ , and  $T_A = +25^\circ\text{C}$ .



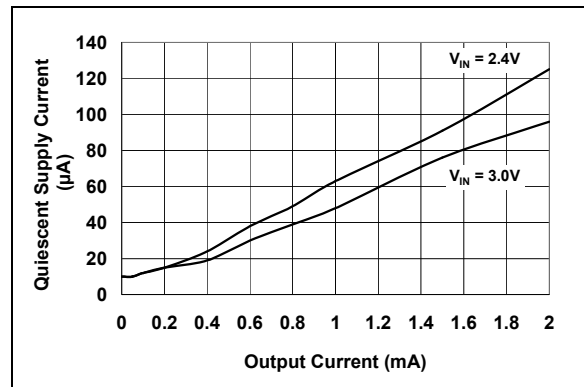
**FIGURE 2-7:** Output Voltage ( $V_{OUT}$ ) vs. Output Current ( $I_{OUT}$ ).



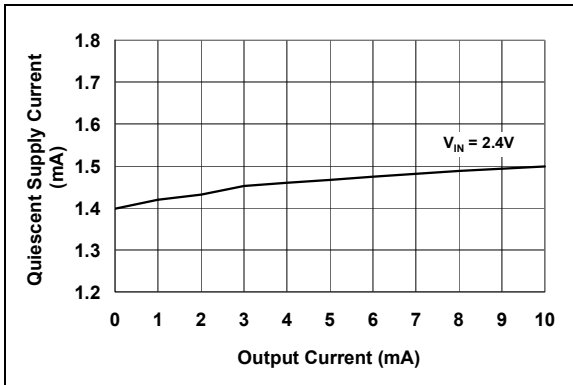
**FIGURE 2-10:** Quiescent Supply Current ( $I_Q$ ) vs. Output Current ( $I_{OUT}$ ) - Normal Mode.



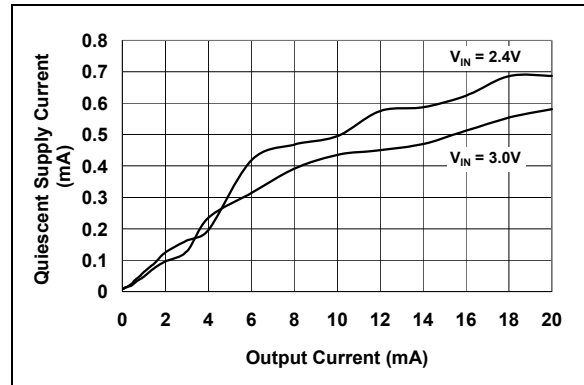
**FIGURE 2-8:** Output Voltage ( $V_{OUT}$ ) vs. Input Voltage ( $V_{IN}$ ).



**FIGURE 2-11:** Quiescent Supply Current ( $I_Q$ ) vs. Output Current ( $I_{OUT}$ ) - SLEEP Mode.



**FIGURE 2-9:** Quiescent Supply Current ( $I_Q$ ) vs. Output Current ( $I_{OUT}$ ) - Normal Mode.

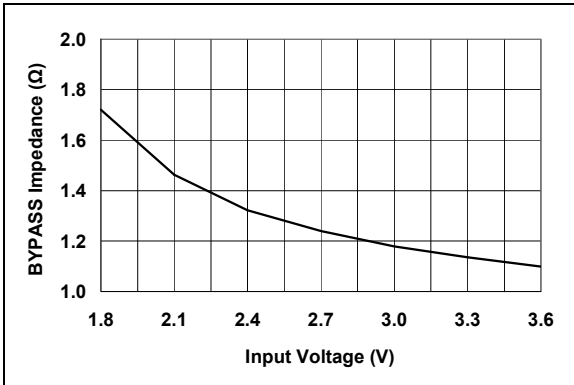


**FIGURE 2-12:** Quiescent Supply Current ( $I_Q$ ) vs. Output Current ( $I_{OUT}$ ) - SLEEP Mode.

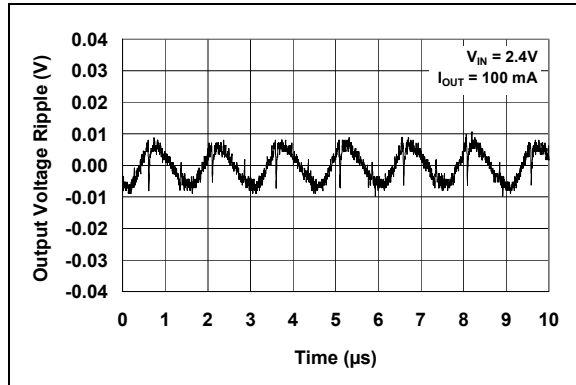
# MCP1256/7/8/9

## TYPICAL PERFORMANCE CURVES (CONTINUED)

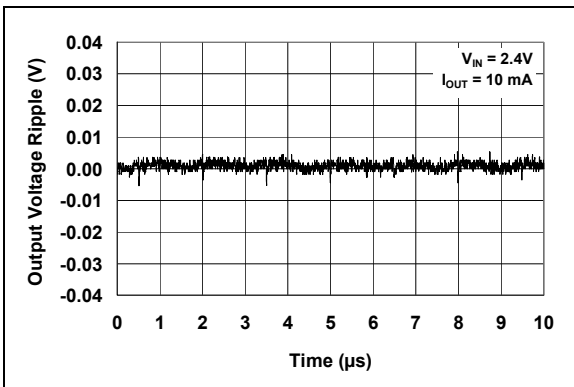
NOTE: Unless otherwise indicated,  $C_{IN} = C_{OUT} = 10 \mu\text{F}$ ,  $C_1 = C_2 = 1 \mu\text{F}$ ,  $I_{OUT} = 10 \text{ mA}$ , and  $T_A = +25^\circ\text{C}$ .



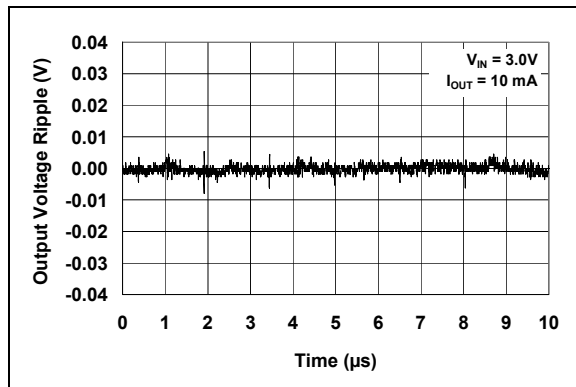
**FIGURE 2-13:** *BYPASS Impedance ( $R_{BYPASS}$ ) vs. Supply Voltage ( $V_{IN}$ ).*



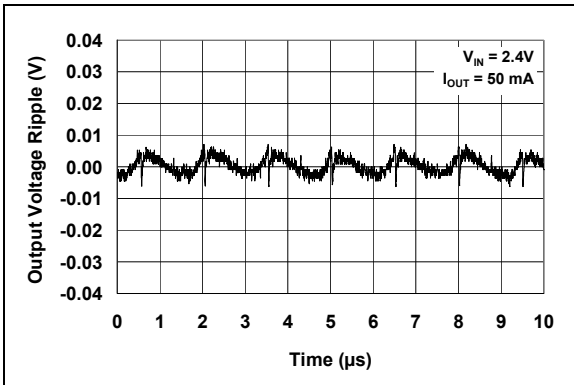
**FIGURE 2-16:** *Output Voltage Ripple vs. Time - Normal 2x Mode.*



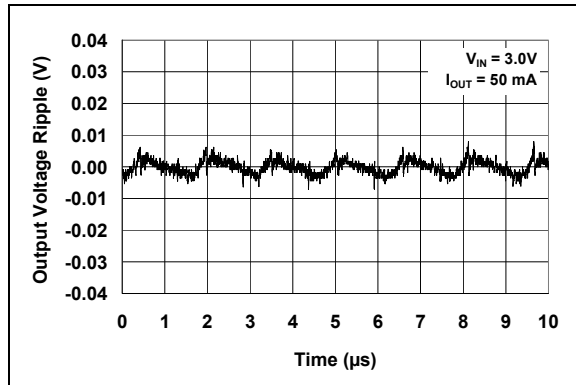
**FIGURE 2-14:** *Output Voltage Ripple vs. Time - Normal 2x Mode.*



**FIGURE 2-17:** *Output Voltage Ripple vs. Time - Normal 1.5x Mode.*



**FIGURE 2-15:** *Output Voltage Ripple vs. Time - Normal 2x Mode.*

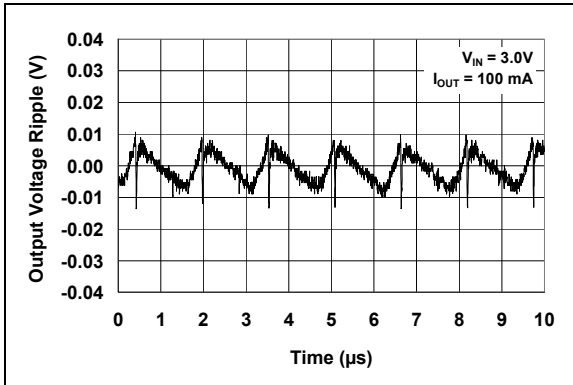


**FIGURE 2-18:** *Output Voltage Ripple vs. Time - Normal 1.5x Mode.*

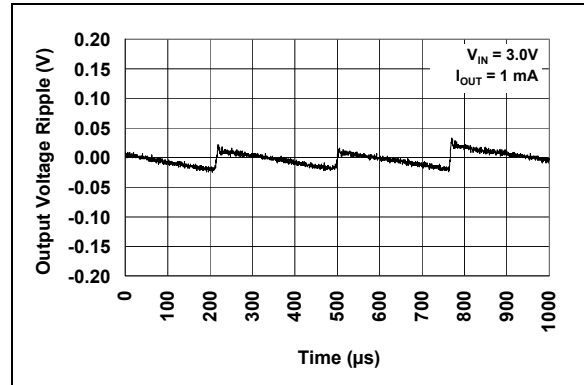


## TYPICAL PERFORMANCE CURVES (CONTINUED)

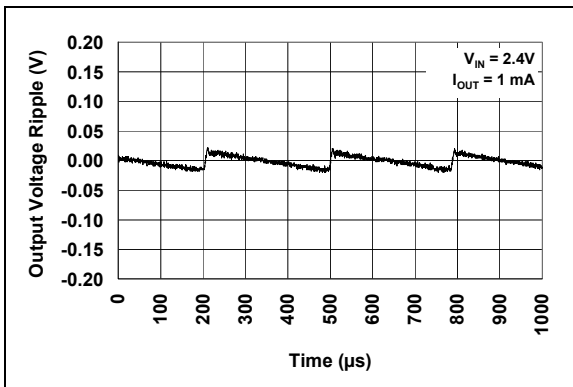
**NOTE:** Unless otherwise indicated,  $C_{IN} = C_{OUT} = 10 \mu\text{F}$ ,  $C_1 = C_2 = 1 \mu\text{F}$ ,  $I_{OUT} = 10 \text{ mA}$ , and  $T_A = +25^\circ\text{C}$ .



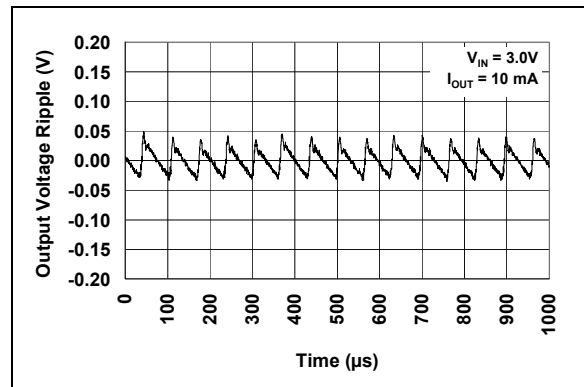
**FIGURE 2-19:** Output Voltage Ripple vs. Time - Normal 1.5x Mode.



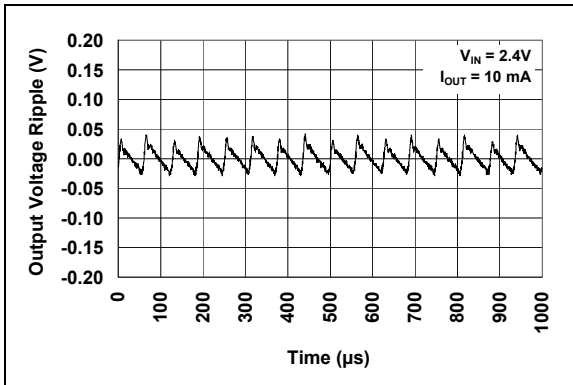
**FIGURE 2-22:** Output Voltage Ripple vs. Time - SLEEP Mode.



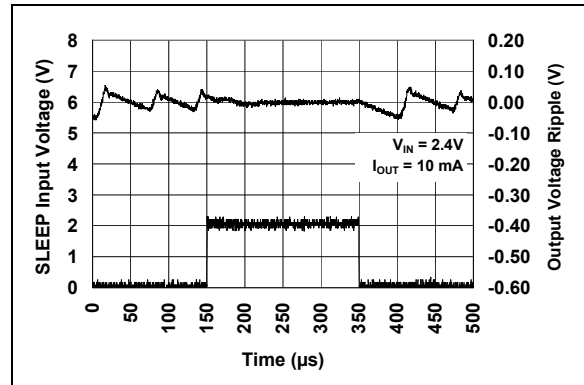
**FIGURE 2-20:** Output Voltage Ripple vs. Time - SLEEP Mode.



**FIGURE 2-23:** Output Voltage Ripple vs. Time - SLEEP Mode.



**FIGURE 2-21:** Output Voltage Ripple vs. Time - SLEEP Mode.

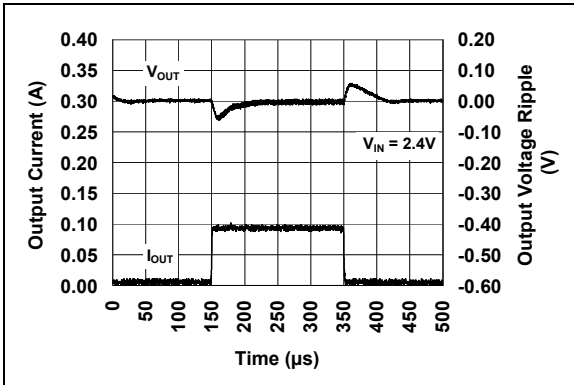


**FIGURE 2-24:** Output Voltage Ripple vs. Time - Mode Transition: SLEEP Mode-to-Normal 2x Mode-to-SLEEP Mode.

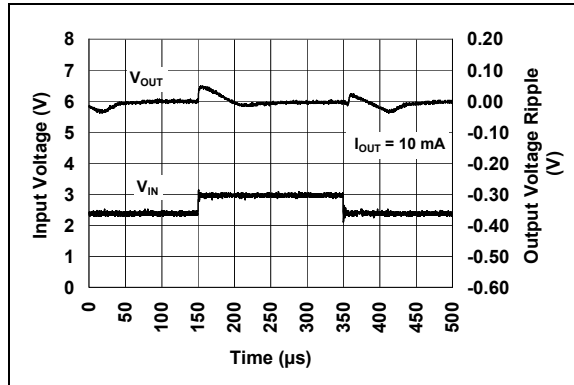
# MCP1256/7/8/9

## TYPICAL PERFORMANCE CURVES (CONTINUED)

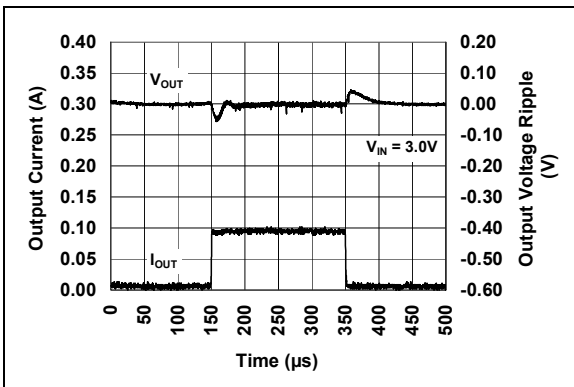
NOTE: Unless otherwise indicated,  $C_{IN} = C_{OUT} = 10 \mu\text{F}$ ,  $C_1 = C_2 = 1 \mu\text{F}$ ,  $I_{OUT} = 10 \text{ mA}$ , and  $T_A = +25^\circ\text{C}$ .



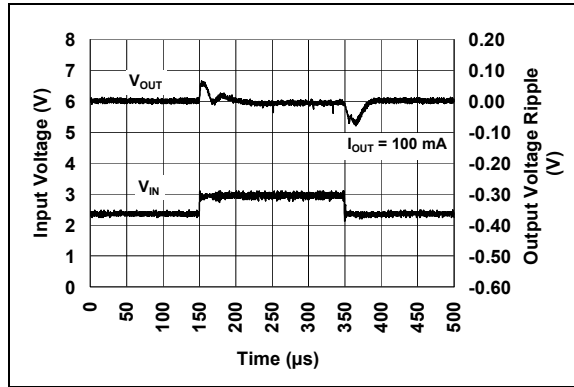
**FIGURE 2-25:** Load Transient Response - Normal 2x Mode.



**FIGURE 2-27:** Line Transient Response.



**FIGURE 2-26:** Load Transient Response - Normal 1.5x Mode.



**FIGURE 2-28:** Line Transient Response.

## 3.0 PIN DESCRIPTION

The descriptions of the pins are listed in Table 3-1.

**TABLE 3-1: PIN FUNCTION TABLE**

Pin No.		Symbol	Function
DFN	MSOP		
1	1	PGOOD $\overline{\text{LBO}}$	Power-Good Indication Open-Drain Output Pin: MCP1256 and MCP1258 Low-Battery Indication Open-Drain Output Pin: MCP1257 and MCP1259
2	2	$\overline{\text{SLEEP}}$ $\overline{\text{BYPASS}}$	Active Low SLEEP Mode Input Pin: MCP1256 and MCP1257 Active Low BYPASS Mode Input Pin: MCP1258 and MCP1259
3	3	C2-	Flying Capacitor Negative Pin
4	4	C1+	Flying Capacitor Positive Pin
5	5	V <sub>OUT</sub>	Regulated 3.3V Output Voltage
6	6	C2+	Flying Capacitor Positive Pin
7	7	V <sub>IN</sub>	Power Supply Input Voltage
8	8	C1-	Flying Capacitor Negative Pin
9	9	GND	0V Reference
10	10	$\overline{\text{SHDN}}$	Active Low SHUTDOWN Mode Input Pin

### 3.1 Status Indication (PGOOD, $\overline{\text{LBO}}$ )

#### 3.1.1 POWER-GOOD OUTPUT PIN (PGOOD)

**MCP1256/8:** PGOOD is high impedance when the output voltage is in regulation. A logic low is asserted when the output falls 7% (typical) below the nominal value. The PGOOD output remains low until V<sub>OUT</sub> is within 3% (typical) of its nominal value. On start-up, this pin indicates when the output voltage reaches its final value. PGOOD is high impedance when  $\overline{\text{SHDN}}$  is low or when  $\overline{\text{BYPASS}}$  is low (MCP1258).

#### 3.1.2 LOW-BATTERY OUTPUT PIN ( $\overline{\text{LBO}}$ )

**MCP1257/9:**  $\overline{\text{LBO}}$  is high impedance when the input voltage is above the low-battery threshold voltage. A logic low is asserted when the input falls below the low-battery threshold voltage. The  $\overline{\text{LBO}}$  output remains low until V<sub>IN</sub> is above the low-battery threshold voltage plus the low-battery hysteresis voltage.  $\overline{\text{LBO}}$  is high impedance when  $\overline{\text{SHDN}}$  is low or when  $\overline{\text{BYPASS}}$  is low (MCP1259).

### 3.2 Mode Selection ( $\overline{\text{SLEEP}}$ , $\overline{\text{BYPASS}}$ )

#### 3.2.1 ACTIVE LOW SLEEP MODE ( $\overline{\text{SLEEP}}$ )

**MCP1256/7:** A logic low signal applied to this pin places the device into a SLEEP mode of operation. In this mode, the device maintains regulation. SLEEP mode performs pulse skip operation reducing the current draw of the device at the expense of increased output voltage ripple.

#### 3.2.2 ACTIVE LOW BYPASS MODE ( $\overline{\text{BYPASS}}$ )

**MCP1258/9:** A logic low signal applied to this pin places the device into a BYPASS mode of operation. In this mode, the input supply voltage is connected directly to the output.

### 3.3 Flying Capacitor Negative (C2-)

A 1  $\mu\text{F}$  ceramic flying capacitor is recommended.

### 3.4 Flying Capacitor Positive (C1+)

A 1  $\mu\text{F}$  ceramic flying capacitor is recommended.

### 3.5 Regulated Output Voltage (V<sub>OUT</sub>)

Regulated 3.3V output. Bypass to GND with a minimum of 2.2  $\mu\text{F}$ .

### 3.6 Flying Capacitor Positive (C2+)

A 1  $\mu\text{F}$  ceramic flying capacitor is recommended.

### 3.7 Power Supply Input Voltage (V<sub>IN</sub>)

A supply voltage of 1.8V to 3.6V is recommended. Bypass to GND with a minimum of 1  $\mu\text{F}$ .

### 3.8 Flying Capacitor Negative (C1-)

A 1  $\mu\text{F}$  ceramic flying capacitor is recommended.

### 3.9 0V Reference (GND)

Connect to negative terminal of and input supply.

### 3.10 Device Shut Down ( $\overline{\text{SHDN}}$ )

A logic low signal applied to this pin disables the device. A logic high signal applied to this pin allows normal operation.

# MCP1256/7/8/9

## 4.0 DEVICE OVERVIEW

The MCP1256/7/8/9 devices are positive regulated charge pumps that accept an input voltage from +1.8V to +3.6V and convert it to a regulated 3.3V output voltage. The MCP1256/7/8/9 provide a low-cost, compact and simple solution for step-up DC/DC conversions, primarily in battery applications, that do not want to use switching regulator solutions because of EMI noise and inductor size.

The MCP1256/7/8/9 are designed to offer the highest possible efficiency under common operating conditions, i.e.  $V_{IN} = 2.4V$  or  $2.8V$ ,  $V_{OUT} = 3.3V$ ,  $I_{OUT} = 100$  mA. A fixed switching frequency, 650 kHz typically, allows for easy external filtering.

The MCP1256/7 provide a unique SLEEP mode feature which reduces the current drawn from the input supply while maintaining a regulated bias on external peripherals. SLEEP mode can substantially increase battery run-time in portable applications.

The MCP1258/9 provide a unique BYPASS mode feature which virtually eliminates the current drawn from the input supply by the device while maintaining an unregulated bias on external peripherals. BYPASS connects the input supply voltage to the output. All remaining functions of the device are shutdown. BYPASS mode can substantially increase battery run-time in portable applications.

The devices supply up to 100 mA of output current for input voltages,  $V_{IN}$ , greater than or equal to 2.2V. The devices are available in small 10-Pin MSOP or DFN packages with an operating junction temperature range of  $-40^{\circ}C$  to  $+125^{\circ}C$ .

### 4.1 Theory of Operation

The MCP1256/7/8/9 devices employ a switched capacitor charge pump to boost an input supply,  $V_{IN}$ , to a regulated 3.3V output voltage. Referring to the Functional Block Diagram, the devices perform conversion and regulation in two phases: charge and transfer. When the devices are not in shutdown, SLEEP or BYPASS, the two phases are continuously cycled through.

Charge transfers charge from the input supply to the flying capacitors,  $C_1$  and  $C_2$ , connected to pins  $C_{1+}$ ,  $C_{1-}$ ,  $C_{2+}$  and  $C_{2-}$ , respectively. During this phase, switches S4 and S6 are closed. Switch S2 controls the amount of charge transferred to the flying capacitors. The amount of charge is determined by a sample and hold error amplifier with feedback from the output voltage at the beginning of the phase.

Once the first phase (charge) is complete, transfer is initiated. The second phase transfers the energy from the flying capacitors to the output. The MCP1256/7/8/9 devices autonomously switch between 1.5x mode and 2x mode. This determines whether the flying capacitors are placed in parallel (1.5x mode), or remain in series

(2x mode), when the energy is transferred to the output. The transfer mode determines which switches are closed for the transfer.

Both phases occur in one clock period of the internal oscillator. When the second phase (transfer) has been completed, the cycle repeats.

### 4.2 Power Efficiency

The power efficiency,  $\eta$ , is determined by the mode of operation, 1.5x mode or 2x mode. Equation 4-1 and Equation 4-2 are used to approximate the power efficiency with any significant amount of output current. At light loads, the device quiescent current must be taken into consideration.

#### EQUATION 4-1:

$$\eta_{1.5x} = \frac{P_{OUT}}{P_{IN}} = \frac{V_{OUT} \times I_{OUT}}{V_{IN} \times 1.5 \times I_{OUT}} = \frac{V_{OUT}}{V_{IN} \times 1.5}$$

#### EQUATION 4-2:

$$\eta_{2x} = \frac{P_{OUT}}{P_{IN}} = \frac{V_{OUT} \times I_{OUT}}{V_{IN} \times 2 \times I_{OUT}} = \frac{V_{OUT}}{V_{IN} \times 2}$$

### 4.3 Shutdown Mode (SHDN)

Driving  $\overline{SHDN}$  low places the MCP1256/7/8/9 in a low-power Shutdown mode. This disables the charge-pump switches, oscillator and control logic, reducing the quiescent current to 0.25  $\mu A$  (typical). The PGOOD output and LBO are in a high impedance state during shutdown.

### 4.4 SLEEP Mode (SLEEP)

The MCP1256/7 provide a unique SLEEP mode feature. SLEEP mode reduces the current drawn from the input supply while maintaining a regulated bias on external peripherals. SLEEP mode can substantially increase battery run-time in portable applications.

The regulation control is referred to as a bang-bang control due to the output being regulated around a fixed reference with some hysteresis. As a result, some amount of peak-to-peak ripple will be observed at the output independent of load current. The frequency of the output ripple, however, will be influenced heavily by the load current and output capacitance.

### 4.5 BYPASS Mode (BYPASS)

The MCP1258/9 provide a unique BYPASS mode feature which virtually eliminates the current drawn from the input supply by the device, while maintaining an unregulated bias on external peripherals. BYPASS connects the input supply voltage to the output. All remaining functions of the device are shutdown. BYPASS mode can substantially increase battery run-time in portable applications.

## 4.6 Power-Good Output (PGOOD)

For the MCP1256/8 devices, the PGOOD output is an open-drain output that sinks current when the regulator output voltage falls below  $0.93V_{OUT}$  (typical). If the regulator output voltage falls below  $0.93V_{OUT}$  (typical) for less than 200  $\mu$ s and then recovers, glitch immunity circuits prevent the PGOOD signal from transitioning low. A 10 k $\Omega$  to 1 M $\Omega$  pull-up resistor from PGOOD to  $V_{OUT}$  may be used to provide a logic output. If not used, connect PGOOD to GND or leave unconnected.

PGOOD is high impedance when the output voltage is in regulation. A logic low is asserted when the output falls 7% (typical) below the nominal value. The PGOOD output remains low until  $V_{OUT}$  is within 3% (typical) of its nominal value. On start-up, this pin indicates when the output voltage reaches its final value. PGOOD is high impedance when SHDN is low or when BYPASS is low (MCP1258).

## 4.7 Low-Battery Output ( $\overline{LBO}$ )

For the MCP1257/9 devices, the  $\overline{LBO}$  output is an open-drain output that sinks current when the input voltage falls below a preset threshold. If the input voltage falls below the preset threshold for less than 200  $\mu$ s and then recovers, glitch immunity circuits prevent the  $\overline{LBO}$  signal from transitioning low. A 10 k $\Omega$  to 1 M $\Omega$  pull-up resistor from  $\overline{LBO}$  to  $V_{OUT}$  may be used to provide a logic output. If not used, connect  $\overline{LBO}$  to GND or leave unconnected.

$\overline{LBO}$  is high impedance when the input voltage is above the low-battery threshold voltage. A logic low is asserted when the input falls below the low-battery threshold voltage. The  $\overline{LBO}$  output remains low until  $V_{IN}$  is above the low-battery threshold voltage plus the low-battery hysteresis voltage.  $\overline{LBO}$  is high impedance when SHDN is low or when BYPASS is low (MCP1259).

## 4.8 Soft-Start and Short-Circuit Protection

The MCP1256/7/8/9 devices feature fold back short-circuit protection. This circuitry provides an internal soft-start function by limiting inrush current during startup and also limits the output current to 150 mA (typical), if the output is short-circuited to GND. The internal soft-start circuitry requires approximately 175  $\mu$ s, typical, from either initial power-up, release from Shutdown, or release from BYPASS (MCP1258/9) for the output voltage to be in regulation.

## 4.9 Thermal Shutdown

The MCP1256/7/8/9 devices feature thermal shutdown with temperature hysteresis. When the die temperature exceeds 160°C, the device shuts down. When the die cools by 15°C, the MCP1256/7/8/9 automatically turns back on again. If high die temperature is caused by output overload and the load is not removed, the device will turn on and off resulting in a pulsed output.

## 5.0 APPLICATIONS

### 5.1 Capacitor Selection

The style and value of capacitors used with the MCP1256/7/8/9 family determine several important parameters, such as output voltage ripple and charge pump strength. To minimize noise and ripple, it is recommended that low ESR (0.1 $\Omega$ ) capacitors be used for both  $C_{IN}$  and  $C_{OUT}$ . These capacitors should be ceramic and should be 10  $\mu$ F or higher for optimum performance.

If the source impedance to  $V_{IN}$  is very low, up to several megahertz,  $C_{IN}$  may not be required. Alternatively, a somewhat smaller value of  $C_{IN}$  may be substituted for the recommended 10  $\mu$ F, but will not be as effective in preventing ripple on the  $V_{IN}$  pin.

The value of  $C_{OUT}$  controls the amount of output voltage ripple present on  $V_{OUT}$ . Increasing the size of  $C_{OUT}$  will reduce output ripple at the expense of a slower turn-on time from shutdown and a higher inrush current.

The flying capacitors ( $C_1$  and  $C_2$ ) control the strength of the charge pump and in order to achieve the maximum rated output current (100 mA), it is necessary to have at least 1  $\mu$ F of capacitance for the flying capacitor. A smaller flying capacitor delivers less charge per clock cycle to the output capacitor resulting in lower available output current.

### 5.2 PCB Layout Issues

The MCP1256/7/8/9 devices transfer charge at high switching frequencies producing fast, high peak, transient currents. As a result, any stray inductance in the component layout will produce unwanted noise in the system. Proper board layout techniques are required to ensure optimum performance.

# MCP1256/7/8/9

## 6.0 TYPICAL APPLICATION CIRCUITS

The MCP1256/7/8/9 devices are inductorless, positive regulated, switched capacitor DC/DC converters. Typical application circuits are depicted in Figure 6-1.

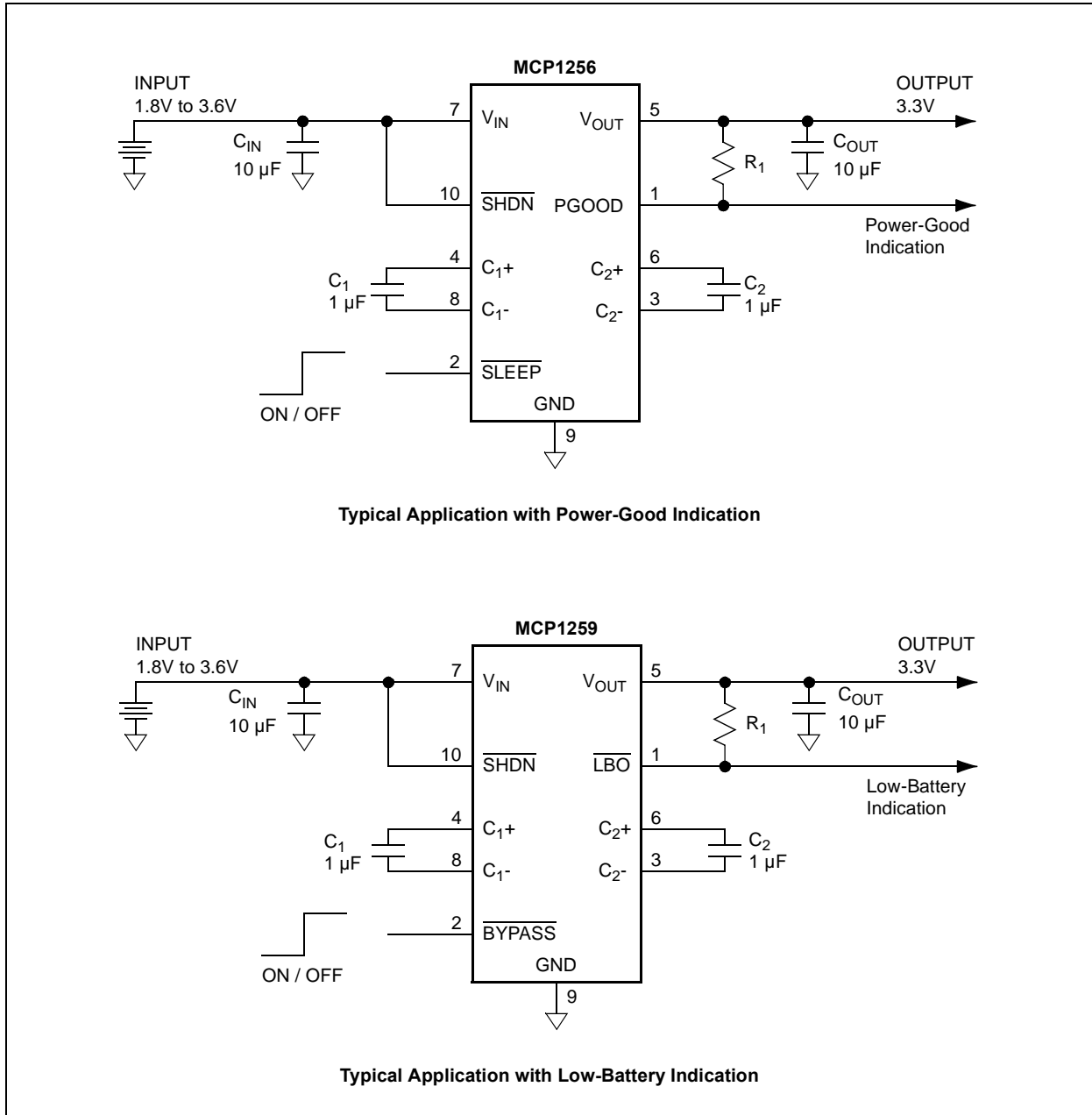


FIGURE 6-1: Typical Application Circuits.

## 7.0 PACKAGING INFORMATION

### 7.1 Package Marking Information

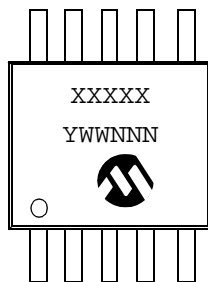
10-Lead DFN

①		⑩
②	XXXXX	⑨
③	XYWW	⑧
④	NNN	⑦
⑤		⑥

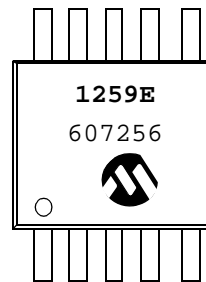
Example:

①		⑩
②	1256	⑨
③	E607	⑧
④	256	⑦
⑤		⑥

10-Lead MSOP



Example:



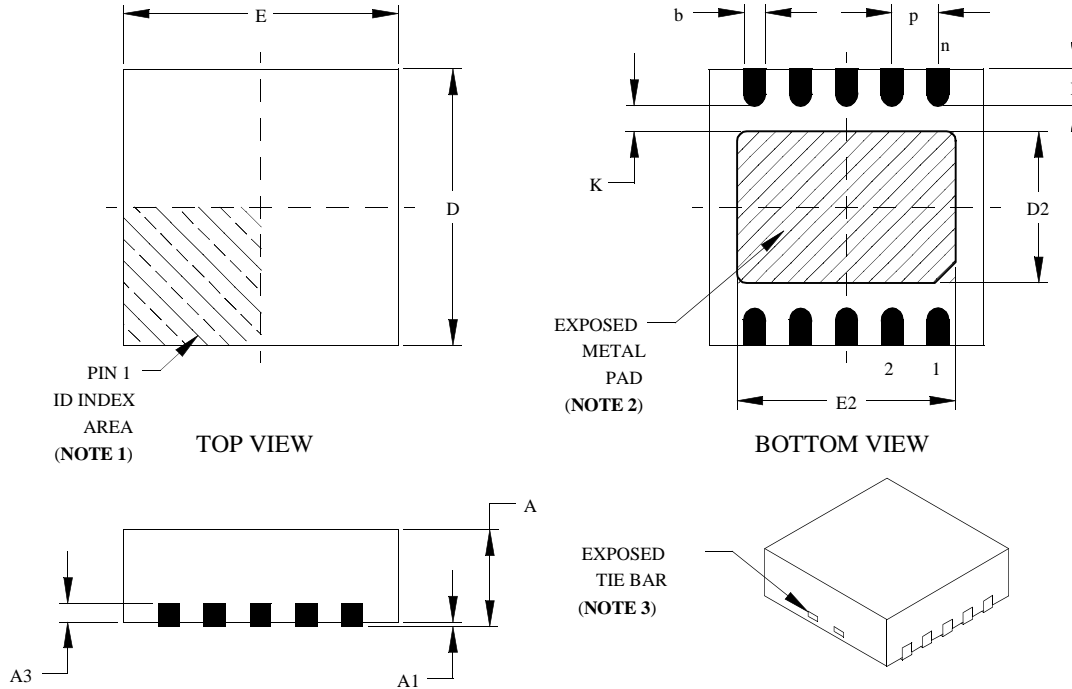
<b>Legend:</b>	XX...X	Customer-specific information
	Y	Year code (last digit of calendar year)
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week '01')
	NNN	Alphanumeric traceability code
	ⓔ3	Pb-free JEDEC designator for Matte Tin (Sn)
	*	This package is Pb-free. The Pb-free JEDEC designator (ⓔ3) can be found on the outer packaging for this package.

**Note:** In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information.

# MCP1256/7/8/9

## 10-Lead Plastic Dual-Flat No-Lead Package (MF) 3x3x0.9 mm Body (DFN) – Saw Singulated

**Note:** For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



Units		INCHES			MILLIMETERS*		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n	10			10		
Pitch	e	.020 BSC			0.50 BSC		
Overall Height	A	.031	.035	.039	0.80	0.90	1.00
Standoff	A1	.000	.001	.002	0.00	0.02	0.05
Lead Thickness	A3	.008 REF.			0.20 REF.		
Overall Length	E	.112	.118	.124	2.85	3.00	3.15
Exposed Pad Length	(Note 3) E2	.082	.094	.096	2.08	2.39	2.45
Overall Width	D	.112	.118	.124	2.85	3.00	3.15
Exposed Pad Width	(Note 3) D2	.051	.065	.067	1.30	1.65	1.70
Lead Width	b	.008	.010	.015	0.18	0.25	0.30
Contact Length §	L	.012	.016	.020	0.30	0.40	0.50
Contact-to-Exposed Pad §	K	.008	—	—	0.20	—	—

\* Controlling Parameter  
 § Significant Characteristic  
**Notes:**

- Pin 1 visual index feature may vary, but must be located within the hatched area.
- Exposed pad varies according to die attach paddle size.
- Package may have one or more exposed tie bars at ends.

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

See ASME Y14.5M

REF: Reference Dimension, usually without tolerance, for information purposes only.

See ASME Y14.5M

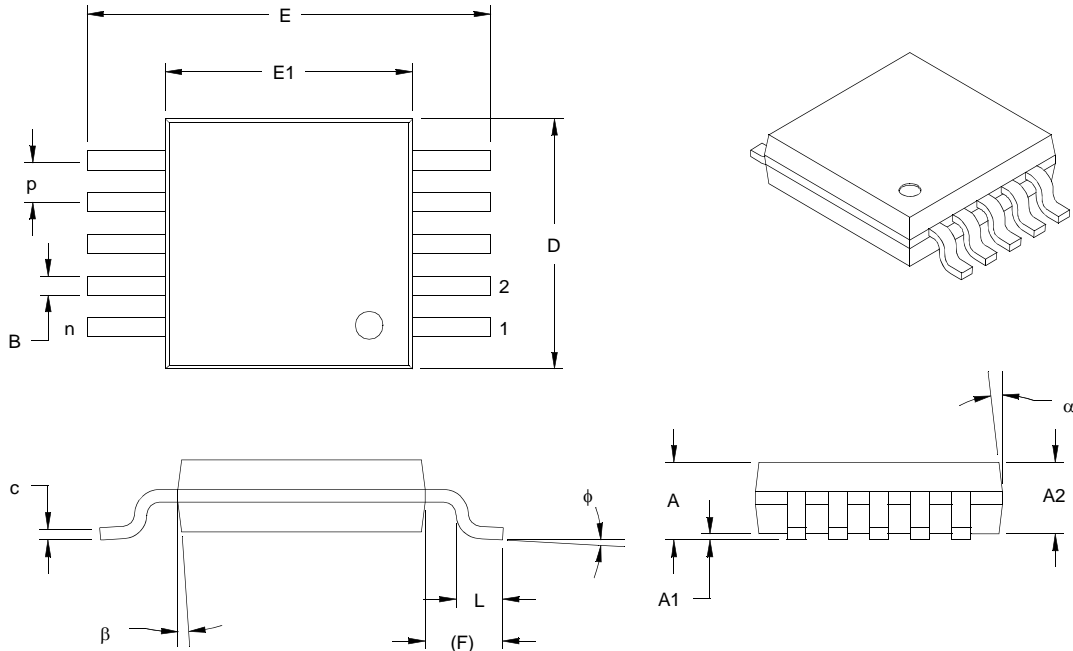
JEDEC equivalent: Not Registered  
 Drawing No. C04-063

Revised 09-12-05



## 10-Lead Plastic Micro Small Outline Package (UN) (MSOP)

**Note:** For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packageing>



Dimension Limits	Units	INCHES			MILLIMETERS*		
		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		10			10	
Pitch	P	.020 BSC			0.50 BSC		
Overall Height	A			.043	–	–	1.10
Molded Package Thickness	A2	.030	.033	.037	0.75	0.85	0.95
Standoff	A1	.000		.006	0.00		0.15
Overall Width	E	.193 BSC			4.90 BSC		
Molded Package Width	E1	.118 BSC			3.00 BSC		
Overall Length	D	.118 BSC			3.00 BSC		
Foot Length	L	.016	.024	.031	0.40	0.60	0.80
Footprint	F	.037 REF			0.95 REF		
Foot Angle	$\phi$	0°	–	8°	0°	–	8°
Lead Thickness	c	.003	–	.009	0.08	–	0.23
Lead Width	B	.006	.009	.012	0.15	0.23	0.30
Mold Draft Angle Top	$\alpha$	5°	–	15°	5°	–	15°
Mold Draft Angle Bottom	$\beta$	5°	–	15°	5°	–	15°

\* Controlling Parameter

**Notes:**

Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" (0.254 mm) per side.

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

See ASME Y14.5M

REF: Reference Dimension, usually without tolerance, for information purposes only.

See ASME Y14.5M

JEDEC Equivalent: MO-187 BA

Drawing No. C04-021

Revised 09-16-05

# MCP1256/7/8/9

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NOTES:

## **APPENDIX A: REVISION HISTORY**

### **Revision A (March 2006)**

- Original Release of this Document.

### **Revision B (January 2013)**

Added a note to each package outline drawing.

# MCP1256/7/8/9

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NOTES:

## PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, refer to the factory or the listed sales office.

<u>PART NO.</u>	<u>X</u>	<u>/XX</u>	<b>Examples:</b>
Device	Temperature Range	Package	
Device	MCP1256:	Positive Regulated Charge Pump with SLEEP Mode and Power-Good Indication	a) MCP1256-EMF: E-Temp, DFN package
	MCP1256T:	Positive Regulated Charge Pump with SLEEP Mode and Power-Good Indication, Tape and Reel	b) MCP1256T-EMF: Tape and Reel, E-Temp, DFN package
	MCP1257:	Positive Regulated Charge Pump with SLEEP Mode and Low-Battery Indication	c) MCP1256-EUN: E-Temp, MSOP package
	MCP1257T:	Positive Regulated Charge Pump with SLEEP Mode and Low-Battery Indication, Tape and Reel	d) MCP1256T-EUN: Tape and Reel, E-Temp, MSOP package
	MCP1258:	Positive Regulated Charge Pump with BYPASS Mode and Power-Good Indication	a) MCP1257-EMF: E-Temp, DFN package
	MCP1258T:	Positive Regulated Charge Pump with BYPASS Mode and Power-Good Indication, Tape and Reel	b) MCP1257T-EMF: Tape and Reel, E-Temp, DFN package
	MCP1259:	Positive Regulated Charge Pump with BYPASS Mode and Low-Battery Indication	c) MCP1257-EUN: E-Temp, MSOP package
	MCP1259T:	Positive Regulated Charge Pump with BYPASS Mode and Low -Battery Indication, Tape and Reel	d) MCP1257T-EUN: Tape and Reel, E-Temp, MSOP package
Temperature Range	E = -40°C to +125°C		a) MCP1258-EMF: E-Temp, DFN package
Package	MF = Dual Flat, No Lead (3x3 mm body), 10-Lead		b) MCP1258T-EMF: Tape and Reel, E-Temp, DFN package
	UN = Plastic Micro Small Outline (MSOP), 10-Lead		c) MCP1258-EUN: E-Temp, MSOP package
			d) MCP1258T-EUN: Tape and Reel, E-Temp, MSOP package
			a) MCP1259-EMF: E-Temp, DFN package
			b) MCP1259T-EMF: Tape and Reel, E-Temp, DFN package
			c) MCP1259-EUN: E-Temp, MSOP package
			d) MCP1259T-EUN: Tape and Reel, E-Temp, MSOP package

# MCP1256/7/8/9

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NOTES:

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**Note the following details of the code protection feature on Microchip devices:**

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