

# Current Mode PWM Control Circuit with 50% Max Duty Cycle

## Description

The CS3844/45 provides all the necessary features to implement off-line fixed frequency current-mode control with a minimum number of external components.

The CS3844 family incorporates a new precision temperature-controlled oscillator to minimize variations in frequency. An internal toggle flip-flop, which blanks the output every other clock cycle, limits the duty-cycle range to less than 50%. An undervoltage lockout ensures that  $V_{REF}$  is stabilized

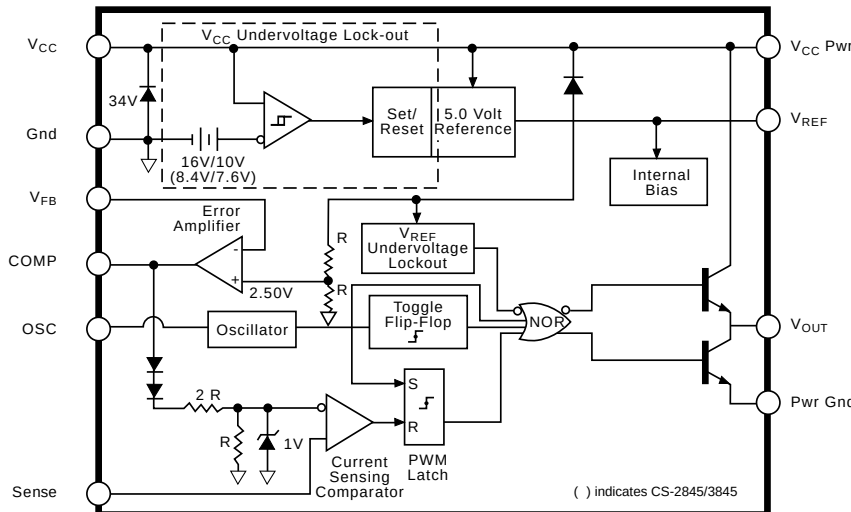
before the output stage is enabled. In the CS2844/CS3844 turn on occurs at 16V and turn off at 10V. In the CS2845/CS3845 turn on is at 8.4V and turn off at 7.6V.

Other features include low start-up current, pulse-by-pulse current limiting, and a high-current totem pole output for driving capacitive loads, such as gate of a power MOSFET. The output is low in the off state, consistent with N-channel devices.

## Absolute Maximum Ratings

|                                                |                                     |
|------------------------------------------------|-------------------------------------|
| Supply Voltage ( $I_{CC} < 30\text{mA}$ )..... | Self Limiting                       |
| Supply Voltage (Low Impedance Source) .....    | 30V                                 |
| Output Current.....                            | $\pm 1\text{A}$                     |
| Output Energy (Capacitive Load).....           | 5 $\mu\text{J}$                     |
| Analog Inputs ( $V_{FB}$ , $V_{SENSE}$ ) ..... | -0.3V to 5.5V                       |
| Error Amp Output Sink Current .....            | 10mA                                |
| Lead Temperature Soldering                     |                                     |
| Wave Solder (through hole styles only) .....   | 10 sec. max, 260°C peak             |
| Reflow (SMD styles only) .....                 | 60 sec. max above 183°C, 230°C peak |

## Block Diagram

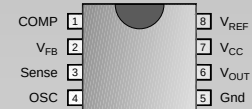


## Features

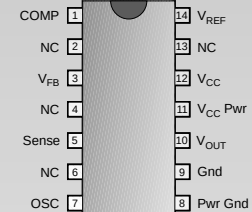
- **Optimized for Offline Control**
- **Temp. Compensated Oscillator**
- **50% Max Duty-cycle Clamp**
- **$V_{REF}$  Stabilized before Output Stage is Enabled**
- **Low Start-up Current**
- **Pulse-by-pulse Current Limiting**
- **Improved Undervoltage Lockout**
- **Double Pulse Suppression**
- **1% Trimmed Bandgap Ref.**
- **High Current Totem Pole Output**

## Package Options

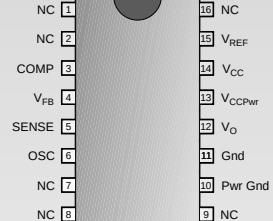
### 8 Lead PDIP & SO Narrow



### 14 Lead SO Narrow



### 16 Lead SO Wide



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Electrical Characteristics:  $-25 \leq T_A \leq 85^\circ\text{C}$  for CS2844/2845,  $0 \leq T_A \leq 70^\circ\text{C}$  for CS3844/3845.  $V_{CC} = 15\text{V}$  (Note 1);  $R_T = 10\text{k}\Omega$ ,  $C_T = 3.3\text{nF}$  for sawtooth mode., unless otherwise stated.

| PARAMETER               | TEST CONDITIONS                                                              | CS2844/CS2845 |      |      | CS3844/CS3845 |      |      | UNITS |
|-------------------------|------------------------------------------------------------------------------|---------------|------|------|---------------|------|------|-------|
|                         |                                                                              | MIN           | TYP  | MAX  | MIN           | TYP  | MAX  |       |
| ■ Reference Section     |                                                                              |               |      |      |               |      |      |       |
| Output Voltage          | T <sub>J</sub> =25°C, I <sub>REF</sub> =1mA                                  | 4.95          | 5.00 | 5.05 | 4.90          | 5.00 | 5.10 | V     |
| Line Regulation         | 12≤V <sub>CC</sub> ≤25V                                                      |               | 6    | 20   |               | 6    | 20   | mV    |
| Load Regulation         | 1≤I <sub>REF</sub> ≤20mA                                                     |               | 6    | 25   |               | 6    | 25   | mV    |
| Temperature Stability   | (Note 2)                                                                     |               | 0.2  | 0.4  |               | 0.2  | 0.4  | mV/°C |
| Total Output Variation  | Line, Load, Temp. (Note 2)                                                   | 4.90          |      | 5.10 | 4.82          |      | 5.18 | V     |
| Output Noise Voltage    | 10Hz≤f≤10kHz, T <sub>J</sub> =25°C (Note 2)                                  |               | 50   |      |               | 50   |      | μV    |
| Long Term Stability     | T <sub>A</sub> =125°C, 1000 Hrs. (Note 2)                                    |               | 5    | 25   |               | 5    | 25   | mV    |
| Output Short Circuit    | T <sub>A</sub> =25°C                                                         | -30           | -100 | -180 | -30           | -100 | -180 | mA    |
| ■ Oscillator Section    |                                                                              |               |      |      |               |      |      |       |
| Initial Accuracy        | Sawtooth Mode, T <sub>J</sub> =25°C                                          | 47            | 52   | 57   | 47            | 52   | 57   | kHz   |
| Voltage Stability       | 12≤V <sub>CC</sub> ≤25V                                                      |               | 0.2  | 1.0  |               | 0.2  | 1.0  | %     |
| Temperature Stability   | Sawtooth Mode T <sub>MIN</sub> ≤T <sub>A</sub> ≤T <sub>MAX</sub><br>(Note 2) |               | 5    |      |               | 5    |      | %     |
| Amplitude               | V <sub>OSC</sub> (peak to peak)                                              |               | 1.7  |      |               | 1.7  |      | V     |
| ■ Error Amp Section     |                                                                              |               |      |      |               |      |      |       |
| Input Voltage           | V <sub>COMP</sub> =2.5V                                                      | 2.45          | 2.50 | 2.55 | 2.42          | 2.50 | 2.58 | V     |
| Input Bias Current      | V <sub>FB</sub> =0V                                                          |               | -0.3 | -1.0 |               | -0.3 | -2.0 | μA    |
| A <sub>VOL</sub>        | 2≤V <sub>OUT</sub> ≤4V                                                       | 65            | 90   |      | 65            | 90   |      | dB    |
| Unity Gain Bandwidth    | (Note 2)                                                                     | 0.7           | 1.0  |      | 0.7           | 1.0  |      | MHz   |
| PSRR                    | 12≤V <sub>CC</sub> ≤25V                                                      | 60            | 70   |      | 60            | 70   |      | dB    |
| Output Sink Current     | V <sub>FB</sub> =2.7V, V <sub>COMP</sub> =1.1V                               | 2             | 6    |      | 2             | 6    |      | mA    |
| Output Source Current   | V <sub>FB</sub> =2.3V, V <sub>COMP</sub> =5V                                 | -0.5          | -0.8 |      | -0.5          | -0.8 |      | mA    |
| V <sub>OUT</sub> HIGH   | V <sub>FB</sub> =2.3V, R <sub>L</sub> =15kΩ to Gnd                           | 5             | 6    |      | 5             | 6    |      | V     |
| V <sub>OUT</sub> LOW    | V <sub>FB</sub> =2.7V, R <sub>L</sub> =15kΩ to V <sub>REF</sub>              |               | 0.7  | 1.1  |               | 0.7  | 1.1  | V     |
| ■ Current Sense Section |                                                                              |               |      |      |               |      |      |       |
| Gain                    | (Notes 3 & 4)                                                                | 2.85          | 3.00 | 3.15 | 2.85          | 3.00 | 3.15 | V / V |
| Maximum Input Signal    | V <sub>COMP</sub> =5V (Note 3)                                               | 0.9           | 1.0  | 1.1  | 0.9           | 1.0  | 1.1  | V     |
| PSRR                    | 12≤V <sub>CC</sub> ≤25V (Note 3)                                             |               | 70   |      |               | 70   |      | dB    |
| Input Bias Current      | V <sub>Sense</sub> =0V                                                       |               | -2   | -10  |               | -2   | -10  | μA    |
| Delay to Output         | T <sub>J</sub> =25°C (Note 2)                                                |               | 150  | 300  |               | 150  | 300  | ns    |
| ■ Output Section        |                                                                              |               |      |      |               |      |      |       |
| Output Low Level        | I <sub>SINK</sub> =20mA                                                      |               | 0.1  | 0.4  |               | 0.1  | 0.4  | V     |
|                         | I <sub>SINK</sub> =200mA                                                     |               | 1.5  | 2.2  |               | 1.5  | 2.2  | V     |
| Output High Level       | I <sub>SOURCE</sub> =20mA                                                    | 13.0          | 13.5 |      | 13.0          | 13.5 |      | V     |
|                         | I <sub>SOURCE</sub> =200mA                                                   | 12.0          | 13.5 |      | 12.0          | 13.5 |      | V     |
| Rise Time               | T <sub>J</sub> =25°C, C <sub>L</sub> =1nF (Note 2)                           |               | 50   | 150  |               | 50   | 150  | ns    |
| Fall Time               | T <sub>J</sub> =25°C, C <sub>L</sub> =1nF (Note 2)                           |               | 50   | 150  |               | 50   | 150  | ns    |

**Electrical Characteristics:**  $-25 \leq T_A \leq 85^\circ\text{C}$  for CS2844/2845,  $0 \leq T_A \leq 70^\circ\text{C}$  for CS3844/3845.  $V_{CC}=15\text{V}$  (Note 1);  $R_T=10\text{k}\Omega$ ,  $C_T=3.3\text{nF}$  for sawtooth mode., unless otherwise stated.

| PARAMETER                     | TEST CONDITIONS                                                                     | CS2844/CS2845 |     |     | CS3844/CS3845 |     |     | UNITS |
|-------------------------------|-------------------------------------------------------------------------------------|---------------|-----|-----|---------------|-----|-----|-------|
|                               |                                                                                     | MIN           | TYP | MAX | MIN           | TYP | MAX |       |
| ■ Total Standby Current       |                                                                                     |               |     |     |               |     |     |       |
| Start-Up Current              |                                                                                     |               | 0.5 | 1.0 |               | 0.5 | 1.0 | mA    |
| Operating Supply Current      | V <sub>FB</sub> =V <sub>Sense</sub> =0V R <sub>T</sub> =10kΩ, C <sub>T</sub> =3.3nF |               | 11  | 17  |               | 11  | 17  | mA    |
| V <sub>CC</sub> Zener Voltage | I <sub>CC</sub> =25mA                                                               |               | 34  |     |               | 34  |     | V     |

#### ■ PWM Section

|                    |  |    |    |    |    |    |    |   |
|--------------------|--|----|----|----|----|----|----|---|
| Maximum Duty Cycle |  | 46 | 48 | 50 | 46 | 48 | 50 | % |
| Minimum Duty Cycle |  |    |    | 0  |    |    | 0  | % |

| PARAMETER | TEST CONDITIONS | CS2844 |     |     | CS3844 |     |     | CS2845/CS3845 |     |     | UNITS |
|-----------|-----------------|--------|-----|-----|--------|-----|-----|---------------|-----|-----|-------|
|           |                 | MIN    | TYP | MAX | MIN    | TYP | MAX | MIN           | TYP | MAX |       |

#### ■ Under-Voltage Lockout Section

|                        |               |    |    |    |      |    |      |     |     |     |   |
|------------------------|---------------|----|----|----|------|----|------|-----|-----|-----|---|
| Start Threshold        |               | 15 | 16 | 17 | 14.5 | 16 | 17.5 | 7.8 | 8.4 | 9.0 | V |
| Min. Operating Voltage | After Turn On | 9  | 10 | 11 | 8.5  | 10 | 11.5 | 7.0 | 7.6 | 8.2 | V |

**Notes:** 1. Adjust  $V_{CC}$  above the start threshold before setting at 15V.

2. These parameters, although guaranteed, are not 100% tested in production.

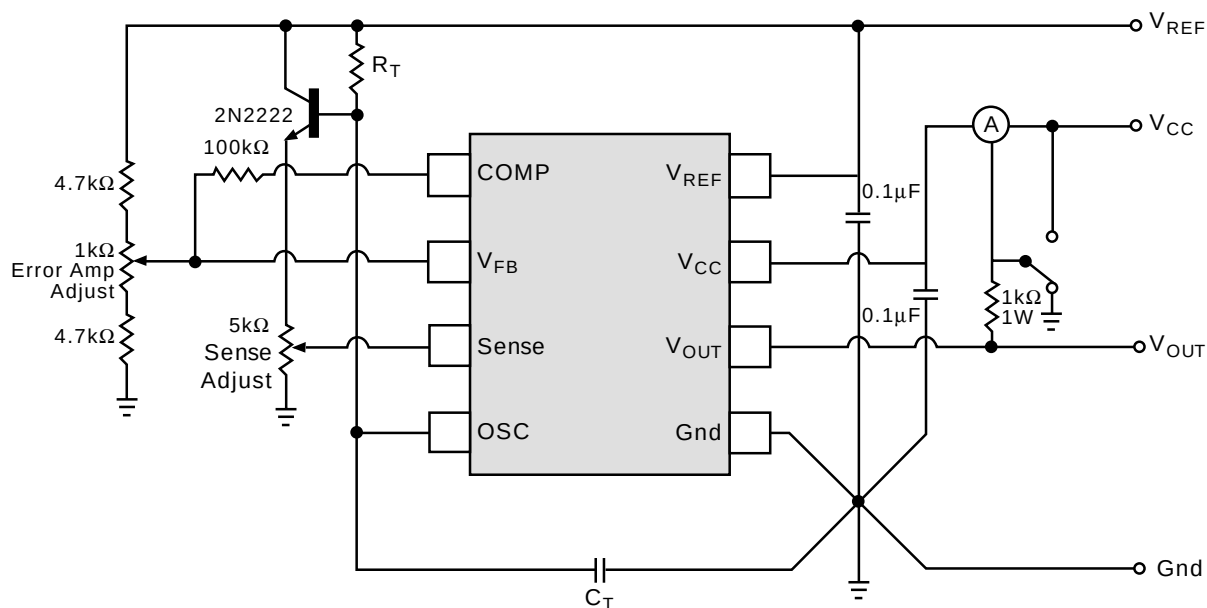
3. Parameter measured at trip point of latch with  $V_{FB}=0$ .

4. Gain defined as:

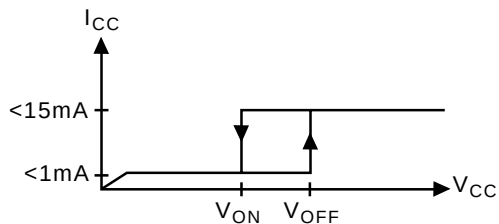
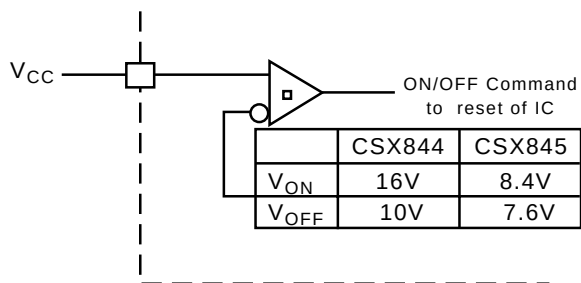
$$A = \frac{\Delta V_{\text{COMP}}}{\Delta V_{\text{Sense}}} ; 0 \leq V_{\text{Sense}} \leq 0.8\text{V}.$$

#### Package Pin Description

| PACKAGE PIN # |                  |                | PIN SYMBOL         | FUNCTION                                                                    |
|---------------|------------------|----------------|--------------------|-----------------------------------------------------------------------------|
| 8L<br>PDIP/SO | 14L<br>SO Narrow | 16L<br>SO Wide |                    |                                                                             |
| 1             | 1                | 3              | COMP               | Error amp output, used to compensate error amplifier.                       |
| 2             | 3                | 4              | $V_{FB}$           | Error amp inverting input.                                                  |
| 3             | 5                | 5              | Sense              | Noninverting input to Current Sense Comparator.                             |
| 4             | 7                | 6              | OSC                | Oscillator timing network with Capacitor to Ground, resistor to $V_{REF}$ . |
| 5             | 9                | 11             | Gnd                | Ground.                                                                     |
|               | 8                | 10             | Pwr Gnd            | Output driver Ground.                                                       |
| 6             | 10               | 12             | $V_{OUT}$          | Output drive pin.                                                           |
|               | 11               | 13             | $V_{CC\text{Pwr}}$ | Output driver positive supply.                                              |
| 7             | 12               | 14             | $V_{CC}$           | Positive power supply.                                                      |
| 8             | 14               | 15             | $V_{REF}$          | Output of 5V internal reference.                                            |
|               | 2,4,6,13         | 1,2,7,8,9,16   | NC                 | No Connection.                                                              |



### Circuit Description



**Figure 1: Startup voltage for CSX844 and CSX845.**

## Undervoltage Lockout

During Undervoltage Lockout (Figure 1), the output driver is biased to sink minor amounts of current. The output should be shunted to ground with a resistor to prevent activating the power switch with extraneous leakage currents.

## PWM Waveform

To generate the PWM waveform, the control voltage from the error amplifier is compared to a current sense signal which represents the peak output inductor current (Figure 2). An increase in  $V_{CC}$  causes the inductor current slope to increase, thus reducing the duty cycle. This is an inherent feed-forward characteristic of current mode control, since the control voltage does not have to change during changes of input supply voltage.

When the power supply sees a sudden large output current increase, the control voltage will increase allowing the duty cycle to momentarily increase. Since the duty cycle tends to exceed the maximum allowed to prevent transformer saturation in some power supplies, the internal oscillator waveform provides the maximum duty cycle clamp as programmed by the selection of OSC components.

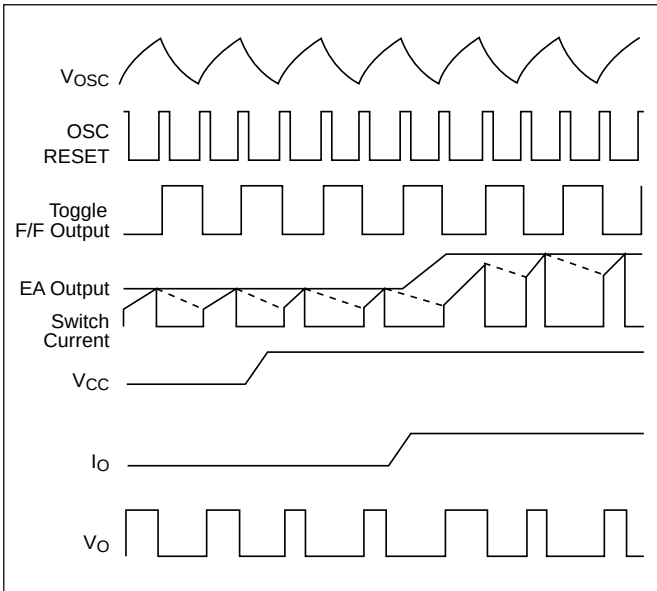


Figure 2: Timing Diagram

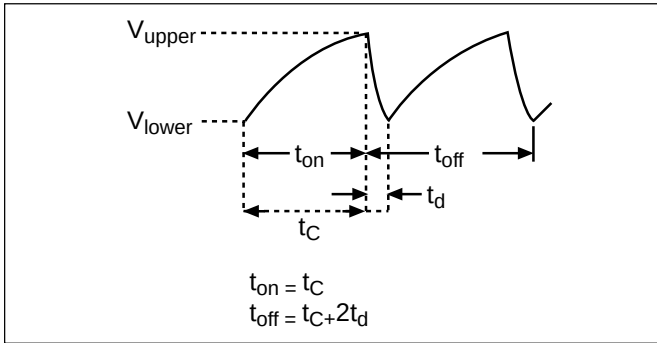


Figure 3: Duty Cycle parameters.

### Setting the Oscillator

The times  $T_c$  and  $T_d$  can be determined as follows:

$$t_c = R_T C_T \ln \left( \frac{V_{REF} - V_{lower}}{V_{REF} - V_{upper}} \right)$$

$$t_d = R_T C_T \ln \left( \frac{V_{REF} - I_d R_T - V_{lower}}{V_{REF} - I_d R_T - V_{upper}} \right)$$

Substituting in typical values for the parameters in the above formulas:

$V_{REF} = 5.0V$ ,  $V_{upper} = 2.7V$ ,  $V_{lower} = 1.0V$ ,  $I_d = 8.3mA$ ,  
then

$$t_c \approx 0.5534 R_T C_T$$

$$t_d = R_T C_T \ln \left( \frac{2.3 - 0.0083 R_T}{4.0 - 0.0083 R_T} \right)$$

For better accuracy  $R_T$  should be  $\geq 10k\Omega$ .

### Grounding

High peak currents associated with capacitive loads necessitate careful grounding techniques. Timing and bypass capacitors should be connected close to Gnd in a single point ground.

The transistor and  $5k\Omega$  potentiometer are used to sample the oscillator waveform and apply an adjustable ramp to Sense.

## Package Specification

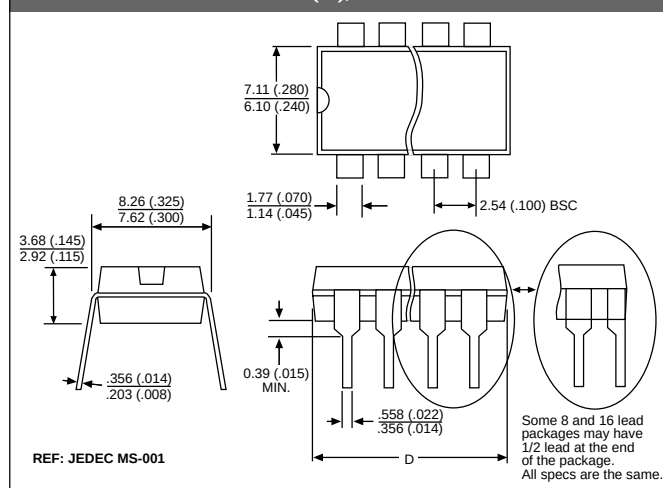
## PACKAGE DIMENSIONS IN mm (INCHES)

| Lead Count       | D      |       |         |      |
|------------------|--------|-------|---------|------|
|                  | Metric |       | English |      |
|                  | Max    | Min   | Max     | Min  |
| 8 Lead PDIP      | 10.16  | 9.02  | .400    | .355 |
| 8 Lead SO Narrow | 5.00   | 4.80  | .197    | .189 |
| 14L SO Narrow    | 8.75   | 8.55  | .344    | .337 |
| 16L SO Wide      | 10.50  | 10.10 | .413    | .398 |

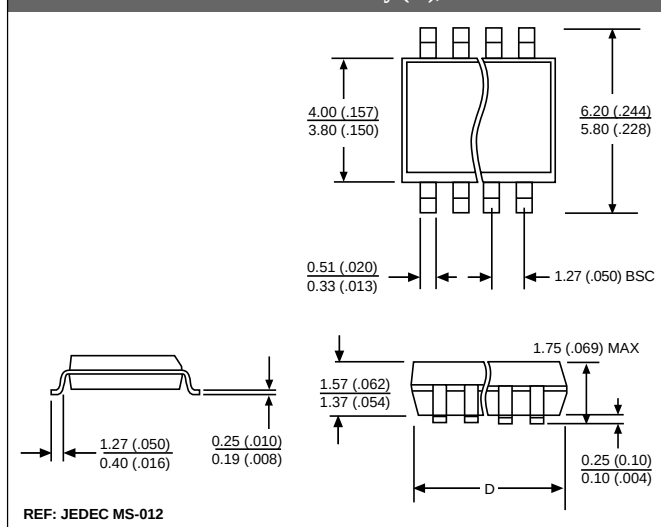
## PACKAGE THERMAL DATA

| Thermal Data    |     | 8 L PDIP | 8L SO Narrow | 14 L SO Narrow | 16L SO Wide |        |
|-----------------|-----|----------|--------------|----------------|-------------|--------|
| $R_{\theta JC}$ | typ | 52       | 45           | 30             | 23          | °C / W |
| $R_{\theta JA}$ | typ | 100      | 165          | 125            | 105         | °C / W |

## Plastic DIP (N); 300 mil wide



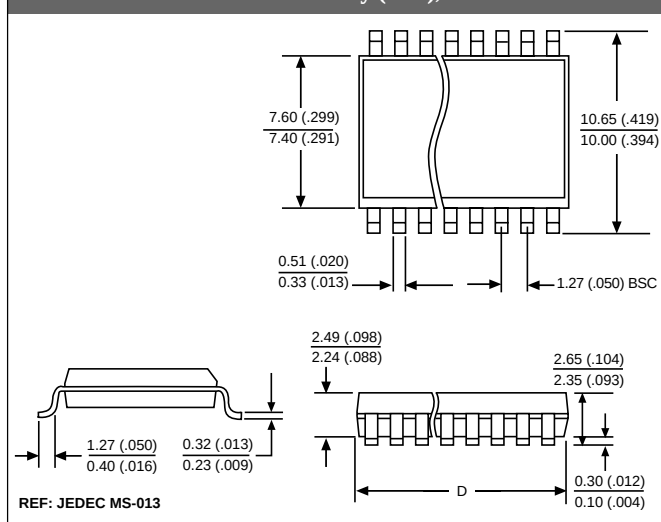
## Surface Mount Narrow Body (D); 150 mil wide



## Ordering Information

| Part Number  | 0°C to 70°C | -25°C to 85°C | Description               |
|--------------|-------------|---------------|---------------------------|
| CS2844LN8    |             | •             | 8L PDIP                   |
| CS2844LD14   |             | •             | 14L SO                    |
| CS2844LDR14  |             | •             | 14L SO (Tape & Reel)      |
| CS2844LDW16  |             | •             | 16L SO Wide               |
| CS2844LDWR16 |             | •             | 16L SO Wide (Tape & Reel) |
| CS2845LN8    |             | •             | 8L PDIP                   |
| CS2845LDW16  |             | •             | 16L SO Wide               |
| CS2845LDWR16 |             | •             | 16L SO Wide (Tape & Reel) |
| CS3844GN8    | •           |               | 8L PDIP                   |
| CS3844GD8    | •           |               | 8L SO                     |
| CS3844GDR8   | •           |               | 8L SO (Tape & Reel)       |
| CS3844GD14   | •           |               | 14L SO                    |
| CS3844GDR14  | •           |               | 14L SO (Tape & Reel)      |
| CS3844GDW16  | •           |               | 16L SO Wide               |
| CS3844GDWR16 | •           |               | 16L SO Wide (Tape & Reel) |
| CS3845GN8    | •           |               | 8L PDIP                   |
| CS3845GD8    | •           |               | 8L SO                     |
| CS3845GDR8   | •           |               | 8L SO (Tape & Reel)       |
| CS3845GD14   | •           |               | 14L SO                    |
| CS3845GDR14  | •           |               | 14L SO (Tape & Reel)      |
| CS3845GDW16  | •           |               | 16L SO Wide               |
| CS3845GDWR16 | •           |               | 16L SO Wide (Tape & Reel) |

## Surface Mount Wide Body (DW); 300 mil wide



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