CM3406

1.5A, 210KHz Step-Down Converter

DESCRIPTION

The CM3406 is a monolithic step-down switch mode converter with a built-in internal power MOSFET. It achieves 1.5A continuous output current over a wide input supply range with excellent load and line regulation.

Current mode operation provides fast transient response and eases loop stabilization. Fault condition protection includes cycle-by-cycle current limiting and thermal shutdown. The CM3406 requires a minimum number of readily available standard external components.

EVALUATION BOARD REFERENCE

Board Number	Dimensions
EV3406DS-00A	2.3"X x 1.4"Y x 0.5"Z

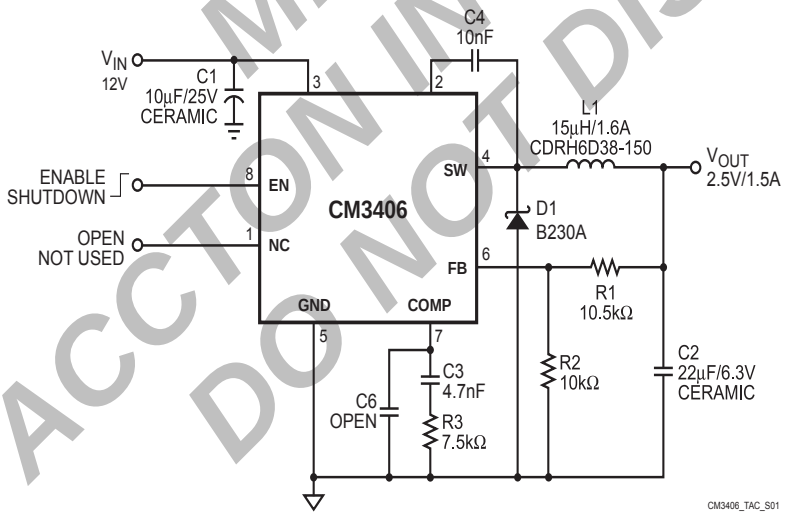
FEATURES

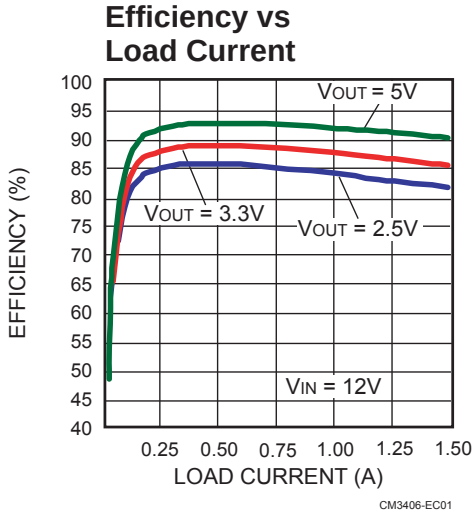
- 1.5A Continuous Output Current
- 0.2Ω Internal Power MOSFET Switch
- Stable with Low ESR Output Ceramic Capacitors
- Up to 95% Efficiency
- 20μA Shutdown Mode
- Fixed 210KHz Frequency
- Thermal Shutdown
- Cycle-by-Cycle Over Current Protection
- Wide 4.75V to 22V Operating Input Range
- Output Adjustable from 1.23V to 18V
- Programmable Under Voltage Lockout
- Available in 8-Pin SO and PDIP Packages

APPLICATIONS

- Distributed Power Systems
- Battery Chargers
- Pre-Regulator for Linear Regulators

TYPICAL APPLICATION





ORDERING INFORMATION

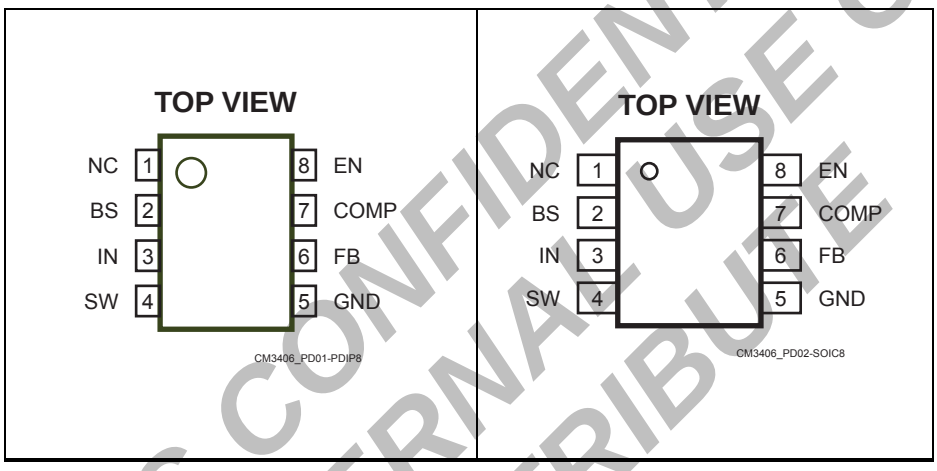
Part Number*	Package	Top Marking	Temperature
CM3406DP	PDIP8		–40°C to +85°C
CM3406DS	SOIC8	CM3406DS	

* FOR LEAD FREE, ADD SUFFIX –LF (EG. CM3406DP–LF)

** For Tape & Reel, add suffix –Z (eg. CM3406DS–Z)

For Lead Free, add suffix –LF (eg. CM3406DS–LF–Z)

PACKAGE REFERENCE



ABSOLUTE MAXIMUM RATINGS (1)

Supply Voltage (V_{IN})..... 24V
Switch Voltage (V_{SW}).....–1V to V_{IN} + 1V
Bootstrap Voltage (V_{BS}) ..... V_{SW} + 6V
Feedback Voltage (V_{FB}) .....–0.3V to +6V
Enable/UVLO Voltage (V_{EN}).....–0.3V to +6V
Comp Voltage (V_{COMP}) .....–0.3V to +6V
Continuous Power Dissipation (T_A = +25°C)(2)
PDIP8 ……..1.3W
SOIC8 ……..1.2W
Junction Temperature.....150°C
Lead Temperature .....260°C
Storage Temperature..... –65°C to +150°C

Recommended Operating Conditions (3)

Input Voltage (V_{IN}).....4.75V to 22V
Operating Temperature..... –40°C to +85°C

Thermal Resistance (4)

	θ_{JA}	θ_{JC}	
PDIP8	95	55	°C/W
SOIC8	105	50	°C/W

Notes:

1) Exceeding these ratings may damage the device.
2) The maximum allowable power dissipation is a function of the maximum junction temperature T_J(MAX), the junction-to-ambient thermal resistance θ_{JA}, and the ambient temperature TA. The maximum allowable continuous power dissipation at any ambient temperature is calculated by P_D(MAX)=(T_J(MAX)-T_A)/ θ_{JA}. Exceeding the maximum allowable power dissipation 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 JESD51-7, 4-layer PCB.

ELECTRICAL CHARACTERISTICS

V_{IN} = 12V, T_A = +25°C, unless otherwise noted.

Parameter	Symbol	Condition	Min	Typ	Max	Units
Feedback Voltage	V_{FB}	4.75V ≤ V_{IN} ≤ 22V	1.195	1.230	1.265	V
Upper Switch On Resistance (5)				0.2		Ω
Lower Switch On Resistance (5)				12		Ω
Upper Switch Leakage		V_{EN} = 0V, V_{SW} = 0V			10	μA
Current Limit (4)				2.5		A
Current Sense Transconductance Output Current to Comp Pin Voltage	G_{CS}			1.85		A/V
Error Amplifier Voltage Gain	A_{VEA}			400		V/V
Error Amplifier Transconductance	G_{EA}	ΔI_C = ±10μA	450	700	1000	μA/V
Oscillator Frequency	f_S			210		KHz
Short Circuit Frequency		V_{FB} = 0V		130		KHz
Maximum Duty Cycle		V_{FB} = 1.0V		90		%
Minimum Duty Cycle		V_{FB} = 1.5V			0	%
Enable Threshold		I_{CC} > 100μA	0.7	1.0	1.3	V
Enable Pull Up Current		V_{EN} = 0V	1.0	1.2		μA
Under Voltage Lockout Threshold Rising			2.37	2.50	2.62	V
Under Voltage Lockout Threshold Hysteresis				210		mV
Supply Current (Shutdown)		V_{EN} ≤ 0.4V		20	35	μA
Supply Current (Quiescent)		V_{EN} ≥ 3.0 V, V_{FB} =1.4V		0.9	1.1	mA
Thermal Shutdown				160		°C

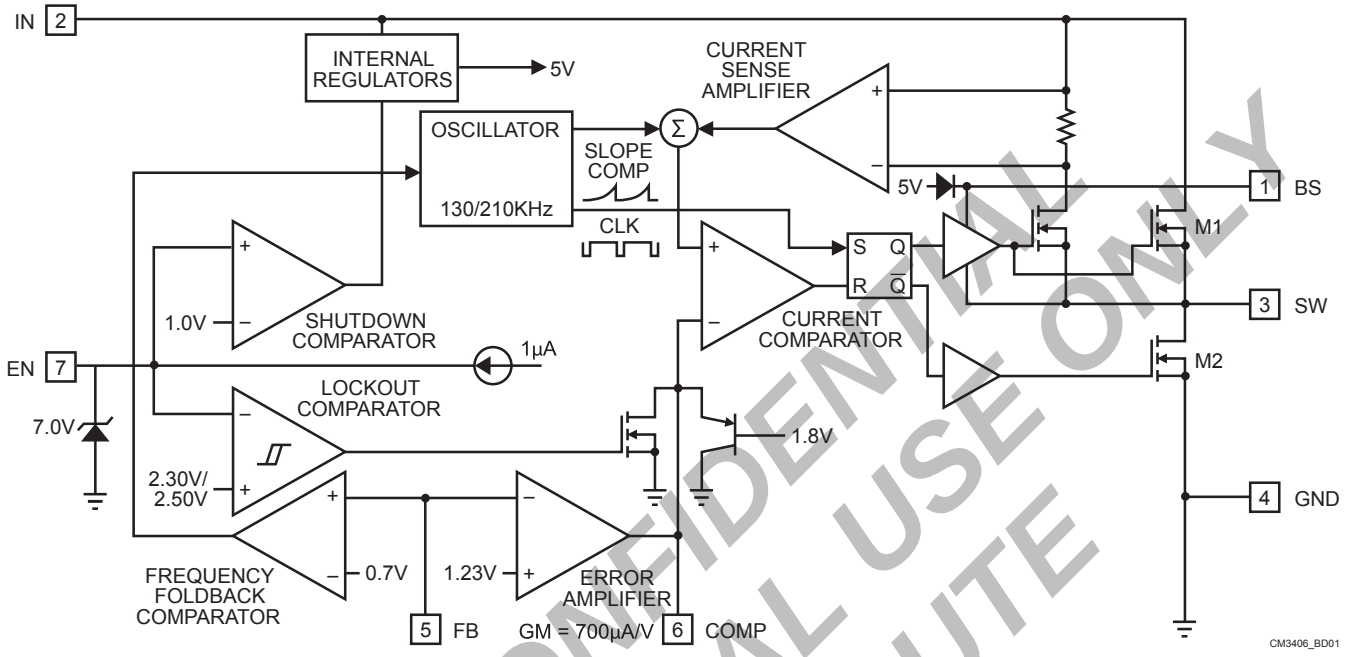
Note:

5) Guaranteed by design.

PIN FUNCTIONS

Pin #	Name	Description
1	NC	No Connect. Open, not used.
2	BS	Bootstrap (C5). This capacitor is needed to drive the power switch's gate above the supply voltage. It is connected between SW and BS pins to form a floating supply across the power switch driver. The voltage across C5 is about 5V and is supplied by the internal +5V supply when the SW pin voltage is low.
3	IN	Supply Voltage. The CM3406 operates from a +4.75V unregulated input. C1 is needed to prevent large voltage spikes from appearing at the input.
4	SW	Switch. This connects the inductor to either IN through M1 or to GND through M2.
5	GND	Ground. This pin is the voltage reference for the regulated output voltage. For this reason care must be taken in its layout. This node should be placed outside of the D1 to C1 ground path to prevent switching current spikes from inducing voltage noise into the part.
6	FB	Feedback. An external resistor divider from the output to GND, tapped to the FB pin sets the output voltage. To prevent current limit run away during a short circuit fault condition the frequency foldback comparator lowers the oscillator frequency when the FB voltage is below 700mV.
7	COMP	Compensation. This node is the output of the transconductance error amplifier and the input to the current comparator. Frequency compensation is done at this node by connecting a series R-C to ground.
8	EN	Enable/UVLO. There is about 7V internal zener connected between EN and GND as block diagram shows. The zener has 10mA maximum current rating. A voltage greater than 2.62V enables operation. Leave EN unconnected if unused. An Under Voltage Lockout (UVLO) function can be implemented by the addition of a resistor divider from V_{IN} to GND. For complete low current shutdown it's the EN pin voltage needs to be less than 700mV.

BLOCK DIAGRAM



APPLICATION INFORMATION

COMPONENT SELECTION

Setting the Output Voltage

The output voltage is set using a resistive voltage divider from the output voltage to FB pin. The voltage divider divides the output voltage down to the feedback voltage by the ratio:

$$V_{FB} = V_{OUT} \frac{R2}{R1+R2}$$

Where V_{FB} is the feedback voltage and V_{OUT} is the output voltage.

Thus the output voltage is:

$$V_{OUT} = 1.23 \times \frac{R1+R2}{R2}$$

R2 can be as high as 100kΩ, but a typical value is 10kΩ. Using that value, R1 is determined by:

$$R1 = 8.18 \times (V_{OUT} - 1.23)$$

For example, for a 3.3V output voltage, R2 is 10kΩ, and R1 is 17kΩ.

Inductor

The inductor is required to supply constant current to the output load while being driven by the switched input voltage. A larger value inductor will result in less ripple current that will result in lower output ripple voltage. However, the larger value inductor will have a larger physical size, higher series resistance, and/or lower saturation current. A good rule for determining the inductance to use is to allow the peak-to-peak ripple current in the inductor to be approximately 30% of the maximum switch current limit. Also, make sure that the peak inductor current is below the maximum switch current limit. The inductance value can be calculated by:

$$L = \frac{V_{OUT}}{f_S \times \Delta I_L} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

Where f_S is the switching frequency, ΔI_L is the peak-to-peak inductor ripple current and V_{IN} is the input voltage.

Choose an inductor that will not saturate under the maximum inductor peak current. The peak inductor current can be calculated by:

$$I_{LP} = I_{LOAD} + \frac{V_{OUT}}{2 \times f_S \times L} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

Where I_{LOAD} is the load current.

Output Rectifier Diode

The output rectifier diode supplies the current to the inductor when the high-side switch is off. To reduce losses due to the diode forward voltage and recovery times, use a Schottky diode.

Choose a diode whose maximum reverse voltage rating is greater than the maximum input voltage, and whose current rating is greater than the maximum load current.

Input Capacitor

The input current to the step-down converter is discontinuous, therefore a capacitor is required to supply the AC current to the step-down converter while maintaining the DC input voltage. Use low ESR capacitors for the best performance. Ceramic capacitors are preferred, but tantalum or low-ESR electrolytic capacitors may also suffice.

Since the input capacitor (C1) absorbs the input switching current it requires an adequate ripple current rating. The RMS current in the input capacitor can be estimated by:

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

The worst-case condition occurs at $V_{IN} = 2V_{OUT}$, where:

$$I_{C1} = \frac{I_{LOAD}}{2}$$

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

The input capacitor can be electrolytic, tantalum or ceramic. When using electrolytic or tantalum capacitors, a small, high quality ceramic capacitor, i.e. 0.1μF, should be placed as close to the IC as possible. When using ceramic capacitors, make sure that they have enough capacitance to provide sufficient charge to prevent excessive voltage ripple at input. The input voltage ripple caused by capacitance can be estimated by:

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

Output Capacitor

The output capacitor is required to maintain the DC output voltage. Ceramic, tantalum, or low ESR electrolytic capacitors are recommended. Low ESR capacitors are preferred to keep the output voltage ripple low. The output voltage ripple can be estimated by:

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_S \times L} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \times \left(R_{ESR} + \frac{1}{8 \times f_S \times C2}\right)$$ Where R_{ESR} is the equivalent series resistance (ESR) value of the output capacitor and C2 is the output capacitance value.

In the case of ceramic capacitors, the output voltage ripple is mainly caused by the capacitance. For simplification, the output voltage ripple can be estimated by:

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

Where L is the inductor value.

In the case of tantalum or electrolytic capacitors, the ESR dominates the impedance at the switching frequency. For simplification, the output ripple can be approximated to:

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

The characteristics of the output capacitor also affect the stability of the regulation system. The CM3406 can be optimized for a wide range of capacitance and ESR values.

Compensation Components

The CM3406 employs current mode control for easy compensation and fast transient response. The system stability and transient response are controlled through the COMP pin. COMP pin is the output of the internal transconductance error amplifier. A series capacitor-resistor combination sets a pole-zero combination to control the characteristics of the control system.

The DC gain of the voltage feedback loop is:

$$A_{VDC} = R_{LOAD} \times G_{CS} \times A_{VEA} \times \frac{V_{FB}}{V_{OUT}}$$

Where R_{LOAD} is the load resistor value, G_{CS} is the current sense transconductance and A_{VEA} is the error amplifier voltage gain.

The system has two poles of importance. One is due to the compensation capacitor (C3) and the output resistor of error amplifier, and the other is due to the output capacitor and the load resistor. These poles are located at:

$$f_{P1} = \frac{G_{EA}}{2\pi \times C3 \times A_{VEA}}$$

$$f_{P2} = \frac{1}{2\pi \times C2 \times R_{LOAD}}$$

Where G_{EA} is the error amplifier transconductance.

The system has one zero of importance, due to the compensation capacitor (C3) and the compensation resistor (R3). This zero is located at:

$$f_{Z1} = \frac{1}{2\pi \times C3 \times R3}$$

The system may have another zero of importance, if the output capacitor has a large capacitance and/or a high ESR value. The zero, due to the ESR and capacitance of the output capacitor, is located at:

$$f_{ESR} = \frac{1}{2\pi \times C2 \times R_{ESR}}$$

In this case, a third pole set by the compensation capacitor (C6) and the compensation resistor (R3) is used to compensate the effect of the ESR zero on the loop gain. This pole is located at:

$$f_{P3} = \frac{1}{2\pi \times C6 \times R3}$$

The goal of compensation design is to shape the converter transfer function to get a desired loop gain. The system crossover frequency where the feedback loop has the unity gain is important.

Lower crossover frequencies result in slower line and load transient responses, while higher crossover frequencies could cause system unstable. A good rule of thumb is to set the crossover frequency to below one-tenth of the switching frequency.

To optimize the compensation components, the following procedure can be used:

1. Choose the compensation resistor (R3) to set the desired crossover frequency. Determine the R3 value by the following equation:

$$R3 = \frac{2\pi \times C2 \times f_C}{G_{EA} \times G_{CS}} \times \frac{V_{OUT}}{V_{FB}}$$

Where f_C is the desired crossover frequency, which is typically less than one tenth of the switching frequency.

2. Choose the compensation capacitor (C3) to achieve the desired phase margin. For applications with typical inductor values, setting the compensation zero, f_{Z1}, to below one forth of the crossover frequency provides sufficient phase margin. Determine the C3 value by the following equation:

$$C3 > \frac{4}{2\pi \times R3 \times f_C}$$

Where, R3 is the compensation resistor value.

3. Determine if the second compensation capacitor (C6) is required. It is required if the ESR zero of the output capacitor is located at less than half of the switching frequency, or the following relationship is valid:

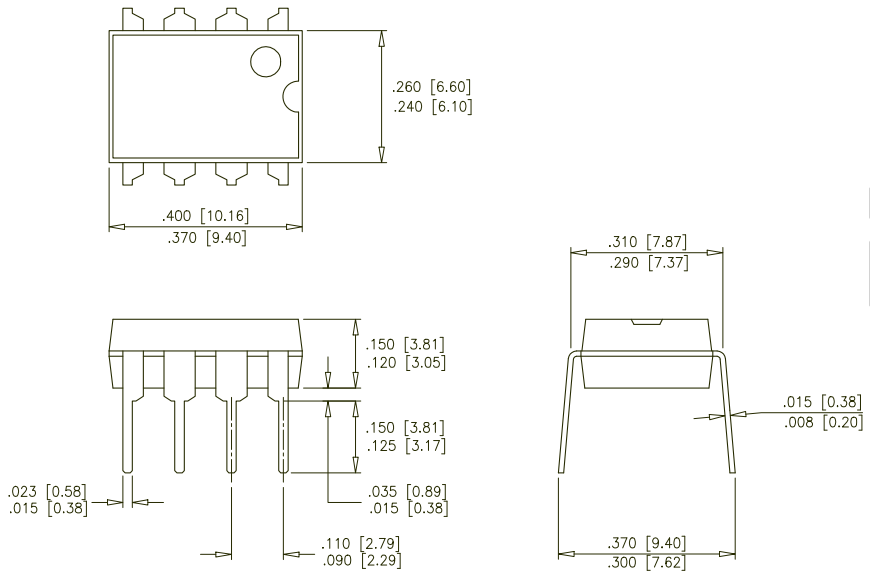
$$\frac{1}{2\pi \times C2 \times R_{ESR}} < \frac{f_S}{2}$$

If this is the case, then add the second compensation capacitor (C6) to set the pole f_{P3} at the location of the ESR zero. Determine the C6 value by the equation:

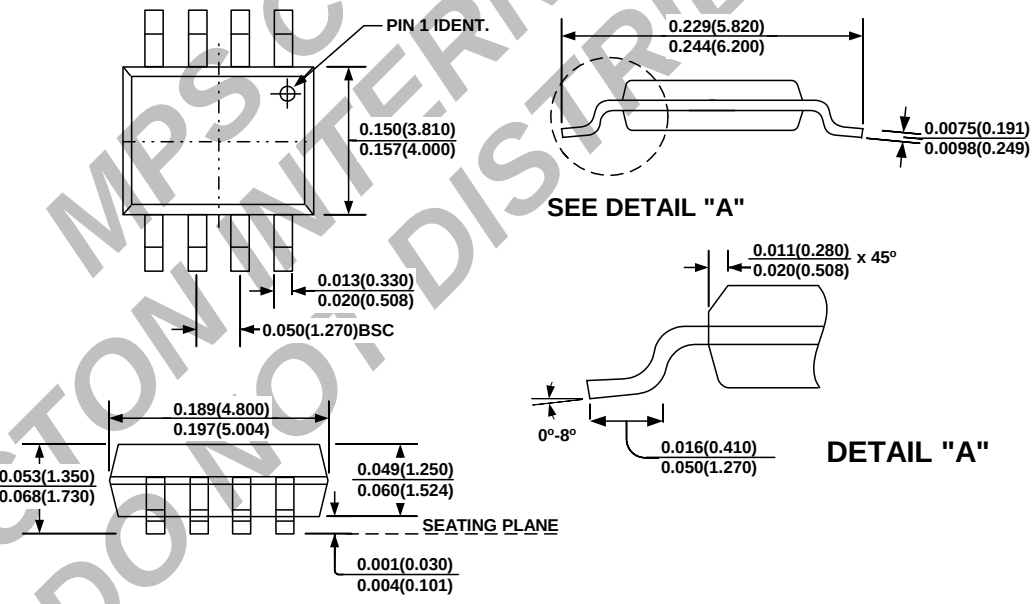
$$C6 = \frac{C2 \times R_{ESR}}{R3}$$

PACKAGE INFORMATION

PDIP8



SOIC8



NOTE:
1) Control dimension is in inches. Dimension in bracket is millimeters.