MICROCHIP

MCP1630

High-Speed, Microcontroller-Adaptable, Pulse Width Modulator

Features

- High-Speed PWM Operation (12 ns Current Sense to Output Delay)
- Operating Temperature Range: -40°C to +125°C
- Precise Peak Current Limit (±5%)
- CMOS Output Driver (Drives MOSFET Driver or Low-Side N-channel MOSFET Directly)
- External Oscillator Input (from PICmicro® Microcontroller)
- External Voltage Reference Input (for adjustable voltage or current output application)
- Peak Current Mode Operation to 1 MHz
- Low Operating Current: 2.8 mA, typical
- Fast Output Rise and Fall Times (5.9 ns and 6.2 ns)
- Undervoltage Lockout
- Output Short Circuit Protection
- Overtemperature Protection

Applications

- Intelligent Power Systems
- Smart Battery Charger Applications
- Multiple Output/Multiple Phase Converters
- Output Voltage Calibration
- AC Power Factor Correction
- VID Capability (Programmed and calibrated by PICmicro Microcontroller)
- Buck/Boost/Buck-Boost/SEPIC/Flyback/Isolated Converters
- Parallel Power Supplies

Description

The MCP1630 is a high-speed Pulse Width Modulator (PWM) used to develop intelligent power systems. When used with a microcontroller, the MCP1630 will control the power system duty cycle to provide output voltage or current regulation. The microcontroller can be used to adjust output voltage or current, switching frequency, maximum duty cycle and other features making the power system more intelligent and adaptable.

Typical applications include smart battery chargers, intelligent power systems, brick DC/DC converters, AC power-factor correction, multiple output power supplies, multi-phase power supplies and more.

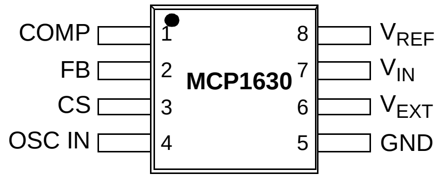
The MCP1630 inputs were developed to be easily attached to the I/O of a microcontroller. The microcontroller supplies the oscillator and reference to the MCP1630 to provide the most flexible and adaptable power system. The power system switching frequency and maximum duty cycle are set using the I/O of the microcontroller. The reference input can be external, a D/A converter output or as simple as an I/O output from the microcontroller. This enables the power system to adapt to many external signals and variables in order to optimize performance and facilitate calibration.

When operating in current mode, a precise limit is set on the peak current. With the fast comparator speed (typically 12 ns), the MCP1630 is capable of providing a tight limit on the maximum switch current over a wide input voltage range when compared to other high-speed PWM controllers.

Additional protection features include: undervoltage lockout, overtemperature and overcurrent.

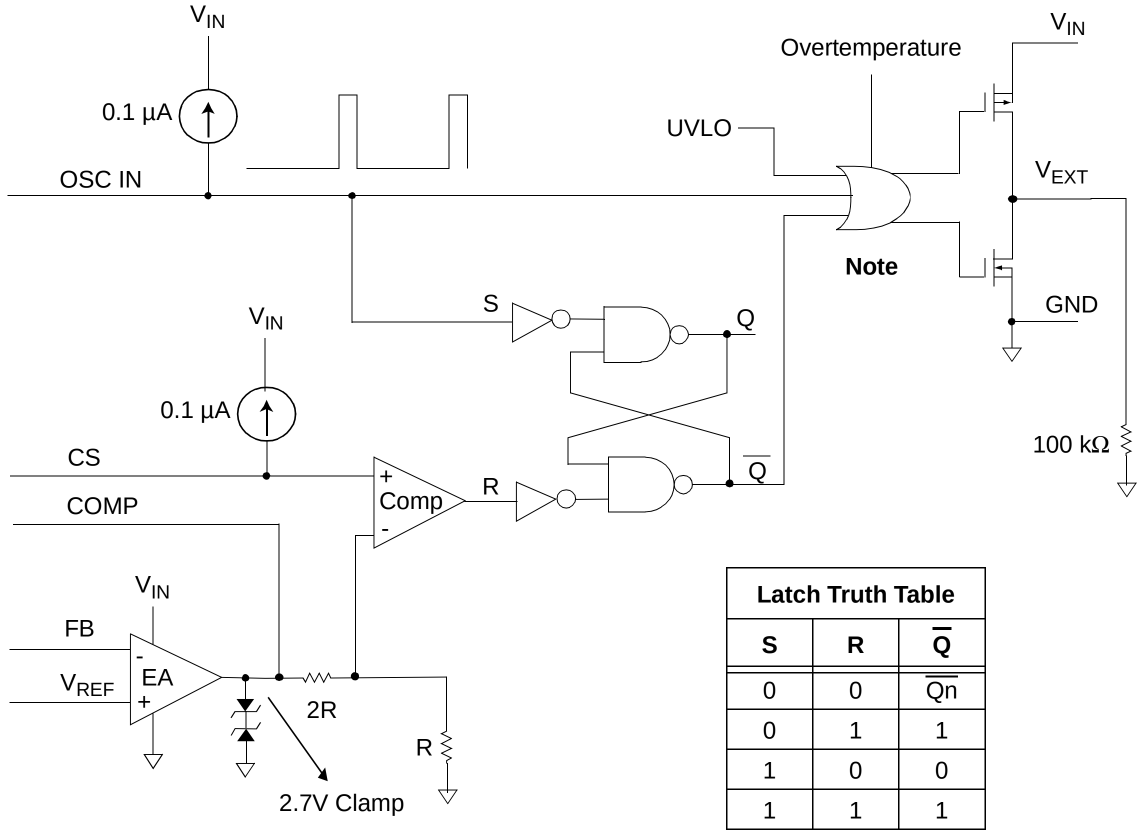
Package Type

8-Pin MSOP



Functional Block Diagram

MCP1630 High-Speed PWM



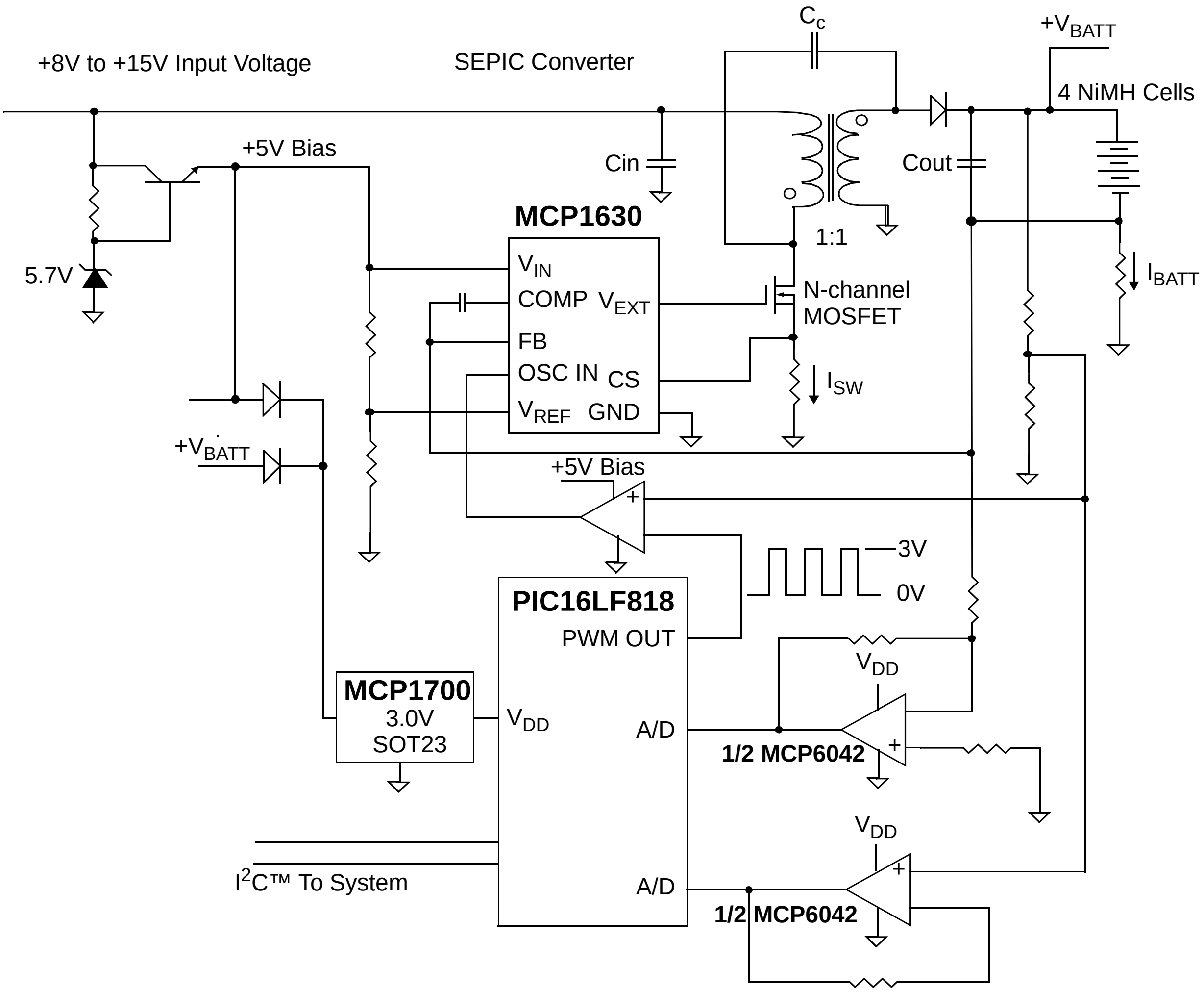
Latch Truth Table

S	R	$\overline{Q}$
0	0	$\overline{Qn}$
0	1	1
1	0	0
1	1	1

Note: During overtemperature, V_{EXT} driver is high-impedance.

Typical Application Circuit

MCP1630 NiMH Battery Charger and Fuel Gauge Application Diagram



1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

V_{DD} 6.0V

Maximum Voltage on Any Pin .. (V_{GND} - 0.3)V to (V_{IN} + 0.3)V

V_{EXT} Short Circuit Current .... Internally Limited

Storage temperature .... -65°C to +150°C

Maximum Junction Temperature, T_J .... +150°C

Continuous Operating Temperature Range .. -40°C to +125°C

ESD protection on all pins, Human Body Model.............. 3 kV

† 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 noted, V_{IN} = 3.0V to 5.5V, F_{OSC} = 1 MHz with 10% Duty Cycle, C_{IN} = 0.1 µF, V_{IN} for typical values = 5.0V, T_A = -40°C to +125°C.

Parameters	Sym	Min	Typ	Max	Units	Conditions
Input Voltage						
Input Operating Voltage	V_{IN}	3.0	—	5.5	V	
Input Quiescent Current	$I(V_{IN})$	—	2.8	4.5	mA	I_{EXT} = 0 mA, $F_{OSC\ IN}$ = 0 Hz
Oscillator Input						
External Oscillator Range	F_{OSC}	—	—	1	MHz	**Note 1**
Min. Oscillator High Time Min. Oscillator Low Time	T_{OH}_MIN. T_{OL}_MIN.	—	10		ns	
Oscillator Rise Time	T_{RISE}	0.01	—	10	µs	**Note 2**
Oscillator Fall Time	T_{FALL}	0.01	—	10	µs	**Note 2**
Oscillator Input Voltage Low	V_L	—	—	0.8	V	
Oscillator Input Voltage High	V_H	2.0	—	—	V	
Oscillator Input Capacitance	C_{OSC}		5		pf	
External Reference Input						
Reference Voltage Input	V_{REF}	0	—	V_{IN}	V	**Note 2, Note 3**
Error Amplifier						
Input Offset Voltage	V_{OS}	-4	0.1	+4	mV	
Error Amplifier PSRR	PSRR	80	99	—	dB	V_{IN} = 3.0V to 5.0V, V_{CM} = 1.2V
Common Mode Input Range	V_{CM}	GND - 0.3	—	V_{IN}	V	**Note 2, Note 3**
Common Mode Rejection Ratio		—	80	—	dB	V_{IN} = 5V, V_{CM} = 0V to 2.5V
Open-loop Voltage Gain	A_{VOL}	85	95	—	dB	R_L = 5 kΩ to V_{IN}/2, 100 mV < V_{EAOUT} < V_{IN} - 100 mV, V_{CM} = 1.2V
Low-level Output	V_{OL}	—	25	GND + 50	mV	RL = 5 kΩ to V_{IN}/2
Gain Bandwidth Product	GBWP	—	3.5	—	MHz	V_{IN} = 5V
Error Amplifier Sink Current	I_{SINK}	5	11	—	mA	V_{IN} = 5V, V_{REF} = 1.2V, V_{FB} = 1.4V, V_{COMP} = 2.0V
Error Amplifier Source Current	I_{SOURCE}	-2	-9	—	mA	V_{IN} = 5V, V_{REF} = 1.2V, V_{FB} = 1.0V, V_{COMP} = 2.0V, Absolute Value

Note 1: Capable of higher frequency operation depending on minimum and maximum duty cycles needed.

2: External oscillator input (OSC IN) rise and fall times between 10 ns and 10 µs used for characterization testing. Signal levels between 0.8V and 2.0V with rise and fall times measured between 10% and 90% of maximum and minimum values. Not production tested.

3: The reference input of the internal amplifier is capable of rail-to-rail operation.

DC CHARACTERISTICS (CONTINUED)

Electrical Specifications: Unless otherwise noted, V_{IN} = 3.0V to 5.5V, F_{OSC} = 1 MHz with 10% Duty Cycle, C_{IN} = 0.1 µF, V_{IN} for typical values = 5.0V, T_A = -40°C to +125°C.

Parameters	Sym	Min	Typ	Max	Units	Conditions
Current Sense Input						
Maximum Current Sense Signal	V_{CS_MAX}	0.85	0.9	0.95	V	Set by maximum error amplifier clamp voltage, divided by 3.
Delay From CS to V_{EXT}	T_{CS_VEXT}	—	12	25	ns	
Minimum Duty Cycle	DC_{MIN}	—	—	0	%	$V_{FB} = V_{REF}$ + 0.1V, V_{CS} = GND
Current Sense Input Bias Current	I_{CS_B}	—	-0.1	—	µA	V_{IN} = 5V
Internal Driver						
R_{DSON} P-channel	R_{DSon_P}	—	10	30	Ω	
R_{DSON} N-channel	R_{DSon_N}	—	7	30	Ω	
V_{EXT} Rise Time	T_{RISE}	—	5.9	18	ns	C_L = 100 pF Typical for V_{IN} = 3V
V_{EXT} Fall Time	T_{FALL}	—	6.2	18	ns	C_L = 100 pF Typical for V_{IN} = 3V
Protection Features						
Under Voltage Lockout	UVLO	2.7	—	3.0	V	V_{IN} falling, V_{EXT} low state when in UVLO
Under Voltage Lockout Hysteresis	$UVLO_{\_HYS}$	50	75	150	mV	
Thermal Shutdown	T_{SHD}	—	150	—	°C	
Thermal Shutdown Hysteresis	T_{SHD_HYS}	—	18	—	°C	

Note 1: Capable of higher frequency operation depending on minimum and maximum duty cycles needed.

2: External oscillator input (OSC IN) rise and fall times between 10 ns and 10 µs used for characterization testing. Signal levels between 0.8V and 2.0V with rise and fall times measured between 10% and 90% of maximum and minimum values. Not production tested.

3: The reference input of the internal amplifier is capable of rail-to-rail operation.

TEMPERATURE SPECIFICATIONS

Electrical Specifications: V_{IN} = 3.0V to 5.5V, F_{OSC} = 1 MHz with 10% Duty Cycle, C_{IN} = 0.1 µF. T_A = -40°C to +125°C.

Parameters	Sym	Min	Typ	Max	Units	Conditions
Temperature Ranges						
Operating Junction Temperature Range	T_A	-40	—	+125	°C	Steady state
Storage Temperature Range	T_A	-65	—	+150	°C	
Maximum Junction Temperature	T_J	—	—	+150	°C	Transient
Thermal Package Resistances						
Thermal Resistance, MSOP8	θ_{JA}	—	208	—	°C/W	Typical 4-layer board

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 noted, V_{IN} = 3.0V to 5.5V, F_{OSC} = 1 MHz with 10% Duty Cycle, C_{IN} = 0.1 µF, V_{IN} for typical values = 5.0V, T_A = -40°C to +125°C.

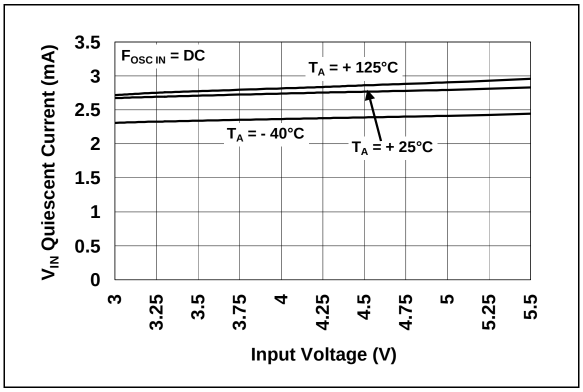


FIGURE 2-1: *Input Quiescent Current vs. Input Voltage.*

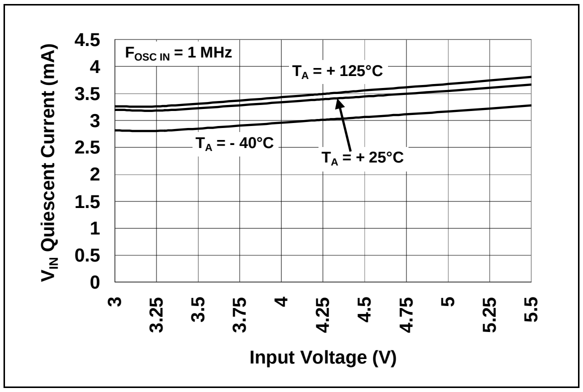


FIGURE 2-2: *Input Quiescent Current vs. Input Voltage.*

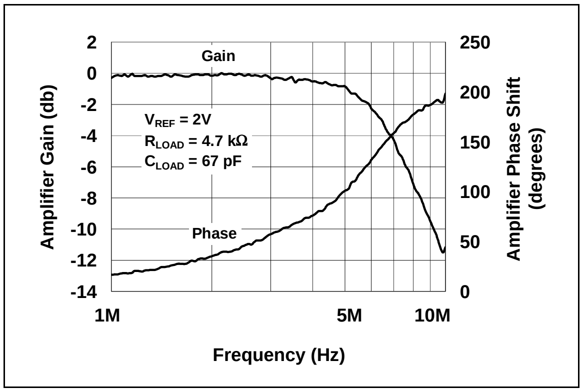


FIGURE 2-3: *Error Amplifier Frequency Response.*

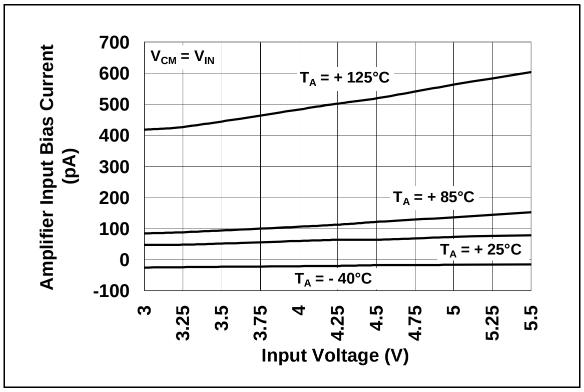


FIGURE 2-4: *Error Amplifier Input Bias Current vs. Input Voltage.*

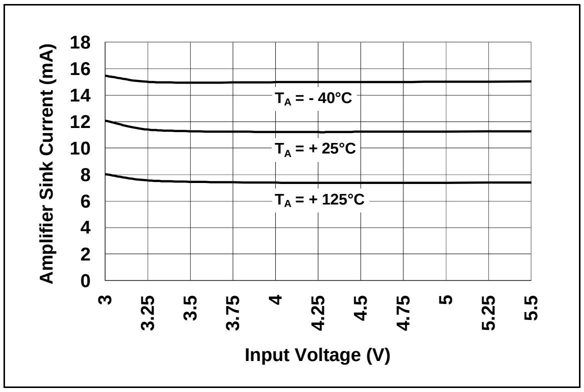


FIGURE 2-5: *Error Amplifier Sink Current vs. Input Voltage.*

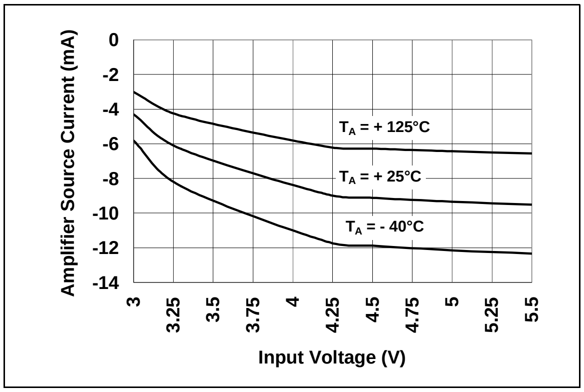


FIGURE 2-6: *Error Amplifier Source Current vs. Input Voltage.*

Note: Unless otherwise noted, V_{IN} = 3.0V to 5.5V, F_{OSC} = 1 MHz with 10% Duty Cycle, C_{IN} = 0.1 µF, V_{IN} for typical values = 5.0V, T_A = -40°C to +125°C.

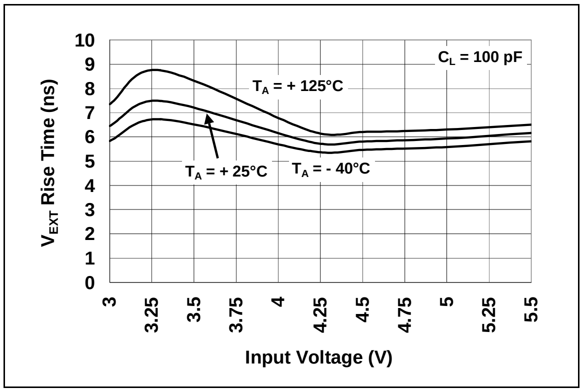


FIGURE 2-7: *V_{EXT} Rise Time vs. Input Voltage.*

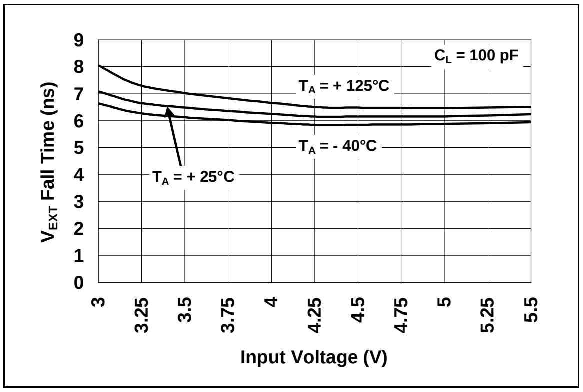


FIGURE 2-8: *V_{EXT} Fall Time vs. Input Voltage.*

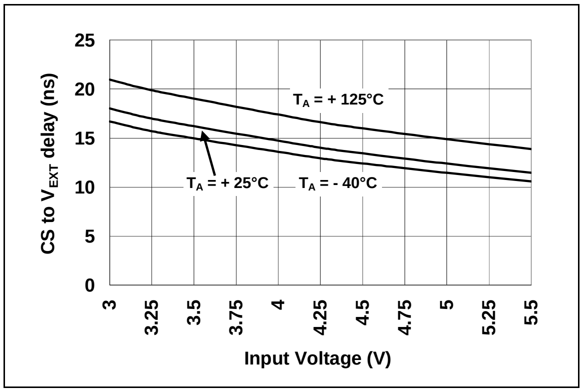


FIGURE 2-9: *Current Sense to V_{EXT} Delay vs. Input Voltage.*

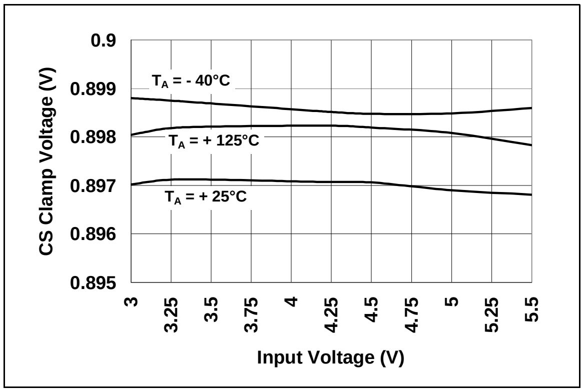


FIGURE 2-10: *Current Sense Clamp Voltage vs. Input Voltage.*

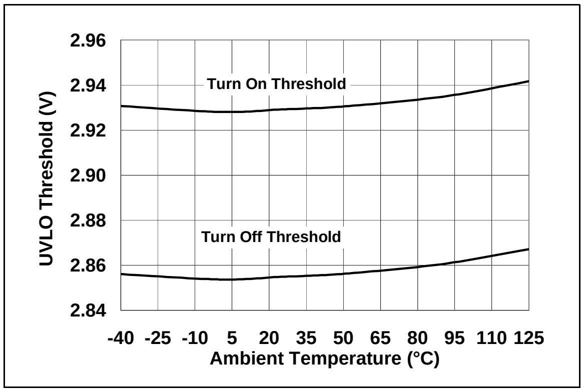


FIGURE 2-11: *Undervoltage Lockout vs. Temperature.*

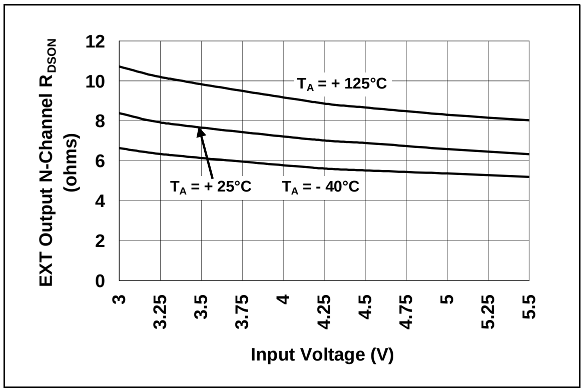


FIGURE 2-12: *EXT Output N-channel R_{DSON} vs. Input Voltage.*

Note: Unless otherwise noted, V_{IN} = 3.0V to 5.5V, F_{OSC} = 1 MHz with 10% Duty Cycle, C_{IN} = 0.1 µF, V_{IN} for typical values = 5.0V, T_A = -40°C to +125°C.

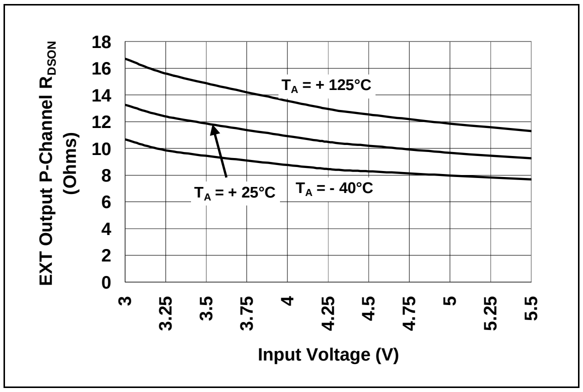


FIGURE 2-13: *EXT Output P-channel R_{DSON} vs. Input Voltage.*

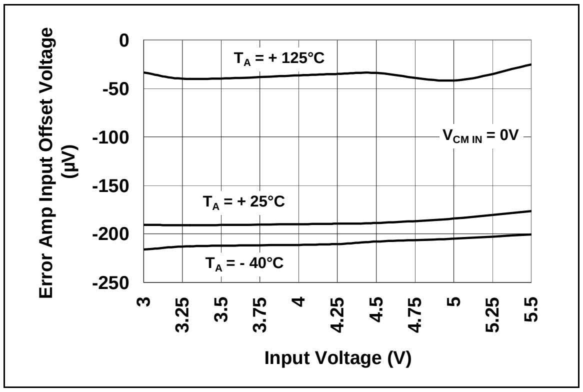


FIGURE 2-14: *Error Amplifier Input Offset Voltage vs. Input Voltage.*

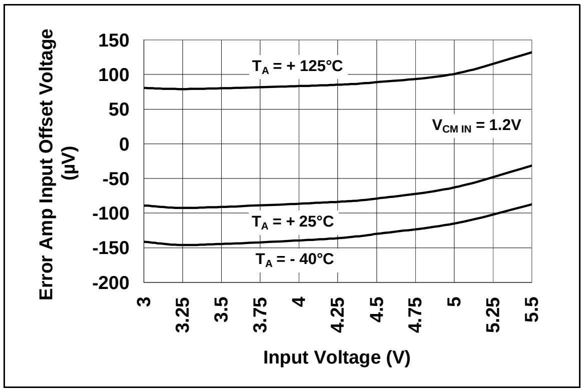


FIGURE 2-15: *Error Amplifier Input Offset Voltage vs. Input Voltage.*

3.0 MCP1630 PIN DESCRIPTIONS

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

TABLE 3-1: PIN FUNCTION TABLE

Pin No.	Name	Function
1	COMP	Error Amplifier Output Pin
2	FB	Error Amplifier Inverting Input
3	CS	Current Sense Input pin
4	OSC IN	Oscillator Input pin
5	GND	Circuit Ground Pin
6	V_{EXT}	External driver output pin
7	V_{IN}	Input bias pin
8	V_{REF}	Reference Voltage Input Pin

3.1 COMP Pin

COMP is an internal error amplifier output pin. External compensation is connected from the FB pin to the COMP pin for control-loop stabilization. An internal voltage clamp is used to limit the maximum COMP pin voltage to 2.7V typical. This clamp is used to set the maximum peak current in the power system switch by setting a maximum limit on the CS input for peak current mode control systems.

3.2 FB Pin

FB is an internal error amplifier inverting input pin. The output (voltage or current) is sensed and fed back to the FB pin for regulation. Inverting or negative feed back is used.

3.3 CS Input

CS is the current sense input pin used for cycle-by-cycle control for peak current mode converters. A ramp can be placed on this input for voltage or average current mode converters.

3.4 OSC Input

OSC is an external oscillator input pin. Typically, a microcontroller I/O pin is used to generate the OSC input. When high, the output driver (V_{EXT}) pin is driven low. The high-to-low transition initiates the start of a new cycle. The duty cycle of the OSC input pin determines the maximum duty cycle of the power converter. For example, if the OSC input is low for 75% of the time and high for 25% of the time, the duty cycle range for the power converter is 0% to 75% maximum.

3.5 GND

Connect circuit ground to the GND pin. For most applications, this should be connected to the analog or quiet ground plane. Noise on this ground can affect the sensitive cycle-by-cycle comparison between the CS input and the error amplifier output.

3.6 V_{EXT} Pin

V_{EXT} is an external driver output pin. This output pin is used to determine the power system duty cycle. For high-power or high-side drives, this output should be connected to the logic-level input of the MOSFET driver. For low-power, low-side applications, the V_{EXT} pin can be used to directly drive the gate of an N-channel MOSFET.

3.7 V_{IN} Pin

V_{IN} is an input voltage pin. Connect the input voltage source to the V_{IN} pin. For normal operation, the voltage on the V_{IN} pin should be between +3.0V and +5.5V. A 0.1 µF bypass capacitor should be connected between the V_{IN} pin and the GND pin.

3.8 V_{REF} Input

V_{REF} is an external reference input pin used to regulate the output of the power system. By changing the V_{REF} input, the output (voltage or current) of the power system can be changed. The reference voltage can range from 0V to V_{IN} (rail to rail).

4.0 DETAILED DESCRIPTION

4.1 Device Overview

The MCP1630 is comprised of a high-speed comparator, high-bandwidth amplifier and logic gates that can be combined with a PICmicro microcontroller to develop an advanced programmable power supply. The oscillator input and reference voltage input are generated by the PICmicro microcontroller so that switching frequency, maximum duty cycle and output voltage are programmable. Refer to Figure 4-1.

4.2 PWM

The V_{EXT} output of the MCP1630 is determined by the output level of the internal high-speed comparator and the level of the external oscillator. When the oscillator level is high, the PWM (V_{EXT}) output is forced low. When the external oscillator is low, the PWM output is determined by the output level of the internal high-speed comparator. During UVLO, the V_{EXT} pin is held in the low state. During overtemperature operation, the V_{EXT} pin is high-impedance (100 kΩ to ground).

4.3 Normal Cycle by Cycle Control (peak current mode)

The beginning of a cycle is defined when OSC IN transitions from a high state to a low state. For normal operation, the state of the high-speed comparator output (R) is low and the $\overline{Q}$ output of the latch is low. On the OSC IN high-to-low transition, the S and R inputs to the high-speed latch are both low and the $\overline{Q}$ output will remain unchanged (low). The output of the OR gate (V_{DRIVE}) will transition from a high state to a low state, turning on the internal P-channel drive transistor in the output stage of the PWM. This will change the PWM output (V_{EXT}) from a low state to a high state, turning on the power-train external switch and ramping current in the power-train magnetic device.

The sensed current in the magnetic device is fed into the CS input, shown as a ramp and increases linearly. Once the sensed current ramp reaches the same voltage level as 1/3 of the EA output, the comparator output (R) changes state (low to high) and resets the PWM latch. The $\overline{Q}$ output transitions from a low state to a high state, turning on the N-channel MOSFET in the output stage which turns off the V_{EXT} drive to the external MOSFET driver terminating the duty cycle. The OSC IN will transition from a low state to a high state while the V_{EXT} pin remains unchanged. If the CS input ramp had never reached the same level as 1/3 of the error amplifier output, the low-to-high transition on OSC IN would terminate the duty cycle and this would be considered maximum duty cycle. In either case, while OSC IN is high, the V_{EXT} drive pin is low, turning off the external power-train switch. The next cycle will start on the transition of the OSC IN pin from a high state to a low state.

4.4 Error Amp / Comparator Current Limit Function

The internal amplifier is used to create an error output signal that is determined by the external V_{REF} input and the power supply output fed back into the FB pin. The error amplifier output is rail-to-rail and clamped by a precision 2.7V. The output of the error amplifier is then divided down 3:1 and connected to the inverting input of the high-speed comparator. Since the maximum output of the error amplifier is 2.7V, the maximum input to the inverting pin of the high-speed comparator is 0.9V. This sets the peak current limit for the switching power supply.

As the output load current demand increases, the error amplifier output increases, causing the inverting input pin of the high-speed comparator to increase. Eventually, the output of the error amplifier will hit the 2.7V clamp, limiting the input of the high-speed comparator to 0.9V, maximum. Even if the FB input continues to decrease (calling for more current), the inverting input is limited to 0.9V. By limiting the inverting input to 0.9V, the current-sense input (CS) is limited to 0.9V, thus limiting the output current of the power supply.

4.5 0% Duty Cycle Operation

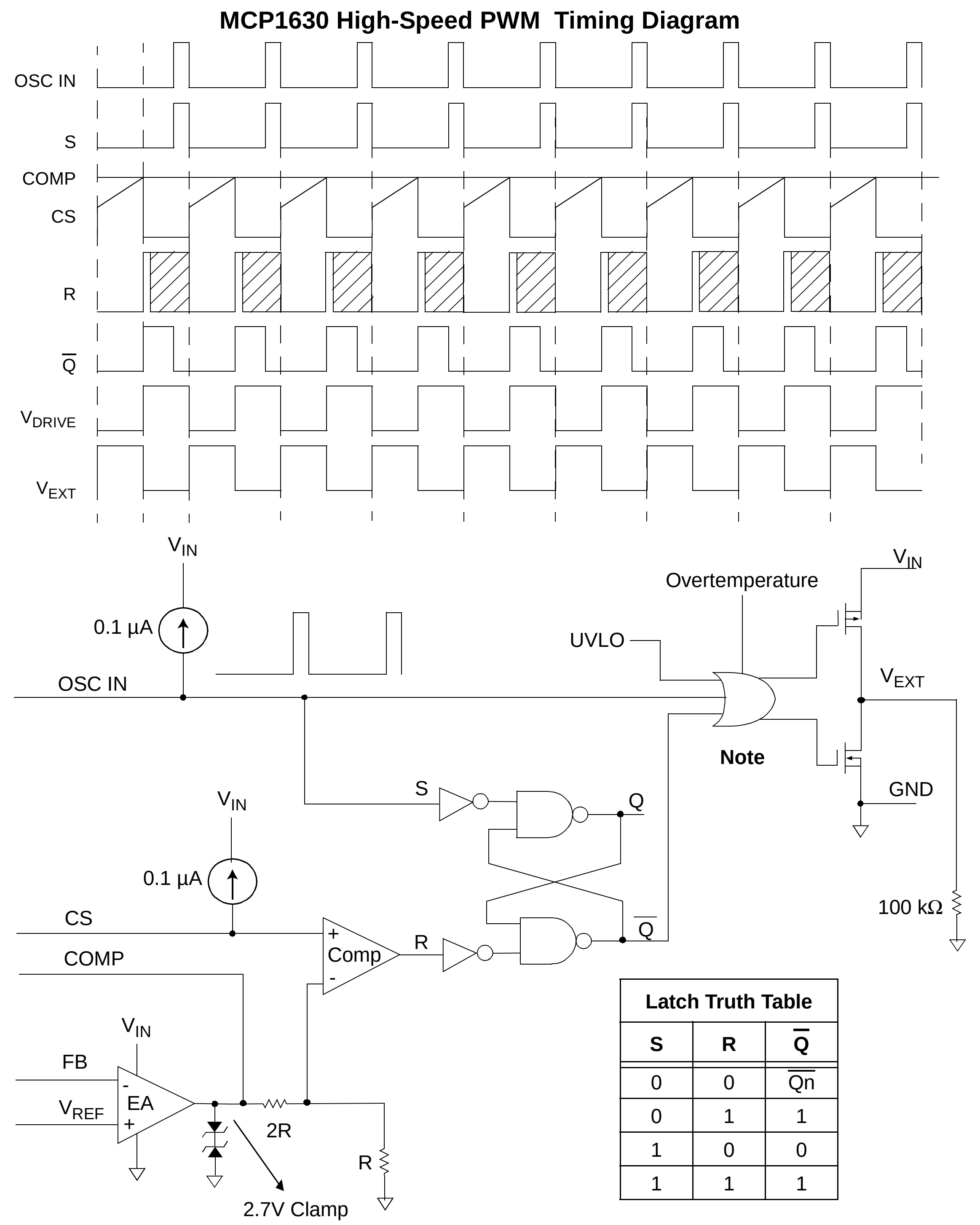
The duty cycle of the V_{EXT} output is capable of reaching 0% when the FB pin is held higher than the V_{REF} pin (inverting error amplifier). This is accomplished by the rail-to-rail output capability of the error amplifier and the offset voltage of the high-speed comparator. The minimum error amplifier output voltage, divided by three, is less than the offset voltage of the high-speed comparator. In the case where the output voltage of the converter is above the desired regulation point, the FB input will be above the V_{REF} input and the error amplifier will be pulled to the bottom rail (GND). This low voltage is divided down 3:1 by the 2R and 1R resistor and connected to the input of the high-speed comparator. This voltage will be low enough so that there is no triggering of the comparator, allowing narrow pulse widths at V_{EXT}.

4.6 Undervoltage Lockout

When the input voltage (V_{IN}) is < the UVLO threshold, the V_{EXT} is held in the low-impedance state. This will ensure that, if the voltage is not adequate to operate the MCP1630, the main power supply switch will be held in the off state. When the UVLO threshold is exceeded, there is some hysteresis in the input voltage prior to the UVLO off threshold being reached. The typical hysteresis is 75 mV. Typically, the MCP1630 will not start operating until the input voltage at V_{IN} is between 3.0V and 3.1V.

4.7 Overtemperature Protection

To protect the V_{EXT} output if shorted to V_{IN} or GND, the MCP1630 V_{EXT} output will be high-impedance if the junction temperature is above the thermal shutdown threshold. There is an internal 100 kΩ pull-down resistor connected from V_{EXT} to ground to provide some pull-down during overtemperature conditions. The protection is set to 150°C typical with a hysteresis of 18°C.



Latch Truth Table

S	R	$\overline{Q}$
0	0	$\overline{Qn}$
0	1	1
1	0	0
1	1	1

Note: During overtemperature, V_{EXT} driver is high-impedance.

FIGURE 4-1: *Cycle-by-Cycle Timing Diagram*

5.0 APPLICATION CIRCUITS/ ISSUES

5.1 Typical Applications

The MCP1630 high-speed PWM can be used for any circuit topology and power-train application when combined with a microcontroller. Intelligent, cost-effective power systems can be developed for applications that require multiple outputs, multiple phases, adjustable outputs, temperature monitoring and calibration.

5.2 NiMH Battery Charger Application

A typical NiMH battery charger application is shown in the **"Typical Application Circuit"** on page 3 of this data sheet. In that example, a Single-ended Primary Inductive Converter (SEPIC) is used to provide a constant charge current to the series-connected batteries. The MCP1630 is used to regulate the charge current by monitoring the current through the battery sense resistor and providing the proper pulse width.

The PIC16F818 monitors the battery voltage to provide a termination to the charge current. Additional features (trickle charge, fast charge, overvoltage protection, etc.) can be added to the system using the programmability of the microcontroller and the flexibility of the MCP1630.

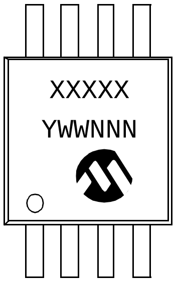
5.3 Multiple Output Converters

By using additional MCP1630 devices, multiple output converters can be developed using a single microcontroller. If a two-output converter is desired, the microcontroller can provide two PWM outputs that are phased 180° apart. This will reduce the input ripple current to the source and eliminate beat frequencies.

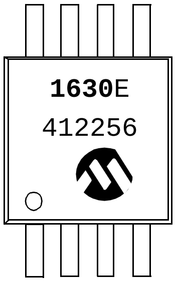
6.0 PACKAGING INFORMATION

6.1 Package Marking Information

8-Lead MSOP



Example:

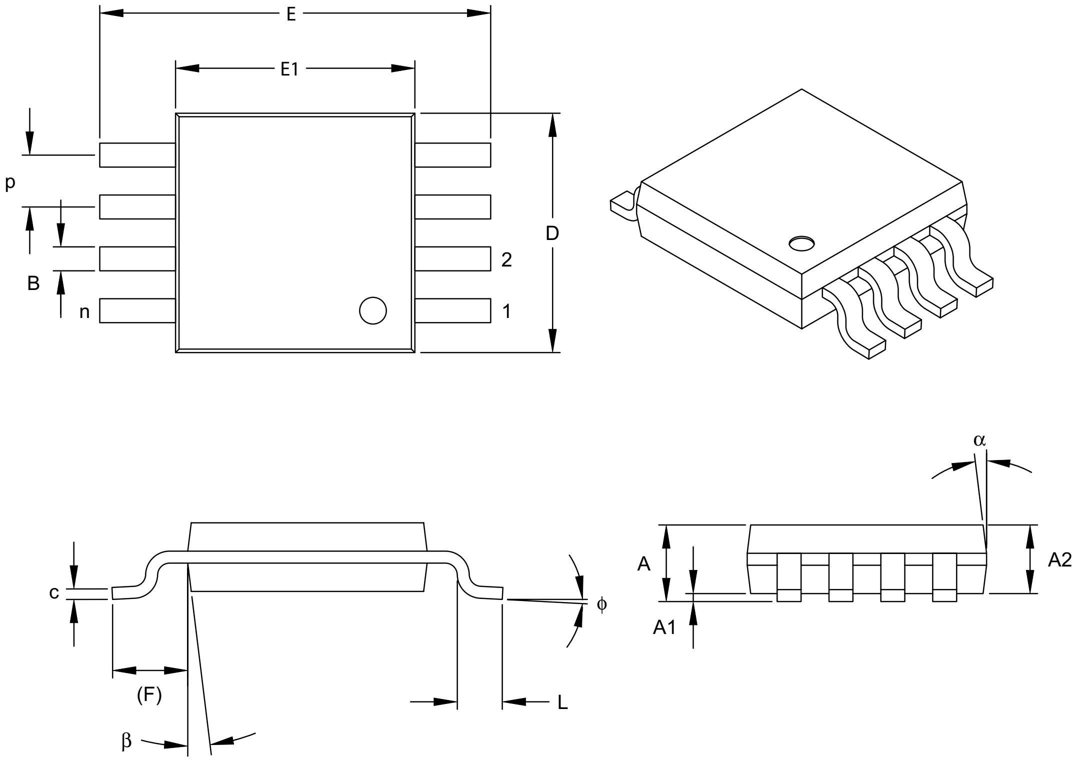


Legend:		
	XX...X	Customer specific information*
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week ‘01’)
	NNN	Alphanumeric traceability code

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.

* Standard marking consists of Microchip part number, year code, week code, and traceability code.

8-Lead Plastic Micro Small Outline Package (MS) (MSOP)



Units		INCHES			MILLIMETERS*		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		8			8	
Pitch	p		.026 BSC			0.65 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 TYP.			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 (Reference)	F		.037 REF			0.95 REF	
Foot Angle	φ	0°	-	8°	0°	-	8°
Lead Thickness	c	.003	.006	.009	0.08	-	0.23
Lead Width	B	.009	.012	.016	0.22	-	0.40
Mold Draft Angle Top	α	5°	-	15°	5°	-	15°
Mold Draft Angle Bottom	β	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" (0.254mm) per side.

JEDEC Equivalent: MO-187

Drawing No. C04-111

PRODUCT IDENTIFICATION SYSTEM

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

PART NO.	X	/XX
Device	Temperature Range	Package

Device:	MCP1630: MCP1630T:	High-Speed PWM High-Speed PWM (Tape and Reel)
Temperature Range:	E	= -40°C to +125°C
Package:	MS	= Plastic MSOP, 8-lead

Examples:

a) MCP1630-E/MS: Extended Temperature, 8LD MSOP package.

b) MCP1630T-E/MS: Tape and Reel Extended Temperature, 8LD MSOP package.

Sales and Support

Data Sheets

Products supported by a preliminary Data Sheet may have an errata sheet describing minor operational differences and recommended workarounds. To determine if an errata sheet exists for a particular device, please contact one of the following:

1. Your local Microchip sales office
2. The Microchip Corporate Literature Center U.S. FAX: (480) 792-7277
3. The Microchip Worldwide Site (www.microchip.com)

Please specify which device, revision of silicon and Data Sheet (include Literature #) you are using.

Customer Notification System

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NOTES:

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

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
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